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dissertation entitled

AN ECONOMIC ANALYSIS OF THE COMPETITIVENESS OF ALTERNATIVE RICE PRODUCTION SYSTEMS: THE CASE OF BAS_FOND RICE PRODUCTION IN MALI-SUD

presented by

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has been accepted towards fulfillment of the requirements for

Ph.D degree in Agriculture Economics

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Date 12/18/97

AN ECONOMIC ANALYSIS OF THE COMPETITIVENESS OF ALTERNATIVE RICE PRODUCTION SYSTEMS: THE CASE OF *BAS-FOND RICE PRODUCTION IN MALI-SUD*

Volume I

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1997

ABSTRACT

AN ECONOMIC ANALYSIS OF THE COMPETITIVENESS OF ALTERNATIVE RICE PRODUCTION SYSTEMS: THE CASE OF BAS-FOND RICE PRODUCTION IN MALI-SUD

by

Georges Dimithè

Facing increasing food shortage, Mali's government needs to identify a cost-effective strategy to boost domestic production of rice. Given the high costs of expanding the existing government irrigated schemes, policy makers require information to assess the potential of expanding *bas-fond* rice production and its competitiveness. This study fills this gap using secondary and primary data. The primary data were collected from a random sample of 334 production units selected from a purposive sample of 12 *bas-fond* villages in Mali-Sud, during the cropping season 1996-97. In each production unit, one rice farmer was monitored throughout the cropping season.

The study used logistic regression models to identified factors associated with the adoption of "improved" varieties, herbicide and fertilizer. A quadratic regression model was used to determined factors affecting rice yields. Standard budgeting techniques are utilized to assess the profitability of *bas-fond* rice production systems, and economic budgets and policy analysis matrices are used to analyze their competitiveness.

The study identifies the major socio-demographic and agronomic characteristics of *bas-fond* rice production. In particular, farm-level data analysis indicates that 98 percent of the farmers manually plowed their rice fields and few farmers puddled their

fields. Most farmers broadcast their seeds on mud (86%) and weeded at least once (91%). About 48 percent used herbicide and 42 percent used chemical fertilizer, predominantly on "improved" varieties.

Logistic regression outputs indicate that the presence of a water control infrastructure and the village experience in cotton production increase the likelihood that farmers will plant "improved" varieties. However, female farmers, small plot size and village distance to the closest market decrease this likelihood. Similarly, the presence of a water control infrastructure, the village experience in cotton production, and planting "improved" varieties increase the likelihood that farmers will adopt fertilizer application.

Bas-fond rice yields are low (1.2 mt/ha) and variable. Still, put together, all *bas-fonds* rice production represents a significant contribution to domestic rice production. A linearilized quadratic regression equation identifies the major determinants of yield. Factors associated with higher yield included herbicide application, presence of water control infrastructure, and seeding rate. Insect attacks, water stress, weeding date after planting, and nitrogen x region interaction decreased yield.

The study identifies four most frequent *bas-fond* rice production systems and shows that all these systems are not only financially profitable, but they are also more profitable than the main upland crops (maize, cotton, and sorghum/millet) competing with rice for farmers' labor. In addition, economic analysis shows that Mali has a comparative advantage in producing rice in these *bas-fond* rice production systems and not in selected the intensive government irrigated schemes. Finally, the study recommends future research directions.

In memory of

my late father ***Ernest Dimithè***, ...
and my late uncle ***Etiènne Mengou Mbanguè***, ...

You who did not leave long enough to see and enjoy the fruits of your sacrifices and advice, may this be for you and a symbol of my commitment to follow your footsteps. With love and dedication.

I also dedicate this work to

my lovely wife (Mebanda Nko'o Lydie Félicité), and my children (F.E. Dimithè, C.O.D. Bityé, E.D. Mengou, and E.D. Dimwamwa) for taking on the biggest challenge of our young life.

ACKNOWLEDGEMENT

I take this opportunity to acknowledge my great intellectual debts to all those who have been my teachers, from primary school days onwards. While numerous people contributed to my education, I would like to recognize a few special contributions. I owe a special debt of this kind to Mr. Bonaventure Djampou, my seven grade teacher in Mbanga/Cameroon, he who first aroused, taught, and encouraged me to work hard and well, blending the building block of my personality into a dream I have been pursuing ever since. Dr. Richard Bernsten for serving as my major professor throughout my program at MSU and as my dissertation director. His guidance and invaluable support throughout my program has been an extremely enjoyable and gratifying experience.

Particular thanks are also due to my guidance committee members (Dr. Eric W. Crawford, Dr. John M. Staatz, Dr. Allan Schmid, and Dr Carl E. Liedholm), as well as Dr. Duncan Boughton. Their careful review and constructive evaluation of this thesis made it a much better document.

My sincere thanks to the many individuals and institutions who have facilitated my field research in Mali. I especially want to express my deepest appreciation to Dr. John M. Staatz and the MSU Food Security II Cooperative Agreement, the West African Rice Development Association (WARDA) particularly Dr. Tom Randolph and Dr. Peter

Matlon, and the Institute of Rural Economics (IER) for giving me this wonderful opportunity[1]. I want them to know that this experience enriched my life well beyond academic considerations.

My task during data collection was immensely facilitated by the collaboration of IER/ECOFIL personnel and researchers in Bamako and Sikasso. I am grateful to them. I am especially grateful to Bino Témé, the Research Director, and fellow researchers Bakary Sékou Coulibaly, Ousmane Sanogo, Dramane Mariko, Alpha O. Kergna, and Salifou Diarra for their support and great heart.

My heartfelt gratitude goes to my enumerators (Lassine Diarra, N'Dogo Kassogué, Lassina Sogodogo, Abdoulaye Doumbia, Abdoulaye Koné, Mody Diallo, Soungalo Dao, Djibril Kébé, Arsiké Macalou, D. Samaké, Bocar Traoré, and Adama Samaké), data entry agents (Cissé Sékou, Korka Coulibaly, and Soungalo Dao), the drivers (Togola Boubacar, Madou Keïta and Madou), and the farmers who willingly put tireless efforts to make data collection and analysis possible. I wish them well.

I am sincerely thankful to the Cameroon Agronomic Research Institute (IRA) and IRA's National Cereal Research and Extension (NCRE) project administrations, for

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[1] This research is a joint project between the MSU Food Security II Cooperative Agreement, IER represented by Ousmane Sanogo (IER agricultural economist, head of the IER sub-sector economic program), the inland valley consortium in Mali represented by Bakary S. Coulibaly (IER agricultural economist and lead Malian agricultural economist in the consortium) and Simpara Mamadou (IER agronomist and hydrologist from the Riz Bas-Fond program, national coordinator of the consortium in Mali), as well as the Farming Systems (ESPGRN) and Bas-Fond Rice (PRBF) research programs, both based in Sikasso. The inland valley consortium is a five years partnership involving eight West African countries (Sierra Leone, Benin, Burkina Fasso, Côte d'Ivoire, Ghana, Guinea, Mali, and Nigeria) for collaboration and exchange in the agro-ecological (physical, hydrological) and socio-economic as well as human characterization of bas-fonds in their respective countries. While no donor institution is directly involved in this initiative, the collaborative national programs benefit from the indirect support of CIRAD, WARDA, IITA, University of Birmingham, FAO, *Sol-Eau-Plante* of the Netherlands), ORSTOM, CORAF, and UIMI.

giving me this training opportunity at Michigan State University. I am particularly thankful to Dr. Atayi A. Emmanuel, Dr John Poku and Dr. Doyle Baker and fellow research team colleagues at IRA (P.I. Boumtjé, N.M. Ndoumbè, R. Mankolo, and L.A. Eniong, R. Assoumou), for encouraging and supporting me throughout this endeavor. Their contribution to my training on the job was extremely rewarding during my program.

I am thankful to fellow African Students at MSU and fellow graduate students (especially Youssouf Camara) and faculty members in the Department of Agricultural Economics, Michigan State University, in "arguments" with whom a good deal of what I learned at MSU was strengthened.

I am also sincerely thankful to fellow Cameroonians in Lansing (the Kamdems, the Forsaks', the Achuonjeis', the Bonus', the Nebas', the Yewahs', Dogmo M., and C.R. Ngallè for making me feel like being at home. Their support kept me moving throughout.

My heartfelt appreciation and gratitude go to my mother (J. Dimwamwa), brothers (L. Moutimbè, J.P.D. Mbanguè, and E.D. Moukembè), sisters (A. Dipanda, R.D. Mabéna, and M. Nguéa) and family members in Cameroon for their encouragements and invaluable sacrifices to ensure my education and the suffering they went through during my program.

To all these people, and many others I have not listed here, much thanks. But above all, I owe this achievement to the mighty *God*, for he has blessed and led my family and I throughout this endeavor. I acknowledge the value of his love and name.

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LIST OF ABBREVIATIONS AND ACRONYMS

APAP	Agricultural Policy Analysis Project.
ARPON	*Amélioration de la Riziculture Paysanne à l'Office du Niger.*
AV	*Association Villageoise* (Village Association).
BCEAO	*Banque Centrale de Etats de l'Afrique de l'Ouest.*
BEAC	*Banque des Etats de l'Afrique Centrale.*
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 CAF Zone).
CFDT	*Compagnie Française de Développement des Textiles.*
CIF	Cost, Insurance, and Freight.
CIRAD	*Centre International de la Recherche Agronomique et de Développement.*
CMDT	*Compagnie Malienne pour le Développement des Textiles* (Malian Company for the Development of Textiles).
CNAUR	(National Commission for Emergency Aid and Rehabilitation).
CNRA	*Comité National de la Recherche Agronomique* (National Committee for Agricultural Research).
CORAF	*Conference des Responsables de la Recherche Agronomique Africains*
CP	*Comité de Programme* (Program Committee).
CRRA	*Centre Régional de la Recherche Agronomique* (Regional Agronomic Research Center).
CRU	*Comité Régional des Utilisateurs* (Regional Commission of Research results Users).
CTR	*Comité Technique Régional* (Regional Technical Committee).
CV	Coefficient of variation.
DG	*Directeur Général* (General Director).
DGA	*Directeur Général Adjoint* (Deputy General Director).
DMA	*Division de la Mécanisation Agricole* (Agricultural Mechanization Division).
DNAE	*Direction Nationale des Affaires Economiques* (National Directorate for Economic Affairs).
DNSI	*Direction Nationale de la Statistique et de l'Informatique* (National Direction of Statistics and Computer Science).
DPEAR	*Département de la Planification Agricole et de l'Economie Rurale.*
DRF	*Directeur des Ressources Financières* (Director of Financial Resources).

DRSPR	*Division de Recherches sur les Systèmes de Production Rurale* (Farming Systems Research Division).
DS	*Directeur Scientifique* (Scientific Director).
ECOFIL	*Programme Economie des Filières* (Subsector Economics Program).
ESPGRN	*Equipe sur les Systèmes de Production et de Gestion des Ressources Naturelles* (Farming Systems and Natural Resources Management Team).
FAC	*Fond d'Aide et de Coopération* (French Development Fund).
FAO	Food and Agricultural Organization of the United Nations.
FED	Fond Economique de Dévelopement.
FEWS	Famine Early Warning System.
FF	French Franc
FOB	Free on board.
FSR	Farming Systems Research.
GDP	Gross domestic product.
GNP	Gross national product.
IDRC	International Development Research Center-Canada.
IER	*Institut d'Economie Rurale.*
IITA	International Institute for Tropical Agriculture.
IMF	International Monetary Fund.
INRZFH	*Institut National de Recherche Zootechnique, Forestière et Hydrobiologique* (National Institute for Zootechnical, Forestry and Hydrobiological Research).
IRAT	*Institut de Recherches Agronomiques Tropicales et de Cultures Vivrières* (Research Institute on Tropical and Food Crops).
IRCT	*Institut de Recherche de Coton et des Textiles Exotiques.*
IRHO	*Institut de Recherche pour les Huiles et les Oléagineux.*
IRRI	International Rice Research Institute
KFW	*Die Kreditanstalt Für Wiederaufbau* (Credit Institutions for Reconstruction)
KIT	The Netherlands Royal Tropical Institut.
LCV	*Laboratoire Central Vétérinaire* (Central Veterinary Laboratory).
LIMDEP	Software for econometrics models with Limited Dependent variables.
MLE	Maximum likelihood estimation
MSU	Michigan State University.
NGO	Non-Governmental Organization.
ODR	*Organization de Développement Rural* (Rural Development Organization).
OHVN	*Opération Haute Vallée du Niger* (Niger River Upper-Valley Development Authority).
OLS	Ordinary least squares
OMBEVI	*Office Malienne du Bétail et de la Viande* (Mali Livestock and Meat Agency).
ON	*Office du Niger.*
OPAM	*Office des Produits Agricoles du Mali* (Mali Agricultural Marketing Agency).
ORM	*Opération Riz Mopti* (Mopti Rice Organization).

ORS	*Opération Riz Ségou* (Ségou Rice Organization).
ORSTOM	*Office de Recherche Scientifique et Technique d'Outre-Mer.*
PAM	Policy Analysis Matrix.
PAS	*Programme d'Ajustement Structurel* (Structural Adjustment Program).
PASEP	*Programme d'Ajustement Structurel des Entreprises Publiques* (Structural Adjustment Program for Public Enterprises).
PRBF	*Programme Riz bas-fond.*
PRISAS	*Programme Régional de Renforcement Institutionnel en Matière de Recherches sur la Sécurité Alimentaire au Sahel.*
PRMC	*Programme de Restructuration du Marché Céréalier* (Cereals Market Restructuring Program).
RTM	*Radio Télévision Malienne.*
RYMV	Rice yellow motel virus.
SAP	*Système d'Alerte Précoce* (Early Warning System).
SIM	*Système d'Information du Marché* (Market Information System).
SPSS	Statistical Package for Social Sciences.
UEMOA	*Union Economique et Monétaire Ouest Africain.*
US	United States.
USAID	United States Agency for International Development.
WARDA	West Africa Rice Development Association.

CHAPTER ONE
INTRODUCTION

1.1. Problem Statement and Importance

Up to 1972-74, Mali was almost self-sufficient in cereals (Diarra, 1994). Following the major droughts in 1972-74, Mali became a large importer of food, including rice, and recipient of food aid (Appendix 5). Although, the situation appears to have improved since 1992 with respect to rice, the government is seriously considering further investments to intensify rice farming in order to boost domestic production. This interest has been reinforced by policy-makers' concerns about the future of the rice sub-sector as they anticipate that rice production and consumption will be affected by both devaluation and current policy changes designed to increase efficiency. The most significant of these policy changes is the deregulation of the input supply and marketing systems which were previously controlled by a public monopoly. These changes introduce new uncertainties, both to farmers' and to government's investments. For example, the removal of guaranteed pan-territorial and pan-seasonal prices for cereals could result in changes in farm-level technology and regional production patterns.

There are two basic interrelated ways to bring about the needed increase in domestic rice production. One way is through macro policy reforms designed to transform the rice subsector and the entire food system and stimulate broad-based economic growth. Such policies are expected to raise real incomes, and/or lower real rice prices while maintaining incentives to the rice subsector's participants (*i.e.*, farmers, processors, wholesalers, and retailers). The challenge for any government is to identify such policies and to implement them successfully. Historically, government initiatives designed to achieve these goals focused on policies that artificially raised food prices for producers and lowered them for consumers through subsidies. However, because such policies have now become fiscally unsustainable, food market reforms have been launched in Mali and throughout Africa.

The other way to increase farm-level productivity is through agricultural research and extension activities that take into account local resources and farmers' specific conditions. This dissertation focuses on this second alternative, while recognizing that increased productivity at the farm-level alone is not enough to achieve a significant boost in production. The study recognizes that, in order to significantly increase farm-level productivity, complementary improvements are necessary. Such improvements include changes in the tax code and better input and output markets, as well as investments to strengthen marketing infrastructure (*i.e.*, roads linking production and consumption areas, market facilities, and market information systems).

Currently in Mali, rice is produced as a food and cash crop under various production systems. Based on the level of water control, input use and production management, these systems can be classified into three broad categories: (1) government-managed irrigation schemes in large or small perimeters, with complete or partial water control and intensive input use, which accounts for most of Mali's domestic rice production, (2) the largely underdeveloped farmer-managed schemes in the *bas-fond*[1] (sometimes referred to as inland valley swamp), and (3) the upland rainfed systems with varying degree of water control and input use.

To date, the government has focused its efforts to increase rice production on both expanding the intensive irrigated area and increasing productivity (yield) in these schemes, primarily because they are seen as an insurance against recurrent droughts. The government could continue to expand these areas, but the cost of expanding and maintaining those irrigation systems is extremely high. In addition, in recent years, issues of sustainability in production have been raised. Furthermore, economic analyses of the fully-controlled rice production systems in five major rice producing countries in West Africa including Mali (*i.e.*, Côte d'Ivoire, Liberia, Sierra Leone, Senegal, and Mali) have repeatedly called into question the emphasis on irrigated rice, based on its high costs of production relative to imported rice (Leplaideur, 1991). However, this concern may have changed with the devaluation.

Alternatively, as a complement to rice production from the irrigated systems, the government could increase rice production by investing in improving the less intensive systems, especially the untapped potential of the *bas-fonds* for which there has been a growing interest among agricultural policy-makers and researchers. Unfortunately, very little is known about *bas-fond* rice production. Most existing studies on rice in Mali have

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[1] While the bas-fond is often referred to as a single system, there exists considerable variability of the production systems within it, ranging from perimeters with little or no water control and no use of improved technologies (*i.e.*, seeds, fertilizer, herbicides) to perimeters with good water control with farmers using improved technologies. The term water control refers to any attempt to deliver, retain or drain water in the field. The type of water control infrastructures varies from simple concrete dikes to simple dams (see Chapter Four for detailed description of these infrastructures).

focused almost exclusively on irrigated rice, especially comparative cost analysis and analysis of milling techniques.

The data required to assess the costs and benefits of these options (*i.e.*, the fully-irrigated and *bas-fond* production systems) are only partially available. Thus, the government needs information about the production potential and constraints to expanding alternative systems, as well as their relative profitability and other production incentives/disincentives associated with each system. With respect to *bas-fond* rice production, scientists and government officials need answers to numerous questions, including: (1) What is the current level of rice production in the *bas-fonds*? (2) Can *bas-fond* farmers produce more rice? In addition, information is needed to assess the financial and economic profitability of the major domestic rice production systems and the impact of the policy environment --measured in terms of discrepancies between private and social products, input costs, and profits-- on production incentives.

To evaluate the rice production potential of the *bas-fond*, one needs to provide answers to the following key questions: (a) How does rice fit into *bas-fond* farmers' production and consumption strategies? In other words, how important is rice production and consumption in Mali-Sud *bas-fond* villages relative to other crops, in terms of area cultivated and quantity consumed? Would farmers have to and are they likely to change their crop mix to produce more rice? (b) What are the characteristics of major *bas-fond* rice production systems in terms of technologies used, productivity level, and major constraints faced by farmers (*i.e.*, institutional, technological, natural and infrastructural, social, and policy-induced)? (c) What determines the current level of intensification and what technical innovations, and public and private incentives are needed to relax the existing constraints and thereby increase productivity?

With respect to the potential for technical innovations, the main questions are: (a) Are there technologies that have been developed and are being promoted by the research and extension institutions for *bas-fond* rice farming and what are their adoption levels? (b) Are these technologies consistent with farm-level technology needs? (c) What is the potential for greater intensification through technical innovation?

This study is designed to address these questions. Primary data collection focused exclusively on the *bas-fond* rice production system. In addition, the interaction between rice and other crops competing for the same resources (*i.e.*, mainly labor and capital) are assessed. Comparisons with the intensive irrigated system are based on data generated by surveys carried out in a sample of representative *bas-fonds*, and the available extensive secondary data on the government-managed irrigated production systems.

This topic was selected in response to the interest of two primary clients, namely, the Mali Institute of Rural Economics (IER) and WARDA. Interactions with these clients revealed considerable interest in developing a better understanding of the performance of the *bas-fond* rice sub-sector under the new policy environment, in order to (1) determine factors limiting productivity, (2) assess the potential contribution of the *bas-fond* sub-system for supplying Mali's future rice needs, compared to alternative sub-systems, and (3) identify potential public investments required to facilitate expansion of the *bas-fond* rice production sub-system.

In addition, the study directly benefits domestic rice producers, by providing advice to the research system and policy-makers regarding investments needed to best relax the constraints facing economic agents in the sub-sector. Finally, consumers benefit from this research, given that the ultimate aim of the study is to drive down the real cost of rice by increasing farm-level productivity for rice.

1.2. Research Objectives

The general objectives of this study are three-fold: (1) to provide a better understanding of the Mali's *bas-fond* rice production systems, including the characteristics of *bas-fond* production sub-systems and factors that determine their level of intensification, (2) to analyze and compare the current and prospective competitiveness of various types of *bas-fond* rice production systems, and (3) to derive implications for public and private investments as well as agricultural research in order to boost domestic rice production. The specific analytical objectives are to:

(i) Provide a brief overview of the overall rice sub-sector, including the major rice production systems, and the social, marketing and policy environments within which *bas-fond* rice production is undertaken.

(ii) Characterize the *bas-fond* farming households in terms of demographic characteristics, equipment and livestock holdings, field type and size, cropped area, farm-level production for rice and major competing crops;

(iii) Identify the rice production technologies used for key farming operations, and generate the corresponding input-output coefficients.

(iv) Develop a typology of the major *bas-fond* production sub-systems.

(v) Assess the major constraints facing farmers in the *bas-fond* production sub-systems, especially with respect to improving the level of water control, increasing input use levels, and labor demand conflicts between rice and three major competing crops (*i.e.*, cotton, sorghum, and maize);

(vi) Identify the major determinants of yield and the distinctive characteristics of farmers with significantly different levels of input use.

(vii) Determine the input-output coefficients for cotton, sorghum, and maize.

(viii) Develop, analyze, and compare synthetic enterprise budgets for assessing the financial returns to rice in the major *bas-fond* production sub-systems, as well as the returns to cotton, sorghum, and maize;

(ix) Develop policy analysis matrices for major *bas-fonds* sub-systems and selected intensive irrigated rice production systems, and discuss the distortionary effects of policies on production incentives.

(x) Derive recommendations for the research system and policy-makers.

