THE EFFECTS OF INTERACTIONS BETWEEN TECHNOLOGY, INSTITUTIONS AND POLICY ON THE POTENTIAL RETURNS TO FARMING SYSTEMS RESEARCH IN SEMI-ARID NORTHEASTERN MALI

VOLUME 1

By

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A DISSERTATION

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ABSTRACT

THE EFFECTS OF INTERACTIONS BETWEEN TECHNOLOGY, INSTITUTIONS AND POLICY ON THE POTENTIAL RETURNS TO FARMING SYSTEMS RESEARCH IN SEMI-ARID NORTHEASTERN MALI

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Bruno Henry de Frahan

This study evaluated the expected production impact of farming systems research (FSR) in the Region of Mopti and examined the potential effects of improving the institutional and policy context on the expected return to FSR. The study relied on reconnaissance surveys, a single-visit survey, and interviews with farmers, key research personnel and agents of the rural community services, which were conducted between June 1987 and December 1988 in Mali.

The program for the FSR team was designed by first ranking the commodity components according to their contribution to efficiency, equity, security and sustainability. Then research areas were selected according to the biophysical and resource endowment constraints of the farming systems, the technological components available from on-station research, and the market and institutional constraints of the farming systems of the Region of Mopti. Farm budgets for current practices and for technologies that FSR could develop were evaluated both in financial and economic terms. Expected diffusion paths of these potential technologies were estimated using historical data on animal traction adoption in the project area. The expected internal rate of return (IRR) to FSR alone is estimated at 2% and is unstable with respect to changes in yields, output and input prices and diffusion parameters. If the FSR project were limited to adapting and transferring results currently available from station research

under the current market and institutional environment, the project would not be economically viable.

Simulating additional public investments such as on-station research, more-developed extension and credit institutions, marketing system improvements and fiscal policy reform indicates that the IRR can be increased up to 26%. The interactive effects between complementary public investments are strong and suggest that policy makers first should focus on reforming fiscal policy and improving the marketing system before investing jointly in on-station research and FSR. Credit and input supply are important, but investing in extension should be delayed until improved technologies are available from the agricultural research system.

The findings of this study also provide suggestions for the organization of agricultural research in Mali: a strong coordination between FSR and on-station research, a focus on marketing and credit constraints, and technological development directed towards low-input and risk-reducing innovations for staple foods and cash crops with market potential.

To my parents, Jacques and Françoise Henry de Frahan,
for their love and generosity.

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I would first like to thank Dr. John Staatz, my major professor and thesis director, for his thoughtful guidance during all stages of the research process. This study benefitted greatly from his field expertise and his insights on the process of economic development in Mali. Drs. Eric Crawford, Carl Eicher and James Oehmke gave me prompt and constructive feedback on earlier drafts of this dissertation. I was also fortunate to have Drs. Glenn Johnson and Richard Bernsten as major professors during my course work and Drs. Lindon Robison and Mordechai Kreinin on my guidance committee. They have all helped shape my education as an agricultural economist.

In Mali, I have many people to thank for their contributions to this study. In particular, Dr. Goïta, director of the Farming Systems Research Division, not only gave me excellent administrative support but also provided me with numerous and valuable contacts within the Malian agricultural research system. Youssouf Cissé and Samba Traoré, my counterparts, and Moussa Diarra, Josué Sogoba, Mahamadou Tandia and Adama Telly, our research assistants, were dedicated researchers as well as untiring companions on our many trips to the Region of Mopti. In addition, special thanks for their work go to the enumerators, Amonon Doumbo, Louis Douyon, Amatigué Guirou and Housseyni Yalcouyé, and Karim Soumaoro, the project car driver-cum-mechanic. Finally, this study would not have been possible without the cooperation of the farmers, herders, fishermen an

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herders, fishermen and extension agents in the Region of Mopti who so actively participated in our research.

The United States Agency for International Development, especially the Bamako Mission, gave invaluable financial, intellectual and logistical support. Special thanks go to Tracy Atwood, Emmy Simmons, S.K. Reddy, Elzadia Washington and David Atwood. The flawless backstopping and overall direction provided by Dr. Michael Weber, the director of the Food Security in Africa Cooperative Agreement at MSU, were sincerely appreciated. I am thankful to Janet Munn, Christina DeFouw and the Agricultural Economics Computer Service team for their help in getting over the day-to-day hurdles involved in completing this dissertation. I am also indebted to the Agricultural Economics Department of MSU for its support during my entire graduate program.

My greatest debt and appreciation are to my wife, Victoire D'Agostino, who offered patience and encouragements throughout my graduate program and during this research. Her editing skills have also made this dissertation a great deal more readable than it would have been otherwise. I deeply thank her. My son, Marc, who would have preferred to play more often with his Daddy during the writing of this dissertation should get a gold star for his patience.

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BNDA

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LIST OF ACRONYMS

BCEAO	Banque Centrale des Etats de l'Afrique de l'Ouest (Central Bank of West African States).
BNDA	Banque Nationale de Développement Agricole (Agricultural Credit), Mali.
CABO	Centre for Agrobiological Research, The Netherlands.
CAC	Centre d'Action Coopérative de la DNACOOP (Representation of the DNACOOP at the circle level), Mali.
CCCE	Caisse Centrale de Coopération Economique (French Economic Cooperation Fund), France.
CEC	Commission of the European Communities.
CESA	Commission Nationale de Suivi et d'Evaluation de la Stratégie Alimentaire (Food Strategy Commission), Mali.
CFA	Communauté Financière Africaine (Financial Community of Western and Eastern Francophone African states, except Guinea and Mauritania).
CFA F	CFA Francs (Currency unit of the CFA Zone).
CIF	Cost, Insurance, and Freight.
CILSS	Comité Inter-Etats de Lutte Contre la Sécheresse au Sahel (Organization of Sahelian States for Coping with Drought).
CIRAD	Centre International de la Recherche Agronomique et de Développement (French Research Institute), France.
CMDT	Compagnie Malienne de Développement des Textiles (Malian Company for the Development of Textiles), Mali.
CNAUR	Commission Nationale d'Aide d'Urgence et de Reconstruction (National Commission for Emergency Aid and Reconstruction), Mali.

CNRA/IER

CTRA/IER

DAF/IER

DDI/IER

DET/IER

DMA

DNA/IER

DNACOOP

DNSI

DPE/IER

DRA

DRA/IER

DRSPR/IER

EDF

FAC

FAD

FSR/E

CNRA/IER	Comité National de la Recherche Agronomique (National Committee for Agronomic Research), IER, Mali.
CTRA/IER	Commission Technique de la Recherche Agronomique (Technical Commission for the Agronomic Research), IER, Mali.
DAF/IER	Division Administrative et Financière (Administrative and Financial Division), IER, Mali.
DDI/IER	Division de la Documentation et de l'Information (Division of Documentation), IER, Mali.
DET/IER	Division des Etudes Techniques (Division of Technical Studies), IER, Mali.
DMA	Division du Machinisme Agricole (Agricultural Mechanization Division), Ministry of Agriculture, Mali.
DNA/IER	Direction Nationale de l'Agriculture (National Direction of Agriculture), Mali.
DNACOOP	Direction Nationale de l'Action Coopérative (National Direction of Cooperative Organizations), Mali.
DNSI	Direction Nationale de la Statistique et de l'Informatique (National Direction of Statistics and Computing), Mali.
DPE/IER	Division Planification et Evaluation (Division of Planning and Evaluation), IER, Mali.
DRA	Direction Régionale de l'Agriculture (Regional Direction of Agriculture), Ministry of Agriculture, Mali.
DRA/IER	Division de la Recherche Agronomique (Division of Agronomic Research), IER, Mali.
DRSPR/IER	Division de Recherches sur les Systèmes de Production Rurale (Farming Systems Research Division), IER, Mali.
EDF	European Development Fund.
FAC	Fonds d'Aide et de Coopération (French Development Fund), France.
FAD	Fonds d'Aide et de Développement, France.
FSR/E	Farming Systems Research/Extension Project, Mali.

GTZ	German Development Agency, Germany.
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics.
IDRC	International Development Research Centre, Canada.
IER	Institut d'Economie Rurale (Agricultural Research Institute), Mali.
ILCA	International Livestock Centre for Africa.
INRZFH	Institut National de Recherche Zootechnique, Forestière et Hydrobiologique (Zootechnical, Forestry and Hydrobiological Research Institute), Mali.
IRAT	Institut de Recherche en Agronomie Tropicale (Tropical Agronomic Research Institute), France.
ISNAR	International Service for National Agricultural Research.
IUCN	International Union for Conservation of Nature, United Kingdom.
MSU	Michigan State University, USA.
NGO	Non Governmental Organization.
ODEM	Opération pour le Développement de l'Elevage à Mopti (Mopti Livestock Development Organization), Mali.
ODIPAC	Opération de Développement Intégré des Productions Arachidières et Céréalières (Integrated Groundnuts and Cereals Development agency), Mali.
ODR	Opération de Développement Rural (Rural Development Agency), Mali.
OHV	Opération Haute Vallée (Niger River Upper-valley Development Authority), Mali.
OMBEVI	Office Malien du Bétail et de la Viande (Livestock and Meat Agency), Mali.
OMM	Opération Mils de Mopti (Mopti Millet Organization), Mali.
ON	Office du Niger (Niger River Irrigated Agricultural Development Agency), Mali.
OPAM	Office des Produits Agricoles du Mali (Agricultural Marketing Agency), Mali.

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OPM	Opération Pêche de Mopti (Mopti Fish Organization), Mali.
OPSS	Opération de Production de Semences Sélectionnées (Improved Seed Production Program), Mali.
ORM	Opération Riz de Mopti (Mopti Rice Organization), Mali.
ORS	Opération Riz de Ségou (Segou Rice Organization), Mali.
OSCE	Office Statistique des Communautés Européennes (Statistical Agency of the European Community), Mali.
OXFAM	Oxford Famine Relief (British NGO).
PAR	Point d'Appui de Recherche (Local Research Station), Mali.
PIRT	Projet d'Inventaire des Ressources Terrestres (Land-resource Inventory Project), Mali.
PPIV	Petits Périmètres Irrigués Villageois (Small Village Irrigation Areas), Mali.
PRMC	Programme de Restructuration du Marché Céréalier (Cereals Market Restructuring Program), Mali.
SAFGRAD	Semi Arid Food Grain Research and Development.
SAP	Système d'Alerte Précoce (Early Warming System), Mali.
SCAER	Société de Crédit Agricole et d'Equipement Rural (Agricultural Credit and Input Distribution Agency), Mali.
SMECMA	Société Malienne d'Etudes et de Construction de Matériel Agricole (Malian Agricultural Mechanization Company), Mali.
SMPC	Société Malienne des Produits Chimiques (Malian Chemical Products Company), Mali.
SONAREM	Société Nationale de la Recherche Minière (National Company for Research on Mining), Mali.
SRCSS/DRA/IER	Section de Réglementation et Contrôle des Semences Sélectionnées (Seed Selection Control), IER, Mali.
SRCVO/DRA/IER	Section de Recherche sur les Cultures Vivrières et Oléagineuses (Food Crop and Oilseed Research), IER, Mali.
TRP	Tilemsi Rock Phosphate.

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UMOA	Union Monétaire des Etats de l'Afrique de l'Ouest (Monetary Union of West African States).
UP	Unité de Production (Farm Production Unit).
USAID	United States Agency for International Development.
USDA	United States Department of Agriculture.
VST	Vétérinaire Sans Frontières (French Veterinary NGO).
WARDA	West African Rice Development Agency.
WB	World Bank.

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1. INTRODUCTION

The potential contribution of agricultural research to increasing production in Africa is a central element of the broader discussion on agricultural development in Africa being conducted by African governments and the donor community. The high payoff to agricultural research found in most parts of the world suggests that technical change has the potential to relieve the food deficits experienced by many African countries, which have seen their populations grow at twice the rate of food production between 1970 and 1985 (Eicher, 1988). However, many studies have shown that the high payoffs to agricultural research crucially depend on infrastructure, institutions, and policies that support the generation and transfer of new technologies (Daniels et al., 1990, p. 37). This observation is particularly appropriate for African countries, where institutions and infrastructure are weak in many cases. Consequently, there is a need to examine carefully the potential contribution of agricultural research before committing the scarce human and financial resources of these countries to technology development. Extension, input and output markets, credit institutions, and economic forces, such as fiscal, monetary and trade policies, are all factors that may affect the transfer of technology. In addition to these institutional and policy factors, studies also show that the failure to organize research effectively and to analyze farmer constraints systematically in the design of research programs have hampered the effectiveness of agricultural research (DAI, 1982; Murphy, 1983).

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Based on an ex-ante evaluation of a farming systems research (FSR) project in Mali, this dissertation examines to what extent these factors may affect the production impact of FSR. This investigation is useful to identify and develop an appropriate research program and to design the implementation of that program. As a case study, this dissertation underscores the need to examine carefully the factors that may affect the potential return to investments in agricultural research and provides guidelines on how to address this issue for eventual investments in agricultural research in Mali and in other African countries. This chapter presents the objectives, context, research methods, and organization of this dissertation.

1.1. Study Objectives

The general purpose of this study is to evaluate the expected production impact of farming systems research in the Region of Mopti and to examine how complementary public investments or policy changes might lead to increases in farm production. Major emphasis is on how effective the investments are in improving farm productivity, although effects on equity, security and sustainability at the farm level are also investigated. This study also examines the expected institutional impact of FSR on the national agricultural research system and draws implications for the organization of the Malian agricultural research system.

More specifically, the objectives of this study are to:

1. develop a method to estimate ex-ante the return to an FSR project and complementary investments;
2. identify a research program for FSR to relax the major constraints faced by farmers in the project area;

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3. estimate the return to the FSR program and examine the stability of the rate of return vis-à-vis the underlying assumptions;
4. identify additional institutional improvements and policy reforms required to complement FSR, in order to improve the overall performance of the production system; and estimate the returns to these complementary investments and the interactive effects between these investments and FSR;
5. propose an appropriate role and organization of a) FSR within the national agricultural research system and b) complementary rural institutions, such as extension and credit.

The conclusions of this dissertation can be useful to other countries deciding on how to strengthen their national agricultural research systems and contribute to the current debate concerning the relevance of the FSR approach to technical change. The research method used for this study can provide useful guidelines to evaluators involved in estimating ex-ante the production impact of an agricultural research program, particularly FSR.

1.2. Background Problem Statement

1.2.1. Institutionalization of Systems Research in the Malian Agricultural Research System

The need for farming systems research in Mali emerged in the late 1970s, when it became clear that the technologies extended by the rural development agencies (ODRs) were often inappropriate to the agroclimatic and socio-economic constraints faced by farmers and that the results of station research needed to be adapted to farmers' specific circumstances. At the 1976 international colloquium on farming systems research held in Bamako, a consensus emerged on the need to create a bridge between commodity

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research and the ODRs, in other words, a third institution which would be in close contact with the needs and problems of rural producers. This consensus re-emerged at the National Committee for Agricultural Research (CNRA), and again in 1978 during a seminar on the "Improvement of Animal Production Systems". The Farming Systems Research Division (DRSPR) was officially institutionalized within the Agricultural Research Institute (IER) in 1979. The DRSPR became the institute's sixth division alongside the Division of Agronomic Research (DRA), the Division of Technical Studies (DET), the Division of Planning and Evaluation (DPE), the Division of Documentation and Information (DDI) and the Administrative and Financial Division (DAF).

Farming systems research in Mali began in 1977, earlier than its formal institutionalization, in four study villages around Fonsébougou in the eastern part of the Region of Sikasso (southern Mali). This FSR project is known as the Fonsébougou Unit of the DRSPR. With Dutch funding and technical assistance, this unit expanded its research activities to include several other villages in the Regions of Sikasso and Ségou. Parallel to the development of the Fonsébougou Unit, another FSR Unit was created in the area between Sikasso and Bougouni in the western part of the Region of Sikasso with funding and technical assistance provided by the International Development Research Centre-Canada (IDRC) since 1980. Technical assistance to this Unit, known as the Bougouni-Sikasso Unit, was discontinued in 1988. In 1986, the US Agency for International Development (USAID) contributed to the installation of the DRSPR's Bamako offices, the training of Malian researchers, and the launching of the division's research activities in the Region of Bamako, an area already served by the Niger River Upper-Valley Development Authority (OHV). This third FSR Unit is known as the OHV Unit.

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Nine years after its creation in 1979, the DRSPR in 1987 had 14 national and 14 expatriate researchers out of a total of 153 national and 32 expatriate researchers within IER. The Division of Agronomic Research (DRA) is by far the largest division, with 101 national and 15 expatriate researchers in 1987, 66% of the total for IER (ISNAR, 1990, p. 26). In 1987, the DRSPR had an operating budget of 310 million CFA F[1], of which 272 million CFA F (88%) was provided by The Netherlands, IDRC, and USAID (Ministère de l'Agriculture, 1988). In the same year, the DRA had 989 million CFA F (3.5 million US dollars) at its disposal, of which 604 million CFA F (61%) came from external sources (principally CIRAD-France and USAID through ICRISAT and SAFGRAD). In terms of financial resources per scientist (nationals and expatriates combined) the DRSPR received a larger allocation than the DRA. In 1987, the DRSPR had 11.1 million CFA F (39,600 US dollars) per researcher while the DRA had approximately 8.5 million CFA F (30,400 US dollars) per researcher, or 23% less per scientist. The large external funding of IER's operations suggests that Mali has not yet achieved a consistent long-term government commitment to agricultural research.

In Mali, France was the first to fund agricultural research, on cotton in 1925 and on rice in 1932. In 1962, two years after independence, the Malian government assumed administrative control of agricultural research with the creation of IER, which it placed under the Ministry of Agriculture. French support and influence remained at a high level, although research emphasis gradually shifted from cash crops to food crops.

Since the creation of IER, the government of Mali has established additional research institutes. The second largest research institute after IER is the National

[1] Equivalent to 1.1 million US dollars at $1 = CFA F 280, excluding technical assistance costs and equipment purchased overseas.

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Institute for Zootechnical, Forestry and Hydrobiological Research (INRZFH), created in 1981 and staffed by 66 researchers in 1986 (ISNAR, 1990, p. 12). Initially under the Ministry of Environment and Livestock, this institute is presently being integrated with IER. Three other institutions are conducting research: the Central Veterinary Laboratory (LCV), with a research staff of 26 persons; the Livestock and Meat Agency (OMBEVI), with a research staff of 50 persons; and the Agricultural Mechanization Division (DMA) of the Ministry of Agriculture, with 10 engineers in 1986 (ISNAR, 1990, pp. 12-15). These five research institutions constitute the "active" agricultural research system in Mali and, with the educational institutes (the Rural Polytechnic Institute-IPR and the teacher training school-ENS, neither having the financial resources to conduct research), include about 337 researchers. By this account, the Malian agricultural research system is the largest in francophone sub-Saharan Africa (ISNAR, 1990, p. 24).

Initially complementing France in supporting the Malian agricultural research system, USAID progressively became the major contributor in the 1980s (Casas, 1987, p. 4). USAID began targeting its support to the development of technologies appropriate for the less favored regions of central and northern Mali through cooperative research programs with the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) and the Semi-Arid Food Grain Research and Development (SAFGRAD). While the objective of the ICRISAT program was to conduct applied research on station, the objective of the SAFGRAD program was to test technologies developed on station in the rural environment. Because the conditions and selection criteria on station were quite different from those of farmers in their own environment, the top-down SAFGRAD approach from experiment station to farmers did not, however, yield the expected results. Consequently, the ODRs had few appropriate research results to offer farmers. For thes

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farmers. For these reasons, USAID in 1985 made the decision to assist the DRSPR in expanding and conducting its research activities in other zones.

1.2.2. Expanding the FSR division into the Region of Mopti

The general objective of USAID's assistance to FSR is to provide institutional support to IER to develop and transfer technologies appropriate to the needs and environment of Malian farmers. For the first phase of this program, USAID proposed supporting the DRSPR in expanding its activities from southern Mali to the OHV zone. The second phase of this program includes an expansion of the DRSPR to the Region of Mopti. Throughout the two phases, USAID wants to help IER build the institutional capacity to conduct FSR, particularly by improving linkages between research and development and by training researchers.

Over the course of the 10-year period anticipated of the program, the USAID contribution will cover (USAID, 1985):

- technical assistance (US $ 6.14 million, 32%),
- training of researchers (US $ 1.84 million, 10%),
- contributions to national and regional offices (US $ 1.01 million, 5%),
- equipment (US $ 1.42 million, 7%),
- operational expenses (US $ 3.52 million, 18%),
- 10% in contingencies,[2]
- an allowance for 5% inflation.[3]

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[2] Estimated at US $ 1.39 million or 7% of the total budget.

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USAID's proposed contribution to recurrent costs would gradually decrease: from 82% in the first seven years to 63% in the last three years. The total cost of the project is estimated at $ 21.3 million, of which $ 19.5 million (92%) will be contributed by USAID and $ 1.8 million (8%) by the government of Mali.

The total cost of expanding the project to the Region of Mopti is $ 5.73 million, 27% of the total project cost, of which $ 5.24 million (91%) will be borne by USAID and $ 0.49 million (9%) by the government of Mali. A multidisciplinary team of researchers comprising four Malians (agricultural economist, sociologist, agronomist and livestock scientist) and two expatriates for four years (agronomist and agricultural economist) is anticipated for the expansion of the DRSPR into the Region of Mopti.

However, because the agroclimatic, socio-economic and institutional constraints appeared more binding in the Region of Mopti than in the OHV zone, an in-depth study was deemed necessary to establish the feasibility of this expansion. In particular, the climate of the Region of Mopti is semi-arid, with rainfall between 300 mm and 600 mm, which severely limits the production potential of the region. In addition, few technologies at the station level are available and appropriate for FSR to adapt and transfer to producers. Poorly developed infrastructure and institutions may further hamper the diffusion of new technologies. Finally, IER's ability to sustain an expanded FSR program in the near future is questionable.

The feasibility study of the expansion of the FSR division into the Region of Mopti was carried out in Mali from June 1987 to December 1988 and reported in Henry de Frahan et al., 1989. This dissertation builds on the feasibility study. It will emphasize the factors that are likely to affect the return to FSR in Mali and address the question raised by IER and USAID concerning the economic return to investing Mali's scarce resources and US

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This evaluation of the return to agricultural research, investigation of the factors affecting that return, and the drawing of implications on the roles and organization of agricultural research and supporting rural institutions come at a time when the government of Mali is drafting a 12-year strategic plan for agricultural research. Other nations in Africa are similarly concerned about the need to strengthen their capacity to carry out agricultural research. The World Bank's Special Program for African Agricultural Research (SPAAR) is exploring these same issues, in addition to questions related to the sustainability of research institutions and the division of research tasks between regional and national research centers.

1.3. Research Methods

The research supporting this dissertation was conducted under the Mali component of the second phase of the USAID-financed "Food Security in Africa Cooperative Agreement." The agreement aims to analyze both country-specific and more general elements of the food security problem in the different sub-regions of the African continent, through comparative analysis of the food and agricultural sectors of a number of African countries. Food security has been defined as the ability of "a country or a region to assure, on a long-term basis, that its food system provides the total population access to a timely, reliable and nutritionally adequate supply of food" (Eicher and Staatz, 1987, p. 216). Central to the concept of a food security strategy is the idea that "the interaction of technological change, institutional reforms, and macro-level policy [can overcome] food production and marketing constraints" (Crawford et al., 1988). This dissertation focuss

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dissertation focusses on how the agricultural research system in Mali can facilitate technological change within the institutional and policy context of the country.

This research originated of the request from the Malian agricultural research institute (IER) to USAID to expand FSR to the Region of Mopti. IER and USAID asked Michigan State University (MSU) to carry out the feasibility study for this expansion. According to the terms of reference of the feasibility study, the primary objective was "to provide an estimate of the investment costs of an expansion of the farming systems research project, and expected benefits in the form of output growth and increased productivity and incomes in the Region of Mopti. This study will also consider factors affecting the returns to agricultural research in general, and the Mali FSR project in particular (i.e., agricultural pricing policy, marketing, and the relationships between technology and food security)." This section presents briefly the organization of the field work, the techniques used for collecting primary and secondary data during the field work, and finally an outline of the core methods chosen for carrying out the financial and economic analyses.

1.3.1. Field Work Organization

The study began in June 1987, with a budget of $230,000 and an expected duration of 18 months. The study team consisted of an agricultural economist from MSU (author of this dissertation), two IER researchers (one M.S. agricultural economist and one agronomist with an M.S. degree), a junior agronomy consultant (with a B.S. in agricultural sciences) and a data entry expert (with a B.A. in economics). The team was formally integrated into the IER farming systems research division and regularly involved in the planning and evaluation meetings of the division and in the IER National

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Specialized Commissions (CTS). The study benefited from the professional advice of two Michigan State University professors (Dr. Staatz and Dr. Crawford), and intellectual and logistical support from IER and the USAID mission in Bamako. Logistical support comprised one all-road vehicle, 4 motorcycles, and an office equipped with a micro-computer. Four enumerators were employed for four months for a formal survey in the Seno plain and Bandiagara plateau. A special study on livestock in the Region of Mopti was carried out by the director and the deputy director of the Mopti Livestock Development Organization (ODEM) under the guidance of the evaluation team.

1.3.2. Field Activities

The bulk of the field work consisted of the identification and ranking of the constraints affecting the productivity of the major farming systems of the project area and the determination of a research program for FSR. Several reconnaissance surveys were used to identify homogeneous agroclimatic zones and delineate three farming systems: agropastoral, pastoral and fishing. The agropastoral system was further sub-divided in three sub-systems: rainfed, flooded and recessional.

A combination of formal and informal surveys was used to identify the production, marketing and institutional constraints affecting the productivity of the major farming systems of the area. The formal survey was a single visit survey designed mainly to identify the biophysical and technical constraints to crop production that affect the rainfed crop-based farming and pastoral systems. The formal survey was designed on the basis of a rapid reconnaissance survey of the area. A disproportionate stratified sampling procedure was used, selecting first the agroclimatic zone, then the farming system, and finally the equipment level. The reconnaissance survey indicated that these three variables

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three variables affect the organization of the farming systems. At the last level of stratification, a sample of 316 farm households from 34 villages was randomly selected. For each household, three questionnaires were administered: one to the head of the household, the second to a wife, and the third to a male dependent. The questions addressed to the wives and male dependents were specifically designed to determine the allocation of labor and land among these two groups and the use of agricultural inputs and production. The choice of the wife and the male dependent within the household was left to the four enumerators who carried out the survey. Most of the questions from the three questionnaires were multiple choice, while only a few were open-ended. None of the questions included the estimation of cultivated area, labor inputs and production outputs because of insufficient personnel.

The informal surveys included group interviews with farmers, and interviews with key research personnel and agents of the rural community services (civil administrators, extension and agricultural credit agents, farmer cooperative agents, non-governmental organizations' personnel, farm input suppliers, and traders). All the informal surveys were conducted by the evaluation team (agricultural economists and agronomists). More details about the field work will be provided in the following chapters.

These surveys and additional secondary data provided the basis for designing a research program for FSR in the Region of Mopti. An evaluation criteria approach with a combination of efficiency, equity, security and sustainability research objectives was used to rank the commodity components of the research program. Research areas were selected according to the biophysical and resource endowment constraints of the farming systems, the technological components available from on-station research, and the market and institutional constraints of the farming systems of the area. Key commodity and disciplinary

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and disciplinary researchers, FSR practitioners and high-level extension technicians thoroughly reviewed the research program. These discussions and a literature review of the recent results from experiment stations indicated technical packages that FSR could develop in the short term. These packages provided the basis for estimating the production impact of the FSR project in the Region of Mopti.

1.3.3. Analysis

A literature review of the methods that currently exist to evaluate ex-ante agricultural research programs was used to frame the methodological approach of this dissertation. Although no method specifically designed for carrying out an ex-ante evaluation of FSR was found in the literature surveyed, methods of varying degrees of sophistication are available to set priorities in agricultural research. The literature review on priority-setting for National Agricultural Research Systems (NARS) in Appendix 1 compares four types of techniques:

1) The scoring or weighted criteria model, which can include congruence analysis, the domestic resource cost (DRC) ratios approach and checklists;
2) The expected economic surplus model, including benefit-cost analysis;
3) The mathematical programming approach;
4) Simulation techniques.

Among these techniques, Norton and Davis (1981) suggest that weighted criteria models, expected economic surplus models and simulation models are the most helpful in identifying and quantifying factors affecting progress in agricultural research. These three techniques will be used in this study.

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First, evaluation criteria will be used to narrow the list of alternative commodities and research areas to be included in the FSR program. Second, the expected economic surplus approach will be used to evaluate the FSR program by measuring society's gains from a shift in supply induced by, for example, the use of new technologies by producers. Third, simulation techniques will be used to measure the relative changes in society's gains from a shift in supply or demand induced by other types of investments, such as improvements in the institutional and policy environment of FSR. These three techniques comprise the methodological approach for this dissertation. Details about the adaptation of these techniques to the purpose of this dissertation will be specified as they are used. A summary of the successive methodological steps is provided in chapter 8.

1.4. Organization of the Dissertation

The remainder of this dissertation is divided into seven chapters. Chapter 2 presents the agroclimatic, socio-economic and institutional characteristics of the Region of Mopti and its farming systems. This chapter also identifies the major constraints of these farming systems. Chapter 3 presents the conceptual framework for the study by synthesizing the current literature on the roles and contributions of different institutions involved in generating and transferring agricultural technologies, particularly in farming systems research. The chapter suggests that the factors affecting the institutional and production impact of FSR be used to guide the analyses that follow. Chapter 4 develops a research program for FSR, including both commodity components and research areas, under different efficiency, equity, security and sustainability criteria. Chapter 5 evaluates the technologies that FSR could develop, in terms of financial profitability, riskiness and

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economic efficiency. Chapter 6 estimates the potential impact of FSR on increasing farm production, primarily on the basis of efficiency and equity, and ranks the major factors affecting the returns to FSR. Chapter 7 examines the production impact of diverse combinations of investments which complement FSR and the interactive effects between these investments and FSR. In this chapter, an investment strategy is proposed for the Region of Mopti. Chapter 8 summarizes the main findings of the dissertation and their implications for a regional investment strategy for increasing agricultural production. Additional implications for the role and organization of agricultural research, FSR and extension in Mali and in other parts of Africa are drawn. Chapter 8 concludes with suggestions on how to conduct ex-ante evaluations of agricultural research, particularly FSR.

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2. FARMING SYSTEMS IN THE REGION OF MOPTI

This chapter presents: 1) the agroclimatic characteristics and the populations of the Region of Mopti, 2) the production, markets and institutional environment, 3) the principal production systems, and 4) the main constraints to these production systems.

2.1. Agroclimatic Characteristics and Populations

Figure 2-1 shows the location of the Region of Mopti (or Fifth Region) in Mali. The region has a diverse agroecology: the seasonally-inundated inland delta of the Niger River, the Bandiagara plateau, and the broad Seno plain which stretches from the Bandiagara cliffs to the border of Burkina Faso. The region covers 77,800 square kilometers and has a population of 1.26 million people (Table 1 of Appendix 2-A).

In the southern part of the region, the climate is sudano-sahelian, with a long-run average of 600mm of rainfall annually at Djénné. Moving to the north, the region becomes sahelian, with rainfall between 200mm and 400mm at Douentza and Ténenkou. However, the records for the period 1977 to 1987 show a significant 10-30% reduction in rainfall and in the number of rainy days relative to these long run averages (Table 2 of Appendix 2-A). The length of the rainy season has also shortened, now to covering the period from late June to early September.


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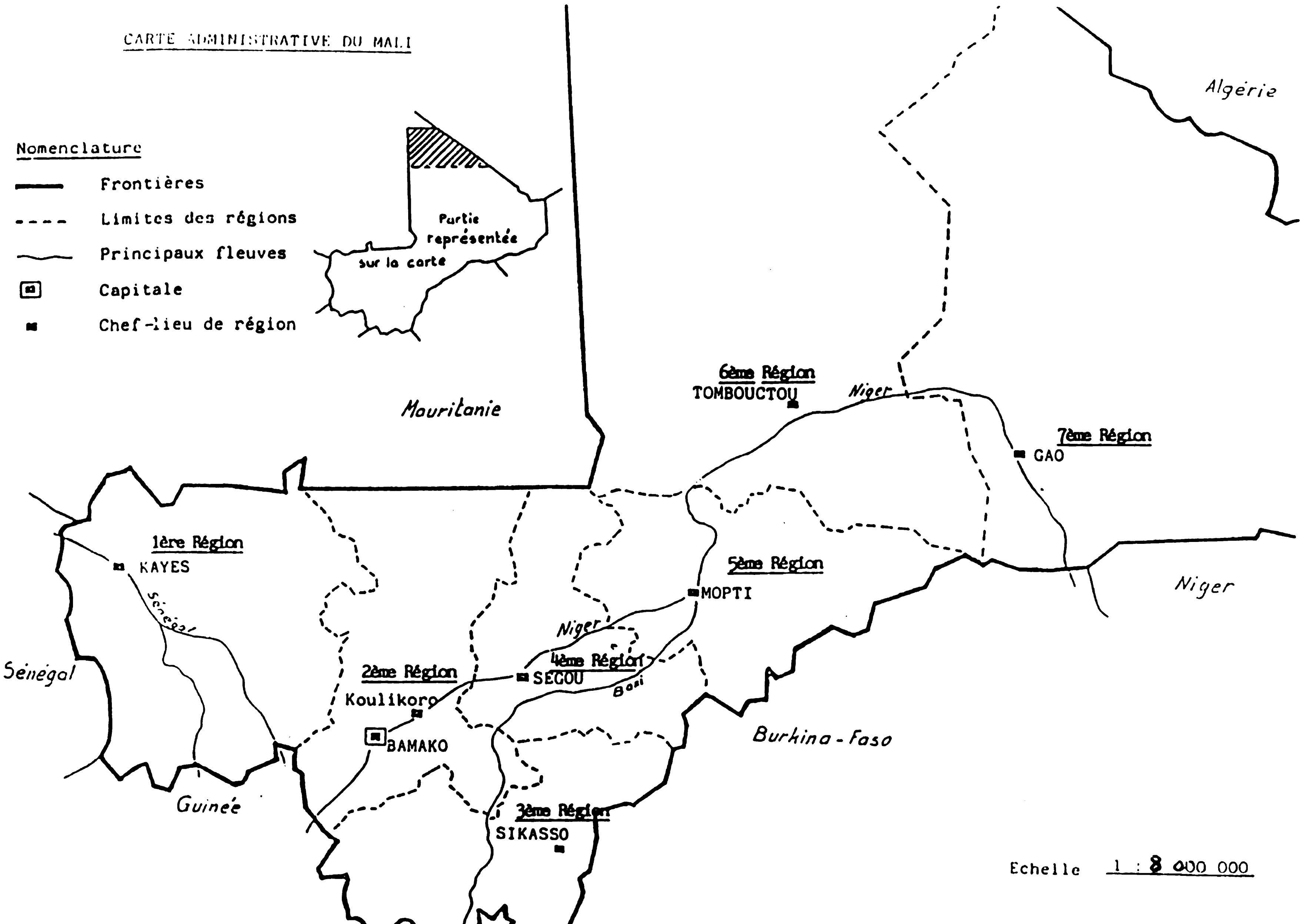

Figure 2-1. Administrative Map of Mali

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2.1.1. The Delta

The Delta is a partially inundated plain comprised of three geographic sub-zones (Figure 2-2). To the south, the active delta extends from the Bani River to lakes Debo and Korientze and is subject to annual flooding. To the north is the lacustrine zone characterized by lakes, pools, and elongated dunes. On the periphery of these two zones is the inactive delta, which has dunes, sandy plains, bush pasturelands, and areas of sparse vegetation (Thom and Wells, 1987).

Both the intensity and timing of flooding as well as the amount of area inundated vary from year to year. In Mopti, the long-run average of the peak flood is 700 cm; 82% of the time the flood fluctuates within 45 cm of this average (ibid., p. 331). Although this variation may not seem large, the slope of the delta is so low that the flooded area can vary a great deal from one year to the next. The height of the floods has decreased considerably, particularly in the last decade. For example, the maximum height of the Bani floods at the Mopti station was 538 cm for the period 1981 to 1986 as opposed to 700 cm for the period 1968 to 1971 (Ministère de l'Agriculture, 1986). Because the land is flat, the extent of the flooding has varied dramatically.

The Delta has an area of 35,889 square kilometers and a population of 606,000 inhabitants, or about 46% of the land area and 48% of the population of the Region of Mopti (Henry de Frahan et al., 1989, p. 38). The population is concentrated in the active delta and the lacustrine zones, which are among the most densely populated portions of Mali. The estimated density is 35 persons per square kilometer. The availability of water, the relatively fertile soils, and the presence of pastures have made these two zones attractive for human settlement. In contrast, the population density in the inactive delta is less than 10 persons per square kilometer.


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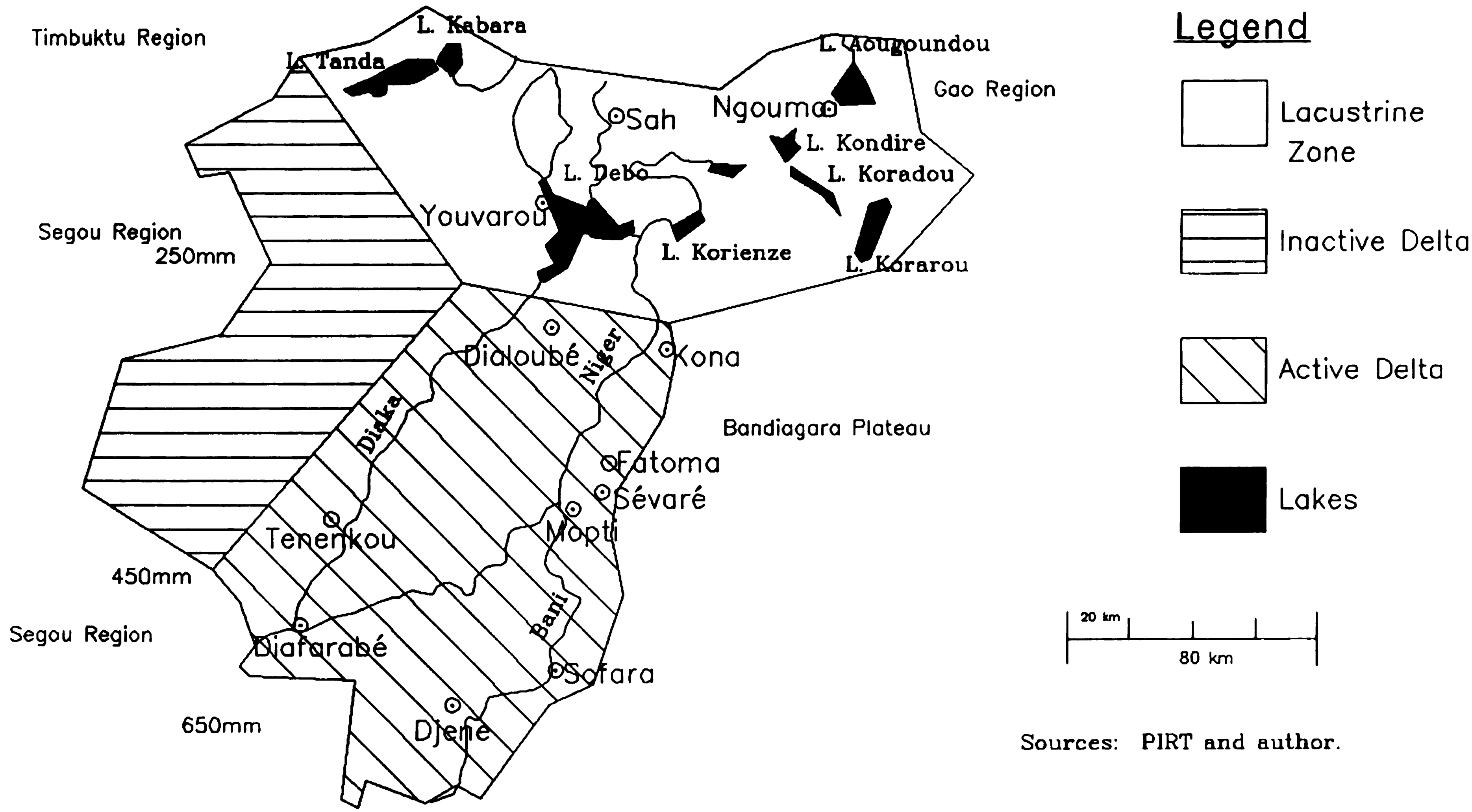

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FIGURE 2.2: THE GEOGRAPHIC ZONES of the Niger Delta in the Region of Mopti

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The principal agricultural activities in the Delta are crop production (primarily rice and millet), livestock and fishing. Rice cultivation, an ancient activity, is practiced under either natural or controlled flooding conditions. The rainfed crops, i.e., millet, sorghum, cowpeas and groundnuts, are cultivated on the elevated land of the Delta. Flood recession agriculture is practiced in the northern, low-lying part of the Delta, which is also an excellent pastoral zone because of its dry-season pastures. These pastures are made up of an herbaceous forage plant, called the "bourgou"[4] (Echinochloa stagnina), which is the root of the word "bourgoutières" or the areas of dry-season pasture in the Delta. Following the recession of the flood, herders migrate to the "bourgoutières". During the Niger and Bani floods the herders return to the non-flooded areas, which provide wet-season pasture. Fishing is principally practiced in the middle and upper parts of the Delta. The town of Mopti is an important commercial and administrative center for this area, with a population of 74,000 inhabitants (Ministère de l'Administration Territoriale et du Développement à la Base, 1987).

2.1.2. The Seno Plain

The Seno is a vast plain ranging from 250m to 300m in altitude (Figure 2-3). To the north, the plain is bordered by an area called South Gourma, characterized by rocky outcrops ringed with dunes. The Bandiagara escarpment constitutes its northwestern frontier and Burkina Faso is the Seno's southeastern border. From north to south the Seno plain appears as parallel successions of smooth sandy dunes followed by sandy-silt plains.

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[4] Fulani word meaning flooded plain.


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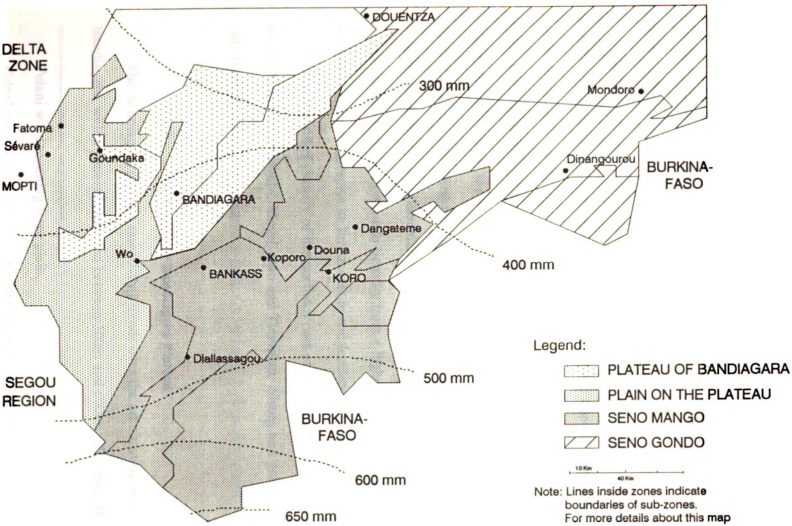

Note: Lines inside zones indicate boundaries of sub-zones. For more details about this map see Henry de Frahan et al. (1989).

Sources: According to PIRT and author.

FIGURE 2.3: THE GEOGRAPHIC ZONES Of The Seno Plain And The Bandiagara Plateau

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The Seno plain and South Gourma cover over 33,695 square kilometers, or 43% of the area of the Region of Mopti. These two areas are inhabited by 473,000 people. The density is 14 persons per square kilometer, which is slightly lower than the regional average of 16 persons per square kilometer. The population of the Seno plain and South Gourma is 37% of the total population of the Region of Mopti (Henry de Frahan et al., 1989, p. 38).

Within the Seno plain there are two sub-zones: the Seno-Mango[5] in the northeast and the Seno-Gondo[6] in the southwest. The Seno-Mango zone is essentially agropastoral, with annual rainfall between 200mm and 400mm. The rainfed crops cultivated include millet, cowpeas, groundnuts, sesame, fonio and Bambara groundnuts. During the dry season, the Seno-Mango also serves as a transhumance zone for the animals from the Delta and the cultivated parts of the Seno plain. Like the Seno-Mango, the Seno-Gondo is essentially a zone of mixed farming with the same rainfed crops. However, the Seno-Gondo benefits from a higher level of rainfall, ranging from 400mm to 700mm. Despite its limitations in soil fertility and rainfall, the Seno-Gondo is considered the millet granary of the northern part of the country and primarily supplies the markets of Bandiagara, Mopti, Gao and Timbuktu. Sheep and goats are more important than cattle in this area.

2.1.3. The Dogon or Bandiagara Plateau

The Bandiagara plateau essentially extends over the administrative "cercle" of Bandiagara, with a general elevation between 300m and 600m. However, there are some

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[5] Fulani word meaning large plain.

[6] Fulani word meaning plain of Gondo, a village in the plain.

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valleys at between 150m and 300m and some rocky peaks rising to as high as 800m. The plateau covers an area of 8,219 square kilometers and has a population of 183,000. The population density is 22 persons per square kilometer, which is the highest density in the rainfed area of the Region of Mopti with the exception of that of the town of Mopti (Table 1 of Appendix 2-A). The area of the plateau represents 11% of the region, and is home to 15% of the region's population (ibid., p. 39).

Only 22% of the total land available on the plateau can be cultivated (Chef de Secteur de Développement Rural de Bandiagara, personal communication, 1987). The land is cultivated with millet, cowpeas, groundnuts, fonio and Bambara groundnuts. The Yamé river crosses the plateau from southeast to northwest. The tributaries of the Yamé and flooded low-lying areas provide numerous opportunities for dry-season vegetable gardens. Small ruminants are more important than cattle in this area.

2.2. Production, Markets, and Institutional Environment

First, this section shows the importance of the regional production in crops, livestock and fish relative to the national production. Second, it presents the regional institutions involved in technology generation and transfer. Third, the section concludes with the major regional characteristics of the agricultural, livestock and fish product marketing.

2.2.1. Primary Sector Production

a) Agricultural Production

Estimates for the period 1974-88 (OSCE, 1989) indicate that the Region of Mopti produced on average 18% of millet and sorghum grown in Mali (Table 3 of Appendix 2-

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A). In the region, millet and sorghum were planted on an average of 280,000 hectares (or 24% of total area cultivated to millet and sorghum in Mali) and yielded an average of 178,000 tons annually for the period 1974-88. Thus the average yield was 650 kg/ha, or 76% of the national average yield in millet and sorghum. While no significant trend is observed in area and production of millet and sorghum at the regional level for the period 1974-88, there are significant positive trends at the national level for both area and production. From 1974 to 1988, the share of the region in millet and sorghum area has decreased by 1.3% every year and the share of the region in millet and sorghum production has decreased by 0.7% every year (Table 3 of Appendix 2-A). Regional maize production contributes only one percent to national maize production (ibid.).

Of an average of 182,000 hectares of rice cultivated in Mali, about 74,000 hectares (41%) were in this region for the period 1974-88 (Table 4 of Appendix 2-A). Regional rice production was on average 60,000 tons (or 27% of national rice production). On average yields remained low (about 770 kg/ha on average, or 64% of the national yield in rice) despite efforts to improve flood control and transfer modern inputs. No significant trend is observed for area and production of rice at the regional and national levels from 1974 to 1988.

Legume production is important in the region. Cowpeas are generally intercropped with millet. Groundnuts and Bambara groundnuts are generally cultivated in pure stands on small plots. Sesame and Guinean sorrel are also cultivated. The Bandiagara plateau is a major production area for vegetables. Onion production is estimated at 20,000 tons a year (Traoré et al., 1988). Onions from this area can be found in many markets in Mali and in surrounding countries.

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b) Livestock and Fisheries

Between 1977 and 1987, the Region of Mopti had an average of 1.21 million head of cattle (23% of the Malian cattle herd of 5.4 million) and 2.16 million head of small ruminants (20% of the Malian goat and sheep herd of 10.8 million). The drought of the mid-seventies and, more dramatically, of 1982-84 severely reduced the livestock population (Table 5 of Appendix 2-A).

The region is a major exporter of live cattle to Burkina Faso and the coastal countries, principally Côte d'Ivoire. In the 1970s these exports were enough to cover imports of both agricultural products and manufactured goods into the region (Direction Générale du Plan et de la Statistique, 1977 and 1981). Since then, however, the number of cattle and small ruminants exported has declined (Table 6 of Appendix 2-A).

The Delta is one of the most productive in-land fishing areas in West Africa. During the 1970s the annual regional catch was approximately 90,000 tons of fresh fish, or 90% of the national catch (Table 7 of Appendix 2-A). Since 1983, the fish catch has dropped to 60,000 tons. Marketed production has fallen even more dramatically, at an annual rate of 13% from 1977 (7,700 tons of smoked and dried fish from the port of Mopti) to 1986 (3,700 tons) (Table 7 of Appendix 2-A).

2.2.2. Regional Organizations in Technology Generation and Transfer

a) The Regional Agricultural Research Stations

The Region of Mopti has two agronomic research stations that are under IER. Based in Mopti, the rice research station works on the improvement of the deep-water and floating rice varieties through varietal selection, hybridization, weed control, cultural practice development, and on-farm testing. Since the West African Rice Development

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Agency (WARDA) transferred the station to IER in the mid-eighties, the research program has slowed because of insufficient operating funds. One consequence of this has been the loss of a germ plasm collection of the local Oryza glaberrima species.

Members of the agricultural research sub-station known as PAR ("Point d'Appui de Recherche"), located in the rainfed Seno plain, conduct trials under the supervision of the Cinzana regional research station. In the same area, the Semi-arid Food Grain Research and Development (SAFGRAD) organization conducted on-farm tests of technologies recommended by the IER Division of Agricultural Research (DRA) between 1979 and 1988.

The National Institute for Zootechnical, Forestry and Hydrobiological Research (INRZFH) manages a hydrobiological laboratory in Mopti, which conducts surveys on fishing and fish consumption with the technical assistance of ORSTOM. INRZFH also has a sub-station which conducts research on forage.

b) The Regional Development Organizations

In the early 1970s the government, on a national scale, expanded its support of agricultural development from the irrigated rice and cotton sub-sectors to the rainfed areas. Several regional development organizations (ODRs) were created. These ODRs were responsible for input delivery and for providing marketing services (in collaboration with public marketing boards) and extension advice. With the advent of market liberalization in the early 1980s, the marketing boards for agricultural inputs and food crops have been gradually eliminated or re-organized and private sector traders have been encouraged to play a greater role in these markets. As a result, the role of the ODRs has been modified to center more on technical advice and infrastructure investment and maintenance.

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The government has located four regional development organizations in the Region of Mopti:

1) ORM (created in 1971), the Mopti Rice Organization, is responsible for rice production systems in the Delta;

2) OMM (created in 1972 but no longer in existence), the Mopti Millet Organization, was charged with millet development and extension activities in the Seno and Bandiagara areas;

3) ODEM (created in 1975), the Mopti Livestock Development Organization, is responsible for animal and pasture improvement throughout the region;

4) OPM (created in 1986), the Mopti Fish Organization, is responsible for the development of fish production, processing and marketing.

Presently, two of the four ODRs are fully operational with external funding. ORM and ODEM have funding from the French Economic Cooperation Fund (CCCE) and the World Bank. OPM operated with some European Development Fund (EDF) financing. OMM has been recently restructured into a Regional Direction of Agriculture (DRA), but has had no external funding since USAID ceased its financial and technical assistance in 1984 because of mismanagement at the organization's headquarters.

ORM has expanded the water-control systems of dikes and sluice gates. These systems do not, however, provide a guarantee against insufficient flooding. As a result of the low rainfall and flooding levels of the last decade as well as inappropriate technical packages, ORM has not been able to increase rice production. ORM has, however, been successful in extending animal traction among rice growers using the water-control system: 40% of the ORM rice growers adopted plows between 1975 and 1985 (ORM, 1987).

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Compared to the two other ODRs producing rice in Mali, ORM is probably the least efficient in producing and processing rice as reflected in the subsidy it receives to market its production. The subsidy received by ORM during the 1986-87 season to align the price of locally produced rice with that of imported rice was 44 CFA F/kg. This subsidy is greater than the 28 CFA F/kg subsidy at the Niger river irrigated agricultural development agency (Office du Niger) and the 21 CFA F/kg subsidy at the Segou Rice Organization (ORS) (Ministère de l'Agriculture, 1987, p. 99). Since the 1987-88 season none of these ODRs has received subsidies.

Cast in the integrated rural development model between 1979 and 1983, OMM was successful in distributing substantial quantities of seed fungicide, fertilizer and animal traction equipment.[7] Yields on average rose by 15%, from 502 kg/ha in 1979 to 586 kg/ha in 1981 (USAID, 1985, A-29). OMM has also participated in the on-farm trials carried out by SAFGRAD. Since 1984, when USAID withdrew funding, OMM has cut back on both activities and staff. However, when OMM was integrated into the DRA of Mopti in 1988, it still had 250 agents charged with providing extension services and collecting agricultural statistics.

ODEM has primarily concentrated its activities on livestock production (veterinary services, vaccination facilities, wells and water holes, slaughter houses, marketing centers, pasture reseeding, and sales of feed concentrates and salt slabs). ODEM's new program includes research on the possibility of farm-level integration of livestock and cropping activities.

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[7] In the late 1970s, OMM was the largest buyer of the fungicide Thioral (4.78 tons in the 1979, the peak year). Between 1973 and 1982, OMM sold 6,183 plows of different categories and 8,181 frames for carts (OMM, 1987a). Eighty to ninety percent of this equipment and draft animals were bought with credit from OMM, with a high recovery rate (Lecaillon et Morisson, 1986, p. 60).

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OPM has sought to improve access to fishing equipment through credit, organize fishermen for sharing equipment and marketing fish products, and improve processing and storage techniques. OPM has run into some problems: the credit program has not been well managed and the recovery rate has been low. However, OPM has been successful in widely extending improved techniques for drying and storing fish.

c) Other Institutional Support Services for Agriculture

Currently the National Agricultural Development Bank (BNDA) only underwrites credit with regional development organizations. The development organizations receive requests for loans from individuals or producer groups and are responsible for administration and follow-up of these loans. For example, ORM holders receive their credit through ORM, herders through ODEM, and farmers outside the areas staffed by an ODR through the regional office of the National Direction of Cooperative Organization (DNACOOP).

The BNDA offers loans at a 9% interest rate for a period of four years. The interest rate is set by the Central Bank of West African States (BCEAO). The BNDA is not subsidized by the state, but by several financing organizations, including the French and German Economic Cooperation Funds (CCCE and DEG). The BNDA has opened a branch in Sévaré (10 km from Mopti) to finance agricultural development activities. Despite a line of credit from the CCCE, its turnover has remained low because few farmer groups, particularly those in the rainfed area, meet the requirements of the loan guarantee.

The National Direction of Cooperative Organization (DNACOOP) is involved in promoting cooperative organization among farmers and in facilitating the access of farmer groups to credit. In the past, DNACOOP also organized crop purchasing.

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The non-governmental organizations (NGOs) involved in rural development mainly include the Catholic mission, International Union for the Conservation of Nature (IUCN), Save the Children, CARE, OXFAM, and a French Veterinary Organization (VST).

2.2.3. Markets and Prices for Agricultural and Livestock Products

The town of Mopti is located between grain producing zones (Sikasso, Ségou and the Seno) and grain consuming zones (Mopti, Gao, and Timbuktu). In this central location, the town is on an important national, and even international, commercial axis for coarse grain. The market at Mopti is considered a consumption market as well as a redistribution market for grain deficit areas to the north (Dioné and Dembélé, 1986; Steffen and Koné, 1988). The Seno plain, the Bandiagara plateau and the Koutiala area supply the Mopti market with millet and sorghum.[8] Paddy rice comes from the Delta and the Office du Niger area. Groundnuts primarily come from the excess supply in Bamako, which originates from the Kayes region (ODIPAC director, personal communication, 1988). Near to the town of Mopti, the market at Sampara is specialized in fish and the market at Fatoma in livestock.

Most of the markets throughout the region collect local products and distribute imported goods for local consumption. The collection of products for export is limited to livestock and, to a lesser extent, fish. Before the series of droughts, the region also exported rice and coarse grains. Since the decrease in local production, the distribution function of the markets has seemed to dominate the assembly function. The smaller the market, the more important its distribution function to consumers. Only livestock

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[8] Koutiala is an important grain market in the Region of Sikasso.

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remains an important export sector for the region (Harts-Broekhuis and de Jong, 1990, pp. 116-117).

a) Markets and Prices for Coarse Grains

One major characteristic of the Malian coarse grain market is that a small proportion of grain production is marketed. Based on surveys conducted during two good cropping seasons (1985/86 and 1986/87) in the Malian Company for the Development of Textiles (CMDT) and OHV zones, Dioné (1989, p. 131) shows that producers in that area sold an average of 7.8% of their grain production.[9] This percentage is much lower than the 10-15% surplus production that is generally assumed in some studies to be marketable, probably indicating that farmers in these two zones consume more (and store more) coarse grains in years of good harvest. On the other hand, producers made total purchases amounting to 80% of their grain sales (ibid., p. 148), or about 6.2% of their grain production. Given these low percentages of coarse grain transactions in the most important grain-producing area of the country and given an urban demand for coarse grains estimated at 9% of the aggregate demand for coarse grains, one may conclude that the nature of the Malian coarse grain market is residual (ibid., p. 208 and p. 325).

Since about 90% of the total demand for coarse grains is located in rural areas, any significant shift in domestic production due to, for example, weather or pests, induces a significant shift in market demand in the opposite direction. The market demand for coarse grain shifts widely from a poor to a good harvest because some coarse grain producers buy grains in deficit years and during deficit seasons, but withdraw from the market or enter the market as sellers in surplus production years.

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[9] This percentage does not include gifts and barters.

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The shift of coarse grain demand in the opposite direction of the shift of coarse grain supply results in wide fluctuations in the market price.

The price volatility observed in the monthly price series collected by the Early Warning System (SAP) in the district towns of the Region of Mopti reflects the thinness of the millet market. Immediately after the harvest in October and November, a period during which most of the marketed millet is sold, millet prices in the same market place in the Seno producing area can double from one year to the next (Table 1 of Appendix 2-B). For example, in Bankass, millet was 30 CFA F/kg in November 1986 and 60 CFA F/kg in November 1987. In November of the following year, millet prices fell back to 30 CFA F/kg. To a lesser extent, a similar fluctuation was observed in Koro. These price variations reflect the variations in millet production, which in turn depends on rainfall; rainfall was good in 1986 and 1988 but insufficient in 1987.

Large intra-annual price variations can be observed over the two-month period from September (pre-harvest) to November (post-harvest). For example, millet prices fell precipitously in the market of Bankass from 100 CFA F/kg in September 1988 to 30 CFA F/kg two months later and in the market of Koro from 120 CFA F/kg to 40 CFA F/kg over the same period (Table 1 of Appendix 2-B).

To illustrate these inter-annual and seasonal price variations, coefficients of variation were calculated from the SAP monthly price series from September 1986 to August 1989. For markets in the Seno producing area, these coefficients of variation are about 50%, indicating that the price of millet is 50% higher or lower than the three-year average in at least one month out of three (Table 1 of Appendix 2-B). These coefficients of variation are slightly lower for the consumption markets at Mopti (38%), Douentza

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(37%), Youwarou (42%), Gao (29%), and Timbuktu (25%), probably because these markets are supplied from diverse sources and from wholesalers involved in storage.[10]

Uncertainty about coarse grain demand is another important constraint to the development of the coarse grain market. Dioné (1989, p. 324) reports that, particularly in the market of Mopti, where most of the cereal supply for the deficit northeastern regions transits, wholesalers are continuously subjected to unstable expectations caused by unforseen interventions by OPAM, food aid releases, and liquidity crises among their clients. In addition to instability in market supply and demand, limited access to formal financing explains to a large extent wholesalers' reluctance to invest in seasonal storage of coarse grains (ibid., pp. 321-25). As a result, most of the grain wholesalers store for a short time with a rapid turnover of their stock, and purchase cereal throughout the year. This was particularly observed for the Mopti wholesalers (Dioné, 1989; Mehta, 1989, p. 77). Changes and uncertainties in the administrative regulations and controls of cereals trade bring additional uncertainties in private cereals marketing (Dioné, 1989, p. 331).

Despite these important constraints to the functioning of the cereals marketing system, markets seem to be well-integrated with each other. Market integration is an important indicator of market performance and can be tested by estimating the Pearson correlations of prices between pairs of markets involved in trade relationships. Correlation coefficients between millet prices are high between Mopti and Koutiala (0.94), Bamako (0.91), and, to a lesser extent, Sikasso (0.90) (Mehta, 1989, p. 128).[11] Market prices of millet in the district towns of the region are also highly correlated with

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[10] For example, the wholesalers in Mopti are supplied by counterparts located in southern Mali, and food aid releases are more frequent in the north of the Region of Mopti and in Gao and Timbuktu than in the south of the region (Mehta, 1989).

[11] Millet prices are selling prices at the wholesale level.

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each other. Correlation coefficients calculated on the monthly prices series collected by the Early Warning System (SAP) between September 1986 and October 1989 are in the range of 0.90 to 0.95 (Tables 1 and 2 of Appendix 2-B). Moreover, monthly millet prices in Gao and to a lesser extent Timbuktu are correlated with those in Mopti (correlation coefficients of 0.89 and 0.70 respectively). This high price correlation indicates that millet markets in Mali are, for the most part, well-integrated. The only exception is the Timbuktu market, which is less integrated because it is far less accessible than the other markets.

Marketing millet from the Seno producing area to Mopti is a profitable activity according to the estimation of the net marketing margin. The estimation of the net marketing margin is based on spatial margins calculated from markets at Bankass and Koro to Mopti, using the monthly price series collected by the SAP between September 1986 and August 1989 (Table 3 of Appendix 2-B).[12] The average spatial margins for two marketing periods (December 1986 - January 1987 and December 1987 - January 1988) are 25 CFA F/kg in Bankass and 22.5 CFA F/kg in Koro.[13] The costs of moving millet from Bankass and Koro to Mopti are estimated at 10 and 13 CFA F/kg respectively (Table 4 of Appendix 2-B). This leaves a net marketing margin of 15 CFA F/kg from Bankass and 10 CFA F/kg from Koro. These two net marketing margins are

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[12] The average margins over the three years are 15 CFA F/kg in Bankass and 11 CFA F/kg in Koro, or 24% and 17% of the price in Mopti (Table 3 of Appendix 2-B). A similar range of spatial margins was estimated in 1981 for the Seno plain to Mopti. Depending on the particular market of the area and the season, the spatial margins fluctuated between 10 and 50 FM/kg (5 and 25 CFA F/kg), or 10-30 % of the price in Mopti (BECIS, 1982, pp. 89-90).

[13] These two marketing periods are chosen to be consistent with the estimation of the net marketing margins between the Koutiala area and Mopti reported in Mehta (1989).

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higher than the average of two net marketing margins estimated by Mehta (1989, pp. 153-55) for moving millet from the Koutiala area (Zangasso) to Mopti. Over the period 1986/87-1987/88 the net marketing margin at the beginning of the marketing season for Koutiala - Mopti averaged 6.5 CFA F/kg. This would indicate that the grain-producing area of Bankass and Koro could compete with the grain-producing area of Koutiala in the Mopti grain market. Although this comparison between net marketing margins is rough, it provides an explanation for the millet trade between the Seno plain and Mopti.

b) Markets and Prices for Livestock

Livestock exports to other distribution markets in Mali or coastal countries, particularly Côte d'Ivoire, are probably the most important source of revenue for the Region of Mopti (OECD, 1987; Harts-Broekhuis and de Jong, 1990). In 1983 the region exported 24% of the 86,500 head of cattle and 45% of the 180,500 small ruminants that the country exported. However, between 1975 and 1985, the share of the region in exporting cattle largely fluctuated: between 13% (in 1982) and 34% (in 1980) (Harts-Broekhuis and de Jong, 1990, p. 120).

Since the late 1970s, Malian cattle exports have actually declined in absolute terms. Côte d'Ivoire, traditionally the largest importer of livestock from Mali, has launched a massive effort to develop livestock production in the north to supply an increasing portion of its demand for meat. Côte d'Ivoire has also bought stocks of frozen meat and other livestock products from South America and the European Economic Community (EEC) at subsidized prices. In addition, the overvaluation of the CFA franc has encouraged Côte d'Ivoire to import meat from countries outside the CFA franc zone. These factors have depressed Malian livestock exports to Côte d'Ivoire.

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On the other hand, domestic demand for livestock has suffered from 1) the decreased purchasing power of consumers, particularly the civil servants since the 1982 budgetary restrictions, and 2) from the increase in cereals prices due to consecutive droughts (OECD, 1987, pp. 159-62).

In 1984 the Ministry of Planning enumerated 23 livestock collection markets, 17 redistribution markets and one terminal market (i.e., market for export and consumption) in the Region of Mopti.[14] Most of these markets actually combine the three functions of collection, redistribution and consumption, although the geographic location of the market determines the relative importance of each function. The RESEMOS ("Recherche Socio-économique de l'Ensemble Urbain Mopti-Sévaré et sa Région") project surveys identified the markets of Fatoma and Kona (respectively 20 km and 74 km north of Mopti) as the most important livestock markets and the market of Mopti as a market predominantly for local consumption. Most of the livestock exports are organized from Fatoma and Kona to Bamako and Côte d'Ivoire (Harts-Broekhuis and de Jong, 1990, pp. 122-125).

Each regions' Governor sets the prices of meat throughout the region but does not control the on-the-hoof prices. In 1988 the official price was 500 CFA F per kilo of beef with bone and 700 CFA F per kilo of boneless beef in the Region of Mopti. Mutton is more expensive. On-the-hoof prices vary according to the season.[15] Under normal drought-free conditions, livestock prices gradually increase during the post-harvest period

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[14] For a complete definition of livestock market categories, see Bocoum (1990, pp. 38-39).

[15] The following explanation of the livestock price cycle is drawn from personal interviews with ODEM agents and from Hesse (1987), Diakité and Kéita (1988), and Harts-Broekhuis and de Jong (1990).

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as the demand for livestock increases and peak at the end of the dry season in May and June for cattle and at the period of the religious Tabaski feast for small ruminants. After the harvest and the peak cereals marketing period, farmers are able to invest any surplus harvest in acquiring livestock, which are in their physical prime at this time. Livestock merchants purchase large numbers of animals to take advantage of the favorable environmental conditions for driving them to urban centers and other countries. As the dry season continues, livestock prices begin to fall as a result of the increased supply and decreased demand. On the one hand, herders increasingly need to sell animals to purchase food and, on the other hand, the deterioration of environmental conditions impairs animal health and body weight and, hence, discourages investment by potential livestock buyers. During the rainy season, the livestock market is depressed due to contracting supply and demand. Once the rains begin in June, cattle owners are reluctant to sell because their animals are about to recoup weight losses suffered during the dry season and resume overall growth. In addition, herds undertake wet-season transhumances which distance them from market centers. Consequently, the supply of livestock on the market declines. During the same period, the hungry season, potential investors (farmers and traders) lack the resources or time to purchase livestock. As a result, livestock prices stabilize until livestock return from transhumances and purchasing power increases again.

The organization of the cattle trade is dominated by the Fulani, the traditional herders of the region. The RESEMOS project surveys indicate that between August and December 1984, the producer-traders constituted the most important group of persons attending the livestock markets (42% of the persons), followed by professional traders (31%), intermediaries (16%), guardians (6%) and butchers (4%). A producer-trader is either a

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either a herder or a farmer who attends the same market a few times a year to sell or buy a few animals (1.5 cattle or 2.5 small ruminants on average). Financial needs motivate most of these sales, while investment or the celebration of a special event motivates purchases. Among the producer-traders, herders are the principal suppliers of the markets. Professional traders are a heterogenous group of buyers: some purchase as few as one animal per week while others purchase as many as several thousand animals per year. At the time of the RESEMOS survey, the number of sellers largely exceeded the number of buyers (Harts-Broekhuis and de Jong, 1990).

Cattle trade is generally separate from small ruminant trade, as both trades are organized by different merchants in separate geographic locations (ibid., 1990, pp. 122-25). There is a greater degree of specialized skills among traders involved in cattle than those involved in small ruminants. The average transaction is also greater among cattle traders: 50% of cattle traders buy more than ten animals on a market day, while 50% small ruminant traders buy fewer than five animals. In contrast to the cattle trade, there is a more diverse ethnic representation in the trade in small ruminants.

In 1988, marketing costs were about 25,000 to 30,000 CFA F per head of cattle exported from Mopti to Abidjan by truck (Diakité and Kéita, 1988, p. 15). Merchants in the region consider the level of official taxes and duties as acceptable, but complain about the additional costs of unauthorized and hidden taxes.[16] These unofficial charges amount to about 10,000 - 15,000 CFA F per head, or approximately two thirds of the transportation costs and official charges to go from Mopti to Abidjan (ibid., 1988). Stryker et al. (1987, p. 65) confirms that "corruption has increased markedly in recent

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[16] The export tax is fixed at 2,000 CFA F per head of cattle and at 500 CFA F per small ruminant. Added to this are import administrative fees (CPS) of 3%, i.e. 1,500 CFA F for cattle and 300 CFA F for small ruminants (Stryker et al., 1987, p. 66).

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The milk market is dominated by the Fulani. Fulani women sell milk to their regular customers or in the weekly markets. Prices fluctuate seasonally according to supply conditions. Around the town of Mopti, prices ranged from 75 to 150 CFA F/liter in 1988, while in rural areas milk is sold at 10 to 50 CFA F/liter or traded for grain. Processing milk into butter adds a profitable margin for the women (Henry de Frahan et al., 1989, p. 91).

Little information and few data exist concerning fish marketing. Ninety percent of marketed production is in the form of either dried or smoked fish. Although most of it is marketed domestically, a large amount is exported to Burkina Faso, Ghana and Côte d'Ivoire (8 million tons of a total of 35.7 million tons produced from 1972 to 1985 were exported) (OPM, n.d., a).

2.3. Principal Farming Systems

The Region of Mopti includes three distinctive production systems: agropastoral, pastoral and fishing. Because the production enterprises and organization of these systems differ according to their agroecological environment, this section presents separately the production systems of the rainfed area from those of the inner delta.

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2.3.1. Farming Systems in the Seno and Bandiagara Plateau

The Seno plain and Bandiagara Plateau are primarily inhabited by the Dogon and, to a lesser extent, by the Fulani.[17] While the Fulani travel regularly over the plain and plateau, they are originally from the northern plain (the Diankabou, Dioungani and Dinangourou districts of the Koro "cercle") and the southern plain (the Diallassagou and Sokoura districts of the Bankass "cercle"). The central part of the plain and the Bandiagara plateau, which have the highest population density (22 persons per square kilometer), are almost exclusively inhabited by the Dogon. Other ethnic groups inhabit this area: the Mossi close to the Burkina Faso border and the Daffin or Marka in the southern Seno plain. The Dogon production system is largely an agropastoral system, while the Fulani production system is a pastoral system gradually evolving into an agropastoral system.

a) The Agropastoral System

This section describes the agropastoral system most common in the Seno plain and several isolated plains of the Bandiagara plateau. Relative to the production system described here, the production system of the Bandiagara plateau includes more gardening and small livestock enterprises, is more labor intensive, and uses more land-saving inputs since arable land is the dominant constraint (Cohen, 1981). This section discusses first the major farm enterprises of the agropastoral system, then the allocation of land and labor, and finally, the cropping systems and the use of surplus production.

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[17] Koro, one of the three administrative "cercles" of the area, is 80% Dogon and 15% Fulani (Koro "Commandant de Cercle", personal communication, 1987).

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i) Farm Enterprises

The principal cereal crop is pearl millet, which occupies an estimated 80-85% of crop area (OMM, 1987a). Millet is often intercropped with cowpeas. This study's formal survey indicated that millet-cowpea intercropping is currently practiced by 88% of this area farm household heads in communal fields and by 50% of dependent men and 22% of women in their individual plots. Most commonly creeping cowpeas are grown because of their high fodder yields. In addition to cowpeas, secondary crops include groundnuts, fonio, Bambara groundnuts, sesame and sorrel. Groundnut and fonio areas are each estimated at 5-7% of the total cultivated area, while Bambara groundnuts area is about 2-3% (ibid.). A small amount of maize and sorghum is grown in areas around the household compound or in low-lying areas and valleys. The maize and Bambara groundnuts varieties are short-season varieties harvested during the hungry season shortly before the millet and sorghum harvest. Raising various types of livestock, including chickens, goats, sheep, donkeys, and more rarely oxen supplements cropping activities. Cattle are generally entrusted to the Fulani, who return with them after the harvest to graze the stubble.

ii) Land and Crop Allocation

The agropastoral area is principally settled with small farms of 3-12 hectares, or approximately 0.4 to 0.8 hectare cultivated per active household member.[18] Farm size varies according to the agroclimatic environment, the number of adult family members, and the type of agricultural equipment (Table 2 of Appendix 2-C). Farm size is larger in

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[18] Cultivated area per farm unit and adult family member are based on estimations presented in Table 1 and 2 of Appendix 2-C. The total cultivated area per farm and adult family member is calcualted by multiplying the millet area per farm and adult family member by 1.2.

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the northern and southern parts of the Seno plain, where the population density is lower, and for equipped farms. In the central part of the Seno plain and Bandiagara plateau, farm size drops to 3 hectares, or less than 0.5 hectare per adult family member.

Land is assigned to each lineage by village elders, with usufruct rights inherited from father to son. Households heads divide the family land into communal and individual parcels. Because the objective of production on the communal fields is to assure an adequate grain supply for the family during the year, these fields are sown to millet and receive priority over the other fields in terms of labor allocation. Analysis of the formal survey data confirms that family fields are predominately planted in millet-cowpea and millet-cowpea-sorrel intercropping, and in decreasing order of importance, in millet, fonio, sorghum, groundnuts and lastly Bambara groundnuts grown in pure stands.

Individual parcels are generally sown to secondary crops that are used to accompany the main millet and sorghum dishes or are sold at the weekly market to obtain cash. The principal crop grown on women's fields is groundnuts for 44% of the women interviewed, followed by millet-cowpea and millet-cowpea-sorrel intercropping (31%), millet in pure stands (16%) and then Bambara groundnuts. On men's individual fields, millet-cowpea-sorrel, and millet-sorrel intercropping and millet pure stand crops are the most important crops; groundnuts are less important. The farm household heads grow very few secondary crops in their individual fields besides interplanting cowpeas with millet.

The formal survey shows that the area devoted to family fields is still expanding in the survey area for 49% of the farm heads interviewed. This expansion is generally at the expense of fallow periods: 51% of household heads increased the area devoted to family fields in this manner. In contrast, the area devoted to individual fields is not

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expanding at a similar rate: 23% of the women and 38% of the men had expanded the area devoted to their individual fields. The survey indicates that labor is the most limiting factor to the expansion of cereal crops on these individual fields, while lack of available field space ranks second. Seventy percent of those who had decreased the area they cultivated cited insufficient labor as the cause; among those who had made no change in their crop area, 47% said this was because labor was not available (Henry de Frahan et al., 1989, p. 97).

iii) Labor Allocation

Communal fields are worked collectively by members of the farm unit under the direction of its head, who also manages the distribution of the communal production. Sowing and weeding are first carried out on these fields before this work is done on individual fields. Each adult family member cultivates his/her individual parcels alone. The adult man or woman provides the inputs and owns the output. Generally, payments in cash or kind arising either from agricultural tasks performed outside of the farm household, or from migration, do not belong to the individual but to the patrimony of the farm household. The predominance of the household over the individual testifies to the continuing presence of patriarchal forms of labor organization.

Sixty-eight percent of farmers interviewed said that the first weeding is the most labor-intensive field operation, while 14% said planting and 10% said harvesting. According to Cunard (1983), farmers often sow a larger area than they can realistically expect to weed given their labor resources. This is done to reduce the risk of crop loss due to climatic and biological uncertainties.

Animal traction facilitates weeding, makes agricultural work less tiring (according to 44% of farmers interviewed), enables increases in planted area (22% of farmers) and increase

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increases soil moisture (10% of farmers). Among households using some equipment, women do less weeding in communal fields and cultivate a greater number of individual fields. This suggests that introducing animal traction into farming operations releases women to work on their own activities.

There is little use of hired labor in agriculture. The survey reveals that 27% of the farm household heads used workers outside of their own farm to carry out the first weeding, 14% used outside labor for the second weeding and 7% used outside labor for the harvest. During the weeding season, cash and food reserves are at their lowest and likely are not sufficient to pay laborers a wage rate (or its equivalent in food) superior to the opportunity cost of working their own land.

Aside from the individuals who specialize in trade and iron-works, non-farm activities among farm household members are very limited. There is, however, important seasonal and long-term migration to urban areas, particularly among young men, to earn cash for buying food, clothing, and agricultural inputs, and local taxes.

iv) Cropping System

The traditional cropping system does not involve land preparation other than clearing before planting. With the first rains, a few grains of millet are sown in holes at the top of small mounds of earth, which date from the previous planting season. During the first and second weeding, the weeds are uprooted with a locally-manufactured hoe, gathered in the rows between the millet plants and finally buried under ground. These mounds containing decomposed weeds give are called "organic mounds" and will be used to sow the following year's crop. The benefits of this ancient practice are threefold: 1) soil enrichment, 2) protection of young seedlings from blowing sand, and 3) capture of run-off for better water retention. Cowpeas are sown between the millet plants during the fir

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the first weeding, on some of the newly made organic mounds. Manure is brought to the fields when available and spread around the base of the millet plants. The harvest of millet is performed by uprooting the plants and laying them down flat. The millet heads are then cut and carried to the homesteads where they are stored.

Millet is often the first crop grown in rotation immediately following the fallow period. Secondary crops are generally grown at the end of the rotation period, except groundnuts, which are planted at the end as well as at the beginning of the rotation in women's individual fields.

Cropping practices vary according to the location of the field. Fields close to the village (the "laras" in Dogon) receive greater care than those located further away (the "baracou"). With regards to maintaining soil fertility, fields around the homestead receive organic matter from household waste while those further away are periodically fallowed and benefit from the tethering of animals during the dry season. Fields around the homestead are mainly cultivated with a millet-cowpea intercropping while fields further away also may have small areas of secondary crops. The plant density of millet and cowpeas is generally higher on the fields around the homestead. Crop varieties sown around the homestead are earlier and are given priority for the first weeding.

Where crop production is no longer entirely manual, modern techniques such as animal traction are integrated into the traditional husbandry practices without fundamentally changing them. Hence, the new cropping system is called a transitional system. The transitional system differs from the traditional system in the practice of plowing before planting (especially in the southern part of the Seno plain, where the soil is loamier and the rainy season longer), by the treatment of seed with fungicide (practiced by the majority of farmers), and by mechanical weeding (especially in loamy and sa

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and sandy loam zones). Chemical fertilizer is rarely used because of its low and uncertain profitability. Donkeys are the principal source of animal traction in the sandier zones and, less commonly, a pair of oxen in the loamier zones. The survey indicates that 33% of the farmers in the Seno plain had at least obtained a plow once. The proportion of donkey plows to oxen plows was two to one.[19] Mechanized farms tend to plant cowpeas and groundnuts in pure stands because intercropping makes mechanized weeding operations difficult.

v) Levels and Allocation of Production

Coarse grain yields are low because inorganic fertilizers are not commonly used and higher population pressures are breaking down the traditional bush fallow rotation systems, particularly in the central Seno plain and on the plateau. On average, millet yields range from 250 kg/ha in the northern part, 400 kg/ha in the central part, and 500 kg/ha in the southern part for millet-cowpea intercropping (OMM, 1974, 1975, 1980, 1981, and 1984 to 1986). The yield, plant density and production of cowpeas is limited by field and storage insects and soil-fertility problems. For millet-cowpea intercropping, cowpea grain yields range between 20 to 50 kg/ha and fodder yields between 200 to 500 kg. dry matter per hectare. With animal traction, yields are slightly higher because of the better preparation of the fields and the timeliness of weeding.

Millet is the most traded of the crops produced. Sixty-seven percent of farmers reported that millet sales were the most important of all agricultural product sales in

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[19] Animal traction adoption rates vary with the agroecology of the zone as well as other factors. Among farmers, the adoption rate in 1988 was the greatest in the central Seno plain (46%), while it was the lowest in the northern and southern parts (20%) (Table 1 of Appendix 2-C). As observed in other parts of Africa (Pingali, Bigot and Binswanger, 1987), the adoption rate is the greatest in the area with the highest population density. It is also the area with better soils and rural infrastructure.

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terms of revenue. Eleven percent of farmers indicated that groundnuts were the most important agricultural product sold. Ninety-two percent of the farmers reported that the greatest proportion of expenditures on agricultural products was for millet.

After paying local taxes, any surplus production above home consumption needs tends to be invested in small and large ruminants, the care and keeping of which is traditionally entrusted to Fulani herders. Raising small ruminant is increasingly a means of survival for farmers who use these animals for diverse purposes (labor payment, taxes, fees, and other expenditures). Small ruminants comprised the largest percentage of animal product sales for 60% of the farm heads interviewed. Only 23% of farmers reported buying small ruminants.

Despite relatively low yields, the traditional millet-cowpea intercropping is still the mix which is best adapted to the region's severe environmental conditions (sporadic rainfall, wind erosion, poor soils) and to producers (food for consumption, minimizing risk for potential harvest losses, optimal use of land and labor). The predominant characteristics of the agropastoral system include: the high population density in the central Seno plain and Bandiagara plateau, the decreased ability of the fallow rotation system to restore soil fertility due to the reduction of idle time, the minimal use of purchased inputs, the strong labor bottlenecks for weeding, and the lack of cash crops or other income generating activities.

b) The Pastoral System

The Fulani are traditionally transhumant herders who drive their herds from rainy season to dry-season pastures. They specialize in extensive herding of small and large ruminants and are most concerned with the growth of their cattle herd and in production of milk. After the harvest, the herds move to the southern Seno plain, where they spend

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the beginning of the dry season grazing stubble fields and Acacia albida leaves and pods near ponds. In December, when the flood begins to recede, the herds move to the "bourgou" areas. When the rains and the flood begin, the herds return to northern rainfed pastures.

As a consequence of recent droughts, the Fulani have increasingly become involved in crop production to reduce their vulnerability to climatic uncertainties. After a poor harvest the terms of trade between millet and livestock are less favorable for livestock, and having even a minimal assurance of millet from own production becomes important for these herders. As part of their increased participation in agriculture, 8% of Fulani in the northern part of the Seno plain and 4% in the southern part have acquired plows, according the survey. Oxen plows are more popular among Fulani than among Dogon because of the Fulani's greater access to oxen. In the northern Seno plain, 45% of those Fulani who own plows have oxen plows and 55% have donkey plows. Among the Dogon, the proportion is 33% and 67% respectively.

The Fulani pastoral system and the Dogon agropastoral system continue, however, to complement each other. The Fulani care for a portion of Dogon farmers' livestock in exchange for access to pastures and watering places during the dry season. The Fulani also trade milk for millet or other agricultural products. In addition, organic wastes from Fulani herds improve soil fertility on Dogon farmers' fields.

2.3.2. Farming Systems in the Delta

The major farming systems in the Delta include the agropastoral, pastoral and fish-based systems.

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a) The Agropastoral System

The agropastoral system in the Delta actually comprises three sub-systems: the rainfed crop-based system, the flooded crop-based system, and the flood recession crop-based system. Farmers are involved to different degrees in each of these sub-systems, depending on the geographic location of the farm. This can sometimes cause serious labor bottlenecks (Henry de Frahan et al., 1989, pp. 126-28).

i) Particularities of the Rainfed Crop-based System

Rainfed cultivation is located at the edge of the flooded zone, i.e., on the periphery of the active delta and lacustrine zone at elevations above the zone of inundation and in the inactive delta. Crops are more diversified in the rainfed zone of the Delta than in the Seno plain. Millet and sorghum are the principal rainfed crops, and they are often intercropped with cowpeas, groundnuts, sorrel, tobacco, tomatoes, and Bambara groundnuts. Squash, watermelons, and rainfed rice are intercropped with maize. Fonio, sweet potatoes and potatoes are grown individually. Areas formerly grown in rice are increasingly planted in sorghum and millet on ridges as a result of climatic risks.

The practice of making mounds of organic material for planting millet is less common here than in the Seno Plain. Sorghum is sown in holes which are dug in non-sandy areas and then filled with manure, while millet is cultivated in sandy areas. As in the Seno plain, early millet varieties (with three-month cycles) are generally cultivated in the fields around the house, which are rich in manure. Late varieties of millet and sorghum (four-month cycles) are cultivated on the fields further from the village compounds. Some long-cycle varieties of millet, sorghum and groundnuts have disappeared because of the decline in rainfall over the last decade.

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ii) The Flooded Crop-Based System

The flooded crop-based system has three main irrigation methods: natural flooding, controlled flooding on the ORM polders and the total control of irrigation on the small village irrigated perimeters (PPIV). Rice cultivation with natural flooding and rice cultivation with controlled flooding are widespread in the active delta. Most of the small village irrigated perimeters are located within a radius of 50 kilometers of the town of Mopti where pump installation has been concentrated.

Cultivation based on the natural flooding system and, to a lesser extent, cultivation based on the controlled flooding system are entirely dependent on the combined effects of the rainy season and the flood stages of the Niger River. Date of initial flooding, flood duration, peak flood level, and rate of flood recession are all factors that affect the yields of crops. Rice is sown during the early, which provide the necessary moisture for the plants to reach 30 to 40 centimeters before the floods arrive. Floodwaters enable growth to continue but must rise at a rate below that of plant growth to prevent plants from drowning (five centimeters a day for the native floating rice species, Oryza glaberrima). Rice plants must be flooded for a minimum of two months, but the highest level of the floodwaters should not exceed three meters. Traditional dikes around rice fields only partially control fluctuations in flood submersion and recession. Because farmers cannot predict run-off and flood level, cultivation based on natural floods remains a precarious activity with a highly variable production. On average, paddy rice yield is about 500 kg/ha (ibid., 1989, p. 135).

Controlled flooding enables the management of the floodwater rise after germination and the drainage of the polders by means of dikes, canals and gates. This management is provided by the ORM staff. ORM rice polders are cultivated both by farme

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farmers whose principal activity is agriculture ("paysans directs") and by civil servants and merchants ("paysans indirects") using hired labor. Only improved species of Oryza sativa are allowed in the ORM rice polders. In the last decade about 40% of the ORM rice growers owned a plow and draft oxen. The ownership of oxen, however, fell to 30% in 1985 (ORM, 1987). Hired labor is common and supplied by young men from the Bandiagara plateau after the first weeding of the rainfed crops. Between 1977 and 1987, paddy rice yields on harvested areas fluctuate from 700 to 1,500 kg/ha (ibid.).

Like the natural flooding system, the controlled flooding system provides no guarantee against insufficient rain and flooding. The climatic disturbances of the last decade in the active delta have led ORM to reduce allotted area from 40,000 to 20,000 hectares and extend rice varieties adapted to lower water levels.

To counter disruptions in rainfall and floodwater levels, ORM and local development committees have supported small-scale irrigation schemes of 20 to 30 hectares, irrigated from the river by small diesel pumps.[20] Rice but also vegetables, including potatoes, lettuce, beans, watermelons, tomatoes, and onions are cultivated in irrigated gardens near urban centers. ORM recommends the rice varieties IR 15-29 and IR 15-61 with transplanting for the irrigated plots. Pump irrigation is a new form of cultivation which requires rigorous management on the part of ORM and the farmers, who have no prior experience with it. In spite of many technical and management problems, paddy rice yields of 5-6 tons/ha were recorded in several fields in the

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[20] In addition to the current 140 hectares, a joint ORM, African Development Bank and World Bank program is funding the development of 700 hectares of small irrigated village perimeters, while the European Development Fund is starting a program of 500 hectares (CCE, 1987). Because the location of these small irrigated perimeters is heavily politilized, these schemes are casually called small political perimeters ("petits périmètres politiques")!

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perimeters (ORM, 1988). Such yields demonstrate the potential for increased production in these perimeters.

iii) The Flood Recession Crop-based System

In the Region of Mopti recessional cultivation is found exclusively in the lacustrine zone. Crops grown include sorghum, millet, cassava, sweet potatoes, cowpeas, sorrel, tomatoes, eggplants and onions. How these different crops are planted around the ponds and lakes is linked to the recession of the floodwater. Farmers may plant sorghum on the areas uncovered first by the retreat of the floodwater (January to February). With the next retreat farmers plant millet, but also other crops such as cassava, sweet potatoes, and cowpeas that are sometimes interplanted with sorghum. Land preparation for these crops is generally carried out with a short-handled hoe or with a plow. To sow, farmers make a shallow hole with a pointed stick, then dig another smaller hole inside the first into which they drop the seed.[21] The seed is then covered with fine sand. Residual soil moisture of the sandy clay soils provides the fundamental support for flood-plain crops during their early growth phase. The rains that ensure the further development of the crop are expected to arrive by July. The frequency of weeding is lake-specific. In the Sao lake for example, farmers generally carry out three manual weedings. The first two weedings are carried out during the dry season and the third takes place during the rainy season. The third weeding is the most time-consuming because of the high level of weed infestation and the difficult working conditions with the

[21] Some farmers in the district of N'Gouma transplant millet and sorghum from nurseries to fields left moist in the wake of receding floodwaters. Both techniques for transplanting and sowing prevent bird damage to the seeds and seedlings following germination.

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rains. The harvest of recession sorghum and millet takes place generally in September, before the arrival of the new flood.

Consequently, the varieties of sorghum and millet cultivated around the ponds and lakes manage to survive and even develop for five to six months with only residual soil moisture from the lake water. These varieties are photoperiod sensitive with a nine- to ten-month cycle. During the dry season, the portion of the plant above ground is dormant, but the roots continue to extend in search of moisture. With the arrival of rains, the plants are well prepared to capture the new moisture. If the flood is not severe, plants mature and grains can be harvested before rising waters inundate the fields. Sorghum yields are usually 800 kg/ha (Thom and Wells, 1987, p. 338).

In the last decade, lower floodwater levels have inundated smaller land areas and reduced the importance of these lakeside agricultural activities. Moreover, sand storms constitute a menace for most of the lakes situated in the Korientze and N'Gouma districts. Sand encroachment is especially a problem for those lakes which have become dry. Farmers from these two districts report that floating rice was the most widespread crop before the 1973 climatic changes. Presently the cultivation of floating rice has almost disappeared, yielding its place to the cultivation of upright rice varieties in some Korientze lakes.

The climatic and hydrological hazards have also led to many changes in agricultural practices. For example, sharecropping used to be the common institutional arrangement for bringing land into cultivation in the lakes and ponds. It is now disappearing because land owners no longer require rent from their tenants as a result of the reduction in the cultivable area and production. Plantings which used to be carried out in December and

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January in some lakes are presently delayed until March and April because of the late arrival of the floods.

b) The Pastoral System

In the Delta, the feeding of herds requires the constant movement of livestock and herders to benefit from wet and dry season pastures. Seasonal movement, or transhumance, follows a regular and specific pattern. In early July the herds leave the active delta for the wet-season pastures of the inactive delta and the Sahel where they also find salt deposits which provide mineral supplements. In October and November, after the ponds dry up and the wet-season pasture is exhausted, herds return to the periphery of the active delta and congregate in the waiting areas until the floodwaters recede. The herds then enter the lush recessional pastures, the "bourgoutières", as the waters recede from southwest to northeast.

Entrance to the "bourgoutières" has been regulated by the Dina code, a set of rules instituted by Sekou Amadou in the nineteenth century (Cissé, 1985). This code is still actively enforced by the traditional authorities of the Delta, often in conflict with the 1969 governmental abolition of traditional water, land, and pasture rights. The Dina code divides the flooded pastures into units of different size called "leydi". In each of these a traditional social structure is charged with the allocation of pasture rights, the making of decisions related to access to the pastures and modalities of their use, the fixation of payments for pasture and finally, the determination of the dates and order in which herds will access the pastures.

There are special statutes for: 1) village pastures for milk-producing cows, 2) the transhumance routes and 3) the temporary shelters where herds crossing the "leydi" rest. Outside the active delta, the use of rainfed pastures is not controlled but the main tran

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transhumance routes are recognized and in principle protected from encroachment by crop production.

The typical herd is traditionally divided into smaller groups which are managed according to the method of organization developed in the Dina code. The bulk of the herd, known as the "garti", comprises the majority of dry and pregnant cows, the majority of the bulls and heifers, some older steers and a limited number of mating bulls. A small percentage of lactating cows and their calves accompany the "garti", their principal role being to provide milk for the herdsmen. The "garti" is the only unit that fully participates in

transhumance. The majority of lactating cows, their calves, some heifers, steers and mating bulls, form the part of the herd known as the "bendi". This part of the herd provides milk for sale or domestic consumption. Another part of the herd is known as the "dumpti" and comprises two or three suckling cows for each family. These animals are only separated from the rest of the "bendi" during the rains (August to October), joining the "bendi" when it migrates to the rainfed pastures. Being few in number, the "dumpti" animals can easily benefit from a supplement of millet bran, cotton seed and salt. The "dumpti" cows are among the best milkers in the herd. They are kept apart from the mating bulls to avoid untimely conception.

To these three sub-groups of animals identified during the reconnaissance survey must be added two other sub-groups identified and described by the International Livestock Center for Africa (ILCA, 1981). These two groups are the "tjipi" and the "aladji". The "tjipi" is a part of the "bendi" and is composed of cows, which from January to March, are led to various villages in the flooded zone in order to trade milk for rice. The "aladji" is composed primarily of oxen for transport. The "aladji" oxen accompany

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the "tjipi" cows on commercial expeditions or take part in transhumance as part of the "garti" or "bendi". The "aladji" also includes a small number of draft oxen which belong to absentee farmers or to Fulani who also cultivate rice. During most of the dry season the "aladji" is kept close to the villages to help plow the rice fields immediately after harvest (February-March) and when the first rains come (May-July). The "aladji" rejoins the "garti" when it departs for the arid land pastures.

In the last two decades there has been evidence that this system is causing environmental stress (OECD, 1987; Thom and Wells, 1987; Diakité and Kéita, 1988). Increased human and livestock populations and the official abolition of traditional rights have worsened pressure on available resources. The Malian administration is currently responsible for enforcing decisions on the use of grazing areas, in consultation with representatives of the herders, the local administration and ODEM. However, official regulations are vaguely defined and removed from the still active traditional socio-political structures of the area. Few conflicts are actually solved by the government administration between groups of herders or between herders and crop producers over the use of land and pasture. When these conflicts are solved, it is often done in an arbitrary and partial manner (Diakité and Kéita, 1988).

Gradually, herders have been losing the ownership of their herds and have had to resort to hiring themselves out to livestock investors to manage their herds (OECD, 1987; Diakité and Kéita, 1988, p. 6). On the one hand, successive droughts have impoverished traditional herders, who have lost all or part of their herds through unremunerative sales or through famine and disease. On the other hand, farmers and particularly traders and civil servants, who have been relatively more protected from the consequences of the drought, have invested in livestock. As hired herders, traditional her

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herders are losing not only control over their herds but also interest in protecting natural resources as instructed by the traditional rules. Ancestral savoir-faire in herd management is also disappearing.

c) The Fish-based System

Fishermen in the Delta area can be divided into groups according to the type of fishing they engage in: nomadic and semi-nomadic. These two types are widely practiced in the lacustrine zone, but much less so in the active delta.

Semi-nomadic fishermen also farm in the wet season. However, they differ from farmers who occasionally fish because most of what the semi-nomadic fishermen catch they sell, while farmers fish to supplement the family diet. The semi-nomadic fishermen are also better equipped with fishing gear than farmers and usually move from site to site according to information concerning the abundance of fish.[22] The movements of fishermen follows the migration of fish from south to north. Fishing begins with the flood recession in November and December and intensifies until April for the duration of the recession. The majority of the fishing gear used by semi-nomadic fishermen is in the process of being banned (e.g., casting nets) in order to enable the fish population to recover from overfishing. As in the pastoral system there are many conflicts among fishermen over their rights to fish, aggravated by ill-defined official regulations.

The semi-nomadic fishermen organize collective fishing days in the Niger, Bani and Diaka rivers and in lakes and ponds. Before the fishing days, fishermen agree on the payment of taxes and rights with the administrative and traditional authorities.

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[22] Fishing gear differs according to the period and type of fisherman. Farmer fishermen use primarily nets, harpoons and hooks. Semi-nomadic fishermen use hoop nets, seine nets, fishing lines with many hooks, and casting nets, enabling them to catch large numbers of fish.

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Fishermen from other areas always pay more than local fishermen because these visitors are usually better equipped with fishing gear. Fish caught during these fishing days authorized by the Forestry Agency (Services des Eaux et Forêts) belong to the owners of the fishing gear. The catch is then dried or smoked for sale to wholesale merchants from Mopti. Some semi-nomadic fishermen are organized in cooperatives supported by the Mopti Fish Organization (OPM).

Nomadic fishermen specialize in fishing and do not farm at all. They are constantly moving along the waterways in search of fish. In contrast to the other fishermen, nomadic fishermen own motorized canoes for transporting family and baggage, in addition to paddle canoes, which are used for fishing.

2.4. Constraints to Farming Systems

This section distinguishes the constraints due to biophysical factors (mainly rainfall, flood, soil fertility and pests), due to input availability (labor, land, and capital), and due to market possibilities, infrastructure and institutions. The section starts with the agropastoral system of the rainfed area, then continues with the agropastoral systems of the flooded area, the pastoral system and the fish-based system.

2.4.1. The Rainfed Crop-based Farming System

a) Biophysical Constraints

The average rainfall from 1979-87 was 20% lower than the historical average, and was poorly distributed over the course of the crop cycle (Table 2 in Appendix 2-A). During the actual drought years, the most common millet varieties in the Seno plain had either cycles which were too long (the NBB millet variety has a cycle of 110 to 130 days) or p

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or poor drought resistance (the NKK millet variety with a cycle of 100 to 110 days).[23] In contrast, farmers in the Bandiagara plateau have a more diversified set of millet varieties, some of which have short cycles (80 to 100 days) or are drought resistant (Henry de Frahan et al., 1989, pp. 150-54).

The sandy soils of the area are deficient in phosphorus, nitrogen and organic matter and have a low capacity to retain water. Many areas on the Bandiagara plateau are characterized by shallow, rocky soils which prevent any form of cultivation. Soil nutrient deficiencies and low soil water retention are considered as the two major natural constraints that limit yields of rainfed crops in the semi-arid area (OECD, 1987; Sanders et al., 1988).

Strong winds and run-off water are additional natural constraints in the rainfed area. Soil erosion due to wind endangers newly-emerged seedlings in the Seno plain. Soil erosion from run-off water is particularly severe on the Bandiagara plateau.

Rainfed crops are subject to insect attacks both in the field and in storage. Ear-boring caterpillars (Raghuva) and, to a lesser extent, stem-boring caterpillars (Acigona) are the major pests on the most common millet varieties (Henry de Frahan et al., 1989, pp. 150-54). Insect attacks on cowpeas are more severe in the field than in storage, but the severity depends on the varieties (ibid., p. 107). Cantharides and grasshoppers are sporadic problems. Witchweed (Striga) infests cereal and cowpea fields, particularly where soil fertility is low. Diseases, such as mildew and black rust are not acute.

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[23] In the survey, 58% of the respondents said that the NBB cycle was too long and 46% of the respondents said that NKK has poor drought resistance. Fewer farmers complained about the cycle of the local cowpea varieties: 29% reported that the cycle was too long, while 37% found the cycle satisfactory.

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of the Seno plain as an area with "very high population pressure" and the central and southern parts of the Seno plain and the Bandiagara plateau as an area with "excessive population pressure." Population pressure on arable land has led farmers to shorten fallow periods and till more marginal lands. Particularly in the central part of the Seno plain and in the Bandiagara plateau, the survey indicated that the use of animal traction has reduced the fallow period. Consequently, soil fertility is deteriorating and grazing areas are shrinking.

Besides animal traction and fungicide, the use of other purchased inputs, such as insecticides and chemical fertilizers, is largely absent. Chemical fertilizers are only used for vegetable gardening in the Bandiagara plateau. Such use is profitable and these fertilizers are easily obtainable from Mopti. Elsewhere, a combination of several factors can explain the minimal utilization of purchased inputs. Low, variable and unpredictable rainfall, poor soil water retention, and intra- and inter-annual crop price volatility discourage the intensive use of purchased inputs that would save labor and land. For example, a technical package composed of mineral fertilizers, fungicide, insecticide and cultural practices that agricultural research recommended for millet in the Seno plain is only profitable if the rainfall is not below the long-term average and if the millet price is the annual average price, not the post-harvest price (Henry de Frahan et al., 1989, pp. 18-24). This suggests that rainfall deficit and millet price volatility are two key constraints to the use of purchased inputs. The absence of profitable cash crops or other income generating-activities besides migration, and the head tax also hamper investment in agriculture. In addition to the low farm income, access to formal agricultural credit and input supply is very limited to farmers in the rainfed area. These constraints are examined in the next section.

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c) Marketing, Infrastructure and Institutional Constraints

The input marketing infrastructure is not well developed in the rainfed area, even though some farmers have an effective demand for purchased inputs, such as animal traction and seed fungicide. Two examples taken from the reconnaissance survey illustrate this point. The effective demand for plows and carts went unmet in the Seno plain during several years. In 1986, farmer organizations placed an order for 764 carts and 344 donkey plows to the Malian Agricultural Mechanization Company (SMECMA), paying in cash 20% of the price on credit value as a down payment. Two years later, because SMECMA had not yet delivered the equipment, DNACOOP, acting for the farmer organizations, finally imported the cart frames from Senegal and purchased the plows from OMM, which had an unsold stock. Compounding delivery problems are design problems: the equipment manufactured by SMECMA is not always well-adapted to the soil and climatic conditions around the Seno plain where, for example, crop spacing is greater than in other areas (Traoré, 1988). In addition, access to formal agricultural credit is limited to a few farmer organizations that are well connected with DNACOOP and the political leadership of the area.

The delivery of seed fungicide, Thioral, by OMM to farmers fell dramatically from 4,755 kg in 1979 (allowing the treatment of about 73% of the millet area) to 431 kg in 1984 (allowing the treatment of about 7% of the millet area), even though the fungicide was widely accepted by farmers (OMM, 1987b). Thioral's wide and rapid adoption since 1974 is explained by its immediate effect on seeds, its ease of application and its low price. Since OMM stopped delivering in 1984, farmers have purchased the fungicide through their farmer organizations from the Malian Company for Chemical Products

(SMPC) at 60 CFA F a bag.[26] However, the quantity distributed through that channel was insufficient to meet the strong demand. Only 1,407 kg and 780 kg were delivered during the 1987-88 and 1988-89 cropping seasons respectively. Farmers could get the product from the local markets but at a much higher price, ranging between 65 and 130 CFA F a bag, according to the survey.

Price volatility due to the narrow and residual market of millet is accentuated by additional factors. Costly licensing procedures and export restrictions have persisted until recently, although the domestic trade of coarse grains was liberalized since 1982. In addition, the taxes levied during the post-harvest period and debts due at the same period increase producer sales of agricultural products and depress producer prices even further (Dioné, 1989).

The thinness of the agricultural product market applies also for crops such as cowpeas and groundnuts. In addition to the problem of protecting large quantities of these products in storage, the thinness of the market and the consequent price volatility are the major reasons given by farmers, particularly women, for their reluctance to increase production of these products.

Access to markets is relatively easier for farmers of the Bandiagara plateau and the central part of the Seno plain than for farmers of the northern and southern parts of the Seno plain. Although the feeder roads on the plateau are rocky and not maintained, they lead to the Mopti-Bandiagara-Sangha highway. In the central part of the Seno plain, Bankass and Koro ("cercle" capitals) are accessible from the San-Mopti road at Somadougou. Koro is, however, periodically inaccessible during the rainy season. The

[26] One bag of 25 gr. of Thioral allows the treatment of 10 kg of millet seed, enough to plant one hectare.

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northern and southern parts of the Seno plain, on the other hand, are much more isolated. They are located away from the main highways and are not close to any important markets other than Douna in the north and Diallassagou in the south.

Farmer organizations are not yet organized in the marketing of their products, except in the Bandiagara plateau, where onion marketing is well developed. Despite this, many problems of organization, storage and transportation persist for assembling onion despite the support of DNACOOP, GTZ and the Catholic mission (Traoré et al., 1988).

In addition to head taxes, which were between 2,000 and 2,500 CFA F per adult for farmers of the Seno plain in 1987 (Henry de Frahan and Diarra, 1987, p. 58), the Forestry Agency (Service des Eaux et Forêts) collects additional fees and fines for wood cutting. These fees and fines add a significant and often unpredictable burden on farmers. Some forestry agents misuse the forest code to levy unjustified fees and fines on farmers (ibid.). As a result, the Forestry Agency is often viewed by farmers as a repressive agency rather than an extension and development agency. This widespread opinion about this agency jeopardizes agroforestry actions in the area.

In summary, low and variable rainfall, poor soil fertility and inadequate soil water retention in combination with insect attacks, labor shortages in the critical planting and weeding periods, and the diminishing access to land are the major physical and resource endowment constraints to increased production in the rainfed area. On the other hand, the absence of any profitable cash crops or other income-generating activities, the financial burden from taxes and other fees, and the price volatility for existing crops hamper a larger use of modern inputs such as animal traction adoption, fertilizer and pesticides, and the development of a formal agricultural credit system. As a result, input and product marketing infrastructure is not well developed. This, in turn, hinders the adoption and dissemination of existing technologies for farmers who are able and willing to invest in agriculture.

2.4.2. The Flooded and Flood Recession Crop-based Farming Systems

Because the production constraints are similar, the flooded and flood recession crop-based systems are considered together.

a) The Biophysical Constraints

Between 1977 and 1987, low rainfall has prevented Oryza sativa rice grown on the ORM polders from developing sufficiently before the arrival of the flood during the drought years. Furthermore, the deterioration in the hydrological regime resulted in less than 12% of the area being harvested in the ORM polders in four out of eleven years (Henry de Frahan et al., 1989, pp. 25-26). Although lower on average, yields from areas outside the ORM polders are less affected by low rainfall and flood levels mainly because these areas are sown in the local Oryza glaberrima species, which has a stronger drought resistance and a better adaptability to different floodwater levels than the Oryza sativa species (ibid., pp. 159-61; Niaré, personal communication, 1988).

Farmers' uncertainties about rainfall and floodwater have prevented them from adopting the technical package proposed by ORM, which consists of end-of-season plowing, weeding before the arrival of the flood and the application of chemical fertilizer. Despite a profitable marginal rate of return estimated at 109% under sufficient rainfall and floodwater conditions, the three major components of the package have never been widely accepted by ORM rice growers (Henry de Frahan et al., 1989, pp. 24-25). For example, the fertilized area of the ORM holdings has never exceeded 7% and has fallen to

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to about 2% since 1983 (ORM, 1987). On the other hand, rice growers were keen to adopt the DM 16 rice variety that was part of the ORM package (but never available from ORM) for its earliness, its adaptability to different levels of flooding, its yield performance, and the long, fine and tasty grain (Henry de Frahan et al., 1989, pp. 24-25 and p. 71).[27]

Wild rice species (Oriza bartii and Oryza longistaminata) are the most common weeds affecting rice yields. These weeds have to be cut down from canoes while the floodwater level is still high. End of season plowing is an additional way to get rid of these weeds. Borers are frequent on Oryza sativa species. Rodents and granivorous birds also affect yields.

In addition to the late arrival and low volume of the floods, sand storms endanger recessional cultivation. These storms fill some lakes with sand where ten years ago recessional cultivation was still very productive. As a result, the flood recession crop-based system is evolving to include rainfed crops, gardening and livestock activities.

b) Resource Endowment Constraints

Seasonal labor bottlenecks constitute the most important resource endowment constraint for both systems. For the flooded crop-based system, these bottlenecks particularly occur for rice growers who postpone the first weeding until there is strong evidence that the floodwater is going to reach their plots. With the increased diversification into rainfed agriculture, weeding of both flooded and rainfed fields overlap and one of the two, generally rice field weeding, is delayed. Animal traction is used for early and end-of-season plowing, although not for weeding because of the

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[27] Some DM 16 plants from ORM and the Mopti rice research station were stolen and planted by farmers (Diarra, personal communication, 1988).

floodwater. The use of animal traction is limited because the lack of draft oxen or the poor condition of the animals after the dry season. For example, in 1985, one quarter of ORM rice growers who owned plows did not own draft oxen (ORM, 1987).

Labor bottlenecks are even more acute for farmers involved in recessional cultivation, because of their higher degree of crop diversification. This crop diversification has raised labor organization and allocation problems similar to those identified for the other crop-based systems.

Access to flooded land is becoming increasingly a constraint because of the reduction in the floodwater level. Some rice growers have lost plots formerly cultivated, both inside and outside the ORM polders. Access to capital is generally not a problem for ORM rice growers because most of them are involved in off-farm income-generating activities and ORM intervenes for them to obtain credit from the BNDA. However, rice growers outside these ORM polders generally have no other income-generating activities and no access to formal agricultural credit, which is cheaper than informal credit. As a consequence, they have difficulties investing in animal traction.

c) Input Availability, Infrastructure and Institutional Constraints

Rice growers on ORM polders benefit from the supply of modern inputs managed by ORM. However, the inputs available from ORM are not always the most appropriate for these rice growers. For example, the preference expressed for the DM 16 rice variety had still not been met in 1988. Yet, this variety was developed in 1965 (Goïta, 1986) and tested in the 1970s (Dembélé, 1986). Insufficient rainfall and floodwater and the lack of funding to run water pumps have inhibited the seed multiplication and production process at the Mopti rice research station and at ORM (Henry de Frahan et al., 1989, p. 71). The supply of agricultural inputs is also limited by the inaccessibility of some crop-producing areas during the flood period, particularly Tenenkou and Youwarou, which are located on the western and northern edges of the inner delta.

Conflicts between rice growers and herders are frequent. Some ORM rice polders have been established in traditional waiting areas where herds used to stand before entering the "bourgoutières" (de Jong et al., 1989, pp. 277-78). An OECD study (1987, p. 135) shows that, from an economic standpoint, growing rice in these areas is not necessarily the optimal use of these lands. The OECD study estimates that the value of the best recessional pasture is 30,000 to 40,000 CFA F/ha, while rice provides a net income of only 21,000 CFA F/ha.[28]

To conclude, farmers of the agropastoral system in the flooded area have responded to the more frequent rainfall and flood deficits by diversifying their activities, particularly into rainfed crops. The increased diversification of these two systems has, however, created additional labor bottlenecks for weeding. Partly because of climatological stress but also because of the inappropriateness of ORM's recommended technical packages to cope with this stress, the use of purchased inputs, which were expected to increase yields, has remained low. The competition for less-available flooded lands has exacerbated latent conflicts among farmers and between farmers and herders.

2.4.3. The Pastoral System

a) The Biophysical Constraints

Animal nutrition is generally considered the first constraint to livestock production in the Region of Mopti (OECD, 1987; Diakité and Kéita, 1988). This constraint is not

[28] On the basis of a yield of 900 kg paddy rice, which is only possible in years with favorable rainfall and hydrological conditions.

linked to the method of raising cattle and small ruminants. On the contrary, the OECD (1987) report shows that extensive herding, with transhumance between the dry and rainy season pastures, is the most appropriate and effective type for the region. Rather, inadequate animal nutrition is a consequence of 1) the low soil fertility in phosphorus and nitrogen, 2) the deterioration of the pastures due to overgrazing and climatological factors, 3) the reduction of grazing areas due to population pressure on arable land, and 4) the small quantity of crop residues due to the extensive nature of the crop-based farming systems. To compensate for the poor mineral content of pastures, ODEM has marketed mineral blocks. However, these mineral blocks lacked sufficient calcium and phosphorus to supplement livestock feedings adequately.

The deterioration of the rainfall and hydrological regimes over the last decade has reduced the possibilities for biomass regeneration. This climatological deterioration has rapidly translated into the degradation of the grazing areas with regard to both perennial grasses and ligneous species and has exacerbated the disequilibrium which already existed between herd size and carrying capacity. In addition to the degradation of the grazing areas, parasitic diseases persist among transhumant cattle and small ruminants.

b) Access to Grazing Areas

Access to grazing areas is the greatest constraint to increased herd size. In the face of uncertain rainfall and hydrological regimes, farmers tend to cultivate more land, and those who used to specialize in rice or recessional crops are diversifying into rainfed agriculture. In addition, non-agricultural production systems, such as fish-based and pastoral systems, are diversifying into agriculture. As a consequence, population pressure on the arable land provokes conflicts between crop producers and herders over the use of the traditional grazing areas. These conflicts generally result in a progressive loss of control over the grazing areas by the herders (OECD, 1987; Diakité and Kéita, 1988). In very few instances has that control been regained: facing growing protest from herders, ORM returned three rice polders to herders in 1983 (de Jong et al., 1989, p. 278).

c) Marketing, Infrastructure and Institutional Constraints

The marketing possibilities for livestock have been decreasing, mainly because of the decline in purchasing power among domestic consumers and the fall of import demand from coastal countries, particularly Côte d'Ivoire. Export taxes and administrative fees also discourage exports. Despite these limited market opportunities, both herders and farmers continue to invest in livestock because the region offers few alternative investment opportunities. The social prestige attached to being the owner of a large herd is another important factor explaining the amassing of livestock.

The pressure of the influx of animals on waiting and grazing areas in the inner delta is gradually relaxing because of a well-digging project, initiated by ODEM, on the wet season pastures peripheral to the inner delta. This infrastructure will slow the arrival of animals in the waiting areas, and consequently limit overgrazing in these areas. The equipment for these boreholes has been obtained through credit allocated to groups of herders.

The 1969 abolition of traditional rights to land and pasture is threatening the balance between environment and resources, particularly during periods of droughts. The decision to give equal access to resources of the region has more than doubled the number of users, increasing the pressure of the human and livestock populations on these natural resources (Thom and Wells, 1987, p. 342). Environmental degradation is well advanced and is expected to continue unless rainfall levels increase and the use of the natural resources by herders and rice growers is restricted.

In sum, the climatological deteriorations have exacerbated the disequilibrium which already existed between herd size and carrying capacity, partly as a result of the abolition of the traditional herding rights. The increasing human and livestock population pressures on the traditional grazing areas, the shrinking market possibilities and the persistent investment in livestock are accentuating even more this disequilibrium. As a result, herders are losing the control on their herds to new incoming investors.

2.4.4. The Fish-based System

Since the 1970s, the productivity of the fish-based system has declined because of the reduction in the fish population and the waste in processing and marketing fish products. The reduction of the fish population is the cumulative effect of several factors. The first is the lack of a coherent fishing and fish replenishment policy. The second factor is the deterioration of the hydrological regime, which has resulted in the concentration of fishing in fewer and smaller bodies of water. This has aggravated fish depletion and spawned conflicts over fishing rights. The third factor is the increase in the human population involved in fishing as a result of the diversification of the farming systems' resource base. The combination of these three factors has dramatically endangered the fish population in the Delta area.

The productivity of the fish-based system is also affected by the waste in the processing and marketing of fish products. The Mopti Fish Organization's attempts to reduce this waste yielded encouraging results when external funds were provided to finance extension. Improved techniques for drying and storing fish were widely extended (Koné, personal communication, 1988). However, with the end of external financing, these results have faded. It is unclear whether this is due to the reduction in the extension activities oriented to fishermen or to the low cost effectiveness of the techniques that were been extended.

2.4.5. Conclusions

All production systems in the Region of Mopti dramatically suffered from the decline in rainfall and floodwater levels that characterized the period 1968-1988. As a result, the regional contribution to national production in millet/sorghum fell from 24% over the period 1974-77 to 16% over the period 1985-88 and the regional contribution in rice declined from 38% to 28% over the same period (Tables 3 and 4 of Appendix 2-A). Similarly, the regional contribution to the national cattle herd fell from 25% (1980-82) to 20% (1985-87), while the proportion of small ruminants from the region remained at the same level (20%) over these two periods (Table 5 of Appendix 2-A). The fresh fish catch fell at an annual rate of 3% from 1970 to 1987 (Table 7 of Appendix 2-A). These statistics indicate that the importance of the Region of Mopti has declined in these activities for which it has traditionally had a competitive edge.

These climatological shocks on the production systems and other natural constraints to crop and livestock production have revealed the fragility of these systems. Low soil fertility and water retention, wind and water erosion and pests on crops (particularly insects) and livestock (particularly parasites) have contributed to the vulnerability of these systems. Besides these natural constraints, seasonal labor scarcity afflicts the agropastoral systems, while access to grazing areas is a major problem for the pastoral system. For all these systems a lack of capital prevents producers from investing in inputs that would save labor or land. The lack of capital is associated with several economic and institutional factors: crop price volatility due to the thinness of the agricultural markets; absence of any profitable cash crops or other income-generating activities besides migration and, occasionally, livestock; head taxes and administrative fees; and limited access to formal agricultural credit. As a result, the input and agricultural product marketing infrastructure is not well developed, which in turn hampers agricultural development. Furthermore, market outlets for livestock products are shrinking as a result of the decline in purchasing power among domestic consumers and the fall of import demand from coastal countries, particularly Côte d'Ivoire.

These factors, combined with an increased population pressure, endanger the sustainability of the production systems of the area. Without the means to invest in soil fertility, farmers are forced to neglect the traditional rotation system of long fallow periods and to cultivate marginal lands, all of which depletes soil, grazing and timber resources. Farmers have also reacted to economic and environmental stress by diversifying their activities, which has worsened pressure on natural resources. As a consequence, tenure conflicts over the use of arable land, pastures, forage, wells and fishing areas are mounting, particularly in the Delta area, while soil fertility, perennial and ligneous species, bourgou areas, and the fish population are endangered. Some producers have migrated to urban centers or more favorable agricultural areas, such as southern Mali. Traditional herd owners have became guardians for new livestock owners.

These constraints to production in the Region of Mopti are daunting. Whether FSR can contribute to relaxing these constraints is the question that will be examined in the following chapters.

3. CONCEPTUAL FRAMEWORK FOR THE STUDY

3.1. Introduction

Conceptually, farming systems research (FSR) can be examined in the framework of the what is called Institutional Agricultural Technology System, the system for technology development and transfer (Kaimowitz et al., 1989, p. 4). The main functions of the technology system are generally performed in two complementary institutional systems: the National Agricultural Research System (NARS) for technology development and the Technology Transfer System for technology transfer.[29] Generally, the NARS includes FSR in addition to on-station experiment research (OSR). The transfer system includes all the institutions or agents active in technology production (i.e., the process of producing physical inputs and/or information) and delivery and in monitoring and evaluating the use of new technologies. The extension service is a transfer system institution that facilitates the promotion and, in some cases, the distribution of new technologies. Monitoring and evaluating the use of technologies are often functions carried out either by the extension service or FSR. However, there is not a strict adherence to institution-specific tasks or responsibilities among the different components of the technology system. Some research institutions may be involved in

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[29] In this study, for simplification , the Institutional Agricultural Technology System is shortened to technology system, the National Agricultural Research System to research system or NARS, the Technology Transfer System to transfer system and the on-station experiment research to on-station research or OSR.

producing, delivering and evaluating new technologies, while some technology transfer institutions may play an active role in generating and adapting new technologies.

Therefore, the conceptual framework needs to encompass the key technology system institutions and linkages that exist between FSR and the complementary technology system institutions, in addition to the internal structure of FSR. For example, the availability of inputs, credit, and extension services are extrinsic factors to FSR that influence the contribution of FSR. A broader conceptual framework can indicate the potential relative contributions of FSR and other technology system institutions to improving the productivity of the Region of Mopti's farming systems.

Productivity improvement does not depend solely on the technology system's performance. It also depends on a wide range of policies and institutions outside the technology system that may affect directly or indirectly the farming systems. Fiscal, monetary, price and trade policies may cause price distortions in the production and marketing systems which impede allocative efficiency. Policies developing infrastructure, communication, information, education and health may ultimately improve allocative efficiency of the production and marketing systems. Because FSR performance depends so much on the performance of these complementary institutions or actions, assessing the expected impact of FSR on the farming systems' productivity is complex. The complexity of the assessment inhibits some policy-makers and donors from funding or using the results of ex-ante evaluations of FSR.

Because similar problems exist for ex-post assessments, some evaluators prefer to measure the intermediate products of agricultural research as opposed to the final products in order to assess ex-post the impact of agricultural research (World Bank, 1985; Merrill-Sands, 1988; USAID, 1989a). Confronted with the problems of the intervening institutions and of the time frame for inmature research projects (those which have not yet had an impact on production), these evaluators assess the institutional impact of agricultural research, which can be considered as the intermediate products of agricultural research as opposed to the production impact, which is the final product of agricultural research. For example, ISNAR has assessed the institutional impact of FSR "in terms of the extent to which FSR has improved research systems' capacities to meet the needs of their clients more effectively and efficiently" (Merrill-Sands, 1988, p. 1).

Assessing the institutional impact of FSR as opposed to the production impact is undoubtedly helpful to identify the critical factors affecting the NARS's capacity to integrate and sustain effectively and efficiently the diverse agricultural research functions. In the short run, this method generates useful, specific and proper recommendations for improving the functioning of the research system and, presumably, the system's contribution to increasing farming systems' productivity. In the long run, assessing a research system on the basis of its institutional capability to develop technologies appropriate for its clients on a sustainable basis is probably as important as assessing the immediate production impact that might fade once "temporary and internally nonsustainable factors, such as an infusion of funds and technical assistance from outside, have disappeared" (World Bank, 1985, p. 19).

This conceptual framework incorporates the lessons drawn from ex-post studies assessing the institutional impact of FSR. This allows, first, to account on an empirical basis for institutions that are active in improving the farming systems' productivity and, second, to substantiate recommendations that this study will propose to improve the performance of the diverse functions of the technology system. The lessons are drawn primarilly from four comparative studies: a review of the World Bank's support for research and development in ten developing countries (ibid.)[30], the World Bank's study on Managing Agricultural Development in Africa (MADIA)[31], a USAID review of twelve FSR/E projects (1989a)[32] and a comparative study on FSR carried out by ISNAR in nine countries[33].

Assessing only the expected institutional impact of FSR in Mali's Region of Mopti is, however, unsatisfactory for policy-makers and donors because they are also interested in measuring the impact of FSR in terms of increase in production, income, or marketable produce and comparing the results with other development activities. Donors need a yardstick to evaluate the outputs of different institutions or actions. Therefore, the expected production impact of FSR and other institutions or actions needs to be valued and compared to the costs incurred in implementing these changes. As a result, the conceptual framework needs to include the expected production impact of FSR and other institutions or actions. This approach is not common in the available literature. To our knowledge, only one study has assessed ex-post the benefits and the

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[30] The ten countries were Brazil, India, Indonesia, Kenya, Mali, Morocco, Nigeria, Sudan, Thailand, and Turkey.

[31] The MADIA study involved a detailed analysis of six East and West African countries (Kenya, Malawi, Tanzania, Cameroon, Nigeria, and Senegal) covering the 25-year, post-independence period.

[32] The twelve countries of the USAID review included Bostwana, the Gambia, Lesotho, Malawi, Senegal, Tanzania, Zambia, Nepal, Philippines, Guatemala, Honduras and ROCAP.

[33] The nine countries included in the ISNAR review are Senegal, Zambia and Zimbabwe in Africa, Bangladesh, Indonesia and Nepal in Asia, Ecuador, Guatemala and Panama in Latin America.

costs of an FSR project (Matínez and Saín, 1983); none has assessed ex-ante FSR projects in any depth.

This chapter is organized in two sections. The first section outlines the potential roles and contributions of the NARS and the technology transfer system. The second section focusses on the potential roles and contributions of FSR and then suggests the factors affecting the contribution of FSR. These factors are broken down into factors having a direct institutional impact and factors having a direct production impact.

3.2. Roles of the Institutions of the Agricultural Technology System

Figure 3.1 presents a simplified structure of the whole Agricultural Technology System. The Institutional Agricultural Technology System is part of that Technology System. It performs basically two functions: technology development and technology transfer. Independent of the Institutional Agricultural Technology System, other agents or organizations outside the formal institutions may perform the same functions. These agents or organizations are considered part of the Agricultural Technology System, but not part of the Institutional Agricultural Technology System (Kaimowitz, et al., 1989). In this study, only the institutional aspects of the Agricultural Technology System's functions and linkages are considered because they are permanent, formal and fit more easily into a general framework. Stoop (1988, p. 13) provides examples of contributions made by the informal sector to technology transfer. The following two sections summarize the functions and contributions of the two systems responsible for technology development and technology transfer, respectively. This presentation will be used to conceptualize the framework for the study.

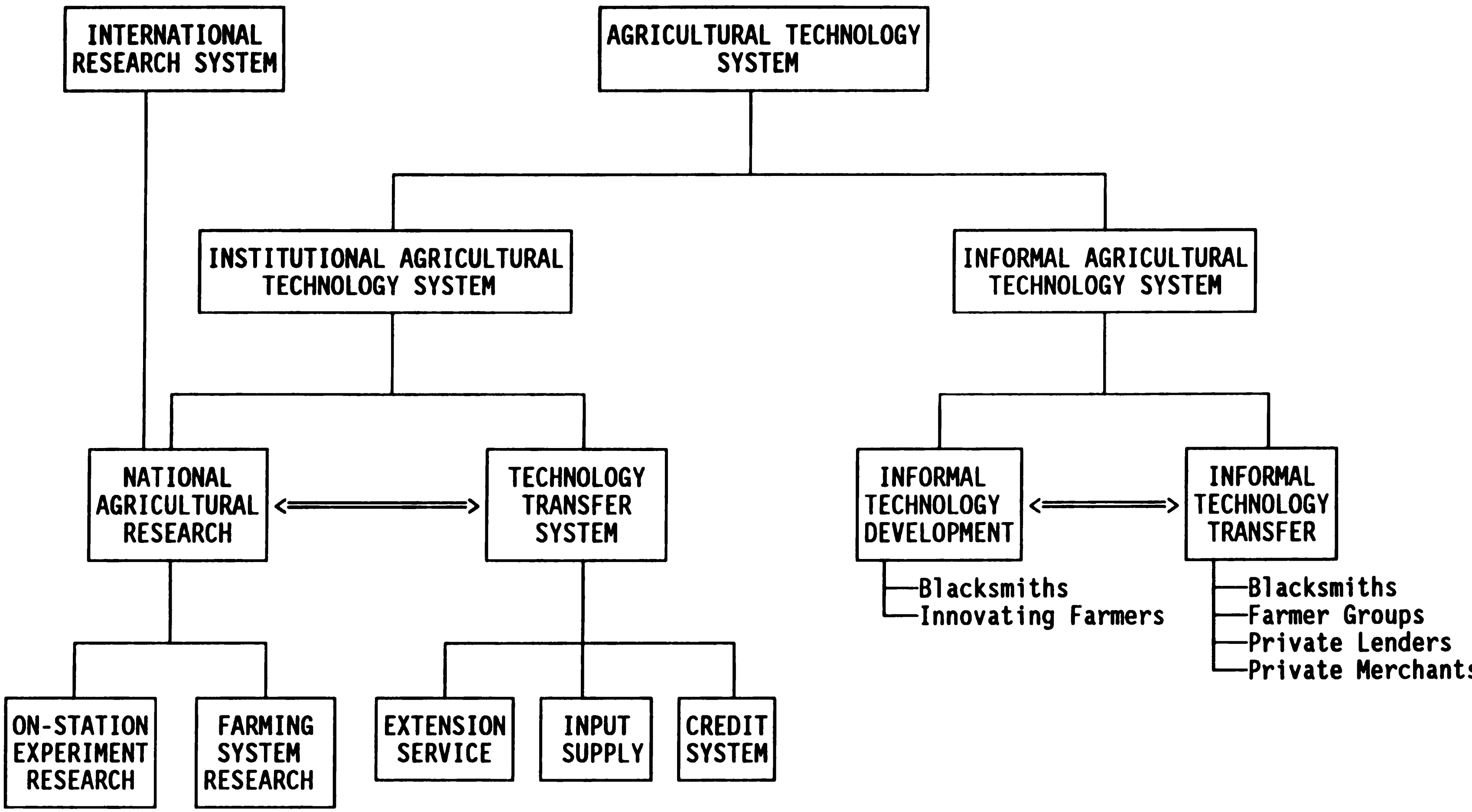

Figure 3-1. Simplified Structure of the Agricultural Technology System

3.2.1. Roles and Limitations of the National Agricultural Research System

The National Agricultural Research System is briefly presented under four headings. First, the definition and functions of the NARS and the institutional linkages within the NARS are presented. Second, different types of agricultural research and their respective goals are identified. Third, the potential agricultural research contributions are examined. Fourth, some agricultural research limitations are underlined.

a) Definition and Functions of the NARS and Linkages within the NARS

According to ISNAR (1984), "a NARS is composed of all entities in the country conducting agricultural research, whether through specialized national research institutes, universities, or the private sector, including research conducted by seed and agro-chemical companies, or through rural development commodity development projects, and non-governmental organizations. It also includes the linkages to major client groups: policymakers, technical assistance and donor organizations, extension services, producers, and international research organizations" (in Stoop, 1988, p. 1).

The principal function of a NARS is to develop improved technologies. To do this, a successful NARS assumes seven secondary functions (ibid., p. 1):

1. priority setting and research agenda formulation;
2. financial resource mobilization and effective utilization;
3. physical research infrastructure development and maintenance;
4. scientific human resource development and maintenance;
5. effective utilization of all scientific capabilities available at national and international levels;

6. effective information flow management between researchers and extension, farmers, policy-makers, and the public;
7. research program monitoring and evaluation.

The performance of these seven functions depends on effective linkages internal or external to the NARS.[34] Schematically, the external linkages consist of transferring and learning processes among the different parties involved in development, including the final users of technology, the technology system's local and national institutions, the international research and development (R&D) system and the diverse institutions outside the technology system, such as the policy making structure and the donor community.

Stoop (ibid., pp. 2-4) reports four common factors affecting the performance of these linkages.

1. The research system's capacity to generate useful information for its clients and the clients' capacity to absorb and utilize this information.
2. The institutional barriers between the research and educational systems and between the research and extension systems, as well as the institutional barriers within the research system, between the different specialized institutions.
3. Human, cultural, and/or traditional barriers among researchers.
4. Poor management practices within a NARS or a research institute.

These functions and key linkages will be considered in the conceptual framework.

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[34] Internal linkages deal with the communication among researchers within a NARS and external linkages deal with the communication of the NARS with its major clients, other NARS and International Agricultural Research Centers (Stoop, 1988, p. 2).

b) Types of Agricultural Research and Goals

The stages of agricultural research aimed at increasing the productivity of farmers form a continuum. It is, however, possible to distinguish three different categories of research, each of which represents a stage of the research process and has a specific complementary contribution to the research system. These categories of research are commonly classified as basic (or strategic), applied, and adaptive (World Bank, 1985, p. 22; SPAAR, 1987, p. 17).[35]

First, basic agricultural research generates new knowledge and new research methodologies needed for generating new technology. Second, applied agricultural research creates new technology by finding practical use for existing knowledge (e.g., a new variety). New agricultural technologies are designed to improve production possibilities and information for economic decision making. Agricultural technology generally is composed of two elements: the physical components of the technology and the process of optimally using the technology, which includes information, technical knowledge and skills (World Bank, 1985, p. 20). Third, adaptive agricultural research adapts available new technology to the requirements of specific locations and users, so that the new technology can be used more efficiently in locations and circumstances different from the ones for which the new technology was originally developed.

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[35] Although the correspondence is not perfect, socio-economists often use a different terminology to name basic, applied and adaptive research: discilpinary, subject matter and problem-solving, respectively.

SPAAR considers socio-economic research outside the above three categories. We include it in the applied research category. Socio-economic research consists of policy and sector analyses, resource management and environmental sustainability issues, research priority setting, socio-economic constraint and potential studies, etc. It is needed in support of agricultural research programs (SPAAR, 1987, p. 18). A good example of effort is the Bureau d'Analyses Macro-Economiques (BAME) established in Senegal within the national agricultural research institute.

Although the distinction between applied and adaptive research is tenuous, the technology-generating process is relatively more substantial in applied research than in adaptive research while the information-generating process with respect the already generated technology is relatively more central to adaptive research.[36] Most adaptive research focusses on recommended crop rotations, fertilizer levels, planting methods, plant density and spacing, pest control and tillage (Byerlee and Heisey, 1987, p. 1).

All sub-Saharan African countries conduct a mix of adaptive and applied agricultural research. Applied research is emphasized in experiment research stations and is organized according to commodity, discipline or factor. Adaptive research is usually conducted on farms by an FSR unit either established in the NARS or the transfer system. Basic research is rare in Africa due to limited human and financial resources, although there is an acknowledged need to confront complex agricultural problems in these countries (SPAAR, 1987, p. 17).

c) Potential Agricultural Research Contributions

Since adaptive and applied research are more common in Africa, their potential contributions are discussed below. It is meaningful to distinguish the potential direct contributions of applied agricultural production research from its potential indirect contributions (Pinstrup-Andersen, 1974, pp. 14-16). According to Pinstrup-Andersen, the three potential direct contributions of applied agricultural production research are the following:

1. Increasing technical productivity of at least one resource (including the change in the composition of the product).

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[36] Extension would then be an information-transferring process (Byerlee and Heisey, 1987, p. 5).

2. Reducing production risk.

3. Increasing available information for further research and improving research capacity.

Pinstrup-Andersen (ibid.) argues that any additional contribution of applied agricultural production research will be an indirect consequence of one of the three direct contributions. For example, applied agricultural production research cannot increase farm returns per se, but it can contribute to increasing farm returns by improving technical productivity of one or more resources, or by reducing risk. Increases in farm returns depend on other factors independent of the research process, such as prices in input and output markets. And prices, in turn, are determined by input and output marketing infrastructure and policies. The essential distinction between direct and indirect contributions of applied agricultural production research shows that the achievement of development goals depends only partly on applied agricultural production research.

In certain cases, applied research has generated technologies with the potential to improve production efficiency but these technologies have not been successful because of particular agroclimatic and economic conditions. In these cases, adaptive research has made the most significant contribution. (Merrill-Sands and McAllister, 1988, p. 2). This is generally the case where constraints limiting productivity are variable and complex. In sub-Saharan African countries it is not unusual to find agricultural technologies, even those developed specifically for these countries, that are inappropriate for the existing production environments and farming conditions. As a result, the adoption of new technology has been very slow and limited to a relatively small number of farms. It is, thus, not surprising that returns to scale of applied agricultural research have been low.

Adaptive research can be viewed as having two distinctive research functions: (1) to identify improved technologies relevant to the priority needs of specific groups of farmers and (2) where necessary, to adapt improved technologies to the local conditions.

The costs incurred to adjust and fine-tune the technological components available from applied research are likely to be high with respect to the final output, particularly where the adaptive research results are specific to very particular local conditions. Byerlee and Heisey (1987, p. 9) with others (Herdt and Mandac, 1981; Byerlee, 1987; Shapiro and Mueller, 1977) show that in many small farmer situations, returns from adaptive research would be greater if it focussed on technical efficiency (e.g., improving timing and method of use of a fertilizer or a pesticide) rather than on allocative efficiency (e.g., estimating the optimal level of the fertilizer or the pesticide). They concluded that the returns to adaptive research would be higher "where 1) there are strong interactions between inputs and location-specific variables such as rainfall and soil type, 2) emphasis is placed on conditions for use/non-use of an input and on technical efficiency in using the input, rather than on optimal levels, 3) cross-sectional variability can be readily identified to allow extrapolation of results and 4) cross-sectional variability can substitute for time-series variability in response estimation" (p. 12).

An additional function needs to be carried out to ensure that appropriate technologies are developed. Farmers, probably with the exception of large commercial ones, are unable to communicate their research needs directly to the research institutes because of institutional arrangements and social barriers. Because of that situation, research is often irrelevant to actual farm problems and research results are not

adopted.[37] This means that feeding back priority technical problems of local specific groups of farmers to focus commodity and disciplinary research needs to be carried out by one institution. FSR and the Training and Visit extension approach (T&V) were established in response to the need to provide a continuous flow of information to the research manager and/or the individual researcher on the potential gains in production, productivity and risks from applied research. This function will be discussed in more depth in the following sections devoted to the roles of extension and FSR.

d) Agricultural Research Limitations

Agricultural research cannot resolve all the problems faced by the agricultural sector. In many cases, agricultural research is not the most effective response. In providing guidelines for strengthening national agricultural research systems in Sub-Saharan Africa, the Special Program for African Agricultural Research (SPAAR, 1987, p. 16) raises three fundamental questions to decide whether agricultural research can contribute to national development goals. The SPAAR asks first whether improved technology is the most effective answer; second, whether the anticipated constraints to technology adoption are likely to be resolved once the improved technology is available; third, what is the priority ranking of the specific commodities and research areas. For many agricultural research programs, the SPAAR maintains that these questions are seldom adequately answered.

The identification of constraints on economic development can help determine whether agricultural research is required. In many cases, institutional arrangements and policy reforms are more effective at a given point in time than investment in agricultural

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[37] Another reason for irrelevant research results is that the on-station conditions are often very different from the on-farm conditions (see yield gap explanation in Stoop, 1988).

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research for dealing with rural development problems. For example, a more direct way to increase the productivity of some farming systems would be to improve the functioning of input and output markets, reform land and water rights or make changes in fiscal policy. Once the institutional and policy environment is improved, however, technologies may become the binding constraint and, hence, investment in agricultural research and technology transfer mechanisms become appropriate. As a result, research investment strategy should be framed within the identification of the key binding constraint at any given time and the development of a sequence of actions to improve productivity as the binding constraints change over time. Recently, Eicher (1988) has concluded that the stage of institutional, scientific, and political maturity of individual African states plays an important role in the success and sustainability of rural development projects and programs. Eicher shows that not tailoring projects and programs to the stage of the individual nation's maturity simply postpones the day when NARS will no longer need international support.

When agricultural research is appropriate to reach certain development goals, its contribution still depends on existing institutions and public policy (Pinstrup-Andersen, 1982, p. 189). Coordination of research strategy, institutional arrangements and public policy is important to achieve the greatest possible contribution of an agricultural-led strategy (Pinstrup-Andersen, 1982; Eicher, 1989, p. 8). Among the six sub-Saharan Africa countries surveyed by the MADIA study (Lele et al. 1989, p. 10), the countries in which both agriculture and agricultural research have performed relatively well are those in which sound and stable domestic policies toward agriculture have been implemented.[38] They are not necessarily those with the greatest financial resources.

Eicher (1989) makes the same observation, stating that the five prime movers of agricultural development are favorable economic development, human capability, new technology, rural capital formation, and rural institutions. Consequently, the contribution of FSR to improving the farming systems' productivity needs to be framed within the national and regional context of existing institutions and policies. Now, we turn to the functions and contributions of the institutions directly complementary to agricultural research.

3.2.2. Roles of the Technology Transfer System

The Technology Transfer System is briefly presented in three headings. First, the definition and functions of the transfer system are given. Second, the role and organization of extension, one major institution of the transfer system, are identified. Third, linkages between extension and research, input supply and farmers are examined, as well as different models of technology transfer organizations.

a) Definition and Functions

Technology transfer includes technology supply, technology delivery and monitoring and evaluating the use of technologies (Kaimowitz et al., 1989, p. 3). Technology supply is the production of the physical inputs and/or information. Technology delivery is the promotion and distribution of the technology to the potential users. This function also includes the provision of complementary services required for the efficient use of the

[38] Among the six countries, the good-performance countries in agricultural research are Kenya, Malawi and Cameroon.

technology, such as training, credit, machinery maintenance, veterinary services and market information. Monitoring and evaluating the use of technologies provides an assessment of the adoption level and constraints. Recently the World Bank (1989, p. 11) has added that there is a potential role for extension in policy reform. Extension can provide information on how present policies affect farmers and extension and the implications of proposed policy changes for agriculture to governments. Extension has played this role for years in the United States.

The World Bank study (1985, p. 23) shows that, in many countries, the national extension service tends to concentrate their efforts on such transfer functions as input supply, credit supervision and agricultural data collection while educational functions are neglected. In fewer countries, technology supply and delivery are carried out by the private sector, while knowledge transfer (i.e., information and training) is provided by the public sector. In other countries, technology transfer is provided by a combination of government institutions, parastatal agencies, and cooperatives (ibid., p. 59).

b) Extension Role and Organization

The term "technology transfer" rather the more familiar term "extension" is used to assure that all technology transfer functions are considered (Kaimowitz et al., 1989, p. 3). According to a World Bank definition (1985, p. 23), agricultural extension involves primarily "the information and teaching functions of technology transfer. In addition, agricultural extension provides the communication link between users of agricultural technology and the people involved in initiating or directing its development (such as policymakers, planners, and researchers)." Consequently, extension implies a more focussed role in information, training and communication than the broader role played by the transfer system. Like other institutions of the technology system, extension contributes to increasing technical and allocative efficiency.

Practically, extension can be organized in several ways. One possibility is that the agency can specialize in extension per se, concentrating its responsibilities in communication and training. Alternatively, the agency can be active in input supply and services in addition to extension. Both types of organization have advantages and disadvantages (ibid., p. 100).

A specialized extension agency can concentrate and control its human and financial resources in fewer manageable activities. But, particularly in countries in which institutions are weak, the specialized agency needs the parallel participation of other agencies to carry out other technology transfer functions. This would require a strong coordination among agencies responsible for technology transfer, on the one hand, and between these agencies and policy-makers and planners, on the other.

A less specialized extension agency has the advantage of coordinating its diverse activities and, hence, a greater flexibility in allocating its resources according to its needs. The less specialized extension tends, however, to focus its resources on more visible activities, such as input supply and services, to the detriment of less tangible activities of extension.

c) Linkages between Extension and Research, Input Supply and Farmers

To contribute efficiently and effectively to the transfer of technology to the intended users, extension needs to be linked to the three other elements of the technology system: research, input supply and farmers. The World Bank study (ibid., p. 79) reports that extension-research linkages probably are the most serious institutional problem in developing an effective technology system, particularly in countries in which research and extension are functions carried out by separate institutions. Because of these inadequate linkages, the demands of small farms for technology are not well articulated, with the results of poor research impact (Lele et al., 1989, p. 43).

According to this World Bank study (1985), only a few projects are in the process of establishing formal structures through which farmers can feed back their needs to researchers and, hence, participate in the planning and programming of research and extension. Most of the projects have a top-down organization.

Integration of extension with supply and services is successful in several cases but there are still administrative and logistical difficulties in transporting, storing, and marketing inputs because of long distances, poor roads, and a large number of potential customers. One solution to the problem of supplying farmers with agricultural inputs would be to involve extension agents in organizing farmers to purchase inputs in bulk by the use of contract purchases, for example.

These linkages will be studied in more detail in the section on the factors affecting the institutional impact of FSR. The rest of this section examines some existing models of technology transfer organizations.

Rhoades et al. (1985) have provided three models schematizing the different linkages between research, extension and farmers. As reported by Stoop (1988, pp. 14-16), these models are:

- the top-down model;
- the feedback model;
- the farmer-back-to-farmer model.

The top-down model presents the transfer of technology as a one-way process from research to extension to farmers. This process does not allow farmers to communicate their needs and problems to the extension agents and pass them to researchers. Hence, neither the extension service or the farmers participate in the design of the technology. This rigid model might work in situations where farming systems are relatively simple, uniform and predictable.

The feedback model adds a feedback function to the previous model. Farmers are able to communicate with the extension agents and, in turn, the extension agents with the researchers. There is still a filter between the farmers and the researchers which hinders the flow of information. To improve the communication between the researchers and the farmers, FSR is introduced to bridge the two communities. In many cases, this "modified feedback" model has not been effective in integrating FSR work into the on-station research because of institutional barriers.

The "farmer-back-to-farmer" model allows the farmer to be an active participant in all of the four stages of research. With extensionists and researchers, the farmer defines the problems, proposes, tests/adapts and evaluates solutions. No rigid stepwise process is imposed. The model is dynamic and allows flexibility in the roles played by the different participants and in the choice of methods.

With respect to the "modified feedback" model, the "farmer-back-to-farmer" model stimulates a higher degree of farmer participation in the entire research process and the integration of on-station and on-farm research. This model is better suited for dealing with complex and diverse farming systems but requires a higher degree of maturity and independence from the researchers and the extension agents (ibid., pp. 16-17).

3.2.3. Conclusions

Two major conclusions can be drawn from this review of the organization, functions, contributions and limitations of the different institutions of the Institutional Agricultural Technology System and the linkages between them. First, FSR is a subset of a more general set of other institutions which have important complementary functions with each other. Particularly, the NARS and the Technology Transfer System have strong complementary research functions within the Institutional Agricultural Technology System. In turn, the NARS and the Institutional Agricultural Technology System include institutions with interdependent functions. These complementary functions are critical for FSR to have any impact on the productivity of the farming systems. Second, the impact of the different institutions of the Institutional Agricultural Technology System on the productivity of the farming systems also depends on a wide range of policies and institutions outside the technology system. This shows that FSR cannot be evaluated without examining the institutional and policy environments. Examining the interconnectedness of FSR and its institutional and policy environment increases the degree of freedom in the search for improvements in farming systems with limited production potential.

3.3. Farming Systems Research

After described the general institutional framework in which FSR fits, this section focusses on FSR. First, the definition, objectives and types of FSR approaches are presented. Second, the factors affecting the institutional impact of FSR on the technology transfer system are identified. Third, the factors affecting the production impact of FSR are examined. In this study, the institutional impact of FSR is considered as the intermediate output of FSR, while the production impact is considered as the final output of FSR. For both impacts a flow chart will schematize how the main factors affect the institution building and productivity improvement.

3.3.1. Definition, Objectives and Types of FSR Approach

According to CIMMYT (1984, p. 363), FSR is "any research that views the farm in a holistic manner and considers interactions in the system." Its major objective is to "increase the productivity of farming systems by generating appropriate new technology." When FSR's more specific objectives are to identify and test improved technologies which can be easily integrated into existing target farming systems, FSR becomes site-specific, and on-farm research methods are called for. On-farm research methods involve farmers in identifying potential technological improvements and in carrying out on-farm tests. Experiment station research is also a critical input to develop technological components and interpret on-farm tests.

This type of FSR approach has been widely promoted by CIMMYT and other International Agricultural Research Centers (IARC) under the name "on-farm research with farming systems perspective (OFR/FSP)" and is the one generally in mind when FSR is discussed.[39] Farming systems and extension (FSR/E) is another way to refer to that same approach (Hildebrand and Waugh, 1983). ISNAR (1988, pp. 1-2) has used

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[39] This type of FSR is sometimes referred to as "downstream" FSR. As opposed to "downstream" FSR, "upstream" FSR "seeks to generate prototype solutions which will facilitate major shifts in the potential productivity of farming systems (Gilbert et al., 1980, p 10)." "Upstream" research often involves many years of research and is commonly carried out by the International Agricultural Research Centers (IARC) while "downstream" research is carried out by the National Agricultural Research System.

"on-farm client-oriented research (OFCOR)" to distinguish this type of FSR from the two types of FSR identified by Simmonds (1985, pp. 12-13).

The other two types of FSR have been called by Simmonds (ibid., pp. 12-13) "FSR sensu stricto" and "new farming systems development (NFSD)." FSR sensu stricto consists of descriptive and analytical research activities limited to the academic study of entire farming systems without direct implications for agricultural research and policy reforms. NFSD research promotes completely new farming systems to replace current practices (e.g., alley farming to replace shifting cultivation). While OFR/FSP seeks to generate step-wise improvements in farming practices by adapting new technology to the farmers' circumstances, NFSD suggests radical alterations by adapting circumstances to technology. Empirical studies have shown the limitations of NFSD research. Farmers are reluctant to seize a completely new farming system and researchers have difficulties proposing an efficient new system. As a result, the conceptual framework will include the OFR/FSP class of research, and only this class will receive further attention in this section.

Typically, the stages for an OFR/FSP program include (Norman, 1976; Byerlee, Collinson et al., 1980; Martínez and Arauz, 1983):

1) a descriptive phase, during which the farming system is studied with a view to identifying the farmers' objectives and principal constraints impinging on the system;

2) a planning phase, during which research priorities are set and a number of technologies are selected for their potential to alleviate constraints identified during the first phase (they are then developed and tested through station research);

3) an experimentation phase, during which a smaller number of the most promising technologies are evaluated on farmers' fields with their participation;

4) a pilot extension phase, during which technologies best able to overcome the identified constraints undergo exposure to real production conditions across a larger number of farmers, with a view to assessing their likely future diffusion and adoption.

Because the establishment of research priorities in the planning phase affects as much or even more the efficiency of research than the implementation itself, this critical turning point is further examined. For applied agricultural production research, Pinstrup-Andersen and Franklin (1977, pp. 419-21) suggested a sequence of steps aimed at specifying working research priorities. Prior to the identification and test of alternative technologies to solve problems, one of the key steps of the sequence is the identification of relevant researchable problems that limit the achievement of established objectives. The identification is independent of possible solutions. For example, if one established objective is increasing the production of a specific staple food, the researchable problem limiting the production of the food staple may be a particular disease, a low and erratic rainfall or a weeding constraint. Once the problem is expressed in terms of the factors causing low production, alternative solutions to the problem are then identified. In practice, a "technology-free specification of the problem" faces, however, some difficulties, such as ranking the factors causing low production that are often complex and interdependent.

In the literature surveyed, there is generally unanimity that there are three objectives of OFR/FSP, but scholars differ on the relative importance of each objective.

In addition to generating appropriate new technologies for farmers, it is expected that OFR/FSP will improve the relevance of research efforts through a better flow of information about farmers' needs to the research system and inform policy-makers and planners on measures that could help generate and transfer improved technologies. The relative importance of this last objective is more controversial than the other two. At one extreme, FSR has been urged to incorporate a "political economy perspective" to formulate macro-level policy recommendations (Davidson, 1987, p. 69). At the other extreme, FSR has been encouraged to limit its scope to farming systems per se and not be used to "examine or solve all rural-sector problems" (Herdt, 1987, p. 5). Since agricultural researchers have provided the institutional roots for FSR and, consequently, FSR has been biased toward bio-technical modifications in farming systems (Gilbert et al., 1980, p. 4). However, since changes in non-technical factors such as marketing and pricing policies, rural institutions and infrastructure are often extremely important, "FSR could easily lose its credibility if micro research is not supplemented by macro research on the political, economic, and institutional constraints (Eicher in Gilbert et al., 1980, p. ix)."

The debate concerning the relative importance of the three objectives of FSR is still alive today. While recognizing the benefits of using data from on-farm research to address policy issues, CIMMYT has taken an intermediate position, stating that FSR should limit its role of informing policy-makers at the local level and certainly not become "the nucleus for agricultural development policy formation at the national level" (Tripp et al., 1990). Reviewing twelve FSR/E projects, USAID has recommended that FSR/E practitioners place greater "attention on identifying means to remove or relax institutional constraints that impede farmers' access to agricultural support services" (USAID, 1989a, p. 5).

In any case, local circumstances provide the best guide to the proper balance of the three objectives. For example, in West Africa's centralized political systems, FSR might have a larger impact on policy orientation if it has a direct institutional link with policy-makers at the national level as well as those at the local level. If FSR reveals that the productivity of the farming systems is most severely constrained by macroeconomic or regional policies, then an important contribution of FSR becomes the analysis of the micro-macro linkages influencing the farming systems and the estimation of the expected benefits that might be obtained and costs that might be incurred by removing these constraints. The results of this estimation can then be communicated to policy-makers.

Disagreement over the role of FSR in formulating institutional and policy reforms has resulted in the emergence of a complementary type of FSR activity. Instead of focussing only on improving farming practices as does OFR/FSP or FSR/E, farming systems infrastructure and policy support (FSIP) examines the potential of certain technologies in an environment of improved infrastructure and policy support. However, these two approaches are not substitutes. By testing technical modifications to the farming system, FSR/E leads to better understanding of it and contributes to more effective FSIP. By promoting institutional and policy changes, FSIP expands the range of alternative technologies to be tested through FSR/E. The complementarity of these two FSR approaches is particularly meaningful for improvements in systems with limited potential, like those in the semi-arid areas of Mali. Therefore, these two approaches are adopted for this study. FSR is viewed as a tool to improve the relevancy of biological science research in agricultural research organization and to recommend incentives for farmers in the socioeconomic, institutional, and policy areas.

The following section will present the factors affecting the institutional impact of FSR on the agricultural technology system, which is considered as the intermediate output of FSR. The identification of the factors affecting the institutional impact of FSR can assist in the formulation of specific recommendations regarding the NARS's capacity to carry out more effectively and efficiently the agricultural research functions. However, the value of FSR to society is realized if and only if the research results are utilized directly or indirectly in production process, which is considered as the final output of FSR. Therefore, the factors affecting the production impact of FSR need to be identified.

3.3.2. Factors Affecting FSR's Institutional Impact

For Collinson, "the logic of on-farm research within a farming perspective (OFR/FSP) is irrefutable but its organizational implications remain difficult to swallow" (1986, p. 1). Reviewing about ten FSR programs and projects, Gilbert et al. (1980, p. 71) demonstrate that resolving FSR's inter- and intra-institutional issues is the key to FSR's future success. Likewise, USAID's review of twelve FSR projects has concluded that "the gap between actual and expected impact was caused not by any shortcoming in the FSR/E concept per se but rather by the failure of FSR/E projects to address core, operational, and generic constraints to implementing the FSR/E concept" (USAID, 1989a, p. 3). Broadening the discussion to the NARS, Nestel (1989, p. 9) reports that many program reviews cite serious managerial and operational problems with the NARS. According to his observations, "the technical quality of the research being carried out in most NARS is seldom as much of a problem as the institutional and organizational constraints" (p. 17). Referring to an assessment made by Horton (Nestel, 1989, p. 9), he concludes that in general "NARS are better at handling the technical aspects of research than the institutional aspects". This view has also been supported by a study on World Bank research and extension projects (ibid., p. 9). This section reviews the institutional factors affecting FSR because the implementation of the FSR concept as well as the organization of research in the NARS greatly affects the impact of agricultural research.

A review of the available literature has permitted the classification of the major factors affecting FSR's institutional impact into the following categories[40]:

- a problem-solving approach;
- the integration of OSR and FSR;
- linkages between research and farmers;
- linkages between research and extension;
- linkages between research and policy-makers;
- linkages between NARS and the global research system;

These factors are developed next. A diagram of these factors will be drawn at the end of this section.

a) Factors Conducive to a Problem Solving Approach

The primary concern of FSR practitioners is to contribute to increasing farm productivity and income. Therefore, FSR must have a problem solving orientation. The problem solving approach must be systems oriented, interdisciplinary, location specific,

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[40] The literature reviewed includes primarily Gilbert et al. (1980), CIMMYT (Eicher and Staatz, 1984), Collinson (1986), Merill-Sands (1988), Merill-Sands and McAllister(1988), Ewell (1988), Biggs (1989), Kaimowitz et al. (1989), Tripp et al. (Eicher and Staatz, 1990) and USAID (1989a).

on-farm, and must involve the target (client) group. These five characteristics are briefly developed.

Systems orientation is needed for a comprehensive and proper diagnosis of the farming system, taking into account crop, animal, and household subsystems and the interactions of these subsystems with the economic, social, institutional and policy environment. Hence, solutions may be more specific to a subsystem or a key enterprise or cropping pattern in the farming system. Caldwell (1987, p. 175) reports that the study of the household subsystem in FSR has been ambiguous. For example, non-agricultural family priorities and the impact of technological changes on family welfare (defined more broadly than direct incomes and disaggregated among the family members) have not been well addressed to date by FSR. Although focussing more on the household subsystem adds complexity and costs to FSR, Caldwell argues that, particularly in Africa, it is worthwhile.

According to Herdt (1987, p. 4), because FSR looks at the productivity, profitability, acceptability and sustainability of systems, the approach ought to be interdisciplinary. Herdt (1987), Ewell (1988), USAID (1989a, p. 3), and Tripp et al. (1990) have shown that a truly interdisciplinary approach is still a challenge that has yet to be met.[41]

A comparative study carried out by ISNAR identifies three elements essential to fostering interdisciplinary collaboration: 1) strong team leadership from a scientist with disciplinary breadth and solid field experience; 2) effective participation of each scientist in an annual research evaluation and programming; and 3) incentives given to scientists

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[41] Interdisciplinary research requires that scientists from various disciplines are involved the research program and that the effort is mutually planned, executed , and evaluated (Bingen and Poats, forthcoming cited in Merill-Sands, 1988, p. 16).

for continually adjusting their research agendas according to the research development of their colleagues and interpreting their results according to mutually agreed-upon goals of the whole research program (Merrill-Sands, 1988, p. 17). A broad, client-oriented research agenda also stimulates an interdisciplinary approach. ISNAR's comparative study has shown that FSR programs that benefit from significant social science input are the best at involving farmers in the research process. However, in most of the cases surveyed, the social science input disappears after the early diagnostic stage of the program, mainly because of a lack of available, experienced social scientists. This narrows the initially broad perspective of the research (Ewell, 1988, p. 41).

To be problem-solving, FSR needs to recognize the locational specificity of technical and human factors. Identification of recommendation domains has been used for this purpose.[42] Ewell (ibid., p. 41) notes that many FSR programs surveyed by ISNAR have lost their emphasis on targeted clients and their specific needs. Under the pressure to expand quickly, these programs have become over-extended, resulting in a loose dispersion of surveys and trials, creating logistical problems and jeopardizing collaboration with station-based researchers. In contrast, Tripp et al. (1990) report that too exhaustive work has been carried out in relatively small areas with little opportunity to extrapolate to a wider area. This contrasting view demonstrates that efficiency considerations need to be brought into the determination of the research focus.

On-farm trials help adapt available, new technological components to farm-level environmental and management conditions and, therefore, contribute to solving

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[42] Introduced by CIMMYT, the term "recommendation domain" refers both to a geographical area with roughly homogeneous agro-ecological conditions for a particular enterprise, and to a group of farmers whose socioeconomic conditions are similar enough so that they might adopt a particular innovation (Byerlee, Collinson, et al., 1980).

technological problems faced by farmers. In addition, they facilitate collaboration between farmers and FSR practitioners and complement the on-station work which develops the new technological components.

The participation of the client group is ensured by selecting collaborators for surveys and trials within the target group of farmers or recommendation domain. Representativeness, willingness and accessibility of these collaborators are the three criteria for selection (Ewell, 1988, p. 28). In the ISNAR survey, simultaneous application of the three criteria was seldom observed due to logistical and training shortcomings and to external pressures in the selection process. Ewell (ibid., p. 41) maintains that a purposive selection of collaborators is a valid procedure if explicit goals and clearly articulated criteria are used.

Tripp et al. (1990) warn that an appropriate balance must be found between the sophistication of the research method and the real capacity to develop and transfer technology, taking into account the limitations of the institutional and policy environments.

b) The Integration of OSR and FSR

As reported by Tripp et al. (ibid.) and shown by Merrill-Sands and McAllister (1988), the way in which FSR is institutionalized within the NARS will determine its effectiveness. It has been difficult to integrate FSR with commodity and disciplinary research in a sustainable manner in most of the situations surveyed in ISNAR's comparative study because of institutional and logistical problems. These problems have resulted in a poor coordination of research between OSR and FSR.

According to Merrill-Sands and McAllister (ibid., pp. 4-8), the degree to which OSR and FSR are integrated can be assessed according to how five research functions are performed. Without going into details, these five functions are: 1) the service function, performing broad-scale on-farm screening, testing and evaluation of technologies developed on station, 2) the adaptive research function, diagnosing on-farm problems and adjusting existing technology to the particular set of problems, 3) the feedback function, channeling relevant information to the station-based research priority-setting, 4) the applied research function, generating technology components on-station and complementing the FSR's adaptive research function, and 5) the support function, providing expertise to FSR as the feedback function does to OSR.

Ideally, FSR provides the service and feedback to OSR as well as adapts research results from OSR, on the one hand. OSR provides applied research results to and supports for FSR, on the other hand. ISNAR's comparative study indicated that 1) the adaptive and applied research functions have been the most successfully implemented of the various tasks in the nine country FSR programs it surveyed; 2) the service function has been unevenly implemented; and 3) the feedback and support functions have been the least fully implemented (ibid., pp. 13-18).

Although research managers are constrained by conditions over which they have little control (i.e., human and financial resources, OSR's capacity to do applied research, development policy), there exist mechanisms that have been successful in strengthening OSR-FSR integration. Merrill-Sands and McAllister (ibid., p. 41) have suggested the following management mechanisms:

- joint problem diagnosis and collaborative research priority identification;
- joint programming and review;
- joint field visits;
- joint decisions on recommendation release;

- formal collaboration in trials and surveys;
- informal consultations;
- formal guidelines for allocating time and funds to collaborative activities;
- assignment of responsibility for coordination to a specific individual or group.

These management mechanisms need to be adapted to the specific institutional setting for effective OSR-FSR integration.

c) Linkages between Research and Farmers

Effective farmer participation in the research process increases the cost-effectiveness of research and keeps research priorities focussed on the primary clients (Biggs, 1989, p. 1). Farmer participation is, however, not very common (Herdt, 1987, p. 5), or is often superficial (Tripp et al., 1990) and not sustained after the early diagnostic phase (Biggs, 1989). As a result, the farmer's perspective is not well incorporated into the research process. Consequently, conditions determining whether new technology is appropriate for the farmer are not properly assessed and technology adoption often does not take place.

Many reasons explain poor farmer participation. One is the prevalence of highly centralized and vertically structured research and extension systems characterized by a top-down research process (USAID, 1989a, p. 4). Others include: 1) FSR programs tend to lose their ardor in updating farm-level information and involving farmers in the research process and tend to adopt mechanistic survey procedures; 2) FSR programs have problems in selecting representative farmers who are also good collaborators because of a lack of systematic and defensible selection procedures; and 3) FSR programs have problems in synthesizing and communicating information obtained from farmers (Biggs, 1989).

The degree of farmer participation in the research process can be improved by taking into account the following lessons learned from ISNAR's comparative study.[43] A policy commitment to farmers, translated into a national development policy and agricultural research policy, is a prerequisite for committing adequate funding, administrative support, incentives and rewards to working with farmers. Besides surveys and trials, meetings with farmers can play an important role in improving farmer participation, provided that these meetings are properly designed and organized. The ISNAR study also suggested that developing a partnership with local politicians, community representatives, local development agencies and organizations can be very productive in involving farmers in the research process (ibid., pp. 31-33).

Another way to integrate the farmers' perspective with research is to encourage farmers to apply pressure on existing research services (Tripp et al., 1990). However, the ability of farmers to influence the research system depends greatly on the institutional and political maturity of the country.

d) Linkages between Research and Extension

In addition to working with farmers and on-station researchers, FSR should interact with extension 1) to understand the conditions in which farming systems evolve, 2) to be aware of the farmer demands for technology, and 3) to transfer technology more

[43] Biggs (1989, p. 3) defined the degree of farmer participation according to four participation modes: contractual, consultative, collaborative and collegial. The type of participation mode is chosen with respect to the primary research activity to be implemented.

widely. This allows FSR to be more efficient in adapting technologies derived from research and providing feedback for on-station research priorities.

Although FSR has been conceptualized and implemented to bridge the gap between research and extension, weaknesses in the relationship between research and extension persist. Seven of the twelve FSR projects reviewed by USAID (1989a, p. 3) did not link research with extension because of inadequate incentive structure to encourage a productive partnership between research and extension (ibid., p. 5). Tripp et al. (1990) found few examples of effective collaboration between research and extension, even where FSR has been implemented. The ISNAR comparative study also found weak links between FSR and extension, mainly because the conditions required for effective links have not been established or have not been a priority in most FSR projects (Ewell, 1989, p. 25).

Kaimowitz et al. (1989) identify three categories of factors influencing the links between research and technology transfer: political, technical and organizational. Lessons for the institutionalization of FSR can be drawn from their study. First, links between research and technology transfer can be improved by positive external pressure from national policy-makers, donors, farmers and the private sector. Little external pressure is generally applied except from donors. As a result, research and technology transfer institutions are governed only by internal pressures and, hence, perform poorly (ibid., p. 9).

Second, when the environment is more diverse or unknown, as it is in a semi-arid zone, research and extension tasks become more complex and dispersed and, consequently, require a more open communication system (ibid., p. 13). In addition, depending on the type of technology to be transferred, FSR practitioners might target key technology transfer agents. For example, coordination with input suppliers is advisable for technology such as fertilizer and pesticides, as is coordination with blacksmiths and credit agencies for animal traction technology.

Third, institutional structures within the technology system determine the links between research and extension. For example, stronger research-extension links may be achieved if extension is concerned only with the dissemination of technical information, being free from other tasks (ibid., p. 20). Other important determinants of structural design have been addressed by Kaimowitz et al. (ibid., pp. 19-21) and will be useful to draw more precisely implications for FSR and technology system design at the end of this study. Personnel and financial management policies and practices may also facilitate research-extension coordination and communication. These are treated in detail in Kaimowitz et al. (ibid., pp. 22-25) and, likewise, will be useful later.

The ISNAR comparative study underlines additional organizational factors for building effective links between FSR and extension (Ewell, 1989, pp. 25-27). First, links between FSR and extension are likely to be more effective when they are built at the early stages of an FSR project, i.e., involving extension in the planning of research so that linkages are already set up to transfer later on technology. Second, these links need to be built at multiple levels of the administrative hierarchy of the institutions involved in technology development and transfer, from the field level to the ministerial level, because FSR alone cannot solve the linkage problem. Third, extension agents need to receive higher education and better training to reduce the gap in status between researchers and extensionists and to develop their analytical skills so as to improve their contribution to the FSR agenda setting. Nomination of a senior research-extension liaison officer may help bridge the status gap between research and extension and may add professionalism in the research-extension linkage function.

e) Linkages between Research and Policy-makers

Linkages with policy-makers are particularly instrumental in:

- defining FSR's priorities and monitoring FSR's impact;
- formulating and implementing the necessary policy actions to strengthen FSR's role within the NARS and the technology system;
- allocating the proper human and financial resources;
- communicating technical, institutional and policy constraints to guide rural development policy;

These functions have not been carried out successfully. Seven of twelve USAID projects reviewed were located in countries where there was a weak agricultural research policy or precise definition of FSR's role, a lack of trained manpower, and very limited funding commitment on the part of the government to meet recurrent costs (USAID, 1989a, pp. 5-6). This common situation has been also observed by the World Bank reviewing research and extension projects in ten different countries. First, in some countries, policy-makers do not have the capability to effectively identify, prepare, and appraise the necessary actions to support the development of research and extension functions. Second, existing political, institutional, and financial constraints in the countries have not been realistically taken into account in the design of the research and extension projects. Third, the sustainability of these projects is not addressed. The important development of physical research facilities has not been matched by improvements in the management of these facilities or by the development of institutional arrangements that would lead to their proper use (World Bank, 1985, pp. 4-

5). Finally, structural adjustment and over-staffing in some countries have made domestic recurrent funds scarce and hampered research (Lele et al., 1989, pp. 43-44).

f) Linkages between NARS and the Global Research System

The international community is defined here as the international agricultural research centers (IARC) and the donors. In the first section, linkages between domestic research and the IARCs are discussed. In the second section, linkages between domestic research and donors are identified.

i) Linkages between Domestic Research and the IARCs

Many of the IARCs, particularly IRRI, CIMMYT, ICRISAT and IITA, have been involved in the development and promotion of an FSR strategy for a long time (Tripp et al., 1990). These centers have had two kinds of FSR activities (Gilbert et al., 1980, pp. 72-74). The first type of activity is working directly with national programs to develop national FSR capabilities through training and technical assistance. The second type of activity is developing sub-program areas and methodologies that eventually might be adapted to local conditions by national programs. In 1980 it was agreed that regional and international research centers should perform both types of activities. Today the fundamental issue for the IARCs is how to improve the capability of the NARSs to develop endogenously their own research programs which include FSR (Lele et al., 1989, pp. 44-45; Eicher, 1988).

The SPAAR (1987, p. 13) has recommended that national research institutions make full use of opportunities arising from the regional activities of the IARCs to improve domestic research efficiency. In addition, the idea of reinforcing existing or creating new institutional frameworks (not necessarily through regional research institutes but through other forms of regional cooperation) for regional collaboration has been advocated (SPAAR, 1987; Eicher, 1988, pp. 32-33).[44] By encouraging sustainable national research systems it is hoped that national research systems will be better able to control their own research agendas, express specific demands for IARCs support, and meet recurrent costs.

ii) Linkages between Domestic Research and Donors

In the late 1970's and 1980's, USAID, followed by the World Bank and other European donors, took a leading role in promoting and sponsoring FSR activities (Tripp et al., 1990).[45] The donors have introduced the concept of FSR in the developing world in an attempt to redress a "top down" orientation in the design and extension of new technologies. The donors generally have become close partners with national researchers interested in applied research with a farming systems perspective.

The donors are likely to continue to be a major source of technical assistance and training for agricultural research, particularly in resource-poor developing countries such as the Sahelian countries. As a result, they will continue to influence the research agenda in developing countries. They will continue to emphasize women's rights, energy conservation and environmental issues. Increasingly, the concept of sustainability in agriculture rather than food self-sufficiency is being emphasized by the donors.

Tensions over accounting regulations exist between African research managers and donor agencies (SPAAR, 1987, p. 15). On the one hand, African managers request a closer integration of the donor-funded projects into the national programs to simplify

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[44] A good example of networking is the Southern African Center for Cooperation in Agricultural Research (SACCAR).

[45] Problem-solving work with a farming systems perspective has been earlier used by the British in Africa, Asia and India and by the French in francophone Africa (Tripp et al., 1990).

research management and increase flexibility in the use of the funds. On the other hand, the donor agencies are committed to short-term objectives and must comply with precise accounting rules imposed by their own governments. Donors are willing to integrate their projects into national programs and contribute to the recurrent costs of their projects provided that resource management and financial control in the host institutions are reformed.

In its review of research and development projects, the World Bank (1985, p. 13) has recommended more technical expertise to supervise the quality of research programs and that institutional improvements go beyond the physical implementation of research projects. Lele et al. (1989, p. 45) and Eicher (1988, p. 36) have reached the same conclusions: donor assistance should be concerned with substantive research issues. Rather than developing research programs that are unfocused and uncoordinated with other research programs, donors should support research programs that are well reasoned and strategically related to national priorities.

g) Conclusions

This section has presented the major factors affecting the institutional impact of FSR, in other words, the extent to which the research system's capacities to meet the needs of target producer groups more effectively and efficiently have improved.

Figure 3.2. shows a simplified, idealized flow chart of the different institutions which affect FSR's impact and their responsibilities. FSR is traditionally placed within the national agricultural research system (NARS) and is associated with commodity-oriented and disciplinary agricultural research carried out at experiment stations (OSR). In the figure, next to the NARS, where technology is generated and adapted to local circumstances, is the technology transfer system, which mainly performs three functions:

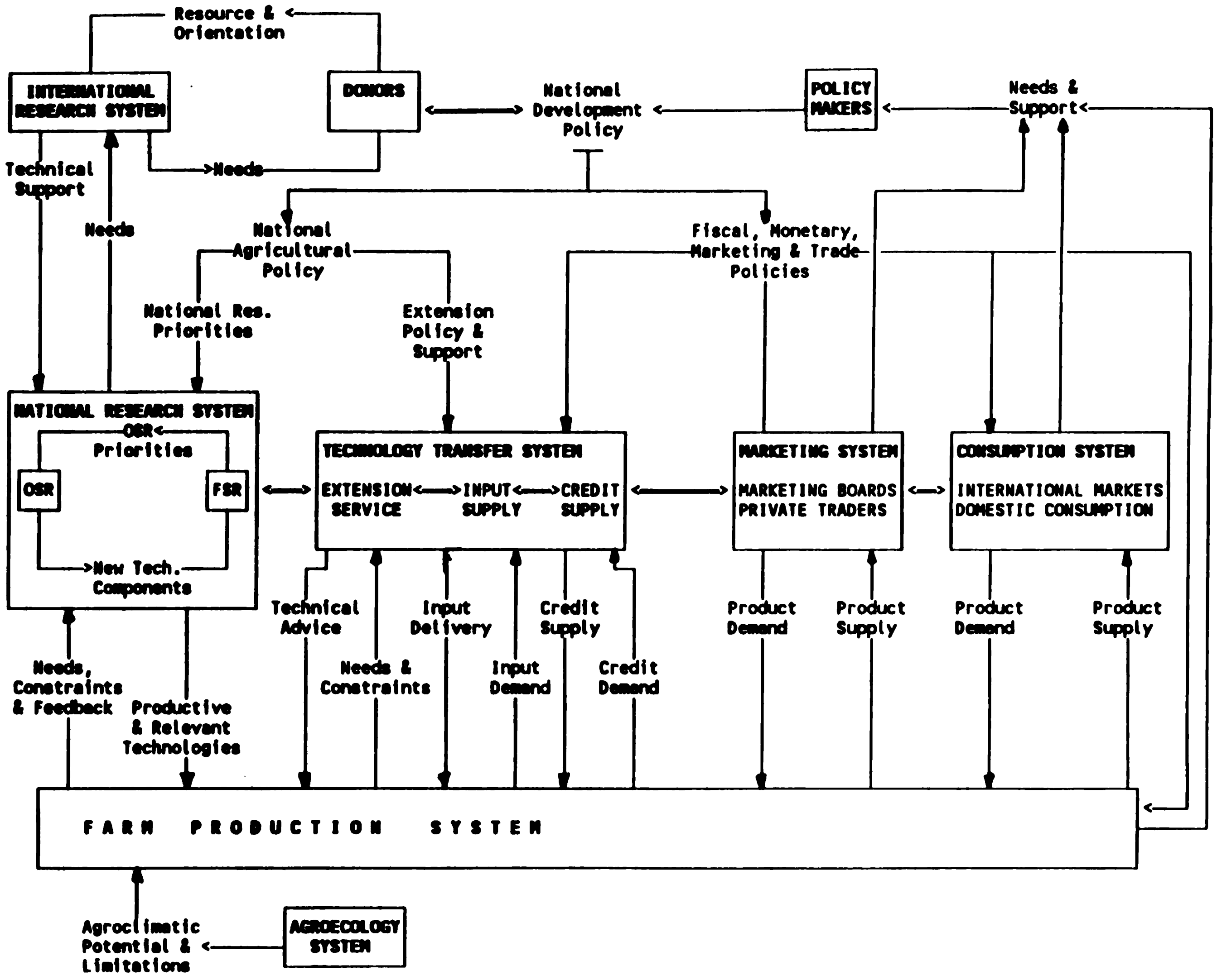

Figure 3-2. Institutional Environment of FSR

extension, input supply and credit supply. Altogether, the NARS and the transfer system constitute the institutional agricultural technology system. The NARS is linked to the international research system, to the policy system and to the donor community. Likewise, the transfer system is linked to the policy system and the donor community. In addition, the transfer system is influenced by the fiscal, monetary, marketing and trade policies of the national development plan.

As shown in the figure, the NARS and the transfer system have specific products to deliver to the production system as well as specific inputs to receive from it. Primarily, the NARS generates productive and relevant technologies for the production system by analyzing the needs and constraints of farmers and feedback regarding new technology. The extension service adapts technical advice and marketing information with respect to the needs and constraints of farmers. Input supply agencies and companies adjust their production and distribution of inputs to demand. Credit agencies provide the capital to help new, costly technology adoption.

The impact of FSR on the production system not only depends on FSR's institutional setting but also on how other systems interact with the production system. These other systems include the agroecology, marketing and consumption systems. Though a large part of farm production is consumed on the farm, the consumption system is differentiated from the production system in Figure 3.2 to take account of urban and rural market consumption. In addition to interacting with the production and consumption systems, the marketing system interacts with the technology transfer system, primarily for input supply. Public institutions and policies also affect the marketing, consumption and production systems. In conclusion, the NARS, the transfer system and the policy, marketing, consumption, production and agroecology systems are very interdependent.

3.3.3. Factors Affecting FSR's Impact on Farm Production

According to Tripp et al. (1990), the contribution of FSR to strengthening agricultural research has been more important in the areas of research orientation, methods, and organization than in technology development. In other words, the institutional impact of FSR has been relatively more important than the production impact. To date, there have been only a limited number of successes in increasing the productivity of small farms. The development and introduction of improved maize varieties and planting practices in Ghana have been the only FSR production success documented in Africa (ibid.). In Panama, Martínez and Saín (1983, p. 46) evaluated the economic rate of return of on-farm research in the Caisan at between 194 and 255 percent under the most likely scenarios. Because Panama's FSR was undertaken under a very specific set of conditions, the results of this economic evaluation cannot be taken as a benchmark for other FSR projects. However, this study will be useful for addressing methodological issues in chapter 6.

This section examines the factors affecting the farm production impact of FSR. First, the concept of production impact is specified in terms of efficiency, equity, security and sustainability, the four main criteria for assessing the production impact of FSR. Then, the factors affecting each of these four areas are reviewed. Finally, a conceptual framework for analyzing the factors affecting the production impact of FSR is suggested.

a) Definition of the Production Impact

According to the premise upon which FSR is based, once FSR has improved the research system's capacity to meet the needs of producer groups more effectively and efficiently, then FSR can develop productive and relevant technologies and recommendations that will affect the technological structure of the agriculture sector.

The extent to which new technologies and recommendations developed by FSR are adopted by extension and producer groups determines the impact of FSR on production (Merrill-Sands, 1988, p. 1). Although adoption figures indicate the appropriateness of new technologies and recommendations with respect to farmer objectives, resources and circumstances, other important criteria are missing in the above definition. To what extent new technologies and recommendations improve the productivity of farmers' scarce resources, farm income and income distribution, and reduce the risk of total crop (or livestock) failure should also be used to evaluate FSR's production impact. More recently, environmental effects and recurrent costs have received increasing attention. In sum, the output of the research process needs to be evaluated in terms of efficiency, equity, security and sustainability.

b) Factors Affecting the Efficiency Impact of FSR

A good starting point to identify the factors affecting the production impact of an FSR program is to review briefly the concept of efficiency and how to measure it. Basically, efficiency in agricultural production is defined as the ratio of farm output per unit of input, measured in terms of usefulness or value (Knight, 1933; Boulding, 1981). By introducing a technical change, agricultural research may change the output-input ratio. When all the inputs and outputs are accounted for, the change in this ratio resulting from technical change measures the contributions of agricultural research to increased efficiency. However, the costs of agricultural research that allows technical change must be included in the measurement of the total gains in efficiency.

Standard benefit-cost analysis is a practical method to measure the contribution of research to increasing agricultural efficiency. Benefits of research are the incremental net benefits generated by the technical change. These benefits include the benefits retained in the form of higher incomes to producers and the benefits passed on to consumers in the form of lower food prices.[46] Costs of research are the incremental costs of research to generate the technical change. Several efficiency indicators exist. The most common is the internal rate of return (IRR), which provides an average rate of return per dollar invested over the period studied.[47]

Presenting a method for carrying out a benefit-cost analysis for agricultural research, Bottomley and Contant (1988) identify eight distinct elements of a research

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[46] Other benefits might include: marketing and supply system improvements, changes in the quality of a product for a better transportability, nutritional content or tastiness, food self-sufficiency, employment creation, rural income improvement, rural to urban migration reduction, and foreign exchange generation or saving. Some of these benefits may be subsumed into that of increasing economic efficiency but most of these benefits would need to be accounted with the use of a special shadow pricing and/or weighting procedure.

[47] Another common efficiency criterion is ranking investments according to their net present value. If the investments evaluated are mutually exclusive (as is the case when one agricultural research program has to be selected among several because of limited human and financial resources), then the ranking given by the net present value (NPV) criterion might be different from the ranking given by the IRR, depending on the opportunity cost of capital chosen for the computation of the NPV. The choice between the NPV or IRR criterion to rank alternative projects depends on whose opportunity cost is to count (Schmid, 1989). Also the scale of the various research efforts comes into play when evaluating mutually exclusive alternatives. For meaningful IRR comparisons, the efforts need to involve similar levels of investment. For example, the selection of a relatively small project with a high IRR may preclude taking on a larger effort with a more moderate IRR. If the remaining capital left over when the small project is undertaken is invested at a low rate, then the overall return of this option may be lower than that of the larger alternative.

program that affect its internal rate of return.[48] These eight elements include: the annual cost of research, its duration, its initially anticipated probability of success, on-farm implementation costs, on-farm benefits, the rate of adoption, the adoption ceiling, and the life of the innovation. These eight elements are used to identify the factors affecting the efficiency of an FSR program.

i) Research Costs, Duration and Probability of Success

These three characteristics of a FSR program are grouped together because of their strong interdependence. Duration can be shortened if research costs are expanded. Probability of success increases as research costs and duration are augmented.