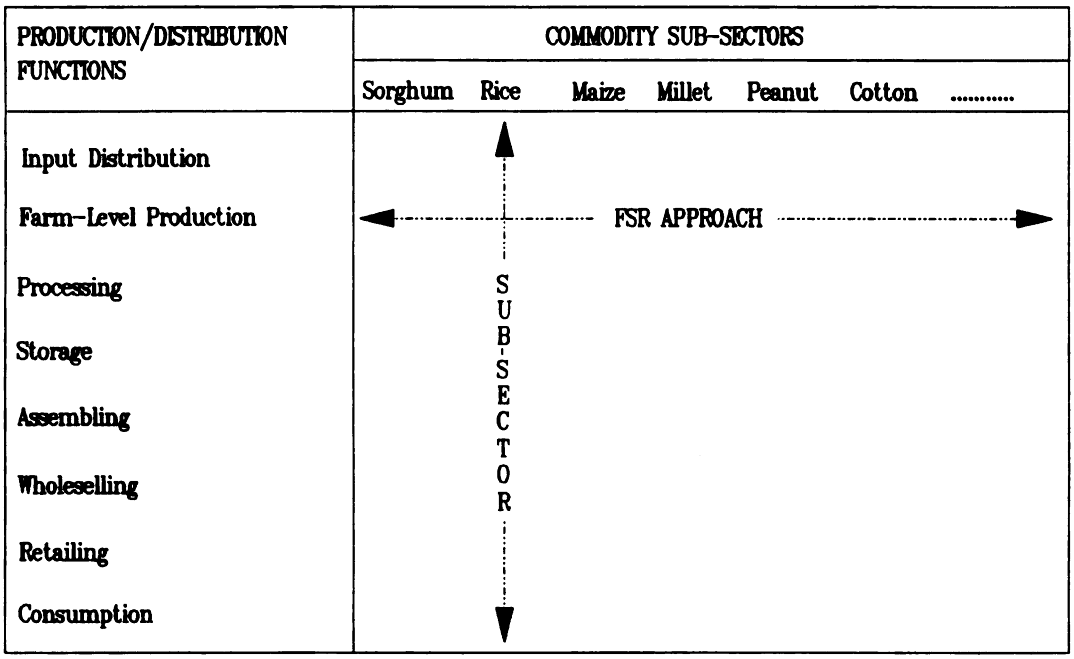
1.3. Conceptual Framework

Conceptually, this research is organized around the farming systems (FSR) and the sub-sector frameworks. This section briefly presents these two approaches and highlights how they guided the study's design and the subsequent analyses.

1.3.1. Concepts Definition: The Farming System and the Sub-Sector Approaches

A simple but useful way for visualizing and analyzing a farming system and a sub-sector is through the food system matrix (Figure 1.1).

Figure 1.1: A Simplified Representation of the Food System Matrix.



Source: Adapted from Boughton and Témé (1992).

The sub-sector approach was originally conceptualized by Shaffer in a series of papers on economic research (1968_a, 1968_b, 1968_c, 1970) and further developed by Holtzman (1986). The food system matrix (Figure 1.1) graphically represents the food system as "the entire set of actors and institutions involved in input supply, farming, processing and distributions of agricultural production" (Staatz and Bernsten, 1992). Each column in the matrix represents a commodity sub-sector, while each row represents an individual stage or function in the production and transformation of commodities in the food system. These stages are linked by coordination mechanisms such as prices, quality control, property rights, contracts, and other regulations. Furthermore, research and extension activities are undertaken at each of the stages. A commodity sub-sector can therefore be defined as the entire range of activities and services in the production and distribution of this specific commodity or a group of related commodities (Shaffer, 1968). In contrast, the FSR framework focuses mostly on a specific stage of the food system, most commonly farm-level production.

In studying any particular commodity sub-sector, one must first determine how to delineate the system. This process is guided by three fundamental questions: (1) what is the outer edge of the sub-sector boundary (*i.e.*, what product types --including quality-- are involved and what is the geographical area under consideration), (2) how many of the functions must be included, and (3) what is the appropriate separation between different channels of production transformation? In general, these boundaries are drawn pragmatically, depending of the question being investigated. For this particular study, the product is *bas-fond* rice, which is equivalent in quality to broken rice. The geographical area involved is Mali-Sud.

1.3.2. Fundamental Characteristic of the Sub-Sector Framework

Embedded in the sub-sector concept is a fundamental recognition that there is a chain of dynamic relationships among the different stages of the food system, which require coordination for the system to perform efficiently. As a result, focusing analyses on only a single stage of this system is insufficient because the different stages mutually affect each other. A global assessment is therefore required to identify effectively the weaknesses and strengths of each component of the sub-sector. In this respect, the sub-sector analysis follows a system approach[1]. It has both horizontal and vertical dimensions. The horizontal dimension refers to production units within each particular stage of the sub-sector where a similar function is or set of functions are performed. The vertical dimension refers to the vertical coordination of all stages of a single commodity, or relatively homogeneous groups of commodities associated with the sub-sector. In addition, the vertical dimension cuts across all stages of the system, where different functions are performed.

1.3.3. Key Components of the Sub-Sector

The progression of a product from its raw material form to its final forms (*i.e.*, consumption stage) in the economy can be differentiated into key structural components. These components need to be specified in a way that will contribute to the overall conceptual framework's ability to facilitate the expected analyses. The key components of the sub-sector include: the sub-sector functions, its coordination mechanisms, and its participants.

The sub-sector functions are the sequential steps or transformation from production through distribution. These functions are typically grouped into input supply, raw and processed material production, wholesaling, and retailing functions. Individually, their analysis provides an understanding of the horizontal dimension of the

[1] A system can be defined as any set of elements or components that are interrelated and interact among themselves.

sub-sector structure. Coordination mechanisms link the functions. These mechanisms are either hierarchical or based on sales in spot markets or through contracts. Their analysis provides an understanding of the vertical dimension of the sub-sector structure. Participants in the sub-sector are the actors who perform one or more functions in the sub-sector and use various mechanisms to coordinate their activities.

These sub-sector functions and coordination mechanisms are performed within specific channels of product transformation and specific environments. A channel of product transformation corresponds to any traceable path through the sub-sector's production-distribution-consumption sequence. Their aggregation defines the sub-sector itself. The sub-sector environment is the context within which the functions, coordination mechanisms, and the participants operate. It is composed of the various rules, information flows (*e.g.*, level and pattern of distribution), and service institutions such as input suppliers and rules enforcement institutions. Thus, it determines the type of relations existing in the system (*e.g.*, contractual, market, barter, or none).

1.3.4. Farming Systems as a Complement to the Sub-Sector

As was noted earlier when stating the research problem, the Mali rice sub-sector has been fairly well studied, with the exception of its *bas-fond* component. The study focuses on the particular cell at the intersection of the FSR and subsector arrows in the matrix presented in Figure 1.1, and looks at *bas-fond* rice production within this cell. However, this research recognizes that what happens at other stages of the rice subsector affects production at the farm level. It is therefore important to assess how *bas-fond* rice production fits into the broader rice sub-sector, in terms of domestic rice supply sources, for whom and when the supply is available, and with respect to what rice quality --as well as how various steps affect farm-level production in the *bas-fond*.

Indeed, as the national economy goes through the structural transformation process, the degree of exchange between different stages of the food system increases. As a result, farmers increasingly demand technologies that reflect their clients' constraints, opportunities, and preferences. For example, although productivity and profitability are examined primarily at the farm level, they will depend not only on the technology's performance, but also on a wide range of institutions and policies outside the technology system. Thus, for the rice sub-sector to be profitable at the farmer level, it must be profitable in other sub-sector stages (*i.e.*, marketing, processing, and consumption) as well. Yet, historically, research on rice in Mali has focused on a single stage, often production or marketing (Staatz and Bernsten, 1992), overlooking interactions with other stages in the commodity subsector.

Similarly, interactions with other commodities at the same stage are important, especially because *bas-fond* fields are cultivated by small-scale farmers who also cultivate upland fields. While these farmers are still largely subsistence oriented, there is a pressure on them to become more integrated into the market system. Thus, because they have diverse objectives and motivations, it is impossible to subsume these multiple objectives under a single and simple goal such as "increased rice yield in the *bas-fond*". Given that *bas-fond* fields cultivation interacts with upland farming activities, the study therefore recognizes that the interrelationships which link upland and *bas-fond* activities are a particularly important dimension of the *bas-fond* agroecosystems. These interactions are both complementary and competitive. For example, rice may be grown as a food crop in the *bas-fond*, whereas crops grown in the upland fields are used for household income generation. To be able to produce both upland and *bas-fond* crops, farmers must deal with the competing demand between their upland and *bas-fond* fields, mostly for scarce labor input. Given this context, the FSR framework provides an effective way to conceptualize and integrate these interactions in the research.

In FSR, farmers are at the center of these interactions, with their needs and resources of their families intimately linked. Households allocate certain quantities and qualities of basic types of inputs (*i.e.*, land, labor, capital and management) in a manner which, given the knowledge they possess, maximizes attainment of the goals they are striving for (Norman, 1976). The environment in which they operate can be divided into two parts: the technical elements and the human element (Norman, 1976).

The technical elements determine the type and physical potential of livestock and crop enterprises that the farmers can engage in. These elements have received most of the research attention in Mali. Technical elements can be divided into physical and biological factors. Examples of physical factors include water and soil. Water-related constraints (*i.e.*, too much or too little water) can be reduced through irrigation with partial or complete water control. Alternatively, water control problems can be reduced by breeding plants suitable to the existing water conditions, such as tall varieties that are tolerant to submersion. Similarly, the soil deficiencies can be corrected through fertilization to improve fertility, and/or better land preparation to improve its structure.

Examples of biological factors include crop physiology, diseases, and insect attacks. A breeding program can be designed to influence these biological factors such as shortening crop maturity or increasing disease and insect resistance.

The human elements can be subdivided into exogenous and endogenous factors. The exogenous factors include social norms and beliefs which affect farmers' acceptance to changes (e.g.; the view that rice growing is a women's activity), political and economic institutions outside the control of individual farmers (e.g.; markets and prices, input supply systems and extension, credit and input distribution and related policies). Endogenous factors are those over which individual farmers have some type of control, such as the amount of land, labor, and capital devoted to a particular crop.

Similar to the commodity sub-sector approach, the farming systems framework also stresses the need for a holistic approach. The objective here is to increase the system's productivity in the context of the entire range of private and societal goals, given the constraints and potentials of the existing farming systems. Although the FSR framework is holistic in its orientation and thus not limited solely to the farm-level production stage, in practice the degree of comprehensiveness of FSR is tempered by resource availability, including time (Gilbert *et al.*, 1980). As a result, in practice, FSR has been biased toward introducing bio-technical modifications in the farming systems, although often there is some recognition that changes in non-technical factors such as markets, pricing policy, and infrastructure are equally important (Gilbert *et al.*, 1980).

Despite the conceptual differences between the FSR and the sub-sector frameworks, both approaches emphasize the use of rapid reconnaissance methods as an essential step in identifying constraints and research priority (Boughton and Témé, 1992). Also, both frameworks emphasize the importance of client participation in the design, development and testing of technologies to relax constraints (Boughton and Témé, 1992).

1.4. Research Hypotheses

This study was guided by the following hypotheses:

(1) There exits a set of socio-economic characteristics associated with individual farmers (e.g.: gender, age, education, access to capital, awareness level, participation in decision making, etc..) that differentiates between farmers who adopt/do not adopt improved technologies such as improved seeds, fertilizer, and herbicide.

(2) The existence of a water control infrastructure in the *bas-fond* is a necessary but not sufficient condition for technology adoption.

(3) Due to the ineffectiveness of water control, rice production in improved *bas-fonds* is economically (*i.e.*, socially) less profitable than in the traditional *bas-fonds* (without water control and fertilizer input),

(4) Although maize and cotton production are financially more profitable than rice production, and sorghum production is financially less profitable than rice, these crops complement each other in satisfying farmers' socio-economic goals.

(5) The *bas-fond* and the intensive irrigated rice production systems are complementary in terms of their contribution to the country's rice supply.

When transportation costs and tastes and preferences are considered, the irrigated system has a comparative advantage in supplying urban areas while the *bas-fond* system has a comparative advantage in satisfying the rice requirements of rural areas in and around the *bas-fonds*.

(6) The rice production systems (including the intensive irrigated systems) that are most financially and economically profitable are those that have benefitted from positive incentives at the farm level, such as subsidies and technical support.

1.5. Dissertation Organization

This dissertation is organized into eight chapters. Chapter One states the research problem and its importance, and the study's objectives, hypotheses, and conceptual framework. Chapter Two provides background information on Mali's overall economy, its agricultural sector, and the rice subsector. Chapter Three presents the research approach and the data collection method used. Chapter Four identifies and critically analyzes the major agronomic and hydrologic characteristics of *bas-fond* rice production.

Chapter Five analyzes the economics of *bas-fond* rice production from the point of view of the farmers. In Chapter Six, the returns to rice production in the *bas-fond* villages are compared to the returns to cotton, maize and sorghum production --the major crops competing with rice. Chapter Seven presents a comparative analysis (using economic enterprise budgets) of *bas-fond* rice production and a limited sample of intensive irrigated rice production systems, as well as an analysis of the impact of discrepancies between private and social returns to production incentives. Chapter Eight summarizes the major findings of this study and identifies policy implications for technical research and policy-makers, notes the limitations of the study, and proposes future research needed.

CHAPTER TWO
AN OVERVIEW OF THE MALIAN ECONOMY

2.1. The Macroeconomy

2.1.1. A Sluggish Economic Growth Led to Market Liberalization

With an average per capita GNP of $US 270 in 1993 (World Bank, 1995), Mali ranks among the low-income economies. The country's GNP has been fluctuating over time, making it difficult to identify a trend. In the 1960s and 1970s, the Malian economy experienced continued falling terms of trade worsened by inappropriate financial and economic domestic policies, and unfavorable climatic conditions that translated into a stagnating agricultural production, increased food deficit, and a distorted market environment (World Bank, 1992).

In the 1980s, per capita income declined by 0.1 percent per annum. Total external public debt as a percentage of GNP more than doubled between 1980 and 1991, growing from 45.4 percent to 104.8 percent in these two years (World Bank, 1993). However, the net present value of debt burden, which was equivalent to 227.3 percent and 442.7 percent of the country's exports of goods and services in 1980 and 1991, respectively (World Bank, 1993), fell to 266.8 percent in 1993 (World Bank, 1995).

In an effort to reverse the country's economic trend, in 1982, the Malian government initiated a Structural Adjustment Program (SAP) in collaboration with the

World Bank and the International Monetary Funds (IMF), with the objective to reduce government involvement in production, transformation, and marketing activities to their bare essentials. The most important policy changes which were halted in 1986/87 then revamped in 1988 have included: (1) trade liberalization, (2) input and output markets liberalization, and (3) the 1994 domestic currency devaluation.

The impact of the reforms undertaken until 1993 were encouraging (World Bank/Mali, 1995). As evidence of this, government employees have been receiving their salaries regularly and on time, public finances have improved, the private sector and market forces have been playing a major role in the economy, and inflation has been maintained below an average of 3 percent annually (from an annual average of 10% in the 1970s and 1980s). Furthermore, the shift from a socialist to a democratic government, seems to have contributed to more economic growth through a reduction of capital flight. Following the 1994 devaluation, the country experiences a rapid growth (+6%). However, despite the encouraging results, it is believed that the competitiveness of Mali's production has not been fully developed thereby limiting employment creation and economic growth.

Data on unemployment do not exit (Ministère de l'Agriculture, de l'Elévage et de l'Environnement, 1992). However, there is strong evidence of increasing unemployment since the launching of the SAP in the 1980s, especially among school graduates. The growing unemployment reflects that the private sector has been slow to take over from the government (Ministère de l'Agriculture, de l'Elévage et de l'Environnement, 1992).

2.1.2. Demographic Characteristics

With about 8.7 millions inhabitants growing at an annual rate of 2.5 percent, Mali is one of the West African countries with the lowest population growth rate (with Guinea and Burkina Fasso). With an average fertility rate of 7.0 births per female, population is projected to triple by the year 2025 (World Bank, 1993). Because northern Mali is a semi-desert, the bulk of the population is concentrated in the Niger Valley and in the south-eastern region of the country. About 27.5 percent of the population lives in urban areas (Appendix 2.6).

2.1.3. Social Indicators

Key social indicators as reported by the World Bank (1990, 1993, and 1995) are as follows: primary school enrollment (25% in 1992), secondary school enrollment (7% in 1992), adult illiteracy (national, 68% and female, 76% in 1990), life expectancy (46 years in 1993), babies with low birth weight (10% in 1991), infant mortality (157/1,000 live births in 1993), and per capita daily caloric intake (2,253.81 kcal in 1988-89, which represented 91.9% of the needs).

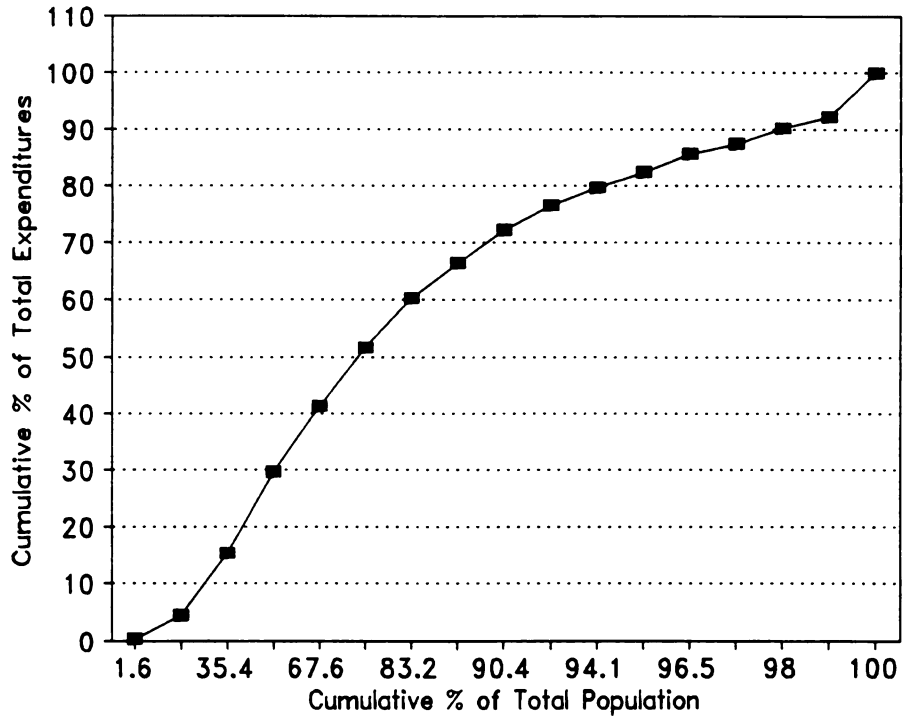
In general, both adult and infant mortality have been decreasing since the 1960s (Ministère de l'Agriculture, de l'Elévage et de l'Environnement, 1992; and World Bank, 1995). However, health problems are still a major concern mainly due to the insufficient infrastructure needed to satisfy a growing demand for health services based on population growth rate. For example, in 1990, it was estimated that only 15 to 20 percent of the population have access to a medical service (Ministère de l'Agriculture, de l'Elévage et de l'Environnement, 1992), and that in 1993 there were 21,180 inhabitants for each medical doctor --against 43,320 in 1970-- and 2,050 inhabitants for each nurse --against 2,670 in 1970-- (World Bank, 1995).

2.1.4. A Dominant Food-Based Expenditure Pattern and an Unequal Income Distribution

Reducing poverty remains the major challenge for the Mali government. The most recent household consumption expenditures survey (1988-89) shows that, on the average, each Malian spends about cfa.F 134,945 ($US 281) annually, of which 54.5 percent is attributed to food consumption, 14.3 percent to clothing, and 2.7 percent to health expenses.

The 1988-89 household consumption expenditures survey revealed an unequal distribution income among the population when annual expenditure levels are used as proxy (Appendix 2.1). Figure 2.1 shows that, when population is ordered by level of consumption expenditures, the bottom 34.5 percent accounts for 15.4 percent of national expenditures, spending between zero and 75,000 cfa.F individually each year, while the top 23.4 percent accounts for 48.4 percent of national expenditures, with a spending level above 150,000 cfa.F per capita annually.

Figure 2.1: Cumulative Population Distribution by Proportion of National Consumption Expenditures, Mali, 1988-89.



2.2. The Agricultural Sector

2.2.1. The Physical Environment

2.2.1.1. Rainfall Pattern and Agro-Ecologies

Like most soudano-sahelian countries, Mali's climatic situation is characterized by irregular rainfall, ranging from 200 mm in the north to 1,400 mm in the south. Based on rainfall distribution, the country has been divided into three agro-ecological zones: (1) the semi-arid zone (500-900 mm of rainfall) in the north, (2) the sub-humid zone (900-1,000 mm of rainfall) in the center, and (3) the humid zone (above 1,100 mm of rainfall) in the south. There are two distinct seasons irregularly distributed over the years. The rainy season lasts 3 to 6 months (June to October). Average annual temperatures range from 23°C in November-February to 31°C in March-May.

2.2.1.2. Irrigation

Extending over 1.24 million km^2 (477 sq. miles), Mali is one of the largest countries in West Africa. Compared to other Sahelian countries, Mali possesses more irrigable land area. It is estimated that about 500,000 to up to two million hectares of land can potentially be developed for irrigation (World Bank, 1992). Yet, to date, only about 200,000 hectares have been improved, 75 percent of which are currently being used (World Bank, 1992). Developing the country's irrigable land potential makes it possible to dampen the unfavorable effects of irregular rainfall pattern. This has been done through government-managed irrigation schemes in large or small perimeters along the Niger (1,700 km) and Senegal rivers and other small rivers south of the country, and in largely underdeveloped farmer-managed schemes in *bas-fonds* and flooded plains.

2.2.2. Trends in Crop Production

Mali's agricultural production is characterized by its low level of diversity, and a high degree of production variability that often leads to food deficits. The dominant crops are cotton, cereals (sorghum, millet, rice and maize), and groundnut (Table 2.1 and Table 2.2).

Table 2.1: Production ('000 T) Statistics of Major Crops in Mali, 1960-93

YEAR	Cotton	Sorghum/ Millet	Maize	Groundnut	Rice (Paddy)
1970/71	57	715	58	176	137
1971/72	70	715	72	188	157
1972/73	72	625	20	109	116
1973/74	55	587	35	108	131
1974/75	71	911	51	138	179
1975/76	105	896	37	215	196
1976/77	133	831	68	129	298
1977/78	183	961	115	178	303
1978/79	133	910	103	164	158
1979/80	151	746	76	146	240
1980/81	110	708	45	135	122
1981/82	98	950	61	128	135
1982/83	129	1,097	89	94	153
1983/84	141	876	144	75	216
1984/85	145	1,348	101	54	109
1985/86	176	1,270	140	85	214
1986/87	201	1,207	213	107	225
1987/88	199	1,672	179	101	237
1988/89	249	1,573	215	172	288
1989/90	230	1,268	225	157	338
1990/91	276	1,660	197	180	282
1991/92	273	1,185	257	184	454
1992/93	320	1,485	193	127	410
1993/94	240	1,644	283	149	428
1994/95	294	1,460	322	215	469
$CV_{1970-94}$	0.481	0.319	0.651	0.303	0.460
$CV_{1985-94}$	0.186	0.135	0.238	0.283	0.295

Source: DNA/DNSI (Enquête Agricole de Conjoncture, 1994).

Table 2.2: Area (ha) Statistics of Major Crops in Mali, 1970-94.

YEAR	Cotton	Sorghum/ Millet	Maize	Groundnut	Rice (Paddy)
1970/71	72	698	35	138	129
1971/72	82	574	35	151	114
1972/73	88	736	27	147	131
1973/74	73	667	44	127	145
1974/75	80	795	34	138	137
1975/76	91	873	34	186	233
1976/77	122	874	37	132	175
1977/78	103	1,152	60	175	244
1978/79	119	915	43	134	112
1979/80	123	924	46	164	243
1980/81	111	1,107	41	162	143
1981/82	85	1,172	69	171	116
1982/83	105	1,362	47	145	182
1983/84	111	1,395	126	120	188
1984/85	119	1,297	89	83	165
1985/86	146	1,266	109	89	185
1986/87	151	1,240	129	93	191
1987/88	149	1,273	118	125	163
1988/89	189	1,875	143	166	231
1989/90	188	1,857	175	147	231
1990/91	205	2,022	170	248	197
1991/92	215	1,685	186	169	200
1992/93	247	1,883	191	170	184
1993/94	201	2,286	257	189	202
1994/95	269	2,382	284	255	284
$CV_{1970-94}$	0.410	0.400	0.736	0.267	0.256
$CV_{1985-94}$	0.210	0.232	0.326	0.341	0.165

Source: DNA/DNSI (Enquête Agricole de Conjoncture).

Cotton is the main cash crop. It is grown mostly in the southern part of the country under CMDT *(Compagnie Malienne de Développement des Textiles*[1]) management. Cotton provides greater financial security to the farmers, as the input supply (seeds, fertilizer, pesticides, in-king loan for animal traction) is guaranteed by CMDT, which also guarantees an output price set ahead of time and a market outlet, as well as an active and effective technical support.

Millet/sorghum, and maize are the major rainfed staples. During the time period 1970-94, sorghum/millet accounts for about 75 percent of total area planted annually (Figure 2.2) in millet/sorghum, rice and maize, and 80 percent of the resulting total grain production (Figure 2.3).

Figure 2.2: Average Annual Cereals Area Planted in Mali, 1970-94.

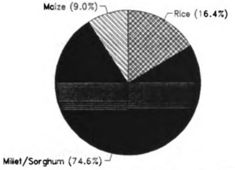
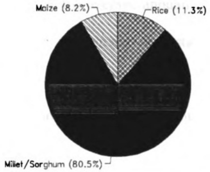


Figure 2.3: Average Annual Cereals Production in Mali, 1970-94.



The high variability in grain production is mainly attributed to fluctuating rainfall, but also to the area planted (which may fluctuate in part because of rainfall). However,

[1] CMDT is a semi-autonomous industrial and commercial enterprise whose primary mission is to ensure an integrated development of the cotton sub-sector, but also to provide public services for rural development activities (see section 2.3 for details).

the degree of production variability differs from one crop to another. For example, during the period 1970 to 1994, the coefficient of variation (CV[1]) of the annual domestic production of rice (0.460) is higher than the one for millet/sorghum (0.319), and smaller than the CV for maize (0.651), as reported in Table 2.1. In other words, the CVs for the annual productions of sorghum/millet and maize grain (Table 2.1) are lower than the corresponding CVs for area harvested (Table 2.2), whereas this situation is the reverse for rice. Finally, for both production and area harvested, the CVs have been lower for cotton, sorghum/millet, maize, and rice production and area harvested since the last major drought in 1982-84.

An analysis of historical grain production patterns since the last major drought indicates that, on the average, Mali produces 94 percent of domestic grain requirement annually (Appendix 2.2). During this period (*i.e.*, 1987-88 to 1990-91), grain production felt short of the national requirement by about 22 percent on the average annually in the very bad years, while in the best years of production, 99 percent domestic grain requirement was met annually on the average (Appendix 2.2). The negative impact exerted by the large and unpredictable variations in cereal production on the national food security contribute in part to fluctuations in imports levels.

Compared to other main cereals, rice has important distinctive advantages. First, it is the only cereal grown under irrigation in a drought-prone area, thereby serving as an insurance against drought. Second, it is of paramount political importance in the

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[1] The coefficient of variation (CV) of production for a particular crop is the ratio of the standard deviation of its production levels for the period under consideration to the average production during the same period.

sense that it is the main staple for the politically powerful urban consumers (any supply shortage has the potential to induce social turmoil and riots) in part because it requires less time to cook (which makes it appropriate in a context of increased opportunity cost of women's time, especially in urban areas). Because of its political importance, the government has made sure that rice is available at any time.

2.2.3. Agricultural Sector Contribution to the National Economy

2.2.3.1. The Domestic Supply Share of National Cereals Consumption

In 1993, Mali's agricultural sector accounted for the major share of GDP (42%), foreign exchange (75%), and employment (83%). As expected from an economy undergoing structural transformation, Mali's agricultural share of GDP declined by 19 percent between 1970 and 1993, while during the same period, industry's share increased by 4 percent, services by 14 percent, and manufacturing by 2 percent (World Bank, 1995). The contribution from Mali-Sud's agricultural sector to the national economy is fairly significant. For example, Mali-Sud produced 81.8 percent[1] of the national cereal consumption (Semega, 1991).

2.2.3.2. The Agricultural Share of Foreign Exchange Earnings

While the average growth rate of exports in general declined between 1970 and 1991 from 8.3 percent to 6.7 percent, the share of primary commodities in merchandise exports increased from 89 percent in 1970 to 93 percent in 1991 (World Bank, 1993).

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[1] This proportion includes millet (42.0%), sorghum (26.5%), and maize (13.3%).

Cotton and livestock are the two most important earners of foreign exchange in agriculture. The bulk of Mali's cotton production is exported. The cotton share of the value of total agricultural product exports averages approximately 43.3 percent for the period 1970-93 (Appendix 2.3). In fact, this share has been increasing over time (28.3% in the 1970s, 37.3% in the 1980s, and 61.6% in 1990-93). Similarly, the livestock share of the value of total agricultural product exports averages approximately 29.2 percent for the period 1970-93 (11.3% in the 1970s, 40.3% in the 1980s, and 25.8% in 1990-93). Mali-Sud accounts 100 percent of the national cotton production. The region's potential in livestock is also appreciable. In the first half of the 90s, Mali-Sud accounted for 38 percent of the national production of cattle and 15 percent of sheep/goats (Mamadou, 1995).

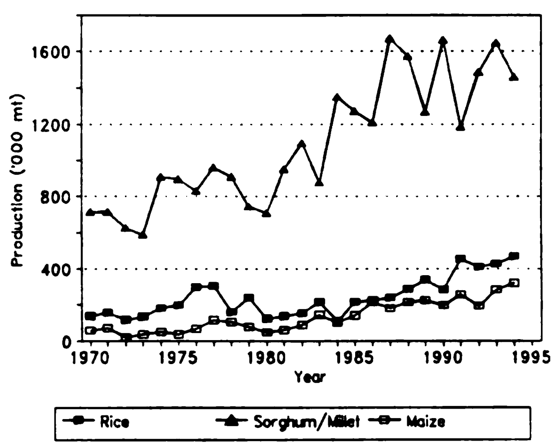
2.2.4. Mali, Net Importer of Food and Recipient of Food Aid

In general, the diet of a Malian is not diversified and it is dominated by cereals, which translate into a disproportionate amount of glucidic caloric supply (Appendix 2.4). It is therefore not surprising that one of the country's food security objective is to diversify food supply (Ministère de l'Agriculture, de l'Elévage et de l'Environnement, 1992). While until the 1972-74 drought Mali was considered self-sufficient in cereals, following the drought, per capita food production has failed to keep pace with the rapidly expanding demand for food. For example, between 1979 and 1991, per capita food production declined by an average of 0.7 percent per year (World Bank, 1993).

As the gap between national food production and demand widened in the late 1980s, largely because of recurrent droughts, rural-urban migration, and low agricultural productivity, Mali became increasingly dependant on commercial imports and food aid[1]. Most of the cereal imports have been rice, with imports (not including aid) accounting for approximately an average 25.6 percent of total rice consumption annually since the 1984 drought (Appendix 2.5). Historically, millet, maize, and sorghum imports have been minimal, except in years of drought when maize and sorghum have also been received as food aid (Staatz and Dembélé, 1989).

Although up to 1985, persistent drought contributed to major food deficit in Mali, starting from the mid-1980s, millet, sorghum, maize and rice production have been increasing (Figure 2.4, Table 2.1, and Table 2.2).

Figure 2.4: Annual Production of Major Food Crops in Mali, 1970-94.



[1] For example, the World Bank (1990, 1993) reports that cereal imports more than doubled between 1980 (87 thousand metric tons) and 1991 (226 thousand metric tons), while during the same period food aid in cereals also increased by about two-thirds (from 22 thousand metric tons to 37 thousands of metric tons).

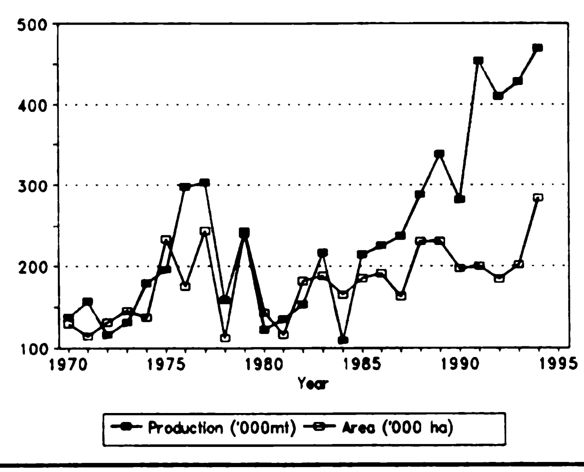
The World Bank Development Report (1993) indicates that while the average growth rate of imports in general declined in the last two decades (5.2% in 1970-80, and 3.5% in 1980-91), the share of food in merchandise imports declined as well (29% in 1970 and 18% in 1991). While less than 90 percent of the country's food demand was satisfied by domestic production in the 1980s, about 99.4 percent was met in 1990 (Ministère de l'Agriculture, de l'Elévage et de l'Environnement, 1992). Indeed, some areas were able to produce a marketable surplus, due to better climatic conditions.

2.3. The Rice Subsector

2.3.1. Trends in National Rice Production

Up to 1984, persistent drought contributed to major rice deficit in Mali. Even though as shown in Figure 2.5 domestic production has been increasing (by more than 50 percent between 1986 and 1993), the country has not been able to satisfy demand.

Figure 2.5: Rice Production in Mali, 1970-94.



However, the situation appears to be changing since the mid-1980s. Yet, it is not clear what the contribution of *bas-fond* rice production has been because a complete inventory of the *bas-fonds* has not been made yet. The recent increase in domestic production has been attributed largely to: (1) consumer price increase in 1988 (30-50%), brought about by market liberalization policies and supply shortage due to delays in imports, that made rice more profitable (2) productivity (yield) gains in the *Office du Niger* (which represents on the average 43.4 percent of the annual national production between 1970 and 1994, with a standard deviation of 10.3%)-- from an annual average of 2.0 t/ha in the 1980s to about 4.2 t/ha in the 1990s, (3) yield increase and rice area expansion in the irrigated perimeters in Sélingué and Baguinéda, (4) the proliferation of small rice mills following the market reforms, and (5) the 1994 devaluation which increased prices.

Prior to the market reforms, *Office du Niger* had the monopoly of rice milling in Mali. The State milling capacity averages 80,000 tons per year. But since 1986, private milling opportunities in the *Office du Niger* area have expanded (*e.g.*, from few in 1986, to 196 mills in 1990, and 383 in 1993), thereby changing the structure of the rice subsector by helping to reduce concentration and changing the marketing options for both farmers and retailers (Diarra, 1994).

2.3.2. Regional Distribution of Rice Production

A distinctive feature of rice production in Mali is its high concentration in the Niger Valley and Delta, especially in Ségou and Mopti (Table 2.3). Both Ségou and

Mopti account for about 76.4% of the national annual production since 1970 (with a standard deviation of 5.6%). The distinctive features of the production systems is their medium to large irrigated schemes with relatively large scale individual parcels (*i.e.*, 2-15 ha), and the relatively high level of input use. The second rice producing area is in the southern part of the country, in the cotton producing area, where most of the *bas-fonds* and flooded plains are located. In this area, individual parcels are small (less than a quarter of a hectare), the level of input use is minimal, and rice production interacts with farmers' upland production system.

Table 2.3: Regional Distribution of Rice Production (mt) in Mali, 1970-94.

Year	Kayes	Koulikoro	Sikasso	Ségou	Mopti	Toumbouctou	Gao*	National
1970-71	1,703	11,878	10,322	59,254	38,726	NA	15,512	137,395
1971-72	5,801	2,769	11,854	76,583	49,171	NA	10,952	157,130
1972-73	409	4,372	8,349	72,872	26,184	NA	3,714	115,900
1973-74	27	8,938	7,813	89,055	21,904	NA	2,973	130,710
1974-75	501	538	12,257	67,967	77,850	NA	19,530	178,643
1975-76	1,821	43	21,385	90,233	51,328	NA	31,226	196,036
1976-77	2,284	381	12,894	95,455	166,882	NA	20,333	298,229
1977-78	1,045	7,023	31,444	150,012	85,049	NA	28,630	303,203
1978-79	1,154	5,884	12,705	93,118	33,547	NA	11,883	158,291
1979-80	4,863	7,840	21,787	95,940	80,965	12,207	16,515	240,117
1980-81	4,192	0	12,621	69,290	23,988	4,878	6,584	121,553
1981-82	1,919	9,577	14,360	62,801	31,294	na	14,805	134,756
1982-83	1,208	409	20,849	76,613	29,107	4,588	19,859	152,633
1983-84	199	2,691	18,811	101,595	64,045	20,289	8,356	215,986
1984-85	1,101	1,403	10,599	87,682	4,654	1,687	2,228	109,354
1985-86	16	3,681	7,672	109,532	54,825	9,766	28,349	213,841
1986-87	96	1,455	25,275	114,311	53,812	21,504	8,685	225,138
1987-88	193	2,692	15,957	124,982	66,232	9,752	16,760	236,568
1988-89	na	46	8,639	155,072	70,578	27,852	25,610	287,797
1989-90	na	2,350	24,539	160,014	91,639	27,035	32,172	337,749
1990-91	531	8,301	13,225	153,534	56,272	38,592	11,911	282,366
1991-92	8,535	22,472	54,102	219,966	81,953	51,568	15,753	454,349
1992-93	2,171	14,548	50,223	218,645	67,882	43,317	13,232	410,018
1993-94	2,621	18,016	57,604	238,752	63,687	35,925	11,004	427,609
1994-95	3,437	17,431	61,324	234,390	102,706	42,159	7,679	469,126
$CV_{1970-95}$	1.061	1.032	0.738	0.464	0.555	NA	NA	0.460
$CV_{1985-95}$	1.265	0.908	0.667	0.293	0.231	0.460	0.503	0.295

"na" stands for "not available".

"NA" stands for "Not Applicable". The reason here is the fact that during the period 1970-71/78-79, Tombouctou was part of Gao.

* The production statistics from 1970-71 to 1978-79 include data from Tombouctou which was then part of a larger Gao Region.

Source: DNA/DNSI (Enquête Agricole de Conjoncture).

While only one administrative region (Ségou) produces a surplus over its rural consumption needs in an average or good year, some regions are deficits in all years, notably the northern and extremely drought-prone regions of Tombouctou and Gao, as well as the central urban regions of Koulikoro. Year-to-year variability of rice production varies across regions and the variability of production in any given administrative region is greater than that for total national production (Table 2.3). Because large populations are concentrated in the main producing regions (Appendix 2.6), changes in production conditions lead to large swings in the amount of rice flowing into and out of these regions.

2.3.3. Major Rice Production Systems in Mali

Rice is produced under various production systems. Based on water source and the level of water flow control, the various production systems can be classified into three sub-systems: (1) The fully controlled irrigation systems, which are either in large perimeters (*Office du Niger*, Baguinéda, Manantali, and Selingué) or in small perimeters along the Niger and Senegal rivers, (2) The partially controlled irrigated production system is found in smaller irrigated perimeters (*Opération Riz Ségou, Opération Riz Mopti, Opération Riz Sikasso*) and smaller rivers south of Mali, and (3) The traditional rainfed and *bas-fond* systems, which are found mostly in the south of Mali. An elaborate description of these production systems is summarized by Table 2.4.

Table 2.4: Brief Description of Rice Production Systems in Mali.

Characteristics	Rice Production Systems				
	Large irrigated perimeters with complete water control	Medium/small irrigated perimeters with complete water control	Large irrigated perimeters with partial water control	*Bas-fonds*	Natural submersion
Prod. unit size	2-15 ha, family farms.	0.1-0.5 ha, family farms.	1-2 ha, family farms.	0.1-0.25 ha, family farms.	
Where in Mali	*Office du Niger*, Sélingué Baguinéda.	San	Ségou (ORS) and Mopti (ORM).	Mostly in Mali-Sud.	Mostly in Mali-Sud.
Importance	30% of irrigated rice.	2.7% of irrigated rice.	60% of irrigated rice.	5% of Mali-Sud.	
Water source	continuous irrigation from a dam through primary and secondary irrigation canals.	water pump through primary and secondary irrigation canals.	river through primary irrigation canals.	rainfall water runoff with or without water control by diking.	over flooding rivers.
Technical support	managed and technically supported by government agencies. More and more private involvement.	Managed and technically supported by government agencies.	Managed and technically supported by government agencies.	none except by CMDT, Peace corps and NGOs when there is water control investment made by them.	none.
Rental costs to farmers	400-600 kg of paddy/ha.	generally in cash, cfa.F 56,000-150,000/family (*i.e.*, \$120-\$324/family).	180-250 kg of paddy per ha.	input costs (mostly labor) at his/her charge, no credit.	
Loan recov. rate	80-100%		60-90%		
Av. paddy yield	2.4-5 t/ha	2.4-5 t/ha	1.5-2.5 t/ha	0.2-3.1 t/ha	
Major constraints	large investment and maintenance costs.	large investment and maintenance costs.	highly dependent on erratic rainfall, degraded water control infrastructure.	highly dependent on erratic rainfall, low level of mechanization, exacerbating weed pressure.	the level of water goes up quickly when there are good rains; when rains are not good, starting is uncertain; attacks from fishes; harvesting tends to be difficult since there is no water control. Farmers end up harvesting in the deep water.

As mentioned earlier, government has focused its efforts to increase rice production on both expanding the intensive irrigated area and increasing productivity (yield) in these schemes, primarily because they are seen as an insurance against drought. Yet, the cost of expanding and maintaining those irrigation systems is extremely high (*e.g.*, the rehabilitation cost of the water control system of canals and diversion dam is estimated to be around 2,600,000 cfa.F/ha). As a result, the untapped potential of the *bas-fonds* has increasingly been explored as a complement to the large government schemes. But, there currently exists insufficient evidence to assess this potential and the constraints to expanding the *bas-fond* system.

2.3.4. National Rice Consumption

Rice represents about 16.7 percent of total per capita cereal consumption, and 6.4 percent of the total expenses of the Malian households (DNSI, 1994). While for sorghum, the less the income, the higher the share of sorghum consumption among the cereals (49% highest income group, 69% for the middle, and 72% for lowest), rice consumption is the highest among the middle income group (61%), followed by the high (59%) and low (44%) income groups (DNSI, 1994). Approximately 78.7 percent (1,769.71 kcal/year/individual) of glucidic energy supply, the main source of energy in the Malian nutrition, come from cereals (Semega, 1991). While millet, maize, and sorghum account for about 85 percent of cereal calories, rice provides the remaining 15 percent (Staatz *et al.*, 1989).

The 1988-89 consumption expenditure survey revealed that the national average rice consumption per capita is about 34 kg per annum, which in absolute terms is third among the cereals after millet and sorghum (Appendix 2.7). This average is higher in urban areas (58.0 kg) than in rural areas (24.3 kg). It appears that the major rice producing areas in the country (Ségou and Mopti) do not necessarily have the highest per capita rice consumption level. Rather, current trends in consumption indicates Tombouctou and Gao have the highest per capita rice consumption levels in the country, followed by Ségou and Mopti. These regions' per capita rice consumption are above the national average while per capita annual rice consumption in Koulikoro, Kayes and Sikasso is below the national average.

The consumption of rice has increased both in urban and rural areas since the 1980s drought. In Mali's strategic development plan (Ministère de l'Agriculture, de l'Elévage, et de l'Environnement, 1992), it is assumed that per capita rice consumption will continue to increase (especially if the consumer price decline continues) at a 2.1 percent and 0.4 percent growth rate in urban and rural areas, respectively. The bulk of the rice consumed comes from farmers own production (30.5%) or purchases (65.3 %)--Appendix 2.6. While in urban areas, most of the rice consumed is purchased in the market, up to 41.4 percent is purchased in rural areas (Appendix 2.6). Virtually all the rice consumed in administrative regions of Kayes and Koulikoro are purchased. Although domestic rice production has been increasing (Figure 2.5), the country has not been able to satisfy demand (Appendix 2.2).

2.3.5. The Institutional Environment

2.3.5.1. Introduction

The behavior and performance of *bas-fond* rice farmers depend on a wide range of factors, including the institutional environment that defines the set of opportunities available to them. This environment consists of the national research institute (*i.e.*, IER), the government agency responsible of promoting cotton production (CMDT), the main rice development agency of the country (*Office du Niger*), the market information system (*i.e.*, SIM), as well as government policies. All these organizations have effects beyond *bas-fond* rice farming and a complete discussion of them exceeds the scope of this research. It is nevertheless important to recognize their importance in influencing behavior in *bas-fond* rice production. This section provides a short description of these institutions by emphasizing their relationships with *bas-fond* rice production.

2.3.5.2. The Bas-fond Rice Research

Bas-fond rice research in Mali was launched in the mid-1980s by the national agricultural Research Institute --*Institut d'Economie Rurale* (IER)-- (Ahmadi *et al.*, 1995). It is undertaken primarily by the Farming Systems Research Program (ESPGRN) and the *Bas-Fond* Rice projects (PRBF), both based in Sikasso, as well as the Subsector Economics Program (ECOFIL) based in Bamako.

2.3.5.2.1. The Farming Systems Research Program

Farming systems research (FSR) was officially initiated within IER in 1979 with the creation of the FSR Research Division (DRSPR), now ESPGRN[1] (since 1994). Indeed, FSR began in Mali in 1977 in four villages around Fonsébougou in the Sikasso Region (with three national researchers-- a sociologist, a zootechnician, and an agronomist-- and two expatriates- a sociologist, and an agricultural economist) before its institutionalization. This research unit focused on upland crops with special emphasis on socioeconomic diagnoses. It is multidisciplinary in nature. It is currently supported by a consulting mission (KIT[2]) from Amsterdam and works in collaboration with the national thematic research programs and development agencies (mainly, CMDT). These collaborators participate in the design and implementation of the research agenda.

It was not until 1987 that the FSR included research activities directly related to rice and *bas-fonds* in its agenda. Based on a 1987 study of the potential and constraints to rice production in Laminibougou and Doumanaba, the FSR focused on varieties, planting methods, and herbicides trials, as well as demonstration plots between 1987 and 1989. These research trials were not only limited in number, but also site specific.

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[1] DRSPR stands for Research Direction on Farming Systems and Natural Resources (*Direction de la Recherche sur les Systèmes de Production Rurale)*, while ESPGRN stands for Farming Systems and Natural Resources Management Team (*Equipe de Système de Production et de Gestion des Ressources Naturelles*).