Efficiency is affected by these three characteristics. The annual costs of research directly affect the internal rate of return. The time taken to complete the research affects the time needed to obtain benefits and, thus, the internal rate of return. The probability of research success affects the research costs and duration as well as the research benefits because the budget, planning and objectives of the research program may need to be adjusted to increase the probability of success. Such adjustments eventually affect the internal rate of return, particularly when the probability is low and the research program needs to be redesigned.

The costs, duration and probability of success of an FSR program depend on the complexity of the research problem and the ability of the research system to conduct applied and adaptive research. The experience of FSR in southern Mali suggests that a long period of gestation and investment is needed to achieve results for extension. Since 1980, when the multidisciplinary team was set up, the Fonsébougou FSR Unit spent a total of approximately 72 researcher-years and 725 million CFA F in current terms (US

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[48] These eight elements can also be found in Araji, Sim and Gardner (1978).

$ 2.4 million) in operational budget to develop twelve research areas. After seven to eight years of research, five out of the twelve research areas reached the extension phase.[49] Since 1979, when the multidisciplinary team was established, the Bougouni-Sikasso FSR Unit had only five out of seventeen research areas in the extension phase after three to eight years of research. This period saw a total investment of approximately 50 researcher-years with a more limited budget than that of the Fonsébougou FSR Unit.[50]

ii) On-farm Implementation Costs and Benefits

In this study, a technical change is viewed as the introduction of a new factor of production in the production process, not just a change in the technical parameters of a production process involving only the same inputs, as it is often presented. This definition has the advantage of identifying what new factor of production is involved in the technical change. Consequently, attention is turned to assessing the benefits and costs for the producer of adopting the new factor and examining the production, distribution and extension of the new factor (Johnson, 1985, p. 10). According to this definition of technical change, both costs and benefits are affected by the introduction of a new factor of production. Therefore, it is reasonable to consider under the same heading changes in on-farm costs and on-farm benefits.

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[49] These research areas included: management advice, community development approach, soil conservation, training of oxen and improved animal enclosures (Henry de Frahan et al., 1989, p. 30).

[50] The research areas reaching the extension phase included: introduction of maize with reduction in labor through animal traction, improvement of maize-millet intercropping, improvement of rainfed rice cultivation, compost with rock phosphate on maize and the training of oxen (Henry de Frahan et al., 1989, p. 30).

Since gains in efficiency from FSR depend on the extent to which technical change produces more output value for a given value of inputs, technical change that implies increasing the demand for resources in ample supply and decreasing demand for resources in short supply would increase efficiency. Thus, in areas and during seasons of high unemployment and limited access to capital, developing technology that is labor-intensive and does not require a significant increase in capital may increase efficiency. Relative resource scarcities can suggest technologies to be developed and help establish research priorities vis-à-vis efficiency.[51] Moreover, technical change that does not address the structure of the agricultural sector may have unintended effects on adoption pattern and, hence, income distribution because relative resource scarcity may be distributed differently among producers.

Technical change that addresses specific farm production-limiting factors, such as plant disease and soil moisture, increases efficiency. The production-limiting factors and their degree of influence on production can be identified by analyzing the gap between potential and actual farm yields. This wide-spread method can also help narrow research priorities (Gomez, 1977).[52] The impact of narrowing the technical gap on-farm costs and net returns needs, of course, to be considered.

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[51] Because of price distorting policies and institutions, the relative resource and product market prices may not reflect actual relative resource scarcity and preferences respectively. Therefore, these relative prices may not provide an effective guideline for inducing technical change. Public research institutions may tailor research to efficient shadow prices. But, if producers face distorted relative prices, the new technology may not be appropriate to farmers' perceived market environment (Thirtle and Ruttan, 1986, p. 140).

[52] A short review of various methods is presented in Pinstrup-Andersen (1982, pp. 196-201).

The type of production environments for which technology is developed also affects efficiency gains. It is likely that in areas with higher rainfall and better soil, gains in efficiency will be greater. However, focussing technical change on the areas with the greatest production potential may have a negative impact on income distribution for producers from areas with poor potential. This trade-off needs to be recognized when research priorities are established.

Demand conditions, such as the expected future demand for agricultural products, import and export markets, and price and income elasticities play an important role in determining efficiency gains. Technical change for those commodities for which the largest increase in future demand is expected brings greater efficiency, as the value of the farm outputs is enhanced. These demand conditions may have considerable impact on the distribution of the benefits of technical change between producers and consumers and among consumer groups with different price and income elasticities. Information regarding demand conditions, therefore, helps establish research priorities among individual commodities.

In sum, technical change based on relative resource scarcity, production-limiting factors, production potential, and demand conditions may most improve the farm benefit-cost ratio and stimulate the greatest gains in efficiency for a FSR program. The gains in efficiency need, however, to be weighed against the possibility of skewing the current income distribution.

iii) Diffusion Speed and Ceiling and Life of the Innovation

Research that produces results applicable over a broad area has higher returns than research producing results over a narrow area for similar research costs and incremental on-farm net benefits. Likewise, the efficiency of FSR depends on the size and number of areas in which a new technology is spread and adopted over time and space (Tripp et al., 1990). Once a new technology is available to potential adopters, the diffusion process is characterized by three parameters: 1) the time the new technology is available, 2) the speed of diffusion of the new technology, and 3) the ceiling of diffusion or the upper limit of the diffusion process (Thirtle and Ruttan, 1986, p. 75).[53] When the technology recently introduced becomes obsolete and is progressively replaced by a new one, the benefits obtained from the diffusion of the technology fade away. This phenomenon represents the life of the technology. The speed and the ceiling of the diffusion and the life of the innovation are the three characteristics of the diffusion process examined in this section. The time of availability of the new technology has been already examined above.

The diffusion process can be thus explained by the various factors affecting the adoption of the new technology at the firm level for a particular date.[54] This

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[53] The diffusion process is defined as the spread of the new technology across the population of potential adopters measured in terms of cumulative rate of adoption at any given time. Economists make a distinction between diffusion and adoption. Adoption refers to the degree of use of a new technology at one point in time for either an individual firm (adoption at the individual firm's level) or an industry (aggregate adoption). Specifically, Feder, Just and Zilberman (1982) defined final adoption at the individual farmer's level as "the degree of use of a new technology in long-run equilibrium when the farmer has full information about the new technology and its potential" (p. 3). Aggregate adoption is "measured by the aggregate level of use of a specific new technology within a given geographical area or within a given population" (p. 3). Adoption studies focus on the reasons for adoption at one point in time, or the reasons for time of adoption for individual users. In contrast, diffusion is viewed "as a dynamic, aggregative process, over continuous time" (Thirtle and Ruttan, 1986, p. 72). In this study, diffusion does not refer to "the act of making technology available to potential adopters" as some other studies, such as Pinstrup-Andersen (1979, p. 11), have defined it.

[54] The diffusion process can be viewed as successive short-run equilibria between the supply and demand for the new technology (Griliches, 1957). Diffusion represents an aggregative process over time.

relationship between diffusion and adoption can be justified on the ground that "if one can explain the date of adoption by individual firms, then by aggregation one should have the inter-firm or sectorial diffusion curve" (Stoneman in Thirtle and Ruttan, 1986, p. 73). As a result, factors affecting the adoption of a new technology at the firm level should be the same as those affecting the speed and ceiling of diffusion, two elements influencing the efficiency of a FSR program.

At the individual farmer level, numerous studies have analyzed the factors affecting adoption, such as farm size, risk and uncertainty, human capital, labor availability, credit, information, tenure arrangement, innovation and complementary inputs supply, and transportation (Feder, Just and Zilberman, 1982). Coulibaly (1987) reviews the factors affecting the adoption of innovations and classifies them in two categories. The first is the relative advantage of the innovation, including profitability, the characteristics of the innovation itself, the agroclimatic conditions and the institutional support to sustain the innovation. The second category of factors includes the characteristics of the adopters, such as formal education, farm size, labor availability, income, extension visits, and contact with the market. Since these factors have been fairly extensively studied in the literature on agricultural adoption in developing countries, only a few observations are added here.

To the extent that economic policy and institutional arrangements may distort price ratios, the perceived profitability by potential adopters may be distorted as well, resulting in a diffusion process and economic benefits different from which would have prevailed otherwise. Failure to adopt innovations that would have been adopted under an undistorted price regime is reported for fertilizer and hybrid corn in Brazil (Schuh and Tollini, 1979, p. 11). Because of the artificially low return to using fertilizer on hybrid corn, research on fertilizer and hybrid corn slowed down. Brazil invested less in agricultural research than it might have with a different price policy. Policy measures, such as trade and exchange rate policies, which are unfavorable to producers, may cause a substantial reduction in the adoption of new technology and, hence, the economic benefits from a research program. Clearly, the economic policy regime has a major impact on the financial profitability of a new technology, on adoption, and on the economic returns to the agricultural research program which developed the new technology. The policy regime may also have an impact on income distribution.

The characteristics of the actual innovation include compatibility, complexity, triability, observability and riskiness (Rogers, 1983, p. 211). Compatibility refers to the extent to which the new technology is compatible with the physical and socio-economic environment and the various farm level goals in addition to profitability. Among low-income farmers, these goals generally consist of income stability, assurance of a desired mix and sufficient quantity of products for home consumption and reasonable family work loads (Pinstrup-Andersen, 1979, p. 15).

Complexity refers to the degree of difficulty for the potential adopter to understand and use the new technology. This difficulty has been recently documented in Asia (Byerlee, 1986). Because of their higher technicity, technologies of the post-green revolution do not match the technical level of most farmers and, hence, are not always properly used.

In the early phase of the diffusion of a new technology, triability or the possibility of testing the new technology on a small scale facilitates further adoption. Observability or the possibility of visualizing the performance of a new technology also encourages its adoption.

Because low-income farmers are risk averse, a new technology that improves the predictability of returns in any single year, even at the cost of lower average profitability, is likely to be preferred and adopted by these farmers than more profitable but riskier technology. Risk may have several origins: the unpredictability of agroclimatic conditions, the volatility of output markets, and the unreliability of the market for inputs complementary to the new technology (Staatz, 1989, p. 4). Most of the measures aimed at distributing production risks among producers or transferring them to insurance companies, speculators (e.g, a future markets), other actors in the marketing system, or government agencies in developing countries have not been very effective to date. Therefore, risk problems still need to be solved by properly specifying research priorities and designing new technologies (Pinstrup-Andersen, 1982, pp. 209-10).

Adoption of new agricultural technology depends on the specific agro-climatic conditions faced by farmers. When agricultural technology is strictly developed on-station under artificial conditions, such as optimal physical and climatic conditions, such technology may be poorly suited for farmers. Even when agricultural technology is developed under actual farming conditions, such technology may be suited for only narrow ecological environments (Pinstrup-Andersen, 1979, p. 14).

The institutional support to sustain innovation consists mainly in the availability of credit and inputs, extension and markets for outputs (Coulibaly, 1987, p. 21). Lack of access to desired production inputs and credit at the right time and in the right place is a very widespread phenomenon in West Africa, probably because of a lack of profitability for these markets to operate.[55] This has been observed in Mali, even for the marketing

[55] Staatz (1989, p. 6) suggests that developers need to distinguish between situations where adoption is hampered by low farmer liquidity and situations where adoption is blocked by poorly functioning input markets. This confusion may occur in areas where a

of well-known modern technologies (e.g., animal traction, fertilizer and pesticides). Extension is generally widely implemented in West Africa. Its problem is more related to inadequate technical advice with respect to the technological and socio-economic constraints faced by farmers.

The second category of factors affecting the adoption of innovations includes the characteristics of the adopters. Within that category, Coulibaly (1987, pp. 22-23) reports that the most frequently observed factors contributing to adoption of innovations are formal education, age, farm size, labor availability, income, extension visits, and contact with the market. Even if the new technology is scale-neutral, larger farms adopt more quickly because larger farms are able to spread learning costs over a greater output (Lindner, 1980; Feder, Just and Zilberman, 1982; Feder and Slade, 1984).

Coulibaly's study (1987) shows that the adoption of new varieties of cowpeas around the research station of Cinzana (Mali) is subject to the supply of and credit for complementary inputs (such as phytosanitary treatment equipment) as well as marketing outlets for cowpea production. Since the same variety of cowpeas is recommended for the Region of Mopti, his work will be used to estimate an expected adoption rate. In the area of Kayes, Traoré (1989) has used a logit model to identify the factors affecting animal traction adoption. The ratio of household population to family labor (an indicator of food consumption pressure), farm size, livestock ownership (an indicator of income and level of financial assets) and draft animal ownership (a prerequisite for plow ownership) are the major variables explaining adoption.

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development project operates and provides credit in the form of agricultural inputs. If some farmers who do not benefit from such credit fail to adopt the new technology, the lack of a privately functioning input market may be the major constraint to adoption, not the lack of credit.

In sum, the speed and ceiling of the diffusion process and the life of the innovation are determined by a wide range of adoption factors. Moreover, the life of the innovation is also determined by new upcoming technologies, to the extent to which these new upcoming technologies are better suited to the new farming and socioeconomic conditions.

iv) Conclusions

This section has examined eight distinct elements affecting the efficiency of an FSR program: the annual cost of research, its duration, its initially anticipated probability of success, on-farm implementation costs, on-farm benefits, the rate of adoption, the adoption ceiling, and the life of the innovation.

The costs, duration and probability of success of an FSR program depend on the technical complexity of the research problems and the capacity of the research system to conduct applied and adaptive research. Improvement in the farm benefit-cost ratio depends on the extent to which technical change is based on relative resource scarcities, production-limiting factors, production potential, and demand conditions. The speed and ceiling of the diffusion process and the life of the innovation are determined by a wide range of adoption factors. These factors are, first, the relative advantage of the innovation, including profitability, the characteristics of the innovation, the agroclimatic conditions and the institutional support to the innovation. The second group of factors includes the characteristics of the adopters, such as formal education, farm size, labor availability, income, extension visits, and contact with the market. The life of the innovation is also determined by new upcoming technologies, if the new innovation is better adapted to the new farming and socioeconomic conditions.

c) Factors Affecting the Equity Impact of FSR

Equity is particularly important in cases where new agricultural technologies will skew income distribution. The factors affecting the equity impact of an FSR program can be examined with respect to the changes in the income distribution between producers and consumers, between groups of producers, among owners of production factors, and within the farm production unit. These four areas of potential change will be examined successively.

i) Income Distribution between Producers and Consumers

The income distribution between producers and consumers that results from a technical change for a particular commodity depends on the structure of the demand and supply curves, the shift of the demand curve, and the nature of the shift of the supply curve for that particular commodity. This section focusses first on the effects of different demand conditions and, second, on the effects of the supply curve shift on income distribution.

In a specific area, producers tend to obtain the largest proportion of the economic benefits from a technical change affecting the production of a commodity when the commodity is a) exported from the area, b) mostly imported in the area, or c) locally consumed with a price elasticity of demand higher than that of supply. Consumers tend to obtain a large proportion of the economic benefits from a technical change affecting the production of a commodity when the commodity a) is only consumed locally with a price elasticity of demand lower than that of supply, b) has no substitutes or, c) is a large proportion of the total food budget.[56]

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[56] Whenever gains are captured by consumers, the impact of most technical changes in food production on income distribution is progressive since poor people spend a large proportion of their budget on food and the proportional gain in their real income is

When technical change occurs for a basic food staple which is locally consumed with a low price elasticity, then the near-subsistence farmers in addition to the lower-income consumers will benefit disproportionately. The near-subsistence farmers benefit from this particular technical change because these farmers consume a significant portion of their output and must buy additional food to meet household food needs. With technical change, these farmers may produce food in a less expensive way and find cheaper food in the market. These farmers have "internalized" some of the consumer surplus from technical change (Hayami and Herdt, 1977, p. 245). As a large number of Malian farmers are net purchasers of grain (Dioné, 1989), farmers in Mali would benefit from technical change even when it occurs for a basic food staple characterized by a low price elasticity.

The manner in which the gains from technical change are distributed between producers and consumers also depends on the relative rate at which the demand and supply curves shift over time. Markets characterized by rapid growth in demand enable producers to retain a relatively large share of the gains from technical change because the shift in demand counteracts the drop in the product price resulting from the shift in supply. Forecasting the demand growth for products is, therefore, important in estimating the profitability of technical change at the farm level. As demand conditions for agricultural commodities may change the distribution of research benefits between producers and consumers, research priorities for an FSR program should take into account these conditions to avoid an unintended disruption of income distribution.

The nature of the supply shift induced by technical change also affects the distribution of benefits between producers and consumers. Some economists argue that

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larger than that of rich people, who spend proportionately less on food.

the nature of the new technology may induce a divergent, parallel or convergent supply shift and, consequently, affect the distribution of benefits between producers and consumers (Lindner and Jarrett, 1978).[57] This argument is, however, based on the questionable premise that the low average-cost producers, called "inframarginal producers," are located towards the bottom end of the supply curve (near the price axis) and the relative high average-cost producers, called "marginal producers," are located at the top end of the supply curve.[58] For example, in Griliches' study (1959), the adoption of hybrid corn, which increased yields by the same percentage for all producers, generated higher yields to the low average-cost producers relative to the high average-cost producers. If total costs of both groups of producers are not affected by the technology substitution, then the cost structures for all producers are proportionately reduced and the shift in the supply function is proportionate (i.e., divergent). Consequently, fewer benefits are obtained by producers than would have been the case with a parallel or convergent shift.

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[57] A divergent shift is one in which the absolute vertical distance between the supply curves increases as quantity supplied increases. A parallel shift is one in which the absolute vertical distance between the supply curves stays constant as quantity supplied increases. A convergent shift is one in which the absolute vertical distance between the supply curves decreases as quantity supplied increases. Divergent shifts result in fewer benefits to producers than either parallel or convergent shifts (Lindner and Jarrett, 1978).

[58] Rose (1980) argues that a supply curve for an individual agricultural commodity is not a marginal curve exclusive of rent because it includes also marginal rents to fixed inputs in addition to marginal variable costs when other enterprises compete for the same fixed inputs. When supply curves are inclusive of rents, the type of supply shift is difficult to determine. For example, an efficient producer with low variable costs might experience high rents because he or she is probably also efficient in producing other commodities. In such a case, even if costs excluding the rent component may be low, rents may be high and the efficient producer may only supply the commodity at a relatively high price. Therefore, the rent component in individual commodity supply curves makes it particularly difficult to link certain producers with particular points on the supply curve.

According to this argument, evenly-diffused biological innovations are likely to result in fewer benefits for producers as a whole than innovations which induce a parallel or convergent supply shift. This also applies for biological disease control and chemical innovations, such as herbicides and insecticides. Mechanical innovations are likely to be diffused among larger farms because of the scale dependence of such innovations. Because larger farms tend to be also low-cost units, such innovations are more likely to result in a convergent supply shift and, hence, relatively larger benefits for producers as a whole, although the benefits would be concentrated among large-scale producers.

The potential distribution of benefits associated with technical change is important and must be incorporated into decisions on research priorities, particularly when specific national objectives to change income distribution patterns can not be pursued by other means. Price and export subsidies as well as measures facilitating import substitution for the commodity for which technical change is developed are often suggested as possibilities to pursue income distribution objectives. These measures contribute to increasing the financial profitability of producers, although domestic consumers may lose. However, these possibilities may face implementation problems in developing countries. For example, in Mali, the government's capacity to equitably enforce taxes and subsidies is limited.

ii) Income Distribution among Producers

Generally, three groups of producers need to be considered to assess the impact of technical change on income distribution: producers who adopt the new technology, producers who do not adopt the new technology but remain in the agricultural sector, and producers who do not adopt the new technology and leave the agricultural sector (Wise, 1981). The distribution of the adoption of the new technology among producers and, hence, the distribution of the associated benefits mostly depend on the extent to which producers are affected by the various factors of adoption that have been reviewed above, such as farm size, input access, initial wealth level and education level.

Technical change may also occur more quickly in one area than in another because the new technology fits better the agroclimatic conditions. This may lead to a differential welfare impact among producers from areas with different production potential (Renkow, 1989). To prevent an uneven distribution of income benefits, policy measures regarding land tenure and access to credit, water, irrigation facilities, fertilizers and extension services may be implemented to facilitate the technical change for certain groups of producers. In some areas, landless labor does not benefit as much from technical change. Introduction of labor-using innovations, such as biological and chemical technology, and measures to increase the mobility of the labor force may be beneficial to landless labor as well as to society (Pinstrup-Andersen, 1982, p. 213).

iii) Income Distribution among Factors of Production

A technical change that induces factor substitution may have a considerable impact on the distribution of economic benefits among factor owners, depending on the factors and product market conditions (Binswanger and Ryan, 1977, p. 228; Pinstrup-Andersen, 1982, pp. 136-140). For example, a land-saving innovation, such as a biological or a chemical technology, which increases land efficiency where land is in relatively inelastic supply and final product faces an elastic demand, shifts outwards the demand for land and, as a result, increases prices of land. A large part of the economic benefits associated with the introduction of the land-saving technology may then be capitalized into land values. Likewise, a labor-saving technical change due, for example, of the introduction of animal traction may increase wages in areas with low unemployment and inelastic labor supply. However, in areas with high unemployment and a highly elastic labor supply, a labor-saving technical change results in an increase in employment.[59] In case of the introduction of capital-intensive technology, such as animal traction and fertilizer, capital owners and producers of these technologies may acquire a significant portion of the economic benefits associated with such technical change. This may also have a positive impact on employment and incomes outside the agricultural sector. In Mali, where the most important agricultural input is family labor, labor-saving technical change mainly benefits to the family. Because the most common labor-saving technology is animal traction, it may then benefit to capital and livestock owners, and blacksmiths.

iv) Income Distribution within the Farm-Household Unit

The impact of technical change on income distribution within the farm-household unit was, until recently, not often used to assess the priorities of a research program. "Household economics" has been helpful in providing insights into the interrelationships among the production, consumption, marketing and social activities undertaken by the different members of a farm-household unit. Callear (1983) shows that returns to labor are likely to be more crucial for women because of their already great time constraints. As a result, within the same farm-household unit, the opportunity costs of accepting new crops and technologies are often different between men and women.

v) Conclusions

Between producers and consumers, the factors affecting the distribution of the benefits associated with technical change for a particular commodity include the structure of the demand and supply curves, the shift of the demand curve, and the nature

[59] The increase in wage or employment occurs if the market demand for labor due to the increase in labor efficiency offsets the labor-saving effect, an observation which has been widely documented (Pinstrup-Andersen, 1982, p. 138).

of the shift of the supply curve for that particular commodity. For many basic commodities, because many producers are also net buyers, they receive "consumer" benefits from new technologies in addition to producer benefits.

Among producers, the factors affecting the distribution of benefits are primarily the same as those affecting technology adoption: farm size, input and credit access and initial wealth level. Among owners of production factors, the price elasticities of the supply of production factors and the demand for the final product affect the distribution of econmic benefits from technical change. Within the farm-household unit, differences in opportunity costs and responsibilities among members affect the distribution of benefits associated with technical change.

If there are undesirable income distribution effects from technical change for consumers and producers, and if efficiency gains are expected to be important, policy measures such as taxes, subsidies or institutional arrangements can be used to correct the distributional problems. In countries like Mali, the institutional capacity limits the implementation of such policy measures equitably. If the distributional effects cannot be corrected by policy, equity considerations can be used to direct agricultural research priorities. Likewise, if there are undesirable income distribution effects from technical change among producers, measures facilitating technical change for disadvantaged groups of producers are available.

d) Factors Affecting the Security Impact of FSR

All farmers, but especially small farmers, are concerned with meeting subsistence food requirements in addition to increasing farm income. They are not willing to take risks that might endanger not only their subsistence supplies but also their sources of cash income needed to face fiscal and social liabilities. Security is a primary concern for the farmers and must be considered in the evaluation of the production impact of FSR.

Risk results from the uncertainty of the outcomes of a particular situation. The situation is "risky" when the possible outcomes of the situation may positively or negatively alter the well-being of either a well-defined group of people or a single person (Fleisher and Robison, 1983). The riskiness of a situation depends then on the preference of people and the possible outcome of the situation.

The origins of uncertainty are several. For a farmer, the uncertainty of outcomes from farm activities comes from three major sources: yield variability, cost variability, and product price variability (Wharton, 1969, pp. 159-60). Yield, cost and product price variability depends on a host of intervening factors such as weather, pest attacks, input availability, and input and product prices. Some factors are controllable by the farmer or others outside the production unit (e.g., policy-makers, marketing board), while other factors are uncontrollable (e.g., rainfall).

A useful classification of the factors that affect an FSR program's ability to reduce production risk distinguishes between two types of risk. First, because of the transition from a relatively known situation to an unknown situation, technical change may introduce a "subjective" risk to the production process. Because the potential adopter is unfamiliar with the new technology, the yield that he expects from the new technology is more uncertain and is perceived as having a wider variance than the traditional technology that he knows fairly well. Second, technical change may often introduce "objective" risks in the new production process.[60] The variance of the yield with the

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[60] Because, as argued by Fleisher and Robison (1983, p. 5), all measures of probability involve a degree of subjective judgement, "objective" risks do not imply that an event will occur with an empirically "proven" or analytically "true" probability but that

new technology actually is different from the variance of the yield with the traditional technology. For example, the yield variances may be different because of different responses to weather variations or pest susceptibility, or because of the need to have crucial inputs for the new technology on time. The farmer's decision regarding the adoption of the new technology will be of course based on his subjective perception of risk, not on the "objective" risk. This explains why most empirical work has been on the former, not the latter. The distinction between "subjective" and "objective" risk is, however, useful because it clarifies the sources of risk and, hence, makes it possible to design improved technologies and formulate measures that would reduce risk in farm production. This section will review briefly the sources and effects of both types of risk and some actions that could facilitate technical change.

i) "Subjective" Risks

Farmers' technology choices are based in part on their subjective perceptions of risk and, hence, on their exposure to information regarding new technology (Feder, Just and Zilberman, 1982, p. 30). The subjective perception of risk evolves as more appropriate information and observations about the new technology become available to the potential adopters (Kislev and Shchori-Bachrach, 1973; Hiebert, 1974; Lindner, Fisher and Pardey, 1979; Lindner, 1980; O'Mara, 1980; Feder and O'Mara, 1981 and 1982; Feder and Slade, 1984). At the beginning of the learning process, farmers tend to add a significant discount factor to any estimates of yield derived from their perceptions about a new technology (Wharton, 1969, p. 156). Because the decision to adopt a new technology is the result of a learning process, measures that speed up the learning

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the event will occur with a probability within some subjectively set confidence interval that is likely to be more correct than in case of "subjective" risks.

process, such as extension agent farm visits and field demonstrations, facilitate the diffusion of new technology. In addition to information on the technical content of the new technology, information about the political and institutional environment may also reduce the risk perceived by farmers in making technology choices (Dioné, 1989, p. 97).

Some studies have tested the hypothesis that farmers' attitudes towards risk can be explained in part by socio-economic characteristics (Fleisher and Robison, 1983, p. 82). However, no relationship between socio-economic factors and attitudes toward risk were found across studies.[61] The socio-economic characteristics tested included farmer age, education level, family size, land ownership, income sources and level, and credit and information access. Most of the studies did, however, support Arrow's hypothesis of decreasing absolute risk aversion with increasing wealth.

According to Fleisher and Robison (ibid.), the mixed findings may indicate that there needs to be a distinction "between that part of risk taking behavior which is innate to the individual (not a consequence of economic variables or constraints) and that which is income or wealth determined" (p. 86). They call the innate propensity to bear risk "the preferential risk aversion" and the effect of wealth on the ability to bear risk "the induced risk aversion." Huysam (1978) and Berry (1979) argue that induced risk aversion can be favorably modified in favor of adoption of new profitable technology by increasing the farmer's capacity to bear risk. According to their views, what is also needed to diffuse new technology among resource-poor farmers are "institutional policies aimed at equalizing access to factor and product markets." Likewise, Binswanger (1979)

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[61] The review of the studies included the Oregon grass seed farmers (Halter and Mason, 1974; Whittaker and Winter, 1980), Northeast Brazil's small owners and sharecroppers (Dillon and Scandizzo, 1978), Mexican Peubla farmers (Moscardi and de Janvry, 1977), and Indian farmers (Binswanger, 1980).

recommends specific policy alternatives that would improve farmers' capacity to bear production risks and, consequently, help diffuse more profitable but unfamiliar technologies. These policy alternatives include: crop and credit insurance, input and credit subsidies, plant protection measures, famine relief, price stabilization and support, market facilities and information improvement, input access and extension improvement, land tenure reform and other measures that affect resource and wealth distribution.

ii) "Objective" Risks

Technical change involves "objective" risks when the new technology, although more profitable when the returns are estimated over several growing seasons, has yields with a wider variance than the old technology. "Objective" risks are also important when the productivity of a new technology depends on additional external factors that are not under the control of the potential adopter.

Binswanger (ibid.) suggests that the degree of riskiness inherent in a new technology depends on the investment levels associated with the new technology and the shift or change in the yield distribution. With respect to the shift or change in the yield distribution, Binswanger (ibid.) classifies technologies into three categories: 1) "nonprotective inputs" for the technologies that shift the yield distribution without narrowing it (e.g., new seeds, fertilizers or mechanical technologies), 2) "protective inputs" for the technologies that only reduce the yield distribution (e.g., pesticides and disease and drought resistant varieties), and 3) "inputs with a dual role" for the technologies that increase the yield and reduce the yield distribution (e.g., irrigation).

Not surprisingly, because of their risk reducing effect, the technologies in the last two categories are preferred by risk-averse farmers and do not require much promotion.[62]

In contrast, adoption of "nonprotective" new technologies, i.e., technologies which are more profitable on average but riskier, requires an improvement in the farmers' capacity to bear production risk (via the measures mentioned above). However, as Pinstrup-Andersen (1982, p. 210) has noted, these measures are difficult to implement in a developing country context. Therefore, research priorities and technology specifications should still promote the development of risk-reducing technologies i.e., those technologies involving either protective inputs or dual role inputs. Research activities such as breeding for crop yield stability or improving mixed cropping (a traditional technique that minimizes production risk) should continue to receive priority.

iii) Conclusions

FSR programs that develop new technologies must be sensitive to the subsistence requirements and fiscal and social liabilities of resource-poor farmers. Technical change affects the riskiness of the farm production process in two different ways. First, technical change may introduce a "subjective" risk in the new production process. Because he or she lacks familiarity with the new technology, the farmer tends to perceive the new technology as riskier than the traditional technology. Second, technical change may introduce "objective" risks in the new production process. All things equal, the "objective" risks are determined by the actual shift and change in the yield distribution. The subjective perception of risk of a potential adopter with respect to a new technology primarily depends on 1) the information available to farmer about the new technology

[62] For the special case of mean-variance analysis, a larger mean and an equal or smaller variance is a sufficient condition for dominance.

and the political and institutional environment, 2) the farmer's innate propensity to bear risk and 3) his or her socio-economic ability to bear risk. Consequently, measures that improve the farmer's access to appropriate information regarding new technology and to factor and product markets modify the subjective perception of risk and, hence, facilitate the diffusion of more profitable new technologies. Most of these measures may not, however, be feasible in a developing country context. Therefore, technical change may need to be induced with more profitable technologies that do not significantly increase "objective" risks.

e) Factors Affecting the Sustainability Impact of FSR

Sustainability of the farming systems is another important goal for FSR, particularly when market forces do not value resources used in production or consumption at their long-run opportunity costs. The failure of the market to value externalities, such as environmental degradation, donors' free assistance and the effect of price distortions on the allocation of resources, at their opportunity cost necessitates government intervention to correct potential inefficiencies.[63] This section focusses on economic sustainability (i.e., long-term economic efficiency) and environmental sustainability, both of which are of interest to clients of FSR.

i) Economic Sustainability

The economic behavior of farmers is largely influenced by the market forces they face. However, taxes, subsidies, trade restrictions and exchange rate policy may distort market prices so that they do not represent the opportunity costs of resources. Because market prices guide profit-optimizing farmers in the allocation of their resources, price

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[63] An externality is viewed as either an economic gain or loss not reflected in the market price.

distortions may result in an efficiency loss. In particular, price distortions may result in an inefficient choice of technologies. With price distortions, the adoption of a new technology may be financially attractive for adopters but not economically justified for society or vice versa. To prevent efficiency loss in the choices of technologies, some mechanisms (i.e., financial incentives or disincentives and regulation) are needed to offset price distortions when the sources of these distortions cannot be removed. In any case, the economic sustainability of technology choices must be incorporated into research priorities and technology specification so that technological development is not based just on short-run financial conditions.

ii) Environmental Sustainability

If the relative resource endowment at the local level in soil, water, pasture, forest and game is not reflected in relative input prices, absolute availability, or government or community regulation, then environmental sustainability is at risk. In these circumstances, the resource-poor farmers who periodically face food and cash shortages are likely to have an economic behavior driven by short-run survival objectives that may have disastrous long-run consequences on the environment.

Soil erosion and depletion due to wind, run-off water, deforestation and soil-mining agricultural techniques are the most visible environmental damages in rainfed semi-arid areas. Because they occur over the long-run, these damages are difficult to evaluate. In particular, any economic evaluation of measures aimed at limiting these damages faces the problem of the proper discount rate or time preference. For society, the economic discount rate is likely to be low to reflect the concerns of future generations. For a head of household responsible for family survival, the discount rate is likely to be very high.

Both positive and negative environmental impacts of technical change induced by FSR should be considered in an FSR program. These effects should be evaluated on economic and financial grounds. If technical change gives rise to positive environmental effects and is economically but not financially attractive, regulation or financial compensation may induce the socially desired technical change, the choice between regulation or compensation depending on the relative costs of implementing the two alternatives. For financially attractive technologies with negative environmental effects, either the net economic benefits will be sufficiently large to provide compensation to those who are harmed and still leave a net economic surplus, or the net economic benefits will be sufficiently small to limit the use of that particular technology. Appropriate economic policies such as compensation, fees and regulation can promote positive environmental effects. In a developing country context, such economic policy is, however, difficult to enforce. Therefore, technical change should still be oriented towards new technology that affects positively the environment and that is both economically and financially attractive. In sum, environmental sustainability involves pursuing economic as opposed to financial efficiency. It has been considered under a separate heading to underline its importance.

iii) Conclusions

Economic and environmental sustainability are compromised when inappropriate market price ratios bias technological choices towards inefficient technologies and undervalue natural resources. When economic efficiency is at risk, these biases may be corrected through economic policy measures. However, because these desirable, corrective measures are difficult to implement and enforce in a developing country context, researchers must take into account economic and environmental sustainability in addition to financial profitability when developing new technology.

3.3.4. Conclusions

Figure 3.3 shows a simplified flow chart indicating the different factors affecting the return to an FSR program. The chart assumes that the FSR institution is capable of conducting a sound research program. This means that all the conditions for FSR to have a positive institutional impact on the national agricultural research system are met. The ability of the FSR institution to conduct a research program determines the identification of the research priorities, the annual research costs, the research duration and the probabilities of research outcomes. These four elements determine what kind of new technologies are developed with the help of on-station research. The new technology improves the farm benefit-cost ratio to the extent to which the new technology addresses different problems facing the farm production system (i.e., relative resource scarcity, farm production limiting factors, production potential, product demand and input supply conditions). On-farm incremental costs and benefits determine the on-farm incremental net benefits or the profitability of switching from the traditional to the new technology. The on-farm profitability of the new technology as well as the other advantages of the new technology, the characteristics of the potential adopters, the institutional support for technology adoption and the time the new technology is available shape the diffusion process. The life of the new technology is determined by the extent to which the new technology continues to fit into the farming system, product demand and input supply conditions, and the capacity of FSR to renew technology.

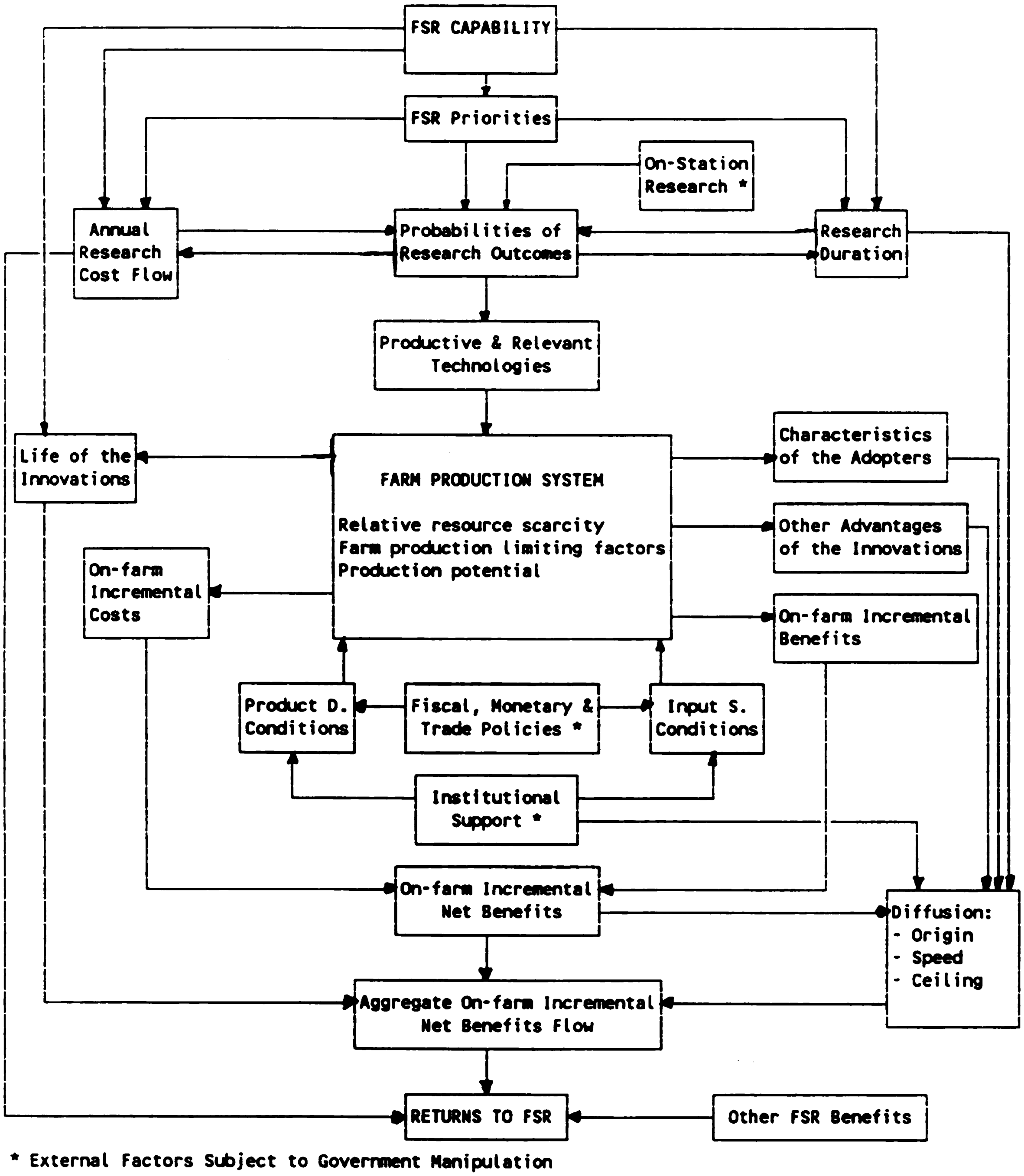

Figure 3-3. Factors Affecting the Return to FSR

The life of the new technology, the on-farm incremental net benefits and the diffusion process define the flow of aggregate on-farm incremental net benefits. Finally, the efficiency of FSR, or the returns to FSR, is the sum of the aggregate on-farm incremental net benefits flow and other FSR benefits such as those generated at the consumption, processing or marketing levels and external economic benefits (e.g., reduction of erosion or pollution), and discounted by the costs of the FSR program.

The asterisks on the simplified flow chart indicate three broad external factors that can be manipulated by government actions and influence the efficiency of an FSR program. They are 1) the capacity of on-station research to conduct relevant applied research, 2) the institutional support for the diffusion of new technology, mainly extension and credit, and 3) fiscal, monetary, trade, and market development and regulatory policies that improve the efficiency of the input and output markets. These three broad factors form the basis of scenarios that represent different types of improvements in the institutional and policy environment of FSR. The effects of these factors on the production impact of FSR will be developed in chapter 7. First, the production impact of FSR under the institutional and policy conditions currently prevailing in the Region of Mopti is evaluated in the following chapters.

4. FSR PROGRAM IDENTIFICATION

Using an evaluation criteria approach suggested by Norton et al. (1989) for The Gambia, this chapter identifies a research program for FSR in the Region of Mopti. This chapter specifies research priorities in terms of commodities and research areas, and selects among priorities according to criteria that reflect the main objectives of the research program. In chapter 3, four broad sets of criteria, reflecting efficiency, equity, security and sustainability objectives were proposed to evaluate FSR's impact on production. Here, we use the same broad objectives to select the research priorities with, however, more emphasis on efficiency. First, commodities are ranked according to a weighing procedure that includes these objectives. Second, research areas are identified and prioritized according to the major constraints of the farming systems of the region and the technological components that are available from on-station research. Finally, the research priorities are ranked by area of research within major commodity groups.

4.1. Commodity Priorities

This first section ranks commodities according to a set of efficiency criteria, then according to sets of equity, security and sustainability criteria.

4.1.1. Efficiency Criteria

Although chapter 3 identifies a large number of factors that affect the efficiency impact of FSR, here we consider those factors affecting the benefits from research that can be measured simply. The potential benefits from research depend partly on the relative importance of the agricultural commodities in terms of value of production, domestic consumption and export opportunities. The relative contribution of the agricultural commodities to the value of total production directly determines the research benefits since, for similar research costs and incremental farm net benefits, research that produces results applicable to commodities that are worth more obviously has higher returns. Current and future domestic consumption as well as export opportunities also directly determine the potential value of the research results. Within the economic surplus framework, research targeted on commodities with expanding demand will have higher returns than research on commodities with stable or declining demand.

Accordingly, this section examines three efficiency criteria to rank commodities: 1) relative value of production, 2) current and future domestic demand, and 3) export opportunities.

a) The Relative Value of Production

Table 4-1 reports the relative value of production of different crops in the Region of Mopti. Based on the 1985 to 1988 harvests (OSCE, 1989), gross average estimates indicate that millet represents 57% of the total value of crop production, rice 21% and cowpeas 10%. Minor crops include groundnuts, Bambara groundnuts, sesame, and onions. Together, the three major crops represent 88% of crop production value. Rice and millet produced in Mopti are important for the national economy also. With only

17% of total population (Ministère de l'Administration Territoriale et du Développement à la Base, 1987), the Region of Mopti produces 28% of national rice production and 16% of the national millet-sorghum production.

Table 4-2 reports the relative value of livestock production. Between 1985 and 1987 (OSCE, 1989), the regional cattle herd represented on average 64% of the total value of livestock in the Region of Mopti, while the sheep and goat herd represented about 36%. About 20% of the national cattle herd and sheep and goat herd were found in this region. In 1976, two years after the drought, livestock represented 15% of the gross domestic product (Delgado, 1981, p. 254). Since then, no dramatic evolution of the livestock sub-sector has been observed. In the 1980s, livestock accounted for about 18% of gross domestic product (Stryker et al., 1987, p. 6) and 20% of gross national product in 1987 (Bocoum, 1990, p. 1).

To compare the value of ruminants to each other and to the value of crop production, the stock value of cattle and small ruminants needs to be converted into an annual flow of value (Table 4-3). Over the 1985-87 period, the average value of cattle meat and milk production was 10.98 billion CFA F (62% of the total value of livestock production) while that of mutton and goat meat was 6.73 billion CFA F (38% of the total). Although the mutton production value does not completely represent the total value of production for the small ruminants since milk production value is not estimated (as leather in both cases), the value of sheep and goat production would still be lower than the value of cattle production.

Table 4-1. Crop Production Value in the Region of Mopti

CROPS (1)	REGION OF MOPTI PRODUCTION (1985-88) (1000 T)	VALUE (1985-88) (Million CFA F)	VALUE (1985-88) (%)	MALIAN PRODUCTION (1985-88) (1000 T)	MOPTI'S SHARE OF NATIONAL PRODUCTION (1985-88) (%)
Millet-Sorghum-Fonio	223	13380	60.4	1362	16.4
Paddy Rice	70	4900	22.1	248	28.2
Cowpeas (2)	22	2420	10.9	NA	NA
Sesame (2)	22	154	0.7	NA	NA
Onions (3)	20	1200	5.4	NA	NA
Groundnuts	1.1	66	0.3	120	0.9
Maize	0.3	21	0.1	200	0.2
Total		22141	100.0		

(1) No estimates exist for minor crops such as Bambara groundnuts and dah.
(2) Estimated at 10% of the millet-sorghum-fonio production.
(3) The production estimate seems exagerated.
Source: Author's estimations based on OSCE (1989) for production figures and Henry de Frahan et al. (1989) for average prices.

Table 4-2. Livestock Value in the Region of Mopti

LIVESTOOCK	REGION OF MOPTI PRODUCTION (1985-87)(1) (1000 Head)	VALUE (2) (1985-87) (Million CFA F)	VALUE (1985-87) (%)	MALIAN STOCK (1985-87) (1000 Head)	RATIO OF MOPTI'S STOCK OVER MALI'S (1985-88) (%)
Cattle	885	42434	64.4	4469	19.8
Sheep & Goats	2095	23418	35.6	11141	18.8
Total		65852	100.0		

(1) 1985-1987 average on OSCE (1989) reported figures.
(2) Based on a weighted value of 47,700 CFA F per head of cattle and 11,200 CFA F per sheep or and goat. The weighted values are estimated by considering the herd structure (Traore et al., 1979, Annex 8, Table 1) and June 1985-May 1987 prices recorded on Fatoma's market (ODEM, 1987a) excluding the seasonal low point of sales (May-July) and discounting the market prices by 10% to obtain farm gate values.
Source: Author's estimations.

Table 4-3. Annualized Value of Livestock Production in the Region of Mopti

COMPONENT	CATTLE	SHEEP & GOATS	TOTAL
MEAT PRODUCTION:			
Stock (1,000 head) (1)	885	2095	
Annual meat production:			
Per head (Kg) (2)	14	4	
Per herd (Metric tons of carcass)	12390	8380	
Annual value of meat prod (Million CFA F) (3)	7315	5854	13170
"Fifth Quarter" (Million CFA F) (4)	1097	878	1975
MILK PRODUCTION:			
Stock producing milk (1,000 head) (5)	195	NA	
Annual milk production:			
Per cow (Kg) (6)	132	NA	
Per herd (Metric tons of milk)	25700	NA	
Annual value of milk prod (Million CFA F) (7)	2570	NA	2570
TOTAL ANNUAL VALUE OF PRODUCTION:			
in million CFA F	10982	6733	17715
in percentage (%)	62	38	100

(1) 1985-87 annual average (OSCE, 1989).
(2) OMBEVI (1978) estimations reported in Delgado (1981, pp. 280-81).
(3) Estimated at a farm gate price of 590 CFA F per kilo of beef and 700 CFA F per kilo of mutton on the basis of June 1985-May 1987 prices recorded on Fatoma's market (ODEM, 1987a) excluding the seasonal low point of sales (May-July) and discounting by 10% the market prices to obtain farm gate prices, and on the basis of carcass weights of 125 kg for cattle and 16 kg for sheep and goats (Delgado, 1981, pp. 264-65).
(4) The value of offal, hides, etc. is estimated at 15% of the meat production.
(5) Estimated on the basis that cows represent 44% of the total herd structure, half of them producing milk (Traore et al., 1979, Annex 8, Table 1).
(6) Annual production of milk for human consumption (ILCA, 1981, p. 199).
(7) Estimated at a farm gate price of 100 CFA F per kilo of milk (Henry de Frahan et al., 1989, p. 91).

Source: Author's estimations.

The wood supply in the Region of Mopti was roughly estimated at 1.08 million steres, from which 60% constitutes the accessible supply (Shaikh, 1985, p. 5). With a stumpage value estimated at 4500 CFA F/stere, the total accessible supply of wood in the Region of Mopti amounts to 2.92 million CFA F (Table 4-4).[64]

Concentrated in the Region of Mopti, fishing represents approximately 3% of gross domestic product (Opération Pêche Mopti, n.d., a). No estimate of fish price exists to estimate the value of the fish catch amounting at 60,000 tons between 1983 and 1987 (Table 7 of Appendix 2-A).

In terms of annual production value, commodities are therefore ranked from high to low value as follows: 1) millet-sorghum-fonio, 2) cattle, 3) small ruminants, 4) rice, 5) wood, and the minor crops indicated in Table 4-4.

b) Domestic Demand

The Region of Mopti is currently cereals-deficit and imports cereals from the southern regions of Mali and from abroad. Statistics show that local cereal production was enough to cover only 55% of the regional food requirement in 1987-88 (OSCE, 1989). This cereals deficit indicates that regional demand for cereals could absorb additional locally produced cereals, if they were produced at a competitive cost. Moreover, national demand for cereals will continue to outpace national production, particularly for rice (Ministry of Agriculture, 1987, p. 87). In years of coarse grain production surplus, as in 1988 and 1989, it is, however, important to find outlets for surplus production, such as export markets and domestic poultry production, to avoid

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[64] The stumpage value of wood refers to the value of the resource at the site, exclusive of transportation and handling costs. The stumpage value corresponds to the cost of producing wood and is estimated by taking the net present cost of production per stere over a life cycle of 20 years (Shaikh, 1985, p. 54).

Table 4-4. Agricultural Research Priorities by Commodity

COMMODITY	EFFICIENCY CRITERIA: TOTAL ANNUAL VALUE OF PRODUCTION(1) (Million CFA F)	(%)	FUTURE DOMESTIC DEMAND (2) (%)	MARKET POSSIBILITIES (3)	EFFICIENCY RANK (4)	EQUITY CRITERIA: PERCENT. PRODUCERS (5) (%)	IMPORTANCE IN BUDGET OF POOR (6)	EQUITY RANK (7)	SECURITY CRITERIA: CV OF PRODUCTION (8) (%)	SECURITY RANK (9)	SUSTAINABILITY CRITERIA RANK
Millet-Sorghum-Fonio	13380	31.9	14	North	1	47	1	1	40	2	Low
Cattle	10982	26.2	4	Export	2	15	4	3	24	3	High
Sheep & Goats	5854	14.0	20	Export	2	15	4	3	12	5	High
Paddy Rice	4900	11.7	40	Local	4	23	2	2	70	1	Low
Wood (9)	2920	7.0	14	Local	5	Few	3	3	Low	6	High
Cowpea	2420	5.8	NA	North	NA	47	2	NA	NA	NA	High
Sesame	154	0.4	NA	Export	NA	47	5	NA	NA	NA	Low
Onions	1200	2.9	NA	Export	NA	15	5	NA	NA	NA	Low
Groundnuts	66	0.2	NA	Local	NA	47	5	NA	NA	NA	Medium
Maize	21	0.1	NA	Local	NA	47	5	NA	NA	NA	Low
Fish	NA	NA	NA	Export	NA	10	5	4	13	4	High
TOTAL	41898	100.0									

(1) From Tables 4-1 and 4-3.
(2) Expected change in domestic demand over the next 5 years based on Ministry of Agriculture (1987, p. 87), Delgado (1981, p. 349) and Shaikh (1985).
(3) Export for export market, North for northern Mali, and Local for local market.
(4) For a weight distribution of 50% on annual value of production, 25% on future domestic demand, and 25% on market possibilities.
(5) From Table 4-5.
(6) From 1 to 5 in decreasing importance.
(7) For an equal weight distribution between percentage of producers and product characteristics.
(8) From Tables 3 to 5 and 7 of Appendix 2-A.
(9) From the most variable to the least variable.
(10) Values for wood are estimated from Shaikh (1985).
Source: Author's estimations.

disinvestment in coarse grain production. Domestic demand for coarse grains will continue to be important in Mali because coarse grain is the major staple in Mali and a large proportion of the Malian population still cannot afford to buy enough to cover their needs, particularly in production deficit years. Gradual increases in income may also sustain domestic demand for coarse grains.

Estimates on the future domestic demand for livestock and fish are not available. The only indication of demand growth for livestock products is the 1974-1977 compounded annual growth rates for domestic consumption of beef and mutton that are estimated at 0.7% and 3.7% respectively (Delgado, 1981, p. 349). Assuming that since then and for the near future all price changes do not affect the demand for livestock products, and population growth, income growth and income elasticities for beef and mutton are similar to those of the 1974-1977 period, then the historical domestic demand growth rates for livestock can be taken as an indication of the future domestic demand growth for beef and mutton. Changes regarding the export demand for beef that have occurred since 1977 are examined in the next section.

Wood demand is two times that of sustainable wood production of the regional natural forests, a situation which is leading to rapid forest depletion (Shaikh, 1985, p. 40). To maintain just the current 50% ratio of sustainable yield to demand, yield would have to grow at least by the same rate as population (2.5%). However, even this rate would not be enough to hold the supply-demand ratio constant, since the excess demand which already exists would continue to deplete the forests and lower future yields.

Based on the available future domestic demand growths for rice, millet, wood, beef and mutton, the expected changes in domestic demand over the next five years for these major commodities are estimated and reported in Table 4-4. The expected changes in demand is the highest for rice (40%), then for sheep and goats (20%), millet and wood (14%) and cattle (4%).

c) Export Opportunities

The Region of Mopti is the most important region of the country in terms of livestock, fish and onion exports both to other regions of Mali and abroad. According to different sources of statistics, export revenues from livestock have, however, declined since the 1973 and 1974 droughts. Fish exports from the port of Mopti have also declined. No statistics are available to confirm a similar decline in onion exports.

After the droughts and imports of Latin American and European beef by West Africa coastal countries beginning in 1975, livestock became the second most important source of export revenue after cotton. In 1976, total livestock export revenues represented roughly 40% of Malian export revenues.[65] Since 1976, the situation has deteriorated for livestock exports, particularly for cattle, mainly because of Mali's slow recovery of productivity combined with increasing international competition for beef in the coastal countries. In 1987, total livestock export revenues fell to 29% (Bocoum, 1990, p. 1)

Fishing exports from Mali rank fourth after cotton, livestock products, and groundnuts. Between 1972 and 1985, an average of 22% of national fish production has been exported, representing 8% of Malian export revenues. Mali is the tenth largest producer of fish in Africa, and among the largest producers in the Sahel (Opération

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[65] According to Traore et al. (1979), the pre-drought livestock share of export revenues was 45% in 1971 and dropped to 31% in 1976 after the droughts. Their estimation of the livestock share of export revenues for 1976 (31%) differs from Delgado's estimation (40%) because of difficulties in estimating real figures from the customs records.

Pêche Mopti, n.d., a). Particularly since 1983 smoked and dried fish exports from the port of Mopti have dramatically declined (Table 7 of Appendix 2-A).

The export potential of regional crop production is more limited than for livestock and fisheries. Rice and millet production in the Region of Mopti is mostly consumed locally. The export market for groundnuts is not encouraging because of depressed world prices for groundnuts and Mali's landlocked position. Most onion production is sold at local assembly markets and then shipped to the main consumption markets of the country and neighboring countries. Sesame, although not currently exported, has the potential to be exported if export market varieties and cost-saving technology are introduced. Developing cowpea and Bambara groundnut production for domestic markets and perhaps also for export is possible if the marketing of these products is better coordinated. There are no significant wood exports from the Region of Mopti.

From an economic standpoint, it would be efficient to orient agricultural research to the commodities in which the Region of Mopti has or could have a comparative advantage. Morris (1989) uses the domestic resource cost (DRC) ratio to show comparative advantage between alternative enterprises, regions and technologies in order to set agricultural research priorities. The DRC ratio is an efficiency indicator that shows what the internal costs of producing a product within a country are, or will be, compared with the cost of importing the equivalent of those internal costs from abroad.

Estimates of DRC ratios for deep floating rice in Stryker et al. (1987) show that the Region of Mopti has a comparative advantage in rice production for local consumption. DRC ratios for the main rainfed crops will be estimated in chapter 5 that will analyze the economic viability of the technical packages that FSR could develop. In that section, DRC ratios will be compared across crop enterprises and regions to identify the commodities in which the region has a comparative advantage with respect to the other regions of the country. In addition, because agricultural research may improve the comparative advantage for some commodities, the DRC ratios will be estimated again with the proposed technologies that agricultural research could develop. As the results of the DRC analysis on crop enterprises will show, the comparative advantage of the Region of Mopti lies with 1) groundnuts for local markets, 2) rice, millet and cowpeas for the local and Gao markets, and 3) sesame for export markets. Although no data are available to estimate DRC ratios for livestock, fisheries, and onions, it is likely that the Region of Mopti also has a comparative advantage in these three areas given the historical importance of its exports.

In sum, export opportunities from the Region of Mopti belong first to livestock, fisheries, onions and sesame for the Bamako and export markets, and then to millet and cowpeas for northern Mali. Rice, groundnuts, maize and wood should be marketed for local consumption only. The commodities are classified, with respect to their market possibilities, into three categories in Table 4-4: export, northern Mali and local markets. The five major commodities for which data on the first two efficiency criteria exist are ranked according to their market possibilities: '1' for export markets, '2' for northern markets, and '3' for local markets.

d) Commodity-Ranking According to Efficiency Criteria

To rank commodities with respect to their expected impact on national income, the three series of ranking are pooled together, using weights that reflect the relative importance given to each efficiency criterion. More weight (50%) is given to the annual value of production, with equal weights (25%) given to the expected future domestic demand and to export opportunities. The major commodities for which data are available are thus ranked as following: 1) millet, 2) livestock, 3) rice, and 4) wood. This ranking will be integrated with equity and security criteria in the final commodity ranking.

To assist with commodity rankings, additional efficiency criteria, such as expected yield increases or cost reductions if research is successful, probability of research success, and expected adoption rates by farmers if the research is successful are relevant (Norton et al., 1989). Some of these efficiency criteria will be considered later in the selection process when research priorities are established.

4.1.2. Equity, Security and Sustainability Criteria

At this stage of the selection process, only limited information exists to commodities according to the potential impact that a research program may have on equity, security and sustainability. A more precise identification of the equity, security and sustainability impact will come later when the FSR program will be evaluated.

a) Equity Criteria

It is assumed that FSR's distributional objectives consist of increasing 1) the income of the rural population, which represents more than 90% of the regional population and 2) the well-being of the low-income rural and urban population. With respect to the first equity objective, increasing rural incomes is tantamount to giving a higher research priority to commodities that constitute the main source of income for the rural population. With respect to the second equity objective, increasing the well-being of the low-income population amounts to giving a higher priority to commodities that are basic foods. Values corresponding to these two equity criteria are successively estimated and reported in Table 4-4.

By measuring the proportion of the rural population whose living depends primarily on a particular commodity, it is possible to rank the commodities according to their relative importance in the composition of rural incomes. We have defined the farming systems in the region according to the main production activity of the system's members, i.e., in terms of the commodity that generates most of the income in the system. Therefore, figures on the number of people relying on the different farming systems are an indicator of the proportion of the rural population whose living depends on a particular commodity. Table 4-5 estimates and ranks the relative size of the different farming systems in terms of population.

The system of production based on rainfed commodities has the highest proportion of the rural population (47%), followed by floating rice (23%), livestock and onions (both 15%), fish (10%), and finally flood recession crops (6%).[66] Most households cut some wood for home use but few live principally from wood production and sales. Accordingly, the commodities are ranked as follows: 1) millet and other rainfed crops, 2) rice, 3) cattle, small ruminants, and onions together, 4) fish, 5) flood recession crops, and 6) wood (Table 4-4).

Since crops, livestock and fish are traded commodities in the Region of Mopti, the rural population will benefit from any technical improvements that decrease the production cost of these commodities. Being both producers and consumers of these commodities the rural population benefits from both the increased producer surplus and the increased consumer surplus.

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[66] Because onion producers are also largely involved in growing rainfed crops, they are counted twice, first in the rainfed crop-based farming system and, second, in the onion-based farming system.

Table 4-5. Percent of Farmers Relying on Different Commodities as the Major Source of Income

System	Population	Percentage	Rank
MIXED SYSTEM:	955200	75.7	
Rainfed Crops (1)	590400	46.8	1
Including Onions (2)	183000	14.5	3
Floating rice:	284800	22.6	2
Natural Flood (3)	212800	16.9	
Controlled Flood (4)	72000	5.7	
Flood Recession Crops (5)	80000	6.3	6
LIVESTOCK SYSTEM:	186200	14.8	3
Inland Delta (6)	121200	9.6	
Seno (7)	65000	5.2	
FISHING ACTIVITY (8)	120000	9.5	5
TOTAL	1261400	100.0	

(1) Population of the rainfed agriculture area less the Fulani population, estimated at 11% (Henry de Frahan et al., 1989).
(2) Population of the circle of Bandiagara.
(3) Residual population.
(4) 12000 ORM farmers with an estimated average family size of 6.
(5) Population of the districts surrounding lakes (Bore, N'Gouma, Korientze, Singegue and part of Youwarou).
(6) 20% of the population of the delta (Gallais et Boudet, 1980, p. 81).
(7) 11% of the population of the rainfed agriculture area (Henry de Frahan et al., 1989, Table J.1).
(8) Estimated on the basis of an annual population growth rate of 2.5% for an initial population of 70000 in 1965 (OPM, n.d.,b, p. 5).
Source: Author's estimations.

The second equity criterion is the relative importance of the commodity in the real-income budget of poor consumers. Because a large proportion of the low-income population's total food budget is spent on food staples, any reduction in unit production costs for staples will disproportionately benefit the lower-income consumers. In addition, near-subsistence farmers will benefit since these farmers consume a significant portion of their output and must buy additional food to meet household food needs. In the Region of Mopti, millet is the basic food staple, followed by locally produced rice. Livestock and fishing products are not food staples. Herders and fishermen also benefit from technical change targeted at basic foods since they will find cheaper millet and rice on the local markets and hence improved terms of trade for their commodities. Gathering wood represents an important cost for the poor, especially in terms of women's time, and is, therefore, ranked after millet and rice.

Both equity criteria rank millet and rice as the first and second commodities, livestock and wood as the third group of commodities, and fish as the fourth commodity.

b) Security Criterion

Two opposite approaches can be taken in formulating a research program to enhance the security impact of FSR. As suggested by Norton et al. (1989), the program can include commodities with stable production across years, so that risk associated with the production of a commodity mix is reduced. Alternatively, the program can include commodities with unstable production across years, and can focus on finding ways to reduce the risk associated with the production of these commodities are studied. Here, the second approach is more relevant because within each farming system in the Region of Mopti, producers depend largely on one commodity and not a mix of commodities. For example, despite a trend towards diversification, farmers in the Delta mainly depend on rice production, farmers in the Seno plain depend on millet and herders depend on cattle, sheep and goats. Assigning the greatest weight to systems with the most unstable production would have research center on reducing yield or production variability as opposed to increasing yields or production levels.

The criterion adopted here for measuring the security of production is the coefficient of variation for the main commodities produced in the Region of Mopti. The coefficients of variation (CVs) are estimated from production series for agricultural commodities published by OSCE (1989) and IUCN (1989) (see Tables 3 to 5 and 7 of Appendix 2-A). Because of the very low shares of groundnuts and maize in total production, data on groundnuts and maize are probably not reliable and, hence, their estimated CVs are not considered. The CVs ranked from (1) to least variable (5), were the following: rice (70%), millet (40%), cattle (24%), small ruminants (12%), and fish catch (13%) (Table 4-4). Crop commodities (rice and millet) have higher CVs than livestock and fish commodities. Rice production has the highest CV, reflecting the fact that regional rice production is 70% higher or lower than the average in at least one year out of three. No CV estimate exists for wood, but it is believed to be lower than for the other commodities because annual wood production is less affected by changes in annual rainfall.

c) Sustainability Criterion

When market forces value resources used in production or consumption below their long-run opportunity costs, then the sustainability of the production system using these undervalued resources is at risk. Economic sustainability examines the economic return to inputs used in a particular enterprise when both inputs and outputs are valued at their economic opportunity costs (for example, when distortions in exchange rate and prices are corrected). Environmental sustainability focuses more on the consequences of the undervaluation of the natural resources, such as soil, water, pasture, forest, game and fish, on the physical environment. These consequences are several: soil, pasture and forest degradation, water pollution or wasting, and game and fish depletion. When these market distortions are difficult to correct through institutional changes or policy measures, economic and environmental sustainability should be addressed when setting priorities for research.

Economic sustainability of a particular enterprise can be evaluated by using an efficiency indicator that is estimated on the basis of the long-run opportunity costs of the domestic resources. The domestic resource cost (DRC) ratio is one efficiency indicator that can be used for this purpose. A major constraint in using DRCs for this purpose is estimating appropriate long-run opportunity costs of resources. For this particular ranking procedure, the DRC ratio is, however, not a criterion that would help rank commodities according to economic sustainability because the estimation of the DRC ratios (see chapter 5) indicates that all the commodities for which a DRC ratio is available can be efficiently produced for at least local consumption.

Environmental sustainability of the production system can be fostered by developing techniques 1) that will augment the production of some commodities that have a positive impact on the conservation of the system, or 2) that will match the production level of some commodities to the sustainable level of the natural resource system. Wood and legumes are commodities that have a positive impact on the conservation of the system, while livestock production and fishing in the Region of Mopti appear currently to exceed the sustainable level (Shaikh, 1985; OECD, 1987; Thom and Wells, 1987; OPM, n.d.). Accordingly, wood and legumes are ranked higher with respect to environmental sustainability than livestock and fish. Cereals, sesame and onions are ranked between wood and legumes, on the one hand, and livestock and fish, on the other hand (Table 4-4).

4.1.3. Commodity Ranking

Ranking research priorities by commodity depends on the relative importance given by policy makers to efficiency, equity, security and sustainability objectives. Considering the first two sets of criteria, millet ranks higher than the other major commodities. Millet is ranked first in terms of efficiency and equity, and second in terms of security. Among livestock commodities, cattle is ranked similar to or higher than small ruminants across all sets of criteria and, therefore, should receive a priority just higher than small ruminants. Ranking rice relative to livestock is ambiguous and depends on the relative importance given to efficiency with respect to equity, security and sustainability. Livestock should rank higher than rice in terms of efficiency, but lower in terms of equity, security and sustainability. Wood is particularly important on equity and sustainability grounds. Wood should, however, not be neglected because its increasing scarcity may eventually reduce national output in the long run and hence have an efficiency effect. Fish ranks low for all the criteria considered.

In conclusion, research priorities should be given first to millet when efficiency and equity are considered together, then to cattle, small ruminants, and rice on efficiency grounds or, alternatively, to rice, cattle, small ruminants on equity, security and sustainability grounds. Research priorities to wood should be considered on the basis of its future production potential because it is an important commodities on sustainability grounds. The likely payoffs to an investment in research for a given commodity should also be considered in the ranking procedure. The following section examines that particular issue.

4.2. Priorities by Research Area

The sequence of steps used to rank the research areas for FSR are the following. First, the biophysical and resource endowment constraints that limit the productivity of the farming systems identified in chapter 2 are used to define the appropriate factor intensity mix for technical change. Second, technological components from on-station research that are currently today or in the near future are used to specify the research areas for technological innovations for FSR. Third, knowledge of input and product marketing and institutional constraints that may limit the transfer and use of new technology are used to specify complementary research areas for FSR or other research institutions in terms of institutional innovations. Although this sequence of steps is presented in a consecutive manner, the procedure really is iterative because of the strong complementarity between technological and institutional innovations. New technology may require more of a certain input, while the current institutional setting may limit the possibility of increasing that input. In that case, either an improvement in the institutional setting or a reduction in the technological requirement is necessary for adoption to proceed.

4.2.1. Rainfed Crop-based Farming System

a) Research Areas Related to the Bio-physical and Resource Endowment Constraints

As discussed in chapter 2, four sets of bio-physical and resource endowment constraints has limited rainfed crop production: 1) rainfall variability and soil nutrient deficiency, 2) a shortage of arable land, 3) seasonal labor scarcity, and 4) wind and water erosion. Because on-station research has developed several technological components to deal with rainfall variability and low soil fertility, more attention will be given to the potential technological innovations that FSR could develop with respect to that area of research. Rainfall variability and soil nutrient deficiency are also the most limiting factors for increased productivity.

i) Rainfall Variability and Soil Nutrient Deficiency

The large variability in rainfall observed during the last 20 years and soil depletion in two basic nutrients (phosphorus and nitrogen) and organic matter are the most important production constraints faced by the rainfed crop farming system. These two constraints suggest the development of technology that would increase water retention and soil fertility. Water retention and soil fertility should be increased together since only increasing water availability will exhaust the available nutrients and only applying fertilizers will increase economic risk because response to fertilizer is dependent upon the availability of water at critical stages of plant development (Sanders, 1988, p. 5).

There exist examples of technologies for the Sahelo-Sudanian zone (350-600 mm of rainfall) that combine increased water retention and moderate fertilizer levels. In the Sahel, ICRISAT has successively tested 1) cropping patterns that increase plant density to facilitate water retention near the roots, and 2) use of moderate doses of chemical fertilizer. These low-input techniques increase the water use efficiency index and give significantly higher yields (ICRISAT, 1985, p. 42; ICRISAT, 1986, p. 41; ICRISAT, 1987, p. 72).[67] These technologies are currently available at the research station level in Mali

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[67] Tied ridging, a technique more appropriate to the Sudanian zone (600-800 mm of rainfall), does not work well on the sandy soils of the Sahelo-Sudanian zone because the ties tend to break down in heavy rain (Nagy, Sanders and Ohm, 1987, p. 44).

but need to be adapted and tested for the particular ecological and socio-economic environment of the Region of Mopti (Henry de Frahan et al., 1989, pp. 26-27). This research work could be part of the FSR program.

Because the use of imported chemical fertilizers on staple food crops such as millet and cowpeas, which are the most important crops of the farming system, is barely profitable, alternative low-input techniques need to be developed. Indigenous rock phosphate is an alternative to the more costly imported chemical fertilizer. On-farm tests of rock phosphate from the Malian Tilemsi's deposit (TRP) have shown significant yield effects in the Seno plain (SAFGRAD, 1979, 1980, 1981, 1982). A single dose of 300 kg/ha TRP has been applied at the outset of two types of three-year rotations: groundnut-millet-groundnut and millet-millet-millet. On two series of tests, production for the three years increased on average by 230 kg for groundnuts and 372 kg for millet for the groundnut-millet-groundnut rotation and by 816 kg for millet for the millet-millet-millet rotation (Henry de Frahan et al., 1989, p. 18, Table 2.7). However, because of the TRP's low solubility, the yield effect shows up only after the second year of application in areas receiving at least 400 mm of rainfall, enough to allow solubility to proceed. The availability of credit is critical to the application of rock phosphate application and there should be at least an one-year grace period. In addition, TRP's dusty nature makes it difficult to apply and, because it can be mistaken for sand, farmers are wary about being taken advantage of by the suppliers. As a result of the low solubility of rock phosphate, methods are being developed to increase its agronomic effectiveness.

Biological innovations are an alternative to chemical fertilizers for raising soil fertility. Legumes have the appealing property of fixing nitrogen, one of the two basic nutrients needed to increase yields. Increases in biological yields from intensifying cereal-cowpea intercropping, the dominant cereal-legume intercropping in the Region of Mopti, have been obtained in research station trials (Fussel and Serafini, 1985). Yields have appreciably increased by slightly augmenting the planting density of the traditional system, by using an early variety of cowpea suitable for intercropping, by applying a mineral fertilizer on the two crops and by insecticide treatments on cowpeas in the field and in storage (Ntaré et al., 1987; Traoré and Martiné, 1987; Sawadogo, 1985). In Mali, agricultural research has recommended a millet-cowpea intercropping system, which has been shown to increase total grain yield by 30% over that which would have been achieved using a mono-crop system (Schilling et al., 1989, p. 7). In the Region of Mopti, Traoré and Martiné (1987) obtained yields of 1014 kg/ha for millet and 141 kg/ha for cowpeas in trials conducted in 1986 in the sub-regional research station of the Seno plain (Koporo), where planting densities were increased to 52,000 and 26,000 plants/ha for millet and cowpeas, respectively. These yields are twice as high as under traditional farm practices. Fussel and Serafini (1985) found that intercropping cowpeas with millet usually improves and stabilizes the overall yield in semi-arid areas of West Africa. In addition, intercropping plays an important role in soil conservation and in protecting crops from disease and insect propagation (Norman, 1974; Finlay, 1976; Beets, 1982). One proposed area of research for FSR is to evaluate at the farm level the improved management of millet-cowpea intercropping suggested by the on-station results.

Because improving millet-cowpea intercropping is likely to face some technical constraints, other possibilities to increase the share of legumes in the cropping system need to be considered as potential research areas for FSR. Improving the productivity of millet-cowpea intercropping is hindered by the difficulty in mechanizing cropping operations and in obtaining the optimal densities and planting dates for the two crops, the lack of appropriate cowpea genotypes for intercropping, and problems in treating cowpeas and in fertilizing both crops (IER-ICRISAT, 1987).

Encouraging results have been obtained from millet and cowpeas grown as monocultures in rotation. With the appropriate insecticide treatment, yields of 1500 to 1800 kg/ha have been possible for single cowpea crops in northern Nigeria (Hays and Raheja, 1977). Coulibaly (1987) reports that the agronomy research station in Cinzana, in the Segou region, obtained average yields of 1,255 kg/ha with new varieties of cowpeas. In on-farm trials around the Cinzana station, yields from new cowpea varieties (mainly KN1 and TN 8863 varieties) increased to 760 kg/ha when the crop was treated with insecticide in the field, from about 100 kg/ha for traditional, untreated varieties. More specifically in the Seno plain, SAFGRAD (1985, 1986, 1987) was able to double cowpea yields in on-farm trials using the early varieties TN 8863 and Gorom-Gorom (Henry de Frahan et al., pp. 19-20). Several constraints may, however, limit the adoption of improved millet and cowpea monoculture systems, including limited supply of and credit for inputs and treatment equipment, as well as few marketing outlets for cowpea production (Coulibaly, 1987).

Besides cowpeas, other legumes, such as groundnuts, Bambara groundnuts and <u>Acacia albida</u> are grown in the Region of Mopti and represent potential research areas for FSR. The nitrogen fixation ability of these crops can be used to increase soil fertility. Improved short-cycle varieties of groundnuts are available through agricultural research, and use of insecticides can improve the quality and the availability of groundnut seed. Also, treating seed with the popular fungicide Thioral before planting would increase germination rates. On-farm applications of TRP on a groundnut-millet-groundnut rotation have resulted in significant yield increases. Multi-location tests of improved

Bambara groundnut varieties have demonstrated the performance of varieties such as CMV4-1 (1875 kg/ha) and CMV9-1 (1309 kg/ha) (Kodio, 1988). Groundnuts are relied upon as a source of income, while Bambara groundnuts provide a source of food at the end of the hungry season.

The presence of Acacia albida in fields supposedly increases crop yields, as the tree is able to fix nitrogen. Studies carried out by Charreau and Vidal (1982) in Senegal show millet yield increases of over 200% as a result of increased soil fertility resulting from the presence of this tree in the crop fields. The results of Christophersen and Karch's economic analysis (1988) show that Acacia albida for soil conservation is financially attractive for the villagers in the Region of Mopti. Moreover, the leaves and pods provide excellent forage for cattle during the dry season, when grasses are scarce. In addition, animals grazing on the leaves contribute to soil fertility by leaving organic waste. As crops can also be grown beneath the trees, the presence of Acacia albida does not significantly reduce cultivated areas.

As a second alternative to chemical fertilizer, research on inoculation and, more recently, research on mycorrhizae have been supported (Sanders, 1988, pp. 11-12). At the experiment station, inoculation of legumes works well but many farm-level problems still have not been resolved. Inoculation of soil with mycorrhizae needs more experimentation. These techniques are not yet available for on-farm applications, but can be integrated as potential research areas for FSR in the intermediate or long run.

ii) Arable Land Shortage

The next constraint on rainfed crop production is the growing shortage of arable land due to increasing population pressure. Population pressure on arable land has led

farmers to shorten fallow periods and till more marginal agricultural lands. Hence, soil fertility has deteriorated and yields have declined.

The development of land-saving and, hence, yield increasing, technologies to respond to this phenomenon has been, until recently, the main focus of on-station research. Unfortunately, this research has left unresolved many technical and economic problems. Land-saving technologies include biological innovations, such as high-yielding varieties, and chemical innovations, such as fertilizer and pesticides. For decades, on-station research in the Sahel has been devoted to plant breeding associated with fertilizer and pesticide treatments, as these two types of innovation have been shown to have highly complementary yield effects. This strategy, however, has not been successful in improving yields at the farm level for the principal cereals, i.e., sorghum and millet (Matlon, 1985). On-station and on-farm yield gaps have been explained by the selection procedures used by research stations. These selection procedures were conducted under a high- management environment (high fertility, tillage and water management) that is unfeasible at the farm level given current farmer circumstances. As a consequence, these selection procedures have produced elite cultivars that are more management-responsive than local varieties but at the same time inferior at lower management levels (ibid.).

As a result of this unsuccessful strategy, changes have occurred in breeding objectives, leading to the development of new varieties adapted to moderate management levels. These varieties are expected to be more stable, resistant or tolerant to a wider spectrum of physical (drought and heat stress) and biological (witchweed and mildew) factors. These varieties will only be available in five to ten years (Nagy, Sanders and Ohm, 1986, p. 52).

However, because more basic agricultural research is needed first, breeding for all types of physical and biological stress resistances for many micro environments is unrealistic in the short and intermediate runs (Sanders, 1988, p. 15). A more realistic and cost-effective approach that is now increasingly recognized by the biological science community consists of: 1) developing techniques that increase water retention and soil fertility, as suggested above, to improve the agronomic environment, and 2) orienting plant breeding to develop new cultivars for the improved and less variable agronomic environment, concentrating on yield improvement, quality characteristics, and disease and insect resistance. Breeding for insect resistance is particularly relevant for the Region of Mopti because insect attacks are frequent on millet in the field (Raghuva headborer) and on cowpeas both in the field and in storage. Although available, insecticides are not profitable.

Local millet varieties grown in the Region of Mopti may provide the germ plasm necessary to initiate the screening process. Local varieties are endowed with certain characteristics that permit them to resist more effectively the difficult conditions in the region. They are hardy and have a relatively long growing cycle, which discourages insect attack (caterpillars and blister beetles) and grain-eating birds. In addition, just like the selected varieties, local varieties have higher potential yields when they are grown in yield-enhancing conditions. A varietal improvement is, however, necessary to compensate for rainfall variability which has occurred in the last two decades.

As a result of the foregoing discussion of rainfall decline, soil nutrient deficiency, and arable land shortage, it is proposed that FSR concentrate in the short run (the first five years): on 1) developing improved agronomic practices, 2) helping on-station research define its breeding objectives, and 3) contributing to the collection of local millet germ plasm with on-station researchers. Then, in the intermediate run (five to ten years), it is proposed that FSR incorporate the newly improved cultivars into the improved agronomic practices. A sequential introduction of improved agronomic practices and then improved cultivars takes account of empirical observations that farmers do not necessarily adopt technologies as a "package" but rather adopt single technologies or "clusters" of technologies en route to total package adoption (Byerlee and Hesse de Polanco, 1986; Mann, 1978).

iii) Seasonal Labor Scarcity

Seasonal labor scarcity constrains increases in agricultural output and should be incorporated in the identification of potential research areas for FSR. Labor is particularly short in the critical planting and weeding periods. Since at the beginning of the growing season, no cash or food reserves are available to hire extra laborers and few laborers are actually in the labor market, any technology that would relieve the labor constraint for the first weeding would increase land productivity. Animal traction is a labor-saving technology already adopted by 33% of the mixed farmers in the Seno plain and is mainly used for transportation, shallow weeding, and shallow land-preparation plowing (Table 1 of Appendix 2-C). However, a study in Burkina Faso has shown that animal traction can be made more economically attractive to farmers by increasing the number of mechanized operations, since farmers generally mechanize one operation rather than all agricultural activities such as soil preparation, planting and weeding (Jaeger and Matlon, 1990). Also, the full benefit of mechanization can be accelerated for first-time users through farmer and animal extension training and an improved market for trained draft animals. Consequently, making more efficient use of animal traction is likely to raise the adoption rate.

FSR should examine two complementary areas of research that are necessary to make animal traction a more efficient technique than manual techniques. The first involves looking at ways to improve the integration of crop and livestock activities. The use and maintenance of draft animals depend on the degree to which crop and livestock activities are integrated in the farm unit.[68] A high degree of integration results in increased productivity for both crops and livestock and, hence, in a more intensive production system. One specific problem with improving crop and livestock integration requires special attention: the management of draft oxen and small ruminants, with the goal of identifying feed, watering, and health problems (Henry de Frahan et al., 1989, p. 125).

The second complementary research area for improving the efficiency of animal traction involves adapting mechanized cropping techniques to farm circumstances in the Region of Mopti in order to preserve the advantages of traditional practices but relax the labor constraints in the peak labor-demand periods. As indicated in chapter 2, the advantages of traditional manual cultivation mainly are the restitution of organic matter to the soil and prevention of sand accumulation. To preserve these critical advantages, agricultural implements and mechanized tillage and weeding techniques cannot simply be borrowed from adaptive research conducted in other areas, but need to be adapted to local farm circumstances (ibid., pp. 112-17). In addition to performing critical farming operations on time and with less effort, the advantages of well-adapted mechanized

[68] A high degree of integration is reached when, on one hand, livestock provide manure for crops and traction power for timely cropping operations such as tillage, weeding and transport, and, on the other hand, agriculture provides the feed necessary to maintain healthy draft animals and produce meat and milk. As a result, crop and livestock integration improves the productivity of labor, land and livestock, and generates income to invest in the farm unit (draft animal replacement and other inputs) and to meet financial obligations, social demands and other expenditures.

farming operations are slightly increased yields (mainly from plowing) and the release of women from weeding communal fields to work on their own activities.

As opposed to mechanical innovations, chemical innovations, such as herbicides, are not yet technically and economically feasible for saving labor in the peak labor-demand weeding period. Little research has been done to tailor herbicides to Sahelo-Sudanian conditions, and economic analyses suggest that weeding is presently more profitable by either animal traction or hand than by herbicides (Nagy, Sanders and Ohm, 1986, p. 52).

iv) Wind and Water Erosion

Strong winds and run-off water are important production constraints for rainfed agriculture in the Region of Mopti. The strong winds on the Seno plain when cereal crops are germinating result in seedlings being covered in sand. On the Bandiagara plateau and on the edges of the inner Delta, run-off erodes the arable land and removes fertile soil. In these zones, where either the slope or the soil structure are conducive to erosion, traditional anti-erosion techniques cannot combat the damage done by wind and water. As several experimental actions in the region demonstrate, a combination of anti-erosion and agroforestry techniques has the potential to limit the effects of wind and water erosion and also improve firewood production (Henry de Frahan et al., 1989, pp. 136-41). Since these anti-erosion and agroforestry techniques are labor intensive, FSR should study the socio-economic feasibility of integrating these techniques into the farming system. Alley cropping has many potential advantages in addition to erosion control, such as providing mulch, firewood, biologically fixed nitrogen, and animal feed, but it is very management-intensive and has not been thoroughly researched in Sahelian countries (Nagy, Sanders and Ohm, 1986, p. 53).[69]

b) Research Areas Related to Marketing and Institutional Circumstances

Since the transfer of the techniques developed to improve water retention, soil fertility, and the timing of critical farming operations are in turn bound by input and product marketing and institutional constraints, additional research areas that would evidence these constraints and suggest appropriate adjustments need to be pursued. Comparing the socio-economic requirements of the techniques proposed above to the socio-economic limitations of the farming systems indicated in chapter 2 can suggest potential complementary areas of research for FSR. Two sets of marketing and institutional constraints are considered: 1) limitations in the technology transfer system, and 2) low farm income and limitations in the agricultural product marketing system.

i) Technology Transfer System Limitations

Difficulties gaining access to capital and inputs are likely to dampen the adoption of chemical fertilizer and animal traction, even if these technologies are profitable. Currently, effective demand for inputs such as plows, carts and fungicides remains unmet in the rainfed area of the Region of Mopti (Henry de Frahan et al., 1989, p. 68 and pp. 70-71). When fungicide is made available, it is sold at twice the Bamako wholesale price. Therefore, areas of research should include studies that 1) identify the constraints to the production and delivery systems for inputs (particularly for fertilizer and animal traction equipment), 2) identify the constraints to the credit system (formal as well as informal), and 3) suggest means to alleviate these constraints. The identification of production and

[69] Alley cropping is a technique where crops are grown in the alley formed by rows of leguminous shrubs or trees.

delivery constraints for agricultural inputs (including credit) is justified not only to foresee problems that might arise during the extension of newly developed technical packages, but to solve the current problems faced by farmers at the beginning of each cropping season.

The dependence of the proposed improved intercropping practices on inputs from local markets underscores the need for FSR to include studies related to the marketing environment and support system of farmers. For farmers, the demand for inputs creates a greater dependence on agricultural services and markets for improved cowpea variety seeds, fertilizers, insecticides and on marketing outlets for their production. In addition, the purchase of agricultural inputs requires significant financial resources and an appropriate credit system. Unless another research unit studies these problems, the mandate of FSR should embrace research on the performance of the marketing and institutional systems within which farmers operate.

ii) Low Farm Income and the Limitations of the Product Marketing System

Cash crops must be developed to raise farm incomes because the coarse grain market is volatile and is not a reliable source of cash income. Cash crops can also be a source of revenue to invest in increasing the production of the farm enterprises, as in southern Mali with cotton. Cash crop sales could also alter transaction periods for coarse grain producers by allowing them to shift grain sales to more profitable periods. In addition to cowpea and groundnut crops, sesame is grown in small plots or intercropped with millet, and could serve as a cash crop. Considered as a minor crop in the traditional cropping system, sesame is not intensively cultivated. As a result, sesame productivity is low, probably not higher than 300 kg/ha. For the export market, it is important that the varieties introduced to farmers be all white in color. Two white sesame varieties that could be adapted to the ecology of the region (38-1-7 and Yendev 55) have performed well on station. In Cinzana, yields of 710 kg/ha and 540 kg/ha, respectively, for the two varieties, were obtained in 1987 with 560 mm of rainfall and a 65 kg application of "super simple" phosphate (Soumano and Traoré, 1988).

The development of sesame for export is contingent upon removing export disincentives. Estimations of domestic resource cost ratios at different levels of marketing (from farm-gate to export markets) indicate that the Region of Mopti has a comparative advantage in sesame with improved management. However, the overvaluation of the CFA franc and export taxation do not allow the region to benefit from this comparative advantage.[70] Therefore, research in developing sesame should consider marketing constraints in addition to adapting technological components for increased productivity at the farm level.

Vegetable gardening, particularly of onions, is a source of income for most of the farmers living on the Bandiagara plateau. Seed conservation and onion processing and marketing are the dominant constraints to increased onion production (Traoré et al., 1988). Seed storage techniques and processing techniques are currently being tested by a German aid funded project (GTZ) and marketing problems are also being studied by different aid organizations (GTZ, Canadian aid, Catholic mission). Since many other organizations are already involved in developing onion production on the Bandiagara plateau, no research areas are planned for FSR.

For cereals and legumes, some modern harvest protection and storage techniques exist, but they have never been compared to the traditional techniques in terms of efficiency. The traditional techniques generally appear effective but only for small

[70] Export tax was removed in 1989.

volumes. Modern techniques, such as the use of chemical insecticides, permit larger volumes to be protected than the traditional techniques (Henry de Frahan et al., 1989, pp. 147-48).

Additional income can be generated by delivering to consumption markets agricultural products of a higher degree of transformation. Improved food processing allows entrance into new markets and generates new employment. It also reduces the labor requirement for processing and frees labor, particularly women's, for other activities. The price differential between raw and processed products must, however, exceed the processing costs for the development of this activity. Some food processing techniques exist at the experimental stage and may be an additional research area for FSR. Improved processing techniques for extracting groundnut oil and shea butter and for grinding millet have been tested (ibid., pp. 144-47). Although these techniques need improvement, FSR could help determine the potential efficiency of and market for these techniques.

c) Conclusions

The preceding analysis has identified a series of potential research areas for FSR concerning the rainfed crop-based farming system in the Region of Mopti. These research areas can be classified according to their sequence (short versus intermediate run) and the category of constraints they address.

In the short run (0 - 5 years), the research areas related to the bio-physical and resource endowment constraints include:

1) Development and tests of technical packages that combine water retention techniques, moderate fertilizer levels (either soluble chemicals or rock phosphate), available pesticides, and improved varieties for the following

crops: a) millet-cowpea intercropping, b) cowpeas, c) groundnuts, d) Bambara groundnuts, and e) sesame;

2) Development and tests of techniques that improve the integration of crop and livestock activities and that mechanize the labor-intensive cropping operations;

3) Development and tests of improved food processing and storage techniques;

4) Collaborative effort with on-station research to define the on-station research objectives in breeding, plant protection and cultural practices, and to collect local millet germ plasm.

The research areas related to the marketing and institutional constraints facing the crop-based farming system include:

1) Research on the socio-economic feasibility of integrating improved anti-erosion and agroforestry techniques into the farming system;

2) Identification of the constraints related to capital markets and to the production and delivery systems for inputs, and the development of recommendations for alleviating these constraints;

3) Market studies for raw products, such as cowpeas, groundnuts and sesame;

4) Evaluation of the economics of alternative processing techniques as well as an evaluation of the market for processed products, such as groundnut oil, shea butter and millet flour.

In the intermediate run (5 to 10 years), the research areas include:

1) Development and tests of technical packages that include the newly improved cultivars;

2) Development and tests of techniques of legume and soil inoculation.

4.2.2. Flooded-crop-based Farming System

The potential research areas for flooded-crop-based farming system are identified on the basis of 1) the bio-physical and resource endowment constraints, and 2) input marketing, product marketing and institutional circumstances of the farming system.

a) Research Areas Related to Bio-physical and Resource Endowment Constraints

As a result of the climatic and hydrological uncertainties, rice growers have diversified their activities to rely more on rainfed agriculture, small ruminant production, and fishing. Agricultural diversification has, however, generated other kinds of constraints to increased productivity. The most important are the labor bottlenecks that arise when farming operations overlap. For example, planting and maintenance periods coincide for rainfed agriculture and controlled-flood rice culture (ibid., p. 128). The solution is to hire wage labor because of the lack of farm equipment and draft oxen or the weakness of the oxen after the dry season. But because hiring labor is not profitable for most farmers, critical cropping operations are not carried out on time.