[2] KIT is the Netherlands Royal Tropical Institute. The KIT logistic and technical support in the ESPGRN has been provided in sequential research phases (DRSPR/Sikasso, 1992). The first phase (1979-83) continued the diagnostic studies initiated in 1977 and started the design of an extension methodology with the collaboration of CMDT. The second phase (1983-86) focused on animal traction and soil erosion while continuing the design of an extension methodology. In the third phase (1986-89), the project extended the research area covered first in the northern (in 1987) and then in the southern (1988) parts of the country. Concurrently, animal production, and women's role and activities were added in the research agenda. The fourth phase (1989-93) emphasized the concerned for sustainability by addressing issues related to soil degradation and overgrazing. The current phase is the fifth phase (1993-96).

Their research results showed a great deal of yield variability across trials (800 to 3800 kg of paddy/ha), depending on the type of *bas-fond*, plot topography, rice variety, soil fertility level, and cropping calendar. Consequently, the current knowledge concerning the *bas-fond* agroecosystem still has substantial gaps. For example, it is impossible to ascertain how the results obtained fit into the relevant agroecosystems, nor to assess the implications of these results for these systems.

2.3.5.2.2. Agronomic Activities

Two collaborative research programs have been initiated between IER and CIRAD: the *Projet Sol-Eau-Plante* (1985-1992), and the *Projet Amélioration de la Riziculture Inondée* (1988-1992). The *Projet Sol-Eau-Plante* was funded by the FAC, and it focused on hydrology and agronomy, using a pluridisciplinary team of researchers. The *Projet Amélioration de la Riziculture Inondée*, which was also funded by FAC, continued the agronomic research initiated by the *Projet Sol-Eau-Plante* (IER, 1992). These projects were technically supported by ORSTOM in hydrology, and IRAT in pedology and agricultural economics.

The research activities conducted by both projects in five sites (Kléla, Samogossoni, Bamadougou, Péniasso, and Kambo) included (1) monitoring and assessing the impact of existing water control infrastructures on yield, production practices and investments on other crops (mainly root crops), and (2) breeding and agronomic trials (in 1990 and 1991 in three sites). The breeding and agronomic research activities established that it was possible to increase rice yield from 1 t/ha (under traditional practices) to 3 t/ha at profitable levels using no water control with land preparation, improved varieties, and fertilization. The yield could only be increased to up to 3.7 t/ha under water control. This surprising result raised the crucial question of the effectiveness of these infrastructures.

2.3.5.2.3. Breeding Activities

Up to 1994, rice breeding activities were limited to on-station variety screening with minimal interaction with the FSR research program. The rice varieties tested (*Sativa* spp.) were originally screened or developed for the northern part of the country, which is much drier. Because southern Mali is more humid, these varieties were exposed to diseases and insects and could not perform to their fullest potential. Traditional varieties, which are generally *Oryza glaberima* species, tend to have stronger drought resistance and better adaptability to different flood water levels than the *Oryza sativa* species.

The current breeding program was initiated in 1994 with the objective to identify or develop varieties (Sativa spp.) that are resistant to the hydrological stresses (mainly drought and submersion) and diseases (mostly rice yellow mottel virus -- RYMV--, but also sheaf blight and pyriculariosis). In addition, the quality characteristics are considered, mainly, the protein content (varies very little in rice), the cooking quality (duration, water absorption capacity--puffiness, overnight storing, etc..), the amylase content (people like medium, non sticky), and the milling quality (recuperation rate).

The breeding activities are designed to develop varieties adapted to three water environments: (i) the shallow areas (about 10% of the research program target area), (ii) the medium areas (more than 70% of the target area), and (iii) the deep areas (about 20% of the target area). There are two problems with the deep water environment, namely, (a) when the water level goes up and remains high, varieties with good elongation potential (or capacity) are the most appropriate, but the yield tends to be lower because of reduced tillering, and (b) when the water level fluctuates, varieties with good submersion tolerance are preferable. Thus, the breeding program's strategy is to screen for submersion tolerance for the medium and deep water environment, and elongation ability for the deep water environment.

The main breeding activities are: (a) varietal screening from introduced material, (b) variety development, and (c) nursery maintenance for resistance to submersion, sheaf blight, and RYMV. However, some agronomy trials (*e.g.*, fertilization) have been conducted to assess performance. The breeding program is organized around five major stages: evaluating existing materials, initial assessment, preliminary varietal trials (on station, 3 replications), advanced comparative variety trials (on station, 6 replications), and on-farm trials (multi-locational, larger plots, 1-3 years of trial).

In general, traditional varieties' plant types (mostly sativa species) are more than one meter long (plant height), with 120-130 days to maturity, and they are all photosensitive. A number of "improved" varieties (mostly *glaberyma* species) from the initial breeding work have been extended. They are all introductions selected in the screening process (*e.g.*, BG 90-2, Gambiaka, and DM 16). A number of varieties developed locally have been proposed for extension (*e.g.*, IRAT 216, BR 4, and Khao Dawk Mali 105). Table 2.5 provides a summary of the major characteristics of these improved varieties.

Table 2.5: Main Characteristics of the Rice Varieties Extended in the *Bas-Fond*, Mali.

Variety	Water Depth (cm)	Days to Maturity (days)	Av. Paddy Yield (t/ha)	Plant Height (cm)	First Year of Extension to Farmers	Other Characteristics
IRAT 216	hydromorphic	100-110	3-4	78-93	1994	
BR 4	< 25	120	4-5	95-105	1994	
BG 90-2	< 25	140	4-5	85-90	> 20	sensitive to RYMV[a]
Khao Dawk Mali 105	> 50	140-150	3-4	140-160	1994	Lodge after flood recedes
Gambiaka	> 50	150	3-4	150-170	> 20	Lodge after flood recedes
DM 16	> 50	160	2	170-190	> 20	Lodge after flood recedes

[a] RYMV stand for Rice Yellow Mottel Virus.

2.3.5.2.4. Sub-Sector Economics Program (ECOFIL)

ECOFIL was created in 1994 within the context of IER restructuring. Its creation grew out of the recognition that research on the input supply system, crop commercialization, processing and consumption were largely occasional and limited in scope (IER/DPAER, 1994). Furthermore, it became increasingly apparent that there was a need to take into account constraints faced by and interactions between different economic agents at different levels of the Mali's food system in order to improve the economic impact of agricultural research. The success of a maize subsector study initiated by IER in 1992 with the collaboration of PRISAS, MSU and the PRMC set the stage for the creation of ECOFIL.

The program's objectives are to: (1) improve the understanding of linkages and inter-dependence between different economic agents in Mali's food system, (2) contribute to the identification of the potential for improving the productivity of various crops' subsectors and the constraints to improving the performance of the overall food system, (3) conduct research activities on the identified constraints in order to improve and/or assess policy decisions, and (4) provide guidance to improve the effectiveness of other research programs.

To launch this program, three priority research areas were identified, namely the livestock subsectors, the rice subsector and the groundnut subsector. To date, five research projects have been initiated, two on livestock[1] and three on rice. Research activities on rice have focused on (1) the impact of the introduction of different types of mills on the competitiveness of the rice subsector, (2) characterizing and assessing the economic performance of different rice production systems in Mali (mainly the *bas-fond* production system, and the irrigated production system with complete water control, and the production systems with controlled submersion), and (3) production cost studies. This research is part of the *bas-fond* rice project. The production costs study was conducted in a limited number of sites. Concurrently, the program conducted a socioeconomic surveys potatoes and has been involved on impact studies.

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[1] The livestock research projects are (1) a study of veterinary products marketing channels, and (2) a diagnostic analysis of production and distribution channels of agro-industrial by-products.

2.3.5.3. Extension Information, Sources of Purchased Inputs, and Credit

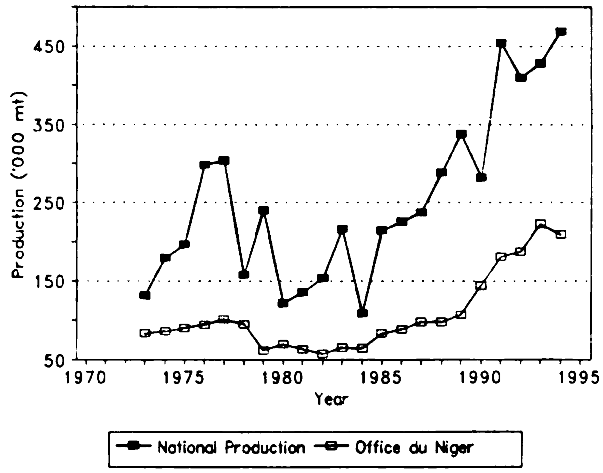
2.3.5.3.1. Office du Niger

The *Office du Niger* was created in 1932 by the French with the objective to (1) primarily produce cotton in order to secure its adequate supply for and revamp the French textile industry after World War I, but also (2) to produce rice for cotton farmers to ensure food security and possibly export. After independence, *Office du Niger* became a semi-autonomous public agency which rents land to farmers for a fixed in-kind fee. After payment of their fees, farmers were required to surrender all their production to the Office at the official price, except an allowance for family consumption.

Due to technical (drainage) and phytosanitary problems, cotton production was abandoned in 1970. Rice then become the major crop with 45,500 ha irrigated from a dam on the Niger river (Makarla-- 1947).

Initially, *Office du Niger*'s activities included selling seeds, oxen and equipment to farmers, providing extension services, marketing, procurement, threshing, transporting, and milling paddy, designing agricultural equipment, and constructing and maintaining the irrigation network. From 1984 on, threshing, land tenure and bagging management, marketing, and procurement have been progressively transferred to village associations (AVs). Currently, *Office du Niger* accounts for a major share of Mali's domestic rice production (Figure 2.6, and Appendix 2.8).

Figure 2.6: *Office du Niger* and Domestic Rice Production in Mali, 1970-94.



In the 1970s and 1980s, *Office du Niger*'s rice production level represented about 40-42 percent of the national production (Appendix 2.8). This share has increased to around 47 percent in the 1990s, mainly due to a productivity gain that increased the yield by about 50 percent (Appendix 2.8).

2.3.5.3.2. CMDT (Compagnie Maliènne de Développement des Textiles)

CMDT was originally CFDT (*Compagnie Française de Développement des Textiles*). As CFDT, the focus was exclusively on cotton production to support the French cotton industry and to provide a source of cash income to indigenous farmers so they could pay their taxes. In 1974, CFDT became CMDT, with 60 percent ownership by the Malian government and 40 percent by CFDT. Cereals were then introduced in rotation with cotton. Production was intensified (animal traction, fertilization, and improved seeds) with revenues from cotton production. This promoted animal husbandry, viewed as a way to save income. Initially, CMDT ensured the collection and purchase of cotton. But, starting from 1975, these activities were progressively transferred to village associations (AVs) which buy cotton from member farmers and sell it to CMDT. Now, this is 100 percent an AV activity.

The AVs were created with the objective to (1) increase farmers' participation and management control in production, (2) improve the credit system set up by CMDT, (3) and guarantee and simplify exchanges (especially cash transactions) between CMDT and farmers. The basic structure of AVs is based on traditional organizational units of the village (*i.e.*, the village council, the village council of household heads, and *tons*). AVs have two sources of revenues: costs of the transactions initially supported by CMDT but now transferred to the AVs and which are paid to the AVs by CMDT (initially cfa.F 2,000 and now 2,750), and the value of the output weight difference (if any) when weighted by the AVs in the villages and by CMDT. These revenues are used to fund building storage rooms; loans to farmers hurt by drought, illness, or other problems; administrative dues; maintenance and management of primary health services (*e.g.*, pharmacy, and maternal and child health), and loans for agricultural inputs/equipment.

In 1983, CMDT set up a special service to ensure the link between research and extension. This linkage is materialized through (1) CMDT's participation in the specialized research technical committees, (2) annual meeting between research and CMDT to discuss research projects, (3) joint on-farm trials involving research and CMDT, (4) researchers' participation in the design of extension methods and bulletins, and in the training of extension agents.

In 1988, CMDT's status changed from a state-run organization to a semi-autonomous industrial and commercial enterprise to which the State assigned two missions through a performance contract called *Contrat Plan Etat - CMDT - Producteurs*. These missions are (1) integrated development of the cotton subsector, and (2) public service provision of rural development activities. The integrated development mission is achieved through two functions: (a) an industrial and commercial function involving buying (from AVs, OHVN and farmers), collecting, shelling cotton seed, and selling cotton fiber and seeds, and (b) developing all activities related to the cotton-based production system. Such activities are research on cotton and cotton seed production, providing advice related to maintaining the production potential, extension activities on crop production/livestock integration and on women's activities, maintaining rural roads, and promoting functional literacy and farmers' organizations. These activities are funded by the cotton subsector. The public service provision of rural development activities include village-level wells and mechanization. These latter activities are government-funded.

Given its new status, CMDT freely chooses its partners and freely set prices no higher than preset ceiling producer prices (cfa.F 125, 105, and 90 per kg for the 1st, 2nd, and 3rd grade cotton seeds, respectively, in 1995). The ceiling prices are supported by a stabilization fund that is itself funded from CMDT cotton subsector's gross margin. If the net margin is positive, 35 percent of this fund is given back to producers as rebates.

Initially, rice production technical support was provided by the government's *Projet Riz*. CMDT took over from this project in the 1980s through specialized extension agents. Under CMDT, rice production is financed by cotton in the sense that extension agents and in-kind loans (inputs) are paid for from cotton revenues. In other words, a farmer must be a cotton producer to have access to inputs through CMDT. But, a farmer's input loan amount depends on his credit limit (no more than 36% of his/her cotton revenues). It is estimated that about 85 to 96 percent of rice producers in CMDT regions are monitored by CMDT (26,100 production units). Farmers tend to divert cotton inputs for rice or other crops.

CMDT extension activities on rice are performed by two offices: the *Bureau d'Etude* and *Projet Petits Bas-Fonds*, and the Production Systems Monitoring and Evaluation Office. The primary activity of *Bureau d'Etude* and *Projet Petits Bas-Fonds* is to improve the traditional *bas-fonds* by (1) evaluating the technical and economic feasibility of water control investments in interested villages, and (2) constructing and maintaining water control infrastructure in those *bas-fonds* whose feasibility study justifies the appropriateness of the investment. Various donors have provided the funding necessary to make these investments for over 16,630 ha of *bas-fond* area-- over one-third the are of the *Office du Niger*-- (Appendix 2.9).

The monitoring and evaluation of production systems was initiated by CMDT in 1981. It now has 41 enumerators in 41 villages (especially since 1988) for the survey modules: village level, household level and parcel's level. Data are collected on a permanent basis and include: infrastructure, population, livestock holdings and equipment, and production practices. In addition, specific surveys are initiated to improve understanding on a specific issue of interest.

2.3.5.3.3. Market Information System

In Mali, several organizations routinely collect data on food crops. The most important of these organizations are the SIM (Market Information System) and the DNSI (National Directorate of Statistics and Information). The SIM is a division of OPAM. It was designed in the late 1988 as a coordinating unit that would collect, process, analyze, and disseminate timely market information to serve private operators (farmers, traders and consumers), decision-makers, and researchers (Aldridge, 1992). In each market, SIM collects producer price, assembly price, and consumer prices, and make this information available to the public through the national radio and press releases (weekly, monthly and bi-annually bulletin) and the national television. By contrast, the DNSI, which is within the Ministry of Plan, is responsible for macroeconomic and census data. These data, which are published in a weekly, monthly or annual bulletins, are generally medium to long-term in nature. The primary clients are decision-makers in the public sector.

Most of the other data generating organizations use data collected by SIM and DNSI. Their role is nonetheless important. For example, the SAP (*Early Warning System*), monitors chronically food-deficit regions to inform government and donors about the overall food security of the population in these areas. The Famine Early Warning System (FEWS) is funded by USAID and has the responsibility to identify early, potential food-supply and access problems with data collected by national services. Other data or information generating institutions are: Rural Development Organizations (ODR) within the Ministry of Agriculture, the National Directorate of Economic Affairs (DNAE) within the Ministry of Finance and Trade (which enforces government regulations on commerce, including the grain trade), private traders' information systems, ad hoc projects, and IER.

The information generated by these organizations are made available to the public through the national television and radio (RTM), rural radio stations, newspapers, bulletins and annual reports. Through a process of learning by doing, these organizations have the potential to play a leading role in the Malian economy by directing production in response to the evolving consumer demand and changing production technology, and generating the needed information to monitor market performance. Their aim is to create an open, competitive, transparent and efficient market environment, and put the country in a position to generate reliable time-series on farm-level prices and quantities produced and marketed. These data will allow quantitative analyses on the degree to which farmers have increased their production and sales in response to the liberalization process, facilitate the private sector's ability to respond to the new opportunities, and provide the information necessary for policy design and assessment.

2.3.6. Government Policies

Important goals of the Malian rice policy have been to (1) reduce imports, (2) stabilize urban prices and supply, (3) increase and stabilize rice farmers' incomes, and

(4) achieve nationwide food security in rice. The primary mean to achieving these goals have been the exploitation of water control resources at the *Office du Niger*, which makes *Office du Niger* the centerpiece of rice policy in Mali. Consequently, most of government investment effort has been focused on the irrigated rice production systems. Even though there seems to be increased production of rice outside the *Office du Niger* system, much of government attention is still focused on the *Office* (Déme, 1993).

Prior to the 1980s, rice policy in Mali was characterized by an official public monopoly manifested by (1) panterritorial and panseasonal prices set by the government[1], (2) official state (OPAM) monopsony and monopoly in grain trade at all levels, (3) public subsidies to producers (inputs) and consumers, and (4) a public monopoly in foreign trade. The official state monopoly was never effective in the market for coarse grains. State purchases ranged between 10 and 40 percent of the marketed volume, and exceeded five percent of total estimated production in only two of the twenty years between 1960 and 1980 (APAP, 1988). State control over the paddy market was much more effective, however, as virtually all paddy was produced on state-managed irrigation schemes where farmers were required to sell their production through an official channel and had no other alternative given the lack of a market for paddy and the absence of private mills (APAP, 1988). This policy resulted into (1) frequent rice supply shortages, (2) speculative behavior in the product market, and (3) low and unstable prices for basic grains.

[1] In principle, prices for each crop were set on the basis of the estimated cost of production, but in fact the process was based on compromise among the interests of consumers, processors, and state budget, with the result that official prices were maintained at low levels (APAP, 1988).

The policy response to these problems involved numerous initiatives. In the 1980s, a newly designed food strategy (1978), a five-year collaborative effort in grain market reform called PRMC (*Programme de Restructuration du Marché Céréalier or Cereals Market Restructuring Project*)[1], and the relaunching of adjustment programs (PASEP in 1988 and PAS in 1991[2]) transformed the rice policy environment. Among these major policy initiatives, the ones that stand out the most include the increase in cereals producer prices[3], cereals marketing liberalization under the PRMC (import tax reduction from 32.7 percent to 10 percent in 1981 in order to deal with the growing food deficit, dismantelling of OPAM monopsony in 1986, and the removal of legal prohibition of private trade of paddy in 1989, which resulted in higher consumer prices and provided strong incentives for illegal imports), and the removal of producer and consumer subsidies in 1987 (except for paddy purchased by parastatals).

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[1] The PRMC was initiated in 1981 and it proceeded in three phases: (1) a phased increase in official grain prices aimed at bringing them in line with market prices and providing higher incentives to farmers, (2) progressive liberalization of private grain trade, beginning with domestic trade in coarse grains and extending gradually to domestic trade in rice and to export of local grain (APAP, 1988), and a third phase in 1990-93.

[2] PASEP is the Sectoral Adjustment Programme for Public Enterprises, while PAS is the Structural Adjustment Programme.

[3] The increase in producer prices was brought about by a reassessment of minimum wage rates (cfa.F 250/day in 1977/78, 400 in 1980/81, and 600 in 1982-1988). The expected increase in production was constrained by factors such as poor climatic conditions (e.g., 1972-1974 and 1883-84 droughts), food aid, and world market prices.

A lack of a good understanding of the domestic grain market compromised the reform[1]. This was exacerbated by variations in rainfall, the uncertainty of distribution, the vulnerability of crop production to drought, and the government lack of financial and administrative power to guarantee the official price to consumers and producers. The end result in this environment was the instability in the grain market. Nonetheless, the government and many of the donors remain committed, in principle, to guaranteeing prices to farmers as an incentive to increase production (APAP, 1988).

In the late 1980s, the improvement of climatic conditions coupled with increased World and domestic producer price for rice helped boost domestic rice production. The promotion of small mills, especially from the late 1980s onwards help changed the structure of the subsector by reducing concentration, and changing marketing options of farmers and retailers (Diarra, 1994). Three market price discovery mechanisms are used by market agents in transactions: (1) private treaty (*i.e.*, private negotiation of the terms of the deal, usually using prices broadcast on radio), (2) administered pricing (only for *Office du Niger* purchases from farmers), and (3) sealed bid (*Office du Niger* obligation from the government --under a contract-- to sell by seal bid). In 1990 the World Bank

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[1] For example, it was assumed that the market is made up of two groups of economic agents: on one side farmers who are net sellers, and on the other side consumers who buy their grains (traditional assumption in market analysis). An innovative producer survey research conducted by Dioné (1989) in 1985/86 under Michigan State University Food Security II Cooperative Agreement in four producing regions of Mali (CMDT Nord and Sud, and OHV Nord and Sud) shed considerable light on this issue. In particular, the study revealed that many farmers make cash purchases of food. In other words, a significant portion of farmers join the ranks of consumers (they are net buyers of food), especially in bad years, adding to market demand. In good years, many urban consumers who would buy grain in a bad year, in fact obtain grain through non-cash exchanges with relatives in the rural areas. As a result, market demand may be significantly lower in good years than in bad years. This dynamic in achieving self-reliance has important implications for market reforms in terms of the grouping or typology of producers and traders and their market behavior that have been discussed extensively by the APAP 1988 Staff Paper No 23.

recommended that paddy price be maintained at at least cfa.F 70 per kg, because at as low as cfa.F 60 per kg of paddy, 70 percent of the farmers would not be able to cover their costs of production.

In the 1990s, the rice policy environment has been characterized by greater market liberalization, forecasts suggesting that real World prices of rice will continue to rise in the next ten years, China becoming a deficit country, the launching of structural adjustment programs in neighboring countries, price protection measures set up in the two major countries exporting rice to Mali (Guinea and Mauritania), and more recently, domestic currency devaluation.

CHAPTER THREE
RESEARCH APPROACH AND DATA COLLECTION

3.1. Scope of the Study

This research focuses primarily on *bas-fond* rice production. However, as argued in the conceptual framework section in Chapter One, the study also analyzes how this system fits into the broader *bas-fond* farming system, mostly in terms of competition for labor with other crops. Because cotton, sorghum, and maize are major competitors of rice for labor, and represent farmers' main production options, a more detailed analysis of the relative profitability of these enterprises and demand conflicts is necessary. Although other options are available to farmers, only these crops are considered in order for the research to remain manageable, both financially and timewise.

The study also analyzes how *bas-fond* rice production fits into the broader rice sub-sector, in terms of domestic rice supply sources, for whom and when the supply is available, and with respect to rice quality. The geographical area under consideration is the administrative Region of Sikasso, which covers the CMDT regions of Sikasso and Bougouni. This area, located in the southern part of Mali, is where most of the country's *bas-fond* rice is grown.

Finally, in order to understand the *bas-fond* rice production systems and to assess potential for increasing their production level, it was necessary to collect a wide range of farm-level data, including detailed input/output data and socio-economic factors affecting rice production in these villages, as described in section 3.2.

3.2. Contacts and Sources of Data

The data required for this research was collected in two phases. The first phase (July 17 to September 30, 1995) involved reviewing available secondary data, and carrying out an in-country orientation tour and rapid field appraisal. Based on the understanding developed in the first phase, the second phase was undertaken (December 7, 1995 through April 12, 1996). This phase focused on designing and administering a formal field survey and informal group discussions in selected villages of Mali-Sud. This section presents the three data collection methods used during these two phases.

3.2.1. Review of Available Secondary Data

The review of available secondary data provided background data and information on the physical and institutional environment, as well as historical data on crop production, price, rainfall, demographics, and policy initiatives. These data were collected during visits/meetings with officials at WARDA, the Mali's national Institute of Rural Economics (IER), the National Direction of Statistics and Computer Science (DNSI), the National Direction of Agriculture (DNA), and CMDT. The data were used to develop an overview of the rice sub-sector in Mali.

3.2.2. Field Rapid Appraisal

The objective of the in-country orientation tour and the rapid field appraisal was to develop a general understanding of the farming systems in Mali-Sud, especially its *bas-fond* component. It was conducted by a research team, including the author and three national researchers[1]. In an effort to promote inter-program collaboration between Malian researchers called for by IER administration and donor institutions, the main IER programs involved in *bas-fond* research (the Farming Systems and *Bas-Fond* Rice research, all based in Sikasso) were contacted to collaborate in this research effort. In each village, the team was joined by a local representative from CMDT, the Farming systems research program, or Séné Yériwaso (a private consulting firm).

During the visits in the villages, discussions with key informants and group interviews with researchers, extension agents, and farmers provided information on soil types, land tenure, crop varieties, cropping patterns, animal traction, use of modern input (fertilizer, seed treatments), water control management, access to credit, and availability of extension support. Particular attention was paid to identifying issues associated with the level of investment in *bas-fonds*, as reflected by water control infrastructure and the use of purchased inputs. This effort built on a previous IER exploratory study on the *bas-fond* rice production carried out in 1994 by ECOFIL (Coulibaly, 1995)

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[1] These researchers are: Bakary S. Coulibaly (agricultural economist), Ousmane Sanogo (agricultural economist), and Simpara Mamadou (agronomist and hydrologist).

3.2.3. Farm-Level Surveys

3.2.3.1. Brief Overview of the Questionnaires

Insights gained from the rapid appraisal phase of the study guided the design of field questionnaires. The objective of these surveys was to gather additional and more specific data about the *bas-fond* sub-systems, necessary to achieve the study's objectives. These data were collected through structured surveys with farmers and farm/field observations. Three different types of survey modules were implemented, each designed to collect a specific type of data. These include: (1) a village-level questionnaire, (2) a production unit (PU) level questionnaire[1], and (3) an individual parcel questionnaire (split into two modules, one for recall and another for monitoring field activities[2]).

The village-level module focuses on the village,which was administered to the village chief, and was designed to explore further the social organization, land tenure, *bas-fond* history, land distribution guidelines, and conflict resolution issues that effect on *bas-fond* rice production. The PU module solicited data on households' demographic characteristics (*e.g.*, sex, age, and relationships to the head of the household, active labor supply), land holdings and farm assets, household production objectives and priorities, land distribution practices, and farm types and farm operations. The parcel-level module, which was administered to one farmer (with a plot in the *bas-fond*) in each

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[1] A PU is defined here to include individuals involved, on a medium to long-term basis, in the household's production activities (they form the production unit) and are fed from the household's production. It can be a single nuclear family or a group of nuclear families.

[2] It was necessary to split the individual parcel questionnaire into two modules because the survey was launched half way into the cropping season. Activities already completed at the time the survey started were grouped into the recall module, while those expected to be undertaken during the survey were grouped into the monitoring module.

selected household, collected data on the farmers' agricultural production objectives and priorities, the institutional backstopping, cropping calendar, time spent on farm operations by labor category, input use level, expenditures on hired labor and purchased non-labor inputs, production constraints, and crop yields.

3.2.3.2. Questionnaire Administration

These three questionnaire modules were administered by 12 trained enumerators, each based in a selected village. While the village-level and PU-level questionnaires were administered during one or two visits, the farm-level questionnaire was administered through multiple visits as a monitoring activity, according to the timing of the activities. This approach to data collection, known as the cost route approach, has been used by many researchers in Africa[1] (Spencer, 1972; Norman, 1973; Kamuanga, 1982; Fotzo, 1983; and Eponou, 1983).

Although the cost route approach has often been criticized on the grounds that it is not cost-effective and farmers may not sustain their interest during repeated interviews, it was used in this study in an effort to reduce recall errors, and farmers remained cooperative despite frequent interviewing. In most applications of the cost-route approach to data collection, the frequency with which the farmers are formally interviewed depends on the researcher's confidence in the ability of the farmers to

[1] Other methods for collecting micro-level data from farmers include model or case farm study, farm account book, and farm business survey. These alternative approaches were not used either because the farms studied are atypical and could therefore not be used as representing a given system of production (as is the case for model farm study), or because farmers in this part of the world do not keep farm records (case for model farm study).

remember the required details on a past operation. In our case, farmers were interviewed once for major activities that last no more than a few days. Multiple visits with recording were used for activities lasting more than a week.

3.2.3.3. Enumerators Training and Supervision

Both enumerators and data entry agents were recruited in July 1996 from a set of individuals who had previously served as enumerators in formal IER/ECOFIL's surveys. Each enumerator participated in a two-day training course consisting of instructions about the purpose of the study, definition of the terms used in the survey (*e.g.*, PU), and the research schedule, as well as making sure that the questions have the same interpretation for all enumerators. At the end of the training, each enumerator was assigned to a village, then the enumerator was taken to this village where he resided throughout the survey after a formal introduction to the village chief and his assistants. Actual data collection started in September 1995 and proceeded until March 1996.

The research team closely monitored survey implementation within the limits imposed by the logistics and budget constraints. The main objectives of this supervision was to ensure that the enumerators' work was on schedule, to check completed questionnaires for errors and completeness, to provide instructions, explanations and guidance to the enumerators, as well as to carry out group interviews with farmers.

3.2.4. Informal Group Discussions in the Villages

In addition to the formal surveys, focused informal group discussions were carried out in each selected village to inform issues identified during farm-level data collection, but for which the data collected was insufficient to adequately address. Such issues included the village land tenure both in the *bas-fond* and in the uplands, the female gender dominance as *bas-fond* farmers, and the strategic importance of rice production for the households and the individual farmer. Each group interview lasted about two hours and involved separate groups of male and female farmers in the villages. These discussion groups were held during the monitoring tours in the villages.

3.3. Sample Selection Procedure and Methods

Given the diversity of *bas-fond* production environments in Mali-Sud, this research was designed as a case study. Based on the available funding and concerns for assembling a manageable data set, a purposive sample of twelve *bas-fonds* was selected for the study. Village selection was done in Sikasso in collaboration with the local Farming Systems (ESPGRN) and *Bas-Fond* Rice (PRBF) research teams. Researchers proceeded in three phases.

First, relying on the level of knowledge available on the *bas-fonds* in Mali, the research team drafted a list of variables assumed to influence agriculture in the *bas-fond*. This list was then discussed with the researchers and narrowed down to five key categorical variables to be used as a basis for identifying *bas-fonds* that will be included in the sample. These variables are: (1) the existence or not of a water control infrastructure, (2) the village's cotton production history (none, recent crop, "old" crop), (3) the intensity use level of the *bas-fond* (one crop, two crops, more than two crops in a year), (4) the distance to a major market (less than 15 km, more than 15 km), based on walking distance, and (5) the gender of farmers cropping in the *bas-fond* (male dominated, female dominated, male and female equally represented).

Second, a two-way table with a number of *bas-fonds* suggested during the meeting and the key factors identified was then drafted and reviewed by the researchers in order to graphically show the distribution of these five factors and identify biases. Also, the concern to have a sample that took into account the spatial distribution of rainfall was considered. At the end of this review process, six *bas-fonds* were selected for the CMDT region of Sikasso--hereafter referred to as Sikasso villages-- (Kado, Kafuziéla, Longorola, Niéna, Péniasso, and Sikasso), while six were identified in the CMDT region of Bougouni--hereafter referred to as Bougouni villages-- (Banko, Diassola, Faradjélé, Faradié, Sola, and Solo). Table 3.1 presents some characteristics of these villages.

Table 3.1: Some Characteristics of the Sampled *Bas-Fond* Villages, Mali.

Villages	Population	Latitude	Longitude	*Bas-fond* Area (ha)	Arrondissement	Water Control
Kado	3,452	10.5568	-5.7676	108.18	Kadiolo	yes
Kafuziéla	1,625	11.4381	-5.6103	69.32	Sikasso	no
Longorola	540	11.4552	-5.6111	330.00	Sikasso	yes
Niéna	3,457	11.4255	-6.3523	128.50	Niean	yes
Péniasso	840	11.4710	-5.6279	125.00	Sikasso	yes
Sikasso	73,000	11.3094	-5.6659	na[a]	Sikasso	no
Banko	806	11.1086	-7.4169	35.00	Garalo	no
Diassola	221	11.9251	-7.0278	3.00	Sanso	yes
Faradjélé	438	11.3509	-7.6254	30.32	Bougouni	no
Faradié	398	11.9832	-7.4930	34.00	Dogo-Sikasso	yes
Solo	1,400	11.7240	-7.6981	32.00	Keleya	no
Sola	1,900	11.2841	-7.3148	300.00	Zantiebougou	no

[a] "na" indicates that this statistic was not available and could not be measured.
Source: Survey data.

Third, researchers went into these villages, described the study objectives, the random selection procedure and the entire research process and schedule to the village chief and his collaborators, and asked for their verbal consent to include the village in the sample. During this process, the researchers did not experience any refusal or drop out.

After selecting the research sites, the first task was to select a sample of households. This was left to the enumerators who were required to use the same selection method and procedure. From the list households with at least one parcel in the *bas-fond* in each of selected villages, nine of the 12 enumerators selected a random sample of 35 households in collaboration with the village chief and extension agents. Only 30 were included in the sample while the remaining five were supposed to be used to replace drop-outs or refusals, following the order of selection[1]. In two of the remaining villages, all households were selected because the total number was less than 30. These villages are Diassola (19 households) and Faradjélé (27 households). Finally, in the remaining *bas-fond* (Sikasso), only 20 of the selected 35 households were interviewed due to difficulties to contact the farmers who are in a peri-urban area. In total, 336 households were randomly selected in the 12 *bas-fond* sites.

In each selected household, one of the household's *bas-fond* parcels was randomly retained for monitoring. At the beginning of each new interview, each enumerator described the study objectives to each individual respondent and asked for her/his verbal consent to the interview before administering the questionnaire.

3.4. Data Preparation and Analysis

Data preparation involved data entry and cleaning. Data entry proceeded in three phases. First, SPSS[2] data entry file were designed and created. This involved a definition of the variables and their labels, variable types, value labels, and valid entry specifications (*i.e.*, variable value ranges). Second, the questionnaires were coded to simplify data entry and analysis. This was necessary because the questionnaires were

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[1] During the questionnaire administration, the enumerators did not experience any refusal or drop out.

[2] Statistical Package for Social Sciences.

only partially precoded. To do this, it was imperative to develop a code sheet. Each respondent to the three questionnaire modules was given an identification number. All data files used this identification number rather than the name of the respondent. One administrative file linking the village, the households and the parcels was used as a check. The coding was done by the data entry agents, using the code sheet.

Third, the researchers then cross-checked the coded questionnaire to minimize the errors and ensure consistency. In general, individual performance for enumerators and data entry agents was satisfactory. Actual data entry started on February 1, 1996 with three agents and continued until April 11, 1996. While the data were entered as SPSS files in Mali using MSU and IER/ECOFIL computer facilities, data cleaning and analysis were done at the MSU campus in the United States. Data cleaning was done from April through June 1996 using visual inspection and SPSS cleaning rules and ranges. Data analysis then followed, starting with detailed examination of the data to identify mistakes and extremes, using histograms, boxplot, and simple statistics (mean, mode, median, variance). In addition, the statistical assumptions of normality and homogeneity of variances were evaluated using the SPSS test of normality (and probability plots) and the Levene test procedure, respectively.

3.5. Data Limitations

3.5.1. Representativeness of Bas-Fonds and Rice Production Systems

It should be noted that while the five factors used to select the sample villages may describe diversity in *bas-fonds* in Mali-Sud, they may not be equally important.

Therefore, it would have been necessary to determine their relative importance in terms of factors such as area to assess (ex-post) the representativeness of the selected sample and the extent to which the inferences that are drawn from this sample can be generalized to the Mali-Sud area. Unfortunately, the information necessary to facilitate this assessment was not readily available.

However, although the study was designed as a case study, emphasis was given to selecting a sample that is widely dispersed across the *bas-fond* villages in order to be able to make valid and reliable inferences about the various sub-systems and the overall Mali-Sud *bas-fond* rice production. To address this concern, a stratified random sample of *bas-fonds* could have been selected, using toposequence as a key stratification variable, since it is likely to be a major determinant of farmers' investment in improved technologies[1] (especially variety and fertilizer), in addition to variables such as farm household equipment. Three toposequence strata are often referred to in the literature, namely, low, medium and high elevation fields. Although these concepts are theoretically appealing, they are difficult to operationalized, since the meaning of each stratum is defined relative to the particular *bas-fond* under consideration. Thus, it is difficult to make inter-*bas-fond* comparisons. As a result, in order to use toposequence as a meaningful stratification variable, one needs objective criteria to measure not the toposequence but the service that it provides (*e.g.*, water depth, duration of standing water).

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[1] A major characteristic of all *bas-fonds* is that there is a gradient of water availability and soil texture and related physical and chemical properties along the toposequence. As a result, scientists use the gradients along the *bas-fond* slopes to study crop response to stresses. These studies showed the value of screening and understanding processes related to soil properties and water availability along the toposequence (Carsky and Masajo, 1992). In addition, farmers often utilize the diversity of conditions found along the toposequence to diversify their crops.

Because of the difficulty involved in identifying and measuring objective indicators of the service provided by the toposequence, the research team decided to use a purposive sample of *bas-fonds* systems. The option of selecting a random sample of *bas-fonds* systems was rejected because a random sample ensures representativeness only if it is large enough. With a small sample, it is necessary to know the population characteristics in order to ensure representativeness through stratification. While this information was not readily available, a simple typology of *bas-fonds* systems was developed through interviews with key informants. Using this typology as a guide, systems were selected to represent each major *bas-fond* type.

3.5.2. Cross-Sectional Analysis Problems

Given the one-season nature of the data used in the analysis, the findings reported in this dissertation are specific to the particular conditions that prevailed at the time the data were collected, especially for rainfall. Time series would have enabled one to take into account intertemporal considerations in the farmers' environment. This pioneer research could not possibly have been done with time series. Subsequent research would have the possibility to integrate intertemporal variations.

3.5.3. Measurements and Estimation Errors

A good deal of the data collected for this study is recall data. This was especially the case for labor use and input application rates. Typically, recall data are associated with the concern for reliability of the answers provided by the respondants, especially when the information is requested for an operation a farmer performed way back in the past. To minimize such errors, SPSS exploratory techniques (*i.e.*, examine, rules and ranges) were used to examine the data and eliminate outliers. These techniques also helped identify and correct data entry errors and response inconsistencies.

CHAPTER FOUR
BAS-FOND FARMERS CHARACTERISTICS AND RICE PRODUCTION PRACTICES

4.1. Introduction

Because government investment directed at increasing rice production has previously focused primarily on irrigated systems, very little information is available as to the importance of *bas-fond* rice production and its potential for greater intensification. To fill this information gap, this chapter (1) summarizes the characteristics of *bas-fond* farmers (*i.e.*, education, gender, size of production unit and labor availability), (2) describes farmers production practices and (3) discusses the need for effective water control.

4.2. What Is a Bas-Fond

In Southern Mali (Mali-Sud), *bas-fonds* are narrow inland valley swamps that used to be permanent rivers, but which have dried up with declining rainfall. During the rainy season, the water table in these swamps rises due to overflow from small rivers, seepage and slope surface runoffs from adjacent upland, generally supplying water throughout the growing season (Figure 4.1). The standing water level in these *bas-fonds* ranges from a shallow/medium depth (25-50 cm, 2-5 months) to deep water (50-100 cm). Their length may extend over 25 km and their width varies from around 10 m in the upper levels to about 100 m in their lower stretches.

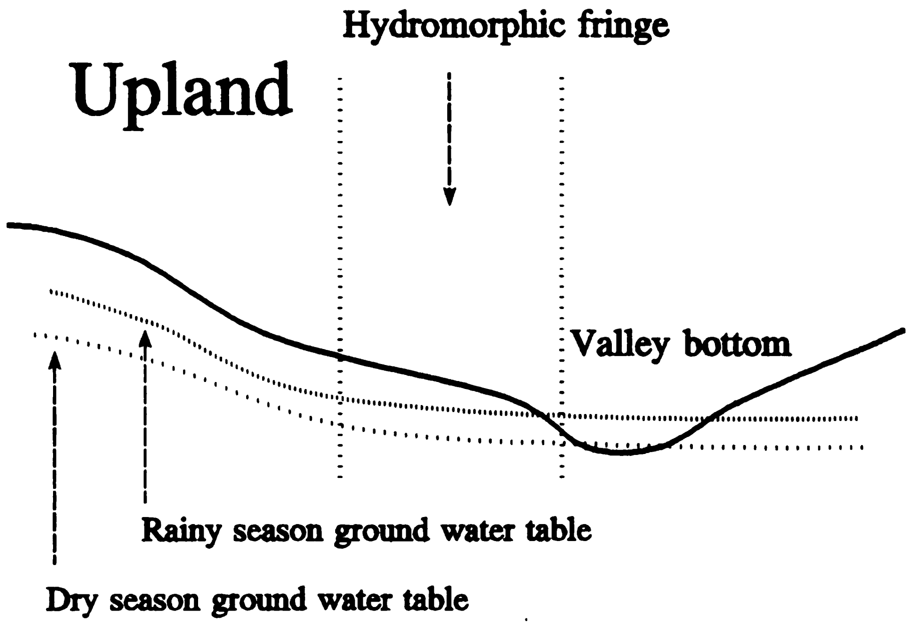

Figure 4.1: Schematic Representation of a *Bas-Fond* Profile, its Fringes, and Ground Water Table.

Because the rate of soil erosion is high in the valley slopes due to limited vegetative coverage, finer particles of sediment accumulate in the bottom of the *bas-fond*. Based on discussions with farmers, both soil erosion and sedimentation create a gradient of soil structure and related physical and chemical properties along the toposequence in the *bas-fond*, an observation which is also supported by the literature (Carsky and Masajo, 1992). In *bas-fonds* without water control, the valley bottom tends to be sandier than the fringe because the rapidly flowing water prevents sedimentation. Various studies have established a close relationship between the edaphic (*i.e.*, soils) and hydrologic (*i.e.*, water) conditions along the *bas-fond* toposequence and variable rice crop growth in the valley (Bertrand, 1973).

Despite their small size (Table 4.1), Mali-Sud's well-watered *bas-fonds* offer farmers an opportunity to produce rice during the rainy season and to cultivate various upland crops in the valleys during the dry season. While this potential is important, it has not been fully utilized. Mali-Sud possesses the largest potential for *bas-fonds* in Mali, equal to about 3-5% of the total Mali-Sud land area. While an exhaustive inventory of all *bas-fonds* in Mali has yet to be made, a partial inventory conducted by CMDT in 1992 revealed a potential of 48,657 ha of *bas-fond*[1], with only five percent hectares under some type of water control (CMDT, 1992).

4.3. Stylized Facts about the Sampled Villages

Although this research focuses on food production rather than social organization, it was apparent to the researchers that the 12 villages sampled differ in terms of socio-cultural characteristics. However, there exists broad social characteristics common to these villages. First, in all villages, kinship relationships strongly influence access to land. Second, with the exception of "urban villages" such as Kado and Sikasso, the villages exhibited dispersed and non-nucleated settlement patterns that translate into hamlets, each of which may represent a section of a dominant lineage, or separate

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[1] This inventory recorded in 1,474 ha of *bas-fond* in the CMDT Region of Niéna, 7,642 ha in Niéna, 10,498 ha in Kléla, 22,549 ha in Kignan, and 6,494 ha in Kadiolo. In addition, about 173,000 ha of flooded plains were recorded.

lineages. In general, each village has a dominant founding lineage (clan) and one or more affinal lineages created by matrilocal marriages or the relocation of migrant settlers (*e.g.*, the Dogon settlers). While the dominant lineage has had superior rights over land, these rights tend to be weakening.

Despite the administrative boundaries, the villages do not have a distinct physical identity because inter-hamlet ties often cut across official boundaries. Rather, each village has a clear social identity which is defined by a single large male lineage and kinship relations. The practice of endogamy (*i.e.*, marriage inside the village) in a Muslim society reflects the tacit view of the village as a large, unilineal descendent group. The village is also a unit of customary rights over resources such as grazing land, hunting bush, and fishing areas. However, these "tribal" villages are far from being homogeneous units. As a result, researchers and extension agents need to understand the existing social organization if they are to work effectively and promote broad-based participation.

From farmers' perspective, crop production and animal husbandry are the most important activities in the 12 villages surveyed, both in terms of PUs' labor allocation and these activities contribution as sources of food and income. However, although secondary in importance, trade, hunting, handicraft, and fishing are a significant source if income in many PUs.

Six of the 12 *bas-fonds* have some type of water control infrastructure, all of which were constructed by CMDT, except in Péniasso, where the funding was provided by a local investment fund (Table 4.1).

Table 4.1: Characteristics of the Sampled *Bas-fonds*, Mali, Rainy Season 1995-96.

Village	Area under cultivation (ha)	Number of parcels	Water control infrastructure	History cotton production (years)
Bougouni				
Banko	35.00	92	no	< 3
Diassola	3.00	53	yes	> 5
Faradjélé	30.00	na	no	< 3
Faradié	34.00	81	yes	< 3
Sola	300.00	172	no	< 3
Solo	32.00	187	no	> 5
Sikasso				
Kado	108.18	111	yes	> 5
Kafuziéla	69.33	378	no	> 5
Longorola	330.00[a]	260	yes	0
Niéna	128.50	526	yes	> 5
Péniasso	125.00[b]	180	yes	> 5
Sikasso	na	na	no	0

[a] Extends over more than one village (Longorola and Zanadougou) and only 57.96 ha benefit from the water control infrastructure.
[b] Only 25 ha benefit from the water control infrastructure.
"na" indicates these data are not available.
Source: Village-Level Survey in 12 *Bas-Fond* Villages in Mali-Sud.

The *bas-fond* area under cultivation in the sampled villages ranges from approximately three to 330 hectares, which are subdivided into 53-526 plots (Table 4.1). However, some parts of these *bas-fonds* are not cultivated because of higher production risks associated with either too much water or no water at all.

Of the 12 villages, 10 have a history of cotton production, although villages in the Sikasso region have generally been growing cotton for a longer period than those in Bougouni (Table 4.1). Thus, one would expect that these villages will benefit from the presence the cotton extension service (*i.e.*, CMDT) which provides greater access to inputs. This issue is discussed in Chapter Five, which focuses on technologies adoption.