The labor allocation problem for diversified cropping systems is a suggested research area for FSR. One possibility would be to develop a labor-saving technology for rice growers by, for example, designing and testing a multiple-purpose agricultural implement adaptable for use in different cropping operations.

A second research area for FSR could be developing technologies that would reduce the effects of climatic and hydrological uncertainties on farm production. For example, a biological innovation, such as improved varieties, could add stability to productivity. Some Oryza glaberrima varieties cultivated under natural submersion possess desirable characteristics, specifically, better drought resistance and a longer dormant stage that would reduce, respectively, the risk of crop failure and germination in water (ibid., pp. 27-28 and 159-61). On-station breeders could collaborate with FSR to collect germ plasm, and catalogue, select and purify the best performing Oryza glaberrima varieties. Later, FSR could test and evaluate these varieties at the farm level. Breeders estimate a leadtime of five years before these varieties could be extended with the research resources currently available. Varietal improvement of Oryza sativa is being undertaken and extendable results are expected in ten years with the existing research resources. Varietal improvement on Oryza sativa is being sought through varietal performance trials on the one hand, and by hybridization on the other (ibid., p.27). According to breeders, yields could be improved by 30% for Oryza glaberrima under traditional management and by 75% for Oryza sativa under improved management. Yield stability may also be improved.

Rainfall and flood uncertainties are not the only constraints for increased productivity. Borers are frequent in Oryza sativa and wild rice species are common inside and outside the ORM polders. Also, mice, rats and granivorous birds are important and active pests. FSR must consider these constraints in developing technical packages.

b) Research Areas Related to the Marketing and Institutional Circumstances

Two other constraints limit the financial profitability of growing rice. First, credit and input availability is restricted to rice growers on polders managed by ORM. With no access to formal credit, rice growers outside these ORM polders have problems investing in animal traction. In the event that some improved varieties of Oryza glaberrima are selected, ways to diffuse these varieties among rice growers who are not under the ORM need to be considered.

Second, the current ORM threshing facility is not efficient. Facing a threshing cost corresponding to about 12% of the unmilled rice yield (IER, 1989, p. 39), rice growers tend to desert the large ORM rice mill for smaller rice mills. As small mechanical rice processing facilities appear to be more attractive to rice growers, an additional area of study for FSR, in collaboration with ORM, would be to look at the efficiency of alternate rice processing techniques with regards to labor and capital.

c) Conclusions

With respect to the flooded crop-based farming system, a short series of potential research areas have been identified for FSR. These research areas can be classified according to their sequence (short versus intermediate run) and the category of constraints with which they deal.

In the short run (0 - 5 years), two research areas related to the bio-physical and resource constraints are suggested for FSR:

1) Identification of the labor bottlenecks of the cropping calendar, and development and tests of labor-saving technology, such as a multiple-purpose agricultural implement;
2) Collaborative efforts with on-station research to collect local Oryza glaberrima germ plasm.

Two research areas related to the marketing and institutional constraints facing the flooded crop-based farming system are suggested for FSR:

1) Identification of the constraints related to the capital market for the rice growers outside the ORM polders, and recommendations for alleviating these constraints;

2) Identification of the most efficient rice processing techniques for rice growers.

In the intermediate run (5 to 10 years), it is proposed that FSR develop and test technical packages that include the newly improved cultivars of Oryza glaberrima and Oryza sativa. The study of diffusion factors for the newly improved Oryza glaberrima varieties needs to examine what kind of institutional support (input supply, extension, credit) would be appropriate for the rice growers outside the ORM polders.

4.2.3. Flood Recession Crop-based Farming System

The recent diversification of the flood recession crop-based farming system into other agricultural activities suggests that research areas identified above to deal with problems raised by the diversification of the flooded crop-based farming system are also applicable here. As a result of the late arrival and low volume of the floods and the encroachment of sand due to wind, the flood recession crop-based farming system is diversifying into rainfed crops, gardening and livestock activities. This diversification has raised labor organization and allocation problems similar to those identified for the flooded crop-based farming system. Therefore, mechanical labor-saving technology and improved varieties are two technological innovations that FSR and on-station research could develop for this system.

As suggested above, on-farm and on-station research could develop a multiple-purpose agricultural implement adaptable for use in different cropping operations.

Screening improved varieties of millet, sorghum and rice for flood-plain agriculture is, however, much more difficult for at least two reasons. First, there has been no on-station research on flood-plain agriculture undertaken in Mali. Second, use of short-season flood-plain varieties as an attempt to remove conflicts in concurrent labor demands for flood-plain and rainfed agriculture will lead to considerable losses at maturity because of bird damage.[71]

Because the flood recession crop-based farming system is complex and has not been well studied, more diagnostic work needs to be done before prescriptions are made. In the short run, the technical packages developed for the flooded crop-based farming system and for the rainfed crop- based farming system may, however, be applied to flood recession crop-based farming system.

4.2.4. Pastoral System

Besides research in the area of agriculture and livestock integration, no specific research areas related to the pastoral system are proposed for FSR. Little contribution to increased productivity of the pastoral system is expected from FSR unless certain changes take place. First, the equilibrium between herd size and carrying capacity of the range needs to be re-established. One solution generally advocated to re-establish the equilibrium between livestock and carrying capacity is to reduce the size of the herds by keeping the best animals and slaughtering the others. This solution, however, conflicts with 1) the limited market possibilities for livestock, 2) the socio-cultural reasons for

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[71] Replacing the traditional flood-plain millet and sorghum late-maturing varieties by early varieties is a solution that has been studied to release labor for weeding the rainfed crops (Henry de Frahan et al., 1989, p. 157).

raising large livestock herds, 3) the desire for large herds to spread risk and maximize milk production, and 4) the lack of alternative investment opportunities.

Second, additional steps need to be taken before agricultural research can contribute to increasing the productivity of the pastoral system. These include: 1) resolving tenure conflicts over the use of arable land, pastures, forage and wells, 2) developing infrastructure for eradicating parasitic diseases among transhumant cattle and small ruminants, 3) developing facilities for providing water in the dry areas, and 4) developing export market outlets by reducing the administrative fees and export taxes. Because a World Bank funded multidisciplinary team is currently studying tenure conflicts in the Region of Mopti and plans to propose a regional plan for the development of its natural resources, no FSR interventions are specifically planned for increasing the productivity of the pastoral system until the conclusions and the reactions to that study are known.

4.2.5. Fish-based System

Few contributions to increased productivity of the fish-based system are expected from FSR before tenure conflicts over the use of water are resolved and regulations that would guarantee fish replenishment are drafted and enforced. Because OPM is currently collaborating with the Mopti-based hydrobiology laboratory and ORSTOM on a study to identify the impact of fishing practices on the fish ecosystem in the Delta area, no FSR interventions are planned in the fisheries sub-sector.

4.2.6. The Ranking of Research Areas

Because of the number and complexity of the potential research areas for FSR and the limited human and capital resources available to the project, the potential research areas need to be prioritized. Some research areas are highly complementary and must be grouped together to take advantage of their large expected interactive effects. For example, a research area focused on improving the use of a purchased input, such as a fertilizer or a pesticide, needs to be complemented by research on the accessibility of that input to farmers. The complementarity of the research areas is likely to be the strongest among research areas related to the same farming system. Therefore, the grouping procedure of the research areas proceeds by farming system and, within each farming system, complementary research areas are pooled together. Then, because each farming system has been defined by its major commodity, the ranking of research priorities by commodity is used to rank these groups of research areas.

With respect to the rainfed crop-based farming system, four groups of research emerge. The first is related to millet and cowpea intercropping and includes research on agronomy, mechanization and capital and input markets. The second group is related to the minor crops (cowpeas, groundnuts, Bambara groundnuts, and sesame) and includes research on agronomy, mechanization, capital and input markets, and agricultural product markets. The third group includes research on post-harvest techniques and agricultural product markets. The fourth group includes research in collaboration with on-station researchers planned in the short run and research on agronomy planned for the intermediate run. Two research areas are left alone: the research area on soil conservation planned for the short run and the research area on nitrogen inoculation planned for the intermediate run.

With respect to the flooded-crop-based farming system, two groups of research areas emerge. The first group includes the research on mechanization and on capital markets. The second group includes the collaboration with on-station research in the short run and the research areas on agronomy and input markets in the intermediate run. The research area on post-harvest techniques can be studied separately.

The commodity ranking developed earlier in the chapter is used to prioritize the groups of research areas identified for FSR. Since millet has been ranked first in terms of efficiency and equity and second after rice in terms of security, the complementary research areas for the rainfed crop-based farming system is accorded a higher priority than those for the flooded crop-based farming system. The groups of research related to rainfed agriculture will not only benefit the rainfed crop-based farming system but also the other systems of the region because of the current diversification of all the systems into rainfed agriculture.

For the purpose of evaluating ex-ante the FSR project, it is proposed that FSR primarily concentrate in the short run on the seven research areas related to the rainfed crop-based farming system and, secondarily, on the four research areas related to the flooded crop-based farming system, if human and capital resources permit. Later on, the research areas identified for the intermediate run may constitute a basis for continuing the FSR program. This is, however, subject to the evolution of the FSR program and the institutional and policy setting.

4.3. Conclusions

This chapter concentrated on selecting research priorities for an FSR program in the Region of Mopti. The research priorities were selected by ranking 1) commodities according to four research objectives: efficiency, equity, security and sustainability, and 2) research areas according to biophysical and resource endowment constraints, technological components from on-station research, and the market and institutional environment. It was proposed that in the short run FSR concentrate primarily on the research areas related to the rainfed crop-based farming system and, secondarily, on the research areas related to the flooded crop-based farming system. The research areas identified for the intermediate run depend on the evolution of FSR and on-station programs, and the institutional and policy setting. Because the development of livestock and fisheries, the two other major resources of the region, depends more on infrastructure, market outlets, and resolving tenure conflicts over the use of pastures and bodies of waters than on contributions that might come from agricultural research, FSR on livestock and fisheries should not be given priority.

The proposed FSR program is comprised of the following research areas: studies relating to the marketing constraints for inputs and agricultural products; focused surveys to obtain a better understanding of certain constraints and the means to alleviate them; tests of technical packages based on available or forthcoming results from station research; and cooperative programs with commodity researchers to identify technological solutions to certain agroclimatic constraints. In the short run, FSR is expected to develop successfully several technical packages for rainfed agriculture. Involvement of FSR in flooded agriculture will depend on the remaining human and capital resources. In the intermediate run, FSR will develop additional technical packages incorporating improved varieties of millet and rice selected through on-station research.

5. TECHNOLOGY EVALUATION

This chapter covers the financial and economic evaluations of the technologies that FSR is expected to develop. First, the expected outputs of FSR are identified. Second, the technological innovations are evaluated in financial terms and the risk involved in adopting these innovations is evaluated with a sensitivity test. Third, the innovations that can improve economic efficiency are identified. Fourth, the expected diffusion paths of these innovations are estimated.

5.1. FSR Output Identification

5.1.1. Expected Products Included in the Evaluation

The FSR program includes studies relating to the marketing constraints for inputs and agricultural products, focused surveys to obtain a better understanding of certain constraints and the means of alleviating them, tests of technology packages based on available or forthcoming results from station research, and cooperative programs with commodity researchers to identify technological solutions to certain agroclimatic constraints. In the short term, FSR is expected to develop several technical packages for rainfed agriculture. Involvement of FSR in flooded agriculture is conditional to the available human and capital resources allocated to the project. In the intermediate term, FSR will develop additional technical packages incorporating improved varieties of millet and rice selected through on-station research.

This evaluation includes only these research areas that are expected to have the greatest effect on farm productivity and generate tangible outputs. The evaluation is based on the following assumptions.

Rainfed agriculture:

1. The research areas on agronomy (incorporating water retention techniques, moderate fertilizer levels and improved varieties), on mechanization and on storage technology will result in four technical packages that will be extended to farmers five years following the establishment of FSR in the region. These four technical packages include the following crop enterprises: millet-cowpea intercropping, and cowpea, groundnut and sesame mono-croppings.
2. The research related to the marketing and institutional environment will be evaluated separately by simulating scenarios that will hypothesize improvements in these environments (see chapter 7). The research related to the development of technical packages incorporating improved varieties of millet that will be available in the intermediate term will be also evaluated separately with the simulation of a scenario including these new improved varieties because the development of these improved varieties need an additional investment in on-station research (see chapter 7).
3. The research areas on food processing technology, soil conservation, and nitrogen inoculation are not evaluated for three reasons. First, there is no data base for estimating the expected benefits that could be obtained from the development of these three research areas. For example, little information is available about potential yield decreases due to the reduction of soil fertility associated with erosion. Hence, quantification of the soil conservation impact is difficult. Second,

the results expected from the development of these research areas will take relatively longer to materialize than those that are included in the evaluation of the FSR project. Third, these results will be applicable only to relatively small target groups.

Flooded agriculture:

The research area related to the development of technical packages incorporating improved varieties of rice that will be available in the intermediate term of the project will be evaluated for both natural and controlled flooding system. This research area will be evaluated separately with the simulation of a scenario including these new improved varieties. The other research areas targeted on mechanization and rice processing technology will not be evaluated because of insufficient data.

Because it is based on fewer potential research areas than discussed in the previous chapter, the evaluation of the FSR project presented in this chapter is partial and, hence, the project value probably is underestimated. The four potential technical packages (millet-cowpea intercropping, and cowpea, groundnut and sesame mono-croppings) are first evaluated in terms of their direct impact on increased productivity at the farm level. This impact is estimated for three different agroclimatic zones: north, center/plateau, and south.[72] Appendix 5-A (Tables 1 to 8) describes the four technical packages for each of the three agroclimatic zones and contrasts them with both traditional local practices (i.e., farms without animal traction) and improved local

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[72] Soil characteristics, rainfall and population pressure on arable land were the three criteria used to define these three agroclimatic zones. Because of the similarity between the cultivable plains of the Bandiagara plateau and the central part of the Seno plain based on these criteria, these two zones have been grouped together for simplification. More details about the division of the rainfed area of the Region of Mopti into agroclimatic zones can be found in Henry de Frahan and Diarra (1987) and Henry de Frahan et al. (1989).

practices, also called transitional practices (i.e., farms with animal traction).[73] The technical packages combine various components that have been tested in experiments in many areas as well as in on-farm trials in the FSR project area. The technical coefficients are derived from on-station and on-farm trial results, expert opinions and surveys. Groundnut mono-cropping is not considered for the northern agroclimatic zone because it includes rock phosphate that is not very soluble under the rainfall conditions of this zone.

These technical packages are a mix of biological, chemical, mechanical and agronomic innovations that may appear excessively complex. If farmers perceive such complexity, these packages may be adopted piecemeal and the positive interaction effects of adopting the entire packages may be delayed until all the technological components are adopted. The complexity of the packages are, however, not excessive given that the technological components are already individually used or known by some farmers, with the exception of the improved varieties and some pesticides (APRON +, Decis, Actellic). The originality of these technical packages is not so much in the introduction of new technological components but in the combination of already known components into packages. The managerial aspect of using these technological components together as well as the access to credit and modern inputs are, however, particularly critical for increased productivity.

These four technical packages are devised to reduce production risk under unfavorable agroclimatic situations and increase yields under favorable conditions. To achieve this twofold objective, the technical packages combine two types of inputs:

[73] Labor inputs for these farm enterprises are taken from a review of several studies. This review can be found in Henry de Frahan et al. (1989, Appendix D).

"protective" inputs and "nonprotective" inputs. The seed varieties, the pesticides and the cropping techniques are primarily "protective" inputs that, as defined by Binswanger (1979), reduce risk but do not tend to increase yields under favorable agroclimatic situations. These technological components have been successfully tested on station and, for most, on farm for their ability to take climatic and biological stress. Chemical fertilizers included in the packages are the "nonprotective" inputs that increase yields under favorable situations but do not reduce risk. The packages include only low doses of fertilizers, however, given uncertainties regarding weather and pests, and therefore profitability of the fertilizers.

As rainfall levels decrease from South to North, the packages include inputs with a higher degree of protection against agroclimatic stress. For example, the millet variety selected for the northern agroclimatic zone is hardy and matures earlier, but is less responsive to fertilization. From South to North, doses of fertilizer decrease to the point that the lowest doses of fertilizer in the North are aimed not to increase yields but to help agriculture remain sustainable as fallow periods are reduced.

5.1.2. Effects Included in the Evaluation

The technical packages included in the analysis are evaluated in terms of the increase in value of output or the reduction in costs of production to the farm. The analysis does not separate out the indirect (or secondary) benefits. According to Gittinger terminology (1984, p. 478), indirect benefits are "changes in income that accrue to sellers of project inputs (...) or to buyers of project outputs used as intermediate goods (...)." These indirect benefits are implicitly included in the economic evaluation when inputs and outputs are valued at their shadow prices, representing either the opportunity cost of intermediate goods and services, or the value in use final goods and services.

The evaluation does not take into account the intangible effects of the project. The intangible effects could include reduction in outmigration from rural areas, regional development, national integration, and conservation of the environment from soil erosion and declining soil fertility. With regard to the institution housing the project, such effects would be primarily the training of scientists and the strengthening of the institutionalization of a systems approach to research in Mali. While important, these intangible effects are difficult to quantify in monetary terms. However, they should be borne in mind by evaluators and decision makers.

The reduction in food aid following an increase in cereal production and incomes in the Region of Mopti is another effect of the project that is not specifically taken into account. In recent years, food aid has been provided mostly to the population living on the Bandiagara plateau but this could be reduced if improvements in farm income increase the effective demand for coarse grains.

The distributional effects of the FSR project will be assessed by considering several social groups: urban consumers, producers who do not adopt the technology and, as a consequence, leave the agricultural sector, producers who do not adopt the technology and stay in the agricultural sector, producers who adopt the technology, and women within the farm households. The effects on security and economic sustainability will be assessed qualitatively.

5.1.3. Project Resources and Time Frame

FSR project costs are those for expanding the DRSPR in the Region of Mopti given in the project document (USAID, 1985). Based on the figures given in the project document and provided in Tables 1 to 3 in Appendix 5-B, the total cost of expanding the project to the Region of Mopti amounts to US $5.73 million and represents 27% of the total amount allocated to FSR under the cooperative agreement between the GRM and USAID, implemented in 1985 for an anticipated period of ten years. Plans call for a multidisciplinary team of researchers comprising four Malians (agricultural economist, sociologist, agronomist and livestock scientist) and two expatriates for four years (agronomist and agricultural economist) for the expansion of the DRSPR into the Region of Mopti. This should suffice for the development of the core research areas identified above. The equipment and operational budgets are detailed in tables 1 to 3 of Appendix 5-B. For the purpose of the evaluation, only buildings are considered to have a salvage value, estimated in year eight as 60% of their initial cost.

The project document envisages seven years of financing for the expansion of the DRSPR. It is anticipated that the first year will be spent constructing offices and housing for the DRSPR team. During the first year, the team will also begin the market studies. The time required to develop the four main technical packages, test them and mount a pilot extension program is estimated at three years, beginning in the second year of the project.

5.2. Financial Analysis of the Technical Packages

The main objective of the financial analysis of the technical packages is to determine the profitability of proposed changes in the farming systems of the different

target groups in order to estimate the adoption rates of the technical packages. The stability of the financial returns to alternative technologies is also important for adoption and will be tested in a sensitivity analysis.

The financial analysis is organized in three sections. First, assumptions are made about prices. Second, financial returns are estimated and analyzed. Third, a sensitivity analysis is used to test the financial stability of the potential technical packages. Once completed, the financial and sensitivity analyses permit the elimination of financially unprofitable and unstable technical packages.

5.2.1. Assumptions about Financial Prices

The profitability of the proposed changes is estimated by constructing financial budgets for each enterprise and for each agroclimatic zone for different technological levels: traditional, transitional and proposed practices. The financial prices and interest rates are those that were prevailing in 1988 in the markets where the FSR project will be implemented. Using real prices in the analysis does not assume an absence of inflation in the future, but it does assume that there will be no change in relative prices. Table 1 in Appendix 5-C reports the market prices used in the financial analysis.

The financial prices of inputs are those charged by the OPSS, the SMPC, the CMDT, the OHV, and the SMECMA in the Bamako area, increased by 20% to allow for transport and distribution costs in the Region of Mopti.[74] The price of local seed is taken as the price observed in weekly markets during the planting period.

The cost of daily labor used in the financial evaluation of the technical packages is determined according to the opportunity cost of the labor. The cost of daily labor used to estimate the financial value of the first two technical packages (millet-cowpea intercropping and the sole millet and cowpea cropping pattern) is determined according to the daily return to labor for millet-cowpea intercropping, the most widespread rainy season activity in the project area. The cost of daily labor used to estimate the financial value of the proposed groundnut-millet-groundnut rotation is determined according to the daily return to labor for work on a local millet-millet-millet rotation, which is expected to be replaced by the proposed rotation. The cost of daily labor used to estimate the financial value of the proposed sesame cultivation is determined according to the daily return to labor for millet in a local millet-millet-millet rotation evaluated in the second year of the rotation. The second year millet crop is expected to be replaced by the proposed sesame cultivation. These labor costs are estimated for each agroclimatic zone and for each method of cultivation (with or without plow).

To simplify the calculation of amortization charges on capital items, constant annuities are used. A capital recovery factor is applied to the value of the initial

[74] The OPSS, based in Segou, is the program responsible for producing improved seeds and delivering them to the regional development agencies. The SMPC is a state chemical products company, based in Bamako. The CMDT is the Malian company for the development of textiles in Southern Mali. The OHV is the Niger River Upper-Valley Development Authority, based in Bamako. The SMECMA is the Malian agricultural mechanization company.

investment.[75] Because the 9% interest rate offered by the National Agricultural Credit Bank (BNDA) is available for only a small number of farmers and the market rate is unknown, an interest rate twice the BNDA's rate is chosen for the financial analysis. An inflation rate estimated at 6% is applied to obtain the real financial interest rate (12%). The recovery period corresponds to the estimated life of the investment. Because the change in net farm income, not the change in costs of production, is the main focus of the financial analysis, no working capital costs are estimated except the interest actually paid on borrowed capital. The amortization charges on capital items are reported in Tables 3 of Appendix 5-C.

Prices of agricultural products were determined by the agroclimatic zone and analytical situation. For example, the prices of millet, cowpeas and groundnuts used in the evaluation of proposed technical packages should reflect the average price over the year because, through improved storage conditions and diversified production, the farmer would be able to market products throughout the year rather than just immediately after the harvest. In contrast, when the traditional and transitional local practices are analyzed, the prices for millet, cowpeas and groundnuts are those prevailing at harvest time.

Whether the prices used for millet, cowpeas and groundnuts are annual or post harvest averages, all estimates are based on observations made by the evaluation team, with the exception of the annual average price for millet. Price data were gathered by the evaluation team during the 1986-87 and 1987-88 agricultural seasons on the Region

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[75] The capital recovery factor corresponds to the annual repayment on a loan of one currency unit for x years with compound interest charged on the unpaid balance (Gittinger, 1984).

of Mopti's weekly assembly markets. The 1986-87 season was a good one, whereas that of 1987-88 was mediocre. The average annual price of millet was determined on the basis of monthly price statistics for millet gathered by the Early Warning System (SAP) for the period September 1986 to August 1988 (Table 1 in Appendix 2-B). These statistics were contrasted to periodic observations made by the evaluation team and were found to correspond to one an other. This annual average price has, however, been reduced arbitrarily by 10% in order to take into account the fact that the SAP statistics are retail, not wholesale, prices.

The price of sesame is based on the price offered to producers by the CMDT (90 CFA.F/kg), reduced by 20% to take into account the distance to the Region of Mopti. This farm-gate price was found to be competitive with the international price of sesame, including the marketing margins and export taxes.

5.2.2. Financial Returns

The change in profitability from one practice to the next can be measured in terms of incremental net income, marginal rate of return, average return to labor and marginal return per person day. The incremental net income per hectare is defined as the additional reward per ha for labor, capital and management contributed by the farm family during the year for a given change in technology or enterprise. However, because farmers consider the increase in cost in addition to the increase in net income when they make decisions about a technology or enterprise change, the marginal rate of return (MRR) is preferred to the incremental net income. The MRR is the ratio of the incremental net income to the incremental costs and reflects the additional net income earned by the additional capital and labor invested in the new practice. The marginal return per person day isolates the effect of additional labor from other factors of production, such as capital and land. Given labor bottlenecks, the marginal return per person day is a relevant measure of profitability. Since capital and labor are the two most limiting factors of production for farm households in the rainfed area of the Region of Mopti, both MRR and marginal return per person day will, therefore, be used.

Financial budgets are estimated for each agroclimatic zone where a package is to be introduced. For each potential technical package the gain in total gross value, the additional total costs, the gain in net income, and the gain in net income per labor day are estimated in absolute terms in Appendix 5-D and in relative terms in Tables 5-1 to 5-3. These estimates are calculated relative to the traditional and transitional technologies. For example, the "millet-cowpea intercropping" and the "millet-cowpea sole cropping" packages are compared with the traditional and transitional millet-cowpea intercropping. The "groundnut-millet-groundnut rotation" packages are compared with the traditional and transitional millet-millet-millet rotations. The "sesame cultivation" package is compared with the traditional and transitional millet-millet-millet rotations.

Breaking up the financial analysis into these three groups of farm enterprises has two advantages. First, it is consistent with farmers' strategies of diversification to provide food grains and income while reducing the risk of total crop failure. Second, it allows each potential package to be compared directly with the production techniques currently used by farmers for the relevant enterprise.

The financial budgets of the potential technical packages are analyzed with respect to three criteria: the marginal rate of return (MRR), the average return to labor and the marginal return per person day.

Table 5-1. Synthesis of the Financial Budgets for the Millet-Cowpea Crops

BUDGET COMPONENT (1)	CURRENT MILLET-COWPEA INTERCROPPING: TRADITIONAL (CFA F/ha)	CURRENT MILLET-COWPEA INTERCROPPING: TRANSITIONAL (CFA F/ha)	%	IMPROVED PRACTICES: MILLET-COWPEA INTERCROPPING (CFA F/ha)	%	IMPROVED PRACTICES: MILLET-COWPEA SOLE CROPPING (CFA F/ha)	%
NORTHERN ZONE:							
Gross Value of Production	20500	22150	8	46000	124	31275	53
Labor Gain from Traditional Technology		8342		4965		6205	
Total Gross Value	20500	30492	49	50965	149	37480	83
Variable Costs	1235	1235	0	11999	872	6898	459
Fixed Costs	0	6384		8227		6845	
Total Costs (2)	1235	7619	517	20226	1538	13743	1013
Net income (3)	19265	22873	19	30739	60	23738	23
Net Income per Day of Labor	397	528	33	716	80	566	43
CENTER AND PLATEAU ZONE:							
Gross Value of Production	27000	28950	7	62600	132	42250	56
Labor Gain from Traditional Technology		10570		4498		6466	
Total Gross Value	27000	39520	46	67098	149	48716	80
Variable Costs	1137	1137	0	17399	1430	7709	578
Fixed Costs	0	7295		9138		11333	
Total Costs (2)	1137	8432	642	26537	2234	19042	1575
Net income (3)	25863	31088	20	40561	57	29674	15
Net Income per Day of Labor	450	603	34	759	69	538	20
SOUTHERN ZONE:							
Gross Value of Production	23400	25200	8	68300	192	52000	
Labor Gain from Traditional Technology		8730		6286		8731	
Total Gross Value	23400	33930	45	74586	219	60731	160
Variable Costs	1050	1050	0	21763	1973	7900	
Fixed Costs	0	6384		16782		18977	
Total Costs (2)	1050	7434	608	38545	3571	26877	2460
Net income (3)	22350	26496	19	36041	61	33854	51
Net Income per Day of Labor	349	456	31	647	85	644	

(1) Percentages are expressed with respect to the traditional technology.
(2) Excluding labor and land costs.
(3) Defined as the return to labor, land and capital.
Source: Synthesis of Tables 1 and 2 in Appendix 5-D.

Table 5-2. Synthesis of the Financial Budgets for the Groundnut-Millet Crops

	CURRENT MILLET-MILLET-MILLET			IMPROVED GROUNDNUT-MILLET-GROUNDNUT			
BUDGET COMPONENT (1)	TRADITIONAL (CFA F/ha)	TRANSITIONAL (CFA F/ha)	%	WITHOUT TRP (CFA F/ha)	%	WITH TRP (CFA F/ha)	%
CENTER AND PLATEAU ZONE:							
Gross Value of Production	15200	16800	11	28560	88	42240	178
Labor Gain from Traditional Technology		5786		1240		-24	
Total Gross Value	15200	22586	49	29800	96	42216	178
Variable Costs	1971	1971	0	6779	244	6779	244
Fixed Costs	0	7295		7296		12065	
Total Costs (2)	1971	9266	370	14075	614	18844	856
Net income (3)	13229	13320	1	15725	19	23372	77
Net Income per Day of Labor	289	293	1	350	21	557	93
SOUTHERN ZONE:							
Gross Value of Production	14300	15700	10	26525	85	31560	121
Labor Gain from Traditional Technology		5504		1178		317	
Total Gross Value	14300	21204	48	27703	94	31877	123
Variable Costs	600	600	0	6699	1017	6779	1030
Fixed Costs	0	6384		6384		11154	
Total Costs (2)	600	6984	1064	13083	2081	17933	2889
Net income (3)	13700	14220	4	14619	7	13944	2
Net Income per Day of Labor	275	295	7	355	29	335	22

(1) Percentages are expressed with respect to the traditional technology.
(2) Excluding labor and land costs.
(3) Defined as the return to labor, land and capital.
Source: Synthesis of Tables 3 and 4 in Appendix 5-D.

Table 5-3. Synthesis of the Financial Budgets for the Sesame-Millet Crops

BUDGET COMPONENT (1)	CURRENT MILLET (2d year) TRADITIONAL (CFA F/ha)	TRANSITIONAL (CFA F/ha)	%	IMPROVED SESAME (CFA F/ha)	%
NORTHERN ZONE:					
Gross Value of Production	15000	16500	10	16500	10
Labor Gain from Traditional Technology		6205		2241	
Total Gross Value	15000	22705	51	18741	25
Variable Costs	695	695	0	4119	493
Fixed Costs	0	6384		6384	
Total Costs (2)	695	7079	919	10503	1411
Net income (3)	14305	15626	9	8238	-42
Net Income per Day of Labor	345	401	16	171	-50
CENTER AND PLATEAU ZONE:					
Gross Value of Production	16000	17600	10	31500	97
Labor Gain from Traditional Technology		6262		1879	
Total Gross Value	16000	23862	49	33379	109
Variable Costs	657	657	0	6601	905
Fixed Costs	0	7295		7296	
Total Costs (2)	657	7952	1110	13897	2015
Net income (3)	15343	15910	4	19482	27
Net Income per Day of Labor	313	333	6	409	31
SOUTHERN ZONE:					
Gross Value of Production	15000	16500	10	39000	160
Labor Gain from Traditional Technology		5760		288	
Total Gross Value	15000	22260	48	39288	162
Variable Costs	600	600	0	6601	1000
Fixed Costs		6384		6384	
Total Costs (2)	600	6984	1064	12985	2064
Net income (3)	14400	15276	6	26303	83
Net Income per Day of Labor	288	317	10	531	84

(1) Percentages are expressed with respect to the traditional technology.
(2) Excluding labor and land costs.
(3) Defined as the return to labor, land and capital.
Source: Synthesis of Table 5 in Appendix 5-D.

a) The Marginal Rates of Return of the Technical Packages

Tables 5-4 to 5-6 show the estimated marginal rates of return (MRR) to the technical packages for each agroclimatic zone.[76] As shown in the tables, the marginal analysis is performed for substitutable crop enterprises in the same way the financial budgets were presented above. A threshold of 50% is considered as the minimum rate at which a technology package will be adopted. This threshold is chosen because the estimated MRR for the transitional practice that has been adopted ranges between 56% and 72% (Tables 5-4 to 5-6).

For the northern zone, in Table 5-4, the marginal analysis eliminates the "millet-cowpea sole cropping" and "sesame cultivation" technical packages for both non-mechanized and mechanized farms. For the center and plateau zone, in Table 5-5, the "millet-cowpea sole cropping" and "groundnut-millet-groundnut rotation without TRP" packages for both non-mechanized and mechanized farms are eliminated. Despite the low 41% MRR, the "millet-cowpea intercropping" technical package is retained for the mechanized farm of this zone because it is familiar to farmers. It requires few changes vis-à-vis the transitional practice. For the southern agroclimatic zone, in Table 5-6, only the "sesame cultivation" technical package is retained. With the highest marginal rate of

[76] The marginal rate of return is the ratio of the marginal net benefit (or net income as previously defined) to the marginal cost, expressed as a percentage. In order to determine the MRR, the different packages along with existing practices need to be ranked according to their net benefits and their total costs. Any activity that has net benefits less than or equal to those of an activity with lower costs is said to be dominated, and therefore eliminated from the marginal analysis. The marginal rate of return is estimated between technologies of incremental cost. A marginal rate of return of 50% indicates, for example, that for every additional franc invested in the proposed package the farmer can expect to recover the franc invested and earn 50 centimes more profit. CIMMYT (1988) considers a rate between 50 and 100% to be the minimum rate at which a technology package will be adopted. The threshold depends on the degree of complexity and unfamiliarity of the technical package proposed. The technology with the highest net benefit together with an acceptable MRR is recommended.

Table 5-4. Marginal Analysis of the Technical Packages for Farms in the Northern Zone

TECHNICAL PACKAGE (1)	NET INCOME (CFAF)	TOTAL COST (CFAF)	MARGINAL NET INCOME (CFAF)	MARGINAL COST (CFAF)	MRR (%) (2)	AVERAGE RATE OF RETURN % (3)
A) NON-MECHANIZED FARM:						
Improved M-C intercropping	30739	20226	6256	6483	96	60
Improved M-C cropping pattern	24484	13743	1616	6118	26	42
M-C interc. transitional practice	22867	7624	3602	6389	56	56
M-C interc. traditional practice	19265	1235				
2nd year of M-M-M trans. practice	15626	7079	1321	6384	21	21
2nd year of M-M-M trad. practice	14305	695				
Improved sesame cultivation	8238	10503	Dominated (5)			
B) MECHANIZED FARM:						(4)
Improved M-C intercropping	21283	20226	5600	6483	86	54
Improved M-C cropping pattern	15683	13743	1152	6124	19	19
M-C interc. transitional practice	14531	7619				
2nd year of M-M-M trans. practice	9421	7079				
Improved sesame cultivation	1387	10503	Dominated (5)			

(1) M-C: Millet-Cowpea
M-M-M: Millet-Millet-Millet rotation
Transitional practice: Mechanized practice with no other external inputs.
Traditional practice: Non-mechanized practice with no external inputs.
(2) From preceding to following.
(3) From the traditional practice.
(4) From the transitional practice.
(5) A technical package is dominated if it incurs higher costs but no additional net income.
Source: From Tables 1 to 5 in Appendix 5-D.

Table 5-5. Marginal Analysis of the Technical Packages for Farms in the Center and Plateau Zone

TECHNICAL PACKAGE (1)	NET INCOME (CFAF)	TOTAL COST (CFAF)	MARGINAL NET INCOME (CFAF)	MARGINAL COST (CFAF)	MRR (%) (2)	AVERAGE RATE OF RETURN % (3)
A) NON-MECHANIZED FARM:						
Improved M-C intercropping	40560	26538	9466	18112	52	58
M-C interc. transitional practice	31094	8426	5231	7289	72	72
Improved M-C cropping pattern	29673	19042	Dominated (5)			
M-C interc. traditional practice	25863	1137				
Improved G-M-G rotation with TRP	23308	18924	7582	4849	156	48
Improved G-M-G rotation w/o TRP	15726	14075	1092	6122	18	9
M-M-M rot. transitional practice	14634	7952	91	7295	1	1
M-M-M rot. traditional practice	14543	657				
Improved sesame cultivation	19483	13896	3573	5944	60	31
2nd year of M-M-M trans. practice	15910	7952	567	7295	8	
2nd year of M-M-M trad. practice	15343	657				
B) MECHANIZED FARM:						
Improved M-C intercropping	27916	26538	7398	18105	41	41
M-C interc. transitional practice	20518	8432				
Improved M-C cropping pattern	17701	19042	Dominated (5)			
Improved G-M-G rotation with TRP	17574	18924	7570	4849	156	80
Improved G-M-G rotation w/o TRP	10004	14075	1156	6122	19	
M-M-M rot. transitional practice	8848	7952				
Improved sesame cultivation	12946	13896	3299	5944	55	55
2nd year of M-M-M trans. practice	9648	7952				

(1) M-C: Millet-Cowpea
G-M-G: Groundnut-Millet-Groundnut rotation
M-M-M: Millet-Millet-Millet rotation
TRP: Tilemsi Rock Phosphate
Transitional practice: Mechanized practice with no other external inputs.
Traditional practice: Non-mechanized practice with no external inputs.
(2) From preceding to following.
(3) From the traditional practice.
(4) From the transitional practice.
(5) A technical package is dominated if it incurs higher costs but no additional net income.
Source: From Tables 1 to 5 in Appendix 5-D.

Table 5-6. Marginal Analysis of the Technical Packages for Farms in the Southern Zone

TECHNICAL PACKAGE (1)	NET INCOME (CFAF)	TOTAL COST (CFAF)	MARGINAL NET INCOME (CFAF)	MARGINAL COST (CFAF)	MRR (%) (2)	AVERAGE RATE OF RETURN % (3)
A) NON-MECHANIZED FARM:						
Improved M-C intercropping	36041	38545	2187	11668	19	37
Improved M-C cropping pattern	33854	26877	7357	19443	38	45
M-C interc. transitional practice	26496	7434	4146	6384	65	65
M-C interc. traditional practice	22350	1050				
Improved G-M-G rotation w/o TRP	14619	13083	400	6099	7	7
M-M-M rot. transitional practice	14220	6984	520	6384	8	8
Improved G-M-G rotation with TRP	13944	17933	Dominated (5)			
M-M-M rot. traditional practice	13700	600				
Improved sesame cultivation	26303	12985	11027	6001	184	96
2nd year of M-M-M trans. practice	15276	6984	876	6384	14	
2nd year of M-M-M trad. practice	14400	600				
B) MECHANIZED FARM:						(4)
Improved M-C intercropping	26566	38545	1443	11668	12	28
Improved M-C cropping pattern	25123	26877	7357	19443	38	38
M-C interc. transitional practice	17766	7434				
Improved G-M-G rotation w/o TRP	8861	13083	145	6099	2	2
M-M-M rot. transitional practice	8716	6984				
Improved G-M-G rotation with TRP	8179	17933	Dominated (5)			
Improved sesame cultivation	19988	12985	10472	6001	175	175
2nd year of M-M-M trans. practice	9516	6984				

(1) M-C: Millet-Cowpea
G-M-G: Groundnut-Millet-Groundnut rotation
M-M-M: Millet-Millet-Millet rotation
TRP: Tilemsi Rock Phosphate
Transitional practice: Mechanized practice with no other external inputs.
Traditional practice: Non-mechanized practice with no external inputs.
(2) From preceding to following.
(3) From the traditional practice.
(4) From the transitional practice.
(5) A technical package is dominated if it incurs higher costs but no additional net income
Source: From Tables 1 to 5 in Appendix 5-D.

return among all the proposed technical packages, sesame cultivation in the southern zone is particularly attractive. This is due in part to the fact that the ratio of sesame and millet prices is more favorable to sesame cultivation in the southern zone than in other areas. In order to maintain the profitability of the package as production increases, new market outlets will need to be found.

Among the MRRs reflecting the profitability of investing in animal traction only, the highest MRR is found for the center and plateau agroclimatic zone (72%) where mechanization is the most widespread (mechanization rate is 42%), while the lowest MRRs are found for the southern and northern agroclimatic zones (respectively 65% and 56%) where mechanization is less widespread (mechanization rates are 16% in the southern zone and 18% in the northern zone).[77] These attractive MRRs for the mechanized technologies provide further evidence of the need to provide agricultural equipment to increase profitability, particularly in the center and plateau areas where the effective demand for equipment is not yet met because equipment is not available.

b) The Returns to Labor

In Table 5-7, both the average return to labor and the marginal return per person day are estimated. First, the total return to labor is determined by the difference between the gross value of production and the total cost of production, excluding any labor cost or labor saving in the estimation of these two variables. The total cost of production includes an opportunity cost of capital of 12% to ensure that the difference between the gross value of production and the total cost of production is the return to labor only and not to capital invested in the production process. In the sensitivity

[77] These MRRs are those estimated between the traditional technology and the transitional technology for the first group of financial budgets in Tables 5-4 to 5-6.

Table 5-7. Average Return to Labor and Marginal Return per Man Day with an Opportunity Cost of Capital of 12%

TECHNICAL PACKAGE (1)	GROSS VALUE OF PRODUCTION (CFA F) (2)	TOTAL COST (CFA F) (3)	RETURN TO LABOR (CFA F)	LABOR INPUT (day)	INCREMENTAL LABOR DAY (day)	AVERAGE RETURN TO LABOR (4) (CFA F/day)	MARGINAL RETURN TO LABOR(CFA F)	MARGINAL RETURN PER MAN DAY (5) (CFA F/day)
A) NORTHERN ZONE:								
Improved M-C intercropping	46000	22754	23246	36.0	5.0	646	7432	1486
M-C interc. traditional practice	20500	1353	19147	48.5	17.5	395	Dominated (6)	
Improved M-C cropping pattern	31275	15461	15814	31.0	3.5	510	2236	639
M-C interc. transitional practice	22150	8571	13579	27.5		494		
2nd year of M-M-M trad. practice	15000	782	14218	41.5	18.0	343	5682	316
2nd year of M-M-M trans. practice	16500	7964	8536	23.5		363		
Improved sesame cultivation	16500	11816	4684	35.0		134	Dominated (6)	
B) CENTRAL AND PLATEAU ZONES:								
Improved M-C intercropping	62600	29855	32745	47.5	4.4	689	11917	2708
M-C interc. traditional practice	27000	1279	25721	57.5		447	Dominated (6)	
Improved M-C cropping pattern	42250	21422	20828	43.1	9.1	483	1364	150
M-C interc. transitional practice	28950	9486	19464	34.0		572		
Improved G-M-G rotation with TRP	42240	21290	20951	51.0	0.7	411	6490	9271
M-M-M rot. traditional practice	15200	739	14461	50.3	3.6	287	1735	482
Improved G-M-G rotation w/o TRP	28560	15834	12726	46.7	16.4	272	4872	297
M-M-M rot. transitional practice	16800	8946	7854	30.3		259		
Improved sesame cultivation	31500	15633	15867	43.0	14.0	369	7213	515
2nd year of M-M-M trad. practice	16000	739	15261	49.0		311	Dominated (6)	
2nd year of M-M-M trans. practice	17600	8946	8654	29.0		298		

Table 5-7 (cont'd).

TECHNICAL PACKAGE (1)	GROSS VALUE OF PRODUCTION (CFA F) (2)	TOTAL COST (CFA F) (3)	RETURN TO LABOR (CFA F)	LABOR INPUT (day)	INCREMENTAL LABOR DAY (day)	AVERAGE RETURN TO LABOR (4) (CFA F/day)	MARGINAL RETURN TO LABOR(CFA F)	MARGINAL RETURN PER MAN DAY (5) (CFA F/day)
C) SOUTHERN ZONE:								
Improved M-C intercropping	68300	43363	24937	46.0	7.0	542	3174	453
Improved M-C cropping pattern	52000	30237	21763	39.0		558		
M-C interc. traditional practice	23400	1181	22219	64.0		347	Dominated (6)	
M-C interc. transitional practice	25200	8363	16837	39.0		432	Dominated (6)	
M-M-M rot. traditional practice	14300	675	13625	50.0	4.0	273	1819	455
Improved G-M-G rotation w/o TRP	26525	14718	11806	46.0	16.0	257	3963	248
Improved G-M-G rotation with TRP	31560	20175	11385	49.3		231	Dominated (6)	
M-M-M rot. transitional practice	15700	7857	7843	30.0		261		
Improved sesame cultivation	39000	14608	24392	49.0	19.0	498	15749	829
2nd year of M-M-M trad. practice	15000	675	14325	50.0		287	Dominated (6)	
2nd year of M-M-M trans. practice	16500	7857	8643	30.0		288		

(1) M-C: Millet-Cowpea.
G-M-G: Groundnut-Millet-Groundnut rotation.
M-M-M: Millet-Millet-Millet rotation.
TRP: Tilemsi Rock Phosphate.
Transitional practice: Mechanized practice with no external inputs.
Traditional practice : Non-mechanized practice with no external inputs.

(2) Labor gain excluded.

(3) Labor cost excluded, but including a 12% opportunity cost of capital for the cropping season.

(4) Return to labor divided by total labor days.

(5) Marginal return to labor divided by the incremental labor day.

(6) A technical package is dominated if it incurrs more labor input but no additional net benefit.

<u>Source</u>: From Tables 1 to 5 in Appendix 5-D.

analysis, the opportunity cost of capyital is increased to 25%.[78] Second, the average return to labor is calculated by dividing the total return to labor by the number of days of work.

The marginal return per person day is estimated in the following two steps. First, the marginal return to labor is estimated between enterprises with incremental labor input.[79] Second, the marginal return to labor is divided by the number of additional person-days employed to arrive at the marginal return per person day, which indicates how much the additional work day is worth when invested in a more labor-intensive crop enterprise.

i) The Average Return to Labor

As indicated in Table 5-7, the "millet-cowpea intercropping" and the "millet-cowpea sole cropping" technical packages increase the average return to labor vis-à-vis the traditional and transitional technologies in the northern zone. The "millet-cowpea intercropping" package increases the average return the most. In the center and plateau zone, the "millet-cowpea intercropping", the "groundnut-millet-groundnut with TRP" and the "sesame cultivation" technical packages also increase the average return to labor. In the southern zone, the "millet-cowpea intercropping", the "millet-cowpea sole cropping" and the "sesame cultivation" technical packages increase the average return to labor vis-à-vis the traditional and transitional technologies. In all zones, the mechanization of the

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[78] The size of these two opportunity costs of capital is assumed to represent the range in loan rates given by private merchants to farmers during the cropping season.

[79] The marginal return to labor is the difference in the returns to labor between two alternative activities. In order to calculate the marginal return to labor, the activities to be compared need to be ranked according to the size of their return to labor and the size of their labor input. Any activity that has a return to labor less than or equal to the return to labor of an alternative activity with lower labor input is said to be dominated and therefore eliminated from the marginal analysis.

traditional technology increases the average return to labor for the "millet-cowpea intercropping" and for the "millet-millet-millet rotation". Particularly with respect to the millet-cowpea intercropping, the average returns to labor increase by about 30% with animal traction in the three zones. In sum, animal traction technology and technical packages that FSR could develop will increase the average returns to labor.

ii) The Marginal Return Per Person Day

The last column of Table 5-7 shows the marginal return per person day for the technical packages. The dominated practices are eliminated from the marginal analysis. Traditional millet-cowpea intercropping is dominated by the transitional technology and by the proposed technical packages.

The proposed technical packages must show a marginal return per person day greater than the current estimated opportunity cost of labor. The average returns to labor estimated for the traditional and transitional practices are used as the opportunity costs of labor. In the northern zone, the marginal returns per person day for the proposed millet-cowpea technical packages are higher than the corresponding opportunity costs of labor. In the center and plateau zone, these marginal returns of the "millet-cowpea intercropping", the "groundnut-millet-groundnut rotation with TRP" and the "sesame cultivation" technical packages are higher than their corresponding opportunity costs of labor. In the southern zone, the marginal returns per person day of the "millet-cowpea intercropping" and the "sesame cultivation" technical packages are higher than their corresponding opportunity costs of labor.

Compared to the marginal analysis carried out on the returns to capital and labor, the marginal analysis on the returns to labor retains a larger set of technical packages. Though the marginal analysis on the returns to labor does not help narrow the number of potential technical packages that FSR could develop, it shows that the technical packages that passed the test of the marginal analysis on the returns to capital and labor also augment labor productivity, an important consideration for farmers in the area.

c) Conclusions

Analysis of the financial budgets permits unprofitable or marginally profitable packages to be eliminated. Primarily on the basis of the estimated marginal rate of return, average return to labor and marginal return per person day the technical packages presented in Table 5-8 are retained in the sensitivity analysis.

Table 5-8. Technical Packages Included in the Sensitivity Analysis

	TECHNICAL PACKAGES (1)			
ZONE AND LEVEL OF TECHNOLOGY	P1	P2	P3	P4
Northern Zone				
Non-mechanized	X			
Mechanized	X			
Center and Plateau Zones				
Non-mechanized	X		X	
Mechanized	X		X	
Southern Zone				
Non-mechanized	X		X	X
Mechanized	X		X	X

(1) P1 : "Millet-cowpea intercropping".
P2 : "Millet-cowpea mono-cropping".
P3 : "Groundnut-millet-groundnut rotation".
P4 : "Sesame cultivation"

5.2.3. Sensitivity Analysis

Increased profitability is not the only condition for adoption. Risk in a region characterized by weather, pests and market uncertainties is another important consideration. Risk-averse farmers are willing to sacrifice some profit for a reduction in risk. Sensitivity analysis is a common and simple tool to test the stability of the financial returns to alternative technologies when the values of key variables change.[80] The key variables include yields, output and input prices, and interest rates. The technology that shows the most stable financial return is the less risky. Sensitivity analysis is carried out by varying a value or combination of values, and then determining the consequences of this change on the financial (or economic) results (Gittinger, 1984). The changes of the parameters apply for all the technologies (traditional, transitional and proposed packages).

First, the effect of changes in the values of critical variables on the marginal rate of return is examined. The commodity price or yield for each proposed package is the first critical variable. Whether one varies the price or the yield, the sensitivity analysis is the same since, in both cases, the gross benefit is multiplied by the same factor. The cost of production inputs is the second critical variable considered in the sensitivity analysis. Finally, the effect of changes in the opportunity cost of capital on the average return to labor and the marginal return per person day is examined. For both sensitivity analyses, the range in values is chosen according to what is realistic, and effects are examined across agroclimatic zones and levels of technology.

a) On the Marginal Rates of Return of the Technical Packages

Results of the first sensitivity analysis are presented in Tables 1 to 3 of Appendix 5-E. Changes in output price or yield and input costs are made for the proposed technical packages and for the traditional and transitional technologies. These changes

[80] More sophisticated tools are available to test the riskiness of adopting new technologies: the expected utility model, the mean-variance approach, and the expected value of the loss function. Data constraints (for example, data on farmers' preferences to draw an utility function and on yield distributions) prevented the use of these techniques in this study.

reflect variations of ± 10%, ± 20% and ± 50%. This range of variation is the most probable.

In the northern zone (Table 1 in Appendix 5-E), the profitability of the "millet-cowpea intercropping" technical package is not as stable as the transitional technology for both changes in output price or yield and input costs. With a 20% reduction in output price or yield or a 20% increase in input costs, the MRR of the "millet-cowpea intercropping" technical package becomes lower than the transitional technology, whereas the MRR of the "millet-cowpea intercropping" technical package is higher than the MRR of transitional technology at the base line. With these 20% variations, the MRR of the "millet-cowpea intercropping" technical package is no longer financially attractive.

In the center and plateau zone (Table 2 in Appendix 5-E), the "millet-cowpea intercropping" technical package is also not as stable as the transitional technology for both changes in price or yield and input costs. With a 10% reduction in output price or yield or a 10% increase in input costs, the MRR of the "millet-cowpea intercropping" technical package is no longer attractive for both non-mechanized and mechanized farms, while the MRR of the transitional technology is still attractive at a 20% level of variation. The "groundnut-millet-groundnut rotation with TRP" technical package remains very attractive for the mechanized farms with a 20% reduction in output price or yield or a 20% increase in input costs. In contrast, a 20% reduction in output price or yield or a 20% increase in input costs renders this technical package unprofitable for the non-mechanized farms. The "groundnut-millet-groundnut rotation with TRP" technical package is not as stable as the transitional technology and the "millet-cowpea intercropping" technical package for the non-mechanized farms, but it is more stable than the "millet-cowpea intercropping" technical package for the mechanized farms.

In the center and plateau zone, the "sesame cultivation" technical package is more stable with respect to changes in input costs than with respect to changes in output price or yield. The "sesame cultivation" technical package is more stable than the "groundnut-millet-groundnut rotation with TRP" technical package with respect to changes in input costs, but less stable than the "groundnut-millet-groundnut rotation with TRP" and the "millet-cowpea intercropping" technical packages with respect to changes in output price or yield. The "sesame cultivation" technical package is not as stable as the transitional technology in any circumstances.

Because the "sesame cultivation" technical package is more profitable in the southern zone than in the center and plateau zone, it remains attractive in the southern zone with a 20% reduction in output price or yield or with a 50% increase in input costs (Table 3 in Appendix 5-E). In the center and plateau zone, sesame is no longer profitable with a 10% variation. The "sesame cultivation" technical package in the southern zone, as well as in the center and plateau zone, is not as stable as the transitional technology.

In sum, with respect to changes in output price or yield and input costs, the transitional technology shows a greater stability than any other technical package that could developed by FSR. In the northern zone, the "millet-cowpea intercropping" technical package is profitable up to a 10% reduction in output price or yield or a 10% increase in input costs, which is a very narrow range of profitability given the uncertainty surrounding the yield estimates that can be expected from this technology. In the center and plateau zone, the relative stability of the technical packages depends on circumstances (non mechanized versus mechanized farms and changes in input costs versus changes in output price or yield). Profitability of the "millet-cowpea intercropping" and "sesame cultivation" technical packages is not any longer attractive with a 10% reduction in output price or yield or with a 10% increase in input costs. The profitability of the "groundnut-millet-groundnut rotation with TRP" technical package is more resistant to a reduction in output price or yield or an increase in input costs. In the southern zone, the "sesame cultivation" technical package remains attractive up to a 20% reduction in output price or yield or a 50% increase in input costs. Unless outlets are not found for sesame, which currently has very limited markets, developing sesame may run into marketing constraints since sensitivity to output is large.

b) On Average Returns to Labor and Marginal Returns per Person Day for the Technical Packages

As indicated by Table 4 in Appendix 5-E, the relative profitability of the technical packages measured in terms of the average return to labor and marginal return per man day are not modified when using a 25%, rather than a 12%, opportunity cost of capital. The traditional millet-cowpea intercropping practice is still dominated by the transitional technology and by the proposed technical packages. The average returns to labor for the technical packages that FSR could develop stay above the average returns to labor of the traditional and transitional technologies. The marginal returns per person day for the technical packages that FSR could develop are still above the average returns to labor for the traditional and transitional technologies, these average returns to labor corresponding to the current opportunity costs of labor.

c) Conclusions

The sensitivity analysis reveals that the financial profitabilities of the "millet-cowpea intercropping" and "sesame cultivation" technical packages in the center and plateau zone are very unstable with changes in price or yield and input costs. In that zone, the profitability of the "millet-cowpea intercropping" and "sesame cultivation" technical packages are no longer attractive with a 10% reduction in output price or yield or a 10% increase in input costs. The financial profitability of the "millet-cowpea intercropping" in the northern zone, "groundnut-millet-groundnut rotation" in the center and plateau zone and "sesame cultivation" in the southern zone is relatively more stable. The "sesame cultivation" technical package is more stable with respect to changes in input costs but less stable with respect to changes in output price or yield. The marginal analysis on the return to labor alone does not alter the findings of the marginal analysis on the return to capital and labor.

The instability of the technical packages is mitigated, however, because when yields from the technical packages are low (in a year of inadequate rainfall for example), the prices of commodities tend to increase. However, the compensatory effect of yield and price would work to stabilize gross farm income only if the price on the local market is determined by the level of local production. Since the coarse grain market in Mopti is relatively well integrated with markets in the southern area of the country (Bamako, Koutiala, Sikasso; see Table 2 in Appendix 2-B), the compensatory effect might be low. This suggests that the instability of the financial outcomes resulting from variation in prices and yields remains critical and requires research on agricultural commodity markets and agricultural innovations that could help stabilize gross farm incomes in the Region of Mopti.

In addition, the instability induced by potential changes in costs of production indicates the importance of focusing research also on the market for agricultural inputs, not only to ensure their availability at the farm-level but also to reduce their costs of production and distribution. For example, the initial financial budgets were constructed on the basis of a gross commercial mark up of 20% for the transportation and distribution of inputs in the Region of Mopti. If this mark up could be reduced to 10%, the financial profitability of the potential technical packages could be significantly improved.

In conclusion, the sensitivity analysis for the financial budgets reveals that most of the proposed packages are unstable and supports the view that the success of systems research in the Region of Mopti depends heavily on the agricultural input and product markets. FSR should make these priority areas for research.

5.3. Economic Analysis of the Technical Packages

The economic analysis of the technical packages is organized into three sections. First, assumptions are made to convert financial prices into economic prices. Second, farm enterprises for which agricultural research may improve the economic efficiency are identified using the domestic resource cost (DRC) ratio as an efficiency indicator. Comparisons of DRC ratios estimated for different commodities, technologies and agroclimatic zones indicate the areas in which the Region of Mopti has or could have a comparative advantage. Third, the expected diffusion paths of the technologies that FSR could develop are estimated using historical data on animal traction adoption in the area.

5.3.1. Assumptions about Economic Prices

The economic analysis uses prices from which all market distortions, such as subsidies or taxes, have been removed. All subsidies and taxes are considered as transfer payments between groups of producers or consumers in the same country. Furthermore, if any inputs or products are imported, then not only must taxes and subsidies be removed in the valuation of these goods but also an adjustment must also be made for the rate of exchange. In the case of Mali, the exchange rate is determined by the Monetary Union of West African States (UMOA). Due to the balance of payments deficit and the structure of taxes and subsidies, the CFA franc is overvalued in Mali vis-à-vis the US dollar. Taking into account only the balance of payments deficit, the overvaluation or exchange rate subsidy was on the order of 33% for the period 1981-1985 (Stryker et al., 1987).[81] An overvalued exchange rate favors imports at the expense of exports. Economic analysis corrects this bias in order to evaluate the project on the basis of 1) the opportunity cost to the country as a whole of the resources invested in the activities of the project and, 2) on the value in use to the country of the

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[81] Stryker et al. (1987, pp. 39-40) employ the elasticity approach to derive the magnitude of the overvaluation of the CFA franc in Mali. The method employed consists of correcting the level of the official exchange rate (OER) by adding a term that adjusts it to the rate that would need to prevail in the market for foreign exchange if there were no current account deficit (DEF). For small deviations this equilibrium rate of exchange (SER) is approximated by:

$$SER = OER + OER^{*}\{DEF/(\epsilon_S{}^{*}X + \eta_D{}^{*}M)\}$$

where 'ϵ_S' is the elasticity of supply of foreign exchange, 'η_D' is the elasticity of demand for foreign exchange, 'X' the existing level of exports, and 'M' is the existing level of imports, both expressed in units of foreign exchange. Using rough approximations for ϵ_S at 1.0 and η_D at 2.0, the overvaluation is estimated at 33% for the period 1981-85. This overvaluation rate is underestimated because the distortion effects of the high tariffs and system of import controls on the domestic prices during that period are not taken into account. Consequently, the SER represents the equilibrium value of the exchange rate in the presence of existing trade policies. To correct for these trade policies, the rate of protection (t_M) and export restriction (t_X) need to be estimated and used in the following general formula (Schiff, 1986):

$$SER = OER + OER^{*}\{DEF + [t_M{}^{*}\eta_D{}^{*}M/(1+t_M) - t_X{}^{*}\epsilon_S{}^{*}X/(1-t_X)]\}/[\epsilon_S{}^{*}X + \eta_D{}^{*}M]$$

outputs of the activities.[82] As in the financial analyses, economic prices are used at their 1988 levels.

The financial prices of inputs have been adjusted to arrive at their economic value. There are two categories of inputs. On the one hand, the financial prices of locally produced inputs must have the value of taxes removed and subsidies added to arrive at their economic value. On the other hand, there are inputs that are essentially imported but have value added locally (through processing, assembly, marketing, etc.). For this second category of inputs, the customs duty on the imported component must first be removed, and then an exchange rate premium added to the duty-free imported component in order to take account of the overvaluation of the CFA franc vis-a-vis other currencies. As a final step, any domestic taxes applied must be deducted and any subsidies added to arrive at the economic price.

The first category of inputs includes mainly improved seed (millet and cowpeas from OPSS, groundnuts from ODIPAC, and sesame from CMDT), locally raised draft animals, and locally produced Tilemsi rock phosphate. In Mali, the costs of seed production exceed the sale price of seeds, because the subsidy is arbitrarily set at 20%.[83] The economic value of draft animals is taken to be the market price in the Region of Mopti. The economic price of domestically produced Tilemsi rock phosphate is the same as its financial price.

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[82] The opportunity cost of a scarce resource is the benefit foregone as a result of not employing that resource in its next best alternative use, while the value in use is that sum of money that a purchaser is prepared to pay in order to obtain the final good or service (Gittinger, 1984).

[83] Even if this subsidy has been set incorrectly this should not significantly affect the results of the economic analysis because the cost of seed accounts for only a small proportion of the costs of production of rainfed crops, with the exception of groundnuts.

The second category of inputs includes mainly pesticides, fertilizer and agricultural equipment. The economic values of these inputs are shown in Table 2 of Appendix 5-C. An 8% subsidy on agricultural equipment in Mali has been added to the financial price of these inputs to arrive at the economic value.

The economic cost of daily labor is determined in the same way as the financial cost of daily labor, except that the financial values of the inputs and outputs used in the determination of the cost of daily labor are replaced by their corresponding economic values.

The calculation of economic amortization charges is presented in Table 4 of Appendix 5-C. It is carried out in the same manner as the financial amortization charges, except for the use of economic prices instead of financial prices.

The economic value of millet, cowpeas and groundnuts is estimated at their respective market prices in the expectation that these three agricultural products will be consumed within the Region of Mopti. These products are currently not heavily traded across the border. In contrast, sesame will be produced specifically for export. The economic value of sesame at the farm-gate is obtained by adding export taxes to the producer price and applying the exchange rate premium to take account of the overvaluation of the CFA franc.[84]

5.3.2. Economic Efficiency by Farm Enterprise, Technology and Agroclimatic Zone

The efficiency of using domestic resources and technology to produce a given commodity is measured when the economic cost of the domestic factors of production

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[84] Export taxes are added to the producer price because they are considered a transfer of payment from producers to the government.

(essentially labor, capital, land, and water) used in producing the commodity are contrasted with the cost of importing the equivalent of those domestic costs from abroad. In other words, the domestic-value added per unit of output is compared to the value-added measured in world prices. The ratio of the shadow costs of nontradables used in domestic production to the international value-added calculated at the shadow exchange rate is called the domestic resource cost (DRC) ratio. Because the DRC ratio directly compares the cost of the domestic resources used with that of the foreign product, it indicates which commodities the country or the region can produce competitively in international terms and with which technology.

The DRC ratio also indicates the areas in which the country has a comparative advantage. Both numerator and denominator of the DRC are expressed in terms of the domestic currency by multiplying the denominator by the efficiency price of foreign exchange, i.e., the shadow exchange rate (SER). The SER represents the marginally efficient rate of converting non-tradable factors of production into tradable value added. With that conversion rate, the efficiency prices of tradable outputs and inputs expressed originally in terms of foreign currency are converted into their opportunity cost at the margin in terms of domestic factors of production. As a result, the DRC ratio is a ratio that indicates whether the activity is more or less efficient than the activity somewhere in the economy that is marginally efficient (Stryker et al., 1987, p. 38). A DRC ratio under one means that the country or the region has a comparative advantage in the activities associated with such a DRC ratio. A DRC ratio over one means that the country or the region does not have a comparative advantage in the activities associated with such a DRC ratio. A negative DRC ratio due to a negative numerator may exist when the value of the non-tradable components of the value of the outputs exceeds the value of the non-tradable components of the value of the domestic inputs expended in producing these outputs. Such a DRC ratio is extremely favorable. In contrast, when the denominator is negative, the negative DRC ratio indicates that the production of the commodity wastes foreign exchange.

The DRC ratios are calculated according to a generalized formula that 1) estimates the ratios at different points of comparison (farm, rural market, wholesale point), and 2) includes the non-tradable components of the value of production (seeds consumed locally, hay and manure). Hence, the numerator of the ratio includes:

Non-tradable components of the input costs

+ Non-tradable components of the collection and distribution costs

- Non-tradable components of the value of the production.

The denominator of the ratio includes:

Tradable components of the value of production

- Tradable components of the input costs

- Tradable components of the collection and distribution costs.

Data on the economic prices of inputs are taken from Tables 2 and 4 of Appendix 5-C and are separated into tradable and non-tradable components. The tradable components of the input prices include a 33% upward correction for the CFA franc overvaluation. This correction will be increased to 50% in a sensitivity analysis because it is likely that the overvaluation is underestimated. The prices of the tradable and non-tradable components of inputs are reported in Table 1 of Appendix 5-F.

To evaluate whether the Region of Mopti has a comparative advantage in producing millet, groundnuts, sesame and rice for local consumption or exports, the values of production of these commodities are estimated with respect to border parity prices. To estimate the border parity prices for import-substituting commodities (millet, groundnuts and rice), the commodities' internationally quoted free-on-board (FOB) prices are the starting point. The FOB prices are then converted into cost-insurance-and-freight (CIF) values in local currency (converted at the shadow exchange rate) and brought to the relevant points of comparison by adding the appropriate economic port charges and delivery costs. The internationally quoted FOB prices are the projected 1990 prices as quoted by the World Bank, adjusted to 1988 dollars. Delivery charges incurred in bringing the commodity from the port to the different points of comparison are assumed to be the same as in bringing the commodity from the different points to the port. The value of these delivery charges are taken from Stryker et al. (1987, Annex B) and adjusted to 1988 CFA francs.

For groundnuts, which have internationally traded joint products, joint product international reference prices are brought to the border and then up-country to the relevant points of comparison. Extraction ratios are applied to each joint product in order to derive the "raw product equivalent" price after product transformation, while the domestic costs of producing and marketing the joint products include the processing costs (AIRD, 1987, p. 13). Here, two processing technologies are compared. The first is the mechanical oil press technique, which is labor-intensive, has a low oil extraction rate (39%) and is hypothetically located in Mopti. The second is the industrial technique, which is capital-intensive, has a higher oil extraction rate (59%), and is located in Koulikoro (60 km east of Bamako).

For exported sesame seeds, the relevant border price is FOB, not CIF. The international sesame seed price taken as the starting point of the border parity price calculation is an average of the 1987 and 1988 per kilo values of sesame seed imported to the US from four African countries (Nigeria, Morocco, Sudan and Egypt). Those values are calculated from prices at point of export published by USDA (1989) and roughly correspond to FOB prices. Appropriate port charges and delivery costs are then subtracted from the FOB price in order to derive a producer price.

Details concerning the calculation of the import parity prices for millet, groundnuts and rice and export parity price for sesame seed are contained in Tables 2 to 6 of Appendix 5-F. Prices of non-traded outputs are those observed locally during the informal survey: cowpea prices at farm and Mopti markets, and hay, cattle live weight and manure values at farm-gate. A sensitivity test on the internationally quoted FOB prices will show the effects of changes in the world trade market on the competitiveness of agriculture in the Region of Mopti.

First, the DRC ratios are estimated for the major crops of the Region of Mopti with the current technologies and compared with DRC ratios estimated for the same crops in other areas of the country. Table 1 in Appendix 5-G shows the calculation of the DRC ratios for the major crops of the Region of Mopti. at different consumption levels: farm, rural market (Mopti, Sikasso and Segou), wholesale market (Bamako) and consumption market (Gao). Because these markets are the most important in the country, the DRC ratios estimated at these points provide the basis for determining where and for which commodities the Region of Mopti currently has a comparative advantage. The estimations of the DRC ratios for the crops grown in regions other than Mopti are taken from Stryker et al. (1987, Annex B) and are supplemented by additional points of comparison (Mopti and Gao for rice and millet, and Sikasso for rice).[85] The

[85] Four adjustments are made to the DRC ratios estimated in Stryker et al. (1987). First, double counting of the transportation costs is eliminated. Since the wholesale market of Bamako is located farther than the Sikasso and Segou rural markets on the

results of the DRC ratios' calculation for the current technologies are summarized in Table 5-9 from Table 1 of Appendix 5-G.

According to the sizes of the DRC ratios in Table 5-9, the Region of Mopti has a substantial comparative advantage in producing millet, cowpeas and rice for farm consumption and for the rural market of Mopti and the consumption market of Gao. The comparative advantage in producing millet and cowpeas for the wholesale market of Bamako is marginal. For this market, the Region of Mopti has about the same DRC ratios as those estimated for southern Mali and, therefore, could economically compete with southern Mali for the wholesale market. However, this competitive position of the Region of Mopti in millet is economic, not actual. In addition, it is subject to the condition that cowpeas be jointly produced with millet and that cowpeas have a high local market value. For the consumption market of Gao, the Region of Mopti is in a better economic position to compete to produce and market millet than southern Mali.[86] The Region of Mopti has a greater comparative advantage in producing rice for local consumption than the Office du Niger, but has about the same comparative advantage in producing rice for Gao as the Office du Niger. Producing rice for the

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road from the border, the transport costs from the border to Sikasso and Segou should not be the costs of transporting goods from the border to Bamako and then to Sikasso or Segou but the costs of transporting goods directly from the border to Sikasso and Segou. Second, the labor opportunity cost for the millet and sorghum crops is reduced from 600 CFA F/kg to a more realistic 450 CFA F/kg. Third, the labor requirement for the mechanized millet and sorghum crops is reduced from 50 days/ha to 38 days/ha on the basis of the literature synthesized in Table 1 of Appendix 4-C. Fourth, the extension costs for the millet and sorghum crops are reduced by half because extension is primarily directed to cotton and not grain production. For the millet and sorghum commodities, these adjustments cut by 10% the DRC ratios estimated at wholesale level (Bamako) by Stryker et al. (1987).

[86] This relative advantage of the Region of Mopti over southern Mali is because Mopti is geographically located between Gao and southern Mali.

wholesale market of Bamako is not economically competitive with importing rice for this market.

In terms of technological change (Table 5-9), the transitional technology is more efficient than the traditional technology for producing millet and cowpeas in the rainfed area of the Region of Mopti and for producing millet in southern Mali. The technical package that FSR could develop for millet-cowpea intercropping in the Region of Mopti improves the economic efficiency of producing millet and cowpeas for farm consumption and for the rural market of Mopti and the consumption market of Gao, but not for the wholesale market of Bamako (Table 5-10, a synthesis of Table 2 in Appendix 5-G).

In the Delta, the natural flooding rice technology is more efficient than the controlled flooding rice technology for all markets (Table 5-10). The technical packages that could be developed by agricultural research improve the economic efficiency of producing rice under natural flood and under controlled flood for any market. Still, with agricultural research, producing rice in the Region of Mopti for the wholesale market of Bamako is not economically competitive with importing rice for this market.

With respect to the new rainfed crops introduced with the proposed technical packages, the groundnut-millet rotation with rock phosphate and the sesame improved cultivation show promise (Table 5-10). The groundnut-millet rotation with rock phosphate is an efficient technique to produce groundnuts and millet for farm consumption and the rural market of Mopti. This proposed technique is marginally efficient for the consumption market of Gao, but inefficient for the wholesale market of Bamako. The industrial mechanical oil press and industrial processing techniques are about equally as efficient. The sesame improved cultivation appears to be an efficient technique and would allow sesame exports.

Table 5-9. Domestic Resource Costs Ratios for Current Enterprises by Region (Synthesis)

COMPONENT	SENO CENTER MILLET/COWPEA		DELTA FLOODING RICE		MALI SUD (3) MILLET/SORGHUM		OFFICE DU NIGER RICE (3)
	TRADITIONAL	TRANSITIONAL	NATURAL	CONTROLLED	MANUAL	TRANSITIONAL	IRRIGATED
NET COSTS FOR PRIMARY FACTORS (CFA F/ha):							
Farm Level	6030	-689	11022	39128	21430	19533	90111
Rural Market Level (Mopti)	9729	3380	17142	50878	44710	50573	153732
Rural Market Level(Sikasso)	NA	NA	30576	76672	31617	33575	162041
Rural Market Level (Segou)	NA	NA	28545	72773	NA	NA	115460
Wholesale Level (Bamako)	26679	22025	33218	81745	48887	56142	169942
Consumption Level (Gao)	20160	14854	26761	69346	46338	52744	154658
VALUE ADDED FOR TRADABLES (CFA F/ha):							
Farm Level	61154	64236	49364	105571	69960	117792	225135
Rural Market Level (Mopti)	47785	49530	40171	86717	70699	81049	183044
Rural Market Level(Sikasso)	NA	NA	27267	61340	68547	89775	167104
Rural Market Level (Segou)	NA	NA	30602	67742	NA	NA	188034
Wholesale Level (Bamako)	28626	28454	23874	54826	52472	68342	148881
Consumption Level (Gao)	42390	43596	34627	75472	60805	79452	185200
RESOURCE COST RATIOS:							
Farm Level	0.10	-0.01	0.22	0.37	0.31	0.17	0.40
Rural Market Level (Mopti)	0.20	0.07	0.43	0.59	0.63	0.62	0.84
Rural Market Level(Sikasso)	NA	NA	1.12	1.25	0.46	0.37	0.97
Rural Market Level (Segou)	NA	NA	0.93	1.07	NA	NA	0.61
Wholesale Level (Bamako)	0.93	0.77	1.39	1.49	0.93	0.82	1.14
Consumption Level (Gao)	0.48	0.34	0.77	0.92	0.76	0.66	0.84

Source: Synthesis of Table 1 in Appendix 5-G.

Table 5-10. Domestic Resource Cost Ratios for Current and Proposed Enterprises in the Region of Mopti

COMPONENT	SENO CENTER MILLET-COWPEA INTERCROPPING			SENO CENTER MILLET-GROUNDNUT ROTATION WITH TRP		SENO SOUTH SESAME IMPROVED CULTIVATION	DELTA RICE NATURAL FLOODING		DELTA RICE CONTROLLED FLOODING	
	TRADIT.	TRANSIT.	IMPROVED	MECH.PRESS	IND.PROCESS	FERTILIZATION	CURRENT	IMPROVED	CURRENT	IMPROVED
NET COSTS FOR PRIMARY FACTORS (CFA F/ha):										
Farm Level	6030	-689	-1975	57217	55435	40888	11022	5557	39128	39009
Rural Market Level (Mopti)	9729	3380	-1391	83323	82018	42834	17142	13513	50878	57780
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	30576	30977	76672	105492
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	28545	28337	72773	98588
Wholesale Level (Bamako)	26679	22025	26152	196684	175883	54699	33218	34412	81745	114476
Consumption Level (Gao)	20160	14854	13139	167428	153343	NA	26761	26017	69346	92521
VALUE ADDED FOR TRADABLES (CFA F/ha):										
Farm Level	61154	64236	78670	231116	249694	72774	49364	62765	105571	169826
Rural Market Level (Mopti)	47785	49530	52210	157557	159017	64321	40171	50813	86717	136438
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	27267	34039	61340	91501
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	30602	38373	67742	102838
Wholesale Level (Bamako)	28626	28454	21075	94581	91018	61838	23874	29628	54826	79965
Consumption Level (Gao)	42390	43596	43443	154528	135930	NA	34627	43607	75472	116525
RESOURCE COST RATIOS:										
Farm Level	0.10	-0.01	-0.03	0.25	0.22	0.56	0.22	0.09	0.37	0.23
Rural Market Level (Mopti)	0.20	0.07	-0.03	0.53	0.52	0.67	0.43	0.27	0.59	0.42
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	1.12	0.91	1.25	1.15
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	0.93	0.74	1.07	0.96
Wholesale Level (Bamako)	0.93	0.77	1.24	2.08	1.93	0.88	1.39	1.16	1.49	1.43
Consumption Level (Gao)	0.48	0.34	0.30	1.08	1.13	NA	0.77	0.60	0.92	0.79

Source: Synthesis of Table 2 in Appendix 5-G.

In sum, the areas in which the Region of Mopti has a comparative advantage are millet, cowpeas and rice for the consumption markets of Mopti and Gao. For these consumption markets, the region benefits from a better competitive position than the other producing areas of the country. As indicated, agricultural research may improve the comparative advantage of the region in these commodities for the same markets. The proposed technical packages for groundnuts and sesame appear efficient for local consumption and for exports respectively. Therefore, from an economic standpoint, it would be efficient to orient agricultural research to millet, cowpeas, groundnuts, sesame and rice. However, because of the current market distortions such as the overvaluated CFA franc, import taxation and export disincentives, the Region of Mopti may not completely benefit from its comparative advantage in these areas of agriculture .

A sensitivity test indicates that efficiency in producing sesame for exports is particularly sensitive to a change in world market FOB prices (Tables 3 and 4 in Appendix 5-G). On the other hand, the comparative advantage of the Region of Mopti holds in millet, cowpeas and rice for local consumption and Gao, and groundnuts for local consumption. Increasing the CFA franc's overvaluation from 33% to 50% (a 13% change) does not fundamentally change the conclusions reached with a 33% overvaluation, except that producing millet for Bamako becomes efficient with the traditional and transitional technologies (Table 5 in Appendix 5-G).

5.4. Estimation of the Expected Diffusion Paths

One important element in measuring the benefits of FSR is the estimation of the expected diffusion paths of the technical packages across the area. First, the parameters of the expected cumulative growth in the percent of farmers who will progressively adopt the proposed technical packages are estimated on the basis of diffusion paths that have occurred for animal traction in the Region of Mopti. Animal traction is the only modern innovation that has been widely diffused in the rainfed area and for which adoption dates were collected through evaluation project's field surveys in 1987-88. In addition, investment in animal traction equipment and draft animals constitutes the largest expenditure of the proposed technical packages, which makes the use of the historical diffusion paths of animal traction appropriate. Second, the expected diffusion paths, expressed in terms of the percent of farmers, are converted into area terms since the expected profitability of the proposed technical packages has been also expressed in terms of area (net income per hectare).

5.4.1. Estimation of the Expected Diffusion Parameters

A formulation commonly used to represent the diffusion path of innovations over time is the logistic growth function (Rogers, 1957; Feder, Just and Zilberman, 1982; Thirtle and Ruttan, 1986). The logistic function is characterized as follows:

$$P(t) = K/[1+e^{-(a+bt)}]$$

where 'P' represents the cumulative growth in the percent of farmers who adopt the innovation; 'K' is the long-run upper limit on diffusion (the "ceiling" of the adjustment function); the slope 'b' is a measure of the rate of acceptance of the new technology; and the intercept 'a' reflects aggregate adoption at the start of the estimation period and positions the curve on the time scale. According to Griliches (1957), who used the logistic function to describe the diffusion of hybrid corn in the United States, the parameter 'b' of the logistic function depends on factors affecting the demand for innovations, the parameter 'a' depends on factors affecting the supply of innovations, and the parameter 'K' depends on factors affecting the long-run demand for innovations, assuming that in the long-run the supply conditions of the innovation are the same for all zones.[87]

The three parameters of the expected diffusion paths for the technical packages are estimated in two steps. First, historical data on animal traction adoption collected in the rainfed area of the Region of Mopti are used to estimate the parameters of diffusion paths that have occurred. The diffusion parameters of animal traction are estimated with an ordinary least-squares (OLS) regression, using a logistic function representing the cumulative growth in the percent of farmers who have adopted animal traction over time from 1966 to 1987. Because of the agroclimatic environment and the institutional setting change from one agroclimatic zone to the other in the Region of Mopti, three logistic functions are estimated by the OLS regression, one function representing the cumulative growth over time from 1966 to 1987 for each agroclimatic zone. This reduces the differences among zones to differences in the values of a few parameters.

The first column of Table 5-11 presents the estimated parameters and the adjusted R squared for the mixed farmers of the three agroclimatic zones.[88] The values of all parameters are statistically significant at the 1% level. Figure 5-1 shows the fitted diffusion curves for the mixed farmers by agroclimatic zone. Because the diffusion paths

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[87] That the parameter 'b' depends on factors affecting the demand for innovations is correct if the supply of the innovation is not the limiting factor, which might not always be the case in the Region of Mopti. Griliches (1957) views the adjustment path along the aggregate adoption curve as successive short-run equilibria between the supply and demand for the innovation. When the long-run supply of the innovation is very elastic, then the demand function depending on profitability and other factors determines the adjustment path.

[88] The value of K, the ceiling, is the one that optimizes the fit of the regression, a technique similar to the one used by Griliches (1957).

Table 5-11. Parameters of Diffusion Paths for Animal Traction in the Rainfed Area

PARAMETER (1)	MIXED FARMERS	HERDERS
NORTHERN ZONE:		
a	-5.41	-5.41
b	0.23	0.21
Normalized b (%)	11.11	5.70
K (%)	48.00	27.00
Adjusted R squared	0.86	0.93
CENTER AND PLATEAU ZONE:		
a	-6.50	NA
b	0.33	NA
Normalized b (%)	21.03	NA
K (%)	64.00	NA
Adjusted R squared	0.94	NA
SOUTHERN ZONE:		
a	-10.50	-10.50
b	0.80	0.48
Normalized b (%)	1.90	5.80
K (%)	20.00	12.00
Adjusted R squared	0.89	0.95

(1) OLS regression using a logistic functional form expressed as K/[1+exp-(a+bt)]. All the parameters are atatistically significant at the 1% level. The parameters b are normalized by multiplying them by K to make them comparable between agro-climatic zones. The value of K, the ceiling, is the one that optimizes the fit of the regression, a technique similar to the one used by Griliches (1957).

Source: Author's estimations.

are pictured before diffusion has ceased, total diffusion and the date at which the ceiling is achieved are forecasted using the estimated diffusion parameters. For the herders, the estimated parameters and the adjusted R squared are reported in Table 5-12, second column. The fitted diffusion curves for the herders are graphed by agroclimatic zone in Figure 5-2. Only diffusion of animal traction in the northern and southern zones are considered for herders since they do not inhabit the center and plateau zone. For the northern and southern zones, the intercept 'a' estimates do not change whether the target group adopting animal traction is composed of mixed farmers or herders. This is expected because the intercept 'a' should reflect only the supply conditions of the equipment and draft animals which are similar for both groups of adopters in each agroclimatic zone. The normalized rate of acceptance 'b' and upper limit 'K' estimates for the herders are about half of those for the mixed farmers. This indicates that demand for animal traction on the part of herders is not as strong as for mixed farmers, which is expected considering that farming is not the first occupation of the herders. Therefore, the profitability of adopting animal traction is probably not as high for herders as for mixed farmers.

Second, a relationship between the values of the parameters estimated for the diffusion of animal traction and the factors of adoption is sought to extrapolate the results to the diffusion of the proposed technical packages. Although the rate of acceptance 'b' of the innovations depends on several demand factors such as profitability, the reduction in income or yield variability (a proxy for risk) and the availability of arable land for land-increasing technologies (i.e., animal traction), only one indicator of profitability is used here as an independent variable to explain the variation in the rate of acceptance. Since only three observations are available (one per agroclimatic zone),

Table 5-12. Relationship between MRR and Rate of Acceptance for Animal Traction (b)

ZONE	DATA (1) Normalized b (%)	MRR (%)
Northern Zone	11.11	56.40
Southern Zone	15.90	64.90
Center & Plateau Zone	21.03	71.80
ESTIMATED PARAMETER (2):		
Ceiling	100.00	
Origin	-4.85	
Slope	0.05	
Adjusted R squared	0.99	

(1) Data for the normalized rate of acceptance (b) and MRR are taken for mixed farmers, respectively from Tables 5-11 and 5-4 to 5-6.
(2) Using an OLS logistic regression on the above data with a functional form expressed as K/[1+exp-(a+bt)].
Source: Author's estimations.

the limited degrees of freedom prevent the use of additional explanatory variables for the OLS regression. The marginal rate of return (MRR) of adopting animal traction is chosen as the single independent variable for the following reasons. First, the MRR indicates the profitability of substituting the new technology for the old and, therefore, reflects the decision process which makes the same comparison. Second, the range of estimated MRRs for animal traction adoption are similar to the range of the estimated MRRs for the technical packages that FSR could develop and, consequently, extrapolation of the estimated 'b' values from animal traction to the potential innovations is realistic.

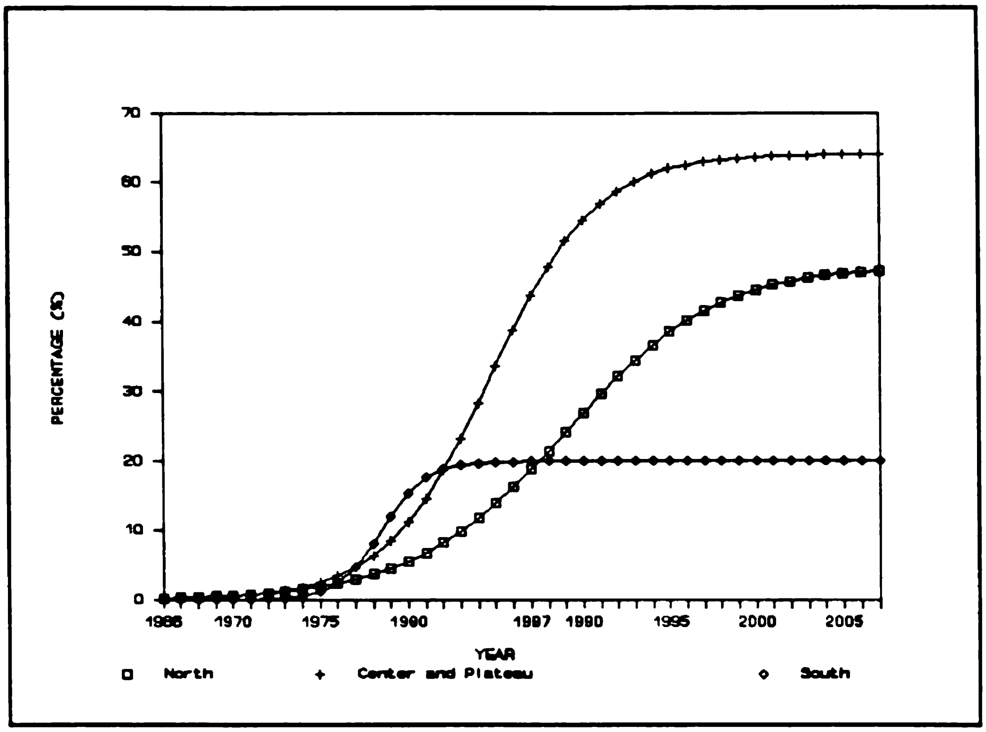

Figure 5-1. Cumulative Percentage of Growth of Mixed Farmers Adopting Animal Traction

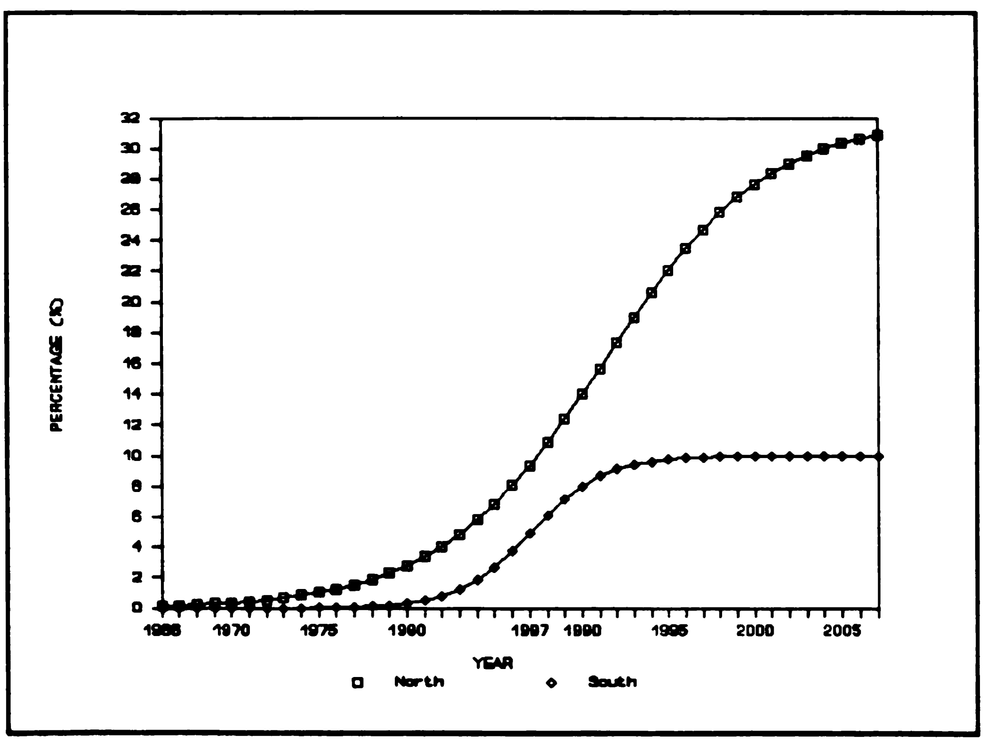

Figure 5-2. Cumulative Percentage of Growth of Herders Adopting Animal Traction

Using this approach to explain the cross-sectional difference in the estimates of the acceptance rate assumes, however, that the impact of short-run fluctuations in prices, incomes, innovation supply and other factors on the diffusion process are ignored. Griliches (1957) could assume a constant profitability in adopting the new technology and use it to explain different rates of acceptance across U.S. districts because the returns to hybrid-corn "were large enough to swamp any short-run fluctuations in prices and other variables." This assumption "might, however, become serious where we consider other technical changes requiring substantial investments, and not as superior to their predecessors as was hybrid corn." Because this assumption probably does not hold in the case of the diffusion of animal traction (a lumpy investment) in the rainfed area of the Region of Mopti, the estimation of the expected diffusion paths for the proposed technical packages is still rough. Sensitivity analysis will be used to test the stability of the project's worth to changes in the parameters of the diffusion paths.

The rates of acceptance 'b' found for the mixed farmers adopting animal traction are regressed on their corresponding MRRs. Because the estimated rates of acceptance 'b' increase exponentially with respect to MRR, a logistic functional form (not a linear functional form) with a ceiling as MRR increases was chosen for the OLS regression.[89] The relationship between the parameter 'b' and the MRR is presented in Table 5-12. As a result of the lower rate of acceptance found for herders (Table 5-11), the values of this parameter estimated for the mixed farmers will be discounted proportionally for the herders. Reducing 'b' by 40% for the herders is thought to be realistic.