In general, *bas-fond* lands ownership is communal. Plots are allocated to their users (predominantly women) based on customary rules. In the rainy season, these valleys are planted to rice and, to a lesser degree, to vegetables and potatoes. Increasingly, potatoes are becoming important cash crops. In the dry season, however, the majority of the *bas-fonds* are fallowed and used for grazing livestock. See section 4.5.1 for a discussion of the *bas-fond* land tenure and type of water control investments.

4.4. Demographic Characteristics of PUs in the Sampled Villages

4.4.1. Size and Demographic Composition

4.4.1.1. PUs are Large with at Least Two Households

In the 12 villages surveyed, the production units (PU) are generally large, both in terms of the number of households and the number of individuals. On the average, there are about two households per PU. However, this mean value is significantly (P=0.007) higher and more variable in the sub-sample of villages located in the CMDT region of Sikasso (mean=2.53 with a standard deviation of 2.19) than in villages in the Bougouni region (mean=2.0 with a standard deviation of 1.42). When all PUs are considered, 57.6 percent of them have more than one household (range = 35.0-83.3

percent). The percent of PUs with more than one household is higher for the sub-sample of Sikasso villages (63.9%) than for that of Bougouni (51.2%).

4.4.1.2. Large Households Averaging 15 People include 46-64% Females

Across the entire sample, each PU is composed of an average of 15 people (including children) with a standard deviation of 10.9. However, the average number of PU members is significantly (P=0.061) higher and more variable[1] in Sikasso villages (17 people) than in Bougouni villages (14 people). In both regions, about one-half (45.7% to 55.8%) of the PU members who are 15 years or older are female.

4.4.1.3. Farm Labor Availability

Although across the sample, PUs have an average of 15 people, only 66.5 percent of these members significantly contribute[2] to farm production activities. However, among males, the proportion who contributed agriculture labor is higher (85.9%) and less variable[3] than that of female (64.4%) members. While PUs in Bougouni are smaller than those in Sikasso, the percent of its members who contribute to agricultural activities

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[1] The standard deviation for the size of PUs in the Bougouni and Sikasso villages are 8.34 and 12.77, respectively. The number of people living in a PU in the Sikasso villages ranges from between three to 94, as opposed to two to 61 in Sikasso. Overall, only 8.7 percent of the PUs have less than six members and 63.2 percent have more than 10. While both groups of villages have the same proportion of PUs with more than 10 members (about 63.0%), Sikasso villages have more PUs with five to 10 people (30.4% vs 25.9%) and less PUs with less than 6 individuals (6.5% vs 10.8%) than Bougouni.

[2] PU heads were asked to classify individuals' contribution to agriculture labor as significant or not. Non significant contributors among the PU members include small children and old people who perform little or no farm work.

[3] The standard deviation for the male farm labor across the sample is 26.1, compared to 40.6 for females.

is higher and less variable[1] regardless of gender (80.5% in Bougouni vs 51.8% in Sikasso) as well as among male (91.6% in Bougouni vs 80.0% in Sikasso) and female (86.8% in Bougouni vs 40.8% in Sikasso) members in the two groups of villages.

The number of hours of farm labor each PU member provides during a given period of the cropping season depends on several factors, including the number of hours other family members do farm work, the extent of off-farm commitments such as trading or hunting, the task performed, and their attitude towards leisure. Thus, the labor a PU actually has available for farm activities is less than its stock of labor (*i.e.*, the potential number of hours of work PU members could provide). Because differences in gender and age affect individuals' work ability, economists often estimate labor input in person-days, where a person-day refers to a person working a certain number of hours per day.

In practice, it is difficult to accurately measure the differences in labor input mentioned above. Various researchers have used weights based on criteria such as average caloric intake for different labor categories (Haswell, 1953), age categories (Spencer, 1972), and age/gender categories (Norman, 1973). However, given these measurement difficulties, this study does not use any weighting scheme.

4.4.1.4. Gender and Age Distribution of PUs' Heads

In both the Bougouni and Sikasso regions, virtually all PUs (99.4%) are headed by relatively old males. For the entire sample, PU heads average 56 years of age.

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[1] The standard deviation of the percent of PU members who contribute to farm labor regardless of gender is 15.0 in Bougouni and 27.4 in Sikasso. While the percent of male PU members contributing to agriculture labor is 18.0 in Bougouni and 31.5 in Sikasso with a standard deviation of 31.5, the percent among female members is 21.6 in Bougouni and 42.3 in Sikasso.

However, PU heads are slightly older in the Sikasso villages (58 years with a standard deviation of 12.7) than in the Bougouni villages (55 years with a standard deviation of 14.2). While the youngest PU head is about 25 years old in Sikasso and 18 years in Bougouni, only about 2.1 percent of all PUs' heads are less than 30 years old, and 77.8 percent are more than 40.

4.4.1.5. Implications for Research and Extension

The large size of the PU in Mali-Sud *bas-fond* villages seems to suggest the existence of a large pool of farm labor in these units and that labor-intensive technologies may be appropriate. However, access to farm equipment, farm size, and the labor requirements of technologies need to be considered in assessing the importance of the farm labor stock available in PUs. Later in this chapter, the correlation between the PU labor size and total area the PU cultivates, and its implications for increased production through labor-intensive technologies or area extensification are examined.

4.4.2. Education Level of the Members

4.4.2.1. The Formal Schooling Rate Is Low, Especially among Females

For the entire sample of PUs surveyed, only 10.6 percent of the members in each PU (both genders combined) have formal schooling[1] (Table 4.2). In general, the formal schooling rate is higher in the more urbanized villages such as Sikasso (46.4%), Niéna

[1] The term formal schooling refers to education in formal schools at the end of which a certificate of achievement is awarded to graduates. In contrast, adult literacy training refers to any type of education provided to farmers in rural areas (reading and writing), generally by extension staff, with the objective to improve interactions, technology adoption and application.

(18.6%), and Kado (15.7%). For the entire sample, the formal schooling rate is lower among female members (4.1%) than among male members (9.7%). The only villages with a female formal schooling rate ≥ 10 percent are Sikasso (32.6%) and Kado (10.0%), which can be explained by the urban nature of these villages. In contrast, the low rates in the other villages can be attributed to the lack of schools, as well as the dominant Muslim religion and the cultural bias against female education in the rural milieu. In general, the schooling rate is significantly lower in Bougouni villages than in Sikasso villages, both across genders, as well as within each gender group.

Table 4.2: Average Formal Schooling and Adult Literacy Training Rates Per Production Unit, by Gender, Mali, 1996.

Education/Gender	Entire Sample	Bougouni	Sikasso
Number of PU Sampled	334	166	168
Formal Schooling (%):			
Male	9.7	5.9	13.4
Female	4.1	1.9	6.3
Both	10.6	4.9	16.0
Adult Literacy training (%):			
Male	18.0	22.2	13.9
Female	3.5	6.0	1.1
Both	7.4	10.0	4.8

Source: Survey of 334 Production Units from 12 *Bas-Fond* Villages in Mali-Sud.

4.4.2.2. Adult Literacy Training Rate Is Low, Especially among Females

Similarly, Table 4.2 shows that while adult literacy training is low across the entire sample (7.4%), it is higher for males than females, both across and within the two regions, and it is higher in Bougouni than in Sikasso, with and without regard to gender (Table 4.2). A comparison of the formal schooling and adult literacy training rates across the entire sample shows that, the PUs' average formal schooling rates are higher than the adult literacy training rates (Table 4.2). However, for the entire sample, while about the same percentage of females in a PU have formal schooling (4.1%) as have adult literacy training (3.5%), twice as many of PU's male members have adult literacy training (18.0%), compared to those having formal schooling (9.7%).

Overall, about 76.0 percent of the PU heads have no education at all, and only 13.1 percent have adult literacy training. However, as expected, the proportion of PU head with no education (*i.e.*, no formal education and no adult literacy training) is higher in the villages with a low level of urbanization such as Kado (4.5%) and Sikasso (65.0%).

4.4.2.3. Implications for Research and Extension

The low rates of formal schooling and/or adult literacy training suggest that to be effective, researchers and extension agents must take it into account farmers' limited education background in their daily interactions with farmers. In particular, this implies that (a) the technological packages that are developed and promoted should be simple in their content and application, and (b) researchers and extension agents should rely on communication strategies that take into account farmers' education (*e.g.*, radio messages in local languages, and visuals)[1].

4.5. Agricultural Production in Sampled Production Units

4.5.1. Farm Equipment and Livestock Holdings

The data collected during this study show that animal traction is widely used in Mali-Sud (Table 4.3). In all villages sampled except Sikasso and Longorola, more than 40 percent of the PU have at least one oxen and one plow. However, very few PUs own a multi-purpose plow, harrow or a seeder. Interestingly, PUs in villages involved in cotton production tend to own more equipment than those with no cotton experience[2]. This is because the cotton extension service (CMDT) provides farm equipment credit for cotton producers.

An analysis of the correlation between the total area cropped by a PU (upland and *bas-fond* combined) and their farm equipment holding (*i.e.*, plows, oxen, and donkeys) revealed a significantly strong positive relationship (*i.e.*, $r \geq 0.6$) with (i) oxens in 10 of the 12 sampled villages except Sola and Sikasso, (ii) donkeys in five villages, (iii) plow

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[1] In a broader context, it would be important to promote greater interest to education, as this could have a potentially significant impact on technology adoption, assuming the technologies are appropriate and effective. As Schultz (1990) note, "the decisive factors of production in improving the welfare of the poor people are not space, energy and cropland; the decisive factors are the *improvement in population quality and advances in knowledge*." Generally, education, be it formal or adult literacy, accounts for much of the improvement in the quality of human capital. However, because national education policies tend to favor urban at the expense of rural people, research and extension should focus on developing technologies that are relatively simple.

[2] An analysis of the association between the level of each type of equipment owned by a PU and village years of experience with cotton production (using Pearson chi-square --χ^2--, Phi, coefficient of contingency and Cramer's V) revealed a highly significant relationship (i.e., $P < 0.001$) between these two variables.

in eight villages (Appendix 4.1 and 4.2). However, this equipment is primary used in the cotton fields and other collective upland fields. Nonetheless, their use reduces farmers' (especially women) labor requirements in the upland, thereby increasing their availability to work in the *bas-fond* fields.

Table 4.3: Proportion (%) of Production Units With at Least One Unit of Each Farm Equipment Type, by Village, Mali, 1996.

Village	No. PU[b]	Plows	Carts	Multi-purpose plow[a]	Harrows[a]	Seeders[a]	Oxen	Donkeys
Bougouni								
Banko	30	70	33	20	3	13	73	30
Diassola	19	68	10	21	0	5	53	10
Faradjélé	27	72	44	48	0	33	85	37
Faradié	30	43	23	27	0	3	40	23
Sola	30	77	27	33	0	27	60	23
Solo	30	47	33	7	7	3	47	23
Sikasso								
Kado	30	50	43	37	23	37	57	33
Kafuziéla	30	100	100	80	0	30	93	87
Longorola	30	27	33	10	0	0	3	20
Niéna	28	86	54	32	14	29	79	57
Péniasso	30	93	87	70	7	50	77	67
Sikasso	20	10	20	0	0	0	0	20

[a] Each PU has only one unit of each of these implements.
[b] Number of Production Units (PU) sampled.
Source: Survey of 334 Production Units in 12 *Bas-Fond* Villages in Mali-Sud.

4.5.2. Number of Fields per Production Unit

During the 1995-96 rainy season, the 334 PUs surveyed planted 2,298 fields. Of these, 42.6% were upland fields and 57.4% were *bas-fond* fields. When all upland and *bas-fond* fields are combined, the average PU managed seven fields (with a standard deviation of four). While this average number, which is equivalent to one field for every two PU members, is ≥ 10 in only three villages (Faradjélé, Faradié and Péniasso), it tends to be higher in the Bougouni villages than in Sikasso.

In seven of the 12 sampled villages[1], there is a highly significant ($P \leq 0.01$) and strong positive correlation (*i.e.*, $r \geq 0.6$) between the total number of PU members ≥ 15 years old and the total number of fields planted (Appendix 4.4). These relationships hold both within and across gender groups. In contrast, in the other five villages, no significant relationship was found. While the absence of strong correlation between labor stock and number of fields in Kado can be explained by the fact that Kado is an urban center in which most of the sampled farmers work outside their homes, it is not clear why this relationship was not significant in Niéna, Solo, Sola, and Diassola.

4.5.3. Field Sizes

Data from the sampled PUs show that upland fields are generally larger than the *bas-fond* fields. Upland fields averaged 1.2 ha (with a standard deviation of 1.3) compared to 0.3 ha (with a standard deviation of 0.5) for the *bas-fond* fields. In both cases, these averages were higher in the Sikasso villages than in those in Bougouni. For

[1] These seven villages are: Banko, Faradjélé, Faradié, Kafuziéla, Longorola, Péniasso, and Sikasso.

the entire sample, 48.2 percent of the upland fields were < 1.0 ha, 29.4 percent were < 0.5 ha, and 14.4 percent were < 0.25 ha. In contrast, 96.3 percent of the *bas-fond* fields were < 1.0 ha, 84.3 percent were < 0.5 ha, and 47.1 percent were < 0.25 ha.

In eight[1] of the 12 sampled villages, there is a highly significant ($P \leq 0.01$) and strong positive correlation (*i.e.*, $r \geq 0.6$) between the total number of PU members ≥ 15 years old and the total area planted in the upland, both within and across gender (Appendix 4.5). In contrast, there is no correlation between these two variables in Sola, Solo, Niéna and Sikasso.

However, there is a highly significant ($P \leq 0.01$) and strong positive correlation (*i.e.*, $r \geq 0.6$) between the total number of PU female members ≥ 15 years old and the total area planted in the *bas-fond* in only two of the 12 villages (Banko and Longorola) and a significant ($P \leq 0.05$) but weak relationship ($r \approx 0.4$) in Faradjélé, Faradié, Sola, and Niéna (Appendix 5). In contrast, there is no correlation between these two variables in Diassola, Solo, Kado, Kafuziéla, and Sikasso.

The correlation results across gender in the uplands are fairly consistent with the ones observed when the number of fields is used instead of area planted, except in the urban centers (*i.e.*, Sikasso and Kado). These results suggest that policies aimed at promoting increased rice production through area expansion should be different for these two groups of villages. A strong correlation between area planted and number of PU members available for farm work suggests a potential labor constraint. Thus, increasing the rice area planted may require reducing the area planted to other crops or the

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[1] These villages are: Banko, Diassola, Faradjélé, Faradié, kado, Kafuziéla, Longorola, and Péniasso.

introduction of labor-saving technologies, if the labor stock remains unchanged. Whether or not farmers would be likely to adopt such changes is an empirical question that needs to be addressed before any such policy can be promoted.

Alternatively, area extensification has a better chance of being successful if labor-saving technologies are made available and accessible in order to relax the labor constraint and allow farmers to increase rice area without necessarily having to reduce the size of their upland fields, assuming the rice enterprise is financially profitable relative to other farm enterprises and farmers have access to input and output markets. In villages where only a weak or no relationship exits between labor availability and farm size, the success of rice extensification strategies may be more successful, even with labor-intensive technology. However, in either case (*i.e.*, where there is or there is no relationship), the success of rice extensification strategies is constrained by the limited *bas-fond* land, as is discussed in Chapter Five section 5.4.2.2.

4.5.4. Cropping Systems

Based on area and number of fields planted during the 1995-96 rainy season, mixed cropping was less frequent than sole cropping, both across and within the two CMDT regions (Appendix 4.6).

Based on the total number of farm enterprise fields planted, rice fields were by far the most frequent (43%) of all fields in the entire sample (Appendix 4.6), followed by pure stands of maize (11%), peanut (9%), finger millet (8%), cotton (8%), and sorghum/millet intercrop (8%). However, in terms of area cropped, rice fields accounted for a smaller proportion (16%) of the total area planted than maize (21%), cotton (20%), and sorghum/millet intercrop (17%).

While these results suggest that rice is an important crop in the *bas-fond* villages, they also confirm that (1) based on total area planted, cotton is more important in the CMDT region of Sikasso (25%) than in that of Bougouni (14%), and (2) the dominant upland cropping system in these villages is the rotation cotton/cereal rotations. While the main cereals fields in the much drier CMDT region of Bougouni is the millet/ sorghum intercrop, maize and rice fields are most frequent in the Sikasso region.

4.5.5. Field Types

In general, PUs plant three types of fields: collective fields, men's individual fields, and women's individual fields. PUs give the highest priority to collective fields in terms of their allocation of available labor and farm implements, and most production decisions are made by the head of the PU. In contrast, individual fields are the responsibility of their owners.

The analysis reveals that, contrary to a widely held perception, all three field types are found in the upland as well as in the *bas-fond*. In terms of number of fields planted during the 1995-96 planting season, in the upland, collective fields are the most frequent (78.9%) of all fields types, and men's individual fields represent less than five percent (4.5%) of the area planted (Table 4.4 and Appendices 4.6). In contrast, in the *bas-fond*, women's individual fields are the most frequent (86.1%) of all fields types, and men's individual fields also represent less than five percent (3.1%) of the area planted.

In terms of area planted, collective fields are larger (mean = 1.5 ha in the upland and 0.8 ha in the *bas-fond*) than individual fields (mean < 0.8 ha in each locations). In both the upland and the *bas-fond*, women's individual fields are smaller than collective and men's individual fields, due partly to the continuous reapportioning of their plots. These results, which are based on the entire sample, also hold at the regional level.

Although these results on the distribution and relative size of the main three field types identified confirm that rice production is dominated by women's individual fields, it is important to note that a significant proportion of the rice area is under collective (10.7%) and men's individual (3.1%) fields. This is particularly true in the Sikasso villages, both in terms of total rice area planted and number of rice fields (Table 4.5). Subsequent discussions will argue that these two groups of farmers have gender-specific concerns that influence their thinking, feeling, and ability to act. Thus, the composition and distribution of *bas-fond* field types suggests that research and extension strategies should be sensitive to gender-centered perspectives.

On a crop-by-crop basis, across the entire sample, upland crops are predominantly sown in collective fields, except for finger millet (in pure stand or in association with bambara nuts-- *dah*) and peanuts (to a lesser degree) for which the majority of the fields are women's individual parcels (Appendix 7). This is true both based on the number of fields planted and the total area cropped.

Table 4.4: Percent Distribution of the Number and Average Size of Fields Planted by All Sampled Production Units, by Field Types, Mali, Rainy Season 1995-96.

Statistics	Upland Field Types				*Bas-Fond* Field Types			
	Both	Collective	Individual		Both	Collective	Individual	
			Men	Women			Men	Women
Entire sample								
Count	1,304	1,029	59	216	989	106	31	852
Percent (%)	100.0	78.9	4.5	16.6	100.0	10.7	3.1	86.1
Mean (ha)	1.2	1.5	0.5	0.3	0.3	0.8	0.8	0.2
Standard deviation (ha)	1.3	1.4	0.5	0.3	0.5	0.6	2.1	0.2
Bougouni								
Count	853	600	46	207	438	6	8	424
Percent (%)	100.0	70.3	5.4	24.3	100.0	1.4	1.8	96.8
Mean (ha)	1.0	1.3	0.4	0.3	0.2	0.6	0.5	0.2
Standard deviation (ha)	1.1	1.2	0.4	0.3	0.2	0.8	0.5	0.2
Sikasso								
Count	451	429	13	9	551	100	23	428
Percent (%)	100.0	95.1	2.9	2.0	100.0	18.1	4.2	77.7
Mean (ha)	1.6	1.7	0.8	0.3	0.4	0.8	0.9	0.3
Standard deviation (ha)	1.6	1.6	0.5	0.1	0.6	0.6	2.4	0.2

Source: Survey of 334 Production Units in 12 *Bas-Fond* Villages in Mali-Sud.

Table 4.5: Percent Distribution of the Number and Size of Rice Fields Planted by All Sampled Production Units, by Field Type and Village, Mali, Rainy Season 1995-96.

Village	Number of Fields	% Number of Rice Fields, by Village			% Rice Area Planted, by Village		
		Collective	Individual		Collective	Individual	
			Men	Women		Men	Women
Bougouni	438	1.4	1.8	96.8	4.2	4.9	91.0
Banko	54	0.0	0.0	100.0	0.0	0.0	100.0
Diassola	20	10.0	10.0	80.0	24.9	8.7	66.4
Faradjélé	104	2.9	1.0	96.2	11.9	0.1	88.3
Faradié	108	0.9	0.0	99.1	0.9	0.0	99.1
Sola	29	0.0	0.0	100.0	0.0	0.0	100.0
Solo	123	0.0	4.1	95.9	0.0	13.6	86.4
Sikasso	551	18.1	4.2	77.7	38.4	9.2	52.5
Kado	36	94.4	2.8	2.8	93.4	2.2	4.4
Kafuziéla	162	1.9	0.6	97.5	2.9	0.6	96.6
Longorola	108	25.9	0.0	74.1	34.1	0.0	65.9
Niéna	9	11.1	0.0	88.9	52.7	0.0	47.3
Péniasso	193	6.2	9.8	83.9	11.7	25.8	62.5
Sikasso	43	51.2	4.7	44.2	76.0	2.6	21.4
All villages	989	10.7	3.1	86.1	28.5	7.9	63.6

Source: Survey of 334 Production Units in 12 *Bas-Fond* Villages in Mali-Sud.

4.6. Characteristics of Bas-Fonds Production Systems

Bas-fonds are highly complex and heterogenous agroecosystems. First, *bas-fond* fields are generally cultivated by small-scale farmers who also cultivate upland fields. Because these farmers are still largely subsistence oriented, there is pressure on them to become more integrated in the market system. Second, although different production skills are required, there exists an interrelationship between rice and upland crops such as cereals and potatoes. Finally, *bas-fond* rice production systems are influenced by the water regime (deficit, excess or optimum) which is determined by the *bas-fond* topography (flat or undulated) and water drainage quality (good or poor)-- factors that influence input use level, crop preference, and labor gender.

This section discusses of rice farmers' production resources and related issues, farmers' production practices and cropping calendar, as well as the adoption of "improved" varieties, fertilizer and herbicide application, and the distinctive characteristics of the adopters. The section ends with an analysis of rice yields and their determinants and a discussion of the potential contribution of *bas-fond* production to Mali's domestic rice supply.

4.6.1. Farmers' Production Resources: Water, Land, and Labor

4.6.1.1. Water Management Is of Central Importance

The level and spatial distribution of rice yield and growth is controlled primarily by climatic and edaphic conditions (Reinhold, 1991). The most important climatic factors are water availability during the growing season, relatively high air and soil temperature, adequate solar radiation, and relatively rain-free conditions during the ripening period[1]. Important edaphic factors (*i.e.*, soil related) include a relatively leveled field and good internal drainage, and favorable chemical and physical properties in the soil itself. However, water availability is the most critical of all these factors (Reinhold, 1991).

The major benefits from flooded soil are that it enhances the availability of nutrients (especially nitrogen, phosphorus, iron, and magnesium), reduces competition from weeds, and provides a favorable micro-climatic environment (Reinhold, 1991). Under rainfed conditions, the major determinants of the rice crop water requirements are the plant's stage of growth, surface runoff, percolation loses, evapotranspiration, the nature of the water flow (stagnant or flowing), and the quality[2] of water (Reinhold, 1991). Surface runoff and percolation loses depend upon the soil type, land preparation practices, and the depth of the ground water table. The quality of irrigation is often judged by its immediate effects on the rice crop, as well as its long-term effect on soil productivity.

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[1] The life cycle of a rice plant (85-210 days) is divided into three overlapping phases: (1) the vegetative phase which includes seed germination (length depends on sowing method), tillering (production of tillers), and leafing (production of leaves), (2) the reproductive phase, composed by panicle initiation, internode elongation and heading (or anthesis or complete emergence of the panicle from the flag leaf sheath), and (3) the ripening phase (heading to full maturity). The reproductive (35 days) and ripening (25-35 days) phases are fairly constant. The difference in total growth duration is determined by the length of the vegetative phase, which is affected by the cultivar's photosensitivity and temperature, plant density, and soil fertility (Reinhold, 1991).

[2] Water quality refers to the clay particle and chemical content (silicate, calcium, carbonate, nitrogen, magnesium, potassium) of water, as well as the resulting ph and acidity, all of which affect the inorganic composition of the rice plants.

Although all rice varieties are physiologically, morphologically, and anatomically adapted to grow in wet or flooded soils conditions, Moorman *et al.* (1977) using toposequence to quantify the soil moisture threshold beyond which rice plants suffer moisture stress, found stress to be higher for *bas-fond* rice than for upland rice varieties (Izaac *et al.*, 1990). This finding and the above discussion on the importance and determinants of water requirement for the rice plants suggest that careful management (not just the control) of the water flowing into the river bed and into the individual plots is essential in order to fully exploit the crop's physical production potential. Especially for modern rice farming, water management is very important as it stimulates better and more stable growth which is required for high grain production.

Water management involves controlling the water so that sufficient water is available at various stages of the plant growth, or removing it when there is excess water. This is particularly relevant in Mali-Sud, given the erratic rainfall across location and over the cropping season, as is noted in section 4.6.1.1.1 below. Also, research in Asia has shown that water management is more critical for broadcast seeding -- the most common sowing method used in Mali-Sud *Bas-fond*-- than for transplanted rice because of its effect on germination and weed control (Mabbayad and Obordo, 1970_b).

4.6.1.1.1. Rainfall and Rice Production

Rainfall patterns in Mali and throughout West Africa are largely determined by the annual fluctuations of the intertropical convergence front (ITCF), which develops as the monsoon and harmattan collide[1]. At the zone of convergence, a line of atmospheric perturbations is created, generating rains as the ITCF begins its seasonal ascent towards the north. Thereafter, the harmattan repels the monsoon. As this repulsion takes places, the ITCF begins its seasonal descent southward, leaving behind a dry season. Figure 4.2 and Figure 4.3 depict the distribution of precipitation across the Bougouni, Kadiolo and Sikasso meteorological stations in Mali, averaged over the last fourteen years (1980-93):

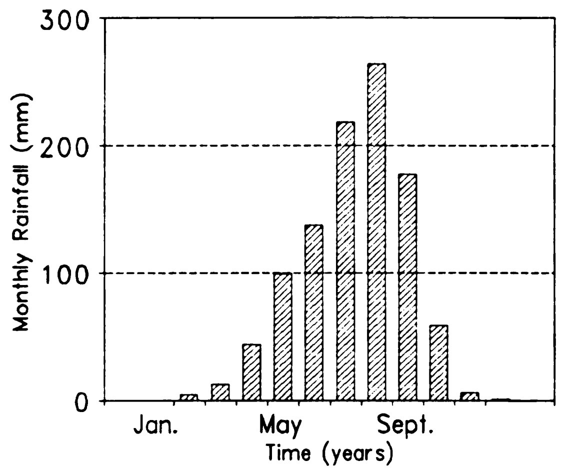

Figure 4.2: Average Monthly Rainfall.

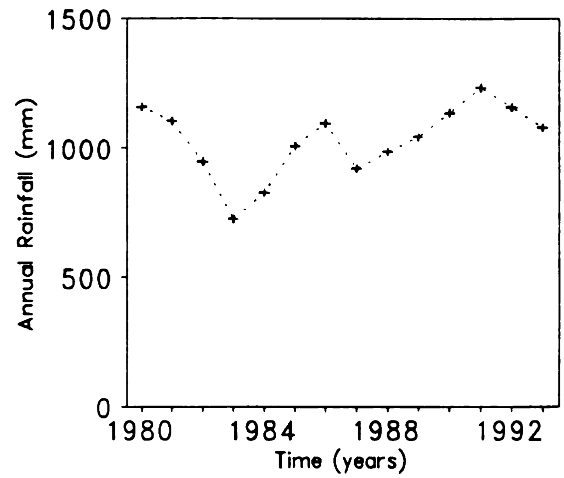

Figure 4.3: Average Annual Rainfall.

Figure 4.2 shows a unimodal rainfall pattern, with the rainy season occurring between May and October. While rainfall is highest around August, during September-October precipitation becomes increasingly erratic and ceases altogether after November. An analysis of the variability of precipitation data from the Bougouni, Kadiolo and Sikasso meteorological stations over time indicates that, since the last major drought in 1987, while monthly rainfall has been erratic (Appendix 4.9), the amount of precipitation

[1] The monsoon is a moist wind blowing from the south to the west off the Atlantic Ocean, while the harmattan is a dry wind blowing from the north to the east off the Sahara desert.

has been increasing, following a decline in the late 1970s to early 1980s (Figure 4.3). Discussions with farmers revealed that this irregular pattern of precipitation has historically contributed to discourage rice farming because the amount of moisture available to the rice plant is often insufficient to ensure acceptable yield levels. Thus, in many *bas-fonds*, water control is a necessary condition for rice production.

Previous research in Asia and Africa has shown that, rice production requires: (i) abundant precipitation (or irrigation water supplied by dams) at the beginning of the season to allow for timely land preparation and planting, (ii) less frequent rainfall during the vegetative phase of the growing plant, but sufficient to replace losses due to evaporation, transpiration, percolation, and runoff, and (iii) high solar radiation during the reproductive and ripening phases to favor photosynthesis and grain formation (Reinhold, 1991). During the reproductive and ripening phases, water stress is particularly damaging to grain production.

4.6.1.1.2. Benefits of Water Control

Investing in water control is important to improving *bas-fond* rice production, not only because it lessens weed competition and increases the presence of critical growth and productivity factors (*i.e.*, water and nutrients), particularly in drought prone areas, but also because it:

(i) leads to an expansion of the command area as the ground water table goes up, thereby allowing farmers to plant a significantly larger proportion of the *bas-fond* area that otherwise could not be cropped[1];

(ii) allows farmers to maintain the desired level of water in the *bas-fond* for a longer period of time than would otherwise be possible, which allows the rice crop to escape late season drought;

(iii) reduces drought-induced risks, thereby increasing the rate of adoption of new technologies, and thus the returns to research and extension;

(iv) releases labor for other activities through the reduction in non-aquatic weed pressure, especially when land preparation is done properly;

(v) offers farmers the opportunity to increase their land use intensity by allowing them to first plant crops such as maize, followed by transplanted rice;

(vi) reduces the conflicts on farm labor demand between upland and bas-fond farm through a better control of water flow in the *bas-fond*;

(vii) contributes to ensure a sustainable rice production environment by reducing soil erosion when infrastructure such as contour ridges are used.

(viii) encourages farming families (mostly men) who had previously abandoned rice production because of declining rainfall to return to the *bas-fond* and to intensify rice production.

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[1] Attempts were unsuccessful to estimate how much the command area has increased in each sampled bas-fond after water control was introduced.

However, in practice, the extent to which these benefits are captured depends on the effectiveness of the water control. In the particular case of the *bas-fonds* studied, there currently exists no effective plot-level water control because fields do not have internal dikes. In this context, the empirical question about the effectiveness of the existing infrastructure in increasing yields is an issue, which is discussed in section 4.5.9.

4.6.1.1.3. Types of Water Control Infrastructure

Classification Criterion

Bas-fonds can be grouped into two broad categories, based on the types of water control infrastructure in the valley: *bas-fonds* with no water control investment at all and those with some water control infrastructure. While six of the 12 *bas-fonds* sampled have some type of water control infrastructure, the level of investment varies from a system of simple dikings with floodgates (*e.g.*, Sikasso) to small dams with primary canals (*e.g.*, Kado). However, this classification is rather simple. A more complete and useful categorization of the *bas-fond* would take into account critical hydrological variables such as maximum sustained water depth, rate of increase in water depth, and length of flooding period. Unfortunately, such information is not available in Mali.

Although of central importance, this study recognizes that flooding depth and other surface hydrological variables are not the only determinants of a rice-growing environment. A range of other physical (*e.g.*, soil quality), biological (*e.g.*, pathogens and predators), and socioeconomic factors interact with hydrology to define a given rice environment (Carsky and Masajo, 1992).

The observed tremendous spatial variability of the physical, hydrological, and socioeconomic factors was a major constraint to improving the simple classification of *bas-fonds* into *bas-fonds* with or without water control. While hydrologists in Sikasso have been collecting important hydrological data, this effort has been limited to only a few *bas-fonds*.

Types of Investments

The types of water control infrastructure built in the villages differ in complexity and cost. However, based on the nature of the infrastructure constructed in Mali-Sud, it is possible to distinguish four types of investments:

(i) Terraces only (e.g., Niéna village)

Terraces are built according to the contours in the valley to collect rainfall runoff. When this infrastructure is built without levelling the field, yield still depends on the amount of rainfall. However, if the field is levelled, yield would depend on both rainfall and on the effectiveness of the infrastructure in allowing farmers to control water levels.

(ii) Terraces on a Layer of Compacted Clay (e.g., Diassola village).

Financed by the AFVP (*Association Française des Volontaires du Progrès*), this infrastructure is characterized by a small dam (one meter height) cutting across the *bas-fond* (perpendicular to the stream) to limit surface water runoff. To raise the water table, the dam is reinforced at its bottom by a layer of compacted clay, thereby reducing water loss through infiltration. The water level in the *bas-fond* is controlled by one or more floodgates. Key informants in CMDT claim that the main advantage of this type of investment is its low cost (110,000 to 300,000 cfa.F/ha). While yields under this infrastructure range from 2.5 to 3 t/ha, the main disadvantages are that the command area extends over only a few hundred meters and water management is difficult, especially when the *bas-fond* is not levelled as is the case in all sampled villages.

(iii) Terraces with drainage canals (e.g., Péniasso village)

Found mostly in the alluvial plains, this infrastructure consists of a simple dike on the valley's banks, a water catchment infrastructure, a drainage infrastructure (which could also be the catchment infrastructure), a canal channeling water into the *bas-fond*, a drainage canal, and secondary canals. Generally, with this type of infrastructure, the *bas-fond* is subdivided in four production fringes: the *bas-fond* fringe, a fringe for floating rice able to grow in up to three meters of water, a fringe for erect rice (up to 60 cm water depth), and the security fringe (about 15 cm water depth[1]).

(iv) Terraces with drainage canals and internal dikes (e.g., left bank of Kléla village)

This type of infrastructure represents the most advanced system with internal dikes constructed on the contours. As a result, it provides a better internal water control. In such *bas-fonds*, the water depth is generally around 50 cm, which makes them appropriate for erect rice plant types. The main problem with these systems is that to

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[1] Most "improved" rice varieties are short (less than 1.00 m) erect plant types.

be most effective, the polders should be small to avoid uneven water level within the polders. However, this increases investment costs.

The Process of Building Water Control Investments

In general, water control infrastructure in Mali-Sud *bas-fonds* has been built by the cotton parastatal CMDT and, to a lesser degree, by NGOs. CMDT follows three phases in establishing *bas-fond* water control infrastructure. The first phase is the identification stage, carried out either directly by CMDT agents or indirectly in response to an application from the village. The second phase (implementation stage) involves technical and economic feasibility studies. During this phase, the decision regarding where the infrastructure will be built is made. During the final phase, farmers participate in the planning, implementation and management of the infrastructure. Generally, men are recruited as unpaid labor to construct the infrastructure while women provide food. The main source of funds for these investments has been the Economic Development Fund --FED (Appendix 2.9).

4.6.1.1.4. Problems Associated with Water Control

Although water control infrastructure is built to improve water availability and management, its construction often creates several technical and socioeconomic problems. The most significant of these problems in Mali-Sud include:

(i) The weed pressure tends to be higher

In all sampled *bas-fonds*, farmers argued that after water control infrastructure is set up, weeds are a greater problem, requiring more labor or herbicide to control the weeds. While experience from Asia suggests the contrary, this observation suggests that the quality of water control provided by these systems does not effectively control weeds in many *bas-fonds* in Mali-Sud.

Farmers have addressed the heavy weed pressure problem in various ways. The most commonly tried solutions are to carry out land preparation at the end of season and/or hire labor to weed. Alternative, a very small number of farmers apply post-emergence herbicides or plant in rows to make weeding easier. See section 4.5.7 for a detailed discussion of herbicide availability and adoption rates.

(ii) The opening and closing time of the flood-gate is problematic

Because of variable topography, the level of water in the *bas-fond* is rarely even. This creates major water management conflicts, especially in fields without plot-level water control[1]. In all sampled *bas-fonds*, including those with some type of water control infrastructure, it is common to find plots that are about to be flooded (deep plots) while others still need more water (shallow plots). As a result, while farmers in deep plots want the flood-gate to be opened, those in shallow plots want it to be kept closed for a longer period of time. Therefore, research is needed to assess the appropriate strategies to improve the management of the flood-gate and how to get farmers to agree

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[1] None of the sites studied had plot-level water control.

on a common strategy. Probably the best strategy would be promote effective plot-level water control technologies.

While one way to solve this problem is to level the *bas-fond*, CMDT *bas-fond* project administration argues that the level of investment required is beyond farmers' or CMDT financial capacity. To date, CMDT has only encouraged farmers to discuss the issue and agree on a strategy. While this approach is not fully satisfactory, farmers often cope with the problem by adjusting planting time and selecting rice varieties based on the expected flood level. As a result, farmers with deep plots plant early or transplant taller varieties with good submersion tolerance. In contrast, farmers with shallow plots plant late or transplant shorter varieties with good tolerance to water stress. However, the erratic nature of rainfall makes it difficult to predict how much precipitation will fall in a particular year, and the limited choice of varieties available to farmers reduces farmers' ability to manage this water problem. See section 4.5.6.1 for a discussion of available rice varieties.

(iii) Choosing the Site of the Infrastructure Poses a Problem

In general, to the extent that water control investments are effective, the command area is limited to a section of the *bas-fond*. If the *bas-fond* extends beyond one village, then the decision as to where to build the infrastructure is potentially a problem because the investment will tend to favor one village over another.

(iv) Gender-Based Conflicts Develop

Sometimes following infrastructure improvements, men have taken the *bas-fond* back from women to produce rice as a cash crop. In an effort to solve this problem, as a pre-condition to invest in water control, CMDT adopted a policy requiring villages to agree that fields will not be taken back from the women. However, one can reasonably argue that this CMDT policy is also aimed at ensuring that men continue to give priority to cultivating their cotton fields.

In addition, the literature and CMDT informants argue that male and female farmers favor water control infrastructure investments for conflicting reasons. In most cases, men are mainly interested in water control investment to ensure a permanent source of water for their animal and to provide water for vegetable production and/or fishing. In contrast, women desire better water control so they can produce rice. These conflicting objectives have sometimes created problems. For example, in some cases, men refused to open up the flood-gate when the rice was mature because they wanted to retain as much water as possible in the *bas-fond*. As a result, women had to harvest in deep water. Also, there are reported cases where animals have invaded the rice fields to drink water.

(v) Ensuring an Equitable Redistribution of Parcels Is Hard to Achieve

In most *bas-fonds*, after the infrastructure was constructed, the land was redistributed to farmers. However, because an equitable redistribution is almost impossible to achieve, farmers with more social power (based on factors such as ethnic group, relationships) have tended to benefit the most from water control investments, given that quality of plots is determined by their location, relative to the water source.

4.6.1.2. Land Tenure

In rural areas throughout Mali-Sud, land tenure is based on customary law which is heavily patriarchal. Land is communally owned and community members hold usufruct rights (*i.e.*, they have a use right without the possibility to sell). Generally, the valley belongs to the first settlers in the village, who often constitute the dominant lineage. While these first settlers have superior rights over land, individual plots are assigned to each household at its request, for as long as the plot is continually cultivated. There is no land market in the village, nor do farmers rent land for cash or in-kind payments. Generally, the usufruct rights in both the *bas-fond* and the upland applies only during the rainy season. During the dry season, random grazing is rampant, except in the plots with vegetables.

While this strong gender-based tenure system makes it extremely difficult for women to own land, they have access to land through their husband or their household head. Previously, land distribution took place at two levels: the village-level and the household-level. At the village-level, the "chief of the lands" (*dougou kolo tigui*) who in some cases also the village chief (*dougou tigui*), allocated land parcels to the head of the household, both in the *bas-fond* and in the upland. In return, each household head paid a symbolic price of 10 cola nuts.

After *bas-fond* land has been allocated to a household, the household head partitions the household's share among the wives who wish to have a plot. Each time a newly-married wife joins the family, the household reapportions its land to accommodate the newcomer. Over time, as more and more women became interested in rice farming, a third level of *bas-fond* land allocation developed as, today, the newly-married women in the households get rice plots from their aging mother-in-laws. This practice of reapportioning household land has resulted into multiple small, but extremely valuable parcels.

4.6.1.3. Labor, Gender and Rice Production

4.6.1.3.1. The Changing Demographics of Rice Farmers

The Changing Gender Composition

Currently, *bas-fond* rice production is a female-dominated activity, especially in rural areas. When the entire sample is considered, 88 percent of the 120 farmers monitored[1] were women. While there is a widely held perception that rice is solely a women's crop, this was only the case in seven of the 12 villages (*i.e.*, Banko, Diassola, Sola, Solo, Kafuziéla, Longorola, and Niéna) where all of the *bas-fond* farmers monitored were women. In contrast, in Faradjélé, Faradié, Péniasso, and Sikasso 8, 3, 13, and 30 percent of the rice farmers monitored were men, respectively. Surprisingly, in Kado, 98 percent of the rice farmers are men. Interestingly, the large proportion of

[1] As mentioned in Chapter Three, only 120 of the 334 sampled farmers were monitored throughout the cropping season.

male rice farmers were observed in villages with a relatively greater degree of urbanization (*i.e.*, Sikasso and Kado).

For most key informants and according to the literature, *bas-fond* rice production used to be a male-dominated activity. However, over time, as rice production became less profitable due to declining rainfall and soil fertility, men tended to abandon this activity to women. Although there seems to be some truth to this argument, it became clear to the research team that the rationale for this changing trend is more complex.

During organized group discussions, men argued that the key factors explaining female dominance in rice production is the limited space in the *bas-fonds*, which makes it impossible for everybody to have a parcel in the *bas-fond*. As a result, men "gentlemanly" turned over their plots to women. However, during these discussions, it also seemed apparent that additional important factors include the relatively heavy weed pressure and difficulty of land preparation in the *bas-fond*, compared to in the uplands, as well as competition for labor from men's cotton and maize enterprises. Indeed, previous research has shown that *bas-fond* fields are significantly more labor intensive (workdays per ha) than upland fields (Izaac *et al.*, 1990). Due to the heavy weed pressure, more time and effort are required to weed these fields than men cannot afford to provide at the time when labor demand for cotton and other cereals is greatest.

In addition, cotton is more attractive to male farmers because its cultivation guaranteed access to inputs and credit, and growers were offered a guaranteed and stable price by CMDT. With the remaining of their time, male farmers chose to plant maize because it is a major staple during the hunger period.

Finally, key informants report that men abandoned the *bas-fond* as rainfall became unreliable, soil fertility began to declined dramatically, and rice became less profitable compared to crops such as cotton. The issue of relative profitability of major competing crops is revisited with more details and budget analyses in Chapter Six.

One significance of the observed gender composition of rice farming is its impact on the likelihood of adopting[1] "improved" technologies (*i.e.*, seeds, fertilizer and herbicide) and its implication for research and extension. While the study found no correlation between farmers' gender and the adoption of "improved" varieties or herbicide, there is a significant (P=0.01) but weak positive correlation (r=0.2281) between gender and the use of fertilizer, with men (78%) more likely to use fertilizer than women (36%).

While the observed male propensity to use fertilizer may be explained by the fact that men tend to control household income, these results should be interpreted with caution because the sample of 120 farmers monitored included only 15 males, compared to 105 females. However, it is highly likely that the 15 males represent a larger proportion of the male rice farmers sub-population, compared to the females.

Changing Structure of Rice Farmers' Age

About 90 percent of the sampled female farmers are 60 years old or more. At the village-level, this statistic is greater than 80 percent in each of the villages, except in Sikasso where only 43 percent of the women are at least 60 years of age and 36

[1] In this study, an adopter of an improved technology is defined as a farmer who planted an "improved" variety, and apply fertilizer and/or herbicide during the 1995-96 cropping season.

percent are in their 50s. This age structure of female rice farmers contrasts with that of males. It appears that male rice farmers tend to be younger than their female counterparts, with about 60 percent of them 60 years old or more and 33 percent in their 50s.

These results seem to confirm the general perception that rice farmers tend to be older members of the society, with more than 80 percent of both men and women rice farmers being more than 50 years of age. In fact, key informants reported that in the past rice farmers were older women whose labor was considered negligible for upland crop production. Overtime, this labor composition has been changing, with more and more young women becoming involved in rice production in the *bas-fond*.

The reasons for this changing age pattern of *bas-fond* farmers are not clear. Possible determining factors are (1) the spread of mechanization (mainly animal traction) which has reduced labor demand in the upland fields, and (2) the attractiveness of the discretionary power that rice farmers enjoy over the use of crop harvest. Generally, men decide on how crop production from the uplands is to be used. Upland crop harvests are stored in the household granary because they are considered essential for the household's food security, and this allows men to better control the household income.

In contrast, women who crop rice have a discretionary power over the use of their rice harvest. Although this harvest is often used as a complement to the upland harvests in securing the family food consumption needs, it symbolizes a gender-based social freedom for women by increasing their ability to satisfy their needs and social obligations (*e.g.*, welcoming visitors). As a result, generally, the rice harvest is stored in the woman's personal granary. Discussions with women's groups revealed the importance they placed on this freedom and their strong feeling about their rice plots and production.

Of particular interest is how age relates to the likelihood of adopting "improved" technologies (*i.e.*, seeds, fertilizer and herbicide). While many studies have found a significant correlation between age and adoption, correlation analysis in this case failed to indicate any relationship, both within and across gender groups. However, the failure to show any relationship could be attributed to the fact that only few young farmers are included in the sample, since almost every rice farmer is of the older group.

4.6.1.3.2. Labor Categories in Rice Farming

Labor used in rice farming can be grouped into three categories: (1) collective family labor (or exchange labor), (2) individual family labor, and (3) hired labor[1]. Collective family labor refers to cases where PU A helps PU B in exchange for in-kind payments (rice harvest) or labor time in A's fields. Individual family labor refers to any PU member working in the PU's fields. Labor can be hired on an individual basis or as a group (*tons*).