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[89] Because the parameter 'b' depends on the long-run upper limit 'K', the values of 'b' are in fact normalized by multiplying them by 'K' to make them comparable between agroclimatic zones.

The values of the intercept 'a' estimated for the diffusion of animal traction in the three agroclimatic zones are used for the expected diffusion of the proposed technical packages. The intercept 'a' depends on factors affecting the supply conditions of the innovation. However, because one important component of the technical packages is animal traction, the 'a' values are lower for those who have already adopted animal traction. Reducing 'a' by one-half for these farmers is considered realistic.

The upper limits on diffusion 'K' for each proposed technical package are modified according to the financial profitability, the stability and the complexity of the technical packages, the socio-professional characteristics of the adopter, and the climatic, socio-economic and institutional environment. More specifically, the upper limit 'K' changes according to the profitability of the technical package, the type of farming system (mixed farming versus herding), land availability and market conditions in each agroclimatic zone. For example, as a result of the smaller upper limits of diffusion found for animal traction among herders (Table 5-11), the values of this parameter for the proposed technical packages are reduced by half for the herders (Table 5-13).

Table 5-13. Value of the Parameter K (%), the Ceiling of the Diffusion Curves

FARMING SYSTEM		TRANSITIONAL TECHNOLOGY	MILLET-COWPEA INTERCROPPING	ROTATION G-M-G (1)	SESAME
AGROPASTORAL SYSTEM:					
NORTH	Non-equipped	48	21	NA	NA
	Equipped	NA	17	NA	NA
CENTER/ PLATEAU	Non-equipped	64	20	14	NA
	Equipped	NA	NA	33	18
SOUTH	Non-equipped	20	NA	NA	43
	Equipped	NA	NA	NA	90
PASTORAL SYSTEM:					
NORTH	Non-equipped	32	11	NA	NA
	Equipped	NA	9	NA	NA
SOUTH	Non-equipped & Equipped	10	0	NA	21

(1) Groundnut-Millet-Groundnut
Source: Author's estimations.

5.4.2. Estimation of the Target Areas

The cumulative growth in the percentage of farms that adopt the proposed packages is converted into area, using the field surveys results and national estimates of cultivated area. The areas that might benefit from the technical packages are limited to the four rainfed agroclimatic zones (Seno North, Center, South and Plateau) for which the four packages have been designed. For the "millet-cowpea intercropping" package, the millet area estimated by the Opération Mil Mopti (OMM) is used. Estimates of the millet area for these four zones are given in Table 1 in Appendix 2-C. The population of these four agroclimatic zones accounts for 57% of the population of rainfed agriculture zones and 30% of the total population of the Region of Mopti (376,000 out of 1,261,000 inhabitants). These percentages represent the part of the population that could benefit from FSR in the Region of Mopti. The economic analysis applies to these groups.

The cultivated area that could benefit from the "groundnut-millet-groundnut rotation" and "sesame cultivation" packages are based on the areas currently cultivated in groundnuts (estimated at 5% of millet area) and in sesame (estimated at 10% of millet area), respectively.[90] These areas may expanded if the profitability of these two technical packages are large enough to induce a wide diffusion.

As the diffusion paths for animal traction vary with respect to the agroclimatic zone and the principal occupation of the adopter (farming or herding), it is expected that the diffusion of the proposed technical packages will also vary depending on the target group. Moreover, since animal traction is an important technological component of the proposed packages, it is also expected that the diffusion paths of the proposed technical packages will vary according the technological level of the potential adopter. Therefore,

[90] According to personal communication with Soumano, DRA/IER, 1988.

the target groups are defined in terms of their agroclimatic zone, their principal occupation and their technology level.

The size of the target groups in terms of population and cultivated area is estimated by multiplying the relative size of each target group within each agroclimatic zone by either the population or the cultivated area of the zone (see Table 1 of Appendix 2-C). Table 2 of Appendix 2-C presents these estimates. For the area and population estimates to be correct, the area cultivated by the farm household and the population size of the farm household must be independent of the type of farming system and level of technology. This independence could not be tested with the available secondary and formal survey data. The only available information from the formal survey is that the number of adult family member per household ranges between 6 to 13 with no statistically significant difference among farming systems and technology levels within agroclimatic zones. As indicated by studies in other regions of Mali, it is likely that independence of these characteristics does not exist.[91] If mechanized households farm proportionally more land than non-mechanized households, a correction factor should be applied to account for possible overestimation of the area cultivated by the non-mechanized group, and underestimation of the area cultivated by the mechanized group.

5.5. Conclusions

This chapter evaluated the technological innovations that FSR is expected to generate. For rainfed agriculture, it is expected that the research areas on agronomy

[91] In the OHV and CMDT zones mechanized farms are characterized by a larger number of persons and a larger cultivated area than non-mechanized households (D'Agostino, 1988).

(incorporating water retention techniques, moderate fertilizer levels and improved varieties), mechanization and storage technology will result in four technical packages to be extended to farmers five years following the establishment of FSR in the region. These four technical packages include the following crop enterprises: millet-cowpea intercropping, and cowpea, groundnut and sesame mono-croppings. These technical packages are devised to reduce production risk under unfavorable agroclimatic situations but increase yields under favorable conditions. The proposed technical packages pertain to approximately 60% of the population of the rainfed agriculture zones or 30% of the total population of the Region of Mopti.

A financial analysis of each package valued the incremental gross benefits and incremental costs of production per hectare. In order to carry out this analysis, coefficients from the results of station and multilocation trials were adapted to the agroclimatic conditions of farms in the Region of Mopti. The prices of inputs were those actually being charged in 1987-88, and the price of agricultural products were the average annual prices observed in the Region of Mopti over the same period.

After eliminating unprofitable or marginally profitable packages, financial analysis of the four technical packages reveals marginal rates of return between 41 and 175%, depending on the package, the zone and whether or not the potential adopter is mechanized. The marginal return per person day is between 453 and 9,271 CFA francs (using a 12% opportunity cost of capital), a figure generally higher than the present opportunity cost of labor.

The sensitivity analysis for the financial budgets of the proposed technical packages reveals that most of the proposed packages are unstable given a 10 to 20% change in prices, yields or costs of production. Adoption of these technical packages will be difficult if agricultural input and product markets as well as the yields of the proposed packages are not stabilized. This implies that increased production from rainfed agriculture in the Region of Mopti is conditional upon the reliability of markets and the success of on-station research in developing improved technological components.

Comparisons of DRC ratios estimated for different commodities, technologies and agroclimatic zones indicate 1) the areas in which the Region of Mopti has a comparative advantage and 2) farm enterprises for which agricultural research may improve economic efficiency. The areas in which the Region of Mopti has a comparative advantage are millet, cowpeas and rice for the consumption markets of Mopti and Gao. For these consumption markets, the Region of Mopti benefits from a better economic competitive position than the other producing areas of the country. Agricultural research may improve the comparative advantage of the region in these commodities for the same markets. The proposed technical packages for groundnuts and sesame appear efficient for local consumption and for exports respectively. Efficiency in producing sesame for exports is, however, sensitive to a change in world market FOB prices. With a 50% overvaluation of the CFA franc, producing millet for Bamako becomes efficient with the traditional and transitional technologies but not with the proposed technical packages. Though it is efficient to orient agricultural research to millet and cowpeas, groundnuts, sesame and rice, the Region of Mopti may not completely benefit from its comparative advantage in these areas because of current market distortions such as the overvalued CFA franc, import taxation and export disincentives.

The expected diffusion paths of the technologies that FSR could develop are estimated using historical data on animal traction adoption in the area.

The diffusion paths for animal traction are estimated with an ordinary least-squares regression, using a logistic function representing the cumulative growth in the percent of farmers who have adopted animal traction over time from 1966 to 1987 in the three different agroclimatic zones of the project's area. Then, a relationship between the values of the parameters estimated for the diffusion of animal traction and the factors of adoption is established in order to extrapolate the results to the diffusion of the proposed technical packages. Finally, the cumulative growth in the percent of farms who would adopt the potential packages is converted into area terms, using the results of field surveys and national estimates of cultivated areas.

THE EFFECTS OF INTERACTIONS BETWEEN TECHNOLOGY, INSTITUTIONS AND POLICY ON THE POTENTIAL RETURNS TO FARMING SYSTEMS RESEARCH IN SEMI-ARID NORTHEASTERN MALI

VOLUME 2

By

Bruno Henry de Frahan

A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

6. EX-ANTE EVALUATION OF FSR

The objective of this chapter is to evaluate the expected production impact ofthe FSR project at the farm level and to rank the major factors that could affect the expected return to FSR. The literature review in Appendix 1 has presented different techniques to estimate the expected net benefits from agricultural research. The economic surplus approach was recommended for several reasons. First, the approach assumes that the research goals are raising the level of national income and equity. These goals are probably consistent with what the Malian policy makers and donors might adhere to. Second, the economic surplus approach permits the identification and quantification of factors affecting progress in agricultural research. For example, this approach can explicitly capture the effects of institutional changes or policy measures on both the total benefits of research and the distribution of those benefits. Third, this approach can deal with a multi-period process and uncertainty.

First, some assumptions with respect to the use of the expected economic surplus approach are made to simplify the estimation procedure. Second, the estimation procedure is laid down. Third, the expected efficiency and equity effects of the project are estimated and discussed. Fourth, the major factors affecting the return to FSR are identified and ranked with a sensitivity analysis carried out on the return to the FSR project.

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6.1. Assumptions Related to the Expected Economic Surplus Approach

To simplify the use of the economic surplus approach, some assumptions are made about the structure of the regional supply and demand curves. Producers in the Region of Mopti are considered "price takers" and face a perfectly elastic demand curve for cereals and oilseeds. It is not expected that FSR will be able to reverse the food situation in the Region of Mopti from net deficit to net surplus for agricultural products such as millet, rice, cowpeas and groundnuts.[92] Moreover, it is assumed that, in conjunction with the development of sesame production in the area, efforts will be made to integrate local markets for sesame with export markets, so that producers will face a perfectly elastic demand for sesame. Consequently, the evaluation will proceed with fixed output prices.

Supply curves, on the other hand, are highly inelastic in the short run. First, fixed inputs such as land and farm labor resources are fully employed. Second, the crops included in the economic analysis are those already employing most of the available resources. Consequently, estimated price elasticities of production for rice and millet-sorghum in the short and long run are low for Mali (USDA, 1985). In sum, the postulated regional supply-demand structure for crops is one of a perfectly elastic demand curve facing a perfectly inelastic short-run supply curve. Therefore, the change in total economic surplus is roughly equivalent to the change in producer surplus, all the more so because a significant proportion of household cereals production is consumed by the household.

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[92] As indicated earlier, 1987-88 cereals availability covered 55% of the regional food requirement (OSCE, 1988).

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Since the expected economic surplus amounts to the expected producer surplus, the evaluation consists of estimating the following three aggregate components. The first component consists of the incremental benefits to the target groups as a result of the project. In the present context, the increased incomes accruing to farm households as a result of the transfer and adoption of the new technical packages represent the main incremental benefits. Benefits that accrue to groups other than farmers as a result of the project will be indicated but not estimated. The second component is the incremental costs of production (or processing or marketing) incurred by project target groups as a result of adopting technical packages developed and tested by the research system. The third component represents the costs of the project and complementary investments necessary for the project to affect target groups. The relevant period over which these benefits are estimated is 20 years, corresponding to a period for which the project will continue to have an impact on the target groups. For each year during this period the incremental net benefits (net cash flow) are calculated by subtracting from the incremental benefits accruing to target groups the incremental costs of production, the costs of the project, and the complementary investments necessary for the project to have an impact, such as investments in the credit and extension system, and seed production. These complementary investments will be specifically evaluated in chapter 7.

The value of the FSR project can be expressed with respect to three commonly used evaluation criteria: 1) the net present value (NPV), which corresponds to the economic surplus, 2) the benefit-cost ratio or net benefit-investment ratio, and 3) the internal rate of return (IRR).

For the first two indicators, the incremental benefits and costs are discounted using a discount rate of 12%. The discount rate should represent the cost of capital in the country ben

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the country benefiting from the project (the opportunity cost of capital) or the degree of preference of society for present rather than future returns (the social rate of time preference). Discounting allows costs and benefits that accrue at different points in the future to be compared in terms of their value in today's currency. The present value of the incremental benefits less the present value of the incremental costs corresponds to the net present value (NPV) of the project. The value of the project can also be expressed as the ratio of the present value of the benefit stream to the present value of the cost stream (benefit-cost ratio) or the ratio of the present value of the net benefits to the present value of the investment outlay (net benefit-investment ratio).[93] These two ratios are particularly useful when a donor has several possible projects to choose from.

Finally, the value of the project is expressed using the internal rate of return (IRR), which is that discount rate that, when applied to the net cash flow over the project life, will yield a net present value of zero. The IRR represents, therefore, the annual yield on resources invested in the project. A project with a higher internal rate of return than the threshold rate of return is considered attractive. The threshold rate of return generally corresponds to the opportunity cost of capital (Gittinger, 1984).

6.2. FSR Project Evaluation Procedure

To estimate the economic return accruing to the FSR project, the "with project" situation is compared to the "without project" situation. The economic return to the project corresponds to the incremental net benefit stream over time as a result of the

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[93] To estimate the net benefit-investment ratio, the present value of the net benefits is the discounted value of the incremental net benefits each year after the net cash flow becomes positive. The present value of the investment outlay is the discounted value of the incremental net benefits during the early years before the net cash flow becomes positive.

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project, which can be calculated by subtracting the "without project" net benefit stream from the "with project" net benefit stream. Instead of estimating separately the "with" and "without project" net benefit streams over time and subtracting them, the incremental net benefit of adopting the proposed technical packages is estimated on a per hectare basis and then multiplied by the expected area that will benefit from the technical change every year.

However, the estimation method needs to be corrected for the continued adoption of animal traction, which is expected to occur anyway. Without the project, farmers will continue to adopt animal traction according to the diffusion paths identified for the past two decades if similar conditions of supply for and demand of animal traction persist (see Figures 5-1 and 5-2). With the project, non-mechanized farmers of some target groups may choose to adopt animal traction alone and not the proposed technical packages. Therefore, the incremental net benefits generated from adopting animal traction under the "without project" situation will be subtracted from the "with project" net benefit stream, while the incremental net benefits generated from adopting animal under the "with project" situation will be included in the "with project" net benefit stream.

The economic analysis is carried out in five steps. The first step consists of transforming financial budgets, which have been estimated per unit area for each package and for each zone, into economic budgets. These economic budgets are presented in Tables 1 through 5 of Appendix 6-A. The economic budgets are expressed in CFA francs per hectare per year (CFA F/ha/year) for each technical package and for each target group. Only the increases in gross benefits and in costs of production are retained for the second step.

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The second step consists of multiplying these incremental economic results, expressed in CFA F/ha/year, by the annual expected cumulative area benefiting each year from a proposed technical package. This area has been determined for each proposed technical package and target group by applying an annual adoption rate to the available area. Estimates of the available area and anticipated annual rates of adoption for each technical package and target group are those calculated in the preceding section. The economic results of this second step are expressed in CFA francs per year (CFA F/year) for each technical package and target group. Consequently, this second step yields an annual flow of incremental gross benefits and incremental costs of production. By subtracting the latter from the former, an annual flow of incremental net benefits aggregated for each technical package and target group is obtained. These results are given in Tables 2 to 4 of Appendix 6-B for, respectively, the millet-cowpea intercropping, the groundnut-millet rotation and the sesame cultivation technical packages.

The incremental net benefit flows generated from adopting animal traction under the "without project" situation are estimated for each target group, using the estimated incremental net benefits of adopting animal traction and the projections of the historical diffusion path of animal traction for the next 20 years (Table 5-12, Figures 5-1 and 5-2). In Table 1 of Appendix 6-A, the incremental net benefits flow generated from adopting animal traction under the "with project" situation are estimated on the basis of the diffusion parameters of animal traction for each target group.[94] The incremental net

[94] It is considered that, under the "with project" situation, the diffusion paths of animal traction alone will continue at half the rate of the diffusion paths of animal traction that would have prevailed under the "without project" situation. This assumes that half of the potential adopters of animal traction which would have chosen to adopt animal traction under the "without project" situation are actually adopting the "millet-

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benefit flows generated under the "without project" situation are subtracted from the incremental net benefit flows generated from adopting animal traction alone under the "with project" situation. The difference of these two sets of incremental net benefits flows are included in the economic value of the project.

The third step consists of summing annually and individually the incremental gross benefit and incremental costs of production which have been estimated annually for each target group and technical package. This step gives a flow of annual incremental gross benefits, a flow of annual incremental costs of production and, by subtracting the latter from the former, a flow of annual incremental net benefits aggregated for all target groups and proposed technical packages.

The fourth step consists of bringing together the results of the third step with the costs of the FSR project. This step is accomplished in Table 1 of Appendix 6-C. In this table, the incremental annual gross benefits accruing to farms adopting the technical packages constitute the inflows, while incremental annual costs of production accruing to farms adopting the technical packages and the annual costs of implementing the FSR project constitute the outflows of the project. The flow of annual incremental net benefits of the project (net cash flow) is calculated by subtracting the outflows from the inflows.

The fifth step consists of calculating the three evaluation criteria of the FSR project. The first criteria is the net present value at a 12% opportunity cost of capital. The second criteria is the internal rate of return. The third criteria is the net benefit-investment ratio at a 12% opportunity cost of capital. The value of these three criteria is given at the bottom of Table 1 in Appendix 6-C and reported in Table 6-1.

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6.3. Results of the FSR Project Evaluation

The results of the economic evaluation of the FSR project are presented first in terms of efficiency effects and, second, in terms of income distribution effects.

6.3.1. Efficiency Effects

The results of the economic evaluation of the FSR project are summarized in Table 6-1. With a 12% opportunity cost of capital the project has a negative net present value of $US 1,864,000. The estimated economic rate of return is 2%, insufficient to cover the costs of the resources included in the project if they were borrowed at any rate above 2%. With a 12% opportunity cost of capital the net benefit - investment ratio is .4.

Table 6-1. Economic Value of the Project

CRITERIA	VALUE
NET PRESENT VALUE ($US '000)	
at 10%	-1745
at 12%	-1864
at 15%	-1949
at 20%	-1950
INTERNAL RATE OF RETURN (%)	2
NET BENEFIT-INVESTMENT RATIO (at a 12% opportunity cost of capital)	0.4

Source: Synthesis of Table 1 in Appendix 6-C.

It must be stressed, however, that these estimates of the return to systems research in the Region of Mopti have been calculated on the basis of technological innovations that FSR could rapidly identify and subsequently test and integrate into the existing farming systems. Given that the commodity research results currently available for the semi-arid area are limited in number and potential, it is not surprising that the

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returns to systems research based on these results should be equally low. Moreover, the returns to systems research in this region reflect only one part of a two way flow between commodity and systems research, that of results from commodity research to systems research. The potential of FSR to reorient research priorities of other research programs is not evaluated here. In the long run, if coordination between commodity and systems research is strengthened, systems research will benefit from feeding back its own results to commodity research. In other words, the institutionalization of a systems approach to research in Mali is not taken into account in this evaluation.

In addition, the effects of other research areas included in the FSR program, either related to the rainfed crop farming system or the flooded crop farming systems, are not presently evaluated. The external effects of the project are also not considered, particularly the reduction of food aid and outmigration. Moreover, the institutional and socio-economic environment is taken as it is currently, without any improvement. If FSR contributes to improving the institutional and socio-economic environment as suggested, then the returns to FSR would likely increase. Such changes in the institutional and socio-economic environment and in the availability of on-station research results will be considered in chapter 7.

The contribution of each technical package to the total incremental farm net benefits raised by the FSR project can be estimated, using Table 1 in Appendix 6-C. Table 6-2 presents the increase in gross benefits, costs of production and net benefits, aggregated across target groups. The technical package which contributes the most to total incremental farm net benefits is the "sesame cultivation" package (60%), followed by the "millet-cowpea intercropping" (34%), and finally the "groundnut-millet-groundnut rotation" package (6%). The low contribution of the "groundnut-millet-groundnut rotation' package to total in

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rotation" package to total incremental farm net benefits is due (1) the package's low financial return being attractive only to farmers in the center and plateau zone, and (2) possible market saturation problems if greater areas are cultivated in this way. It is nevertheless possible that other types of rotation including a secondary cash crop could be developed and tested by the FSR project. At the present time, however, no promising results for a more profitable package are available.

The "sesame cultivation" package makes a solid contribution to the total incremental farm net benefits. However, the marketing and export possibilities have yet to be explored. Future farming systems research in the Region of Mopti will need to address specifically the marketing side of the development and adoption of the technical packages to avoid market saturation problems.

Table 6-2. Economic Comparison of the Technical Packages ($US '000)

	INCREASE IN (1)			
TECHNICAL PACKAGES	GROSS BENEFITS	COSTS	NET BENEFITS	%
1. "Millet-cowpea intercropping"	1367	1042	325	34
2. "Millet-cowpea sole cropping"	0	0	0	0
3. "Groundnut-millet-groundnut rotation"	155	102	53	6
4. "Sesame cultivation"	812	250	562	60
TOTAL	2335	1394	940	100

(1) Based on a discount rate of 12%.
Source: Synthesis of Table 1 in Appendix 6-C.

6.3.2. Distributional Effects

Because no effects on agricultural product prices are expected from the FSR project, consumer welfare does not change and the change in producer surplus is equivalent to the change in economic surplus. Therefore, the benefit of technological

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development due to the FSR project accrues to the producers of the Region of Mopti, particularly to the mixed farmers and herders of the rainfed agriculture area for which technical packages have been developed. The situation of those producers who will not adopt the new technical packages remains the same with the project as without the project because the relative input - output prices are expected to be unaffected by the project. For the same reason, farmers who would leave the agricultural sector because they do not adopt the new technical packages are expected to be few in number.

However, some target groups will benefit more from the project than others. By calculating the contribution of each target group to the total incremental farm net benefits resulting from the project, it is possible to show which target groups will receive the largest and most immediate results. Table 6-3 shows the aggregate incremental farm net benefits for each target group in absolute and relative terms (columns 5 and 6). The target group that would most benefit from the project is the mixed farmers of the southern zone. Their share of the total incremental farm net benefits amounts to 51%. For other groups, the share of total incremental farm net benefits is as follows: the mixed farmers of the center and plateau zone (25%), the mixed farmers of the northern zone (16%), herders in the southern zone (5%) and herders in the northern zone (3%).

Comparison of the last three columns of Table 6-3 indicates whether the increased incomes that would result from the FSR project favor some target groups at the expense of others when the relative distribution of population and cultivated area among target groups is considered. The mixed farmers of the southern zone account for 29% of the population and area cultivated in the project area while they benefit from 51% of the total incremental farm net benefits. Consequently, these farmers benefit proportionately more than the other producers, relative to the availability to them of the main factors of production, i.e., labor and la

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production, i.e., labor and land. According to this reasoning, both the mixed farmers of the center and plateau zone and the herders of the southern zone are relatively disadvantaged.

Table 6-4 compares the distribution of the increased farm net benefits across population strata to the distribution of the population across the same strata. The strata are defined by agroclimatic zone, farming system and level of technology. Relative to its population weight, the southern zone is more advantaged than the northern zone, center and plateau zones. Relative to their population weights, mixed farmers and mechanized producers are also relatively advantaged.

The distribution of income within agricultural households could be improved by raising the earnings of women. This could be achieved by improving the productivity of secondary crops such as groundnuts and sesame in which women traditionally specialize. The "groundnut-millet-groundnut rotation" technical package contributes 6% of the economic value of the project and the "sesame cultivation" technical package contributes 60%. Women's incomes are therefore increased by the project. However, as these secondary crops become more commercialized, they are likely to be overtaken by men. Improving the productivity of the millet and cowpea crops might also raise the earnings of women since they are involved in the processing and the marketing of these two crops. Systems research in the Region of Mopti should may study women's participation in marketing and intra-family income distribution to confirm this.

TARGET GROUP	P0	P1	P3	P4	P0 to P4	%	AREA %	POPULATION %
	INCREMENTAL FARM NET BENEFITS (1)							
Northern non-mechanized mixed farmers	-6653	43700	0	0	37047	13	16	12
Northern mechanized mixed farmers	0	9268	0	0	9268	3	4	3
Center&Plat. non-mech. mixed farmers	-11497	53643	4340	0	46486	16	20	24
Center & Plateau mech. mixed farmers	0	0	11527	12812	24339	9	15	18
Southern non mechanized mixed farmers	0	0	0	84266	84266	31	[illegible]	[illegible]

Table 6-3. Incremental Farm Net Benefits by Target Group

TARGET GROUP	INCREMENTAL FARM NET BENEFITS (1) P0	P1	P3	P4	P0 to P4	%	AREA %	POPULATION %
Northern non-mechanized mixed farmers	-6653	43700	0	0	37047	13	16	12
Northern mechanized mixed farmers	0	9268	0	0	9268	3	4	3
Center&Plat. non-mech. mixed farmers	-11497	53643	4340	0	46486	16	20	24
Center & Plateau mech. mixed farmers	0	0	11527	12812	24339	9	15	18
Southern non-mechanized mixed farmers	0	0	0	84266	84266	31	23	23
Southern mechanized mixed farmers	0	0	0	56963	56963	20	6	6
Northern non-mech. livestock farmers	-1497	9953	0	0	8456	3	5	4
Northern mechanized livestock farmers	0	627	0	0	627	0	0	0
Southern livestock farmers	0	0	0	14609	14658	5	11	11
TOTAL	-19598	117190	15867	168651	282110	100	100	100

(1) In thousands of CFA francs based on a discount rate of 12%.
P0 : Transitional technology on millet-cowpea intercropping.
P1 : "Millet-cowpea intercropping".
P3 : "Groundnut-millet-groundnut rotation".
P4 : "Sesame cultivation".
Source: Synthesis of Tables 1 to 4 in Appendix 6-B.

Table 6-4

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Table 6-4. Distribution of the Relative Incremental Farm Net Benefits by Stratum (1)

ZONE:	NORTH	CENTER & PLATEAU	SOUTH
Population (%)	19	42	40
Net Benefit (%)	19	25	56

FARMING SYSTEM:	MIXED FARMING	LIVESTOCK
Population (%)	85	15
Net Benefit (%)	92	8

MECHANIZATION:	NON-MECHANIZED	MECHANIZED
Population (%)	73	27
Net Benefit (%)	68	32

(1) In percentages based on a discount rate of 12%.
Source: Adapted from Table 6-3.

6.4. Factors Affecting the Return to FSR

Sensitivity analysis examines the consequences of changing the major assumptions that serve as the basis for the estimation of the economic value of the project on the stability of this economic value. It also reveals what conditions are crucial for the success of the project. By ranking the key components of the project according to their potential impact on the economic returns, sensitivity analysis signals to those responsible for evaluating or implementing the project which components merit special attention.

The method used here for the sensitivity analysis of the economic value of the project is adapted from Bottomley and Contant (1988). The variables included in the sensitivity analysis are the major components of the economic value of the project:

1) the level of yields or farm gross benefits,
2) the level of farm costs,
3) the rate of acceptance,
4) the diffusion ceiling,

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5) the life of the innovation,

6) the cost of the project,

8) the time needed to move from developing research areas to the extension stage.

First, the technique used for the sensitivity analysis is outlined. Then, the results are presented and interpreted.

6.4.1. The Sensitivity Analysis Technique

In order to identify which variables have the greatest potential to destabilize the economic value of the project, each variable tested takes on a series of different values. The range in values must be the same for each variable included in the sensitivity analysis in order to compare the stability of the variables to each other. The range in values of the variables included in the sensitivity analysis is primarily determined by extremes in the prices of agricultural and livestock products in the weekly markets of Region of Mopti between 1987 and 1989. These extreme values are plus or minus 50% of the median value used in the economic analysis. The variables that render the economic value of the project particularly unstable are those variables that cause a larger percentage change in the economic value of the project than the initial percentage change in the variables.

To test changes in farm gross benefits (or yields), in farm costs, in the cost of the project and in the parameters of diffusion, increases and decreases of 10, 20, and 50% of these variables were used.

The life of an innovation is the period over which the innovation is in use before being superseded by another. Given the current assumption that an innovation has an expected life of 15 years, increasing or decreasing this by one year represents a 6.7%

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change in longevity.[95] To maintain a round number of years, one year is taken as approximating a 10% variation. Similarly, a three year increase or decrease in the life of the innovation represents a 20% change, and 7 years 50%.

The time needed to move from developing research areas to the extension stage can be brought forward or delayed according to advances or setbacks in the proposed research program. Given that a minimum of 5 years is necessary for technical packages developed and tested through systems research to be passed on to pilot extension, a delay or advance of one year corresponds to a 20% variation. A delay or advance of two years approaches a 50% variation.[96] The number of years for the research program is decreased or increased according to whether the first year of pilot extension is brought forward or delayed. In the case of a 1-2 year reduction in the time required for a package to reach the pilot extension stage, the cost of the project is reduced and the salvage value of the buildings is realized earlier. In the case of a 1-2 year delay in the pilot extension stage, the cost of the project is increased and the salvage value of the buildings is realized later. The salvage value of the buildings varies with the time taken to complete research (70% of the initial value for 5 years, 65% for 6 years, 60% for 7 years, 55% for 8 years, and 50% for 9 years).

6.4.2. Factors Affecting the Return to FSR

Results of the sensitivity analysis of the economic value of the project are given in Table 2 of Appendix 6-C. At a 12% discount rate, the net present value of the project

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[95] From the first year of pilot extension (year 6 of the project) to the last year included in the evaluation of the project (year 20), there are 15 years.

[96] It is not possible to choose a better approximation if we want to keep a variation of 50% while maintaining a round number of years.

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remains negative even for a positive 50% change in the farm gross benefits, the diffusion acceptance rate, the diffusion ceiling, or the innovation life, or for a negative 50% change in the farm costs, the project costs or the time needed to complete research. None of the seven major components of the project alone can positively affect the outcome of the project even taken at their most favorable value. As a result, more than one component of the project needs to be investigated to render the project profitable.

The net present value of the project estimated at a discount rate of 12% appears sensitive to two of the seven variables tested: the annual project cost and the incremental farm gross benefit. The relative changes in the NPV achieved by the project as a result of changes in the seven variables tested are presented in Table 3 of Appendix 6-C. The seven variables are ranked according to their impact on the net present value of the project in Table 4 of Appendix 6-C using a ranking method from Bottomley and Contant (1988). Each of the variables tested is discussed in the order of the sensitivity ranking.

1. **Annual project costs** are the component of the project to which the NPV is most sensitive. As Table 3 in Appendix 6-C shows, if the project costs drop by 10%, the NPV will increase by 15%. Because large project costs are incurred during the first seven years of the project life during which no significant incremental farm net benefits are gained, the NPV of the project is particularly sensitive to variation in those costs which fall earlier in the project life. Moreover, since the present value of those project costs are three times ($ 2.80 million) the present value of the incremental farm net benefits ($ 0.94 million), the effect of varying those costs on the NPV of the project is, not surprisingly, higher than the effect of varying any other component of the project. Even if some savings are made in technical assistance and construction (the two largest

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cost items of the project) to reduce the project costs by 20%, for example, the project would still be unprofitable. Hence, the other components of the project also need to be considered to improve the economic value of FSR.

2. **Incremental farm gross benefits** are the second most sensitive component of the project. As Table 3 in Appendix 6-C shows, if the incremental farm gross benefits increase by 10% with no corresponding increase in costs, the NPV of the project will rise by 13%. Moreover, the effect of the change in incremental farm gross benefits on the NPV of the project is underestimated because the change in incremental farm gross benefits affects farm net benefits which in turn affect adoption, an important variable determining the returns to FSR. Researchers and planners involved in FSR should, therefore, pay particular attention to the additional farm gross benefits that the project is likely to generate, as well as to the possible variability in those additional farm gross benefits. On the one hand, the increases in farm gross benefits depend on increases in yields and, therefore, on the yield performance of the technical packages that FSR might develop. On the other hand, the increases in farm gross benefits depend on product prices and, therefore, on market performance. Increases in the economic farm gross benefits will be larger for exportable products because of the overvaluation of the CFA franc.

3. **The time taken to complete research** is the third most sensitive component of the project, because of the delay incurred in obtaining benefits but also because of the extra costs of the project added for each extra year of research. This test does not separate out the pure effect of the time taken to complete the research as distinct from the additional or reduced costs which go with it. FSR managers can exert control over

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the research period by hiring a highly experienced research staff and facilitating administrative tasks.

4. **Incremental farm costs** are the next most sensitive component of the project. As for changes in incremental farm gross benefits, The project's variability is underestimated in this case, as in the case for changes in incremental farm gross benefits, because the change in incremental farm costs affects farm net benefits which in turn affects adoption. Because of the overvaluation of the CFA franc, the economic incremental farm costs can be reduced if the technical packages incorporate fewer imported inputs.

5. **The diffusion acceptance rate** is not as sensitive a component as one might expect, probably because the change in the incremental farm net benefit flows due to changes in the diffusion acceptance rate come so late that the discounted value of this change is much reduced. Since the diffusion acceptance rate depends on factors affecting the demand for innovations, particular attention must be given to the development of readily adopted technical packages.

6. **The diffusion ceiling** is not a very sensitive component of the project because, again, the change in the incremental farm net benefit flow comes so far in the future that the discounted value of this change is not much affected. The diffusion ceiling depends on factors affecting the long-run demand for innovations (such as the long-run profitability of the innovations) that is in turn affected by the long run market potential for agricultural products. Developing new technologies with respect to the long-run market opportunities is essential to a higher diffusion ceiling.

7. **The life of the innovations** appears to be the least sensitive component of the project. The eventual obsolescence of a newly developed technology should not influence

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The variability of the economic returns to FSR due to changes in the major components of the project is underestimated in the case of changes in incremental farm gross benefits and incremental farm costs because individual changes in these two variables affect the incremental farm net benefits, which in turn affect the diffusion parameters. A more realistic sensitivity analysis would acknowledge this interdependence by using, for example, the relationship that has been established between the marginal rate of return and the rate of acceptance. The interdependence between the project's costs and the time needed for moving from developing research areas to the extension stage is another case of underestimating the variability of the economic returns to FSR. Information about FSR performance in the two oldest FSR research units based in Southern Mali could be used to measure this interdependence.[97] Sensitivity analysis that synchronously varies strongly interdependent variables would more correctly indicate the instability of the returns to FSR due to changes in the major components of the project.

The sensitivity analysis indicates that several important pre-conditions for a profitable FSR do not presently exist in the Region of Mopti. Basically, the costs of the project are too high with respect to the expected flow of incremental net benefits. Yield increases or agricultural product prices are too low. The time needed to develop economically profitable and readily adopted technical packages is too long. Decreases in

[97] Because these two FSR units have benefited from two very different levels of financial and technical support from 1978 to today, it would be possible to find a rough relationship between project costs and time needed to develop a research area.

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farm production unit costs are too small. The diffusion paths of the proposed technical packages are too slow. However, because the costs of the project and the research period cannot be realistically reduced without jeopardizing the quality of FSR, these two components of the project are not subject to further investigation. Conditions that merit special attention to make FSR profitable are, therefore, those that affect the incremental farm net benefits and diffusion paths.

The conditions that affect the incremental farm net benefits and diffusion paths are mainly 1) the performance of on-station research in generating improved technological components from which FSR can draw, 2) the performance of the marketing system in reducing marketing margins and seasonal price variations for inputs and outputs, and 3) the conduciveness of the institutional setting to transferring technological innovations. The performance of on-station research to generate improved technological components from which FSR can draw affects yield increases or input saving and, hence, the incremental farm gross benefits or incremental farm production costs. The performance of the marketing system in reducing marketing margins and seasonal price variations for inputs and outputs also affects the incremental farm gross benefits and incremental farm production costs. The conduciveness of the institutional setting to transferring technological innovations affects the adoption of technology and, hence, the diffusion paths. The incremental farm net benefits also affect the diffusion paths. These conditions for making FSR a profitable investment will be investigated in chapter 7.

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6.5. Conclusions

An economic surplus approach was used to estimate the returns to FSR. It is reasonable to assume that the regional supply-demand structure for crops is one of a perfectly elastic demand curve facing a perfectly inelastic short-run supply curve. Therefore, the change in total economic surplus is equivalent to the change in producer surplus, all the more so because a significant proportion of household cereals production is consumed by the household. These assumptions about the structure of the regional supply and demand curves simplify the use of the economic surplus approach.

The main incremental net benefits consist of the increased net incomes accruing to farm households as a result of the transfer and adoption of new technical packages developed and tested by the FSR project. With a 12% discount rate the present value (PV) of the costs of the resources committed to the FSR project amounts to $US 2.80 million while the PV of the incremental farm net benefits amounts to only $US 0.94 million. This results in a negative net PV of $US 1.86 million and a low internal rate of return of 2%.

The economic value of the FSR project is, however, undervalued since some research areas that the FSR might develop are not included in the economic value of the project. The potential of FSR to reorient research priorities of other research programs or to guide market and institutional improvements is also not evaluated. Some possible external effects of the project were not included in the economic value of the project, particularly the reduction of food aid and outmigration from increases in farm income. In sum, the ex-ante evaluation of FSR indicated that if FSR were limited to adapting and transferring new technological components currently available from station research and if it were the only major new public investment in the Region of Mopti, it would have a low return.

The net benefits resulting from adoption of the technical packages are distributed unevenly across target groups. The mixed farmers of the southern zone account for 29% of the population and area cultivated in the project area while they receive 51% of the total incremental farm net benefits.

The distribution of net economic benefits favors women since the technical packages that would affect them account for 66% of the total incremental farm net benefits. Some indirect effects on women's earnings are likely to arise from the productivity increases of food crops such as millet and cowpeas. This should be confirmed by a more detailed study on women's participation in processing and marketing agricultural products and on intra-family income distribution.

Sensitivity analysis on the return to FSR reveals that the following set of conditions, which affect the incremental farm net benefits and diffusion paths, are critical to making FSR profitable: 1) the performance of on-station research in generating improved technological components from which FSR can draw, 2) the performance of the marketing system in reducing marketing margins and seasonal price variations for inputs and outputs, and 3) the conduciveness of the institutional setting to transferring technological innovations. An improvement in only one of these conditions is not likely to be sufficient to make FSR profitable.

The principal finding of this ex-ante evaluation is that if the FSR project were limited to adapting and transferring results currently available from station research under the current market and institutional environment, the project would not be economically viable. However, with improvements in the technological components

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available from on-station research, in the input and output marketing systems, and in the institutional environment of the Region of Mopti, the economic value of FSR could be higher. Therefore, the decision to extend FSR into the Region of Mopti should account for both the conditions which exist today and the conditions which might exist in the future. The possibility and the potential impact of developing more appropriate technological components at the agricultural station level and improving the marketing system and institutional environment in the Region of Mopti are studied in chapter 7.

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7. THE ECONOMICS OF PUBLIC INVESTMENTS COMPLEMENTARY TO FSR

The ex-ante evaluation indicated that if FSR were limited to adapting and transferring new technological components currently available from station research and if it were the only major new public investment in the Region of Mopti, it would have a low return. However, it was hypothesized that the return to the FSR project would increase if more appropriate technologies were developed at the agricultural station level and if the market and institutional environment improved. Consequently, this chapter presents the results of additional analysis to estimate the relative economic benefits of improving the stock of available technological components from which FSR can draw and of making the market and institutional environment more conducive to technology adoption.

In the first section of this chapter, three public investments that would complement FSR are defined and evaluated individually. In the second section, scenarios representing different combinations of public investments and FSR are evaluated in terms of their joint production impact. The interactive effects of complementary investments are estimated and used to propose alternative sequences of public investments over time in third section.

7.1. Evaluation of the Investments that Complement FSR

The three public investments that complement FSR and could directly affect farm productivity are: 1) investment in additional on-station research, 2) investment in the technology transfer

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technology transfer system (including extension, input delivery, and credit supply), and 3) investment to promote improvements in the marketing of agricultural products and fiscal policy reform. Although this third type of investment involves two separate types of reforms, they are considered together to reduce the number of simulations.

7.1.1. Additional On-Station Research

According to breeders and agronomists, additional investment in on-station research in Mali could result in improved varieties of millet and deep floating rice, thereby broadening the portfolio of technological components available for on-farm research. According to interviews with breeders, five years of agricultural research would be required to develop an improved millet variety for the northern zone and an improved Oryza glaberrima variety for the natural flooded area, while about ten years would be required to develop an improved Oryza sativa variety for the controlled flooded area. The costs of additional on-station research are estimated in Table 7-1 on the basis of the 1990 budget proposal for the agricultural research station in Mopti. The shadow exchange rate is used to convert these costs into US dollars.

The improved varieties are included in technical packages that are devised on the basis of the opinions of biological scientists. The yields observed at the station level are discounted to take into account the yield gap between the experiment station and the farmers' fields. Table 1 of Appendix 7-A contrasts the technical package that includes the improved millet variety suitable for the northern zone with the traditional and

Table 7-1. Additional Research Economic Costs (in $ US '000)

ITEMS	'000 CFA.F/YEAR	'000 $/YEAR	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6 to 10	PV at 12%
On Oriza glaberrima Rice (1):									
Personnel Costs	7750	20	20	20	20	20	20		72
Operating Costs	12264	31	31	31	31	31	31		113
[illegible] (1):				[illegible]	20	20	20	20	112

Table 7-1. Additional Research Economic Costs (in $ US '000)

ITEMS	'000 CFA.F/YEAR	'000 $/YEAR	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6 to 10	PV at 12%
On Oriza glaberrima Rice (1):									
Personnel Costs	7750	20	20	20	20	20	20		72
Operating Costs	12264	31	31	31	31	31	31		113
On Oriza sativa Rice (1):									
Personnel Costs	7750	20	20	20	20	20	20	20	112
Operating Costs	12264	31	31	31	31	31	31	31	178
On Millet:									
Personnel Costs(2)	5125	13	13	13	13	13			40
Operating Costs(3)	4088	10	10	10	10	10			32
Total	49240	126	126	126	126	126	103	51	547

(1) The financial 1990 Mopti station budget proposal, including 3 scientists (1 Ph.D. and 2 B.S), 4 technicians and 12 support staff persons converted in $ US with the shadow exchange rate.

(2) The financial costs of 3 scientists (1 Ph.D. and 2 B.S.), 2 technicians and 6 support staff persons adapted from the 1990 Mopti station budget proposal converted in $ US with the shadow exchange rate.

(3) One third of the financial operating expenses reported in the 1990 Mopti station budget proposal converted in $ US with the shadow exchange rate.

Source: Author's survey.

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transitional technologies currently in use in the rainfed areas. Table 2 of Appendix 7-A contrasts the technical packages that include the improved rice varieties with the technologies used in the flooded areas. The technical package with the improved millet variety is expected to increase yields by 20% when the package is compared to a package with the same set of inputs but the current millet variety.[98] The improved Oryza glaberrima variety is expected to increase yields by 30% and the improved Oryza sativa variety to increase yields by 77% with chemical fertilizers.

The improved millet and rice varieties that agricultural research could develop would increase significantly the returns to current technologies. The millet-cowpea intercropping technical package with the improved millet variety increases net income by 87% and net income per day of labor by 114% compared with the millet traditional technology (Table 7-2, a synthesis of Table 1 in Appendix 7-B). However, in contrast, the same package with the current millet variety only increases net income by 60% and net income per day of labor by 80%. The improved rice variety for naturally flooded areas increases net income by 47% and net income per day of labor by 43% (Table 7-3, an synthesis of Table 2 in Appendix 7-B). The improved rice variety for controlled flooding areas when used with chemical fertilizers increases the net income by 35% and the net income per day of labor by 27%.

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[98] The technical package with the improved millet variety increases yields by 75% when the package is compared to the transitional technology and by 92% when the package is compared to the traditional technology.

Table 7-2. Synthesis
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Table 7-3. Synthesis

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Fixed Costs
Total Costs (2)
Net income (3)
Net Income per Day of

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Table 7-2. Synthesis of the Financial Budgets for the Millet-Cowpea Intercropping with Improved Seeds for the Northern Zone

BUDGET COMPONENT (1)	CURRENT MILLET-COWPEA INTERCROPPING			IMPROVED MILLET-COWPEA INTERCROPPING			
	TRADITIONAL (CFA F/ha)	TRANSITIONAL (CFA F/ha)	%	CURRENT IMPROVED SEED (CFA F/ha)	%	EXPECTED IMPROVED SEED (CFA F/ha)	%
Gross Value of Production	20500	22150	8	46000	124	51600	152
Labor Gain from Traditional Technology		8342		4965		4568	
Total Gross Value	20500	30492	49	50965	149	56168	174
Variable Costs	1235	1235	0	11999	872	11999	872
Fixed Costs	0	6384		8227		8227	
Total Costs (2)	1235	7619	517	20226	1538	20226	1538
Net income (3)	19265	22873	19	30739	60	35942	87
Net Income per Day of Labor	397	528	33	716	80	848	114

(1) Percentages are expressed with respect to the traditional technology.
(2) Excluding labor and land costs.
(3) Defined as the return to labor, land and capital.
Source: Synthesis of Table 1 in Appendix 7-B.

Table 7-3. Synthesis of the Financial Budgets for Rice with Improved Seeds

BUDGET COMPONENT (1)	NATURAL FLOODING			CONTROLLED FLOODING		
	CURRENT (CFA F/ha)	IMPROVED (CFA F/ha)	%	CURRENT (CFA F/ha)	IMPROVED (CFA F/ha)	%
Gross Value of Production	45583	57083	25	96393	165107	71
Labor Increase from Current Technology		1474			20070	
Total Gross Value	45583	55609	22	96393	145037	50
Variable Costs	9000	11456	27	32120	63429	97
Fixed Costs	20371	20371		15427	15427	
Total Costs (2)	29371	31827	8	47547	78856	66
Net income (3)	16212	23782	47	48846	66181	35
Net Income per Day of Labor	295	421	43	627	797	27

(1) Percentages are expressed with respect to the current technology.
(2) Excluding labor and land costs.
(3) Defined as the return to labor, land and capital.
Source: Synthesis of Table 2 in Appendix 7-B.

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Moreover, the improved millet and rice varieties increase the average rates of return to the technical packages (Tables 7-4 and 7-5). For non-mechanized farmers, the average rate of return for adopting the millet-cowpea intercropping technical package with the improved millet variety is 88%, while the average rate of return for adopting the same package with the current millet variety is 60%. For mechanized farmers, the average rate of return is 94%, as opposed to 54%. In the Delta, the return is 308% for adopting the improved Oryza glaberrima variety and 55% for adopting the improved Oryza sativa variety with chemical fertilizers. These expected rates of return will be used to estimate the expected rates of acceptance of these technical packages.

The financial budgets of the technical packages including the improved millet and rice varieties are transformed into economic budgets under the same price assumptions given earlier (see section 5.3.1). These economic budgets are presented in Tables 1 and 2 of Appendix 7-C.

The improved rice varieties included in the technical packages described above improve the economic efficiency of growing rice under natural and controlled flooding for any market as indicated by the DRC ratios in Table 5-10. Producing rice for the Bamako wholesale market is still not economically competitive with importing rice for this market. Although the DRC ratio for the millet-cowpea intercropping technical package is not estimated for the northern zone, it is reasonable to assume that the DRC ratio will increase with the improved millet varieties since the yield increases while the cost of purchased inputs remains identical.

Table 7-5. Marginal Analysis of the Technical Packages for Farms in the Delta

TECHNICAL PACKAGE	NET INCOME (CFAF)	TOTAL COST (CFAF)	MARGINAL NET INCOME (CFAF)	MARGINAL COST (CFAF)	MRR (%) (1)	AVERAGE RATE OF RETURN % (2)
A) NATURAL FLOODED:						
Improved	23783	31826	7571	2456	308	308

Table 7-5. Marginal Analysis of the Technical Packages for Farms in the Delta

TECHNICAL PACKAGE	NET INCOME (CFAF)	TOTAL COST (CFAF)	MARGINAL NET INCOME (CFAF)	MARGINAL COST (CFAF)	MRR (%) (1)	AVERAGE RATE OF RETURN % (2)
A) NATURAL FLOODED:						
Improved	23783	31826	7571	2456	308	308
Current	16213	29371				
B) CONTROLLED FLOODING:						
Improved	61238	83799	17335	31309	55	55
Current	43903	52490				

(1) From preceding to following.
(2) From the traditional practice.
Source: From Table 2 in Appendix 7-B.

Table 7-4. Marginal Analysis of the Technical Packages for Farms in the Northern Zone with Improved Varieties

TECHNICAL PACKAGE (1)	NET INCOME (CFAF)	TOTAL COST (CFAF)	MARGINAL NET INCOME (CFAF)	MARGINAL COST (CFAF)	MRR (%) (2)	AVERAGE RATE OF RETURN % (3)
A) NON-MECHANIZED FARM:						
[illegible] maize [illegible] new var.	35942	20226	5203	0	large	88
[illegible]				[illegible]	96	60

Table 7-4. Marginal Analysis of the Technical Packages for Farms in the Northern Zone with Improved Varieties

TECHNICAL PACKAGE (1)	NET INCOME (CFAF)	TOTAL COST (CFAF)	MARGINAL NET INCOME (CFAF)	MARGINAL COST (CFAF)	MRR (%) (2)	AVERAGE RATE OF RETURN % (3)
A) NON-MECHANIZED FARM:						
Improved M-C intercropping w. new var.	35942	20226	5203	0	Large	88
Improved M-C intercropping	30739	20226	6256	6483	96	60
Improved M-C cropping pattern	24484	13743	1616	6118	26	42
M-C interc. transitional practice	22867	7624	3602	6389	56	56
M-C interc. traditional practice	19265	1235				
B) MECHANIZED FARM:						(4)
Improved M-C intercropping w. new var.	26354	20226	5072	0	Large	94
Improved M-C intercropping	21283	20226	5600	6483	86	54
Improved M-C cropping pattern	15683	13743	1152	6124	19	19
M-C interc. transitional practice	14531	7619				

(1) M-C: Millet-Cowpea
M-M-M: Millet-Millet-Millet rotation
Transitional practice: Mechanized practice with no other external inputs.
Traditional practice: Non-mechanized practice with no external inputs.
(2) From preceding to following.
(3) From the traditional practice.
(4) From the transitional practice.
<u>Source:</u> From Table 1 in Appendix 7-B.

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Diffusion parameters are estimated for the characteristics of the innovations and potential adopters the same way the diffusion parameters were estimated for the technical packages developed by FSR alone. The relationship found above (see section 5.4.3) between the MRR and the acceptance rate 'b' is used for estimating the expected diffusion paths of the technical packages including the improved varieties. The parameter 'a' positioning the diffusion path of animal traction on the time scale estimated earlier for the northern zone is used for estimating the diffusion paths of the technical packages including the improved millet and rice varieties. However, for farmers growing rice under controlled flooding, i.e., the ORM holders, the parameter 'a' is halved because these farmers already benefit from extension services that facilitate the supply of new technology. The upper limits of diffusion 'K' are set at 80% for farmers growing rice under natural flooding and at 90% for farmers growing rice under controlled flooding. The expected diffusion paths estimated in terms of percentage of area are then converted into area terms. The cultivated area of the natural flooded rice system is 80,000 ha (McIntire, 1981, p. 333) and the cultivated area of the controlled flooded rice system is 18,000 ha (harvested area of a relatively good year, ORM, 1987).

Additional on-station research (OSR) would bring no substantial additional on-farm net benefits if that type of research were not associated with an FSR perspective. This argument is historically based on the finding that on-station research has been unsuccessful for semi-arid environments without on-farm research components (Matlon, 1985). Therefore, returns to OSR are only estimated when FSR is associated with OSR. In this case, the research period of FSR is extended from seven to nine years to allow FSR to test the improved rice varieties that are released later. The joint investment in FSR and additional on-station research (OSR) has a net present value of $ US 0.72

million at a discount r

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million at a discount rate of 12% and an average rate of return of 21% (Table 7-7). The internal rate of return (IRR) is 14%, a much higher IRR than to FSR alone (2%).

7.1.2. Improvements in the Technology Transfer System

The second investment complementary to FSR would be an improvement in the three main functions of the technology transfer system: extension, input delivery and credit supply. First, extension may play a major role in training farmers to use correctly the technical packages developed by FSR. Extension training and demonstrations for farmers are expected to raise crop yields by 5%. Because the size of the yield effect due to extension is uncertain, a sensitivity test will use higher yield effects (10% and 15%).

Second, the input delivery system can be improved by organizing farmers to negotiate and make group input purchases. Contract purchases of inputs reduce the uncertainty of receiving inputs on time as well as real delivery costs. According to traders and extension agents, the marketing margin for inputs from Bamako to Mopti could be reduced by half, which would reduce the costs of purchased inputs by 10%, assuming a 20% marketing margin.[99] Because the access to inputs is improved, the parameter positioning the diffusion path on the time scale is reduced by half. The acceptance rate of the diffusion path is programmed to increase as the farm net incomes increase (see below).

Third, extending the coverage of the current formal credit system to the rainfed areas of the Region of Mopti would reduce the nominal interest rate from 18%, the

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[99] Dioné (1989, p. 275) suggested that the shortage of supply of equipment observed in high-income zones such as CMDT can be partly solved by a greater participation of the private sector in farm input and equipment distribution. This participation may be achieved only through the implementation of more in-depth policy reforms for licensing, financing, foreign exchange, import regulations and price setting and control.

estimated current private lending rate, to 9%, the current National Credit Bank's rate.[100] However, for the economic analysis, the real opportunity cost of capital remains at 12%.

The additional economic cost of improving the functioning of the technology transfer system is mainly the cost of improving extension, which includes providing technical advice and organizing farmers into village associations to make group purchases and to manage formal credit. For the rainfed area, this additional cost per hectare is estimated at $ US 23 (or half the per hectare economic cost of extension in the CMDT, a fairly well managed development agency for cotton and cereals in southern Mali). For the naturally flooded area of the Delta, this additional economic cost per hectare is estimated at $ US 19 (or half the per hectare economic cost of extension in the ORM). Only half of the per hectare economic cost of CMDT and ORM is used because the technical packages for the rainfed and natural flooded areas require a lighter extension system than the system currently in place in the CMDT and ORM. The technical packages for these two areas in the Region of Mopti are less intensive in purchased inputs and require fewer managerial skills than the technical packages currently extended by the CMDT and ORM.

Improvements in the technology transfer system affect the diffusion parameters. The rate of acceptance 'b' of the logistic diffusion function increases as the financial profitability of the transitional technology and proposed technical packages increases with an improved technology transfer system. The parameter 'a' positioning the diffusion

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[100] Dioné (1989, p. 273) indicated that farmers associations were instrumental in extending access for formal credit to small farm households in the CMDT and OHV areas. Village association participation in managing formal credit programs is a possible approach for supplying credit in the Region of Mopti.

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path on the time scale is reduced by half, as observed from historical data when situations with and without extension are compared.[101] The upper limit of diffusion 'K' increases as the financial profitability of the technical packages increases, taking into account the commodities' market potential.

The returns to improving the technology transfer system alone are estimated on the basis that these investments will 1) facilitate the diffusion of animal traction in the rainfed area at a lower adoption cost for farmers, 2) provide inputs at lower costs, and 3) result in a yield effect of at least 5% on the extension of the transitional technologies. When improvements in the technology transfer system are considered alone, the additional costs and the yield effects due to extension will apply only to the diffusion of the transitional technology. It is assumed that extension agents will concentrate on extending the transitional technology.

Subsequently, when improvements in the technology transfer system are combined with FSR and additional on-station research, the effect of improving the technology transfer system will go beyond the current transitional technology to the proposed technical packages. However, in this case, extension agents will concentrate on extending the proposed technical packages rather than the transitional technology. Therefore, the yield effect due to extension will apply only to the proposed technical packages. As a result, because two (input delivery and credit supply) of the three functions of the technology transfer system will apply to the diffusion of the transitional technology, half of the additional cost of improving the technology transfer system will apply to the

[101] From 1973 to 1982, when extension was operational in the rainfed area, the parameter 'a' of the logistic function, which describes the diffusion path of animal traction, was -6.0 in the center and plateau zone. From 1983 to 1987, when extension was no longer operational, the parameter 'a' dropped to -13.0.

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diffusion of the transitional technology. In contrast, the full additional cost of improving the technology transfer system will apply to the diffusion of the proposed technical packages because the three functions of the technology transfer system will apply to the diffusion of the proposed technical packages.

Based on these assumptions, improvements in the technology transfer system alone increases the present value of incremental farm net benefits by $ US 2.04 million because of a greater adoption of the transitional technology in the rainfed area with lower costs and higher yields (Table 7-7). The additional cost of improving the technology transfer system is equivalent to $ US 3.60 million. The net present value of the improvements in the technology transfer system is negative $ US 1.56 million at a discount rate of 12%. The net present value, however, turns positive when the yield effect due to extension is increased to 14%, which is an unlikely yield effect. If the improvements in the input and credit supply functions were dissociated from the improvements in the extension function of the technology transfer system and simulated alone, the returns to the first two functions would have been positive because of removing an unprofitable extension function.

In sum, the economic analysis of improvements in the functioning of the technology transfer system shows that investment in the extension function should be delayed until the research system is developed adequately to generate improved technologies ready for extension. Investment in the input and credit functions may yield positive returns under the current conditions and, consequently, is advisable.

7.1.3.

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7.1.3. Promoting Improvements in the Marketing System, including Fiscal Reforms

The third investment complementary to FSR is promoting improvements in the agricultural product marketing system and fiscal policy reform. Before presenting and discussing the simulation results for this third investment, feasible measures to improve the agricultural product marketing system and reform fiscal policy are reviewed.

Dioné (1989) suggests three areas for market improvement based of his research in south central Mali. The first is designed to prevent producer prices from falling precipitously in periods of large marketable surplus, the second area to give farmers greater collective bargaining power, and the third is to reduce marketing margins. As argued by Dione (ibid., p. 352), direct public sector involvement in managing surplus production through ambitious producer price support and stabilization policies is not financially and technically sustainable and, therefore, not a feasible option for increasing prices received by farmers.

To prevent producer prices from falling precipitously in periods of large marketable surplus, export restrictions and costly licensing procedures should be eliminated and new domestic outlets should be promoted. For example, easier-to-prepare forms of coarse grains would increase the demand for cereals and, hence, prices received by farmers (ibid., 1989).

Second, to give farmers greater collective bargaining power, farmers can be organized in associations to manage their marketable surplus and counterbalance the actions of few buyers (ibid.).[102] In addition, price and quantity information provided by

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[102] These producers also have significant financial obligations during the post-harvest period that prevent them from postponing their agricultural product sales. These post-harvest "forced sales" not only depress post-harvest coarse grain prices and yield lower post-harvest cereals revenues for these farmers, but also they erode the ability of farmers

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the market information system can help these farmer associations improve the allocation of their sales across time and space if the farmers' liquidity constraints are overcome. With greater competitiveness, both the purchase price and the quantity traded will be higher than they are in an oligopsonistic situation. With conditions approaching those of perfect competition, seasonal price variations will reflect mostly storage costs, and prices between markets will reflect mostly transportation costs.

Third, reducing the marketing margins of agricultural products shifts the farm-level demand functions upwards, thereby increasing the prices received by farmers and the quantity traded. Marketing margins can be reduced by lowering the costs of marketing services (assembly, transportation, processing and storage). Marketing margins are also affected by uncertainties inherent in supply and demand conditions and by official trade regulations. Traders' assembly operations can be facilitated by the participation of farmer associations in the collection of agricultural products at the village level. Uncertainties can be reduced by unambiguous trade regulations and information about market supply, demand and regulations, which can be provided by the market information system (ibid.). Marketing margins can also be reduced by lowering marketing taxes, administrative fees, and export taxes. As demonstrated by the simulation, removing taxes actually has a positive impact on the economic returns because, by reducing the financial marketing margins, prices received by farmers increase and, therefore, stimulate technical change. Although improving the road network to reduce transportation costs is necessary in the Region of Mopti, it is not considered in this study because the cost of improving the road network would be larger than the available funds for strengthening agricultural research.

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These improvements in the agricultural product marketing system might increase prices received by farmers by 10%. This expectation is based on the following observations: 1) farmers currently sell their production at harvest, when farm-gate prices are 15% to 25% lower than the annual average price for millet (Table 1 in Appendix 2-A); 2) the marketing margins between producing areas and Mopti are between 15% and 25% for millet (Table 3 in Appendix 2-A); and 3) export taxes and administrative fees constitute about 10% of farm-gate prices.

The reformed fiscal policies analyzed here involve removing all taxes, subsidies and duty administrative fees on agricultural inputs and outputs. In Mali, this would entail elimination of 1) the 20% subsidy on improved seeds and the 8% subsidy on agricultural equipment, 2) administrative fees of 5% on imports and 3% on exports, and 3) a 5% export tax. Although the CFA franc is overvalued by 33% (Stryker et al., 1987), no monetary devaluation is simulated because devaluation is unlikely in the near future. The devaluation would have increased the farmgate prices of the exported goods and increased the costs of the imported inputs and, therefore, would have a mixed effect on the technical change.

Promoting marketing and policy reforms raise costs, mainly those of operating a regional team of market and policy analysts and enumerators. The personnel and operating costs of such a regional team are based on the 1990 Mopti station budget proposal and converted to US dollars, using the shadow exchange rate. The costs for technical assistance, training, vehicles and research equipment are based on the FSR/E project paper drafted by USAID (1985). These costs for promoting marketing and policy reforms are estimated in Table 7-6.

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The economic returns to promote changes in the marketing system and fiscal policy are estimated on the basis of the incremental farm net benefits generated by a greater adoption of the transitional technology with lower input costs and higher agricultural product prices. Promoting changes in the marketing system and fiscal policy raises the present value of incremental farm net benefits by $ US 1.35 million (Table 7-7). The costs of promoting changes in market conditions and fiscal policy have a present value of $ US 1.11 million. The net present value of these changes is $ US 0.23 million. The average rate of return is 21% and the IRR is 18%. These economic returns are, however, uncertain. They mainly depend on whether policy-makers would actually take into account policy research information generated by the market and policy analysts. As a result, the political willingness to reform market and policy should be assessed before investing in a regional team of market and policy analysts.

These economic returns are probably underestimated since direct and induced effects of these improvements on the other sectors of the regional economy are not included in the estimation. If fiscal reforms were dissociated from improvements in the marketing system, the simulation would probably have shown a higher return to fiscal reforms than to improvements in the marketing system. Fiscal reforms can be implemented almost instantaneously and with low investment costs while improvements in the marketing system require more time and are more costly. Removing tax distortions from the input and output marketing system does generate an economic impact. However, once tax distortions are removed, the economic growth ends with them unless other types of investments improve productivity.

Table 7-6. Additional Marketing Improvement and Policy Reform Costs (in $ US '000)

ITEMS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6 to 20	PV at 12%
Technical Assistance (1)	150	150	150				360
Short Term Assistance (1)	40	20	10				59
Personnel Costs(2)	30	30	30	30	30	30	221
[illegible]	10	10	10	5	5		30

Table 7-6. **Additional Marketing Improvement and Policy Reform Costs (in $ US '000)**

ITEMS	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6 to 20	PV at 12%
Technical Assistance (1)	150	150	150				360
Short Term Assistance (1)	40	20	10				59
Personnel Costs(2)	30	30	30	30	30	30	221
Short Term Training (1)	10	10	10	5	5		30
Vehicles (1):							
1 4WD	20				20 (every 4 years)		44
1 Pick up	16				16 (every 4 years)		35
2 Motorcycles	3			3 (every 3 years)			8
8 Mobylettes	4			4 (every 3 years)			11
Research Equipment (1):							
Computers & Software	10				10 (every 4 years)		22
Operating Costs (2)	50	50	50	40	40	40	323
Total	333	260	250	82	121		1114

(1) Adapted from USAID/MALI. Farming Systems Research and Extension. Project Paper. AID. March 6, 1985 (see Table 3 in Appendix 5-B).

(2) The financial costs of 3 scientists (1 Ph.D. and 2 B.S.), 8 enumerators and 12 support staff persons whose costs are derived from the 1990 Mopti station budget proposal and are converted in $ US with the shadow exchange rate.

Source: Author's survey.

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7.1.4. Conclusions

The joint investment in FSR and additional on-station research (OSR) shows the highest net present value ($ US 0.74 million) relative to other possible investments. Investment in promoting improvements in the marketing system and fiscal policy follows ($ US 0.23 million), while investment in FSR alone and investment in the technology transfer system alone show large negative net present values ($ US 1.86 million and 1.56 million respectively). In the event that funding is limited the joint investment in FSR and OSR is the preferred investment because it yields the highest net present value. Not only does additional on-station research make FSR profitable in the Region of Mopti, but also FSR and additional on-station research are highly complementary. The large interactive effect between FSR and additional on-station research is discussed in the next section.

7.2. Evaluation of Public Investment Combinations

Because investment in on-station agricultural research, farming systems research, technology transfer, and promoting marketing and fiscal improvements are expected to have strong interactive effects, scenarios which combine these investments are simulated. First, selected scenarios are ranked according to their expected returns. Second, the interactive effects are estimated.

7.2.1. Scenario Ranking

All possible combinations of the four proposed public investments are simulated with the restriction that when additional on-station research is examined, it is associated with FSR. The results of the simulations are presented in the first four columns of Table in terms of the pr

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7-7 in terms of the present value: (1) incremental net benefits accruing to the target population, (2) public investment costs, (3) net benefits of the public investments, and (4) the IRR of the public investments.

In Table 7-7 the scenarios are ranked by increasing net present value. Among the two by two combinations of FSR with another public investment, the combinations of FSR with either additional on-station research or improvements in the technology transfer system have a similar NPV and average rate of returns (the RORs are 21% and 23% respectively). The combinations of FSR with promoting marketing and fiscal improvements has a lower NPV and average rate of returns (a ROR of 11%). Among the three by three combinations of FSR with another public investment, the combination that include additional on-station research and promoting improvements in the marketing system and fiscal policy has the highest NPVs and average rates of returns (a ROR of 119%). The scenario combining FSR with additional on-station research, technology transfer improvements and promoting marketing and fiscal improvements (FSR-OSR-E&C-P) yields the highest NPV ($ US 9.34 million). When the scenarios are considered mutually exclusive, this scenario is the best investment.

The marginal analysis carried out on the twelve scenarios confirms that the FSR-OSR-E&C-P scenario is the best investment.[103] In marginal analysis, any scenario that has net benefits less than or equal to those of a scenario with lower costs is said to be dominated, and therefore eliminated from the marginal analysis.[104] The marginal rate

[103] Although the marginal analysis carried out in this section does not refer to infinitesimal incremental changes, the "marginal rate of return" expression is used to be consistent with the terminology commonly used in the literature to evaluate agricultural technologies. Some economists may prefer to use "incremental rate of return" instead of "marginal rate of return".

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of return (MRR) is estimated for non-dominated scenarios of incremental cost and reported in Table 7-7. Using a MRR threshold of 50% to take account of risk, three scenarios are economically attractive: a combination of FSR and improvements in the technology transfer system (a 61% MRR); a combination of FSR, additional on-station research, and promoting marketing and fiscal improvements (a 539% MRR); and a combination of this second scenario and improvements in the technology transfer system (a 79% MRR). Among these three scenarios, the scenario combining all four investments generates the highest net present value together with an acceptable MRR. Therefore, this scenario is considered the best scenario. The average rate of return is estimated at 99% for this scenario (Table 7-7).

Since the yield effect due to extension is uncertain and affects the returns to improvements in the technology transfer system, the scenarios are simulated again with a higher yield effect (10% instead of 5%). The results are presented in Table 7-8. Though the ranking of the scenarios is modified, the FSR-OSR-E&C-P scenario remains the best investment, both in terms of net present value and MRR. The average rate of return increases from 99% to 149%.

The ranking is also affected by the discount rate. For example, with a lower discount rate, the returns to a joint investment in FSR and additional on-station research (FSR-OSR) become larger than the returns to a joint investment in FSR and improvements in the technology transfer system (FSR-E&C). This suggests that, in the short run, existing constraints in the technology transfer system are more important than a lack of station research.

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Given the limitations of human and financial resources and the political implications of, for example, fiscal reforms, the best scenario probably is not feasible. The investment costs of the best scenario are more than three times the costs of the initial FSR project. Human resources for conducting the FSR, additional on-station research, market and policy analysis, and extension called for in this alternative are not currently available. Recurrent costs of these four components exceed the sustainable level at which the Government of Mali is able to contribute. Marketing and fiscal improvements call for a ban of export and import taxes and elimination of export restrictions, which may be politically unacceptable. Under these limitations, second-best scenarios should be considered.

Figure 7-1 shows the relationship between benefit and cost among the eleven scenarios. A frontier benefit-cost function is graphed. It is an envelope curve that includes those scenarios for which additional investment costs generate higher additional farm net benefits when the scenarios are ranked according to increasing investment costs. Seven scenarios meet this criterion and determine the frontier benefit-cost function. All but one scenario are above a 45° line representing the threshold at which the potential benefits of scenarios just cover the incurred costs at a 12% economic discount rate. Yielding an IRR above 12%, these six scenarios are possible alternative investments.

Table 7-7. Economic Values of the Scenarios (Yield effect = 5%)

SCENARIO	INCREMENTAL FARM NET BENEFIT (a)	PUBLIC INVESTMENT COSTS (a)	PROJECT NET BENEFITS (a)	IRR (%) (b)	MARGINAL RATE OF RETURN (%) (d)	AVERAGE ROR	INTERACTIVE EFFECTS (a)	RANK ON THE B-C FUNCTION(c)
FSR	940	2804	-1864	1.7	Dominated	-66.5	NA	
E&C-P	4423	6246	-1823	NA	Dominated	-29.2	-497	
E&C	2039	3596	-1557	NA	Dominated	-43.3	NA	2

Table 7-7. Economic Values of the Scenarios (Yield effect = 5%)

SCENARIO	INCREMENTAL FARM NET BENEFIT (a)	PUBLIC INVESTMENT COSTS (a)	PROJECT NET BENEFITS (a)	IRR (%) (b)	MARGINAL RATE OF RETURN (%) (d)	AVERAGE ROR	INTERACTIVE EFFECTS (a)	RANK ON THE B-C FUNCTION(c)
FSR	940	2804	-1864	1.7	Dominated	-66.5	NA	
E&C-P	4423	6246	-1823	NA	Dominated	-29.2	-497	
E&C	2039	3596	-1557	NA	Dominated	-43.3	NA	2
P	1345	1114	231	18.3	21	20.7	NA	1
FSR-P	4365	3918	447	13.5	Dominated	11.4	2080	
FSR-OSR	4370	3628	742	13.9	20	20.5	2606	3
FSR-E&C	4743	3860	883	14.9	61	22.9	4304	4
FSR-OSR-E&C	10140	7406	2734	18.2	Dominated	36.9	-755	
FSR-E&C-P	11013	5718	5295	24.2	Dominated	92.6	2598	6
FSR-OSR-P	10381	4742	5639	21.7	539	118.9	2586	5
FSR-OSR-E&C-P	18773	9433	9340	26.2	79	99.0	-392	7

(a) PV in thousands of $US at a 12% discount rate.
(b) IRR is undefined when the annual incremental net benefits are negative every year of the project life.
(c) The ranking is based on additional incremental farm net benefits for additional investment costs.
(d) A scenario is dominated if it incurs higher investment costs but no additional net benefit.

Legend: FSR = Farming Systems Research
E&C = Extension, credit and input supply
P = Marketing and fiscal policy
OSR = On-station research

Source: Author's estimations.

Table 7-8. Economic Values of the Scenarios (Yield effect = 10%)

SCENARIO	INCREMENTAL FARM NET BENEFIT (a)	PUBLIC INVESTMENT COSTS (a)	PROJECT NET BENEFITS (a)	IRR (%) (b)	MARGINAL RATE OF RETURN (%) (d)	AVERAGE ROR	INTERACTIVE EFFECTS (a)	RANK ON THE B-C FUNCTION(c)
[illegible]	[illegible]	2804	-1864	1.7	Dominated	-66.5	NA	
[illegible]	[illegible]	[illegible]	[illegible]	NA	Dominated	-18.4	NA	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-6.1	260	[illegible]

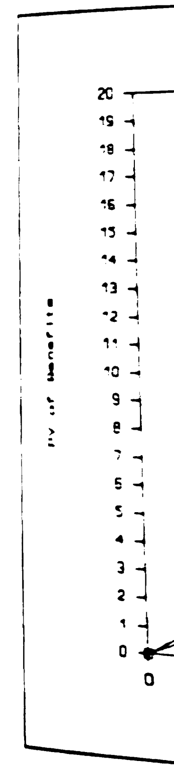
Table 7-8. Economic Values of the Scenarios (Yield effect = 10%)

SCENARIO	INCREMENTAL FARM NET BENEFIT (a)	PUBLIC INVESTMENT COSTS (a)	PROJECT NET BENEFITS (a)	IRR (%) (b)	MARGINAL RATE OF RETURN (%) (d)	AVERAGE ROR	INTERACTIVE EFFECTS (a)	RANK ON THE B-C FUNCTION(c)
FSR	940	2804	-1864	1.7	Dominated	-66.5	NA	
E&C	4273	5239	-966	NA	Dominated	-18.4	NA	
E&C-P	7297	7772	-475	NA	Dominated	-6.1	260	
P	1345	1114	231	18.3	21	20.7	NA	1
FSR-P	4365	3918	447	13.5	Dominated	11.4	2080	
FSR-OSR	4370	3628	742	13.9	20	20.5	2606	2
FSR-E&C	7610	3881	3729	22.3	1181	96.1	6559	3
FSR-OSR-P	10381	4742	5639	21.7	222	118.9	2586	4
FSR-OSR-E&C	14238	7656	6582	24.4	Dominated	86.0	247	
FSR-E&C-P	14955	5742	9213	30.1	357	160.4	2913	5
FSR-OSR-E&C-P	23788	9544	14244	31.0	132	149.2	-408	6

(a) PV in thousands of $US at a 12% discount rate.
(b) IRR is undefined when the annual incremental net benefits are negative every year of the project life.
(c) The ranking is based on additional incremental farm net benefits for additional investment costs.
(d) A scenario is dominated if it incurs higher investment costs but no additional net benefit.

Legend: FSR = Farming Systems Research
E&C = Extension, credit and input supply
P = Marketing and fiscal policy
OSR = On-station research

Source: Author's estimations.



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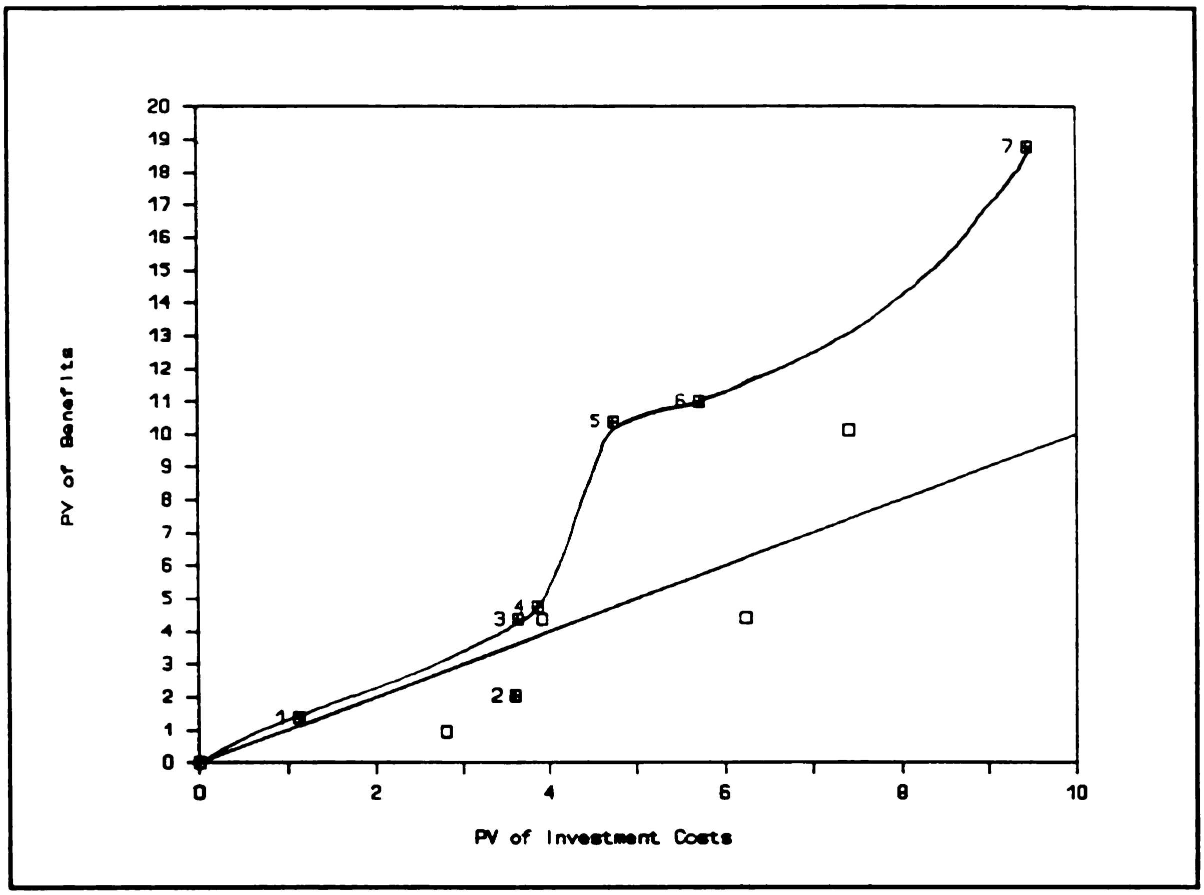

Note: Numbers refer to the scenarios listed in Table 7-7.

Figure 7-1. Frontier Benefit-Cost Function

7.2.2. Interactive Effects

The interactive effect is first estimated for a combination of two investments according to the simple rule that the interactive effect due to a combination of two investments is equal to the net benefits of the combination of the two investments taken together less the net benefits generated by the two investments taken alone. In the same way, the interactive effects are successively estimated for combinations of three and four investments. Table 7-7 gives the estimated net present value of the interactive effects, with the assumptions that the interactions of additional on-station research with

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Among combinations of two investments, the highest positive interactive effect is found for the scenario combining FSR with improvements in the technology transfer system (FSR-E&C). Following this is the scenario combining FSR and additional on-station research (FSR-OSR) and the scenario combining FSR and promoting marketing and fiscal improvements (FSR-P). This ranking, however, depends on the key assumption that investment in additional on-station research would yield a zero NPV, while this investment could actually yield a negative NPV when on-station research is not accompanied by on-farm research. In that case, according to the rule used to calculate the interactive effect, FSR and additional on-station research would have a larger interactive effect. Therefore, this interactive effect is probably underestimated. Hence, ranking the interactive effect between FSR and additional on-station research vis-à-vis the interactive effect between FSR and improvements in the technology transfer system is unclear, while the interactive effect between FSR and promoting marketing and fiscal improvements definitely is the smallest positive interactive effect.

In addition, the interactive effects and, therefore, the ranking of these interactive effects depend on the discount rate, as the returns to investment do. A lower discount rate increases the interactive effect between FSR and additional on-station research relatively more than the interactive effect between FSR and improvements in the technology transfer system. This implies that, when preference is given to long-term objectives over short-term objectives, the complementarity between FSR and additional on-station research becomes relatively stronger.

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The scenario combining technology transfer improvements and marketing and promoting fiscal improvements (E&C-P) shows a negative interactive effect. As economic distortions are removed, the diffusion path of transitional technology is accelerated, resulting in a greater use of extension services.[105] This greater use of extension service increases extension costs relatively more than the net farm incomes and yields a negative interactive effect. This implies that, if farmers actually request additional extension services because of the increased profitability in adopting the available technology and that extension actually expands to meet the increased demand, then the increase in the farm net economic benefits would be lower than the increase in the investment economic costs. The underpricing (actually no costs) of extension services for farmers results in an increased demand for extension from farmers in the simulation. For a 10% yield effect due to extension, the interactive effect turns positive, suggesting that there is a threshold of yield effect between 5 and 10% at which the increase in farm profitability offsets the increase in extension costs. Therefore, investing in the technology transfer system, particularly in the extension function, is not advisable even when removing economic distortions, unless the yield effect due to extension is high or the technologies ready for extension are improved.

Among combinations of three investments, the largest interactive effects are found for combinations that include FSR and promoting improvements in the marketing system and fiscal policy (Table 7-7). The FSR-E&C-P and FSR-OSR-P combinations have large interactive effects of similar size. However, given that the interactive effect between

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[105] The model is built in such a way that, when a scenario includes improvements in the technology transfer functions, the reduction in input costs, the increase in yields due to a demonstration effect, and the extension costs are programmed for all farms adopting the transitional technology.

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FSR and additional on-station research is probably underestimated, the interactive effects for the FSR-OSR-P combination, as well as for the FSR-OSR-E&C combination, is overestimated.[106] Therefore, the FSR-E&C-P combination has the largest interactive effect, followed by the FSR-OSR-P and FSR-OSR-E&C combinations. The large interactive effects found for the first two combinations (those that include FSR and promoting improvements in the marketing system and fiscal policy) suggests that, if some investments other than improving the marketing system and fiscal policy have already taken place, there is still large potential gains from improving the marketing system and fiscal policy.

A lower discount rate increases the interactive effects for the FSR-OSR-P and FSR-OSR-E&C combinations relatively more than the interactive effect for the FSR-E&C-P combination and, hence, affects the above ranking. In that case, the interactive

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[106] The underestimation of the interactive effect between FSR and additional on-station research brings an overestimation into the calculation of the interactive effects of the FSR-OSR-P and FSR-OSR-E&C combinations because the interactive effect for the combination of three investments is calculated by subtracting the interactive effects raised by the combinations of two investments, among other things, from the net returns of the combinations. For example, the expression for calculating the interactive effect of the FSR-OSR-E&C combination is written:

I(FSR-OSR-E&C) = B(FSR-OSR-E&C) - B(FSR) - B(OSR) - B(E&C) - I(FSR-OSR) - I(FSR-E&C) - I(OSR-E&C)

where 'I' represents the interactive effect and 'B' the net returns to the investment or combination of investments.

With the assumptions that B(OSR) and I(OSR-E&C) are nil, the expression becomes:

I(FSR-OSR-E&C) = B(FSR-OSR-E&C) - B(FSR) - B(E&C) - I(FSR-OSR) - I(FSR-E&C)

Therefore, an underestimation in I(FSR-OSR) brings an overestimation in I(FSR-OSR-E&C).

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effect of the FSR-OSR-P combination may become the largest. This ranking is not affected by a yield effect due to extension increasing from 5% to 10% (Table 7-8).

The FSR-OSR-E&C and FSR-OSR-E&C-P combinations have negative interactive effects because, as explained above, the extension costs are larger than the gains in farm net benefits. The interactive effect for the FSR-OSR-E&C combination, however, turns positive for a 10% yield effect due to extension (Table 7-8). Again, this suggests that there is a threshold of yield effect between 5 and 10% at which the increase in farm profitability balances the increase in extension costs. The negative interactive effect for the FSR-OSR-E&C-P combination persists for the same reason given for the E&C-P combination with a 5% yield effect.

In sum, strong interactive effects exist between FSR and the other possible investments, particularly between FSR and E&C, on one hand, and between FSR and OSR, on the other hand. This confirms that the production impact of FSR depends on the performance of complementary institutions of the agricultural technology system or on the marketing and policy environments. The negative interactive effect between improvements in the technology transfer system and improvements in the marketing system and fiscal policy implies that investing in the technology transfer system, particularly in the extension function, is not advisable even when removing economic distortions, unless the yield effect due to extension is high or the technologies ready for extension are improved. When a combination of three investments is considered, the largest interactive effect is between FSR, improvements in the technology transfer system and promoting improvements in the marketing system and fiscal policy, then between FSR, additional on-station research and promoting improvements in the marketing system and fiscal policy, and lastly between FSR, additional on-station research and improvements in t

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Sensitivity analysis of the interactive effects suggests that: 1) when the time preference is given to long-term objectives, complementing FSR with additional on-station research has probably greater returns than complementing with technology transfer improvements; and 2) the interactive effects of combinations including improvements in the technology transfer system are sensitive to the yield effect due to extension. The estimation of these interactive effects are used to determine sequences of public investments over time in the next section.

7.2.3. Conclusions

This section investigated the conditions under which FSR in the Region of Mopti would become a profitable investment. FSR must be associated with additional public investment to be a profitable investment in itself. The additional investment could be 1) additional on-station research, 2) promoting improvements in the marketing system and fiscal policy, or 3) improving the technology transfer system. Large interactive effects between these individual investments and FSR confirm that the production impact of FSR depends on the performance of complementary institutions in the agricultural technology system and on changes in agricultural policy. In particular, improving the functioning of the agricultural marketing system and reforming fiscal policy appear to be the most important pre-conditions for positive and significant returns to FSR.

Among all the possible investment combinations, the scenario combining FSR with additional on-station research, technology transfer improvements and promoting

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7.3. Policy Implications: an Investment Strategy

Under the assumption that human and financial resources are limited in the short run but can be gradually expanded over time, the investments are staggered. Depending on the political acceptability of improving the functioning of the agricultural product marketing system and reforming fiscal policy in the short run, two series of investments are proposed.

The sequence of investments within each series is determined by the interactive effect that is generated when one investment is added to another one. The economic returns to the scenarios estimated in Table 7-7 cannot be used to determine the sequence of investments in each series because these economic returns are estimated for a combination of investments made simultaneously and not sequentially over time. Therefore, although simulating the staggering of investments would be the most accurate method of estimating the returns to the series of investments, comparing the strength of the interaction between investments when these investments are made simultaneously can provide a good indication of the appropriate sequence of investments. The appropriate sequence of investments is a sequence that optimizes the interactive effect between investments.

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In the first series of investments, when improving the functioning of the agricultural marketing system and reforming fiscal policy are considered politically acceptable in the short run, investment in promoting these improvements is the least costly and only profitable scenario among the scenarios that include only one type of public investment (Table 7-7). Promoting improvements in the marketing system and fiscal policy (P) is, therefore, the first recommended investment of the series. Particularly fiscal reforms can be implemented almost instantaneously and with low investment costs. Removing tax-related transfers from the input and output marketing system does generate an economic as well as financial impact. However, because removing these transfers is a one-time measure, the economic growth that it stimulates tend to diminish then unless other investments improve productivity.[107] These investments are considered next.

Investment in FSR is advised next because it adds a significant interactive effect to the first investment whereas investment in the technology transfer system brings a negative interactive effect. The time for investing in FSR depends on the domestic availability of human and financial resources.

The third step in the first series of public investment is investing either in the technology transfer system or in additional on-station research. The recommendation about this step is unclear. Both types of investment add similar interactive effects to the joint FSR-P scenario (Table 7-7). Improvements in the technology transfer system add, however, a greater interactive effect to FSR than additional on-station research does, but the interactive effect between FSR and additional on-station research is underestimated

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and the interactive effect between improvements in the technology transfer system and promoting improvements in the marketing system and fiscal policy is negative. In addition, these interactive effects depend on the rate of time preference. Additional on-station research should probably be given priority over the investment in the technology transfer system because improving first the performance of the technologies at the station level before strengthening extension is a logical succession of investments. This succession of investments is confirmed when preference is given to long run objectives over short run objectives. Carrying out additional on-station research before strengthening the technology transfer system also depends on the technical, financial and institutional feasibility of both investments. Such feasibility should be analyzed in more depth. Simulating the staggering of public investments over time could also be helpful. For example, additional on-station research should come as soon as human and financial resources are adequate because of long leadtimes in research.

The final investment in the first series would be improving the technology transfer system if the preceding investment was additional on-station research. Although improving the technology transfer system adds a negative interactive effect to the FSR-OSR-E&C-P combination, it adds large interactive effects to the FSR-E&C and FSR-E&C-P combinations (Table 7-7). Therefore, this investment should also be considered in the series of investments.

In the second series of investments, improving the functioning of the agricultural marketing system and reforming fiscal policy are considered politically unacceptable in the short run but acceptable in the intermediate run. In this case, only the joint investments in FSR-E&C and in FSR-OSR are profitable among the least costly scenarios (Table 7-7). The joint investment in FSR and E&C yields a net present value unacceptable in the

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unacceptable in the short run, the optimal investment pattern would be to invest simultaneously in FSR and additional on-station research or in the technology transfer system depending on the time preference and the expected yield effect due to extension, then in promoting marketing and fiscal improvements, and finally in the technology transfer system or additional on-station research depending on which investment is left. Starting by improving the input and credit functions with or without FSR is also a possibility that may yield quick returns. These two investment series are expected to yield an IRR between 14 and 26% and an average ROR between 21 and 99%.

The findings of this chapter and this investment strategy have important implications for both the roles and organization of agricultural research and extension in Mali and in the Region of Mopti. These implications are examined in the following chapter.

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8. SUMMARY AND IMPLICATIONS FOR AGRICULTURAL RESEARCH AND EXTENSION

Although FSR has been widely accepted as an appropriate approach to identify problems and solutions regarding farm productivity, several setbacks in institutionalizing FSR in Africa during the last decade have discredited the role that FSR can play in improving farm productivity (Tripp et al., 1990). FSR is still regarded as a significant improvement over the conventional model of technology development and transfer, involving essentially a one-way flow of information from research station to extension demonstration to farmer. The FSR approach has been innovative in that it responds to the need for technologies appropriate to the local specific circumstances of farmers, it includes farmers in the process of technology choice and development, and it allows farmers' problems to set the agenda for specialized disciplinary and commodity research (Collinson, 1986, p. 1). Secondarily, FSR has generated grass-roots information for policy-makers and planners to facilitate technological and policy changes. However, FSR has performed poorly in increasing farm productivity through technology development. The difficulties of institutionalizing FSR and the weaknesses of commodity and disciplinary research programs to back up FSR are generally the two main reasons given to explain the poor performance of FSR (Gilbert et al., 1980, p. 71; Collinson, 1986; Tripp et al, 1990; USAID, 1989a; Merill-Sands, 1988; Eicher, 1988, p. 28). These explanations suggest that more attention should be devoted to examining the pre-

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conditions necessary for FSR to stimulate farm productivity. Accordingly, this study has examined the conditions that would be needed for a possible FSR project in the Region of Mopti to have significant production impact.

Initially, the main objective of this study was to evaluate ex-ante the production impact of a possible FSR project in the Region of Mopti and to indicate the factors that would affect the returns to this project. Because the ex-ante evaluation yielded a low rate of return to FSR, alternative public investments to complement FSR were investigated and proposed. The findings of this study shed some light on possible ways to orient the objectives and organization of agricultural research, FSR and extension in Mali. Since the government of Mali is currently concerned about how to reorganize and strengthen the national agricultural research system (NARS) and extension, these findings are particularly à propos.

The first section summarizes the major findings of the study and the related implications for public investment in the Region of Mopti. The second section discusses the major implications for the roles and organization of agricultural research, FSR and extension in the Region of Mopti, Mali and other African countries. The third section briefly reviews the methods used in the study to evaluate ex-ante the production impact of FSR and combinations of alternative public investments and concludes with recommendations for further ex-ante evaluations of FSR.

8.1. Summary of Findings and Implications for Public Investments

The major findings of this study concern six consecutive areas of research: 1) the major constraints to farming systems in the Region of Mopti, 2) an FSR program to release these constraints, 3) the expected production impact of the FSR program, 4) the

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returns to investments complementary to FSR, 5) the interactive effects of combining these investments with FSR, and 6) the identification of an investment strategy for increased farm production. This review begins with the first three of these areas.

8.1.1. Farming Systems Research in the Region of Mopti

a) Constraints to the Farming Systems in the Region of Mopti

All production systems in the Region of Mopti have dramatically suffered from the low rainfall that characterized the period 1968-88. The average rainfall over the decade 1979-87 was 20% lower than the historical average. During the actual drought periods even the local short-cycle varieties of rainfed crops could not complete their cycle. Oryza sativa rice was not able to develop sufficiently before the arrival of the flood. Both perennial grasses and ligneous species in the wet-season grazing areas were not able to regenerate. The late arrival and weakness of the floods have particularly affected natural flood and flood-control irrigation, recessional cultivation, recessional pasture and the fish population. This climatological deterioration has exacerbated the disequilibrium which already existed between herd size and carrying capacity.

Soil nutrient deficiencies in phosphorus, nitrogen and organic matter in combination with low soil water retention limit yields of rainfed crops and the biomass of the wet-season pasture. Any significant increase in productivity requires the use of chemical fertilizer, manure and water retention techniques. Strong winds and run-off water are additional natural constraints to rainfed agriculture in this area. Sand storms cover the seedlings in the Seno plain and fill some lakes in the lacustrine zone with sand. Run-off erodes arable land and removes fertile topsoil from the Bandiagara plateau and the peripheral areas of the Delta. Rainfed crops are subject to insect attacks both in the

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field and in storage. Raghuva headborer, in particular, frequently attacks millet, and other insects inflict serious damage on cowpeas in storage. Borers are also frequent on Oriza sativa rice. Striga is widespread in millet and cowpea fields, and wild rice species (Oryza bartii and Oryza longistaminata) are commonly found in rice polders. Termites, mice, rats and granivorous birds are active pests on all crops. Parasitic diseases persist among transhumant cattle and small ruminants.

In terms of input availability, seasonal labor scarcity is the most critical constraint to increasing agricultural output, particularly during the critical planting and weeding periods. As a result, animal traction has been well accepted among farmers (33% of the Seno plain mixed farmers and 40% of the ORM rice growers). However, the increased use of animal traction is hampered by unpredictable equipment supply, lack of agricultural credit, and difficulties in maintaining draft animals. In addition, during the cropping season, cash and food reserves are not available for hiring laborers and few laborers are actually in the labor market at this time. In contrast, rice growers more frequently are able to hire laborers from the rainfed areas for weeding, harvesting and threshing because labor demand for rainfed crops is relaxed by this time. Increasing population pressure on arable land results in a break-down of the traditional rotation system of long fallow periods, resulting in the cultivation of marginal land and the consequent depletion of soil and grazing and timber resources.

In addition to variable and unpredictable rainfall, intra- and inter-annual crop price volatility discourages the intensive use of purchased inputs, primarily insecticides and chemical fertilizers. The absence of any profitable cash crops or other income-generating activities besides migration, and the head tax burden hamper investment in agriculture. As a result, input and product marketing infrastructure is not well ieveloped, pa

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developed, particularly in the rainfed area. Agricultural credit and input-supply facilities are inadequate for the minority of farmers who have an effective demand for modern inputs. Market outlets for livestock products are shrinking as a result of the decline in purchasing power among domestic consumers and the fall of import demand from coastal countries, particularly Côte d'Ivoire. Tenure conflicts over the use of arable land, pastures, forage, wells and fishing areas are particularly severe in the Delta and disrupt an optimal allocation of natural resources.

b) FSR Program

Primarily for reasons of efficiency and equity, in the short run FSR should focus on research areas related to the rainfed crop-based farming system. In the intermediate run, FSR could extend its research areas to include the flooded-crop-based farming system, provided that improved rice varieties become available from station research. Because the development of livestock and fisheries, the two other major resources of the region, depends more on resolving tenure conflicts over the use of pastures and bodies of waters and on development of infrastructure and market outlets than on any contribution that might come from on-station research or on-farm research, FSR on livestock and fisheries should not be given high priority in the short run.

Given the constraints to the rainfed crop-based farming system, research for the rainfed crop-based farming system should be oriented towards: 1) developing technical packages that address the problems of water retention, soil fertility, soil conservation, plant protection, and crop and livestock integration; 2) developing food processing and storage techniques; 3) fostering collaboration between commodity and disciplinary researchers to define the on-station research objectives in breeding, plant protection, fertilization, and cultural practices, and to collect and screen local millet germ plasm; 4)

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identifying the constraints to capital market development and to the production and delivery systems for inputs, and developing recommendations for alleviating these constraints; 5) identifying marketing outlets for raw products, such as cowpeas, groundnuts and sesame, and evaluating the market for processed products, such as groundnut oil, shea butter and millet flour; and 6) understanding specific constraints, such as labor bottlenecks and draft animal maintenance, and developing solutions.

Research for the flooded-crop-based farming system should be oriented towards: 1) identifying the labor bottlenecks during the cropping calendar, and developing labor-saving techniques; 2) identifying the most efficient rice processing techniques for rice growers; 3) fostering the collaboration with on-station research to collect local Oryza glaberrima germ plasm and define on-station objectives; 4) identifying the constraints to the capital market for rice growers outside the ORM polders, and developing solutions.

By developing these research areas, FSR may improve the comparative advantage of the region in groundnuts for local consumption, in the joint millet and cowpea cropping and rice for the consumption markets of Mopti and Gao, and in sesame for export.

c) Production Impact of FSR

Under the current marketing, institutional and policy conditions prevailing in the Region of Mopti, an FSR project confined to adapting and transferring results currently available from station research will likely have a low internal rate of return (IRR). The estimated IRR for such a program is 2% and is very sensitive to variations in project costs, yields and prices of agricultural products. To a lesser extent, the time taken to complete research, the incremental farm costs, the diffusion parameters and the life of the innovation also affect the stability of the project's economic value. Such an FSR program would af

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program would affect approximately 60% of the population in the rainfed agriculture zones or 30% of the total population of the region. About half of the direct benefits of FSR would accrue to farms in the southern part of the rainfed area. Benefits are more favorably distributed to women than men. These returns to FSR are underestimated because they exclude the effects of other research areas suggested for FSR and the external effects of reducing food aid and outmigration.

From a purely economic standpoint, an FSR project limited to adapting and transferring new technological components currently available from station research is not advisable under current conditions. The sensitivity test on the economic return to FSR indicates that the following conditions must be met before implementing an FSR project in the Region of Mopti. On-station research must make available technological components with higher yield-increasing effects and/or higher risk-reducing effects than those currently available. The agricultural product marketing system must be able to offer higher and more stable prices to producers or, alternatively, unit costs of production must fall. The technology transfer system must be able to produce and deliver agricultural inputs and supply credit. Finally, the NARS must have the human and financial resources to sustain an expansion of its research activities.

Sensitivity analysis on the financial profitability of the technical packages used in the ex-ante evaluation reflect the same problem areas. Although the technical packages were constructed using the best information available from on-station research and on-farm trials, the financial profitability of most of these packages was unstable given a 10 to 20% change in output prices, yields or costs of production. Given the likelihood of such changes and farmers' risk aversion, this instability implies that the current agricultural input and product market conditions and current technological development

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at the research station level severely limit the capacity of FSR to develop technical packages appropriate to actual farming conditions. On the other hand, this instability also indicates that a relatively small decrease in input costs or increase in output prices or in yield performance would have a relatively large effect on the profitability of these technical packages. These effects would, however, induce technical change only if farmers perceived these changes as fairly stable.

These restrictive conditions for implementing an FSR project do not, however, mean that FSR has no role to play in the Region of Mopti. The economic return provided by the ex-ante evaluation captures the effects of only one FSR function, namely that of diagnosing on-farm problems and adjusting technologies currently available from station research to the particular set of problems faced by farmers. Other important FSR functions excluded from the evaluation are 1) improving the relevance of research efforts through a better conveyance of information about farmers' needs to the research system, and 2) informing policy-makers and planners about measures that could generate and transfer improved technologies. Because the production impact of these two important linkage functions also depends on strengthening commodity and disciplinary research and on measures to facilitate the transfer of improved technologies, the impact is evaluated as the result of complementing FSR with additional on-station research and improving the marketing, institutional and policy environments. The public investments that could complement FSR were evaluated first individually, then in combination with each other and with FSR.

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8.1.2. The Economics of Public Investments that Complement FSR

It was hypothesized that the FSR project could have a greater production impact if new technological components were available from on-station research and if the socio-economic and institutional environment of the Region of Mopti were improved. This section reviews the evaluation of different combinations of FSR, additional on-station research, improvements in the technology transfer system and promoting improvements in the marketing system and fiscal policy, and outlines an investment strategy to improve the productivity of the farming systems in the Region of Mopti.

a) Returns to Investments which Complement FSR

Joint investment in FSR and additional on-station research yielded an internal rate of return of 14%, a much higher IRR than FSR alone (2%), and an average rate of return of 21%. Although underestimated, the interactive effect between FSR and additional on-station research is large, three times larger than the additional investment in on-station research. This large interactive effect indicates the complementarity between on-station research and FSR, which underscores the importance of associating additional on-station research with FSR.

The returns to improving extension, input delivery and credit supply were lower than the costs of improving the technology transfer system, unless the yield effect due to extension increases to 14%, which is an over-optimistic expectation. Because the expected gains from extending current technologies are low relative to the costs of agricultural extension, investment in extension should be delayed until the research system can generate improved technologies. In contrast, improvements in the input and credit supply functions are likely to yield positive returns.

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Three areas for market improvement were considered to increase prices received by farmers and, thereby, stimulate technology transfer and adoption. First, the elimination of export restrictions and costly licensing procedures as well as the promotion of new agricultural outlets would prevent producer prices from falling precipitously during surplus periods. Second, supporting farmer associations and a market information system would give farmers a greater collective bargaining power. Third, encouraging the participation of farmer associations in assembly operations and reducing market uncertainties would lower marketing margins and, hence, increase the prices received by farmers and the quantity traded. The fiscal policy reforms analyzed consisted of removing all taxes, subsidies and duty administrative fees on agricultural inputs and outputs.

Promoting such improvements in the agricultural product marketing system and fiscal policy resulted in an internal rate of return of 18% and an average rate of return of 21%. The promotion of these improvements yield an average ROR similar to a joint investment in FSR and additional on-station research, but with a NPV three times smaller. These returns are, however, underestimated since direct and induced effects of these improvements on other areas of the agricultural sector and on other sectors of the regional economy were not considered.

The economic returns from promoting these marketing and fiscal improvements suggest that removing tax-related transfers from the input and output marketing system has a direct economic impact as well as a financial impact. As the financial costs of marketing are reduced by removing transfers, prices received by farmers for their products increase and prices paid by farmers for farm inputs decrease. These changes in market prices stimulate adoption of new technologies, which results in real economic

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growth. However, because removing such transfers is a one-time measure, the economic growth that it stimulates will tend to diminish unless other types of improvements, such as in the road network and marketing infrastructure, follow. In contrast, investing in agricultural research provides the infrastructure to increase productivity on a long-term basis. Agricultural research has, however, a longer leadtime than removing tax transfers. Which investment should be given priority is discussed in the next section.

b) Complementarity among Selected Public Investments

FSR must be associated with additional public investment to be profitable. Among the two-by-two combinations of FSR with another public investment, the combination of FSR with either additional on-station research or improvements in the technology transfer system have similar NPVs and average rates of returns (the RORs are 21% and 23% respectively). The combination of FSR with promoting marketing and fiscal improvements has a lower NPV and average rate of return (the ROR is 11%). The high returns to combining FSR with other public investments as well as the large interactive effects estimated between FSR and the other investments reinforces the finding that the production impact of FSR depends on the performance of complementary institutions in the agricultural technology system and on the marketing and policy environments.

Whether FSR should first be complemented with additional on-station research or with improving the technology transfer system depends on the time preference. When long-term objectives are favored over short-term objectives, the returns to joint investment in FSR and additional on-station research are larger than the returns to joint investment in FSR and improvements in the technology transfer system. This suggests that, in the short run, existing constraints in the technology transfer system are more important than t

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important than the lack of station research. Without FSR, however, improvements in extension, input supply and credit supply yield a negative rate of return. Improving only the input and credit transfer functions without the costly extension function is a possibility that would probably show a positive return.

Among the three-by-three combinations of FSR with other public investments, the combinations that include FSR and promoting improvements in the marketing system and fiscal policy have the highest NPVs and average rates of return. These combinations reveal large interactive effects, suggesting that even if other investments have already been made, there remains large potential gains from promoting improvements in the marketing system and fiscal policy. The combination that includes additional on-station research in addition to FSR and marketing and fiscal improvements has a higher NPV and rate of return than the combination that includes the technology transfer improvements (the RORs are 119% and 93% respectively). This difference is amplified when preference is given to long-term objectives over short-term objectives. Based on these rates of return and interactive effects, the following investment strategy is proposed.

c) Public Investment Strategy

Among all possible investment combinations, the scenario combining FSR with additional on-station research, technology transfer improvements and promoting marketing and fiscal improvements yields the highest net present value ($ US 9.34 million). In addition, with a satisfactory MRR of 79% and a high average rate of return of 99%, this scenario is considered the best investment among mutually exclusive scenarios.

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This best scenario is, however, probably not feasible given current human and financial resource limitations in Mali. Assuming that human and financial resources might gradually increase over time, the possibility of staggering public investments was examined. If improving the functioning of the agricultural product marketing system and reforming fiscal policy is politically acceptable in the short run, these should be the first changes implemented because of their large and immediate impact. Because market conditions would facilitate technology transfer and adoption, investing in FSR would be an advisable second step. The third step in this series would be to invest in additional on-station research to take advantage of the strong complementarity between FSR and commodity and disciplinary research. This third step should be taken as soon as human and financial resources are adequate because of the long leadtimes in research. However, FSR could already begin adaptive research on the results already available from on-station research and the collection of information and data that could improve the relevance of on-station research efforts. The last step in the investment series would be investing in the technology transfer system. Improving the input and credit supply functions could come earlier in the sequence of investments, but improving the extension function should be delayed until the research system is able to generate improved technologies ready for extension.

If marketing and fiscal improvements are politically unacceptable in the short run, FSR with either additional on-station research or improvements in the technology transfer system should begin the sequence, depending on the time preference of the decision maker. An alternative first step would be to improve the input and credit functions with or without FSR. The second step would be promoting improvements in the marketing system and fiscal policy. Then, depending on the previous investments, additional on-station r

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Although the staggering of investments was not simulated, the IRR for the first series of investment is expected to range between 18% and 26%, and its average rate of return will vary between 21% and 99%. For the second series of investments, the IRR is expected to range between 14% and 26% and the average rate of return will vary between 21% and 99%. These expected returns should be confirmed by simulating the staggering of investments. In addition, since there are uncertainties in key variables that are combined in the final rate of return estimate, risk should be assessed for each proposed investment and series of investments by using, for example, a Monte Carlo simulation procedure (see section 8.3.2.).

In sum, the major finding of this study is that FSR alone is not the most effective means to increase farm productivity in the Region of Mopti. Improving the functioning of the agricultural marketing system and reforming fiscal policy appear to be the most important pre-conditions for positive and significant returns to FSR. Investments in FSR, additional on-station research and the technology transfer system could then follow sequentially. If these pre-conditions cannot be met in the short term, then an alternative pattern of investments would be first investing simultaneously in FSR and additional on-station research, then promoting improvements in the marketing system and fiscal policy, and lastly strengthening the technology transfer system with, however, the possibility of improving the input and credit supply earlier in the sequence of investments.

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8.2. Implications for Agricultural Research and Extension

Until recently, when the President of Mali requested the agricultural research institute (IER) to draft a 12-year strategic plan for agricultural research by June 1990, the Malian agricultural research system has not had a well-defined long-term agricultural research strategy. Only short-term research plans on a commodity or discipline basis are defined at the annual National Technical Specialized Commissions (CTS) and biannual National Scientific and Technical Committees. The National Center for Scientific and Technical Research (CNRST), which is responsible for establishing pluriannual planning for research, lacks the financial and political means to operate. As a result, research programs are not well coordinated and suffer from the lack of clearly defined long-term objectives (ISNAR, 1990). The Malian agricultural research system also suffers from a lack of internal communication and from poorly developed linkages with farmers, development agencies, and policy-makers (Coulibaly, 1987; Henry de Frahan et al., 1989; Staatz, 1989; ISNAR, 1990).

8.2.1. Agricultural Research Strategy in Mali

a) Long-term Research Objectives

The objectives of agricultural research should be consistent with the major production potentials and constraints of the farming systems. For rainfed agriculture in the Region of Mopti, the agricultural research system should develop technologies that are not highly intensive in purchased inputs, as long as the profitability of purchased inputs is low and variable and input marketing is not improved. These technologies should be designed to increase water retention and soil fertility to improve the agronomic environment of the production systems. For the areas with a more stable

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environment, plant breeding should develop varieties for moderate management levels, focusing on yield improvement, quality characteristics, and resistance to disease (mildew), insects (Raghuva) and weeds (Striga). For the more variable areas in the region, plant breeding should continue to emphasize both drought resistance at the critical early and post-flowering phases, and a relatively long growing cycle to avoid the peak swarming period of the boring caterpillars. Plant breeding should, however, de-emphasize programs on short growing season varieties because these varieties are particularly subject to damage from grain-eating birds and insects on the heads. Screening the best performing local varieties for drought, and insect resistance, stable yield and taste is also recommended to provide farmers with a greater diversity of varieties to cope with a variable bioclimatic regime. Other research objectives include: 1) adapting mechanized cropping techniques to farm circumstances, 2) improving the integration of crop and livestock activities, 3) developing anti-erosion and agroforestry techniques, 4) diversifying crop enterprises, and 5) developing food processing and storage techniques.

For the flooded agriculture of the Region of Mopti, the research objectives should include: 1) developing peak-labor-saving technologies (such as a multiple-purpose agricultural implement adaptable for both lowland and upland cropping operations), 2) screening the best performing local rice varieties grown under natural submersion to improve yields and production stability under traditional or moderate management level, 3) improving rice varieties grown under controlled submersion to improve yields and production stability under moderate management level, rather than high management level. For flood recession agriculture, a diagnostic survey should be carried out to identify the research objectives.

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Input from economics and other social-sciences should be incorporated early in the development of these technologies. In addition, the constraints to capital markets, to the production and delivery systems for inputs, and to the agricultural product marketing system should be identified. Means to alleviate these constraints should be investigated. Sources of income from cash crops and food processing should also be examined as part of a strategy to sustain increased agricultural production. Institutional constraints such as those imposed by the rigid enforcement of the forestry code on wood access and by the fiscal regulations on farmers' revenues should also be investigated.

No research objectives are proposed for livestock and fisheries. Resolving tenure conflicts, developing infrastructure for eradicating parasitic diseases and facilities for providing water in the dry areas, and developing market outlets should be given priority over animal research to rehabilitate livestock in the Region of Mopti. Greater priority in the short run needs to be given to resolving conflicts over the use of water and to developing regulations to guarantee fish replenishment than to hydrobiological research. These objectives for agricultural research in the Region of Mopti have important implications for the composition of the FSR team, which will be discussed in section 8.2.2.

b) Research Methodology for the Malian Agricultural Research System

Although the Malian agricultural research system is the largest in terms of research personnel in francophone sub-Saharan Africa, its very limited financial resources prevent researchers from being fully operational and reduces the effective number of 337 person-years of scientists to approximately 145 (ISNAR, 1990).[110]

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Domestic financial resources are expected to continue to limit the agricultural research because, under tight budget restrictions, the government will be unable to increase its total contribution to agricultural research in the near future.[111] Therefore, because of its limited financial resources, the Malian agricultural research system cannot sustain large applied research programs.

With 145 person-years of full-time scientists, the Malian agricultural research system appears to meet domestic human resource requirements to perform adaptive research programs effectively. Financial resources for adaptive research could be increased by reallocating the budget from personnel expenses to operating and equipment expenses. Since June 1987, the government has facilitated the departure of government personnel by giving severance bonuses or advancing the retirement period. The government's savings in research personnel expenditures should be reallocated to operating research budgets to sustain adaptive research.

While concentrating on adaptive research and on-farm tests, the Malian agricultural research system should devote a relatively large share of its limited resources to activities involving external linkages with IARCs, policy-makers, extension services, and farmers, on the one hand, and to domestic research focussed on collection, analysis, and interpretation of data and research results, on the other hand. Some applied research could be conducted domestically on very selective issues critical to development efforts when imported options are not available. One example is a program of varietal

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researchers with at least a masters degree will increase to 60 (ISNAR, 1990).

[111] In 1986, the total annual research budget supported by the national budget was 0.4 % of the agricultural gross domestic product and 44% of total agricultural research expenditures. The budget covers 90% of the 350 person-years of scientists (10% are expatriate researchers) but only 28% of the recurrent and capital costs (ISNAR, 1990).

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improvement by radiation to reduce the shattering of the Oryza glaberrima species.[112] Other examples are the INTSORMIL physiology research to understand the critical factors required for drought resistance in sorghum and millet and the TROPSOILS/INTSORMIL soil research to determine the factors causing soil toxicity.[113] This applied research should, however, not divert large human and financial resources from adaptive research.

For most of the applied research, however, the Malian agricultural research system should rely heavily on regional centers, such as the ICRISAT Sahelian Center and WARDA, and on larger NARS of the same agroclimatic region. In addition to carrying out selected applied research activities, each regional center could be more involved in coordinating applied research in its areas of expertise (speciality) among the NARSs of the region. A collaborative regional research network could be developed on the basis of the comparative advantage in agricultural research of each individual NARS and have its research activities jointly determined by the NARSs' leaderships and each regional center's director through regular review and planning sessions.[114] These regional centers could play additional roles in strengthening NARSs' scientific and institutional capacity to conduct adaptive research and applied research on selected research areas. Probably with ISNAR, they could provide the training and

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[112] Although the radiation is conducted by a Swiss laboratory, the program is managed by the Mopti Rice Research Station.

[113] INTSORMIL (International Sorghum/Millet) and TROPSOIL (Tropical Soils Collaborative Research Program) are two initiatives of the Collaborative Research Support Program (CRSP) developed by the Board for International Food and Agricultural Development (BIFAD), an Advisory Board of the US Agency for International Development.

[114] For more details about this suggestion, see WARDA (1989).

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methodologies required to conduct adaptive and applied research and help design the appropriate research strategy for each individual NARS. These regional centers could also play an active role in mobilizing external funding to complement national programs in their efforts to establish a sustainable research system. The option currently being examined by the SPAAR group of implementing an additional regional center to coordinate agricultural research among the Sahelian countries and strength their scientific and institutional research capacity should be carefully assessed. The coordination function of this additional center may duplicate that of the existing regional centers and place additional administrative burdens on the NARSs' personnel. The existing regional centers are better suited to provide technical support and train researchers in their respective areas of specialization. ISNAR, which has gained experience in assisting developing countries to improve the effectiveness and efficiency of their NARS since 1980, could concentrate its efforts in the Sahelian sub-region on improving communication among the individual NARSs and between the NARSs and the regional centers.

c) Agricultural Research Organization of the Malian Agricultural Research System

Because the cost effectiveness of adaptive research largely depends on strong internal and external linkages and on-farm research activities, emphasizing adaptive research has important implications for the organization of the Malian agricultural research system. Currently, this system is inadequately structured to conduct adaptive research. Many studies on the Malian agricultural research system report poor internal communication between biophysical and social disciplines and, to a lesser extent, between commodity/disciplinary and systems research (Coulibaly, 1987; Henry de Frahan et al., 1989; Staatz, 1989; U

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1989; Staatz, 1989; USAID, 1989b; ISNAR, 1990). Weak external linkages with policy-makers, extension agencies and farmers are also documented.

The simulation results of this study confirm the need to pay more attention to the internal and external linkages to research. First, the strong complementarity between FSR and additional on-station agricultural research calls for removing institutional and training barriers between on-station researchers and FSR practitioners. Second, the strong complementarity between marketing improvements and policy reform, on the one hand, and agricultural research, on the other hand, confirms the need to incorporate economics and other social-science input into the agricultural research process. Third, the strong complementarity between improvements in the technology transfer system and agricultural research calls for strengthening linkages between the regional development agencies that handle extension, input marketing and credit, and agricultural research.

Several proposals for restructuring research to foster effective linkages internal and external to the agricultural research system are currently being suggested in Mali. One possibility is to decentralize agricultural research by reinforcing or creating research centers that would serve homogeneous agroecological zones (ISNAR, 1990, pp. 87-88). These regional research centers would conduct multidisciplinary research programs, concentrating on a few important commodities in their immediate agroecological zone and receiving national responsibilities for their commodities. Such decentralization would result in greater interaction of researchers with both extension staff and farmers because it facilitates the involvement of all these participants in finding the most appropriate opportunities for improving productivity on a whole-farm basis. The risk that on-farm programs evolve independently from on-station agricultural research programs would also be reduced.

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As has been done in Senegal, FSR could be conducted and a network of adaptive trials on farmers' fields established, using these regional research centers. Because they would be located at the same site, on-station research and FSR could be coordinated by the head of the regional center and, hence, benefit from close linkages. For example, joint field visits between the farming systems and commodity or disciplinary researchers become easier to organize, providing commodity or disciplinary researchers with direct and regular contact with farmers. FSR's ability to channel relevant information from farmers' points of views to station-based research priority-setting would improve. An institutional arrangement, such as the more frequent use of the formal link existing between the Division of Planning and Evaluation (DPE/IER) and the Ministry of Planning, that would facilitate the communication of the institutional and policy constraints faced by the farming systems to policy-makers should be investigated.

To foster greater interaction between biological and social scientists within the research institutions, each regional research center could add one economist or social scientist to the commodity and disciplinary technical scientist team (Staatz, 1989, p. 19). The economists or social scientists would specialize along commodity lines and be responsible for investigating all issues in the commodity subsector, from production to processing and marketing. This appointment would create formal and informal opportunities for technical and social scientists to interact with one another and respond to the need to incorporate economics and other social-science input into the agricultural research process, particularly earlier in the design of the technologies themselves. The head of the regional centers would coordinate the research activities between technical scientists and social scientists. Other economists and social scientists would specialize on issues that cut across subsectors, such as production and delivery of agricultural inputs, agricultural credit, la

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agricultural credit, land tenure, and price and trade policy. This team would be based in Bamako and be responsible for contacts with policy-makers and external institutions, such the IARCs and donors. Coordination of the research efforts between these two groups of social scientists would need to be strong and facilitated by adequate travel funds. The head of the Bamako-based social scientist team would primarily be in charge of this coordination. In addition, he or she would regularly consult the Bamako-based technical scientists to strengthen coordination between biological and social sciences.

In sum, the decentralization of research activities across the country in several regional research centers would facilitate effective linkages between research and development institutions, between on-station research and FSR, and between technical and social scientists. The regional research centers would include: 1) technical scientists specialized along commodity or disciplinary areas, 2) social scientists specialized along commodity lines, and 3) FSR practitioners specialized in problem solving research. In Bamako, the social scientists would specialize in issues that cut across commodity subsectors and the technical scientists would support and coordinate the biophysical research activities carried out in the research centers. The two Bamako-based teams would be responsible for the contacts with the other national research institutions, educational institutions, the government (Ministry of Agriculture, Ministry of Planning, Ministry of Finance and Trade, Ministry of Education, etc.), the IARCs and donors. The heads of each Bamako-based team would be responsible for coordinating research activities within their own team and between the regional center-based scientists and the Bamako-based scientists. Interdisciplinary interactions would, therefore, be stimulated at the regional center level and at the national center level.

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Several actions could encourage greater internal and external communication, until the reorganization of the Malian agricultural research system is accepted and put into effect. Providing support to the IER journal and organizing training sessions and workshops across divisions would stimulate greater interaction across disciplines (ibid., p. 18). The institutional linkages that exist between the CMDT, FSR and commodity research could provide an organizational model to link research and development in other areas of the country. The Division of Planning and Evaluation (DPE/IER) could play a greater role in communicating the policy issues debated at the Food Sector Strategy Commission (CESA) and the cereal market liberalization project (PRMC) to the other divisions and in suggesting research activities that would help inform these debates.

8.2.2. Organization of FSR and Research on Policy Reforms for the Region of Mopti

To ensure effective linkages between on-station researchers and FSR practitioners, the research organization suggested above would place the FSR units at the regional research centers where the bulk of commodity and disciplinary researchers would be located. However, by separating the FSR team from the commodity and disciplinary team, there is still the danger of poor linkages between them, even when both are at the same research site. In addition, implementing this type of organization for each agroecological zone is probably not feasible in the short term in Mali given the financial and human limitations of the research system.

A possible solution to this problem is the integration of a farming systems perspective into the traditional discipline-oriented and commodity-based research programs. All scientists of the regional research center could carry out both on-station and on-farm researc

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and on-farm research related to the center's commodity or specialization. In particular, agronomists could take on most of the on-farm and technology transfer responsibilities. Social scientists could reinforce the research programs. In addition to operate at the farmer level, they would examine the marketing issues elsewere in the subsector if no other instittutional arrangement is set up. This way of integrating a farming system perspective into the research programs reduces the risk of compartmentalization of research and fosters more direct and rapid communication between research and extension (Stoops, 1988). For example, this organization would facilitate the feedback function, which channels relevant information to station-based research priority-setting, and this feedback increases effective farmer participation in the research process. As a result, research efforts are better coordinated vertically, from farmers' needs to the research station. This option requires little institutional change or management reorganization, but a change in the incentive structure facing researchers.

Given the current limited human and financial resources of the Malian agricultural research system, the integration of a farming systems perspective into the traditional research programs is appealing, at least as a short-run solution. Several disadvantages of this option, however, suggest that a separate FSR unit closely linked to the commodity and disciplinary team is probably better in the long run (Collinson, 1986). The pre-determined focus of the team members into commodity or discipline inhibits the introduction of a systems perspective. Therefore, this option might not help prioritization efforts across commodities and disciplines, a major contribution from a full systems perspective. Horizontal coordination across farmers' problems, commodities or disciplines is hardly possible in the traditional organization. The team members' primary concern with a commodity or discipline is incompatible with area-oriented extension organization and, h

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organization and, hence, may hinder the development of linkages with extension. Lastly, a single team of researchers is unlikely to overcome effectively the complexity of an adaptive research program. An adaptive research program basically involves two broad sets of research activities that require different research skills. For example, the development of improved varieties requires, on the one hand, disciplinary or commodity researchers to concentrate their research activities on identifying promising local varieties, searching other varieties that can be transferred from other areas with little adaptation, adapting these materials to the local farm circumstances and executing collaborative programs with other research institutions. On the other hand, adaptive research requires subject-matter researchers (such as agricultural economists and agronomists) to concentrate their research activities on collecting, analyzing, and interpreting socioeconomic and agricultural production data and research results with a view to guiding the screening process, assessing the potential performance of the newly developed varieties and providing feedback to the commodity researchers.

In addition to the need to generate appropriate new technologies for farmers, the ex-ante evaluation indicated the need to improve the agricultural marketing system and reform fiscal policy. In that area, research topics specific to the Region of Mopti could include: 1) the comparative advantage of the region in processing raw products for new markets, 2) the domestic market outlets for raw products produced in the region (millet, rice, cowpeas, groundnuts) and export possibilities for sesame, 3) the appropriate measures to reduce marketing margins in the region, 4) the type of support that farmer associations need to manage marketable surplus, negotiate input purchases, and manage formal credit programs, and 5) the incentives to stimulate the production and delivery of animal traction equipment, pesticides and other inputs. Land tenure as well as herding, fishing and water dr

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Social scientists based at the proposed regional research center of Mopti could conduct research on these issues. In case research decentralization is delayed, an independent study on market improvements and policy reforms for the Region of Mopti could be very useful in light of the high economic returns to improvements in the agricultural marketing system and fiscal policy found by this study. Because a close association between the researchers of the proposed study and the policy-makers would facilitate the communication of the recommendations for market improvement and policy reforms, the Division of Planning and Evaluation (DPE) of IER is probably the right choice to house the study. The DPE has frequent and direct contact with the Ministry of Planning and the Food Strategy Commission (CESA). To facilitate the field work and close contacts with the different regional institutions, the members of the study could work closely with the regional Office of the Ministry of Planning in Mopti. This regional Office is a member of the Regional Committee for Development (CRD), where regional development policy is regularly discussed under the chairmanship of the Governor of the region. Because the decision making process is centralized in Mali, the researchers of this study should, however, interact frequently with the Ministry of Planning in Bamako.

Another alternative would be to include an agricultural economist with experience in these broader policy and marketing issues in the FSR team. This agricultural economist would be primarily responsible for identifying marketing outlets for raw and processed products, constraints to rural financial market development, and constraints to production and delivery systems for inputs. Within the FSR team, a second agricultural

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economist would specialize in farm management and be responsible for identifying production constraints at the farm level and evaluating promising technologies. The FSR project would need two agronomists, one specialized in the agronomy of semi-arid rainfed crops and the other specialized in flood irrigation (natural and controlled) and recessional cultivation. The project would also need a livestock specialist to integrate crop and livestock activities and a sociologist to study the possibility of grouping farmers in village associations. In the long run, the skills of the FSR team members will probably need to include experience in transhumant herding and fishing, once the tenure conflicts are solved in these areas.

8.2.3. Roles and Organization of Extension for the Region of Mopti

Since 1988, the Ministry of Agriculture, with World Bank support, has been conducting a program to test and improve extension methods. These extension methods follow the organizational and pedagogic principles of the training and visit (T & V) approach. Extension by training and visit assumes that technology is available for farmers and that the critical constraining factor is the organization of clear extension messages and methods for delivering them. As a result, the extension workers exclusively concentrate on advice and promotional work related to agricultural production and are not involved in other activities that would distract them from their extension tasks (Benor and Harrison, 1977).

In Mali, a pilot extension program started in 1988 with three ODRs, including ORM, and expanded in 1989 to include an additional ODR and three Regional Directions of Agriculture (DRA), including the DRA of Mopti, in 1989. The ODRs participating in the pilot program, however, continue to be involved in the organization and supply of farm i

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and supply of farm inputs (including credit) and the marketing of produce, while the DRAs, due to insufficient operating funds, are only involved in extension work and collection of agricultural statistics. Given the difficulties of obtaining farm inputs and formal credit in the area covered by the DRA of Mopti and the lack of improved technologies ready for extension for both the areas covered by ORM and the DRA of Mopti, the benefit of strengthening extension is questionable. Moreover, in a situation of static technology, extension cannot achieve significant production gains by teaching farmers to make better use of their available resources because, as Schultz (1964) argues, farmers are likely to use already their available resources in an efficient manner. The constraints to increased productivity are likely to be reduced or removed only if there are technological breakthroughs, if farmers' resource base can be expanded through, for example, credit availability or new market opportunities, or if both occur. Based on the findings of this study and preliminary reports of the pilot extension program, intensifying extension through a T & V system is premature in the Region of Mopti. In addition to technology development, access to farm inputs and formal credit should be given priority over extension.

a) Priority among the Technology Transfer Functions

For the rainfed area of the Region of Mopti, the production and delivery of inputs and the supply of agricultural credit are currently the most deficient technology transfer functions. For example, farmers surveyed reported that the lack of quality equipment and formal agricultural credit prevent them from adopting animal traction. The lack of information and training to use the available technologies efficiently was never mentioned. Even though training farmers to use available technologies could improve efficiency, the gain in efficiency would need to be relatively large to cover the costs of extension. In th

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extension. In the case of animal traction, the major innovation for the rainfed agriculture in the Region of Mopti, the simulation results showed that extension must increase yields by 14% to offset its costs. Given farmers' existing resource constraints, such an impact on yields is unlikely. Although further research should study the productivity disparity among farmers and how to narrow it through technical advice, the information and teaching functions of technology transfer should probably not be given top priority at this time. In contrast, the availability of farm inputs and formal credit are essential ingredients for effective technology transfer. Information on market opportunities for both producers and traders is another critical service that could involve the public sector.

Furthermore, the current lack of improved technology to extend to farmers supports the view that focusing extension on offering technical advice to farmers for crop improvement is premature. Apart from the technologies already known by farmers, such as animal traction, fungicide, improved varieties, and some cultural practices, the agricultural research system in the region has no newly improved technology to offer that is appropriate for farmers of either the rainfed or the flooded areas. The simulation confirmed that improving the quality and relevance of agricultural research is a prerequisite for extension work on crop improvement.

The preliminary reports of the pilot extension program implicitly state that the basic conditions for making extension cost effective are missing (World Bank, 1989a). For example, the pilot T & V extension program at ORM suffers from the ineffective organization of seed production and distribution and from ambiguous technical advice. The DRA of Mopti continues to extend pre-defined technical advice for crop improvement instead of adapting technical advice to particular farm circumstances. For example, advice

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example, advice given on plowing, manuring, planting, thinning and weeding fail to take into account farmers' difficulties in obtaining and investing in equipment and draft animals, labor constraints and objectives to minimize risk. The preliminary report also suggests that the T & V system is implemented as a top-down structure insensitive to the farmers' requirements.[115] Such a top-down structure prevents relevant information at the farm-level from guiding agricultural research. Instead, for marginal, dryland farming areas where many farmers are primarily concerned with subsistence crops and where labor and soil fertility may vary greatly from farm to farm, the extension agents should be trained in giving farm management advice rather than conveying technical information.

The development of such skills implies a larger training effort than the one currently provided.[116] The recurrent costs of supporting a highly intensified extension agency - one extension agent for 400 farmers at ORM and the DRA of Mopti - are certainly beyond a sustainable threshold for the government of Mali, particularly in areas where the market for cash crops is limited. Although the T & V approach can be instrumental in improving extension staff performance and refocusing the attention on agricultural production extension, it is not currently appropriate for the Region of Mopti.

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[115] This is evident in one preliminary report which recommends that "contact" farmers who ineffectively participate in the extension program, should be replaced, without any suggestions to investigate the rationale behind these farmers' attitude (World Bank, 1989a).

[116] At the outset of the pilot extension program, trainers had five days of training and extension agents had two to three weeks (World Bank, 1989b).

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b) Organization of the Technology Transfer Functions

The organization of the supply of farm inputs and formal credit should receive priority over extension in the Region of Mopti. This section proposes some general principles to organize the supply of farm inputs and formal credit, and concludes with some recommendations to organize extension.

The distribution and supervision of farm credit should be removed from the duties of the extension agents of the ODRs and standardized under the same system. The involvement of the extension agents of the ODRs in filling out loan applications and collecting debts in addition to their training responsibility has the disadvantages of diluting their extension tasks and confusing the farmers on the precise role of the extension agents, who can be mistaken for debt collectors instead of agricultural advisors. Therefore, giving the responsibility for all credit distribution to the Cooperative Organization would be more consistent with its mandate. The DNACOOP has also a long experience in organizing producers in village associations. These village associations could play an important role in extending formal credit and assuring access to inputs for small households through a system of collective guarantee (Dioné, 1989, p. 361). In the longer run, these local associations could help mobilize local savings as well as provide credit, improving the functioning of rural financial markets.

In addition to the collective management of agricultural loans, these village associations could also negotiate farm input purchases and manage their marketable surplus. The participation of village associations in the collection of agricultural products and distribution of farm inputs would increase the volume of individual market transactions, thereby providing some economies of scale. This, in turn, would facilitate a greater participation of the private sector in agriculture provided that the ODRs gradually discontinu

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gradually discontinue the provision of farm inputs and the commercialization of farm production, on the one hand, and the government eases trade regulations and taxation, on the other hand. For example, the private sector could progressively handle the distribution of farm equipment and chemicals and the processing and marketing of rice, as currently is occurring in the Office du Niger. Seed production and delivery, however, would still require the intervention of the ODRs.

The emergence of village associations and the greater involvement of the private sector in agricultural and financial markets will be particularly critical when newly improved technologies become available from the agricultural research system and ready for diffusion since these technologies will require additional resources such as seeds for the new varieties, fertilizers, pesticides, and farm equipment. At that time, the extension agency may need to expand, reorganize, or upgrade through training to communicate to farmers about the recommended improved technologies. In addition to providing technical advisory services for agricultural production, the extension agency may also need to provide market information to farmers and traders and communicate farmers' problems back to the agricultural research and policy-making systems. The simulation exercise indicated that these extension functions are highly complementary. Therefore, a broader approach to the problem of technology transfer to increase agricultural productivity would be probably better than an extension program that is a-priori restricted to crop improvement alone. A systems approach allows more flexibility in strengthening a given aspect of the transfer system, be it extension, input supply, credit, or marketing.

The contact farmer/farmer group approach promoted by the T & V system is likely to exclude other farmers from advice and services and result in poor technology transfer and incre

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transfer and increased inequity among farmers (Howell, 1982, p. 10). Instead, the "target group strategy", which aims at organizing the rural population into groups by taking into account the diversity among farmers (i.e., gender, degree of mechanization, access to land, capital and labor) would fit into the network of village associations that are eventually involved in input purchases, credit and marketing (Stoop, 1988, p. 24).

To take maximum advantage of the complementarity that exists between research and extension, mechanisms of different types exist (SPAAR, 1987; Ewell, 1989; Stoop, 1988). At the organizational level, a research-extension coordinating unit could be created within the research and extension institutions and filled by liaison officers. Joint planning committees could regularly meet at national and regional levels. They could also include representatives from the public administration and farmers' community and those responsible for input and credit supply and marketing to enhance the coordination of the different functions of the technology transfer system. At the program level, the participation of the extension personnel in the early stages of and throughout an on-farm research effort will be more effective than trying to establish linkages for technology dissemination later. Early participation allows extension to contribute to the planning of research and hence increases the likelihood that research will be relevant to farmers' needs. Consequently, structures and procedures for technology transfer will be already in place when they are needed. Upgrading extension through better education and training and more joint appointments with research are advisable too.

Even with a stronger linkage between extension and research and with improved input distribution and marketing systems, the impact of extension will still be limited in the Region of Mopti. The complexity of the farming systems, the riskiness of the

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physical environment, the poorly developed infrastructure, the dispersion and inaccessibility of villages, the shortage of trained personnel and a lack of a profitable and well-developed cash commodity are all factors that will continue to hamper extension efforts.

8.2.4. Implications for the Organization of Agricultural Research and Extension

For countries like Mali, with limited human and financial resources, the most cost-effective research strategy is to invest in adaptive research and rely on regional centers and larger foreign NARS for most basic and applied research. For these countries the Mali case study shows that the NARS of these countries should be structured to facilitate 1) internal communication between disciplines, 2) external communication with policy-makers, extension agencies and farmers, 3) coordination with regional centers and other NARS, and 4) on-farm research activities. Decentralizing the agricultural research activities of these countries by establishing or reinforcing research centers for each of the major agroecological zones of the country would be one method of organizing research to better utilize scarce resources.

In addition, a form of research organization that facilitates internal and external communication and promotes on-farm activities could yield large benefits. Activities within research institutions (e.g., on-station research and on-farm research), and between these institutions and institutions external to the research system (e.g., extension, input delivery, formal credit, government) would be better coordinated. The Mali case study demonstrates that the degree of synergism among concerted actions is higher than among poorly concerted actions.

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FSR provides a useful framework for adaptive research because it is specifically designed to link the problems of production systems to on-station research and other institutions. The more variable and complex the farming systems, the greater the potential contribution of FSR in terms of research prioritization and appropriate technology development. Two organizational issues that must fit the specific circumstances of the country are the manner in which FSR is incorporated in the national research system and the composition of the FSR team. Where human and financial resources are limited and/or where there is strong internal resistance to re-organizing the national research system, integrating a farming system perspective into the traditional disciplinary or commodity-oriented research programs is one option. However, integrating FSR in this way is likely to lead to several problems: 1) horizontally coordinating farmers' problems, 2) communicating research results to extension agents, and 3) recruiting researchers that are skilled in both on-farm and on-station research. Therefore, this form of integration probably needs to evolve into a separate FSR unit within the national agricultural research system as resources for research are made available. The skills of the FSR team members must reflect the research priorities identified for FSR. These research priorities and skills should be identified during the FSR feasibility study.

Before investing in extension, it is important to identify carefully the constraints to technology transfer. In many cases, the inappropriateness of recommended technologies to farm circumstances rather than the lack of technical advice is the main reason adoption is slow. The low profitability and high yield variability of the recommended technologies, uncertain access to the recommended inputs, and shortages in labor or capital are all factors that may inhibit technical change. In these cases, strengthening extension is inappr

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extension is inappropriate since the relevant problems go beyond merely the communication of technical advice. Extension agents can do more than convey technical information to increase farm production; they can also 1) help farmers interpret market information from an eventual national marketing information system and make short-term forecasts, 2) help develop and promote possible income-generating activities, such as crop processing and handicraft, 3) guide farmers in the allocation of their resources among different farm enterprises, and 4) help organize farmer associations for bulk purchasing of inputs, to become eligible for formal credit, and to market their agricultural surplus more efficiently. In order to promote these roles for extension, however, extension agents must be specifically trained in giving farm management advice.

8.3. Conclusions about Conducting Ex-ante Evaluations of Agricultural Research

8.3.1. Ex-ante Versus Ex-post Evaluations

In contrast to an ex-post evaluation, an ex-ante evaluation of an agricultural research program must try to predict advances in technology, forecast market conditions, and determine potential institutional support for technology transfer. Because these predictions are subject to large estimation errors, the estimated value of any rate of return to agricultural research is highly uncertain. Therefore, the most useful information to come out of an ex-ante evaluation is, by far, a better understanding of the factors that affect the return to research rather than the rate of return figures themselves. Ranking these factors according to their impact on the return to research allows decision-makers to determine the most important constraints to the return to research. Furthermore, simulating improvements in the institutional or policy environment shows to what extent benefits from research depends on these improvements an

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improvements and, consequently, indicates which actions ought to be taken to complement investment in agricultural research. These simulations are also used to estimate marginal rates of return and interactive effects between different types of investment. The marginal rate of return reflects the additional net gains earned by the incremental investment costs. The interactive effect reflects the strength of complementarity between investments and, hence, to what extent investments ought to be considered together. As a result, an ex-ante evaluation of a research program can guide the strategic allocation of resources between agricultural research and complementary investments. For countries where institutions and infrastructure are particularly weak, using ex-ante evaluations for this purpose is much more relevant and useful than limiting the evaluations to a quest for a rate of return figure.

In ex-ante evaluations of investment in agricultural research, the most important stage is to identify the research program that will most effectively relieve the constraints faced by the target groups. Most of the parameters of the economic analysis are derived from the identification of the research program. For example, giving research priority to rainfed crops over rice or livestock has the most dramatic impact on the return to the research program. In contrast to ex-post evaluations where the research program is known, this stage in ex-ante evaluations requires in-depth knowledge of the constraints faced by the target groups and of how these constraints might be relaxed. Because such an investigation calls for extensive interaction with target groups, researchers, extension agents, traders, policy-makers and others and the diagnosis of complex situations, this stage of the evaluation requires a multi-disciplinary approach and is particularly time-consuming.

In ex-ante evaluations, the parameters of the diffusion paths of the technologies that the research program is expected to develop are the most uncertain. While these parameters can be estimated relatively easily with a field survey in an ex-post evaluation, the estimation of these parameters in an ex-ante evaluation is subject to a large degree of subjectivity. Because the parameters of diffusion paths depend on many uncertain variables (input and output price level and variability, yield level and variability, input and credit access, extension, etc.), these parameters are in turn increasingly uncertain. Obtaining an accurate estimation of these parameters are, however, less critical to the benefit-cost analysis in cases sensitivity analysis reveals that economic results are not very sensitive to these parameters, like in this study. Otherwise, one solution to the problem of uncertainty is to disaggregate the parameters of diffusion into their major uncertain components and identify the probability distributions for these components. If these probability distributions and the correlations among them can be estimated (see section 8.3.2.), the problem then becomes how to estimate the appropriate relationship between the parameters of diffusion and their components. Historical data on technology diffusion are helpful in estimating this relationship, but a great degree of uncertainty remains, as future conditions of technology diffusion may be quite different from past conditions. Sensitivity analysis can be used to handle the problem, and in some instances, when the preceding methods are not possible, is the only method available to deal with uncertainty and subjectivity.

In the semi-arid areas, such as the Region of Mopti in Mali, output prices and yield levels may be uncertain for a given year but their range of variability can be fairly well estimated from historical records (price variability from secondary data and yield variability from on-station and on-farm trials). Based on past research programs, leadtimes for agricultural research and research costs are probably the least uncertain variables of an ex-ante evaluation.

In most cases, ex-ante evaluations of investment in agricultural research must begin by identifying 1) the target groups' production constraints (and eventually the constraints to processing and marketing), 2) the proper research program, 3) the expected outputs of this program, 4) the expected diffusion paths, and 5) the expected effects (at the farm level and at higher levels) before proceeding to the economic analysis per se. As a result, comprehensive ex-ante evaluations require more skill, time, and data than ex-post evaluations. However, they are only feasible for a specific research program (such as FSR in one particular area), not for large research programs that include many different commodities for diverse agroclimatic areas.

8.3.2. Conclusions about the Methodology Used in this Study

a) Review of the Methodology

After the identification of a research program for the FSR project, the next step in this study consisted of evaluating the research program, primarily on the basis of its impact on efficiency and equity. For that purpose, enterprise budgets for current practices and for technical packages that FSR could develop were developed in financial terms. Marginal rates of return and marginal returns per person day permitted the elimination of unprofitable or marginally profitable packages. A sensitivity analysis revealed the degree of instability of the technical packages with regard to changes in output prices, yields or costs of production and, hence, the degree of riskiness in adopting these technical packages.

Financial budgets were converted into economic budgets by removing all transfers due to subsidies, taxes or interest rate and exchange rate controls. This conversion allowed, first, the testing of the economic efficiency of producing selected commodities under the current and the proposed technologies and, second, the evaluation of the FSR project in economic terms. The domestic resource cost (DRC) ratio is an efficiency indicator that contrasts the economic cost of the domestic factors used in producing a commodity with the cost of importing the equivalent of those domestic costs from abroad. The DRC ratio indicated 1) the commodities in which the Region of Mopti has a comparative advantage for a specified market, and 2) farm enterprises for which agricultural research could most likely improve economic efficiency. For this particular efficiency analysis, the economic prices of the inputs were separated into tradable and non-tradable components. The economic prices of import-substituting commodities were the import parity prices, while the economic prices of export-substituting commodities were the export parity prices. Changes in the CFA franc's overvaluation and in the FOB and CIF prices indicated the degree of stability of the region's comparative advantage with respect to shocks external to the regional economy.

To aggregate farm benefits at the regional level, expected diffusion paths of the technical packages were represented by a logistic function whose parameters were derived from the diffusion of animal traction observed in the project area and adjusted for profitability and other factors affecting adoption of the technical packages. The expected diffusion paths were expressed in area terms.

An economic surplus approach was used to evaluate the expected returns and distributional effects of the FSR project. Given that the postulated regional supply-demand structure for crops was one of a perfectly elastic demand curve facing a perfectly inelastic short-run supply curve, the change in total economic surplus corresponded to the change in producer surplus minus the cost of the project. The change in producer surplus consisted of the increased net incomes accruing to farm households as a result of the transfer and adoption of new technical packages developed and tested by the FSR project. The present value of the flow of these incremental farm net benefits less the present value of the flow of the project's costs corresponded to the net present value (NPV) of the project, which represented the economic surplus. The net benefit-investment ratio and the internal rate of return (IRR) were also estimated.

The income distribution effects of the project among producers were assessed by comparing the distribution of increased incomes to target groups as a result of the project to the relative distribution of the population and cultivated area among these target groups. The income distribution effects of the project within farm households were assessed by examining the relative contribution of the crops in which women traditionally specialize to the change in the producer surplus due to the project.

Sensitivity analysis was used to rank the major factors affecting the returns to FSR. It tested the stability of the NPV of the project with respect to changes in the following variables: the increase in farm gross benefits (or yields), the increase in farm costs, the parameters of diffusion, the life of the innovations, the cost of the project and the time taken to complete on-farm research.

To estimate the returns to a joint investment in FSR and additional on-station research, enterprises budgets of the technical packages that FSR could develop were first adjusted to include the new technological components that on-station research could generate in the near future with an incremental investment. Second, the expected diffusion paths of these new technical packages were adjusted to reflect the change in profitability resulting from the complementary investments, and the other factors affecting adoption. The expected returns to this joint investment were then calculated on the basis of the increased net incomes accruing to farmers as a result of the transfer and adoption of these new technical packages, taking into account the additional research costs and leadtime of on-station research.

To estimate the returns to improvements in extension, input delivery and credit supply, it was assumed that the major benefit of these improvements would be a greater adoption of the transitional technology with lower input costs and higher yields. First, enterprises budgets of the traditional and transitional technology were modified to include a 10% reduction in input costs due to organizing farmers' associations to contract purchases, a 50% reduction in the interest rate due to access to formal credit by these farmers' associations, and a 5% increase in yields for the transitional technology due to extension demonstration. Because of the uncertainty in the yield effect due to extension, a sensitivity test was carried out. Second, the expected diffusion paths of the transitional technologies were adjusted to reflect their increased profitability due to the changes in extension, input delivery and credit supply. Third, the expected returns to these improvements were calculated on the basis of the increased net incomes accruing to farmers as a result of a greater adoption of a less costly and more efficient transitional technology, taking into account the additional extension costs.

To estimate the returns to an improvement in the agricultural product marketing system and a reform of fiscal policy, it was assumed that prices received by farmers would increase by 10% and that all taxes, subsidies and duty administrative fees on agricultural inputs and outputs would be removed. First, these changes were incorporated into the enterprise budgets for both the traditional and transitional technologies. Second, the expected diffusion paths of the transitional technologies were adjusted to reflect the changed profitability of these technologies and the other factors affecting adoption. Third, the expected returns to these improvements were calculated on the basis of the increased net incomes accruing to farmers as a result of a greater adoption of the transitional technology with lower input costs and higher agricultural product prices.

The expected returns to different combinations of FSR, additional on-station research, improvements in the technology transfer system and improvements in the marketing system and fiscal policy were estimated. In addition to the net present values, the internal rates of return, the marginal rates of return and the average rates of return for the different combinations were calculated to rank the public investments. The interactive effects were successively estimated for combinations of two, three and four investments according to the simple rule that the interactive effect due to a combination of two investments is equal to the net benefits of the combination of the two investments taken together less the net benefits generated by the two investments taken alone. The strength of interaction between complementary investments was used to determine an appropriate sequence of public investments over time.

b) Methodological Refinements

Further research could refine the methodology outlined above. The first methodological possible refinement concerns the need for a time-lag effect to account for differential price responses to marketing system reforms on the one hand and fiscal reforms on the other hand. Because the impact on prices of improving the agricultural product marketing system is slower than the impact on prices of reforming fiscal policy, a time lag could be used in estimating the incremental farm net benefits resulting from improvements in the marketing system. This lag would reduce the returns to the improvements in the marketing system. In addition, estimating the economic returns to the hypothetical fiscal reform, as one option, and to marketing improvements, as a separate option, would provide useful information for policy recommendations. A particular fiscal reform may not be politically acceptable while certain marketing improvements may be. Dissociating the hypothetical fiscal reforms, however, would nearly double the number of scenarios to simulate, from 12 to 23.

A second methodological refinement concerns the need for time lags in investment expenditures and farm benefits when investments occur sequentially. When public investments are made sequentially because of human and financial limitations, the economic returns to the alternative series of public investments should reflect the sequence of events. For example, in the series of investments where the marketing system and fiscal policy are first improved, after which FSR is implemented, additional on-station research is funded, and the technology transfer system is improved, lags in investment expenditures and farm benefits should be introduced according to the sequence of investments. To estimate the economic returns to the second series of investments, a lag should be introduced between the joint implementation of FSR and additional on-station research, on the one hand, and improvements in the marketing system and fiscal policy, on the other hand. Building lags into the simulation will, however, raise some practical difficulties in modifying and expanding the model. The model has already reached the maximum size tolerated by the software LOTUS.

A third methodological refinement concerns the introduction of models to obtain probability distributions of economic returns instead of point estimates of economic returns, as was done in this study. Uncertainty affects most of the variables that were combined in the financial and economic analyses. Using either the conservative or best estimates of the uncertain variables, as was done in this study, may lead to biased decisions. On the one hand, the final estimate is "overconservative" when conservative estimates for the uncertain variables are systematically used. On the other hand, the possibility that other values of the uncertain variables may result in a different final estimate is not considered when the best estimate values for the uncertain variables are used. In this last case, the consequences of any variation around the best estimate values are implicitly disregarded, which may lead to an incorrect decision (Pouliquen, 1983, p. 2).

The possible range that the decision variable can take around the best single value could be estimated by including the probability distributions of the uncertain variables in the evaluation procedure as the uncertain variables themselves were included. Probability distribution functions would be estimated for the variables that most affect the decision variable and also present a high degree of uncertainty. As indicated by the sensitivity analysis carried out on the returns to FSR (see section 6.4.2.), these variables include project costs, time needed to develop the technical packages, agricultural product prices, yields, and diffusion parameters. Probability distribution functions for the project costs and time needed to move from developing research areas to the extension stage could be estimated from interviews conducted in Mali with FSR and on-station researchers and with research administrators. Probability distribution functions for agricultural product prices and for yields could be estimated with available time and cross-sectional series on prices and yields.[117] Because prices and yields affect the financial returns to the technical packages, the price and yield probability distribution functions could be combined to determine single probability distribution functions of the financial returns to the technical packages. Probability distribution functions for the diffusion parameters could be estimated from the standard errors given by the OLS regressions, which assume that these diffusion parameters are normally distributed variables.

Because some of these uncertain variables are interdependent, correlations should be estimated and combined into both the financial and economic analyses. The most important interdependencies are between the following variables: 1)

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[117] A monthly price series of millet is available from the Early Warning System for the period 1986-89 and the district towns of the Region of Mopti (CNAUR, 1988 and 1989). There are, however, no multi-year price data available for the other crops. Probability distribution functions for yields could be estimated from farm trials conducted by SAFGRAD between 1979 and 1981 in the region.

research costs and time needed to develop the technical packages, 2) yields and agricultural product prices, and 3) financial returns to technical packages (which are measured by the MRR, which combines yields and product prices) and rates of acceptance. Negative correlations are expected for the first two groups of variables. A negative correlation results in compensating the effect of variation of one variable through the variation of the other correlated variable. Information about FSR performance in the two oldest FSR units based in southern Mali could be used to estimate the correlations in the first group of variables. Information about rainfall levels and distribution (as a proxy variable for yields) and price series data could be used to estimate the correlation for the second group of variables.

Positive correlations are expected for the third type of interdependent variables. A positive correlation results in aggravating the effect of variation of one variable through the variation of the other correlated variable. The relationship between MRRs and acceptance rates for the diffusion of animal traction in the rainfed area of the Region of Mopti could be used to estimate the correlation for the third group of variables (see section 5.4.1. and Table 5-12) .

Once the major correlations and probability distribution functions were estimated, it would be possible to carry out a Monte Carlo simulation. The Monte Carlo simulation provides a probability distribution function instead of a point estimate for the economic returns to the different scenarios. The Monte Carlo simulation is a common technique used to aggregate probabilities. It computes the probability distribution function of the final decision variable by repeating (usually 50 to 300 times) the analysis and randomly selecting the value of each of the uncertain variables. The results of the simulation then could be statistically analyzed. Trade-offs between the size of the final decision variable (such as the IRR) and its stability could also be presented and discussed. However, because probability distribution functions are not available for some variables (in particular, the prices of some secondary crops) and because the limited memory capacity of the software LOTUS prevents the current model from running with a Monte Carlo sub-routine, a Monte Carlo simulation is not carried out.

The fourth methodological refinement concerns the statistical test of significance of the main and interactive effects of the four public investments investigated in this study. Assuming the final decision variable of each scenario is normally distributed, analysis of variance (ANOVA) can be carried out with the results of the Monte Carlo simulation. ANOVA tables could be constructed and statistical inferences could be made about both the main effects of each public investment and the interactive effects between public investments. If a Monte Carlo simulation could be carried out, this analysis of variance would tell whether, for example, the rates of return to each type of investment or combination of investments are statistically different and at what level.

8.3.3. Recommendations for Conducting <u>Ex-ante</u> Evaluations of Agricultural Research Programs

a) For an FSR Program

This study demonstrates the need to estimate carefully the potential production impact of FSR and to identify the conditions necessary for FSR to succeed. The limited number of successes FSR has had in increasing productivity for resource-poor farmers underscores this need (Tripp et al., 1990). If the rapid prospective economic analysis reported in the USAID project paper (1985, Annex C) had led to an expansion of the FSR program to the Region of Mopti, the results of this study indicate that the decision would have been wrong. The analysis in the project paper assumed that: 1) the extension services deliver the information about the technologies to an adequate number of farmers; 2) that inputs are available and the terms of trade between inputs and products are favorable; and 3) that product markets are not completely inelastic or shrinking. Based on these optimistic assumptions, the prospective analysis shows that the costs of the FSR program could be covered by the gains resulting from the introduction of new technologies with reasonable adoption rates and yield increases (ibid., C-4).[118] Yet, this dissertation indicates that the first two critical assumptions do not hold in the Region of Mopti and that, consequently, the project would have a low rate of return. Therefore, evaluators should not overlook the institutional and economic environments in which an agricultural research program will be implemented. Because time and financial resources are, however, generally limited for carrying out in-depth feasibility studies, this section reviews the important questions to address in rapid ex-ante evaluations of the potential returns to research.

The first question to address in the evaluation process is whether the lack of an FSR approach in the national agricultural research system actually

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[118] For the Region of Mopti, yield increases would have to be around two percent per year on about 25 percent of the cultivated millet land from project year eight to year 20, in order to provide a net benefit in excess of project costs, discounting the net benefit at ten percent (USAID, 1985, C-4).

constitutes the binding constraint to increased farm productivity. Starting the feasibility study with this question facilitates the investigation of alternative solutions to farmers' problems. For example, changes in the policy environment, or improvements in the marketing system or in the financial market may yield higher payoffs than investment in FSR. To address this question the evaluators must carefully investigate the production, processing, and marketing constraints of the farming system. In addition to reconnaissance surveys, interviews with researchers, extension agents, civil administrators and policy-makers are all helpful sources of information to identify these constraints. These informants can also provide information as to the factors that have affected the adoption of previous technologies in the project area to help specify these constraints. The evaluators can also use these interviews to explore the potential ways of relaxing these constraints. If an informant cites stimulation of agricultural research to develop improved technologies as a major solution, the evaluators can ask him or her to outline an agricultural research program that would contribute to removing farm constraints. The informant's outline of the research program also gives the evaluators an idea of which functions of the agricultural research system need to be strengthened and, consequently, how relevant an FSR approach would be to the resolution of the situation.

After the constraints at farm level and at higher levels (i.e., village, region, country) and the need for an FSR approach are identified, the next critical step is to draft a research program for FSR. The elaboration and the peer review of the FSR program are the most intensive activities of the field work. Although the evaluation criteria approach suggested by Norton et al. (1989) for the Gambia were designed

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were designed to set research priorities for an entire NARS, this approach is helpful for ranking FSR priorities in terms of commodities and research areas. The research program is then designed according to the identified constraints, the relative importance of the research functions of FSR, the technological components available to date or in the near future at the experiment station level, and the available human and financial resources. The first two elements frame the objectives of the study, while the last two elements determine how realistically these objectives can be pursued.

To speed up the identification process of the research program for FSR, the evaluators can rely on the views expressed by the informants in the previous stage of the evaluation process. It is, however, likely that a second round of interviews will be necessary to specify the FSR program as well as the expected outputs of the program. Sub-contracting some components of the program identification, as was done for this study, saves time and also bring into the identification process expertise that may be lacking among members of the original evaluation team. Researchers and research administrators can estimate the expenditures, research staff, and leadtime that are necessary to accomplish a specific on-station research activity. In turn, this information can be used to indicate when the technological components will be available to FSR. Ex-post evaluations of similar FSR projects in the country or in neighboring countries are also sources of information for estimating the research budget, staff and leadtime of the FSR program. Historical data on adoption of previous technologies in the project area can indicate the likely diffusion paths of the technologies that the FSR program will develop.

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How useful a formal survey, in addition to a reconnaissance survey, is in contributing additional information for designing an FSR program and evaluating its potential production impact is questionable. In this study the formal survey confirmed some of the findings of the reconnaissance survey, particularly those related to the organizations of the farming systems and the identification of production constraints. The formal survey also enabled to the quantification of many farm parameters. In retrospect, however, the formal survey would have been more useful if it had been planned later in the evaluation process and had focussed on verifying the validity of the FSR program components rather than the production constraints. Some parameters were missing for a proper analysis of some of the FSR program components both in financial and economic terms and these parameters could have been estimated with a formal survey conducted later in the study. In addition, the questionnaires should have included more specific questions on factors affecting the adoption of available technologies (e.g., animal traction and fungicide) and on input and output marketing. Since formal surveys are expensive and time-consuming, evaluators faced with the decision to conduct a formal survey in addition to a reconnaissance survey should, therefore, consider: 1) the types of new information they want to collect in addition to the information already collected by the reconnaissance survey, and 2) the proper timing of the formal survey within the evaluation process. Although there is some pressure within the research community to conduct a formal survey to add credibility, rigor and systematization to the evaluation process, a formal survey should be more than a validation or verification exercise because of its relatively high costs. A

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high costs. A formal survey cannot replace a well-conducted reconnaissance survey which puts evaluators in direct contact with farmers.

Evaluators should not underestimate the data required to identify the areas in which investment in research would improve the comparative advantage of the region, and to estimate the project's worth. Fortunately, secondary data on the shadow exchange rate, taxes and subsidies on goods, traded and non-traded components of goods, opportunity costs of labor and capital, and marketing costs are often available and, hence, facilitate these economic analyses.

An estimate of the FSR project's worth is likely to be incomplete for those responsible for deciding whether to invest in FSR. If the rate of return to FSR is low and unstable, these decision-makers will want to consider alternative investments or the additional investments which must accompany FSR. If the rate of return is attractive and stable, decision-makers will want to know the best institutional setting for FSR and related institutions (e.g., on-station research, extension, input and credit supply). Since donors and policy-makers are increasingly concerned about the sustainability of new institutions, evaluators should address this concern explicitly in the evaluation process.

b) For a Research Program in General

The same recommendations for ex-ante evaluations of FSR apply to adaptive and applied research programs. However, the less applied and the more basic the research program, the less clear are the potential effects of the program at the farm level. Again, the most important issue to address throughout the evaluation process is to what extent investing in agricultural research will solve farmers' problems and what are the investments needed to complement agricultural rese

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agricultural research. The identification of a research program using informal surveys, secondary data and an evaluation criteria approach is also a critical step in the evaluation.

To reduce the time needed for the financial and risk analyses of the technologies that the research program is expected to develop and the economic analysis of the research program, only the most promising technologies and agroclimatic areas can be selected to estimate the economic value of the research program. This selection can be done using expert opinions. Information about the diffusion of previous technologies can then be used to estimate the expected diffusion paths of these technologies. Because these shortcuts reduce the reliability of the estimated economic value of the research program, sensitivity analysis can be used to provide a range of possible economic values rather than a point estimate. As with the more detailed and comprehensive <u>ex-ante</u> evaluations, the most useful information from this quicker analysis is the ranking of the factors affecting the stability of the economic value of the research program rather than the numerical estimates of the economic value itself. A careful interpretation of the sensitivity analysis can substitute for the simulation of alternative market, institutional and policy conditions. However, in this case, only cautious non-quantitative judgments about the impact of improving these conditions can be made.

APPENDICES

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APPENDIX 1

LITERATURE REVIEW ON PRIORITY SETTING FOR NARS AND EX-ANTE EVALUATION OF AGRICULTURAL RESEARCH

The most recent literature on priority-setting for national Agricultural Research Systems (NARS) were found in Norton and Pardey (1987) and Bottomley and Contant (1988), two International Service for National Agricultural Research (ISNAR) publications.[1] Both publications expose and compare techniques to set priorities among different lines of research, the type of research considered being commodity research. Norton and Pardey distinguish four types of techniques[2]:

1) The scoring or weighted criteria model, in which they include as special cases congruence analysis, the domestic resource costs (DRC) ratios approach and checklists;

2) The expected economic surplus, with benefit-cost analysis as a special case;

3) The mathematical programming approach;

4) Simulation techniques.

The scoring or weighted criteria model is carried out in four steps. First, a set of possible research programs is agreed upon. Second, evaluation criteria are selected and receive a weight. Third, each possible research program is reviewed, each criterion receiving a score. Fourth, scores and weights are multiplied so as to produce a combined score for each research program. This model is generally conducted with the help of surveys, panel discussions or the delphi technique. A good, recent application of this approach is found in Norton, Ganoza and Pomareda (1989), a report presenting the results of a preliminary analysis of agricultural research priorities for the Gambia.

Congruence analysis and DRC ratios are special cases of this model in the sense that all the weight in these techniques is placed on the value of production or on comparative advantage, respectively. Checklists contain a list of questions, but no specific weight is given to the answers.

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[1] The literature review on this topic is not exhaustive. Studies consulted but not included in this review are: Anderson and Parton (1983); Barker (1986); Binswanger and Ryan (1977); Davis, Oram, Ryan (1987); Greig (1981); Pasour and Johnson (1982); Pinstrup-Andersen (1979); Pinstrup-Andersen and Franklin (1977); Schuh and Tollini (1979); Shumway (1983, 1977, 1973); Shumway and McCracken (1975).

[2] Earlier AJAE article (Norton and Davis, 1981) presents the same classification with more details.

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The expected economic surplus approach is well-known by resource economists. It measures society's gains from a shift of supply induced, for example, by the use of an innovation by some producers. The supply shift is often associated with a shift of demand induced, for example, by a population or income increase. This approach provides measures of changes in total net social surplus, in consumer surplus and in producer surplus. The estimation of these changes depends on the assumptions made about demand and supply elasticities, the magnitude and the type (divergent, parallel, or convergent shifts) of the supply curve shift, and the shape of the demand and supply curves (Norton and Davis, 1981).

The benefit-cost (BC) approach is based on the concept of discounted net cash flow. It compares the time-valued estimate of the net returns from the innovations generated in a research program as farmers adopt them, with the time-valued costs of the research program itself (Bottomley and Contant, 1988). Similar to the economic surplus approach, it estimates an average rate of return to proposed agricultural research.[3] The BC approach, however, focuses more on the estimation of the producer surplus, postulating a perfectly elastic demand curve and a vertical supply curve (Norton and Davis, 1981).

Mathematical programming is an optimization technique, maximizing a multiple-goal objective function subject to resource constraints of the research system. The result is the recommendation of a research portfolio. This technique is based on the same concept than the weighted criteria technique: in both techniques, setting weights on a set of goals is exogenous to the program and must be done prior to the analysis. A lot more sophisticated than the simple weighted criteria approach, the mathematical programming allows to quantify trade-offs among goals (Norton and Pardey, 1987).

The simulation techniques are used on models that include the demand and supply sides of the farm sector and alternative technologies the research system might generate and producers might eventually adopt. By simulating changes in supply and demand to meet pre-identified goals, the models predict relative contributions and costs of alternative research activities. Flexibility is the major advantage of this technique. However, to be useful, the models need to reach a certain degree of complexity, requiring then many data (usually primary data) and higher level of analysis capacity (ibid.).

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[3] The average rate of return is expressed as an internal rate of return (IRR), a benefit/cost ratio (B/C ratio), or a net present value (NPV). The production function (PF) approach, which is the econometric estimation of production or supply functions incorporating research variables, would provide a marginal rate of return. The PF approach is not an appropriate tool for ex-ante research project evaluations because it would require a high degree of disaggregation to have some value at the project level, would be more demanding of data (usually secondary data) than the economic surplus approach, and would have some complications to incorporate uncertainty (Norton and Davis, 1981; Norton and Pardey, 1987).

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For Norton and Pardey (ibid.), the availability of data, resources and time frame for making decisions and the economic importance of the allocation decision should guide the choice among these four techniques. Reviewing several studies using these four techniques, Norton and Pardey conclude that the weighted criteria and the expected economic surplus techniques, including the benefit-cost technique, have the most potential for application in selecting research priorities in less-developed countries. When the number of commodities to consider is small, the research outputs are relatively easy to quantify, and time and resources are available, then they recommend the expected surplus technique. According to them, the advantages of this approach are several vis-à-vis the weighted criteria technique:

1) The internal rates of return (IRR) to research on different commodities or research areas can be calculated and, hence, compared to each other or to other alternative public investments;

2) The distribution of benefits between producers and consumers can be estimated;

3) Spillover effects can be included as benefits;

4) When the research goals are efficiency and income distribution, then the expected surplus approach does not need to weight individual criteria, while the weighted criteria approach does. However, efficiency and distributional goals remain to be weighted in both approaches.

5) Economic policies can be included explicitly.

The expected economic surplus technique, however, presents some disadvantages vis-à-vis the weighted criteria approach (ibid.):

1) It is more difficult to apply this approach when research areas, such as socio-economics, basic research and systems or multidisciplinary research, are included in the set of investment alternatives because these research areas are not commodity-specific;

2) This approach requires a higher level of expertise in economics and might be difficult for administrators and decision makers to comprehend;

3) This approach cannot incorporate some criteria, such as private-sector incentives because the criteria used by the economic surplus technique are economic efficiency and income distribution.

4) Because it requires less involvement of the administrators and the decision makers, this approach does not have the advantage of the weighted criteria approach to force these people to explicitly select among divergent goals.

5) This approach cannot be applied to a long list of commodities or research areas because of time or data limitations.

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Bottomley and Contant (1988) also compare the priority-setting methods for agricultural research. They add a detailed procedure to conduct the benefit-cost analysis. It comprises the sequential estimation of eight variables of a research program: the annual cost of research, research duration, probability of research success, on-farm implementation costs, on-farm benefits, rate of adoption, adoption ceiling, and life of the innovation. Because a lot of uncertainty surrounds the estimations of these variables, sensitivity tests are used. According to Bottomley and Contant (ibid., p. 88), the advantage of the benefit-cost analysis is to be able to "chart the course of events descriptively."

A thorough application of the expected economic surplus technique is found in an analysis conducted on the five major commodity research and extension programs in Peru (Norton, Ganoza and Pomareda, 1987). Reviewing this analysis, Norton and Pardey (1987) suggest using first a weighted criteria procedure to narrow down the list of alternative commodities to be included in the expected economic surplus analysis.[4] This analysis provided an enlightening way of measuring the effects of alternative pricing policies on both the total level and distribution of research benefits. Projections of yields, costs, and adoption rates are, however, simplified in this application because the estimates are based on technologies that were recently released or on technologies for which experimental results were already available (Norton, Ganoza and Pomareda, 1987).

Other applications of this technique are able to examine the growth and distributional effects of technical change along with direct and indirect effects of research (Ramalho de Castro and Schuh, 1977) and the benefits of research under alternative domestic pricing and international trade policies (Edwards and Freebairn, 1984; Alston, Edwards, and Freebairn 1988; Norton, Ganoza and Pomareda, 1987).

Araji, Sim, and Gardner (1978) estimate the returns to investment in current research and extension programs for nine agricultural commodities in the western region of the U.S. The contribution of cooperative extension to research effectiveness is estimated, but unfortunately for the purpose of this dissertation, no explicit procedure is given. Confronted with the same type of issue, Lu (1980), however, presents the procedure more explicitly. He varies the expected adoption curve according to the levels of research and extension expenditures. Martínez and Saín (1983) use Lu's procedure to estimate the returns to the methodological innovation of on-farm research in Panama.

Ways to deal with the stochastic nature of research payoffs vary among studies. Fishel (1970) uses a Monte-Carlo sampling procedure to generate subjective probability distributions of costs and values. Easter and Norton (1977) use a sensitivity analysis to show the variations in probabilities of success, expected yield increases, product prices,

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[4] Janssen and Lynam (1988) provide a nice example where the understanding of supply-demand linkages has helped to identify the components of a research project that are most critical for successful technology generation and application. In the Atlantic coast of Colombia, they show that market development should receive priority over the generation of production technology.

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and lags between research expenditures and availability of results (Norton and Davis, 1981). Scobie (1984) shows how to estimate a distribution of expected benefits or, alternatively, of expected rates of return. Scobie reports that Greig (1979) uses the additional information provided by the variance of returns to compare two poultry research projects. First, he elicits subjective estimates of the probability distributions of the main parameters of his model by questioning research scientists. Second, using these distributions and drawing repeated samples with a Monte-Carlo technique, he derives a histogram of the present value of each research program (Scobie, 1984). The same technique is described in Reutlinger (1984) and Pouliquen (1983).

In 1981, Norton and Davis concluded that scoring models, simulation models and ex-ante benefit-cost models are the most helpful in identifying and quantifying factors affecting progress in given research lines. However, these authors suggested that three areas needed further methodological work: 1) the evaluation of non-commodity research, 2) analysis of factors affecting progress in given research lines, and 3) the study of private-public interaction in agricultural research, including transmission of research results to farmers. Since then, with the exception of Norton, Ganoza and Pomareda's study in Peru and Bottomley and Contant's publication, no important contribution has been made to the procedure for conducting ex-ante evaluation of agricultural research. It is expected that this study will contribute to the three areas of research mentioned above.

Table 2-A-1

CERCLES
Mopti
Bandiagara
Bankass
Djenne
Douentza
Koro
Tenenkou
Youwarou
Region

Source: M
d

Table 2-A-2.

DISTRICT
Bankass
Koro
Douentza
Mopti
Djenne
Bandiagara
Tenenkou
Youwarou

Source: OM

APPENDIX 2-A

Table 2-A-1. Area and Population in the Region of Mopti

CERCLES	AREA (1) (Square Km.)	POPULATION (2)	POPULATION DENSITY	NUMBER OF DISTRICT
Mopti	7262	243245	33	9
Bandiagara	8219	182869	22	8
Bankass	9504	155999	16	7
Djenne	4561	126083	28	6
Douentza	18903	150608	8	6
Koro	10918	211988	19	7
Tenenkou	11297	114405	10	6
Youwarou	7139	76186	11	6
Region	77803	1261383	16	55

Source: Ministère de l'Administration Territoriale et du Développment à la Base (1987).

Table 2-A-2. Rainfall in the Region of Mopti

	LONG-RUN AVERAGE				LAST DECADE'S AVERAGE		
DISTRICT	Period	Nbr.of Years	Rainfall (mm)	Nbr.of Days	Period	Rainfall (mm)	Nbr.of Days
Bankass	1956-75	19	568.4	48.6	1979-87	458.4	35.2
Koro	1961-75	14	603.1	37.4	1979-87	475.9	31.8
Douentza	1926-75	49	487.1	36.9	1979-87	335.9	29.5
Mopti	1926-75	49	529.4	52.1	1979-87	388.4	37.2
Djenne	1926-75	49	598.2	42.4	1979-87	468.7	34.4
Bandiagara	1926-75	49	565.5	45	1979-87	404.6	33
Tenenkou	1951-75	24	415.4	31.1	1979-87	375.3	28.6
Youwarou	-	-	-	-	1984, 1985, 1987	205.5	18

Source: OMM, 1974, 1975, 1980, 1981, 1984, 1985, 1986.

Table 2-A-3. Area, Production and Yield for Millet-Sorghum-Fonio in the Region of Mopti

	AREA (ha)			PRODUCTION (ton)			YIELD (ton/ha)		
[illegible]	[illegible]	[illegible]	%	MOPTI	MALI	%	MOPTI	MALI	%

Table 2-A-3. Area, Production and Yield for Millet-Sorghum-Fonio in the Region of Mopti

	AREA (ha)			PRODUCTION (ton)			YIELD (ton/ha)		
YEAR	MOPTI	MALI	%	MOPTI	MALI	%	MOPTI	MALI	%
1974	382672	968098	40	278940	963918	29	0.729	0.996	73
1975	310714	946553	33	81942	352904	23	0.264	0.373	71
1976	319376	931885	34	223427	874336	26	0.700	0.938	75
1977	239275	924139	26	171439	1012845	17	0.716	1.096	65
1978	266420	1017661	26	171879	949238	18	0.645	0.933	69
1979	219978	985533	22	82523	762875	11	0.375	0.774	48
1980	313839	1358522	23	167861	734022	23	0.535	0.540	99
1981	298467	1337108	22	157922	999097	16	0.529	0.747	71
1982	360208	1407861	26	136024	1080240	13	0.378	0.767	49
1983	229154	1446911	16	204195	1146889	18	0.891	0.793	112
1984	250113	1341689	19	95248	900874	11	0.381	0.671	57
1985	188060	943948	20	151679	1245080	12	0.807	1.319	61
1986	228436	1262238	18	145230	1287570	11	0.636	1.020	62
1987	211954	1301778	16	254738	1222291	21	1.202	0.939	128
1988	376055	1906998	20	340967	1692514	20	0.907	0.888	102
Mean	279648	1205395	24	177601	1014980	18	0.646	0.853	76
CV (%) (1)	22	16	14	40	19	16	37	26	30
Trend (%) (2)		4	-6		5	-4			

(1) The coefficient of variation (CV) is adjusted when there is a statistically significant trend, using the Cuddy-Della Valle index (Singh and Byerlee, 1990).
(2) Only statistically significant trends are reported.
Source: OSCE, 1989.

Table 2-A-4. Area, Production and Yield for Rice in the Region of Mopti

	AREA (ha)			PRODUCTION (ton)			YIELD (ton/ha)		
			%	MOPTI	MALI	%	MOPTI	MALI	%

Table 2-A-4. Area, Production and Yield for Rice in the Region of Mopti

	AREA (ha)			PRODUCTION (ton)			YIELD (ton/ha)		
YEAR	MOPTI	MALI	%	MOPTI	MALI	%	MOPTI	MALI	%
1974	68755	137331	50	72351	178643	41	1.052	1.301	81
1975	83765	233301	36	51328	196036	26	0.613	0.840	73
1976	105511	175448	60	166882	298229	56	1.582	1.700	93
1977	101138	244162	41	85049	303203	28	0.841	1.242	68
1978	47437	111674	42	33548	158293	21	0.707	1.417	50
1979	88411	242534	36	80965	240117	34	0.916	0.990	92
1980	60059	142823	42	23988	121553	20	0.399	0.851	47
1981	43609	115593	38	11294	134756	8	0.259	1.166	22
1982	72660	181624	40	29107	152634	19	0.401	0.840	48
1983	76094	187885	41	64045	215986	30	0.842	1.150	73
1984	55384	165176	34	4654	109354	4	0.084	0.662	13
1985	58708	175355	33	72615	231769	31	1.237	1.322	94
1986	69551	215254	32	53818	235852	23	0.774	1.096	71
1987	60352	163079	37	64395	236568	27	1.067	1.451	74
1988	122467	231293	53	87231	287842	30	0.712	1.244	57
Mean	74260	181502	41	60085	206722	27	0.766	1.151	64
CV (%)	26	24	17	70	30	47	52	24	40

Source: OSCE, 1989.

Table 2-A-5. Cattle and Small Ruminant Herds in the Region of Mopti

YEAR	CATTLE			SMALL RUMINANTS		
	MOPTI	MALI	%	MOPTI	MALI	%
1977	1320589	4536747	29	2024000	8532000	24
1978	954000	4603000	21	1553000	8652000	18
1979	1028000	4665000	22	2158000	9933000	22
1980	1426000	5850000	24	2548000	11587000	22
1981	1539000	6396000	24	2384000	12393000	19
1982	1789000	6663000	27	2505000	12437000	20
1983	1352000	5676000	24	2264000	11244000	20
1984	1249000	7137000	18	2130000	10382000	21
1985	852000	4344000	20	1955000	12553000	16
1986	886000	4475000	20	2014000	10340000	19
1987	944000	4589000	21	2184000	11000000	20
Mean	1212690	5357704	23	2156273	10823000	20
CV(%)	24	18	14	12	12	10

Source: OSCE, 1989.

Table 2-A-6. Officially Recorded Cattle Exports (1)

YEAR	CATTLE	SMALL RUMINANTS
1980	23357	66597
1981	18058	66247
1982	9587	31084
1983	22704	29737
1984	21399	30895
1985	14383	57797
1986	11979	45110

(1) To Côte d'Ivoire, Ghana, Liberia, and Burkina Faso.
Source: ODEM, 1987b.

Table 2-A-7. Fish Catch and Trade in the Region of Mopti

YEAR (1)	FRESH FISH CATCH (1000 tons)	EXPORTS (2) (ton)	EXPORTS (2) %	NATIONAL MARKETS (2) (ton)	NATIONAL MARKETS (2) %	TOTAL TRADE (2) (ton)
1970	110	5148	46	6048	54	11196
1971	95	3868	44	4975	56	8843
1972	90	2850	36	5005	64	7855
1973	74	1504	29	3719	71	5223
1974	65	988	28	2586	72	3574
1975	86	2837	37	4798	63	7635
1976	90	2747	30	6329	70	9076
1977	88	1952	25	5754	75	7706
1978	77	1321	23	4538	77	5859
1979	84	1954	27	5204	73	7158
1980	90	2113	24	6754	76	8867
1981	78	1237	22	4363	78	5600
1982	76	1270	24	3966	76	5236
1983	62	543	17	2590	83	3133
1984	56	399	20	1596	80	1995
1985	56	376	20	1518	80	1894
1986	62	796	22	2862	78	3658
1987	58					
Mean	78	1196	23	3914	77	5111
CV (%) (3)	13	32		26		27
Trend (%) (4)	-3	-15		-12		-13

(1) Statistics for marketed fish are for the Delta area between 1970 and 1976, but limited to the port of Mopti between 1977 and 1986.
(2) Smoked and dried fish.
(3) The coefficient of variation (CV) is adjusted when there is a statistically significant trend, using the Cuddy-Della Valle index (Singh and Byerlee, 1990).
(4) Only statistically significant trends are reported.
Source: IUCN, 1989.

APPENDIX 2-B

Table 2-B-1. Monthly Price Series of Millet at the District Markets of the Region of Mopti and at Gao and Timbuktu (CFA F/Kg)

Month	Mopti	Bandiagara	Bankass	Djenne	Douentza	Koro	Tenenkou	Youwarou	Timbuktu	Gao
July 1986	65	70	60	60	85	65	55	100	100	95
August	75	96	60	60	90	65	NA	NA	100	110
September	65	70	60	60	75	60	65	100	100	95
October	65	65	50	NA	NA	65	60	80	140	85
November	50	55	30	35	70	45	45	75	145	85
December	55	55	25	35	75	40	60	75	100	75
January 1987	55	45	28	35	75	45	50	70	115	70
Februay	40	45	30	35	70	35	50	65	90	60
March	40	45	30	35	NA	40	NA	60	110	60
April	55	50	NA	40	NA	40	50	65	80	75
May	55	60	45	50	60	35	50	NA	110	75
June	50	65	50	40	65	45	65	70	110	75
July	65	60	45	40	70	50	50	80	135	80
August	80	75	65	60	75	55	65	80	110	80
September	75	75	55	60	75	60	70	90	100	75
October	65	65	55	55	65	55	65	85	100	75
November	70	65	60	60	NA	60	75	80	100	90
December	65	70	55	NA	NA	45	75	80	100	90
January 1988	75	75	60	60	90	50	75	NA	100	85
Februay	100	85	80	70	100	80	75	120	115	100
March	105	100	90	95	120	100	100	130	135	125
April	110	105	90	95	120	100	110	140	135	125
May	100	115	100	90	125	100	125	150	150	125
June	130	135	110	110	NA	105	150	150	165	150
July	150	200	130	160	160	160	165	165	165	160
August	135	165	125	160	NA	130	125	NA	185	150
September	110	115	100	NA	135	120	80	130	165	130
October	75	80	60	75	80	75	80	60	135	125
November	55	50	30	NA	50	40	35	25	100	95
December	50	45	30	30	NA	40	35	40	85	80
January 1989	60	45	33	45	50	40	35	40	75	75
Februay	60	45	40	35	50	40	35	50	80	75
March	50	NA	40	40	50	40	NA	50	85	75
April	50	50	40	40	50	45	50	60	85	80
May	50	50	40	40	50	40	60	65	85	70
June	55	50	NA	37	50	38	50	55	85	75
July	55	50	40	NA	71	38	50	55	85	65
August	50	60	20	37	60	40	35	55	85	60
September	50	50	32	28	62	38	38	55	65	60
October	60	70	40	28	75	62	55	60	75	65
September 86 - August 89:										
Mean	72	74	57	60	78	61	70	82	112	91
Standard Deviation	27	35	29	33	29	31	32	35	29	27

Table 2-B-1 (cont'd.).

Month	Mopti	Bandiagara	Bankass	Djenne	Douentza	Koro	Tenenkou	Youwarou	Timbuktu	Gao
C.V. (%)	38	48	51	56	37	50	46	42	25	29
October - December:										
Mean	61	61	44	48	68	52	59	67	112	89

<u>Source</u>: CNAUR, 1988 and 1989.

Table 2-B-2. Millet Price Correlations between Pairs of Markets (Pearson Coefficients) between July 1986 and October 1989 for Markets in the Region of Mopti and in Timbuktu and Gao

Correlations:	MOPTI	BANDIAGARA	BANKASS	DJENNE	DOUENTZA	KORO	TENENKOU	YOUWAROU	TIMBUKTU	GAO
MOPTI	1.00									
BANDIAGARA	.93	1.00								
BANKASS	.95	.92	1.00							
DJENNE	.95	.95	.95	1.00						
DOUENTZA	.92	.92	.90	.91	1.00					
KORO	.96	.97	.95	.97	.95	1.00				
TENENKOU	.91	.95	.93	.94	.93	.95	1.00			
YOUWAROU	.88	.85	.91	.87	.94	.89	.90	1.00		
TIMBUKTU	.70	.71	.70	.72	.77	.73	.76	.75	1.00	
GAO	.89	.87	.90	.94	.88	.93	.90	.83	.81	1.00

Note: All correlation coefficients are significantly positive at the 0.1% level.

Source: Matrix calculated from millet prices recorded by the Early Warming System (SAP). See Table 1 of Appendix 2-A.

Table 2-B-3. Spatial Margins for Millet from the District Markets of the Region of Mopti, Gao and Timbuktu to Mopti (CFA F/Kg and %)

Month	Bandiagara		Bankass		Djenne		Douentza		Koro		Tenenkou		Youwarou		Timbuktu		Gao	
	CFAF	%	CFAF	%	CFAF	%	CFAF	%	CFAF	%	CFAF	%	CFAF	%	CFAF	%	CFAF	%
July 1986	-5	-8	5	8	5	8	-20	-31	0	0	10	15	-35	-54	-35	-54	-30	-46
August	-21	-28	15	20	15	20	-15	-20	10	13	NA	NA	NA	NA	-25	-33	-35	-47
September	-5	-8	5	8	5	8	-10	-15	5	8	0	0	-35	-54	-35	-54	-30	-46
October	0	0	15	23	NA	NA	NA	NA	0	0	5	8	-15	-23	-75	-115	-20	-31
November	-5	-10	20	40	15	30	-20	-40	5	10	5	10	-25	-50	-95	-190	-35	-70
December	0	0	30	55	20	36	-20	-36	15	27	-5	-9	-20	-36	-45	-82	-20	-36
January 1987	10	18	27	49	20	36	-20	-36	10	18	5	9	-15	-27	-60	-109	-15	-27
Februay	-5	-13	10	25	5	13	-30	-75	5	13	-10	-25	-25	-63	-50	-125	-20	-50
March	-5	-13	10	25	5	13	NA	NA	0	0	NA	NA	-20	-50	-70	-175	-20	-50
April	5	9	NA	NA	15	27	NA	NA	15	27	5	9	-10	-18	-25	-45	-20	-36
May	-5	-9	10	18	5	9	-5	-9	20	36	5	9	NA	NA	-55	-100	-20	-36
June	-15	-30	0	0	10	20	-15	-30	5	10	-15	-30	-20	-40	-60	-120	-25	-50
July	5	8	20	31	25	38	-5	-8	15	23	15	23	-15	-23	-70	-108	-15	-23
August	5	6	15	19	20	25	5	6	25	31	15	19	0	0	-30	-38	0	0
September	0	0	20	27	15	20	0	0	15	20	5	7	-15	-20	-25	-33	0	0
October	0	0	10	15	10	15	0	0	10	15	0	0	-20	-31	-35	-54	-10	-15
November	5	7	10	14	10	14	NA	NA	10	14	-5	-7	-10	-14	-30	-43	-20	-29
December	-5	-8	10	15	NA	NA	NA	NA	20	31	-10	-15	-15	-23	-35	-54	-25	-38
January 1988	0	0	15	20	15	20	-15	-20	25	33	0	0	NA	NA	-25	-33	-10	-13
Februay	15	15	20	20	30	30	0	0	20	20	25	25	-20	-20	-15	-15	0	0
March	5	5	15	14	10	10	-15	-14	5	5	5	5	-25	-24	-30	-29	-20	-19
April	5	5	20	18	15	14	-10	-9	10	9	0	0	-30	-27	-25	-23	-15	-14
May	-15	-15	0	0	10	10	-25	-25	0	0	-25	-25	-50	-50	-50	-50	-25	-25
June	-5	-4	20	15	20	15	NA	NA	25	19	-20	-15	-20	-15	-35	-27	-20	-15
July	-50	-33	20	13	-10	-7	-10	-7	-10	-7	-15	-10	-15	-10	-15	-10	-10	-7
August	-30	-22	10	7	-25	-19	NA	NA	5	4	10	7	NA	NA	-50	-37	-15	-11
September	-5	-5	10	9	NA	NA	-25	-23	-10	-9	30	27	-20	-18	-55	-50	-20	-18
October	-5	-7	15	20	0	0	-5	-7	0	0	-5	-7	15	20	-60	-80	-50	-67
November	5	9	25	45	NA	NA	5	9	15	27	20	36	30	55	-45	-82	-40	-73
December	5	10	20	40	20	40	NA	NA	10	20	15	30	10	20	-35	-70	-30	-60
January 1989	15	25	27	45	15	25	10	17	20	33	25	42	20	33	-15	-25	-15	-25
Februay	15	25	20	33	25	42	10	17	20	33	25	42	10	17	-20	-33	-15	-25
March	NA	NA	10	20	10	20	0	0	10	20	NA	NA	0	0	-35	-70	-25	-50
April	0	0	10	20	10	20	0	0	5	10	0	0	-10	-20	-35	-70	-30	-60
May	0	0	10	20	10	20	0	0	10	20	-10	-20	-15	-30	-35	-70	-20	-40
June	5	9	NA	NA	18	33	5	9	17	31	5	9	0	0	-30	-55	-20	-36
July	5	9	15	27	NA	NA	-16	-29	17	31	5	9	0	0	-30	-55	-10	-18
August	-10	-20	30	60	13	26	-10	-20	10	20	15	30	-5	-10	-35	-70	-10	-20
September	0	0	18	36	22	44	-12	-24	12	24	12	24	-5	-10	-15	-30	-10	-20
October	-10	-17	20	33	32	53	-15	-25	-2	-3	5	8	0	0	-15	-25	-5	-8

Table 2-B-3 (cont'd.).

Month	Bandiagara		Bankass		Djenne		Douentza		Koro		Tenenkou		Youwarou		Timbuktu		Gao	
	CFAF	%	CFAF	%	CFAF	%	CFAF	%	CFAF	%	CFAF	%	CFAF	%	CFAF	%	CFAF	%
September 86 - August 89:																		
Mean	-2	-1	15	24	12	19	-8	-12	11	17	4	6	-12	-17	-41	-67	-19	-32
Standard Dev	12	13	7	14	10	13	11	20	9	12	13	19	16	25	18	41	10	20

Source: Author's estimation from Table 1 in Appendix 2-B.

Table 2-B-4. Costs and Returns to Moving 1 kg of Millet from the Seno Plain to Mopti

Cost Item (1)	From Bankass(2) (CFA F/Kg)	From Koro(3) (CFA F/Kg)
1. Price of sack	0.25	0.25
2. Loading at assembly market	0.50	0.50
3. Transport to Mopti (50 CFA F/Ton/Km) (4)	5.40	8.00
4. Unloading at market of Mopti	0.50	0.50
5. Total costs to delivery in Mopti	6.65	9.25
5. Monthly Storage Costs at Mopti		
Storage Rental & Guardian & Treatment	0.85	0.85
Annual 5% Loss	0.20	0.20
Opportunity Cost of Capital 30% per year	1.19	1.19
Storage cost 2 weeks (Total monthly/2)	1.12	1.12
6. Total accrued costs in Mopti	3.36	3.36
7. Total accrued costs from assembly market to Mopti	10.01	12.61
8. Observed average spatial margin (September 86 - August 89) (5)	25.00	22.50
9. Net wholesale margin (Mopti) (8-7)	14.99	9.89

(1) Based on the cost items estimated by Mehta (1989, pp. 154-55), average of 1986-87 and 1987-88 marketing seasons.
(2) Located at 108 km from Mopti.
(3) Located at 160 km from Mopti.
(4) Transportation costs from Stryker et al. (1987) for dirt roads.
(5) The spatial margin is an average of two spatial margins. The first spatial margin is the difference between the price recorded by SAP in the assembly market (either Bankass or Koro) in December 1986 and the price recorded in Mopti in January 1987. The second spatial margin is taken between the same market places but in December 1987 and January 1988. These two periods have been chosen to compare with Mehta's estimations (1989).

Source: Author's estimation.

APPENDIX 2-C

Table 2-C-1. Cultivated Area, Population and Equipment Rate in the Rainfed Area of the Region of Mopti

ZONE	MILLET CULTIVATED AREA (2) (HA)	(%)	POPULATION (3) (PERSON)	(%)	FARMING SYSTEM (4) AGROPASTORAL (%)	PASTORAL (%)	EQUIPMENT (5) AGROPASTORAL (%)	PASTORAL (%)
NORTH	31250	24	67823	18	79	21	20	8
CENTER	37250	29	119861	32	95	5	46	-
PLATEAU	10100	8	42867	11	90	10	32	-
SOUTH	50550	39	145120	39	72	28	20	4
TOTAL	129150	100	375671	100				
SUB-REGION (1)			655372					

(1) Circle of Bandiagara, Bankass, Koro and Douentza and the districts of Boni, Mondoro, Hombori and Central Douentza of the Circle of Douentza.

Sources: (2) In millet-sorghum-fonio (for the estimation of the cultivated area by zone, see Henry de Frahan et al., 1989).
(3) For the estimation of the population by zonea, see Henry de Frahan et al.(1989).
(4) From Kassambara (1980) and formal survey of the IER-USAID-MSU Project, 1987-88.
(5) From formal survey of the IER-USAID-MSU Project, 1987-88.

Table 2-C-2. Farm Structure of the Farming Systems in the Rainfed Area of the Region of Mopti

FARM CLASS		POPULATION PER FARM(1)	ADULT FAMILY MEMBER PER UNIT (1)	MILLET CULTIVATED AREA (HA)	(%)	POPULATION (2) (PERSON)	(%)	MILLET AREA (HA) PER FARM	ADULT FAMILY MEMBER
AGROPASTORAL SYSTEM:									
NORTH	Non-equipped	14	10	19750	16	42864	12	6.5	0.65
	Equipped	20	13	4938	4	10716	3	9.2	0.71
CENTER	Non-equipped	8	6	19109	15	61489	17	2.5	0.41
	Equipped	14	9	16278	13	52379	14	4.4	0.48
PLATEAU	Non-equipped	12	8	6181	5	26235	7	2.8	0.35
	Equipped	11	8	2909	2	12346	3	2.6	0.32
SOUTH	Non-equipped	8	6	29117	23	83589	23	2.8	0.46
	Equipped	21	12	7279	6	20897	6	7.3	0.61
PASTORAL SYSTEM:									
NORTH	Non-equipped	15	10	6038	5	13103	4	6.9	0.69
	Equipped	18	11	525	0	1139	0	8.3	0.75
SOUTH	Non-equipped & Equipped	14	9	14154	11	40634	11	4.9	0.54
TOTAL				126278	100	365391	100		

Sources: (1) From formal survey of the IER-USAID-MSU Project, 1987-88.
The statistic values are not significantly different at the 5% level.
(2) From Table 1 of Appendix 2-C.

APPENDIX 5-A

Table 5-A-1. Technological Components for the Millet and Cowpea Crops in the Northern Zone

TECHNOLOGICAL COMPONENTS	FARMER PRACTICES		TECHNOLOGICAL ALTERNATIVES	
	NON EQUIPPED	EQUIPPED	INTERCROPPING	SOLE CROPPING (1)
Varieties				
Millet	Local	Local	IBV 8001	IBV 8001
Cowpea	Local	Local	Gorom-Gorom	Gorom-Gorom
Densities				
Millet	10000	10000	26500	10000
Cowpea	5000	5000	13300	31250
Seed Quantity (kg/ha)				
Millet	10	10	5	5
Cowpea	3	3	8	25
Chemical Seed Treatment (gPC/ha)				
Millet	25 g of Thioral	25 g of Thioral	25 g of APRON+	25 g of APRON+
Cowpea	None	None	25 g of Thioral	75 g of Thioral
Mechanized Operations	None	Weeding	Weeding Spraying	Weeding Spraying
Power source	Manual	Donkey	Donkey	Donkey
Chemical Fertilizer	None	None	25 kg/ha of ammonium phosphate	32.5 kg/ha phosphate on cowpea
Chemical Pest Control				
Cowpea	None	None	2 L/ha of Decis	7 L/ha of Decis
Chemical Storage Control				
Cowpea	None	None	1 tablet of Phostoxin	4 tablets of Phostoxin
Feed (kg dry hay)	None	800	800	800 kg of dry hay
Labor (day/ha)	48.0	27.5	36.0	25.0 on millet crop 49.0 on cowpea crop
Yield (kg/ha)				
Millet seed	250	275	400	600
Cowpea seed	40	45	120	500
Dry cowpea hay	400	400	300	400

(1) The recommended pattern is 0.75 ha of millet and 0.25 ha of cowpea.
Source: Author's estimations

Table 5-A-2. Technological Components for the Millet and Cowpea Crops in the Center and Plateau Zone

TECHNOLOGICAL COMPONENTS	FARMER PRACTICES		TECHNOLOGICAL ALTERNATIVES	
	NON EQUIPPED	EQUIPPED	INTERCROPPING	SOLE CROPPING (1)
Varieties				
Millet	Local	Local	NKK	NKK
Cowpea	Local	Local	Gorom-Gorom	Gorom-Gorom
Densities				
Millet	10000	10000	26500	15625
Cowpea	5000	5000	13300	31250
Seed Quantity (kg/ha)				
Millet	10	10	5	5
Cowpea	3	3	8	25
Chemical Seed Treatment (gPC/ha)				
Millet	25 g of Thioral	25 g of Thioral	25 g of APRON+	25 g of APRON+
Cowpea	None	None	25 g of Thioral	75 g of Thioral
Mechanized Operations	None	Weeding	Weeding Spraying	Weeding Spraying
Power source	Manual	Donkey	Donkey	Donkey
Chemical Fertilizer	None	None	50 kg/ha of ammonium phosphate	50 kg/ha of PRT on millet 65 kg/ha phosphate on cowpea
Chemical Pest Control				
Cowpea	None	None	2 L/ha of Decis	7 L/ha of Decis
Chemical Storage Control				
Cowpea	None	None	2 tablets of Phostoxin	5 tablets of Phostoxin
Feed (kg dry hay)	None	800	800	800 kg of dry hay
Labor (day/ha)	57.5	34.0	47.5	37.5 on millet crop 60.0 on cowpea crop
Yield (kg/ha)				
Millet seed	400	440	650	600
Cowpea seed	50	55	160	500
Dry cowpea hay	500	500	400	400

(1) The recommended pattern is 0.75 ha of millet and 0.25 ha of cowpea.
Source: Author's estimations

Table 5-A-3. Technological Components for the Millet and Cowpea Crops in the Southern Zone

TECHNOLOGICAL COMPONENTS	FARMER PRACTICES		TECHNOLOGICAL ALTERNATIVES	
	NON EQUIPPED	EQUIPPED	INTERCROPPING	SOLE CROPPING (1)
Varieties				
Millet	Local	Local	NKK	NKK
Cowpea	Local	Local	Gorom-Gorom	Gorom-Gorom
Densities				
Millet	10000	10000	26500	15625
Cowpea	5000	5000	13300	31250
Seed Quantity (kg/ha)				
Millet	10	10	5	5
Cowpea	3	3	8	25
Chemical Seed Treatment (gPC/ha)				
Millet	25 g of Thioral	25 g of Thioral	25 g of APRON+	25 g of APRON+
Cowpea	None	None	25 g of Thioral	75 g of Thioral
Mechanized Operations	None	Weeding	Weeding Spraying	Weeding Spraying
Power source	Manual	Donkey	2 oxen	2 oxen
Chemical Fertilizer	None	None	50 kg/ha of ammonium phosphate 25 kg/ha of urea	50 kg/ha of PRT on millet 65 kg/ha phosphate on cowpea
Chemical Pest Control				
Cowpea	None	None	2 L/ha of Decis	7 L/ha of Decis
Chemical Storage Control				
Cowpea	None	None	2 tablets of Phostoxin	5 tablets of Phostoxin
Feed (kg dry hay)	None	800	2300	800 kg of dry hay
Labor (day/ha)	64.0	39.0	46.0	37.5 on millet crop 60.0 on cowpea crop
Yield (kg/ha)				
Millet seed	500	550	800	600
Cowpea seed	40	45	180	500
Dry cowpea hay	500	500	400	400
Manure (ton/ha)			1.5	1.5
Live Weight (kg/ha)			20	20

(1) The recommended pattern is 0.75 ha of millet and 0.25 ha of cowpea.
Source: Author's estimations

Table 5-A-4. Technological Components for the Millet and Groundnut Crops in the Center and Plateau Zone

TECHNOLOGICAL COMPONENTS	FARMER PRACTICE NON EQUIPPED			FARMER PRACTICE EQUIPPED			TECHNOLOGICAL ALTERNATIVES WITHOUT TRP			TECHNOLOGICAL ALTERNATIVES WITH TRP		
	MILLET	MILLET	MILLET	MILLET	MILLET	MILLET	GRDNUT	MILLET	GRDNUT	GRDNUT	MILLET	GRDNUT
Varieties	Local	Local	Local	Local	Local	Local	47-10	Local	47-10	47-10	Local	47-10
Densities	10000	10000	10000	10000	10000	10000		15625			15625	
Seed Quantity (kg/ha)	10	10	10	10	10	10	100	10	100	100	10	100
Chemical Seed Treatment												
Thioral (gPC/ha)	25	25	25	25	25	25	200	25	200	200	25	200
Mechanized Operations	None	None	None	Weeding	Weeding	Weeding	Weeding	Weeding	Weeding	Weeding	Weeding	Weeding
Power source	Manual	Manual	Manual	Donkey	Donkey	Donkey	Donkey	Donkey	Donkey	Donkey	Donkey	Donkey
Chemical Fertilizer												
(kg/ha of TRP)	None	None	None	None	None	None	None	None	None	300	None	None
Chemical Storage Control												
Actellic (gPC/ha)	None	None	None	None	None	None	300	None	100	300	None	200
Feed (kg dry hay)	None	None	None	800	800	800	800	800	800	800	800	800
Labor (day/ha)	53.0	49.0	49.0	33.0	29.0	29.0	61.0	31.0	48.0	66.0	35.0	52.0
Yield (kg/ha)												
Millet seed	380	400	360	420	440	400		480			960	
Groundnut seed							530		260	620		340
Dry groundnut hay							424		208	496		272

Source: Author's estimations

Table 5-A-5. Technological Components for the Millet and Groundnut Crops in the Center and Plateau Zone

TECHNOLOGICAL COMPONENTS	FARMER PRACTICE NON EQUIPPED			FARMER PRACTICE EQUIPPED			TECHNOLOGICAL ALTERNATIVES WITHOUT TRP			TECHNOLOGICAL ALTERNATIVES WITH TRP		
	MILLET	MILLET	MILLET	MILLET	MILLET	MILLET	GRDNUT	MILLET	GRDNUT	GRDNUT	MILLET	GRDNUT
Varieties	Local	Local	Local	Local	Local	Local	47-10	Local	47-10	47-10	Local	47-10
Densities	10000	10000	10000	10000	10000	10000		15625			15625	
Seed Quantity (kg/ha)	10	10	10	10	10	10	100	10	100	100	10	100
Chemical Seed Treatment												
Thioral (gPC/ha)	25	25	25	25	25	25	200	25	200	200	25	200
Mechanized Operations	None	None	None	Weeding	Weeding	Weeding	Weeding	Weeding	Weeding	Weeding	Weeding	Weeding
Power source	Manual	Manual	Manual	Donkey	Donkey	Donkey	Donkey	Donkey	Donkey	Donkey	Donkey	Donkey
Chemical Fertilizer												
(kg/ha of TRP)	None	None	None	None	None	None	None	None	None	300	None	None
Chemical Storage Control												
Actellic (gPC/ha)	None	None	None	None	None	None	200	None	100	300	None	100
Feed (kg dry hay)	None	None	None	800	800	800	800	800	800	800	800	800
Labor (day/ha)	55.0	50.0	45.0	35.0	30.0	25.0	57.0	33.0	48.0	65.0	35.0	48.0
Yield (kg/ha)												
Millet seed	480	500	450	520	550	500		700			860	
Groundnut seed							430		260	570		230
Dry groundnut hay							344		208	456		456

Source: Author's estimations

Table 5-A-6. Technological Components for the Sesame Crop in the Northern Zone

TECHNOLOGICAL COMPONENTS	FARMER PRACTICE MILLET (2d year) NON EQUIPPED	EQUIPPED	TECHNOLOGICAL ALTERNATIVE SESAME
Varieties	Local	Local	38-1-7
Densities	10000	10000	166500
Seed Quantity (kg/ha)	10	10	10
Chemical Seed Treatment			
Thioral (gPC/ha)	25	25	None
Mechanized Operations	None	Weeding	Weeding
Power source	Manual	Donkey	Donkey
Chemical Fertilizer			
(kg/ha of phosphate)	None	None	32.5
Feed (kg dry hay)	None	800	800
Labor (day/ha)	41.5	23.5	35.0
Yield (kg/ha)			
Millet seed	300	330	
Sesame seed			300

Source: Author's estimations

Table 5-A-7. Technological Components for the Sesame Crop in the Center and Plateau Zone

TECHNOLOGICAL COMPONENTS	FARMER PRACTICE MILLET (2d year) NON EQUIPPED	EQUIPPED	TECHNOLOGICAL ALTERNATIVE SESAME
Varieties	Local	Local	38-1-7
Densities	10000	10000	166500
Seed Quantity (kg/ha)	10	10	10
Chemical Seed Treatment			
Thioral (gPC/ha)	25	25	None
Mechanized Operations	None	Weeding	Weeding
Power source	Manual	Donkey	Donkey
Chemical Fertilizer			
(kg/ha of phosphate)	None	None	65
Feed (kg dry hay)	None	800	800
Labor (day/ha)	49.0	29.0	43.0
Yield (kg/ha)			
Millet seed	400	440	
Sesame seed			450

Source: Author's estimations

Table 5-A-8. Technological Components for the Sesame Crop in the Southern Zone

TECHNOLOGICAL COMPONENTS	FARMER PRACTICE MILLET (2d year)		TECHNOLOGICAL ALTERNATIVE
	NON EQUIPPED	EQUIPPED	SESAME
Varieties	Local	Local	38-1-7
Densities	10000	10000	166500
Seed Quantity (kg/ha)	10	10	10
Chemical Seed Treatment			
Thioral (gPC/ha)	25	25	None
Mechanized Operations	None	Weeding	Weeding
Power source	Manual	Donkey	Donkey
Chemical Fertilizer			
(kg/ha of phosphate)	None	None	65
Feed (kg dry hay)	None	800	800
Labor (day/ha)	50.0	30.0	49.0
Yield (kg/ha)			
Millet seed	500	550	
Sesame seed			600

Source: Author's estimations

APPENDIX 5-B

Table 5-B-1. Capital Costs Financed by AID (in US$ 1000)

ITEMS	YEAR 1 (1988)	YEAR 2 (1989)	YEAR 3 (1990)	YEAR 4 (1991)	YEAR 5 (1992)	YEAR 6 (1993)	YEAR 7 (1994)	TOTAL	%
TECHNICAL ASSISTANCE:	0.00	340.00	325.00	310.00	305.00	5.00	5.00	1290.00	33.89
Agronomist	0.00	150.00	150.00	150.00	150.00	0.00	0.00	600.00	15.76
Agricultural economist	0.00	150.00	150.00	150.00	150.00	0.00	0.00	600.00	15.76
Short-term ass.(1)	0.00	40.00	25.00	10.00	5.00	5.00	5.00	90.00	2.36
SHORT-TERM TRAINING (1):	0.00	35.00	27.50	27.50	27.50	0.00	0.00	117.50	3.09
Courses	0.00	10.00	10.00	10.00	10.00	0.00	0.00	40.00	1.05
Language training	0.00	7.50	0.00	0.00	0.00	0.00	0.00	7.50	0.20
Observation tours	0.00	7.50	7.50	7.50	7.50	0.00	0.00	30.00	0.79
In-country workshops,	0.00	10.00	10.00	10.00	10.00	0.00	0.00	40.00	1.05
COMMODITIES:									
Vehicles:	0.00	60.00	0.00	0.00	60.00	0.00	0.00	120.00	3.15
2 4WD	0.00	30.00	0.00	0.00	30.00	0.00	0.00	60.00	1.58
2 Pick up	0.00	24.00	0.00	0.00	24.00	0.00	0.00	48.00	1.26
2 motorcycle	0.00	2.00	0.00	0.00	2.00	0.00	0.00	4.00	0.11
8 mobylettes	0.00	4.00	0.00	0.00	4.00	0.00	0.00	8.00	0.21
RESEARCH EQUIPMENT (1):	0.00	24.00	1.50	14.00	26.50	11.50	14.00	91.50	2.40
Computers	0.00	10.00	0.00	0.00	0.00	10.00	0.00	20.00	0.53
Computers Software	0.00	1.50	1.50	1.50	1.50	1.50	1.50	9.00	0.24
Field Equipment	0.00	12.50	0.00	12.50	25.00	0.00	12.50	62.50	1.64
OFFICE EQUIPMENT	0.00	20.00	0.00	0.00	20.00	0.00	0.00	40.00	1.05
FURNISHING (2):	0.00	175.00	25.00	0.00	0.00	0.00	0.00	200.00	5.25
Koporo Station housing	0.00	40.00	0.00	0.00	0.00	0.00	0.00	40.00	1.05
Fifth region generators	0.00	25.00	0.00	0.00	0.00	0.00	0.00	25.00	0.66
Fifth region housing	0.00	50.00	25.00	0.00	0.00	0.00	0.00	75.00	1.97
Fifth region offices	0.00	60.00	0.00	0.00	0.00	0.00	0.00	60.00	1.58
CONSTRUCTION (2):	305.60	348.20	76.00	0.00	0.00	0.00	0.00	729.80	19.17
Koporo Station Development:	113.00	94.00	0.00	0.00	0.00	0.00	0.00	207.00	5.44
Office addition	18.00	0.00	0.00	0.00	0.00	0.00	0.00	18.00	0.47
Professional housing	40.00	39.00	0.00	0.00	0.00	0.00	0.00	79.00	2.08
Staff housing	40.00	30.00	0.00	0.00	0.00	0.00	0.00	70.00	1.84
Guest house	15.00	25.00	0.00	0.00	0.00	0.00	0.00	40.00	1.05
DRSPR:	192.60	254.20	76.00	0.00	0.00	0.00	0.00	522.80	13.74
Office construction	30.00	42.00	0.00	0.00	0.00	0.00	0.00	72.00	1.89
Professional housing	50.00	80.00	30.00	0.00	0.00	0.00	0.00	160.00	4.20
Staff housing	50.00	70.00	20.00	0.00	0.00	0.00	0.00	140.00	3.68
Water tower	16.00	0.00	0.00	0.00	0.00	0.00	0.00	16.00	0.42
Guest house	20.00	20.00	0.00	0.00	0.00	0.00	0.00	40.00	1.05
Garages	0.00	10.00	10.00	0.00	0.00	0.00	0.00	20.00	0.53
Construction coordinator	10.00	10.00	10.00	0.00	0.00	0.00	0.00	30.00	0.79
10% A&E services,supervision	16.60	22.20	6.00	0.00	0.00	0.00	0.00	44.80	1.18
SUB-TOTAL	305.60	1002.20	455.00	351.50	439.00	16.50	19.00	2588.80	68.02

Table 5-B-1 (cont'd.).

Contingency:	0.10	30.56	100.22	45.50	35.15	43.90	1.65	1.90	258.88	6.80
Inflation:	1.05	72.44	304.58	170.22	157.41	230.56	10.01	13.14	958.36	25.18
TOTAL		408.60	1407.00	670.72	544.06	713.46	28.16	34.04	3806.04	100.00

(1) Only 50% of the budget estimates.
(2) Furnishing and construction are rescheduled on years one and two of the project.
Source: USAID, 1985

Table 5-B-2. Recurrent Costs Financed by AID (in US$ 1000)

ITEMS	YEAR 1 (1988)	YEAR 2 (1989)	YEAR 3 (1990)	YEAR 4 (1991)	YEAR 5 (1992)	YEAR 6 (1993)	YEAR 7 (1994)	TOTAL	%
SALARIES:									
Professional Staff:	0.00	14.52	14.52	14.52	14.52	14.52	14.52	87.12	5.78
Agronomist	0.00	1.86	1.86	1.86	1.86	1.86	1.86	11.16	0.74
Economist	0.00	1.86	1.86	1.86	1.86	1.86	1.86	11.16	0.74
Livestock Specialist	0.00	1.86	1.86	1.86	1.86	1.86	1.86	11.16	0.74
Sociologist	0.00	1.86	1.86	1.86	1.86	1.86	1.86	11.16	0.74
2 Research assistants	0.00	3.24	3.24	3.24	3.24	3.24	3.24	19.44	1.29
8 Moniteurs	0.00	3.84	3.84	3.84	3.84	3.84	3.84	23.04	1.53
Support Staff:	0.00	20.46	20.46	20.46	9.42	20.46	20.46	111.72	7.42
2 Accountants	0.00	3.00	3.00	3.00	1.86	3.00	3.00	16.86	1.12
2 Data Specialists	0.00	7.44	7.44	7.44	3.24	7.44	7.44	40.44	2.69
Typist	0.00	1.80	1.80	1.80	0.54	1.80	1.80	9.54	0.63
Messenger	0.00	0.60	0.60	0.60	0.18	0.60	0.60	3.18	0.21
3 Drivers	0.00	5.22	5.22	5.22	2.70	5.22	5.22	28.80	1.91
2 Guards	0.00	0.60	0.60	0.60	0.36	0.60	0.60	3.36	0.22
Warehouseman	0.00	1.80	1.80	1.80	0.54	1.80	1.80	9.54	0.63
VEHICLE MAINTENANCE	0.00	13.50	14.50	14.50	10.50	10.50	10.50	74.00	4.91
OFFICE SUPPLIES	0.00	10.00	10.00	10.00	7.00	7.00	7.00	51.00	3.39
RENTS, UTILITIES, BUILDING MAINTENANCE	0.00	16.50	16.50	16.50	11.55	11.55	11.55	84.15	5.59
EXPENDABLE RES. SUPPLIES	0.00	12.00	12.00	12.00	8.40	8.40	8.40	61.20	4.06
COOPERATIVE RES., STUDIES(1):	0.00	30.60	30.60	30.60	30.60	30.60	30.60	183.60	12.19
with DRA	0.00	15.00	15.00	15.00	15.00	15.00	15.00	90.00	5.98
with DMA, PIRT, INRZFH	0.00	15.00	15.00	15.00	15.00	15.00	15.00	90.00	5.98
with IPR	0.00	0.60	0.60	0.60	0.60	0.60	0.60	3.60	0.24
EVALUATIONS (1):	200.00	0.00	0.00	40.00	0.00	0.00	80.00	320.00	21.25
inc. economic evaluation	200.00	0.00	0.00	0.00	0.00	0.00	0.00	200.00	13.28
SUB-TOTAL	200.00	117.58	118.58	158.58	91.99	103.03	183.03	972.79	64.59
LOP Contingency: 0.10	20.00	11.76	11.86	15.86	9.20	10.30	18.30	97.28	6.46
Inflation : 1.05	47.41	35.73	44.36	71.01	48.31	62.48	126.62	435.93	28.95
TOTAL	267.41	165.07	174.80	245.45	149.50	175.82	327.95	1506.00	100.00

(1) 50% of the budget estimates.
Source: USAID, 1985

Table 5-B-3. **Recurrent Costs Financed by the Government of Mali (in US$ 1000)**

ITEMS		YEAR 1 (1988)	YEAR 2 (1989)	YEAR 3 (1990)	YEAR 4 (1991)	YEAR 5 (1992)	YEAR 6 (1993)	YEAR 7 (1994)	YEAR 8 (1995)	YEAR 9 (1996)	YEAR 10 (1997)	TOTAL	%
SALARIES:													
Professional Staff:		0.00	37.20	37.20	37.20	37.20	37.20	37.20	0.00	0.00	0.00	223.20	45.63
Agronomist		0.00	4.20	4.20	4.20	4.20	4.20	4.20	0.00	0.00	0.00	25.20	5.15
Economist		0.00	4.20	4.20	4.20	4.20	4.20	4.20	0.00	0.00	0.00	25.20	5.15
Livestock Specialist		0.00	4.20	4.20	4.20	4.20	4.20	4.20	0.00	0.00	0.00	25.20	5.15
Sociologist		0.00	4.20	4.20	4.20	4.20	4.20	4.20	0.00	0.00	0.00	25.20	5.15
2 Research assistants		0.00	6.00	6.00	6.00	6.00	6.00	6.00	0.00	0.00	0.00	36.00	7.36
8 Moniteurs		0.00	14.40	14.40	14.40	14.40	14.40	14.40	0.00	0.00	0.00	86.40	17.66
Support Staff:		0.00	3.60	3.60	3.60	14.70	3.60	3.60	0.00	0.00	0.00	32.70	6.69
2 Accountants		0.00	3.00	3.00	3.00	4.20	3.00	3.00	0.00	0.00	0.00	19.20	3.93
2 Data Specialists		0.00	0.00	0.00	0.00	4.20	0.00	0.00	0.00	0.00	0.00	4.20	0.86
Typist		0.00	0.00	0.00	0.00	1.26	0.00	0.00	0.00	0.00	0.00	1.26	0.26
Messenger		0.00	0.00	0.00	0.00	0.42	0.00	0.00	0.00	0.00	0.00	0.42	0.09
3 Drivers		0.00	0.00	0.00	0.00	2.52	0.00	0.00	0.00	0.00	0.00	2.52	0.52
2 Guards		0.00	0.60	0.60	0.60	0.84	0.60	0.60	0.00	0.00	0.00	3.84	0.79
Warehouseman		0.00	0.00	0.00	0.00	1.26	0.00	0.00	0.00	0.00	0.00	1.26	0.26
VEHICLE MAINTENANCE		0.00	0.00	0.00	0.00	4.35	4.35	4.35	0.00	0.00	0.00	13.05	2.67
OFFICE SUPPLIES		0.00	0.00	0.00	0.00	3.00	3.00	3.00	0.00	0.00	0.00	9.00	1.84
RENTS, UTILITIES, BUILDING MAINTENANCE		0.00	0.00	0.00	0.00	4.95	4.95	4.95	0.00	0.00	0.00	14.85	3.04
EXPENDABLE RES. SUPPLIES		0.00	0.00	0.00	0.00	3.60	3.60	3.60	0.00	0.00	0.00	10.80	2.21
COOPERATIVE RES., STUDIES		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SUB-TOTAL		0.00	40.80	40.80	40.80	67.80	56.70	56.70	0.00	0.00	0.00	303.60	62.07
LOP Contingency:	0.10	0.00	4.08	4.08	4.08	6.78	5.67	5.67	0.00	0.00	0.00	30.36	6.21
Inflation :	1.05	0.00	12.40	15.26	18.27	35.61	34.39	39.22	0.00	0.00	0.00	155.15	31.72
TOTAL		0.00	57.28	60.14	63.15	110.19	96.76	101.59	0.00	0.00	0.00	489.11	100.00

Source: USAID, 1985

APPENDIX 5-C

Table 5-C-1. Financial Prices by Agroclimatic Zone

ITEMS	SOUTH		CENTER/PLATEAU/DELTA		NORTH	
	EXPECTED	CURRENT (9)	EXPECTED	CURRENT (9)	EXPECTED	CURRENT (9)
Millet Seeds (CFA F/kg) (1)	75	50	75	55	75	60
Cowpea Seeds (CFA F/kg)	218	150	218	160	218	180
Groundnut Seeds (CFA F/kg)	87	50	87	60	87	80
Sesame Seeds (CFA F/kg)	164		164		164	
O. glaberrima Rice Seeds (CFA F/kg)			109	75		
O. sativa Rice Seeds (CFA F/kg) (1)			109	109		
APRON + (CFA F/bag)	327		327		327	
Thioral (CFA F/bag) (2)	69	100	69	107	69	95
Decis (CFA F/L)	2040		2040		2040	
Actellic (CFA F/sack)	240		240		240	
Phostoxin (CFA F/tablet)	218		218		218	
Plastic Bag (CFA F/bag)	546		546		546	
Tilemsi Rock Phosphate (CFA F/kg) (3)	38		38		38	
Amoniaque Phosphate (CFA F/kg) (3)	185		185		185	
"Super simple" Phosphate (CFA F/kg) (4)	76		76		76	
Urea (CFA F/kg) (3)	175		175		175	
Sprayer T 15 (CFA F/unit) (4)	20871		20871		20871	
Plow (CFA F/unit) (5)	48222	(TM Smecma)	78007	(Bajac B2)		
Smecma Donkey Plow (CFA F/unit) (5)	42985	42982	42985	42982	42985	42982
Oxen (CFA F/pair)	80000	80000	100000	100000		
Donkey (CFA F/unit)	20000	20000	25000	25000	20000	20000
ORM Polder Fees (CFA F/ha)			12600	12600		
ORM Treshing Fees (CFA F/kg)			8.4	8.4		
Millet (CFA F/kg)	50	30	60	40	70	50
Cowpea (CFA F/kg)	100	60	110	70	120	80
Groundnuts (CFA F/kg)	55	40	60	45	65	50
Sesame (CFA F/kg)	65		70		55	
O. glaberrima Rice (CFA F/kg)			50	50		
O. Sativa Rice (CFA F/kg)			70	70		
Cattle on the Hoof (CFA F/kg)	200	200	250	250	200	200
Cowpea Fodder (CFA F/kg)	12	12	15	15	12	12
Groundnut Fodder (CFA F/kg)	12	12	15	15	12	12
Rice Fodder (CFA F/kg)			8	8		
Opportunity Cost of Labor (CFA F/day):						
(6)	349	349	450	450	397	397
(7)	456	456	603	603	528	528
Opportunity Cost of Manure (CFA F/T)	1000	1000	1500	1500	1000	1000
Inflation (%) (8)	6	6	6	6	6	6

Table 5-C-1 (cont'd.).

(1) OPSS price in 1988 increased by 20% for transportation in the region of Mopti.
(2) Expected: SMPC price in 1988 increased by 20% for transportation in the Region of Mopti.
Current: According the formal survey (Decembre 1987 - March 1988).
(3) CMDT price in 1988 increased by 20% for transportation in the Region of Mopti.
(4) OHV price in 1988 increased by 20% for transportation in the Region of Mopti.
(5) SMECMA price in 1988 increased by 20% for transportation in the Region of Mopti.
(6) With respect to the traditional millet-cowpea intercroppping.
(7) With respect to the transitional millet-cowpea intercroppping.
(8) Inflation used to estimate the real interest rate.
(9) CURRENT: Figures estimated from the surveys and used for the traditional and transitional enterprises.
EXPECTED: Estimated figures and used for the improved enterprises.

Table 5-C-2. Economic Prices by Agroclimatic Zone

ITEMS	%	SOUTH EXPECTED	SOUTH CURRENT (9)	CENTER/PLATEAU/DELTA EXPECTED	CENTER/PLATEAU/DELTA CURRENT (9)	NORTH EXPECTED	NORTH CURRENT (9)
Overvaluation Factor (%) (1)	33						
Millet Seeds (CFA F/kg) (2)		75	50	75	55	75	60
Subsidies	20	15		15		15	
Economic value (CFA F/kg)		90	50	90	55	90	60
Cowpea Seeds (CFA F/kg)		218	150	218	160	218	180
Subsidies	20	44		44		44	
Economic value (CFA F/kg)		262	150	262	160	262	180
Groundnut Seeds (CFA F/kg)		87	50	87	60	87	80
Subsidies	20	17		17		17	
Economic value (CFA F/kg)		105	50	105	60	105	80
Sesame Seeds (CFA F/kg)		164		164		164	
Subsidies	20	33		33		33	
Economic value (CFA F/kg)		196		196		196	
O. glaberrima Rice Seeds (CFA F/kg)				109	75		
Subsidies	20			22	15		
Economic value (CFA F/kg)				131	90		
O. sativa Rice Seeds (CFA F/kg)				109	109		
Subsidies	20			22	22		
Economic value (CFA F/kg)				131	131		
APRON + (CFA F/bag)		327		327		327	
Imported Component	80	262		262		262	
Domestic Component	20	65		65		65	
Custom Duties (3)	0	0		0		0	
CPS (4)	5	13		13		13	
Other Taxes	0	0		0		0	
Subsidies	0	0		0		0	
Economic Value (CFA F/kg)		396		396		396	
Thioral (CFA F/bag) (5)		69	100	69	107	69	95
Imported Component	80	55	80	55	86	55	76
Domestic Component	20	14	20	14	21	14	19
Custom Duties (3)	0	0	0	0	0	0	0
CPS (4)	5	3	4	3	4	3	4
Other Taxes	0	0	0	0	0	0	0
Subsidies	0	0	0	0	0	0	0
Economic Value (CFA F/kg)		83	121	83	130	83	115
Decis (CFA F/L)		2040		2040		2040	
Imported Component	80	1632		1632		1632	
Domestic Component	20	408		408		408	
Custom Duties (3)	0	0		0		0	
CPS (4)	5	82		82		82	
Other Taxes	0	0		0		0	
Subsidies	0	0		0		0	
Economic Value (CFA F/kg)		2470		2470		2470	

Table 5-C-2 (cont'd.).

ITEMS	%	SOUTH		CENTER/PLATEAU/DELTA		NORTH	
		EXPECTED	CURRENT (9)	EXPECTED	CURRENT (9)	EXPECTED	CURRENT (9)
Actellic (CFA F/bag)		240		240		240	
Imported Component	80	192		192		192	
Domestic Component	20	48		48		48	
Custom Duties (3)	0	0		0		0	
CPS (4)	5	10		10		10	
Other Taxes	0	0		0		0	
Subsidies	0	0		0		0	
Economic Value (CFA F/kg)		291		291		291	
Phostoxin (CFA F/tablet)		218		218		218	
Imported Component	80	175		175		175	
Domestic Component	20	44		44		44	
Custom Duties (3)	0	0		0		0	
CPS (4)	5	9		9		9	
Other Taxes	0	0		0		0	
Subsidies	0	0		0		0	
Economic Value (CFA F/kg)		264		264		264	
Plastic Bag (CFA F/bag)		546		546		546	
Imported Component	80	436		436		436	
Domestic Component	20	109		109		109	
Custom Duties (3)	0	0		0		0	
CPS (4)	5	22		22		22	
Other Taxes	0	0		0		0	
Subsidies	0	0		0		0	
Economic Value (CFA F/kg)		660		660		660	
Tilemsi Rock Phosphate (CFA F/kg)		38		38		38	
Subsidies	0	0		0		0	
Economic value (CFA F/kg)		38		38		38	
Amonia Phosphate (CFA F/kg) (7)		185		185		185	
Imported Component	80	148		148		148	
Domestic Component	20	37		37		37	
Custom Duties (3)	0	0		0		0	
CPS (4)	5	7		7		7	
Other Taxes	0	0		0		0	
Subsidies	0	0		0		0	
Economic Value (CFA F/kg)		225		225		225	
"Super simple" Phosphate (CFA F/kg)		76		76		76	
Imported Component	80	61		61		61	
Domestic Component	20	15		15		15	
Custom Duties (3)	0	0		0		0	
CPS (4)	5	3		3		3	
Other Taxes	0	0		0		0	
Subsidies	0	0		0		0	
Economic Value (CFA F/kg)		92		92		92	

Table 5-C-2 (cont'd.).

ITEMS	%	SOUTH EXPECTED	SOUTH CURRENT (9)	CENTER/PLATEAU/DELTA EXPECTED	CENTER/PLATEAU/DELTA CURRENT (9)	NORTH EXPECTED	NORTH CURRENT (9)
Urea (CFA F/kg) (7)		175		175		175	
Imported Component	80	140		140		140	
Domestic Component	20	35		35		35	
Custom Duties (3)	0	0		0		0	
CPS (4)	5	7		7		7	
Other Taxes	0	0		0		0	
Subsidies	0	0		0		0	
Economic Value (CFA F/kg)		211		211		211	
Sprayer T 15 (CFA F/unit) (8)		20871		20871		20871	
Imported Component	80	16697		16697		16697	
Domestic Component	20	4174		4174		4174	
Custom Duties (3)	0	0		0		0	
CPS (4)	5	835		835		835	
Other Taxes	0	0		0		0	
Subsidies	0	0		0		0	
Economic Value (CFA F/kg)		25270		25270		25270	
Plow (CFA F/unit) (9)		48222	(TM Smecma)	78007	(Bajac B2)		
Imported Component	80	38578		62405			
Domestic Component	20	9644		15601			
Custom Duties (3)	0	0		0			
CPS (4)	5	1929		3120			
Other Taxes	0	0		0			
Subsidies	8	3858		6241			
Economic Value (CFA F/kg)		62245		100691			
Smecma Donkey Plow (CFA F/unit) (9)		42985	42982	42985	42982	42985	42982
Imported Component	80	34388	34385	34388	34385	34388	34385
Domestic Component	20	8597	8596	8597	8596	8597	8596
Custom Duties (3)	0	0	0	0	0	0	0
CPS (4)	5	1719	1719	1719	1719	1719	1719
Other Taxes	0	0	0	0	0	0	0
Subsidies	8	3439	3439	3439	3439	3439	3439
Economic Value (CFA F/kg)		55486	55481	55486	55481	55486	55481
Oxen (CFA F/pair)		80000	80000	100000	100000		
Donkey (CFA F/unit)		20000	20000	25000	25000	20000	20000
ORM Polder Fees (CFA F/ha)				12600	12600		
Imported Component	20			2520	2520		
Domestic Component	80			10080	10080		
Custom Duties (3)	22			542	542		
CPS (4)	5			99	99		
Other Taxes	23			2318	2318		
Subsidies	0			0	0		
Economic Value (CFA F/kg)				10261	10261		

Table 5-C-2 (cont'd.).

ITEMS	%	SOUTH EXPECTED	SOUTH CURRENT (9)	CENTER/PLATEAU/DELTA EXPECTED	CENTER/PLATEAU/DELTA CURRENT (9)	NORTH EXPECTED	NORTH CURRENT (9)
ORM Treshing Fees (CFA F/kg)				8	8		
Imported Component	20			2	2		
Domestic Component	80			7	7		
Custom Duties (3)	22			0	0		
CPS (4)	5			0	0		
Other Taxes	23			2	2		
Subsidies	0			0	0		
Economic Value (CFA F/kg)				7	7		
OMM Extension		500	500	500	500	500	500
Imported Component	20	100	100	100	100	100	100
Domestic Component	80	400	400	400	400	400	400
Custom Duties (3)	22	22	22	22	22	22	22
CPS (4)	5	4	4	4	4	4	4
Other Taxes	23	92	92	92	92	92	92
Subsidies	0	0	0	0	0	0	0
Economic Value (CFA F/kg)		397	397	397	397	397	397
Millet (CFA F/kg)		50	30	60	40	70	50
Cowpea (CFA F/kg)		100	60	110	70	120	80
Groundnuts (CFA F/kg)		55	40	60	45	65	50
Border Price Adjustment	0	0	0	0	0	0	0
Economic Value (CFA F/kg)		55	40	60	45	65	50
Sesame (CFA F/kg)		65		70		55	
CPS (11)	3	2		2		2	
Export taxes	5	3		4		3	
Economic Value (CFA F/kg)		93		101		79	
O. glaberrima Rice (CFA F/kg)				50	50		
Border Price Adjustment	0			0	0		
Economic Value (CFA F/kg)				50	50		
O. Sativa Rice (CFA F/kg)				70	70		
Border Price Adjustment	0	0	0	0	0		
Economic Value (CFA F/kg)		0	0	70	70		
Cattle on the Hoof (CFA F/kg)		200	200	250	250	200	200
Cowpea Fodder (CFA F/kg)		12	12	15	15	12	12
Groundnut Fodder (CFA F/kg)		12	12	15	15	12	12
Rice Fodder (CFA F/kg)				8	8		
Opportunity Cost of Labor (CFA F/day):							
(12)		343	343	442	442	389	389
(13)		425	425	569	569	486	486
Opportunity Cost of Manure (CFA F/T)		1000	1000	1500	1500	1000	1000
Economic Interest Rate (%)		12	12	12	12	12	12

Table 5-C-2 (cont'd.).

(1) Correcting only for the deficit in the balance of payments, but not the structure of protection, (Stryker et al., 1987).
(2) OPSS price in 1988 increased by 20% for transportation in the region of Mopti.
(3) Custom Duties including the "droit de douane" (DD), "droit fiscal d'importation" (DFI) and the tax of the Office de Stabilisation et de Regularisation des Prix (OSRP).
(4) CPS stnds here for "Contribution pour Prestations de Services particuliers rendus à l'importation".
(5) SMPC price in 1988 increased by 20% for transportation in the Region of Mopti.
(6) For the SMEEPC, the maximum authorized market margin is 20% of the without tax imported value for fertilizers and pesticides.
(7) CMDT price in 1988 increased by 20% for transportation in the Region of Mopti.
(8) OHV price in 1988 increased by 20% for transportation in the Region of Mopti.
(9) SMECMA price in 1988 increased by 20% for transportation in the Region of Mopti.
(10) Adapted from Stryker et al., 1987.
(11) CPS stands here for "Contribution pour Prestations de Services particuliers rendus à l'exportation".
(12) With respect to the traditional millet-cowpea intercroppping.
(13) With respect to the transitional millet-cowpea intercroppping.

Note: The economic price for the agricultural inputs is estimated as following:
(Overvaluation Factor in % / 100 + 1)
* (Imported Component - Custom Duties - CPS) + (Domestic Component - Other Taxes + Subsidies).
The economic price for the agricultural products is estimated as following:
(Overvaluation Factor in % / 100 + 1) * (Farm Gate Price + Export Taxes).

Table 5-C-3. **Financial Amortization Charges by Agroclimatic Zone (CFA F) (1)**

ITEMS	SOUTH		CENTER/PLATEAU/DELTA		NORTH	
	EXPECTED	CURRENT (9)	EXPECTED	CURRENT (9)	EXPECTED	CURRENT (9)
Sprayer T 15 (CFA F/unit):						
Recovery Period (year)	4		4		4	
Nominal Interest Rate (%)	18		18		18	
Real Interest Rate (%)	12		12		12	
Capital Recovery Factor	0.33		0.33		0.33	
Constant Annuity (CFA F/year)	6871		6871		6871	
Maintenance (CFA F/year)	500		500		500	
Area (Ha)	4		4		4	
Amortization Charge (CFA F/year)	1843		1843		1843	
Smecma Donkey Plow (CFA F/unit):	Smecma	Smecma	Smecma	Smecma	Smecma	Smecma
Recovery Period (year)	6	6	6	6	6	6
Nominal Interest Rate (%)	18	18	18	18	18	18
Real Interest Rate (%)	12	12	12	12	12	12
Capital Recovery Factor	0.24	0.24	0.24	0.24	0.24	0.24
Constant Annuity (CFA F/year)	10455	10454	10455	10454	10455	10454
Maintenance (CFA F/year)	500	500	500	500	500	500
Area (Ha)	4	4	4	4	4	4
Amortization Charge (CFA F/year)	2739	2739	2739	2739	2739	2739
Plow (CFA F/unit):	TM Smecm	TM Smecma	Bajac B2	Bajac B2		
Recovery Period (year)	6	6	6	6		
Nominal Interest Rate (%)	18	18	18	18		
Real Interest Rate (%)	12	12	12	12		
Capital Recovery Factor	0.24	0.24	0.24	0.24		
Constant Annuity (CFA F/year)	11729	11729	18973	18973		
Maintenance (CFA F/year)	500	500	800	800		
Area (Ha)	4	4	4	4		
Amortization Charge (CFA F/year)	3057	3057	4943	4943		
Donkey (CFA F/unit):						
Active Life (year)	6	6	6	6	6	6
Mortality Rate (%)	3	3	3	3	3	3
Recovery Period (year)	5.8	5.8	5.8	5.8	5.8	5.8
Nominal Interest Rate (%)	18	18	18	18	18	18
Real Interest Rate (%)	12	12	12	12	12	12
Capital Recovery Factor	0.25	0.25	0.25	0.25	0.25	0.25
Constant Annuity (CFA F/year)	4982	4982	6227	6227	4982	4982
Maintenance (CFA F/year)	9600	9600	12000	12000	9600	9600
Area (Ha)	4	4	4	4	4	4
Amortization Charge (CFA F/year)	3645	3645	4557	4557	3645	3645

Table 5-C-3 (cont'd.).

Oxen (CFA F/pair):				
Active Life (year)	6	6	6	6
Mortality Rate (%)	3	3	3	3
Recovery Period (year)	5.8	5.8	5.8	5.8
Nominal Interest Rate (%)	18	18	18	18
Real Interest Rate (%)	12	12	12	12
Capital Recovery Factor	0.25	0.25	0.25	0.25
Constant Annuity (CFA F/year)	19927	19927	24909	24909
Maintenance (CFA F/year)	27600	27600	36800	36800
Area (Ha)	4	4	4	4
Amortization Charge (CFA F/year)	11882	11882	15427	15427
Tilemsi Rock Phosphate (CFA F/kg):				
Recovery Period (year)	3		3	
Nominal Interest Rate (%)	18		18	
Real Interest Rate (%)	12		12	
Capital Recovery Factor	0.42		0.42	
Constant Annuity (CFA F/year)	16		16	

(1) To simplify the calculation of amortization charges, constant annuities are used. A capital recovery factor is applied to the value of the initial investment using a 18% market interest rate discounted by a 6% inflation rate.

Table 5-C-4. Economic Amortization Charges by Agroclimatic Zone (CFA F) (1)

ITEMS	SOUTH		CENTER/PLATEAU/DELTA		NORTH	
	EXPECTED	CURRENT (9)	EXPECTED	CURRENT (9)	EXPECTED	CURRENT (9)
Sprayer T 15 (CFA F/unit):						
Recovery Period (year)	4		4		4	
Economic Interest Rate (%)	12		12		12	
Capital Recovery Factor	0.33		0.33		0.33	
Constant Annuity (CFA F/year)	8320		8320		8320	
Maintenance (CFA F/year)	500		500		500	
Area (Ha)	4		4		4	
Armotization Charge (CFA F/year)	2205		2205		2205	
Smecma Donkey Plow (CFA F/unit):	Smecma	Smecma	Smecma	Smecma	Smecma	Smecma
Recovery Period (year)	6	6	6	6	6	6
Economic Interest Rate (%)	12	12	12	12	12	12
Capital Recovery Factor	0.24	0.24	0.24	0.24	0.24	0.24
Constant Annuity (CFA F/year)	13496	13494	13496	13494	13496	13494
Maintenance (CFA F/year)	500	500	500	500	500	500
Area (Ha)	4	4	4	4	4	4
Armotization Charge (CFA F/year)	3499	3499	3499	3499	3499	3499
Plow (CFA F/unit):	TM Smecm	TM Smecma	Bajac B2	Bajac B2		
Recovery Period (year)	6	6	6	6		
Economic Interest Rate (%)	12	12	12	12		
Capital Recovery Factor	0.24	0.24	0.24	0.24		
Constant Annuity (CFA F/year)	15140	15140	24491	24491		
Maintenance (CFA F/year)	500	500	800	800		
Area (Ha)	4	4	4	4		
Armotization Charge (CFA F/year)	3910	3910	6323	6323		
Donkey (CFA F/unit):						
Active Life (year)	6	6	6	6	6	6
Mortality Rate (%)	3	3	3	3	3	3
Recovery Period (year)	5.8	5.8	5.8	5.8	5.8	5.8
Economic Interest Rate (%)	12	12	12	12	12	12
Capital Recovery Factor	0.25	0.25	0.25	0.25	0.25	0.25
Constant Annuity (CFA F/year)	4982	4982	6227	6227	4982	4982
Maintenance (CFA F/year)	9600	9600	12000	12000	9600	9600
Area (Ha)	4	4	4	4	4	4
Armotization Charge (CFA F/year)	3645	3645	4557	4557	3645	3645

Table 5-C-4 (cont'd.).

Oxen (CFA F/pair):					
Active Life (year)	6	6	6	6	
Mortality Rate (%)	3	3	3	3	
Recovery Period (year)	5.8	5.8	5.8	5.8	
Economic Interest Rate (%)	12	12	12	12	
Capital Recovery Factor	0.25	0.25	0.25	0.25	
Constant Annuity (CFA F/year)	19927	19927	24909	24909	
Maintenance (CFA F/year)	27600	27600	36800	36800	
Area (Ha)	4	4	4	4	
Amortization Charge (CFA F/year)	11882	11882	15427	15427	
Tilemsi Rock Phosphate (CFA F/kg):					
Recovery Period (year)	3		3		3
Economic Interest Rate (%)	12		12		12
Capital Recovery Factor	0.42		0.42		0.42
Constant Annuity (CFA F/year)	16		16		16

(1) To simplify the calculation of amortization charges, constant annuities are used. A capital recovery factor is applied to the value of the initial investment using a 12% economic interest rate.

APPENDIX 5-D

Table 5-D-1. Financial Budgets for the Millet-Cowpea Intercropping by Zone

ZONE:	SOUTH			CENTER/PLATEAU			NORTH		
TECHNOLOGICAL LEVEL (1):	IMPROVED	TRANSIT.	TRADIT.	IMPROVED	TRANSIT.	TRADIT.	IMPROVED	TRANSIT.	TRADIT.
GROSS BENEFIT (CFA F/HA):									
Millet	40000	16500	15000	39000	17600	16000	28000	13750	12500
Cowpea	18000	2700	2400	17600	3850	3500	14400	3600	3200
Cowpea Fodder	4800	6000	6000	6000	7500	7500	3600	4800	4800
Weight Gain	4000								
Manure	1500								
Gross Benefit	68300	25200	23400	62600	28950	27000	46000	22150	20500
Labor Saving * (2)	6286	8730		4498	10570		4965	8342	
Labor Saving * (3)	-3189			-8147			-4491		
Total Gross Benefit (2)	74586	33930		67098	39520		50965	30492	
Total Gross Benefit (3)	65111			54453			41509		
INCREMENTAL GROSS BENEFIT (CFA F/HA):									
(2)	51186	10530		40098	12520		30465	9992	
(3)	39911			25503			19359		
VARIABLE COSTS (CFA F/HA):									
Millet Seeds	376	500	500	376	550	550	376	600	600
Cowpea Seeds	1746	450	450	1746	480	480	1746	540	540
Seed Treatment: on Millet	327	100	100	327	107	107	327	95	95
on Cowpea	69			69			69		
Fertilization: Phosphate	9274			9274			4637		
Urea	4364			0			0		
Pesticide Treatment	4080			4080			4080		
Stock Treatment (Phostoxin)	436			436			218		
Plastic Bag	1091			1091			546		
Total Variable Costs	21763	1050	1050	17399	1137	1137	11999	1235	1235
AMORTIZATION (CFA F/HA/YEAR):									
Sprayer T 15	1843	0		1843	0		1843	0	
Equipment	3057	2739		2739	2739		2739	2739	
Draft Animal	11882	3645		4557	4557		3645	3645	
Total Amortization	16782	6384		9138	7295		8227	6384	
TOTAL COSTS (CFA F/HA/YEAR)	38545	7434	1050	26538	8432	1137	20226	7619	1235
INCREMENTAL COSTS (CFA F/HA/YEAR):									
(2)	37495	6384		25401	7295		18991	6384	
(3)	31111			18105			12607		

Table 5-D-1 (cont'd.).

AVERAGE RETURN TO LABOR (CFA F/DAY):									
	647	456	349	759	603	450	716	528	397
INCREMENTAL AVERAGE RETURN TO LABOR (CFA F/DAY):									
(2)	116	106		177	154		134	131	
(3)	9			24			3		
NET BENEFIT (CFA F/HA):		17766	22350		20518	25863		14531	19265
(2)	36041	26496		40560	31088		30739	22873	
(3)	26566			27916			21283		
INCREMENTAL NET BENEFIT (CFA F/HA):									
(2)	13691	4146		14697	5225		11474	3608	
(3)	8800			7398			6752		

(1) Improved: Technical package that FSR would develop.
Transitional: Technique currently used by most of the equipped farmers.
Traditional: Technique currently used by most of the non-equipped farmers.
(2) With respect to the traditional technique.
(3) With respect to the transitional technique.
* The labor saving is the number of days saved by the technique multiplied by the opportunity cost of labor estimated for the traditional or transitional techniques. This labor saving is added to the gross benefit to estimate the total gross benefit.

Table 5-D-2. Financial Budgets for the Millet-Cowpea Rotation by Agroclimatic Zone

ZONE:	SOUTH			CENTER/PLATEAU			NORTH		
CROP (1):	MILLET		COWPEA	MILLET		COWPEA	MILLET		COWPEA
GROSS BNEFIT (CFA F/HA):									
Millet	40000			36000			24500		
Cowpea			60000			55000			48000
Cowpea Fodder			6000			6000			3600
Weight Gain	4000		4000						
Manure	1500		1500						
Gross Benefit for the Rotation:		52000			42250			31275	
Labor Saving *(2)	10477		3492	8996		-1124	9335		-199
Labor Saving *(3)	2278		-6833	-2112		-15690	1321		-11361
Total Gross Benefit (2):	55977		74992	44996		59876	33835		51401
Total Gross Benefit (3):	47778		64667	33888		45310	25821		40239
Total Gross Benefit for the Rotation (2):		60730			48716			38226	
Total Gross Benefit for the Rotation (3):		52000			36743			29426	
INCREMENTAL GROSS BENEFIT (CFA F/HA):									
(2)		37330			21716			17726	
(3)		26800			7793			7276	
VARIABLE COSTS (CFA F/HA):									
Seeds	376		5455	376		5455	376		5455
Seed Treatment	327		206	327		206	327		206
Fertilization (Phosphate)			4964			4964			2482
Pesticide Treatment (Decis)			14281			14281			14281
Stock Treatment			1309			1091			873
Plastic Bag			3273			2728			2182
Variable Costs	704		29489	704		28725	704		25479
AMORTIZATION (CFA F/HA/YEAR):									
Fertilization(TRP)	4769			4769					
Sprayer T 15			1843			1843			1843
Equipment	3057		3057	2739		2739	2739		2739
Draft Animal	11882		11882	4557		4557	3645		3645
Total Amortiz.	19708		16782	12065		9138	6384		8227
TOTAL COSTS (CFA F/HA/YEAR):									
Crop	20412		46270	12769		37863	7088		33706
Rotation		26877			19042			13743	

Table 5-D-2 (cont'd.).

INCREMENTAL COSTS (CFA F/HA/YEAR):			
(2)	25827	17905	12508
(3)	19443	10610	6124
AVERAGE RETURN TO LABOR (CFA F/DAY):			
	644	538	566
INCREMENTAL AVERAGE RETURN TO LABOR (CFA F/DAY):			
(2)	295	88	168
(3)	189	-65	37
NET BENEFIT (CFA F/HA):			
(2)	33854	29673	24484
(3)	25123	17701	15683
INCREMENTAL NET BENEFIT (CFA F/HA):			
(2)	11504	3810	5219
(3)	7357	-2817	1152

(1) The suggested cropping pattern is 0.75 Ha of millet in pure stand and 0.25 Ha of cowpea in pure stand.
(2) With respect to the traditional technique.
(3) With respect to the transitional technique.
* The labor saving is the number of days saved by the technique multiplied by the opportunity cost of labor estimated for the traditional or transitional techniques. This labor saving is added to the gross benefit to estimate the total gross benefit.

Table 5-D-3. Financial Budgets for the Groundnut-Millet-Groundnut Rotation in the Center and Plateau Zone

ROTATION:	GROUNDNUT	MILLET	GROUNDNUT	GROUNDNUT	MILLET	GROUNDNUT	MILLET	MILLET	MILLET	MILLET	MILLET	MILLET
TECHNOLOGICAL LEVEL:		WITH TRP			WITHOUT TRP			TRANSITIONAL			TRADITIONAL	
ANNUAL GROSS BENEFIT (CFA F/Ha):												
Millet		57600			28800		16800	17600	16000	15200	16000	14400
Groundnuts	37200		20400	31800		15600						
Groundnut Fodder	7440		4080	6360		3120						
Gross Benefit	44640	57600	24480	38160	28800	18720	16800	17600	16000	15200	16000	14400
Labor Saving *(1)	-3567	4384	-841	-2195	5636	280	5488	6262	5609			
Labor Saving *(2)	-8848	-1996	-6383	-7507	-665	-5273						
Total Gross Benefit (1):	41073	61984	23639	35965	34436	19000	22288	23862	21609			
Total Gross Benefit (2):	35792	55604	18097	30653	28135	13447						
INCREMENTAL GROSS BENEFIT (CFA F/Ha):												
3 Year Average (1)		27032			14601			7387				
3 Year Average (2)		19698			8345							
ANNUAL VARIABLE COSTS (CFA F/HA):												
Seeds	8728	753	8728	8728	753	8728	550	550	550	550	550	550
Seed Treatment	550	69	550	550	69	550	107	107	107	107	107	107
Actellic Treatment	720	0	480	720	0	240						
Total	9998	822	9758	9998	822	9518	657	657	657	657	657	657
AMORTIZATION (CFA F/HA/YEAR):												
Equipment	2739	2739	2739	2739	2739	2739	2739	2739	2739			
Draft Animal	4557	4557	4557	4557	4557	4557	4557	4557	4557			
Fertilization(TRP)	4769	4769	4769									
Total	12065	12065	12065	7296	7296	7296	7295	7295	7295			
TOTAL COSTS (CFA F/HA/YEAR):												
Annual	22063	12887	21823	17294	8117	16813	7952	7952	7952	657	657	657
3 Year Average		18924			14075			7952			657	
INCREEMNTAL COSTS (CFA F/HA/YEAR):												
3 Year Average (1)		18267			13418			7295				
3 Year Average (2)		10972			6122							
AVERAGE RETURN TO LABOR (CFA F/DAY):												
Annual	342	1278	51	342	667	40	268	333	278	274	313	280
NET BENEFIT (CFA F/HA) (1):												
Annual	19010	49097	1816	18671	26319	2187	14336	15910	13657	14543	15343	13743
3 Year Average		23308			15726			14634			14543	

Table 5-D-4 (cont'd.).

NET BENEFIT (CFA F/HA) (2):									
Annual	8285	29439	-13188	6220	26843	-6481	8616	9516	8016
3 Year Average		8179			8861			8716	
INCREMENTAL NET BENEFIT (CFA F/HA):									
3 Year Average (1)		244			919			520	
3 Year Average (2)		-537			145				

(1) With respect to the millet-millet-millet rotation with the traditional technology.
(2) With respect to the millet-millet-millet rotation with the transitional technology.

Table 5-D-5. Financial Budgets for the Sesame Cultivation by Agroclimatic Zone

ZONE:	SOUTH			CENTER/PLATEAU			NORTH		
TECHNOLOGICAL	SESAME	MILLET (2d year)		SESAME	MILLET (2d year)		SESAME	MILLET (2d year)	
LEVEL:	IMPROVED	TRANSIT.	TRADITIONAL	IMPROVED	TRANSIT.	TRADITIONAL	IMPROVED	TRANSIT.	TRADITIONAL
GROSS BENEFIT (CFA F/Ha):									
Millet		16500	15000		17600	16000		16500	15000
Sesame	39000			31500			16500		
Gross Benefit	39000	16500	15000	31500	17600	16000	16500	16500	15000
Labor Saving (1)	288	5760		1879	6262		2241	6205	
Labor Saving (2)	-6027			-4657			-4610		
Total Gross Benefit (1):	39288	22260	15000	33379	23862	16000	18741	22705	15000
Total Gross Benefit (2):	32973	16500		26843	17600		11890	16500	
INCREMENTAL GROSS BENEFIT (CFA F/Ha):									
(1)	24288	7260		17379	7862		3741	7705	
(2)	16473			9243			-4610		
ANNUAL VARIABLE COSTS (CFA F/HA):									
Millet Seeds		500	500		550	550		600	600
Millet Sesame	1637			1637			1637		
Seeds Treatment	0	100	100	0	107	107	0	95	95
Fertilization	4964			4964			2482		
Variable Costs	6601	600	600	6601	657	657	4119	695	695
AMORTIZATION (CFA F/HA/YEAR):									
Equipment	2739	2739		2739	2739		2739	2739	
Draft Animal	3645	3645		4557	4557		3645	3645	
Amortization	6384	6384		7296	7295		6384	6384	
TOTAL COSTS (CFA F/HA/YEAR):	12985	6984	600	13896	7952	657	10503	7079	695
INCREMENTAL COSTS (CFA F/HA/YEAR):									
(1)	12385	6384		13239	7295		9808	6384	
(2)	6001			5944			3424		
AVERAGE RETURN TO LABOR (CFA F/DAY):	531	317	288	409	333	313	171	401	345
INCREMENTAL AVERAGE RETURN TO LABOR (CFA F/DAY):									
(1)	243	29		96	20		-173	56	
(2)	214			77			-230		

Table 5-D-5 (cont'd.).

NET BENEFIT (CFA F/HA):									
(1)	26303	15276	14400	19483	15910	15343	8238	15626	14305
(2)	19988	9516		12946	9648		1387	9421	
INCREMENTAL NET BENEFIT (CFA F/HA):									
(1)	11903	876		4140	567		-6067	1321	
(2)	10472			3299			-8034		

(1) With respect to the second crop of the millet-millet-millet rotation with the traditional technology.
(2) With respect to the second crop of the millet-millet-millet rotation with the transitional technology.

APPENDIX 5-E

Table 5-E-1. Sensitivity Analysis for the Marginal Rate of Return for Technologies for the Northern Zone

TECHNOLOGIES (1)	PRICE OR YIELD -50%	-20%	-10%	0%	+10%	+20%	+50%
A) NON EQUIPPED FARMS:							
Improved M-C Intercropping	Dominated	31	81	96	112	127	173
Transitional	Dominated	34	45	56	67	76	101
Traditional							
B) EQUIPPED FARMS:							
Improved M-C Intercropping	Dominated	26	73	86	99	112	151
Transitional							

TECHNOLOGIES (1)	COSTS -50%	-20%	-10%	0%	+10%	+20%	+50%
A) NON EQUIPPED FARMS:							
Improved M-C Intercropping	285	144	118	96	79	36	9
Transitional	130	80	67	56	47	38	17
Traditional							
B) EQUIPPED FARMS:							
Improved M-C Intercropping	253	129	105	86	71	58	7
Transitional							

(1) M-C: Millet-Cowpea
Source: Author's estimations.

Table 5-E-2. Sensitivity Analysis for the Marginal Rate of Return for Technologies for the Center and Plateau Zone

TECHNOLOGIES (1)	PRICE OR YIELD -50%	-20%	-10%	0%	+10%	+20%	+50%
A) NON EQUIPPED FARMS:							
Improved M-C Intercropping	Dominated	25	38	52	67	182	237
Transitional	4	48	60	72	82	91	116
Traditional							
Improved G-M-G Rotation with TRP	Dominated	23	132	156	180	205	277
Traditional M-M-M Rotation							
Improved G-M-G Rotation w/o TRP	Dominated	Dominated	0	18	31	45	98
Transitional M-M-M Rotation	Dominated	Dominated	Dominated	1	7	13	27
Improved Sesame Cultivation	Dominated	5	37	60	85	113	219
2d Year of Trans. M-M-M Rotation	Dominated	Dominated	1	8	14	20	36
2d Year of Trad. M-M-M Rotation							
B) EQUIPPED FARMS:							
Improved M-C Intercropping	Dominated	18	29	41	53	66	220
Transitional							
Improved G-M-G Rotation with TRP	8	111	133	156	179	202	270
Improved G-M-G Rotation w/o TRP	Dominated	4	11	19	28	37	74
Transitional M-M-M Rotation							
Improved Sesame Cultivation	Dominated	20	37	55	76	99	185
2d Year of Trans. M-M-M Rotation							

TECHNOLOGIES (1)	COSTS -50%	-20%	-10%	0%	+10%	+20%	+50%
A) NON EQUIPPED FARMS:							
Improved M-C Intercropping	383	205	69	52	39	27	2
Transitional	145	95	83	72	62	53	31
Traditional							
Improved G-M-G Rotation with TRP	412	220	185	156	133	27	5
Traditional M-M-M Rotation							
Improved G-M-G Rotation w/o TRP	132	46	31	18	1	Dominated	Dominated
Transitional M-M-M Rotation	44	15	8	1	Dominated	Dominated	Dominated
Improved Sesame Cultivation	217	99	78	60	46	14	Dominated
2d Year of Trans. M-M-M Rotation	53	23	15	8	2	Dominated	Dominated
2d Year of Trad. M-M-M Rotation							
B) EQUIPPED FARMS:							
Improved M-C Intercropping	358	73	55	41	29	19	Dominated
Transitional							
Improved G-M-G Rotation with TRP	398	217	183	156	134	116	29
Improved G-M-G Rotation w/o TRP	96	38	27	19	12	6	Dominated
Transitional M-M-M Rotation							
Improved Sesame Cultivation	172	85	68	55	45	36	17
2d Year of Trans. M-M-M Rotation							

(1) M-C: Millet-Cowpea G-M-G: Groundnuts-Millet-Groundnuts Rotation
M-M-M: Millet-Millet-Millet TRP: Tilemsi Rock Phosphate

Source: Author's estimations.

Table 5-E-3. Sensitivity Analysis for the Marginal Rate of Return for Technologies for the Southern Zone

TECHNOLOGIES (1)	PRICE OR YIELD -50%	-20%	-10%	0%	+10%	+20%	+50%
A) NON EQUIPPED FARMS:							
Transitional	Dominated	41	54	65	75	85	111
Traditional							
Improved Sesame Cultivation	Dominated	57	146	184	225	269	430
2d Year of Trans. M-M-M Rotation	Dominated	Dominated	6	14	21	28	45
2d Year of Trad. M-M-M Rotation							
B) EQUIPPED FARMS:							
Improved Sesame Cultivation	35	112	142	175	210	248	384
2d Year of Trans. M-M-M Rotation							

TECHNOLOGIES (1)	COSTS -50%	-20%	-10%	0%	+10%	+20%	+50%
A) NON EQUIPPED FARMS:							
Transitional	141	89	76	65	55	46	24
Traditional							
Improved Sesame Cultivation	464	254	215	184	158	137	40
2d Year of Trans. M-M-M Rotation	66	30	21	14	7	1	Dominated
2d Year of Trad. M-M-M Rotation							
B) EQUIPPED FARMS:							
Improved Sesame Cultivation	402	231	200	175	154	137	99
2d Year of Trans. M-M-M Rotation							

(1) M-C: Millet-Cowpea
M-M-M: Millet-Millet-Millet

Source: Author's estimations.

APPENDIX 5-F

Table 5-F-1. Economic Costs of Tradable and Non-tradable Inputs

INPUTS	TOTAL ECONOMIC COST AT SER	TRADABLE INPUT COMPONENT (1) (%)	TOTAL TRADABLE INPUTS AT SER	TOTAL NON-TRADABLE INPUTS
SEED				
Millet (CFA F/kg)				
Local	55	10.0	6	50
Improved	90	30.0	27	63
Cowpea (CFA F/kg)				
Local	160	10.0	16	144
Improved	262	30.0	79	183
Groundnuts (CFA F/kg)				
Local	60	10.0	6	54
Improved	105	30.0	31	73
Sesame (CFA F/kg)				
Unimproved	NA	NA	NA	NA
Improved	196	30.0	59	137
Rice O. Glaberrima (CFA F/kg)				
Local	90	10.0	9	81
Improved	131	30.0	39	92
Rice O. Sativa (CFA F/kg)				
Currently extended	131	30.0	39	92
Improved	131	30.0	39	92
PESTICIDES				
APRON + (CFA F/bag)	396	83.5	331	65
Thioral (CFA F/bag)				
Under current extension	83	83.5	69	14
Under improved extension	130	83.5	108	21
Decis (CFA F/L)	2470	83.5	2062	408
Actellic (CFA F/bag)	291	83.5	243	48
Phostoxin (CFA F/tablet)	264	83.5	221	44
SACK (CFA F/sack)	660	83.5	551	109
FERTILIZER				
Rock phosphate (CFA F/kg)	38	40.0	15	23
Ammonia phosphate (CFA F/kg)	225	83.5	187	37
"Super simple" phosphate(CFA F/kg)	92	83.5	77	15
Urea (CFA F/kg)	211	83.5	176	35
CAPITAL RECOVERY (with operating costs in CFA F)				
Insecticide Sprayer	2205	78.7	1736	469
Plow				
TM Smecma	3910	87.8	3433	477
Bajac B2	6323	87.8	5553	769
For donkey:				
Under current extension	3499	87.5	3060	439
Under improved extension	3499	87.5	3060	439
Oxen (a pair for the Delta)	15427	0.0	0	15427
Donkey (for the Seno)	4557	0.0	0	4557
Rock phosphate (kg)	16	40.0	6	10
EXTENSION:				
ORM:				
Under current extension(F/ha)	10268	24.4	2501	7767
Under improved extension(F/ha)	10268	24.4	2501	7767
Current threshing (CFA F/kg)	7	22.5	2	5
Improved threshing (CFA F/kg)	7	22.5	2	5
OMM (CFA F/ha):				
Under current extension	397	22.5	89	308

(1) Data from Tables 2 and in Appendix 5-C.

Table 5-F-2. International Reference Price for Millet, Mopti

COMPONENT		TOTAL ECONOMIC COST AT OER	TRADABLE INPUT COMPONENTS (%)	TOTAL TRADABLE INPUTS AT OER	TOTAL TRADABLE INPUTS AT SER	TOTAL NON-TRADABLE INPUTS	TOTAL ECONOMIC COSTS AT SER
FOB price in 1985 $ US/ton (1)		90		90	90		90
Freight, Insurance in 1985 $ US/ton (2)		75	100.0	75	75		75
Quality adjustment (%) (3)	-20	-18	100.0	-18	-18		-18
CIF price in 1985 $ US/ton		147	100.0	147	147		147
Inflation multiplier (4)		1		1	1		1
CIF price in 1988 $ US/ton		165		165	165		165
1988 exchange rate		300		300	399		399
CIF price in 1988 CFA.F/ton		49392		49392	65691		65691
CIF price in 1988 CFA.F/kg		49		49	66		66
Port Charges in 1988 CFA.F/ton (5):							
Port fees		5902	100.0	5902	7850		7850
Storage handling		4536	100.0	4536	6033		6033
Interest and Insurance (5% CIF)		2470	100.0	2470	3285		3285
Delivery charges, port-to-border in 1988 CFA.F/ton (6):							
Transport		16912	100.0	16912	22493	0	22493
CIF price, Mali frontier(1988 CFA.F/ton)		79212		79212	105352	0	105352
Delivery charges, border-to-Bamako in 1988 CFA.F/ton (6):							
Transport (border to Bamako, 513 km)		12645	60.0	7587	10091	5058	15149
Finance Charge		1333	0.0	0	0	1333	1333
Delivery charges, border to rural market (Mopti) in 1988 CFA.F/ton (7):							
Transport (border to Mopti, 810 km)		19958	60.0	11975	15927	7983	23910
Distribution		27598	60.0	16559	22023	11039	33062
Delivery charges, border to consumption market (Gao) in 1988 CFA.F/ton (7):							
Transport (border to Gao, 1398 km)		34447	60.0	20668	27488	13779	41267
Distribution		27598	60.0	16559	22023	11039	33062
Delivery charges, rural market-to-farm in 1988 CFA.F/ton (7):							
Transport (Mopti to farm, 100 km)		2957	60.0	1774	2360	1183	3542
Distribution		9874	60.0	5924	7879	3949	11829
CIF REFERENCE PRICES, BORDER EQUIVALENT (CFA.F/kg):							
AT WHOLESALE POINT (BAMAKO)		93		87	115	6	122
AT RURAL MARKET (MOPTI)		127		108	143	19	162
AT CONSUMPTION MARKET (GAO)		141		116	155	25	180
AT FARM (Seno Center)		140		115	154	24	178

Table 5-F-2 (cont'd.).

(1) Maize (US), No. 2, yellow, FOB Gulf ports. World Bank price projections for 1990 in constant 1985 dollars.
Source: World Bank. Primary Commodity Price Forecasts. EPDCS Memorandum. August 18, 1986, in Stryker et al. (1987).
(2) Source: WAPA, Ivory Coast - Agricultural Sector Review, 1985, p. 206, in Styker et al.(1987).
(3) Adapted from WAPA, Ivory Coast - Agricultural Sector Review, 1985, p. 206, in Stryker et al. (1987).
(4) Annual rate of inflation of 4% from 1985 to 1988 (GNP deflator in the US).
(5) Adapted from WAPA, Ivory Coast - Agricultural Sector Review, 1985, p. 206, in Stryker et al. (1987) with 4% of annual inflation rate.
(6) Adapted from OPAM/PRMC 1986 in Stryker et al. (1987) with 4% of annual inflation rate.
(7) Adapted from OSPR 1986, p. 106, in Stryker et al. (1987) with a rural market-to-farm distance of 100 km and 4% of annual inflation rate.

Table 5-F-3. International Reference Price for Groundnuts, Import Parity price in Mopti

COMPONENT	TOTAL ECONOMIC COSTS AT OER: Groundnut Oil	TOTAL ECONOMIC COSTS AT OER: Groundnut Meal	TRADABLE INPUTS COMPONENT (%)	TOTAL TRADABLE INPUTS AT OER: Oil	TOTAL TRADABLE INPUTS AT OER: Meal	TOTAL TRADABLE INPUTS AT SER: Oil	TOTAL TRADABLE INPUTS AT SER: Meal	TOTAL NON-TRADABLE INPUTS: Oil	TOTAL NON-TRADABLE INPUTS: Meal	TOTAL ECONOMIC COSTS AT SER: Oil	TOTAL ECONOMIC COSTS AT SER: Meal	TOTAL ECONOMIC COSTS AT SER
FOB price in 1986 CFA.F/ton, Dakar (1)	134000	39000	100	134000	39000	178220	51870	0	0	178220	51870	
Inflation multiplier (2)	1.08	1.08		1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08	1.08
FOB price in 1988 CFA.F/ton, Dakar	144720	42120	100	144720	42120	192478	56020	0	0	192478	56020	
Delivery charges, Dakar to border in 1988 CFA.F/ton (3):												
Transport (Dakar to border, 696 km)	13015	17780	100	13015	17780	17310	23647	0	0	17310	23647	
CIF price in 1988 CFA.F/ton,Mali border	157735	59900		157735	59900	209788	79667	0	0	209788	79667	
Delivery charges, border to Bamako in 1988 CFA.F/ton (3):												
Transport (border to Bamako, 532 km)	9948	13580	60	5969	8148	7939	10837	3979	5432	11918	16269	
Finance Charge	1333	1333	0	0	0	0	0	1333	1333	1333	1333	
Delivery charges, Bamako to rural market (Mopti) in 1988 CFA.F/ton (4):												
Transport (Bamako to Mopti, 634 km)	15622	15622	60	9373	9373	12466	12466	6249	6249	18715	18715	
Distribution	27598	27598	60	16559	16559	22023	22023	11039	11039	33062	33062	
Delivery charges, Bamako to consumption market (Gao) in 1988 CFA.F/ton (4):												
Transport (Bamako to Gao, 1398 km)	34447	34447	60	20668	20668	27488	27488	13779	13779	41267	41267	
Distribution	27598	27598	60	16559	16559	22023	22023	11039	11039	33062	33062	
Delivery charges, rural market (Mopti) to farm in 1988 CFA.F/ton (4):												
Transport (Mopti to farm, 100 km)	2464	2464	60	1478	1478	1966	1966	986	986	2952	2952	
Distribution	9874	9874	60	5924	5924	7879	7879	3949	3949	11829	11829	
Mechanical press technique ratio(%) (5)	23	47		23	47	23	47	23	47	23	47	
Industrial technique ratio (%) (6)	35	42		35	42	35	42	35	42	35	42	
CIF REFERENCE PRICES, BORDER EQUIVALENT (CFA.F/kg):												
CIF price, Bamako (1988 CFA.F/kg)	169	75		164	68	218	91	5	7	223	97	
CIF price, Mopti (1988 CFA.F/kg)	212	118		190	94	252	125	23	24	275	149	
CIF price, Gao (1988 CFA.F/kg)	231	137		201	105	267	140	30	32	297	172	
CIF price, farm gate (1988 CFA.F/kg)	225	130		197	101	262	135	28	29	290	164	
Raw product equivalent CIF price in Bamako from 1 kilo of unshelled groundnut (1988 CFA.F/kg):												
Mechanical oil press technique	39	35		38	32	50	42	1	3	52	46	97
Industrial technique	59	31		57	29	76	38	2	3	78	41	119
Raw product equivalent CIF price in rural market (Mopti) from 1 kilo of unshelled groundnut (1988 CFA.F/kg):												
Mechanical oil press technique	49	55		44	44	58	59	5	11	63	70	133
Industrial technique	74	50		66	39	88	52	8	10	96	63	159
Raw product equivalent CIF price in consumption market (Gao) from 1 kilo of unshelled groundnut (1988 CFA.F/kg):												
Mechanical oil press technique	53	64		46	49	62	66	7	15	69	80	149
Industrial technique	81	57		70	44	94	59	11	13	104	72	176
Raw product equivalent CIF price at farm gate from 1 kilo of unshelled groundnut (1988 CFA.F/kg):												
Mechanical oil press technique	52	61		46	48	61	63	6	14	67	77	144
Industrial technique	79	55		69	43	92	57	10	12	101	69	170

Table 5-F-3 (cont'd.).

(1) Martin, 1988, p. 278.
(2) Annual rate of inflation of 4% from 1986 to 1988.
(3) Based on the 1989's train shipment fee: 23253 CFA.F/ton of cereal from Dakar to Bamako (1228 km).
Source: OPAM, 1990, Personal Communication.
(4) Adapted from OPAM/PRMC 1986 in Stryker et al. (1987) with 4% of annual inflation rate.
(5) Henry de Frahan et al., 1989, p. 145.
(6) Martin, 1988, p. 278.

Table 5-F-4. International Reference Price for Rice, Natural Flooded, Mopti

COMPONENT	TOTAL ECONOMIC COST AT OER	TRADABLE INPUT COMPONENTS (%)	TOTAL TRADABLE INPUTS AT OER	TOTAL TRADABLE INPUTS AT SER	TOTAL NON-TRADABLE INPUTS	TOTAL ECONOMIC COSTS AT SER
FOB price in 1985 $ US/ton (1)	212		212	212		212
Freight, Insurance in 1985 $ US/ton (2)	75	100.0	75	75		75
Quality adjustment (%) (3) -40	-85	100.0	-85	-85		-85
CIF price in 1985 $ US/ton	202	100.0	202	202		202
Inflation multiplier (4)	1		1	1		1
CIF price in 1988 $ US/ton	226		226	226		226
1988 exchange rate	300		300	399		399
CIF price in 1988 CFA.F/ton	67939		67939	90359		90359
CIF price in 1988 CFA.F/kg	68		68	90		90
Port Charges in 1988 CFA.F/ton (5):						
Port fees	5902	100.0	5902	7850		7850
Storage handling	4536	100.0	4536	6033		6033
Interest and Insurance (5% CIF)	3397	100.0	3397	4518		4518
Delivery charges, port-to-border in 1988 CFA.F/ton (6):						
Transport	16912	100.0	16912	22493	0	22493
CIF price, Mali frontier(1988 CFA.F/ton)	98687		98687	131253	0	131253
Delivery charges, border-to-Bamako in 1988 CFA.F/ton (6):						
Transport (border to Bamako, 513 km)	12645	60.0	7587	10091	5058	15149
Finance Charge	1333	0.0	0	0	1333	1333
Delivery charges, border to rural market (Mopti) in 1988 CFA.F/ton (7):						
Transport (border to Mopti, 810 km)	19958	60.0	11975	15927	7983	23910
Distribution	27598	60.0	16559	22023	11039	33062
Delivery charges, border to rural market (Sikasso) in 1988 CFA.F/ton (7):						
Transport (border to Sikasso, 120 km)	2957	60.0	1774	2360	1183	3542
Distribution	27598	60.0	16559	22023	11039	33062
Delivery charges, border to rural market (Segou) in 1988 CFA.F/ton (7):						
Transport (border to Segou, 411 km)	10127	60.0	6076	8081	4051	12132
Distribution	27598	60.0	16559	22023	11039	33062
Delivery charges, border to consumption market (Gao) in 1988 CFA.F/ton (7):						
Transport (border to Gao, 1398 km)	34447	60.0	20668	27488	13779	41267
Distribution	27598	60.0	16559	22023	11039	33062
Delivery charges, rural market-to-farm in 1988 CFA.F/ton (7):						
Transport (Mopti to farm, 35 km)	862	60.0	517	688	345	1033
Distribution	9874	60.0	5924	7879	3949	11829
CIF REFERENCE PRICES, BORDER EQUIVALENT (CFA.F/kg):						
AT WHOLESALE POINT (BAMAKO)	113		106	141	6	148
AT RURAL MARKET (MOPTI)	146		127	169	19	188
AT RURAL MARKET (SIKASSO)	129		117	156	12	168
AT RURAL MARKET (SEGOU)	136		121	161	15	176
AT CONSUMPTION MARKET (GAO)	161		136	181	25	206
AT FARM (Delta Center)	157		134	178	23	201

(1) Rice (Thai), white, milled, 5% broken, government standard.
Export price, FOB Bangkok, World Bank price projections for 1990 in constant 1985 dollars.
Source: World Bank. Primary Commodity Price Forecasts. EPDCS Memorandum. August 18, 1986. in Stryker et al. (1987).

(2) Source: WAPA, Ivory Coast - Agricultural Sector Review, 1985, p. 206, in Stryker et al., 1987.

(3) Adapted from WAPA, Ivory Coast - Agricultural Sector Review, 1985, p. 206, in Stryker et al. (1987).

(4) Annual rate of inflation of 4% from 1985 to 1988 (GNP deflator in the US).

(5) Adapted from WAPA, Ivory Coast - Agricultural Sector Review, 1985, p. 206, in Stryker et al. (1987) with 4% of annual inflation rate.

(6) Adapted from OPAM/PRMC 1986 in Stryker et al. (1987) with 4% of annual inflation rate.

(7) Adapted from OSPR 1986, p. 106, in Stryker et al. (1987) with 4% of annual inflation rate.

Table 5-F-5. International Reference Price for Rice, Controlled Flooding, Mopti

COMPONENT	TOTAL ECONOMIC COST AT OER	TRADABLE INPUT COMPONENTS (%)	TOTAL TRADABLE INPUTS AT OER	TOTAL TRADABLE INPUTS AT SER	TOTAL NON-TRADABLE INPUTS	TOTAL ECONOMIC COSTS AT SER
FOB price in 1985 $ US/ton (1)	212		212	212		212
Freight, Insurance in 1985 $ US/ton (2)	75	100.0	75	75		75
Quality adjustment (%) (3) -20	-42	100.0	-42	-42		-42
CIF price in 1985 $ US/ton	245	100.0	245	245		245
Inflation multiplier (4)	1		1	1		1
CIF price in 1988 $ US/ton	274		274	274		274
Official 1988 exchange rate	300		300	399		399
CIF price in 1988 CFA.F/ton	82186		82186	109307		109307
CIF price in 1988 CFA.F/kg	82		82	109		109
Port Charges in 1988 CFA.F/ton (5):						
Port fees	5902	100.0	5902	7850		7850
Storage handling	4536	100.0	4536	6033		6033
Interest and Insurance (5% CIF)	4109	100.0	4109	5465		5465
Delivery charges, port-to-border in 1988 CFA.F/ton (6):						
Transport	16912	100.0	16912	22493	0	22493
CIF price, Mali frontier(1988 CFA.F/ton)	113645		113645	151148	0	151148
Delivery charges, border-to-Bamako in 1988 CFA.F/ton (6):						
Transport (border to Bamako, 513 km)	12645	60.0	7587	10091	5058	15149
Finance Charge	1333	0.0	0	0	1333	1333
Delivery charges, border to rural market (Mopti) in 1988 CFA.F/ton (7):						
Transport (border to Mopti, 810 km)	19958	60.0	11975	15927	7983	23910
Distribution	27598	60.0	16559	22023	11039	33062
Delivery charges, border to rural market (Sikasso) in 1988 CFA.F/ton (7):						
Transport (border to Sikasso, 120 km)	2957	60.0	1774	2360	1183	3542
Distribution	27598	60.0	16559	22023	11039	33062
Delivery charges, border to rural market (Segou) in 1988 CFA.F/ton (7):						
Transport (border to Segou, 411 km)	10127	60.0	6076	8081	4051	12132
Distribution	27598	60.0	16559	22023	11039	33062
Delivery charges, border to consumption market (Gao) in 1988 CFA.F/ton (7):						
Transport (border to Gao, 1398 km)	34447	60.0	20668	27488	13779	41267
Distribution	27598	60.0	16559	22023	11039	33062
Delivery charges, rural market-to-farm in 1988 CFA.F/ton (7):						
Transport (Mopti to farm, 35 km)	862	60.0	517	688	345	1033
Distribution	9874	60.0	5924	7879	3949	11829
CIF REFERENCE PRICES, BORDER EQUIVALENT (CFA.F/kg):						
AT WHOLESALE POINT (BAMAKO)	128		121	161	6	168
AT RURAL MARKET (MOPTI)	161		142	189	19	208
AT RURAL MARKET (SIKASSO)	144		132	176	12	188
AT RURAL MARKET (SEGOU)	151		136	181	15	196
AT CONSUMPTION MARKET (GAO)	176		151	201	25	225
AT FARM (Delta Center)	172		149	198	23	221

(1) Rice (Thai), white, milled, 5% broken, government standard.
Export price, FOB Bangkok, World Bank price projections for 1990 in constant 1985 dollars.
Source: World Bank. Primary Commodity Price Forecasts. EPDCS Memorandum. August 18, 1986. in Stryker et al. (1987).

(2) Source: WAPA, Ivory Coast - Agricultural Sector Review, 1985, p. 206, in Stryker et al. (1987).

(3) Adapted from WAPA, Ivory Coast - Agricultural Sector Review, 1985, p. 206, in Stryker et al. (1987).

(4) Annual rate of inflation of 4% from 1985 to 1988 (GNP deflator in the US).

(5) Adapted from WAPA, Ivory Coast - Agricultural Sector Review, 1985, p. 206, in Stryker et al. (1987) with 4% of annual inflation rate.

(6) Adapted from OPAM/PRMC 1986 in Stryker et al. (1987) with 4% of annual inflation rate.

(7) Adapted from OSPR 1986, p. 106, in Stryker et al. (1987) with 4% of annual inflation rate.

Table 5-F-6. International Reference Price for Sesame Seeds, Export Parity Price in Mopti

COMPONENT	TOTAL ECONOMIC COST AT OER	TRADABLE INPUT COMPONENTS (%)	TOTAL TRADABLE INPUTS AT OER	TOTAL TRADABLE INPUTS AT SER	TOTAL NON-TRADABLE INPUTS	TOTAL ECONOMIC COSTS AT SER
FOB price in 1988 $ US/ton, Lagos (1)	556	100	556	556	0	556
1988 exchange rate	300		300	399	300	
Inflation multiplier (2)	1.12		1.12	1.12		1.12
FOB price in 1988 CFA.F/ton, Abidjan(3)	166800	100	166800	221844	0	221844
FOB price in 1988 CFA.F/kg, Abidjan	167	100	167	222	0	222
Port Charges in 1988 CFA.F/ton (4):						
Port fees	5902	100	5902	7850	0	7850
Storage handling	4536	100	4536	6033	0	6033
Interest and Insurance (5% FOB)	8340	100	8340	11092	0	11092
Delivery charges, border-to-port in 1988 CFA.F/ton (5):						
Transport	16912	100	16912	22493	0	22493
FOB price in 1988 CFA.F/ton,Mali border	131110		131110	174376	0	174376
Delivery charges, Bamako to border in 1988 CFA.F/ton (5):						
Transport (Bamako to border, 513 km)	12645	60	7587	10091	5058	15149
Finance Charge	1333	0	0	0	1333	1333
Delivery charges, rural market (Mopti) to Bamako in 1988 CFA.F/ton (6):						
Transport (Mopti to Bamako, 634km)	15622	60	9373	12466	6249	18715
Collection	13799	60	8279	11012	5520	16531
Delivery charges, farm-to-rural market in 1988 CFA.F/ton (6):						
Transport (farm to Mopti, 50 km)	1232	60	739	983	493	1476
Collection	4937	60	2962	3940	1975	5914
FOB REFERENCE PRICES, BORDER EQUIVALENT (CFA.F/kg):						
AT WHOLESALE POINT (BAMAKO)	117		124	164	-6	158
AT RURAL MARKET (MOPTI)	88		106	141	-18	123
AT FARM (Seno South)	82		102	136	-21	115

(1) Average of the 1987 and 1988 per kilo values of sesame seed imported to the US from four African countries (Nigeria for 1988 and Egypt, Morocco and Sudan for 1987). The per kilo value is the "Customs Value", based on the foreign market value, export value, or constructed value, and excludes import duties, insurance, and other charge incurred in moving the commodity to US port.
Source: USDA, 1989

(2) Annual rate of inflation of 4% from 1985 to 1988 (GNP deflator in the US).

(3) The average 1987 and 1988 value of US imports of sesame from the African Ports is taken as the value that can be obtained in Abidjan.

(4) Adapted from WAPA, Ivory Coast - Agricultural Sector Review, 1985, p. 206, in Styker et al. (1987) with 4% of annual inflation rate.

(5) Adapted from OPAM/PRMC 1986 in Stryker et al. (1987) with 4% of annual inflation rate.

(6) Adapted from OSPR 1986, p. 106, in Stryker et al. (1987) with a rural market-to-farm distance of 100 km and 4% of annual inflation rate.

APPENDIX 5-G

Table 5-G-1. Domestic Resource Costs Ratios for Current Enterprises by Region

COMPONENT (CFA.F/ha)	SENO CENTER MILLET/COWPEA TRADITIONAL	SENO CENTER MILLET/COWPEA TRANSITIONAL	DELTA FLOODING RICE NATURAL	DELTA FLOODING RICE CONTROLLED	MALI SUD (3) MILLET/SORGHUM MANUAL	MALI SUD (3) MILLET/SORGHUM TRANSITIONAL	OFFICE DU NIGER RICE (3) IRRIGATED
Overvaluation Correction (1)	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Processing Conversion Factor(2)	1.00	1.00	0.63	0.63	1.00	1.00	0.63
TRADABLES:							
Value of Production:							
Farm Level	61416	67558	55998	119548	91546	122061	289688
Rural Market Level (Mopti)	51589	56748	47969	102930	82612	98555	288841
Rural Market Level(Sikasso)	NA	NA	41671	90237	71946	95928	270412
Rural Market Level (Segou)	NA	NA	43203	93178	NA	NA	278184
Wholesale Level (Bamako)	39251	43176	37845	82890	61664	82219	251014
Consumption Level (Gao)	52654	57919	48400	103155	79001	105335	304545
Input Costs:							
Seed	103	103	1080	3928	35	69	3610
Fungicide	69	69			23	23	
Sack				551			8237
Fertilizer:							
Ammonia phosphate							7572
Urea							7418
Extension	89	89		2501	1561	1561	3255
ORM threshing fee				1443			
Capital Recovery Costs:							
Hoes					366	366	366
Tool bar						1078	
Seeder						384	
Harrow							503
Cart						341	341
Plow		3060	5553	5553			1759
Operating Costs:							
Irrigation							15641
Implements						446	333
Threshing							13593
Animal							1925
Collection Costs to Mopti	3541	3895	1165	2237	NA	NA	NA
Collection Costs to Sikasso	NA	NA	NA	NA	1412	1883	NA
Collection Costs to Segou	NA	NA	NA	NA	NA	NA	22142
Processing Costs	0	0	887	1703	0	0	3456
Distribution Costs to Bamako	6822	7504	5285	10148	5793	7725	11982
Distribution Costs to Mopti	NA	NA	NA	NA	8515	11353	15646
Distribution Costs to Gao	6460	7106	5087	9767	14798	19731	29195
Distribution Costs to Sikasso	NA	NA	5719	10980	NA	NA	13157
Distribution Costs to Segou	NA	NA	3917	7520	NA	NA	NA

Table 5-G-1 (cont'd.).

COMPONENT (CFA.F/ha)	SENO CENTER MILLET/COWPEA		DELTA FLOODING RICE		MALI SUD (3) MILLET/SORGHUM		OFFICE DU NIGER RICE (3)
	TRADITIONAL	TRANSITIONAL	NATURAL	CONTROLLED	MANUAL	TRANSITIONAL	IRRIGATED
NON TRADABLES:							
Value of Production:							
Farm Level	20662	21978	27928	43295	13213	17618	28580
Rural Market Level (Mopti)	20348	21633	25976	39547	9105	12140	28118
Rural Market Level(Sikasso)	NA	NA	23856	35476	6194	7800	18066
Rural Market Level (Segou)	NA	NA	24624	36950	NA	NA	22305
Wholesale Level (Bamako)	15673	16490	22294	32478	3024	4032	9340
Consumption Level (Gao)	21938	23382	27228	41951	11879	15838	36685
Input Costs:							
Direct Family Labor	25443	15045	13033	44219	27450	17100	57000
Seed	927	927	9720	9164	486	462	5897
Fungicide	14	14			3	3	
Sack				109			2815
Fertilizer:							
Ammonia phosphate							4744
Urea							4648
Extension	308	308		7767	4852	4852	10117
ORM threshing fee				4967			
Capital Recovery Costs:							
Hoes					125	125	125
Tool bar						368	
Seeder						131	
Harrow							20
Cart						14	14
Plow		439	769	769			71
Animal		4557	15427	15427		12000	12000
Operating Costs:							
Irrigation							13440
Implements						336	250
Threshing							2940
Animal						198	165
Working Capital:							
3-month					915	750	1425
6-month					811	811	3021

Table 5-G-1 (cont'd.).

COMPONENT (CFA.F/ha)	SENO CENTER MILLET/COWPEA		DELTA FLOODING RICE		MALI SUD (3) MILLET/SORGHUM		OFFICE DU NIGER RICE (3)
	TRADITIONAL	TRANSITIONAL	NATURAL	CONTROLLED	MANUAL	TRANSITIONAL	IRRIGATED
Collection Costs to Mopti	3386	3724	4168	8003	NA	NA	NA
Collection Costs to Sikasso	NA	NA	NA	NA	3168	4224	NA
Collection Costs to Segou	NA	NA	NA	NA	NA	NA	19073
Processing Costs	0	0	1404	2696	0	0	6773
Distribution Costs to Bamako	12275	13502	10990	21102	14100	18800	34745
Distribution Costs to Mopti	NA	NA	NA	NA	16004	21339	37312
Distribution Costs to Gao	12021	13223	9467	18176	20406	27208	46805
Distribution Costs to Sikasso	NA	NA	9909	19026	NA	NA	35569
Distribution Costs to Segou	NA	NA	8647	16601	NA	NA	NA
NET COSTS FOR PRIMARY FACTORS:							
Farm Level	6030	-689	11022	39128	21430	19533	90111
Rural Market Level (Mopti)	9729	3380	17142	50878	44710	50573	153732
Rural Market Level(Sikasso)	NA	NA	30576	76672	31617	33575	162041
Rural Market Level (Segou)	NA	NA	28545	72773	NA	NA	115460
Wholesale Level (Bamako)	26679	22025	33218	81745	48887	56142	169942
Consumption Level (Gao)	20160	14854	26761	69346	46338	52744	154658
VALUE ADDED FOR TRADABLES:							
Farm Level	61154	64236	49364	105571	69960	117792	225135
Rural Market Level (Mopti)	47785	49530	40171	86717	70699	81049	183044
Rural Market Level(Sikasso)	NA	NA	27267	61340	68547	89775	167104
Rural Market Level (Segou)	NA	NA	30602	67742	NA	NA	188034
Wholesale Level (Bamako)	28626	28454	23874	54826	52472	68342	148881
Consumption Level (Gao)	42390	43596	34627	75472	60805	79452	185200
RESOURCE COST RATIOS:							
Farm Level	0.10	-0.01	0.22	0.37	0.31	0.17	0.40
Rural Market Level (Mopti)	0.20	0.07	0.43	0.59	0.63	0.62	0.84
Rural Market Level(Sikasso)	NA	NA	1.12	1.25	0.46	0.37	0.97
Rural Market Level (Segou)	NA	NA	0.93	1.07	NA	NA	0.61
Wholesale Level (Bamako)	0.93	0.77	1.39	1.49	0.93	0.82	1.14
Consumption Level (Gao)	0.48	0.34	0.77	0.92	0.76	0.66	0.84

(1) From Stryker et al. (1987).
(2) From Bareme Riz Office du Niger 1985/86 in Stryker et al. (1987).
(3) Adapted from Stryker et al. (1987, Annex B).
Source: Author's estimations.

Table 5-G-2. Domestic Resource Cost Ratios for Current and Proposed Enterprises in the Region of Mopti

	SENO CENTER MILLET-COWPEA INTERCROPPING			SENO CENTER MILLET-GROUNDNUT ROTATION WITH TRP		SENO SOUTH SESAME IMPROVED CULTIVATION	DELTA RICE NATURAL FLOODING		DELTA RICE CONTROLLED FLOODING	
COMPONENT (CFA.F/ha)	TRADIT.	TRANSIT.	IMPROVED	MECH.PRESS	IND.PROCESS	FERTILIZATION	TRADIT.	IMPROVED	TRADIT.	IMPROVED
Overvaluation Correction (1)	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33	1.33
Processing Conversion Factor(2)	1.00	1.00	1.00	1.00	1.00	1.00	0.63	0.63	0.63	0.63
TRADABLES:										
Value of Production:										
Farm Level	61416	67558	99801	266223	289818	81531	55998	54735	119548	159173
Rural Market Level (Mopti)	51589	56748	83832	224800	245440	76036	47969	46887	102930	137046
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	41671	40731	90237	120146
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	43203	42229	93178	124063
Wholesale Level (Bamako)	39251	43176	63782	169878	187402	83785	37845	36991	82890	110364
Consumption Level (Gao)	52654	57919	85562	228350	248503	NA	48400	47308	103155	137346
Input Costs:										
Seed	103	103	764	6555	6555	589	1080	3928	3928	3142
Fungicide	69	69	439	1839	1839					
Sack			1103					551	551	551
Fertilizer:										
Phosphate			9374	1908	1908	5018				18747
Urea										8822
Insecticide Chemical			4124							
Storage Chemical			441	1213	1213					
Extension	89	89	89	89	89	89			2501	2501
ORM threshing fee									1443	2556
Capital Recovery Costs:										
Plow		3060	3060	3060	3060	3060	5553	5553	5553	5553
Insecticide Sprayer			1736							
Collection Costs to Mopti	3541	3895	10490	9465	9465	2958	1165	1514	2237	3960
Collection Costs to Sikasso	NA	NA	NA	NA	27082	NA	NA	NA	NA	NA
Collection Costs to Segou	NA	NA	NA			NA	NA	NA	NA	NA
Processing Costs	0	0	0	5958	3064	0	887	1153	1703	3015
Distribution Costs to Bamako	6822	7504	11085	27833	16372	10233	5285	6871	10148	17970
Distribution Costs to Mopti	NA	NA	NA			NA	NA	NA	NA	NA
Distribution Costs to Gao	6460	7106	10497	26356	15504	NA	5087	6613	9767	17296
Distribution Costs to Sikasso	NA	NA	NA	NA	4094	NA	5719	7435	10980	19444
Distribution Costs to Segou	NA	NA	NA	NA	21153	NA	3917	5092	7520	13316

Table 5-6-2 (cont'd.).

COMPONENT (CFA.F/ha)	SENO CENTER MILLET-COWPEA INTERCROPPING			SENO CENTER MILLET-GROUNDNUT ROTATION WITH TRP		SENO SOUTH SESAME IMPROVED CULTIVATION	DELTA RICE NATURAL FLOODING		DELTA RICE CONTROLLED FLOODING	
	TRADIT.	TRANSIT.	IMPROVED	MECH.PRESS	IND.PROCESS	FERTILIZATION	TRADIT.	IMPROVED	TRADIT.	IMPROVED
NON TRADABLES:										
Value of Production:										
Farm Level	20662	21978	39301	53866	55648	-12376	27928	34132	43295	71080
Rural Market Level (Mopti)	20348	21633	44808	42213	43518	-9806	25976	31594	39547	66480
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	23856	28837	35476	57233
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	24624	29836	36950	59844
Wholesale Level (Bamako)	15673	16490	37211	20325	20571	-3259	22294	26808	32478	51925
Consumption Level (Gao)	21938	23382	49812	48547	52381	NA	27228	33222	41951	68700
Input Costs:										
Direct Family Labor	25443	15045	27016	87019	87019	20840.56	13033	14218	44219	64433
Seed	927	927	1782	15295	15295	1375	9720	9164	9164	7332
Fungicide	14	14	87	364	364					
Sack			218					109	109	109
Fertilizer:										
Ammonia phosphate			1855	2862	2862	993				3709
Urea										1746
Insecticide Chemical			816							
Storage Chemical			87	240	240					
Extension	308	308		308	308	308			7767	7767
ORM threshing fee									4967	8796
Capital Recovery Costs:										
Plow		439	439	439	439	439	769	769	769	769
Animal		4557	4557	4557	4557	4557	15427	15427	15427	15427
Insecticide Sprayer			469							
Collection Costs to Mopti	3386	3724	6091	14453	14453	4516	4168	5419	8003	14172
Collection Costs to Sikasso	NA	NA	NA	NA	24163	NA	NA	NA	NA	NA
Collection Costs to Segou	NA	NA	NA			NA	NA	NA	NA	NA
Processing Costs	0	0	0	41392	576	0	1404	1825	2696	4774
Distribution Costs to Bamako	12275	13502	19946	50081	29459	18412	10990	14288	21102	37367
Distribution Costs to Mopti	NA	NA	NA			NA	NA	NA	NA	NA
Distribution Costs to Gao	12021	13223	19534	49047	28851	NA	9467	12307	18176	32187
Distribution Costs to Sikasso	NA	NA	NA	NA	16720	NA	9909	12882	19026	33692
Distribution Costs to Segou	NA	NA	NA	NA	26597	NA	8647	11241	16601	29398

Table 5-G-2 (cont'd.).

NET COSTS FOR PRIMARY FACTORS:										
Farm Level	6030	-689	-1975	57217	55435	40888	11022	5557	39128	39009
Rural Market Level (Mopti)	9729	3380	-1391	83323	82018	42834	17142	13513	50878	57780
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	30576	30977	76672	105492
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	28545	28337	72773	98588
Wholesale Level (Bamako)	26679	22025	26152	196684	175883	54699	33218	34412	81745	114476
Consumption Level (Gao)	20160	14854	13139	167428	153343	NA	26761	26017	69346	92521
VALUE ADDED FOR TRADABLES										
Farm Level	61154	64236	78670	251559	275154	72774	49364	44702	105571	117299
Rural Market Level (Mopti)	47785	49530	52210	175955	181931	64321	40171	35340	86717	91212
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	27267	20597	61340	51853
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	30602	24438	67742	61897
Wholesale Level (Bamako)	28626	28454	21075	111957	112659	61838	23874	17421	54826	43544
Consumption Level (Gao)	42390	43596	43443	171905	157570	NA	34627	27995	75472	71201
RESOURCE COST RATIOS:										
Farm Level	0.10	-0.01	-0.03	0.23	0.20	0.56	0.22	0.12	0.37	0.33
Rural Market Level (Mopti)	0.20	0.07	-0.03	0.47	0.45	0.67	0.43	0.38	0.59	0.63
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	1.12	1.50	1.25	2.03
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	0.93	1.16	1.07	1.59
Wholesale Level (Bamako)	0.93	0.77	1.24	1.76	1.56	0.88	1.39	1.98	1.49	2.63
Consumption Level (Gao)	0.48	0.34	0.30	0.97	0.97	NA	0.77	0.93	0.92	1.30

(1) From Stryker et al. (1987).
(2) From Bareme Riz Office du Niger 1985/86 in Stryker et al. (1987).
<u>Source</u>: Author's estimations.

Table 5-G-3. Domestic Resource Cost Ratios for Current and Proposed Enterprises in the Region of Mopti with FOB and CIF Prices Reduced by 20%

	SENO CENTER MILLET-COWPEA INTERCROPPING			SENO CENTER MILLET-GROUNDNUT ROTATION WITH TRP		SENO SOUTH SESAME IMPROVED CULTIVATION	DELTA RICE NATURAL FLOODING		DELTA RICE CONTROLLED FLOODING	
COMPONENT	TRADIT.	TRANSIT.	IMPROVED	MECH.PRESS	IND.PROCESS	FERTILIZATION	TRADIT.	IMPROVED	TRADIT.	IMPROVED
NET COSTS FOR PRIMARY FACTORS (CFA.F/ha):										
Farm Level	6030	-689	-1975	57217	55435	40888	11022	5557	39128	39009
Rural Market Level (Mopti)	9729	3380	-1391	83323	82018	42834	17142	13513	50878	57780
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	30576	30977	76672	105492
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	28545	28337	72773	98588
Wholesale Level (Bamako)	26679	22025	26152	196684	175883	54699	33218	34412	81745	114476
Consumption Level (Gao)	20160	14854	13139	167428	153343	NA	26761	26017	69346	92521
VALUE ADDED FOR TRADABLES (CFA.F/ha):										
Farm Level	58452	61263	74278	214418	230086	47484	45604	57876	95945	152780
Rural Market Level (Mopti)	45353	46854	48257	142528	141370	41460	36787	46414	78053	121096
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	24071	29884	53158	77012
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	27406	34218	59560	88349
Wholesale Level (Bamako)	26328	25927	17342	80387	74351	40342	20678	25473	46644	65475
Consumption Level (Gao)	40093	41069	39710	140335	119263	NA	31431	39452	67290	102036
RESOURCE COST RATIOS:										
Farm Level	0.10	-0.01	-0.03	0.27	0.24	0.86	0.24	0.10	0.41	0.26
Rural Market Level (Mopti)	0.21	0.07	-0.03	0.58	0.58	1.03	0.47	0.29	0.65	0.48
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	1.27	1.04	1.44	1.37
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	1.04	0.83	1.22	1.12
Wholesale Level (Bamako)	1.01	0.85	1.51	2.45	2.37	1.36	1.61	1.35	1.75	1.75
Consumption Level (Gao)	0.50	0.36	0.33	1.19	1.29	NA	0.85	0.66	1.03	0.91

Source: Author's estimations.

Table 5-6-4. Domestic Resource Cost Ratios for Current and Proposed Enterprises in the Region of Mopti with FOB and CIF Prices Increased by 20%

	SENO CENTER MILLET-COWPEA INTERCROPPING			SENO CENTER MILLET-GROUNDNUT ROTATION WITH TRP		SENO SOUTH SESAME IMPROVED CULTIVATION	DELTA RICE NATURAL FLOODING		DELTA RICE CONTROLLED FLOODING	
COMPONENT	TRADIT.	TRANSIT.	IMPROVED	MECH.PRESS	IND.PROCESS	FERTILIZATION	TRADIT.	IMPROVED	TRADIT.	IMPROVED
NET COSTS FOR PRIMARY FACTORS (CFA.F/ha):										
Farm Level	6030	-689	-1975	57217	55435	40888	11022	5557	39128	39009
Rural Market Level (Mopti)	9729	3380	-1391	83323	82018	42834	17142	13513	50878	57780
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	30576	30977	76672	105492
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	28545	28337	72773	98588
Wholesale Level (Bamako)	26679	22025	26152	196684	175883	54699	33218	34412	81745	114476
Consumption Level (Gao)	20160	14854	13139	167428	153343	NA	26761	26017	69346	92521
VALUE ADDED FOR TRADABLES (CFA.F/ha):										
Farm Level	63857	67209	83062	247814	269303	98064	53124	67653	115197	186872
Rural Market Level (Mopti)	50218	52206	56163	172585	176665	87083	43555	55212	95380	151779
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	30464	38194	69523	105990
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	33798	42528	75925	117327
Wholesale Level (Bamako)	30923	30981	24809	108774	107685	83335	27070	33783	63008	94454
Consumption Level (Gao)	44688	46123	47176	168722	152597	NA	37824	47762	83654	131014
RESOURCE COST RATIOS:										
Farm Level	0.09	-0.01	-0.02	0.23	0.21	0.42	0.21	0.08	0.34	0.21
Rural Market Level (Mopti)	0.19	0.06	-0.02	0.48	0.46	0.49	0.39	0.24	0.53	0.38
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	1.00	0.81	1.10	1.00
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	0.84	0.67	0.96	0.84
Wholesale Level (Bamako)	0.86	0.71	1.05	1.81	1.63	0.66	1.23	1.02	1.30	1.21
Consumption Level (Gao)	0.45	0.32	0.28	0.99	1.00	NA	0.71	0.54	0.83	0.71

Source: Author's estimations.

Table 5-6-5. Domestic Resource Cost Ratios for Current and Proposed Enterprises in the Region of Mopti with a Exchange Rate Overvaluation Of 50%

	SENO CENTER MILLET-COWPEA INTERCROPPING			SENO CENTER MILLET-GROUNDNUT ROTATION WITH TRP		SENO SOUTH SESAME IMPROVED CULTIVATION	DELTA RICE NATURAL FLOODING		DELTA RICE CONTROLLED FLOODING	
COMPONENT	TRADIT.	TRANSIT.	IMPROVED	MECH.PRESS	IND.PROCESS	FERTILIZATION	TRADIT.	IMPROVED	TRADIT.	IMPROVED
NET COSTS FOR PRIMARY FACTORS (CFA.F/ha):										
Farm Level	6026	-691	-2099	56818	55036	40776	10867	5388	38875	38640
Rural Market Level (Mopti)	9726	3378	-1515	82924	81619	42723	16987	13344	50625	57411
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	30421	30808	76418	105124
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	28390	28168	72520	98219
Wholesale Level (Bamako)	26676	22023	26028	196284	175484	54588	33063	34243	81492	114107
Consumption Level (Gao)	20157	14852	13015	167029	152944	NA	26606	25848	69093	92152
VALUE ADDED FOR TRADABLES (CFA.F/ha):										
Farm Level	69136	72931	91004	254830	273848	83126	56489	72056	120859	196205
Rural Market Level (Mopti)	53799	56060	60034	174996	176591	73574	46101	58550	99554	158476
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	31520	39595	70879	107697
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	35288	44494	78113	120508
Wholesale Level (Bamako)	32148	32244	24851	101754	96048	70768	27686	34611	63517	94661
Consumption Level (Gao)	47702	49354	50127	169494	146798	NA	39837	50407	86847	135974
RESOURCE COST RATIOS:										
Farm Level	0.09	-0.01	-0.02	0.22	0.20	0.49	0.19	0.07	0.32	0.20
Rural Market Level (Mopti)	0.18	0.06	-0.03	0.47	0.46	0.58	0.37	0.23	0.51	0.36
Rural Market Level(Sikasso)	NA	NA	NA	NA	NA	NA	0.97	0.78	1.08	0.98
Rural Market Level (Segou)	NA	NA	NA	NA	NA	NA	0.80	0.63	0.93	0.82
Wholesale Level (Bamako)	0.83	0.68	1.05	1.93	1.83	0.77	1.19	0.99	1.28	1.21
Consumption Level (Gao)	0.42	0.30	0.26	0.99	1.04	NA	0.67	0.51	0.80	0.68

Source: Author's estimations.

APPENDIX 6-A

Table 6-A-1. Economic Budgets for the Millet-Cowpea Intercropping by Agroclimatic Zone

ZONE:	SOUTH			CENTER/PLATEAU			NORTH		
TECHNOLOGICAL LEVEL (1):	IMPROVED	TRANSIT.	TRADIT.	IMPROVED	TRANSIT.	TRADIT.	IMPROVED	TRANSIT.	TRADIT.
GROSS BENEFIT (CFA F/HA):									
Millet	40000	16500	15000	39000	17600	16000	28000	13750	12500
Cowpea	18000	2700	2400	17600	3850	3500	14400	3600	3200
Cowpea Fodder	4800	6000	6000	6000	7500	7500	3600	4800	4800
Weight Gain	4000								
Manure	1500								
Gross Benefit	68300	25200	23400	62600	28950	27000	46000	22150	20500
Labor Saving * (2)	6168	8567		4425	10398		4858	8161	
Labor Saving * (3)	-2977			-7678			-4127		
Total Gross Benefit (2)	74468	33767		67025	39348		50858	30311	
Total Gross Benefit (3)	65323			54922			41873		
INCREMENTAL GROSS BENEFIT (CFA F/HA):									
(2)	51068	10367		40025	12348		30358	9811	
(3)	40123			25972			19723		
VARIABLE COSTS (CFA F/HA):									
Millet Seeds	452	500	500	452	550	550	452	600	600
Cowpea Seeds	2095	450	450	2095	480	480	2095	540	540
Seed Treatment: on Millet	396	121	121	396	130	130	396	115	115
on Cowpea	83			83			83		
Fertilization: Phosphate	11228			11228			5614		
Urea	5284			0			0		
Pesticide Treatment (Decis)	4940			4940			4940		
Stock Treatment (Phostoxin)	528			528			264		
Plastic Bag	1321			1321			660		
OMM Extension	397	397	397	397	397	397	397	397	397
Total Variable Costs	26726	1469	1469	21442	1557	1557	14903	1653	1653
AMORTIZATION (CFA F/HA/YEAR):									
Sprayer T15	2205			2205			2205		
Equipment	3910	3499		3499	3499		3499	3499	
Draft Animal	11882	3645		4557	4557		3645	3645	
Total Amortization	17997	7144		10261	8055		9349	7144	
TOTAL COSTS (CFA F/HA/YEAR)	44722	8613	1469	31702	9612	1557	24252	8797	1653
INCREMENTAL COSTS (CFA F/HA/YEAR):									
(2)	43254	7144		30145	8055		22600	7144	
(3)	36110			22090			15455		

Table 6-A-1 (cont'd.).

AVERAGE RETURN TO LABOR (CFA F/DAY):									
	513	425	343	650	569	442	604	486	389
INCREMENTAL AVERAGE RETURN TO LABOR (CFA F/DAY):									
(2)	170	83		208	126		216	97	
(3)	87			82			119		
NET BENEFIT (CFA F/HA):	16587	21931		19338	25443		13353	18847	
(2)	29746	25154		35323	29736		26606	21514	
(3)	20601			23220			17621		
INCREMENTAL NET BENEFIT (CFA F/HA):									
(2)	7815	3223		9880	4293		7758	2667	
(3)	4013			3882			4267		

(1) Improved: Technical package that FSR would develop.
Transitional: Technique currently used by most of the equipped farmers.
Traditional: Technique currently used by most of the non-equipped farmers.
(2) With respect to the traditional technique.
(3) With respect to the transitional technique.
* The labor saving is the number of days saved by the technique multiplied by the opportunity cost of labor estimated for the traditional or transitional techniques. This labor saving is added to the gross benefit to estimate the total gross benefit.

Table 6-A-2. Economic Budgets for the Millet-Cowpea Rotation by Agroclimatic Zone

ZONE:	SOUTH			CENTER/PLATEAU			NORTH		
CROP (1):	MILLET		COWPEA	MILLET		COWPEA	MILLET		COWPEA
GROSS BENEFIT (CFA F/HA):									
Millet	40000			36000			24500		
Cowpea			60000			55000			48000
Cowpea Fodder			6000			6000			3600
Weight Gain	4000		4000						
Manure	1500		1500						
Gross Benefit for the Rotation:		52000			42250			31275	
Labor Saving *(2)	10280		3427	8850		-1106	9132		-194
Labor Saving *(3)	2127		-6380	-1991		-14788	1214		-10440
Total Gross Benefit (2):	55780		74927	44850		59894	33632		51406
Total Gross Benefit (3):	47627		65120	34009		46212	25714		41160
Total Gross Benefit for the Rotation (2):		60567			48611			38076	
Total Gross Benefit for the Rotation (3):		52000			37060			29575	
INCREMENTAL GROSS BENEFIT (CFA F/HA):									
(2)		37167			21611			17576	
(3)		26800			8110			7425	
VARIABLE COSTS (CFA F/HA):									
Seeds	452		6546	452		6546	452		6546
Seed Treatment	396		250	396		250	396		250
Fertilization (TRP)			6010			6010			3005
Pesticide Treatment (Decis)			17292			17292			17292
Stock Treatment			1585			1321			1057
Plastic Bag			3963			3302			2642
Variable Costs	848		35646	848		34721	848		30791
AMORTIZATION (CFA F/HA/YEAR):									
Fertilization	4769			4769			0		
Sprayer T 15			2205			2205			2205
Equipment	3910		3910	3499		3499	3499		3499
Draft Animal	11882		11882	4557		4557	3645		3645
Total Amortizat.	20561		17997	12825		10261	7144		9349
TOTAL COSTS (CFA F/HA/YEAR):									
Crop	21409		53643	13673		44982	7992		40141
Rotation		29468			21500			16029	

Table 6-A-2 (cont'd.).

INCREMENTAL COSTS (CFA F/HA/YEAR):			
(2)	27999	19943	14377
(3)	20855	11888	7233
AVERAGE RETURN TO LABOR (CFA F/DAY):			
	578	738	813
INCREMENTAL AVERAGE RETURN TO LABOR (CFA F/DAY):			
(2)	235	295	424
(3)	152	169	328
NET BENEFIT (CFA F/HA):			
(2)	31099	27110	22046
(3)	22532	15560	13546
INCREMENTAL NET BENEFIT (CFA F/HA):			
(2)	9168	1667	3199
(3)	5945	-3778	193

(1) The suggested cropping pattern is 0.75 Ha of millet in pure stand and 0.25 Ha of cowpea in pure stand.
(2) With respect to the traditional technique.
(3) With respect to the transitional technique.
* The labor saving is the number of days saved by the technique multiplied by the opportunity cost of labor estimated for the traditional or transitional techniques. This labor saving is added to the gross benefit to estimate the total gross benefit.

Table 6-A-3. Economic Budgets for the Groundnut-Millet-Groundnut Rotation in the Center and Plateau Zone

ROTATION:	GROUNDNUT	MILLET	GROUNDNUT	GROUNDNUT	MILLET	GROUNDNUT	MILLET	MILLET	MILLET	MILLET	MILLET	MILLET
TECHNOLOGICAL LEVEL:		WITH TRP			WITHOUT TRP			TRANSITIONAL			TRADITIONAL	
ANNUAL GROSS BENEFIT (CFA F/Ha):												
Millet		57600			28800		16800	17600	16000	15200	16000	14400
Groundnuts	37200		20400	31800		15600						
Groundnut Fodder	7440		4080	6360		3120						
Gross Benefit	44640	57600	24480	38160	28800	18720	16800	17600	16000	15200	16000	14400
Labor Saving *(1)	-3562	4377	-840	-2192	5628	280	5479	6253	5600			
Labor Saving *(2)	-8825	-1991	-6365	-7488	-664	-5258						
Total Gross Benefit (1):	41078	61977	23640	35968	34428	19000	22279	23853	21600			
Total Gross Benefit (2):	35815	55609	18115	30672	28136	13462						
INCREMENTAL GROSS BENEFIT (CFA F/Ha):												
3 Year Average (1)		27032			14599			7378				
3 Year Average (2)		19713			7290							
ANNUAL VARIABLE COSTS (CFA F/HA):												
Seeds	10474	903	10474	10474	903	10474	550	550	550	550	550	550
Seed Treatment	666	83	666	666	83	666	130	130	130	130	130	130
Actellic Treatment	872	0	581	872	0	291						
Total	12011	987	11721	12011	987	11430	680	680	680	680	680	680
AMORTIZATION (CFA F/HA/YEAR):												
Equipment	2739	2739	2739	2739	2739	2739	2739	2739	2739			
Draft Animal	4557	4557	4557	4557	4557	4557	4557	4557	4557			
Fertilization(TRP)	4769	4769	4769									
Total	12065	12065	12065	7296	7296	7296	7295	7295	7295			
TOTAL COSTS (CFA F/HA/YEAR):												
Annual	24076	13052	23786	19307	8282	18726	7975	7975	7975	680	680	680
3 Year Average		20305			15438			7975			680	
INCREMENTAL COSTS (CFA F/HA/YEAR):												
3 Year Average (1)		19625			14759			7295				
3 Year Average (2)		12330			7463							
AVERAGE RETURN TO LABOR (CFA F/DAY):												
Annual	312	1273	13	309	662	0	267	332	277	274	313	280
NET BENEFIT (CFA F/HA) (1):												
Annual	17002	48926	-146	16661	26146	274	14304	15878	13625	14520	15320	13720
3 Year Average		21927			14361			14603			14520	

Table 6-A-3 (cont'd.).

NET BENEFIT (CFA F/HA) (2):									
Annual	11739	42557	-5670	11365	19854	-5263	8825	9625	8025
3 Year Average		16208			8652			8825	
INCREMENTAL NET BENEFIT (CFA F/HA):									
3 Year Average (1)		7407			-160			82	
3 Year Average (2)		7383			-173				

(1) With respect to the millet-millet-millet rotation with the traditional technology.
(2) With respect to the millet-millet-millet rotation with the transitional technology.

Table 6-A-4. Economic Budgets for the Groundnut-Millet-Groundnut Rotation in the Southern Zone

ROTATION:	GROUNDNUT	MILLET	GROUNDNUT	GROUNDNUT	MILLET	GROUNDNUT	MILLET	MILLET	MILLET	MILLET	MILLET	MILLET
TECHNOLOGICAL LEVEL:		WITH TRP			WITHOUT TRP			TRANSITIONAL			TRADITIONAL	
ANNUAL GROSS BENEFIT (CFA F/Ha):												
Millet		43000			35000		15600	16500	15000	14400	15000	13500
Groundnuts	31350		12650	23650		14300						
Groundnut Fodder	5472		2208	4128		2496						
Gross Benefit	36822	43000	14858	27778	35000	16796	15600	16500	15000	14400	15000	13500
Labor Saving (1)	-2505	4314	-859	-501	4889	-859	5011	5752	5724			
Labor saving (2)	-6716	-1456	-6656	-4925	-873	-6656						
Total Gross Benefit (1):	34317	47314	13999	27277	39889	15937	20611	22252	20724			
Total Gross Benefit (2):	30106	41544	8202	22853	34127	10140						
INCREMENTAL GROSS BENEFIT (CFA F/Ha):												
3 Year Average (1)		17577			13401			6895				
3 Year Average (2)		10917			6673							
ANNUAL VARIABLE COSTS (CFA F/HA):												
Seeds	10474	903	10474	10474	903	10474	500	500	500	500	500	500
Seed Treatment	666	83	666	666	83	666	121	121	121	121	121	121
Actellic Treatment	872	0	291	581	0	291						
Total	12011	987	11430	11721	987	11430	621	621	621	621	621	621
AMORTIZATION (CFA F/HA/YEAR):												
Equipment	3499	3499	3499	3499	3499	3499	3499	3499	3499			
Draft Animal	3645	3645	3645	3645	3645	3645	3645	3645	3645			
Fertilization(TRP)	4769	4769	4769									
Total	11914	11914	11914	7144	7144	7144	7144	7144	7144			
TOTAL COSTS (CFA F/HA/YEAR):												
Annual	23925	12900	23344	18865	8131	18574	7765	7765	7765	621	621	621
3 Year Average		20056			15190			7765			621	
INCREMENTAL COSTS (CFA F/HA/YEAR):												
3 Year Average (1)		19435			14569			7144				
3 Year Average (2)		12291			7425							
AVERAGE RETURN TO LABOR (CFA F/DAY):												
Annual	198	860	-177	156	814	-37	224	291	289	251	288	286
NET BENEFIT (CFA F/HA) (1):												
Annual	10392	34413	-9344	8412	31758	-2637	12845	14486	12959	13779	14379	12879
3 Year Average		11820			12511			13430			13679	

Table 6-A-4 (cont'd).

NET BENEFIT (CFA F/HA) (2):									
Annual	6181	28644	-15142	3988	25996	-8434	7835	8735	7235
3 Year Average		6561			7183			7935	
INCREMENTAL NET BENEFIT (CFA F/HA):									
3 Year Average (1)		-1859			-1168			-249	
3 Year Average (2)		-1374			-752				

(1) With respect to the millet-millet-millet rotation with the traditional technology.
(2) With respect to the millet-millet-millet rotation with the transitional technology.

Table 6-A-5. Economic Budgets for the Sesame Cultivation by Agroclimatic Zone

ZONE:	SOUTH			CENTER/PLATEAU			NORTH		
TECHNOLOGICAL	SESAME	MILLET (2d year)		SESAME	MILLET (2d year)		SESAME	MILLET (2d year)	
LEVEL:	IMPROVED	TRANSIT.	TRADITIONAL	IMPROVED	TRANSIT.	TRADITIONAL	IMPROVED	TRANSIT.	TRADITIONAL
GROSS BENEFIT (CFA F/Ha):									
Millet		16500	15000		17600	16000		16500	15000
Sesame	56020			45247			23701		
Gross Benefit	56020	16500	15000	45247	17600	16000	23701	16500	15000
Labor Saving (1)	288	5752		1876	6253		2237	6196	
Labor Saving (2)	-5532			-4280			-4229		
Total Gross Benefit(1)	6307	22252	15000	47123	23853	16000	25938	22696	15000
Total Gross Benefit(2)	50488	16500		40967	17600		19472	16500	
INCREMENTAL GROSS BENEFIT (CFA F/Ha):									
(1)	41307	7252		31123	7853		10938	7696	
(2)	33988			23367			2972		
ANNUAL VARIABLE COSTS (CFA F/HA):									
Millet Seeds		500	500		550	550		600	600
Sesame Seeds	1964			1964			1964		
Seed Treatment	0	121	121	0	130	130	0	115	115
Fertilization	6010			6010			3005		
Total	7974	621	621	7974	680	680	4969	715	715
AMORTIZATION (CFA F/HA/YEAR):									
Equipment	3499	3499		3499	3499		3499	3499	
Draft Animal	3645	3645		4557	4557		3645	3645	
Total	7144	7144		8056	8055		7144	7144	
TOTAL COSTS (CFA F/HA/YEAR):	15119	7765	621	16030	8735	680	12113	7859	715
INCREMENTAL COSTS (CFA F/HA/YEAR):									
(1)	14498	7144		15350	8055		11398	7144	
(2)	7353			7295			4254		
AVERAGE RETURN TO LABOR (CFA F/DAY):	835	291	288	679	306	313	331	368	344
INCREMENTAL AVERAGE RETURN TO LABOR (CFA F/DAY):									
(1)	547	4		367	-7		-13	23	
(2)	544			374			-37		

Table 6-A-5 (cont'd.).

NET BENEFIT (CFA F/HA):									
(1)	41189	14486	14379	31093	15118	15320	13825	14837	14285
(2)	35369	8735		24937	8865		7359	8641	
INCREMENTAL NET BENEFIT (CFA F/HA):									
(1)	26810	108		15772	-202		-460	552	
(2)	26634			16072			-1282		

(1) With respect to the second crop of the millet-millet-millet rotation with the traditional technology.
(2) With respect to the second crop of the millet-millet-millet rotation with the transitional technology.

APPENDIX 6-B

Table 6-B-1. Economic Analysis of the Transitional Millet-Cowpea Intercropping by Stratum and Year

ITEM BY STRATUM	VALUE PER HECTARE	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEARR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
STRATUM 1																					
Cumulative rate of adoption (%Ha):		2.70	5.46	8.22	10.85	13.34	15.61	17.60	19.23	20.43	21.13	21.24	20.80	19.98	19.10	18.42	18.02	17.85	17.82	17.88	17.97
Area (Ha):	19750	533	1078	1623	2143	2635	3084	3475	3797	4036	4173	4195	4107	3946	3773	3638	3558	3524	3520	3531	3549
Incremental gross benefit (Thousand CFAF):	10	5229	10576	15923	21024	25851	30256	34092	37251	39596	40940	41156	40293	38713	37016	35692	34907	34573	34534	34642	34818
Incremental costs (Thousand CFAF):	7	3811	7708	11605	15323	18841	22052	24848	27150	28859	29839	29996	29367	28215	26978	26013	25441	25198	25169	25248	25377
Incremental net benefit (Thousand CFAF):	3	1418	2868	4318	5701	7010	8205	9245	10101	10737	11102	11160	10926	10498	10038	9678	9466	9375	9365	9394	9442
STRATUM 2																					
Cumulative rate of adoption (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	4938	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 3																					
Cumulative rate of adoption (%Ha):		4.39	8.17	11.27	13.75	15.67	17.11	18.16	18.86	19.25	19.31	19.02	18.32	17.23	15.90	14.58	13.49	12.70	12.20	11.90	11.73
Area (Ha):	25290	1111	2065	2850	3477	3963	4328	4592	4770	4868	4885	4810	4633	4358	4022	3688	3411	3213	3086	3010	2967
Incremental gross benefit (Thousand CFAF):	12	13719	25499	35193	42935	48937	53444	56704	58902	60112	60322	59396	57210	53816	49665	45541	42120	39675	38107	37169	36638
Incremental costs (Thousand CFAF):	8	8940	16617	22935	27980	31891	34828	36953	38385	39174	39311	38707	37283	35070	32366	29678	27449	25856	24834	24222	23876
Incremental net benefit (Thousand CFAF):	4	4779	8882	12258	14955	17046	18616	19751	20517	20938	21011	20689	19928	18745	17299	15863	14671	13820	13274	12947	12762
STRATUM 4																					
Cumulative rate of adoption (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	19187	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 5																					
Cumulative rate of adoption (%Ha):		0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Area (Ha):	29117	4	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Incremental net benefit (Thousand CFAF):	10	41	62	62	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73	73
Incremental costs (Thousand CFAF):	7	29	43	43	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Incremental net benefit (Thousand CFAF):	3	13	19	19	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23
STRATUM 6																					
Cumulative rate of adoption (%(Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	7279	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6-B-1 (cont'd.).

ITEM BY STRATUM	VALUE PER HECTARE	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEARR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
STRATUM 7																					
Cumulative rate of adoption (%Ha):		1.40	2.91	4.48	6.10	7.71	9.24	10.62	11.73	12.47	12.85	13.03	13.25	13.61	14.08	14.58	15.06	15.50	15.87	16.19	16.45
Area (Ha): 6038		85	176	271	368	465	558	641	708	753	776	787	800	822	850	881	910	936	958	977	995
Incremental net benefit (Thousand CFAF):	10	834	1727	2659	3610	4562	5474	6289	6946	7388	7613	7721	7849	8064	8339	8643	8928	9183	9399	9585	9742
Incremental costs (Thousand CFAF):	7	608	1258	1938	2631	3325	3990	4583	5062	5384	5549	5627	5720	5878	6078	6299	6507	6693	6850	6986	7100
Incremental net benefit (Thousand CFAF):	3	226	468	721	979	1237	1484	1705	1884	2003	2064	2094	2128	2187	2261	2344	2421	2490	2549	2599	2642
STRATUM 8																					
Cumulative rate of adoption (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha): 525		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit(Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 9																					
Cumulative rate of adoption (%Ha):		1.19	2.27	3.17	3.85	4.33	4.66	4.87	5.01	5.10	5.16	5.19	5.21	5.23	5.23	5.24	5.24	5.24	5.24	5.25	5.25
Area (Ha): 14154		168	321	448	545	613	659	690	709	722	730	735	738	740	741	741	742	742	742	742	743
Incremental net benefit (Thousand CFAF):	10	1742	3328	4644	5650	6355	6832	7153	7350	7485	7568	7620	7651	7672	7682	7682	7692	7692	7692	7692	7703
Incremental costs (Thousand CFAF):	7	1200	2293	3201	3894	4379	4708	4930	5065	5158	5215	5251	5273	5287	5294	5294	5301	5301	5301	5301	5308
Incremental net benefit (Thousand CFAF):	3	541	1034	1444	1756	1975	2124	2224	2285	2327	2353	2369	2378	2385	2388	2388	2391	2391	2391	2391	2394
STRATA 1 TO 9:																					
Area (Ha): 126278		1901	3646	5198	6540	7683	8636	9405	9991	10386	10571	10534	10285	9873	9393	8955	8628	8422	8313	8267	8259
Cumulative rate of adoption (%Ha):		1.5	2.9	4.1	5.2	6.1	6.8	7.4	7.9	8.2	8.4	8.3	8.1	7.8	7.4	7.1	6.8	6.7	6.6	6.5	6.5
Incremental net benefit (Thousand CFAF):		21565	41192	58481	73293	85778	96079	104311	110522	114653	116516	115965	113075	108336	102775	97630	93720	91196	89805	89161	88976
Incremental costs (Thousand CFAF):		14588	27920	39721	49878	58487	65628	71363	75713	78625	79963	79631	77692	74500	70766	67335	64748	63097	62204	61807	61711
Incremental net benefit (Thousand CFAF):		6977	13272	18760	23414	27291	30451	32947	34809	36028	36553	36334	35383	33837	32009	30296	28972	28099	27601	27353	27262
Incr. gross benefit (Thou. $ US):	300 = 1 $ US	72	137	195	244	286	320	348	368	382	388	387	377	361	343	325	312	304	299	297	297
Incremental costs (Thou. $ US):	300 = 1 $ US	49	93	132	166	195	219	238	252	262	267	265	259	248	236	224	216	210	207	206	206
Incr. gross benefit (Thou. $ US):	300 = 1 $ US	23	44	63	78	91	102	110	116	120	122	121	118	113	107	101	97	94	92	91	91

Table 6-B-2. Economic Analysis of the Improved Millet-Cowpea Intercropping by Stratum and Year

ITEM BY STRATUM	VALUE PER HECTARE	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEARR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
STRATUM 1																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.09	0.18	0.32	0.60	1.08	1.93	3.33	5.46	8.32	11.58	14.67	17.13	18.82	19.87	20.49	20.83	21.03
Area (Ha):	19750	0	0	0	19	35	64	118	214	381	658	1079	1644	2288	2898	3382	3716	3926	4046	4115	4152
Incremental gross benefit (Thousand CFAF):	30	0	0	0	577	1063	1943	3582	6497	11566	19975	32756	49908	69458	87976	102669	112809	119125	122827	124922	126045
Incremental costs (Thousands CFAF):	23	0	0	0	429	791	1446	2667	4836	8610	14870	24385	37154	51708	65493	76432	83980	88681	91438	92997	93833
Incremental net benefit (Thousands CFAF):	8	0	0	0	147	272	497	915	1660	2956	5105	8371	12754	17750	22483	26238	28829	30443	31389	31924	32212
STRATUM 2																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	1.07	1.81	2.97	4.64	6.80	9.22	11.54	13.45	14.84	15.76	16.33	16.67	16.87	16.98	17.05	17.09	17.11
Area (Ha):	4938	0	0	0	53	90	147	229	336	455	570	664	733	778	806	823	833	839	842	844	845
Incremental gross benefit (Thousand CFAF):	20	0	0	0	1045	1775	2899	4516	6627	8974	11242	13096	14457	15344	15896	16232	16429	16547	16606	16646	16666
Incremental costs (Thousands CFAF):	15	0	0	0	819	1391	2272	3539	5193	7032	8810	10262	11329	12024	12457	12720	12874	12967	13014	13044	13060
Incremental net benefit (Thousands CFAF):	4	0	0	0	226	384	627	977	1434	1942	2432	2833	3128	3320	3439	3512	3554	3580	3593	3601	3606
STRATUM 3																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.03	0.05	0.10	0.18	0.32	0.58	1.03	1.80	3.04	4.92	7.44	10.34	13.17	15.49	17.15	18.22	18.87	19.24
Area (Ha):	25290	0	0	7	14	25	45	81	146	260	454	769	1244	1881	2616	3330	3917	4337	4607	4771	4866
Incremental gross benefit (Thousand CFAF):	40	0	0	280	560	1001	1801	3242	5844	10406	18171	30779	49791	75287	104705	133283	156777	173588	184395	190959	194761
Incremental costs (Thousands CFAF):	30	0	0	211	422	754	1357	2442	4401	7838	13686	23182	37501	56703	78860	100384	118079	130740	138879	143823	146687
Incremental net benefit (Thousands CFAF):	10	0	0	69	138	247	445	800	1442	2569	4485	7597	12290	18584	25845	32899	38699	42848	45516	47136	48074
STRATUM 4																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	19187	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 5																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	29117	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 6																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	7279	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6-B-2 (cont'd.).

ITEM BY STRATUM	VALUE PER HECTARE	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEARR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
STRATUM 7																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.05	0.10	0.21	0.43	0.86	1.67	2.99	4.80	6.75	8.35	9.41	10.01	10.32	10.48	10.56	10.59	10.61	10.62
Area (Ha):	6038	0	0	3	6	12	26	52	101	181	290	407	504	568	604	623	633	637	640	641	641
Incremental gross benefit (Thousand CFAF):	30	0	0	91	182	364	789	1579	3066	5495	8804	12356	15300	17243	18336	18913	19216	19338	19429	19459	19459
Incremental costs (Thousands CFAF):	23	0	0	68	136	271	588	1175	2283	4091	6554	9198	11390	12837	13650	14080	14305	14396	14464	14486	14486
Incremental net benefit (Thousands CFAF):	8	0	0	23	47	93	202	403	784	1404	2250	3158	3910	4407	4686	4833	4911	4942	4965	4973	4973
STRATUM 8																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.54	1.00	1.79	2.94	4.37	5.77	6.89	7.63	8.07	8.31	8.43	8.50	8.53	8.55	8.56	8.56	8.56	8.57
Area (Ha):	525	0	0	3	5	9	15	23	30	36	40	42	44	44	45	45	45	45	45	45	45
Incremental gross benefit (Thousand CFAF):	20	0	0	59	99	178	296	454	592	710	789	828	868	868	888	888	888	888	888	888	888
Incremental costs (Thousands CFAF):	15	0	0	46	77	139	232	355	464	556	618	649	680	680	695	695	695	695	695	695	695
Incremental net benefit (Thousands CFAF):	4	0	0	13	21	38	64	98	128	154	171	179	188	188	192	192	192	192	192	192	192
STRATUM 9																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	14154	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	37	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATA 1 TO 9:																					
Area (Ha):	126278	0	0	1	2	4	7	11	16	22	29	37	45	53	60	66	70	73	75	76	77
Cumulative adoption rate (%Ha):		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1
Incremental gross benefit (Thousand CFAF):		0	0	430	2463	4380	7728	13373	22625	37151	58981	89815	130323	178200	227801	271984	306119	329484	344144	352873	357818
Incremental costs (Thousands CFAF):		0	0	325	1883	3346	5894	10178	17177	28127	44538	67676	98053	133952	171156	204310	229934	247479	258489	265046	268762
Incremental net benefit (Thousands CFAF):		0	0	105	580	1034	1834	3194	5448	9024	14443	22139	32270	44248	56645	67674	76185	82005	85655	87827	89057
Inc. gross benefit (Thous. $ US):	300 = 1 $ US	0	0	1	8	15	26	45	75	124	197	299	434	594	759	907	1020	1098	1147	1176	1193
Incremental costs (Thous. $ US):	300 = 1 $ US	0	0	1	6	11	20	34	57	94	148	226	327	447	571	681	766	825	862	883	896
Inc. net benefit (Thous. $ US):	300 = 1 $ US	0	0	0	2	3	6	11	18	30	48	74	108	147	189	226	254	273	286	293	297

Table 6-B-3. Economic Analysis of the Groundnuts-Millet-Groundnuts Rotation by Stratum and Year

ITEM BY STRATUM	VALUE PER HECTARE	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEARR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
STRATUM 1																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	908	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 2																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	247	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 3																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.32	0.55	0.93	1.54	2.47	3.80	5.48	7.37	9.19	10.70	11.83	12.59	13.07	13.37	13.54	13.65	13.71	13.74
Area (Ha):	1897	0	0	6	10	18	29	47	72	104	140	174	203	224	239	248	254	257	259	260	261
Incremental gross benefit (Thousand CFAF):	27	0	0	162	270	487	784	1270	1946	2811	3784	4704	5487	6055	6461	6704	6866	6947	7001	7028	7055
Incremental costs (Thousands CFAF):	20	0	0	118	196	353	569	922	1413	2041	2747	3415	3984	4396	4690	4867	4985	5044	5083	5102	5122
Incremental net benefit (Thousands CFAF):	7	0	0	44	74	133	215	348	533	770	1037	1289	1504	1659	1770	1837	1881	1904	1918	1926	1933
STRATUM 4																					
Cumulative adoption rate (%Ha):		0.00	0.00	1.22	2.74	5.78	10.98	17.76	24.10	28.40	30.73	31.84	32.34	32.56	32.65	32.69	32.71	32.71	32.72	32.72	32.72
Area (Ha):	1439	0	0	18	39	83	158	256	347	409	442	458	465	469	470	470	471	471	471	471	471
Incremental gross benefit (Thousand CFAF):	20	0	0	355	769	1636	3115	5047	6840	8063	8713	9029	9167	9245	9265	9265	9285	9285	9285	9285	9285
Incremental costs (Thousands CFAF):	12	0	0	222	481	1023	1948	3156	4278	5043	5450	5647	5733	5783	5795	5795	5807	5807	5807	5807	5807
Incremental net benefit (Thousands CFAF):	7	0	0	133	288	613	1167	1890	2562	3020	3263	3382	3433	3463	3470	3470	3478	3478	3478	3478	3478
STRATUM 5																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	1456	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 6																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	364	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 6-B-3 (cont'd.).

ITEM BY STRATUM	VALUE PER HECTARE	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEARR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
STRATUM 7																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	302	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 8																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATUM 9																					
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	708	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
STRATA 1 TO 9:																					
Area (Ha):	6314	0	0	24	49	101	187	303	419	513	582	632	668	693	709	718	725	728	730	731	732
Cumulative adoption rate (%Ha):		0.0	0.0	0.4	0.8	1.6	3.0	4.8	6.6	8.1	9.2	10.0	10.6	11.0	11.2	11.4	11.5	11.5	11.6	11.6	11.6
Incremental gross benefit (Thousand CFAF):		0	0	517	1039	2123	3899	6317	8787	10874	12498	13732	14654	15301	15726	15969	16151	16232	16286	16313	16340
Incremental costs (Thousands CFAF):		0	0	340	677	1377	2517	4079	5691	7084	8197	9062	9717	10179	10485	10662	10792	10851	10890	10910	10929
Incremental net benefit (Thousands CFAF):		0	0	177	362	746	1381	2238	3095	3790	4300	4670	4937	5122	5240	5307	5359	5381	5396	5403	5411
Inc. gross benefit (Thous. $ US):	300 = 1 $ US	0	0	2	3	7	13	21	29	36	42	46	49	51	52	53	54	54	54	54	54
Incremental costs (Thous. $ US):	300 = 1 $ US	0	0	1	2	5	8	14	19	24	27	30	32	34	35	36	36	36	36	36	36
Inc. net benefit (Thous. $ US):	300 = 1 $ US	0	0	1	1	2	5	7	10	13	14	16	16	17	17	18	18	18	18	18	18

Table 6-B-4. Economic Analysis of the Sesame Cultivation by Stratum and Year

ITEM BY STRATUM	VALUE PER HECTARE	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEARR 7	YEAR 8	YEAR 9	YEAR 10
STRATUM 1											
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	1975	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0
STRATUM 2											
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	494	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0
STRATUM 3											
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	2529	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	31	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	15	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	16	0	0	0	0	0	0	0	0	0	0
STRATUM 4											
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.68	1.19	2.03	3.34	5.22	7.63	10.28
Area (Ha):	1919	0	0	0	13	23	39	64	100	146	197
Incremental gross benefit (Thousand CFAF):	23	0	0	0	304	537	911	1495	2337	3412	4603
Incremental costs (Thousands CFAF):	7	0	0	0	95	168	285	467	729	1065	1437
Incremental net benefit (Thousands CFAF):	16	0	0	0	209	370	627	1029	1607	2347	3166
STRATUM 5											
Cumulative adoption rate (%Ha):		0.00	0.00	0.09	0.28	0.82	2.37	6.39	14.72	26.09	35.19
Area (Ha):	2912	0	0	3	8	24	69	186	429	760	1025
Incremental gross benefit (Thousand CFAF):	41	0	0	124	330	991	2850	7683	17721	31393	42340
Incremental costs (Thousands CFAF):	14	0	0	43	116	348	1000	2697	6219	11018	14860
Incremental net benefit (Thousands CFAF):	27	0	0	80	214	643	1850	4987	11501	20375	27480
STRATUM 6											
Cumulative adoption rate (%Ha):		0.00	0.00	1.38	3.97	10.83	25.99	49.14	70.19	82.03	86.97
Area (Ha):	728	0	0	10	29	79	189	358	511	597	633
Incremental gross benefit (Thousand CFAF):	34	0	0	340	986	2685	6424	12168	17368	20291	21514
Incremental costs (Thousands CFAF):	7	0	0	74	213	581	1390	2633	3758	4390	4655
Incremental net benefit (Thousands CFAF):	27	0	0	266	772	2104	5034	9535	13610	15901	16859

ITEM BY STRATUM	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
STRATUM 1										
Cumulative adoption rate (%Ha):	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0
STRATUM 2										
Cumulative adoption rate (%Ha):	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0
STRATUM 3										
Cumulative adoption rate (%Ha):	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0
STRATUM 4										
Cumulative adoption rate (%Ha):	12.75	14.72	16.11	17.01	17.56	17.88	18.06	18.17	18.22	18.26
Area (Ha):	245	282	309	326	337	343	347	349	350	350
Incremental gross benefit (Thousand CFAF):	5725	6589	7220	7618	7875	8015	8108	8155	8178	8178
Incremental costs (Thousands CFAF):	1787	2057	2254	2378	2458	2502	2531	2546	2553	2553
Incremental net benefit (Thousands CFAF):	3938	4532	4966	5239	5416	5513	5577	5609	5625	5625
STRATUM 5										
Cumulative adoption rate (%Ha):	39.84	41.68	42.33	42.55	42.63	42.65	42.66	42.67	42.67	42.67
Area (Ha):	1160	1214	1233	1239	1241	1242	1242	1242	1242	1242
Incremental gross benefit (Thousand CFAF):	47916	50147	50932	51180	51262	51304	51304	51304	51304	51304
Incremental costs (Thousands CFAF):	16817	17600	17875	17962	17991	18006	18006	18006	18006	18006
Incremental net benefit (Thousands CFAF):	31099	32547	33056	33217	33271	33298	33298	33298	33298	33298
STRATUM 6										
Cumulative adoption rate (%Ha):	88.77	89.39	89.60	89.67	89.70	89.71	89.71	89.71	89.71	89.71
Area (Ha):	646	651	652	653	653	653	653	653	653	653
Incremental gross benefit (Thousand CFAF):	21956	22126	22160	22194	22194	22194	22194	22194	22194	22194
Incremental costs (Thousands CFAF):	4750	4787	4794	4802	4802	4802	4802	4802	4802	4802
Incremental net benefit (Thousands CFAF):	17206	17339	17365	17392	17392	17392	17392	17392	17392	17392

Table 6-B-4 (cont'd.).

ITEM BY STRATUM	VALUE PER HECTARE	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEARR 7	YEAR 8	YEAR 9	YEAR 10
STRATUM 7											
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	604	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0
STRATUM 8											
Cumulative adoption rate (%Ha):		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	53	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0	0
STRATUM 9											
Cumulative adoption rate (%Ha):		0.00	0.00	0.11	0.22	0.41	0.78	1.46	2.64	4.57	7.36
Area (Ha):	1415	0	0	2	3	6	11	21	37	65	104
Incremental gross benefit (Thousand CFAF):	41	0	0	83	124	248	454	867	1528	2685	4296
Incremental costs (Thousands CFAF):	14	0	0	29	43	87	159	304	536	942	1508
Incremental net benefit (Thousands CFAF):	27	0	0	54	80	161	295	563	992	1743	2788
STRATA 1 TO 9:											
Area (Ha):	12628	0	0	15	53	132	308	629	1077	1568	1959
Cumulative adoption rate (%Ha):		0.0	0.0	0.1	0.4	1.0	2.4	5.0	8.5	12.4	15.5
Incremental gross benefit (Thousand CFAF):		0	0	546	1744	4462	10640	22214	38953	57781	72753
Incremental costs (Thousands CFAF):		0	0	146	468	1184	2834	6100	11243	17416	22460
Incremental net benefit (Thousands CFAF):		0	0	400	1276	3278	7805	16113	27710	40365	50294
Inc. gross benefit (Thous. $ US):	300 = 1 $ US	0	0	2	6	15	35	74	130	193	243
Incremental costs (Thous. $ US):	300 = 1 $ US	0	0	0	2	4	9	20	37	58	75
Inc. net benefit (Thous. $ US):	300 = 1 $ US	0	0	1	4	11	26	54	92	135	168

ITEM BY STRATUM	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
STRATUM 7										
Cumulative adoption rate (%Ha):	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0
STRATUM 8										
Cumulative adoption rate (%Ha):	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Area (Ha):	0	0	0	0	0	0	0	0	0	0
Incremental gross benefit (Thousand CFAF):	0	0	0	0	0	0	0	0	0	0
Incremental costs (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0
Incremental net benefit (Thousands CFAF):	0	0	0	0	0	0	0	0	0	0
STRATUM 9										
Cumulative adoption rate (%Ha):	10.75	14.13	16.87	18.76	19.92	20.58	20.93	21.12	21.22	21.28
Area (Ha):	152	200	239	266	282	291	296	299	300	301
Incremental gross benefit (Thousand CFAF):	6279	8261	9872	10988	11649	12020	12227	12351	12392	12433
Incremental costs (Thousands CFAF):	2204	2900	3465	3856	4088	4219	4291	4335	4349	4364
Incremental net benefit (Thousands CFAF):	4075	5362	6408	7131	7560	7802	7936	8016	8043	8070
STRATA 1 TO 9:										
Area (Ha):	2203	2347	2433	2484	2513	2529	2538	2543	2545	2546
Cumulative adoption rate (%Ha):	17.4	18.6	19.3	19.7	19.9	20.0	20.1	20.1	20.2	20.2
Incremental gross benefit (Thousand CFAF):	81876	87124	90184	91979	92979	93533	93833	94003	94068	94109
Incremental costs (Thousands CFAF):	25558	27344	28389	28999	29340	29529	29630	29688	29710	29725
Incremental net benefit (Thousands CFAF):	56317	59780	61795	62980	63639	64004	64202	64315	64358	64385
Inc. gross benefit (Thous. $ US):	273	290	301	307	310	312	313	313	314	314
Incremental costs (Thous. $ US):	85	91	95	97	98	98	99	99	99	99
Inc. net benefit (Thous. $ US):	188	199	206	210	212	213	214	214	215	215

APPENDIX 6–C

Table 6-C-1. Economic Value of the Project (US $ '000) (1)

ITEM	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
INFLOW (INCREMENTAL CROP BENEFIT)																				
Transitional millet-cowpea technology	72	137	195	244	286	320	348	368	382	388	387	377	361	343	325	312	304	299	297	297
Improved millet-cowpea technology	0	0	1	8	15	26	45	75	124	197	299	434	594	759	907	1020	1098	1147	1176	1193
Groundnuts-Millet-Groundnuts Rotation	0	0	2	3	7	13	21	29	36	42	46	49	51	52	53	54	54	54	54	54
Sesame Cultivation	0	0	2	6	15	35	74	130	193	243	273	290	301	307	310	312	313	313	314	314
Transitional millet-cowpea technology(w/o project)	71	136	193	243	285	320	349	374	394	410	424	435	444	452	458	463	467	470	472	474
TOTAL INFLOW	1	1	7	19	38	75	138	229	341	459	580	715	862	1009	1137	1236	1303	1344	1369	1383
OUTFLOW																				
ON-FARM PRODUCTION COST:																				
Transitional millet-cowpea technology	49	93	132	166	195	219	238	252	262	267	265	259	248	236	224	216	210	207	206	206
Improved millet-cowpea technology	0	0	1	6	11	20	34	57	96	148	226	327	447	571	681	766	825	862	883	896
Groundnuts-Millet-Groundnuts Rotation	0	0	1	2	5	8	16	19	24	27	30	32	34	35	36	36	36	36	36	36
Sesame Cultivation	0	0	0	2	4	9	20	37	58	75	85	91	95	97	98	98	99	99	99	99
Transitional millet-cowpea technology(w/o project)	48	92	131	165	196	218	239	256	270	282	292	300	306	311	316	319	322	324	326	328
TOTAL ON-FARM PRODUCTION COST	1	1	4	11	21	38	67	110	167	235	315	410	517	627	723	798	848	880	899	910
PROJECT COSTS:																				
Capital Costs Financed by USAID:																				
Technical Assistance	0	340	325	310	305	5	5													
Short-Term Training	0	35	28	28	28	0	0													
Vehicles	0	60	0	0	60	0	0													
Research Equipment	0	26	2	14	27	12	14													
Office Equipment	0	20	0	0	20	0	0													
Furnishing	0	175	25	0	0	0	0													
Construction	306	348	76	0	0	0	0	-438												
Contingency (10%)	31	100	46	35	44	2	2													
Sub-total	336	1102	501	387	483	18	21	-438												
Recurrent Costs Financed by USAID:																				
Salaries																				
Professional Staff	0	15	15	15	15	15	15													
Support Staff	0	20	20	20	9	20	20													
Vehicle Maintenance	0	14	15	15	11	11	11													
Offices Supplies	0	10	10	10	7	7	7													
Rents, Utilities, Building, Maintenance	0	17	17	17	12	12	12													
Expendables Research Supplies	0	12	12	12	8	8	8													
Cooperative Research, Studies	0	31	31	31	31	31	31													
Evaluations	200	0	0	40	0	0	80													
Contingency (10%)	20	12	12	16	9	10	18													
Sub-total	220	129	130	174	101	113	201													

Table 6-C-1 (cont'd.)

ITEM	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	YEAR 6	YEAR 7	YEAR 8	YEAR 9	YEAR 10	YEAR 11	YEAR 12	YEAR 13	YEAR 14	YEAR 15	YEAR 16	YEAR 17	YEAR 18	YEAR 19	YEAR 20
Recurrents Costs Financed by the Government of Mali:																				
Salaries																				
Professional Staff	0	37	37	37	37	37	37													
Support Staff	0	4	4	4	15	4	4													
Vehicle Maintenance	0	0	0	0	4	4	4													
Office Supplies	0	0	0	0	3	3	3													
Rents, Utilities, Building, Maintenance	0	0	0	0	5	5	5													
Expendable Research Supplies	0	0	0	0	4	4	4													
Cooperative Research, Studies	0	0	0	0	0	0	0													
Contingency (10%)	0	4	4	4	7	6	6													
Sub-total	0	45	45	45	75	62	62													
TOTAL PROJECT COSTS	556	1277	676	606	659	194	285	-438												
TOTAL OUTFLOW	557	1278	680	617	679	232	351	-328	167	235	315	410	517	627	723	798	848	880	899	910
TOTAL ON-FARM INCREMENTAL NET BENEFITS	0	0	3	8	17	37	71	119	174	223	266	305	345	382	414	438	454	464	470	474
INCREMENTAL NET BENEFITS (Net cash flow)	-556	-1276	-673	-598	-641	-157	-213	557	174	223	266	305	345	382	414	438	454	464	470	474

NET PRESENT WORTH AT 12% OPPORTUNITY COST OF CAPITAL ($US '000) = -1864
INTERNAL RATE OF RETURN (%) = 1.68
NET BENEFIT-INVESTMENT RATIO AT 12% OPPORTUNITY COST = 0.36

(1) Direct Effects Only.

Table 6-C-2. Sensitivity Analysis of the Project's Economic Value

VARIABLES	NPV at 12% ($ '000) -50%	-20%	-10%	0% (2)	+10%	+20%	+50%
1. Annual Project Costs	-462	-1303	-1583	-1864	-2144	-2392	-3233
2. Incremental Farm Gross Benefit	-3031	-2331	-2097	-1864	-1630	-1394	-696
3. Time Taken to Complete Research	-1080	-1461	NA	-1864	NA	-2155	-2414
4. Incremental Farm Costs	-1167	-1585	-1724	-1864	-2003	-2143	-2561
5. Diffusion Acceptance Rate	-2543	-2127	-1990	-1864	-1748	-1642	-1374
6. Diffusion Ceiling	-2332	-2051	-1958	-1864	-1770	-1677	-1396
7. Innovation Life	-2319	-2028	-1913	-1864	-1819	-1744	-1636

Source: Author's estimations.

Table 6-C-3. Relative Results of the Sensitivity Analysis of the Project's Economic Value

VARIABLES	PERCENTAGE CHANGE IN NPV AT OR CIRCA (%) -50%	-20%	-10%	0%	+10%	+20%	+50%
1. Annual Project Costs	75	30	15	0	-15	-28	-73
2. Incremental Farm Gross Benefit	-63	-25	-13	0	13	25	63
3. Time Taken to Complete Research	42	22	ERR	0	ERR	-16	-30
4. Incremental Farm Costs	37	15	8	0	-7	-15	-37
5. Diffusion Acceptance Rate	-36	-14	-7	0	6	12	26
6. Diffusion Ceiling	-25	-10	-5	0	5	10	25
7. Innovation Life	-24	-9	-3	0	2	6	12

Source: Author's estimations.

Table 6-C-4. Ranking of the Results of the Sensitivity Analysis of the Project's Economic Value

VARIABLES	RANKING AT OR CIRCA (1) -50%	-20%	-10%	+10%	+20%	+50%	AVERAGE RANKING(2)	RANK ORDER(3)
1. Annual Project Costs	1	1	1	1	1	1	1.00	1
2. Incremental Farm Gross Benefit	2	2	2	2	2	2	2.00	2
3. Time Taken to Complete Research	3	3	3	3	3	4	3.17	3
4. Incremental Farm Costs	4	4	3	4	4	3	3.67	4
5. Diffusion Acceptance Rate	5	5	5	5	5	5	5.00	5
6. Diffusion Ceiling	6	6	6	6	6	6	6.00	6
7. Innovation Life	7	7	7	7	7	7	7.00	7

(1) Decreasing ranking of the variables according to the NPV relative variation (See Table 3 of this Appendix).
(2) Average of the rankings calculated in (1).
(3) Decreasing ranking of the variables according to their relative influence on the NPV of the project.
Source: Author's estimations.

APPENDIX 7-A

Table 7-A-1. Millet-Cowpea Intercropping for the Northern Zone

	CURRENT MILLET VARIETIES			IMPROVED MILLET VARIETIES		
TECHNICAL LEVEL (1):	IMPROVED	TRANSITIONAL	TRADITIONAL	IMPROVED	TRANSITIONAL	TRADITIONAL
Varieties:						
Millet	IBV 8001	Local	Local	IBV 8001	Local	Local
Cowpea	GoromGorom	Local	Local	GoromGorom	Local	Local
Density (plants/Ha):						
Millet	26500	10000	10000	26500	10000	10000
Cowpea	13300	5000	5000	13300	5000	5000
Seeds (kg/Ha):						
Millet	5	10	10	5	10	10
Cowpea	8	3	3	8	3	3
Seed Treatment:						
Millet, Commercial Product:	APRON +	Thioral	Thioral	APRON +	Thioral	Thioral
Dose (gCP/kg)	5	2.5	2.5	5	2.5	2.5
Quantity (gCP/Ha)	25	25	25	25	25	25
Quantity (bag/Ha)	1	1	1	1	1	1
Cowpea, Commercial Product:	Thioral			Thioral		
Dose (gCP/kg)	2.5			2.5		
Quantity (gCP/Ha)	20			20		
Quantity (bag/Ha)	1			1		
Fertilizer:						
Amonium Phosphate (kg/Ha)	25			25		
Urea (kg/Ha)						
Pesticide Treatment on Cowpea:						
2 treatments with Decis (L/Ha)	2			2		
Cowpea Stock Treatment:						
Phostoxin (1 tablet/100 kg)	1			1		
Plastic bag (1 bag/100 kg)	1			1		
Sprayer	T 15			T 15		
Equipment	Donkey Plow	Donkey Plow	Manual Hoe	Donkey Plow	Donkey Plow	Manual Hoe
Draft Animal	1 donkey	1 donkey		1 donkey	1 donkey	
Animal Maintenance:						
Cowpea Fodder (dry kg/4 months)	800	800		800	800	
Labor (person day/Ha):						
Field Preparation	2.0	2.0	2.0	2.0	2.0	2.0
Fertilization (phosphate)	1.0			1.0		
Millet Seeding	3.0	3.0	3.0	3.0	3.0	3.0
Cowpea Seeding	2.0	1.0	1.0	2.0	1.0	1.0
First Weeding	6.0	6.0	18.0	6.0	6.0	18.0
Fertilization (urea)						
Second Weeding	6.0	6.0	12.0	6.0	6.0	12.0
First Pesticide Application	1.0			1.0		
Second Pesticide Application	1.0			1.0		
Millet Harvest	6.0	5.0	4.5	7.0	5.0	4.5

Table 7-A-1 (cont'd.).

Cowpea Harvest	5.0	2.0	2.0	5.0	2.0	2.0
Transportation and Storage	3.0	2.5	6.0	3.0	2.5	6.0
Total Labor (person day/Ha)	36.0	27.5	48.5	37.0	27.5	48.5
Labor Saving (person day/Ha) (2)	12.5	21		11.5	21	
Labor saving (person day/Ha) (3)	-8.5			-9.5		
Yield (kg/Ha):						
Millet	400	275	250	480	275	250
Cowpea	120	45	40	120	45	40
Cowpea Fodder	300	400	400	300	400	400

(1) Improved: Technical package that FSR would develop.
Transitional: Technique currently used by most of the equipped farmers.
Traditional: Technique currently used by most of the non-equipped farmers.
(2) With respect to the traditional technique.
(3) With respect to the transitional technique.

Table 7-A-2. Floating Rice Cultivation for the Delta

ZONE:	NATURAL FLOODING		CONTOLLED FLOODING	
TECHNICAL LEVEL (1):	TRANSITIONAL	TRADITIONAL	INTENSIVE	NON-INTENSIVE
Rice Variety	Improved O.glaber.	Local O.glaber.	Improved O.sativa	Local O.sativa
Seed Quantity (kg/ha)	100	120	80	100
Bag (1 bag/100kg)	1	0	1	1
Fertilizer:				
Amonium Phosphate (kg/Ha)			100	
Urea (kg/Ha)			50	
Equipment	Plow	Plow	Bajac B2	Bajac B2
Draft Animal	2 oxen	2 owen	2 oxen	2 owen
Draft Animal Maintenance:				
Rice Hay (dry kg/4 months)	4600	4600	4600	4600
Labor (person day/Ha):				
First Plowing			10	
Field Preparation	20	20		20
Seeding	1	1	2	2
Fertilization			2	
Weeding	15	15	30	21
Harvest	18	15	30	20
Treshing	3	2	8	4
Transportation	3	2	6	3
Last Plowing			14	
Total Labor (person day/Ha)	60	55	102	70
Labor Saving (person day/Ha)	-5		-32	
ORM Fees	None	None	Yes	Yes
Yield (kg/Ha):				
Paddy Rice	650	500	1700	960
Harvest Factor (%) (2)	30	30	35	35
Rice Fodder (dry kg)	2167	1667	4857	2743
Manure (T/2 oxen/year/Ha)	1.5	1.5	1.5	1.5
Weight Gain (kg/2 oxen/year/Ha)	20	20	20	20

(1) Transitional or Intensive: Technical package that FSR would develop.
Traditional or Non-intensive: Technique currently used by most of the rice producers.
(2) Adapted from De Datta, 1981, p. 33.

APPENDIX 7-B

Table 7-B-1. Financial Budgets for the Millet-Cowpea Intercropping Enterprise in the Northern Zone

	CURRENT MILLET VARIETIES			IMPROVED MILLET VARIETIES		
TECHNICAL LEVEL (1):	IMPROVED	TRANSITIONAL	TRADITIONAL	IMPROVED	TRANSITIONAL	TRADITIONAL
GROSS BENEFIT (CFA F/Ha):						
Millet	28000	13750	12500	33600	13750	12500
Cowpea	14400	3600	3200	14400	3600	3200
Cowpea Fodder	3600	4800	4800	3600	4800	4800
Gross Benefit	46000	22150	20500	51600	22150	20500
Labor Saving * (2)	4965	8342		4568	8342	
Labor Saving * (3)	-4491			-5020		
Total Gross Benefit (2)	50965	30492		56168	30492	
Total Gross Benefit (3)	41509			46580		
INCREMENTAL GROSS BENEFIT (CFA F/HA):						
(2)	30465	9992		35668	9992	
(3)	19359			24430		
VARIABLE COST (CFA F/HA):						
Millet Seeds	376	600	600	376	600	600
Cowpea Seeds	1746	540	540	1746	540	540
Seed Treatment: on Millet	327	95	95	327	95	95
on Cowpea	69			69		
Fertilization: Phosphate	4637			4637		
Urea	0			0		
Pesticide Treatment (Decis)	4080			4080		
Stock Treatment (Phostoxin)	218			218		
Plastic Bag	546			546		
Total Variable Costs	11999	1235	1235	11999	1235	1235
AMORTIZATION (CFA F/HA/YEAR):						
Sprayer T 15	1843	0		1843	0	
Equipment	2739	2739		2739	2739	
Draft Animal	3645	3645		3645	3645	
Toatl Amortization	8227	6384		8227	6384	
TOTAL COSTS (CFA F/HA/YEAR)	20226	7619	1235	20226	7619	1235
INCREMENTAL COSTS (CFA F/HA/YEAR):						
(2)	18991	6384		18991	6384	
(3)	12607			12607		

Table 7-B-1 (cont'd).

AVERAGE RETURN TO LABOR (CFA F/PERSON DAY):	716	528	397	848	528	397
INCREMENTAL AVERAGE RETURN TO LABOR (CFA F/PERSON DAY):						
(2)	319	131		451	131	
(3)	188			320		
NET BENEFIT (CFA F/HA):		14531	19265		14531	19265
(2)	30739	22873		35942	22873	
(3)	21283			26354		
INCREMENTAL NET BENEFIT (CFA F/HA):						
(2)	11474	3608		16677	3608	
(3)	6752			11823		

(1) Improved: Technical package that FSR would develop.
Transitional: Technique currently used by most of the equipped farmers.
Traditional: Technique currently used by most of the non-equipped farmers.
(2) With respect to the traditional technique.
(3) With respect to the transitional technique.
* The labor saving is the number of days saved by the technique multiplied by the opportunity cost of labor estimated for the traditional or transitional techniques. This labor saving is added to the gross benefit to estimate the total gross benefit.

Table 7-B-2. Financial Budgets for the Floating Rice Cultivation

ZONE:	NATURAL FLOODING		CONTOLLED FLOODING	
TECHNICAL LEVEL (1):	TRANSITIONAL	TRADITIONAL	INTENSIF	NON-INTENSIF
GROSS BENEFIT (CFA F/Ha):				
Paddy Rice	32500	25000	119000	67200
Rice Fodder	17333	13333	38857	21943
Weight Gain	5000	5000	5000	5000
Manure	2250	2250	2250	2250
Gross Benefit	57083	45583	165107	96393
Labor Saving *	-1474		-20070	
Total Gross Benefit	55609		145037	
INCREMENTAL GROSS BENEFIT (CFA F/HA):	10026		48644	
VARIABLE COSTS (CFA F/HA):				
Rice Seeds	10910	9000	8728	10910
Bag	546	0	546	546
Fertilization: Phosphate			18547	
Urea			8728	
ORM Polder Fees			12600	12600
ORM Treshing Fees			14280	8064
Total Variable Costs	11456	9000	63429	32120
AMORTIZATION (CFA F/HA/YEAR):				
Equipment	4943	4943	4943	4943
Draft Animal	15427	15427	15427	15427
Total Amortization	20371	20371	20371	20371
TOTAL COSTS (CFA F/HA/AN)	31826	29371	83799	52490
INCREMENTAL COSTS (CFA F/HA/YEAR:	2456		31309	
AVERAGE RETURN TO LABOR (CFA F/PERSON DAY):	421	295	797	627
INCREMENTAL AVERAGE RETURN TO LABOR (CFA F/PERSON DAY):	126		170	
NET BENEFIT (CFA F/HA):	23783	16213	61238	43903
INCREMENTAL NET BENEFIT (CFA F/HA):	7571		17335	

(1) Transitional or Intensive: Technical package that FSR would develop.
Traditional or Non-intensive: Technique currently used by most of the rice producers.

* The labor saving is the number of days saved by the technique multiplied by the opportunity cost of labor estimated for the traditional or transitional techniques. This labor saving is added to the gross benefit to estimate the total gross benefit.

APPENDIX 7-C

Table 7-C-1. Economic Budgets for the Millet-Cowpea Intercropping Enterprise in the Northern Zone

	CURRENT MILLET VARIETIES			IMPROVED MILLET VARIETIES		
TECHNICAL LEVEL (1):	IMPROVED	TRANSITIONAL	TRADITIONAL	IMPROVED	TRANSITIONAL	TRADITIONAL
GROSS BENEFIT (CFA F/Ha):						
Millet	28000	13750	12500	33600	13750	12500
Cowpea	14400	3600	3200	14400	3600	3200
Cowpea Fodder	3600	4800	4800	3600	4800	4800
Gross Benefit	46000	22150	20500	51600	22150	20500
Labor Saving * (2)	4864	8171		4475	8171	
Labor Saving * (3)	-4337			-4848		
Total Gross Benefit (2)	50864	30321		56075	30321	
Total Gross Benefit (3)	41663			46752		
INCREMENTAL GROSS BENEFIT (CFA F/HA):						
(2)	30364	9821		35575	9821	
(3)	19513			24602		
VARIABLE COSTS (CFA F/HA):						
Millet Seeds	452	600	600	452	600	600
Cowpea Seeds	2095	540	540	2095	540	540
Seed Treatment: on Millet	314	91	91	314	91	91
on Cowpea	66			66		
Fertilization: Phosphate	4451			4451		
Urea	0			0		
Pesticide Treatment (Decis)	3917			3917		
Stock Treatment (Phostoxin)	209			209		
Plastic Bag	524			524		
OMM Extension	397	397	397	397	397	397
Total Variable Costs	12426	1629	1629	12426	1629	1629
AMORTIZATION (CFA F/HA/YEAR):						
Sprayer T 15	1774			1774		
Equipment	2843	2843		2843	2843	
Draft Animal	3645	3645		3645	3645	
Total Amortization	8263	6489		8263	6489	
TOTAL COSTS (CFA F/HA/YEAR)	20689	8117	1629	20689	8117	1629
INCREMENTAL COSTS (CFA F/HA/YEAR):						
(2)	19060	6489		19060	6489	
(3)	12571			12571		

Table 7-C-1 (cont'd.).

AVERAGE RETURN TO LABOR (CFA F/PERSON DAY):	703	510	389	835	510	389
INCREMENTAL AVERAGE RETURN TO LABOR (CFA F/PERSON DAY):						
(2)	314	121		446	121	
(3)	193			325		
NET BENEFIT (CFA F/HA):		14033	18871		14033	18871
(2)	30175	22204		35386	22204	
(3)	20974			26064		
INCREMENTAL NET BENEFIT (CFA F/HA):						
(2)	11304	3333		16515	3333	
(3)	6941			12031		

(1) Improved: Technical package that FSR would develop.
Transitional: Technique currently used by most of the equipped farmers.
Traditional: Technique currently used by most of the non-equipped farmers.
(2) With respect to the traditional technique.
(3) With respect to the transitional technique.
* The labor saving is the number of days saved by the technique multiplied by the opportunity cost of labor estimated for the traditional or transitional techniques. This labor saving is added to the gross benefit to estimate the total gross benefit.

Table 7-C-2. Economic Budgets for the Floating Rice Cultivation

ZONE:	NATURAL FLOODING		CONTOLLED FLOODING	
TECHNICAL LEVEL (1):	TRANSITIONAL	TRADITIONAL	INTENSIF	NON-INTENSIF
GROSS BENEFIT (CFA F/Ha):				
Paddy Rice	32500	25000	119000	67200
Rice Fodder	17333	13333	38857	21943
Weight Gain	5000	5000	5000	5000
Manure	2250	2250	2250	2250
Gross Benefit	57083	45583	165107	96393
Labor Saving *	-1185		-20214	
Total Gross Benefit	55898		144893	
INCREMENTAL GROSS BENEFIT (CFA F/HA):	10315		48500	
VARIABLE COSTS (CFA F/HA):				
Rice Seeds	13092	10800	10474	13092
Bag	660	0	660	660
Fertilization: Phosphate			22457	
Urea			10568	
ORM Polder Fees			10261	10261
ORM Treshing Fees			11352	6411
Total Variable Costs	13752	10800	65772	30424
AMORTIZATION (CFA F/HA/YEAR):				
Equipment	6323	6323	6323	6323
Draft Animal	15427	15427	15427	15427
Total Amortization	21750	21750	21750	21750
TOTAL COSTS (CFA F/HA/YEAR)	35502	32550	87522	52174
INCREMENTAL COSTS (CFA F/HA/YEAR):	2952		35348	
AVERAGE RETURN TO LABOR (CFA F/PERSON DAY):	360	237	761	632
INCREMENTAL AVERAGE RETURN TO LABOR (CFA F/PERSON DAY):	123		129	
NET BENEFIT (CFA F/HA):	20396	13033	57371	44219
INCREMENTAL NET BENEFIT (CFA F/HA):	7363		13152	

(1) Transitional or Intensive: Technical package that FSR would develop.
Traditional or Non-intensive: Technique currently used by most of the rice producers.

* The labor saving is the number of days saved by the technique multiplied by the opportunity cost of labor estimated for the traditional or transitional techniques. This labor saving is added to the gross benefit to estimate the total gross benefit.

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