Table 4.6 below shows the relative importance of each type of labor in the *bas-fond*. Overall, individual family labor is the dominant form of labor used in *bas-fond* rice production, and it is the only important source of labor for cleaning and fertilizer application. It is interesting to note that, for the total sample, group hired labor (*ton* and

[1] The diversity in labor type poses most of the classical valuation problems. These problems are addressed in Chapter Six in an effort to properly estimate production and opportunity costs.

village associations) represents less that four percent of the total work time in any particular *bas-fond* parcel. However, it is far more important in Niéna at harvest (45.9%) and threshing (32.7%), and less so at weeding in Longorola (16.1%) and Péniasso (18.3%). In contrast, exchange labor is most important in those activities (*i.e.*, threshing and transport) where timeliness is not a big constraint, so farmers do not have to devote all their efforts to their own crop at the same time.

Table 4.6: Distribution (%) of *Bas-Fond* Rice Production Work Time, by Labor Category and Farming Activity, Mali-Sud, Rainy Season 1995-96.

Farming Activity	Labor Categories			
	Exchange Labor	Individual Family Labor	Individual Hired Labor	Ton and Village Association
Cleaning	4.2	91.3	4.5	0.0
Plowing	12.8	66.0	20.9	0.3
Planting	18.1	45.9	35.3	0.6
Weeding	10.5	68.1	17.6	3.9
Fertilizer appl.	0.4	99.5	0.1	0.0
Harvest	28.0	40.0	28.5	3.5
Transport	30.1	45.1	24.2	0.6
Threshing	35.4	38.8	21.5	4.3

Source: Survey of 120 Rice Parcels Monitored in 12 *Bas-Fond* Villages in Mali-Sud.

4.6.2. Spatial Organization of Production

The spatial organization of *bas-fond* crop production depends on the land topography, which determines in part the amount of water available (Figure 4.1). In all *bas-fonds*, water availability, soil texture and related physical and chemical properties vary along the toposequence. Farmers often utilize this hydrological diversity to diversify their crops.

Various studies have shown the value of screening and understanding processes related to soil properties and water availability along the toposequence (Izaac *et al.*, 1990). For example, farmers select varieties according to water needs and resistance to flooding (*i.e.*, submersion capacity). Farmers cultivating plots with deeper water plant longer cycle, generally floating varieties, and sow earlier to ensure that the seeds germinate and grow sufficiently tall to survive the earlier entry of water in the parcels. In contrast, farmers cultivating higher (shallow) plots plant shorter cycle, generally erect varieties, because of the danger of desiccation of immature plants after flood recedes. They must also avoid planting too early because of the possibility of fields drying out between the first rain and the arrival of flood.

The *bas-fond* toposequence is frequently divided in three fringes: the upper-third, the middle-third, and the lower-third (Figure 4.1). In the upper slope where drought is most likely and soil erosion risk is high if vegetative cover is removed, farmers typically grow sorghum, maize, groundnut, and tubers. The valley middle-third of the valley (phreatic or hydromorphic fringe) where shallow groundwater saturates the soil is considered best for rice production during the rainy season since it does not flood too much. During the dry season, farmers plant sweet potatoes and potatoes after harvesting the rice. Alternatively, some farmers first plant early maize, followed by transplanted rice, especially when good water control has expended the command area laterally.

However, double cropping was observed only in the village Sikasso, a major urban consumption area where upland fields are far from the center.

In the lower-third of the *bas-fond* (valley bottom), soils are strongly hydromorphic due to shallow groundwater or flooding throughout most of the year. As a result, this portion of the *bas-fond* is not generally used, especially when there is no water control.

4.6.3. Farming Activities

Traditionally dominated by shifting cultivation systems with 15-20 years fallow periods, upland agricultural production in Mali has been based on permanent cultivation systems since the introduction of cotton and animal traction. In contrast, by its nature, *bas-fond* rice production has always been practiced as a permanent cultivation system. The main rice production operations are land preparation, seeding, weeding, fertilization, harvesting, and threshing. Weeding takes place after seeding and before flood arrival. There is little field work between weeding and harvesting. Once harvested, the paddy is piled in the field to dry and threshed on the ground. All these activities occur at different points in time during the cropping season.

In general, most farming operations are done manually. The time at which a farmer undertakes these activities depends on the timing and amount of water supply, upland crop production activities, the type of rice varieties (late or early maturing) used, and farm equipment availability. For example, soil preparation, whether accomplished manually or with animal traction, is possible only when there has been enough rains to break the hardpan which form on the soil during the preceding dry season.

4.6.4. Land Preparation

Land Preparation Methods

Land preparation involves land clearing and conventional tillage. However, while the majority (98%) of the 120 farmers monitored actually plowed their field[1], only 17 percent cleared the field[2] before plowing. The remaining 83 percent of the farmers plowed directly without clearing the field, thereby incorporating the vegetative cover into the soil to serve as green manure.

Whether or not a farmer incorporates the vegetative cover depends on the amount of vegetation on the field. If she/he considers the coverage to be too much, she/he will try to clear the field before plowing. The yield impact of incorporating the vegetative cover could not be assessed in this study, given the limited number of farmers involved, and factors such as differences in variety planted and relative water stress for the rice plants in different fields. However, studies show that this practice has a positive effect on yield, as the incorporated organic material is converted into plant nutrients after it has decayed (Mabbayad and Obordo, 1970_a).

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[1] The rest of the farmers sow without plowing (*i.e.*, 18% of the farmers in Kafuziéla and 4% in Longorola).

[2] On a village-by-village basis, while 90 percent of the farmers in Diassola cleared their fields before plowing, everybody in Faradié, Faradjélé, Longorola, Niéna, and Péniasso plowed the field without clearing. In the other five villages, no more than 30.0 percent cleared their fields. These villages are: Banko (30%), Sola (10%), Solo (18%), Kado (10%) and Kafuziéla (30%).

The Need for Research on the Timeliness and Quality of Land Preparation

In the villages surveyed, while land preparation is generally done when the land is sufficiently wet (wet-land preparation method), the common Asian practice of puddling is rare. Yet, research has established that puddling minimizes water loss and increases nutrient availability (particularly phosphorous) by increasing the contact between the clay and the root system of the rice plant (Mabbayad and Obordo, 1970_a).

An analysis of the time lag between tillage and planting revealed that about 82 percent of the farmers planted less than two weeks after plowing started. Yet, research from Asia have established that land preparation should be done at least two weeks before planting to (i) save the seedlings from the effect of high concentration of harmful substances[1] generated during the decomposition of the organic material incorporated in the wet soil, and (ii) to allow the plant to utilize the ammonium released by decayed organic matter (Mabbayad and Obordo, 1970_a). To prevent loss of nitrogen through denitrification[2], the field must be flooded from the first plowing to planting.

While research results from Asia may not be directly applicable in Mali, the time lag between tillage and planting, reinforced by farmers' complaint about the heavy weed pressure, suggest that late and poor quality of land preparation reduces yield. Thus, research on the timeliness and quality land of preparation could identify yield-increasing crop management recommendations.

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[1] Such harmful substances which include carbon dioxide (CO_2), organic acids and other products of anaerobic decomposition of the organic material reaches their highest concentration in the soil after two to three weeks and then decline (Mabbayad and Obordo, 1970_a).

[2] Denitrification is a process whereby nitrates (NO_3) are decomposed into nitrites (NO_2), then into elemental nitrogen by the action of bacteria which take up oxygen.

A Difficult Predominant Manual Tillage Provides an Opportunity for Herbicide Use

While most farmers prepare their land manually with family labor[1], in very rare cases farmers use animal traction. Typically, the head of the PU will make the animals available for the *bas-fond* fields when they are no longer needed in the PU's collective fields. However, even though draft animals are rarely used in the *bas-fonds* fields, their use in the uplands reduces labor demand per hectare, thereby relaxing the labor constraint at a time when rice competes with other crops for labor.

Because tillage is done manually with a hoe on predominantly heavy clay soils, farmers have argued that it is probably the most difficult task in rice farming, and one of the reasons why men have abandoned rice production to women. The literature points that the objective of tillage is to (i) control weeds effectively and thereby prevent them from competing with rice seedlings, (ii) to mix the organic materials with the soil so they can be used as nutrients by the plants after they decay, (iii) to reduce water and leaching losses during the subsequent flooding stages, and (iv) to turn the soil into "soft puddle" for ease in transplanting (Mabbayad and Obordo, 1970_a).

While research in Mali to reduce the burden of manual tillage has been very limited, studies in Asia indicate that in rice fields which have been kept flooded and generally soft, initial plowing is not essential so long as the weeds are controlled by a pre-emergence herbicide (Mabbayad and Obordo, 1970_a). Thus, given that farmers

[1] In all 12 villages surveyed, the only source of labor for clearing is family labor, except in Sikasso (100% hired labor) and Kafuziéla (22% family labor and 78% exchange labor). In contrast, tillage labor is much more diverse even though family labor is still the dominant source (75-100% of total tillage labor used). The additional labor needed are exchange labor, except in Niéna, Sikasso, Kado and Longorola where as much as 85%, 59%, 36% and 35% of the total tillage labor used was hired, respectively.

consider weed control a major problem, research directed at assessing the possibility of no tillage with pre-emergence herbicide application could be useful to the farmers. In the Malian context, it is apparent that one of the major considerations in this assessment will be the hydrological condition of the farming environment, as well as the cost and availability of herbicides.

4.6.5. Seeding and Yield Increase Opportunities

Broadcasting on Mud Is the Dominant Rice Planting Method Used by Farmers

Direct seeding and transplanting are the two rice planting methods practiced in the sampled villages. With transplanting, seedlings are first raised in the seedbed and then uprooted and replanted in the main field; whereas with direct seeding, the seeds are sown directly in the main field either by broadcasting or row planting on mud. In locations such as in the *Office du Niger* where irrigation water is adequate and well controlled, direct seeding tends to be extensively used with profitable results. In contrast, 86 percent of the 120 farmers monitored broadcasted their rice seeds and then hoe, five percent plant directly with a hoe, and only nine percent transplant.

Advantages and Disadvantages of Broadcasting on Mud

Farmers justify the prevalence of broadcasting over the other planting methods is primarily by (i) poor water control[1], (ii) the suitability and the quality of the rice seed

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[1] The availability of adequate water is necessary because water helps suppress the growth of weeds. However, during seeding, excess water needs to be drained from the field to ensure good seedling establishment; otherwise seedlings may be covered by mud if the water is muddy, or there may not be sufficient oxygen in the water to enhance plant growth.

used[1], (iii) lower labor requirements which may substantially reduce production costs and are suited to the high labor demand farmers face, (iv) the easiness and quickness of the operation, and (v) a relatively better plant density compared to direct sowing in rows, given the poor quality of seeds.

However, the main disadvantages of broadcasting are that (i) the young directly seeded plants are susceptible to attacks by rats, snails and other predators, (ii) the seeds may be carried away during heavy rains (particularly when there is poor water control), resulting in poor plant density, (iii) weeding tends to be difficult, and (iv) the amount of seeds farmers use is relatively high, compared to transplanted rice. Seed losses to predators can be reduced by broadcasting the seeds in water. However, this practice tends to slow seedling emergence and establishment, and is only appropriate if farmers use suitable varieties. The difficulty of weeding can be reduced by planting in rows. Yet, only three percent of the 120 farmers monitored planted in rows.

Transplanting is often used as a strategy to increase land use intensity (through a reduction of the duration of the rice crop in the field), especially in peri-urban *bas-fonds* like Sikasso where farmers' other fields are far away from the city. Surprisingly, farmers who transplanted their rice used late maturing varieties (150-180 days).

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[1] Farmers have argued that not all rice varieties are suited to direct seeding. In support to this argument, a statistical analysis of the data collected revealed a highly significant ($P < 0.001$) and positive but weak correlation ($r=0.355$) between the planting method and the rice variety farmers use. Indeed, research in Asia has shown that varieties suited to direct seeding are those with agronomic characteristics such as a high seedling vigor, short height, resistance to lodging, and low to moderate tillering capacity (Mabbayad and Obordo, 1970_b). Most of the "traditional" varieties farmers use are tall and lodging-susceptible varieties.

Plant Spacing and Yield Impact

While uniform plant spacing is considered critical to high yields, there exists a tremendous variability in spacing in the fields monitored, mostly because the seeds are broadcast and germination is low. Yet, evidence in Asia on varietal response to spacing indicates that there is an opportunity for yield increase in Mali-Sud through better spacing. Farmers can achieve better spacing through transplanting.

4.6.6. Rice Varieties Used by Farmers

4.6.6.1. Varieties Planted and Adoption Rates

4.6.6.1.1. A Production System Marked by Multiple Varieties

Bas-fond rice farmers plant many different varieties. For example, the 120 farmers monitored during the 1995-96 rainy season reported planting 60 rice varieties, based on the names of the varieties they provided. However, because each variety is named after the person who introduced it in the village, some varieties with different names in different villages may actually be the same variety. Also, it is not certain that all varieties farmers identified as "traditional" are truly "traditional" varieties. Samples of these varieties were collected and efforts to identify and compare them were unsuccessful.

Of the 60 varieties named in the 12 villages surveyed, only nine had "improved" varieties' names. They are: Gambiaka, BR 4, BG 90-92, IRAT, SNA, IER 148, Niger/Zaïre, C 74, and Bouaké (see Table 2.5 for their characteristics). On the average, about seven different varieties were planted in each village, with a standard deviation of three varieties. While only two percent of the 334 farmers surveyed planted three different varieties, 18 percent planted two and 80 percent one. Surprisingly, the same data showed that while 63 percent of these farmers planted "traditional" varieties only, as many as 32 percent planted "improved" varieties only, and six percent used both varieties. Interestingly, while a larger proportion of the "improved" varieties (75%) are found in the *bas-fonds* with water control infrastructure, a larger proportion of the "traditional" varieties (62%) are found in the *bas-fonds* with no water control infrastructure[1]. In fact, statistical analysis showed a highly significant association between water control and the type of varieties farmers planted.

4.6.6.1.2. Life Cycle and Plant Type of the Rice Varieties Farmers Used

Similar to the type of rice varieties planted, there is a great deal of variability in the number of days from germination to maturity among the varieties farmers used during the 1995-96 cropping season. The majority of farmers (53%) used late-maturing varieties (130 days or more), while 32 percent sowed intermediate-maturing varieties (95-130 days), and 15 percent planted early-maturing varieties (less than 95 days). However, a larger proportion of farmers using "traditional" varieties had late (66%) or intermediate (29%) maturing varieties, but a larger proportion of those who planted "improved" varieties used intermediate (38%) or early (33%) maturing varieties.

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[1] Possible reasons for this include: "traditional" varieties have plant heights suitable to the water condition in *bas-fonds* with no water control infrastructure, compared to the "improved" varieties, and/or limited availability of or farmers' exposure to "improved" varieties.

Farmers claimed they tend to plant early-maturing varieties where they expect the water level will be high so the crop can be harvested before the field floods, and plant the late-maturing varieties in areas with less water. However, this claim is not supported by findings from the ESPGRN's agronomist in Sikasso, who reported that farmers commonly plant both variety types in all parts of the field-- possibly because of limited seed availability or uncertainty about what water levels will be.

In general, most "improved" varieties tend to be short, while most "traditional" varieties tend to be tall. It is recognized that short plant types are not the best because of weed competition, drought stress, and flooding common to *bas-fond* with minimum or partial water control (Masajo and Carsky, 1989).

4.6.6.1.3. Farmers' Preferences on Quality Characteristics

Strong preferences for particular rice varieties are based primarily on cooking and taste characteristics, but also on their adaptation to the farmer's field toposequence. In this respect, the main advantage of the so called "traditional" varieties over the "improved" ones is that not only they tend to elongate into long, fluffy, and easily separable kernels when cooked, but also they cook faster. Because of these characteristics, farmers claim they are more economical (time and money) than the "improved" varieties.

In contrast, market quality preferences, which are typically measured in terms of percentage of broken rice, are a function of income level, as rice with low breakage commands a premium price. Other distinguishing characteristics that increase price include whether the rice has been parboiled and whether its bran layer (brown rice) is removed.

4.6.7. Weeding and the Rate of Herbicide Use

4.6.7.1. Importance of Weed Control

Weeds are one of the major causes of low yields in the surveyed villages. They directly reduce yield by competing with the rice plants for nutrients, sunlight, and space. Indirectly, weeds reduce yield by serving as alternate hosts for diseases and insects such as leafhoppers and stem borers. While this research did not inventory the weed species encountered in the fields monitored, studies at the International Rice Research Institute (IRRI) have shown that emergence of weeds and the kind of weeds that emerge are closely related to soil moisture content and depth of the submergence.

4.6.7.2. Scope of Herbicides Application on the Rice Fields Monitored

Farmers are perfectly aware of the depressive effect of weeds on yield. While 91 percent of the farmers weeded their rice field at least once during the cropping season, only 18 percent weeded twice[1]. Surprisingly, of those who weeded at least once, as much as 48 percent used herbicide, while the remaining 52 percent weeded

[1] While in Banko (89%), Faradié (90%), Solo (90%), Péniasso (90%), and Sikasso (40%) not every farmer monitored weeded at all, in the other villages, every farmer weeded at least once. Furthermore, it is only in seven of the twelve villages that farmers weeded twice (i.e., Banko, Faradié, Sola, Kafuziéla, Longorola, Niéna, and Péniasso).

manually[1]. Similarly, while 72 percent of the farmers monitored weeded only once, 49 percent of them used herbicide.

Interestingly, four of the seven villages in which farmers weeded twice have water control infrastructure, and 90 percent of the farmers who did not weed at all planted "improved" varieties. Furthermore, while the proportion of farmers who weeded twice is smaller among those who planted "improved" varieties (3%) than those with "traditional" varieties (24%), the proportion of farmers who applied herbicides is larger among those who planted "improved" varieties (62%) than those with "traditional" varieties (33%). Although the study did not look into whether those farmers who did not weed twice did so because it was not necessary or because they could not afford the time to weed, the effectiveness of water control in suppressing weeds in these *bas-fond* is questionable. Furthermore, these results suggest that (i) the "improved" varieties used by farmers tend to suppress weeds (probably because of their semi-drooping plant architecture), and (ii) farmers using "improved" varieties tend to have a higher propensity to resort to chemical weed control. These inferences are further discussed in Chapter Five.

4.6.7.3. Types of Herbicides Used by Farmers and Reasons for not Using Herbicides

The most often used herbicides are *Round up* (65% of the farmers who used herbicide) and *Ronstar* (29%), both of which are pre-emergence herbicide. Other

[1] In each of the 12 villages, more than 80 percent of the total labor time used for weeding is family labor, except in Longorola, Faradjélé, Kafuziéla and Sikasso where 46, 43, three, and 15 percent of the labor comes from the PU, respectively.

herbicides farmers used are *Gramoxone* (4% of the farmers) and *Primagram* 50 (2% of the farmers). The most frequent of the reasons cited by farmers for not using herbicides are financial constraint (58%) and the lack of knowledge about their existence (18%) or their use (3%). Other reasons include non-availability of herbicide (6%), excess water in the field (4%), the small size of plots (2%), or simply that herbicide application was not necessary (6%). Overwhelmingly, farmers argued that herbicide application could be economically justified. In fact, during group discussions, farmers consistently said they would rather buy herbicide than to buy fertilizer.

Although herbicide application is probably the most effective way to control weeds, they are expensive and can damage crop (if over applied) and cause other second generation problems when factors such as timeliness of application, right dosage and right chemical are not taken into account to ensure their effectiveness. However, thorough land preparation before planting and effective water management reduce weed pressure and make weeding cheaper and easier, especially when the rice is planted in rows. In Chapter Five, the distinguishing characteristics of farmers who used herbicides are identified while in Chapter Six an assessment of the financial impact of herbicide application on the returns to production factors is estimated.

4.6.8. Water Control and the Rate of Fertilizer Use

4.6.8.1. Importance of Fertilizers

Although nature provides most of the nutrients rice plants or any other crop requires for growth, a few of these nutrients are not available in adequate amounts or in a readily-available form. In general, grains require large amounts of nitrogen, phosphorus, and potassium. While there tends to be a general need for nitrogen in most rice growing areas, rice like many other cereals requires a considerable quantity of phosphorus[1] and, less so, sodium[2] (De Datta, 1970). Supplying these nutrients through chemical or organic fertilizer is one of the most effective way to increase rice yield.

Rice plants require as much nitrogen at the early and mid tillering stage (to maximize the number of panicles) as at the ripening stage. Phosphorous favors vigorous growth by stimulating (i) root development and making plants more resistant to drought, (ii) early flowering and ripening, and (iii) tillering. Studies in Asia show that the effectiveness of fertilizer application depends on plant density, application time and method, soil texture and its chemical content (especially its iron content) and organic matter, and water management[3] (De Datta, 1970).

4.6.8.2. Scope of Fertilizer Application in Rice Fields

Cotton is the only crop on which farmers routinely use chemical fertilizer and herbicide because these inputs are provided by CMDT when needed and their value is deducted later when CMDT purchases the output. While farmers have argued that fertilizers are somewhat expensive, as many as 42% of the 120 monitored farmers used

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[1] But, plant response to phosphorous application may be low.

[2] Rice soils are said to contain sufficient potassium to meet the crop requirement.

[3] During fertilizer application, temporary drainage is necessary for top dressing of fertilizer because it increases nutrient absorption and minimizes losses.

chemical fertilizer[1]. As was the case for herbicide, the proportion of farmers who used fertilizer is larger among those who planted "improved" varieties (76%) than among those with "traditional" varieties (22%). Family labor is the single labor source for fertilizer application, except in Sikasso, where 28 percent of the labor used was hired labor.

Farmers who did not use fertilizers gave five different explanations. The most frequent reason is that farmers consider fertilizers expensive (41%). However, organic manure have been used and still may be useful, particularly in subsistence farming areas like the one surveyed. Interestingly, 27% of the farmers said fertilizer was not necessary, while 10 percent think they are not available. Finally, the rest of the farmers did not use fertilizer, either because of excess water in their plot and lack of water management (10%), or because they have been exposed to fertilizers only since last year.

4.6.8.3. Types of Fertilizer Used by Rice Farmers and Average Application Rates

The most frequently used fertilizer is urea, which is sometimes applied in combination with diammonium phosphate (DAP) and a compound 15-15-15 cereal fertilizer. On the average, when used alone, farmers applied about 63 kg of urea (with a standard deviation of 41 kg). Surprisingly, those who applied urea in combination with a source of phosphorous used higher rates: 102 kg of urea (with a standard deviation of 98 kg) in combination with 95 kg of DAP (with a standard deviation of 98 kg), or 83 kg

[1] On a village by village basis, while no farmer used chemical fertilizer in Banko, Faradjélé and Solo, 20 percent used it in Sola, 30 percent in Faradié, Kafuziéla, Longorola and Sikasso, 60 percent in Péniasso, and 100 percent in Diassola, Kado, and Niéna.

of urea (with a standard deviation of 44 kg) in combination with 65 kg of the NPK cereal complex 15-15-15 (with a standard deviation of 35 kg). These application rates, which do not take into account differences in rice farming production systems, are below the recommended rate of 150 kg of urea and 150 kg of DAP per ha. System specific rates are reported in Chapter Six.

4.7. Summary

The objective of this chapter was to identify the socio-economic characteristics of *bas-fond* farmers, and to describe the rice production practices. The study observed that despite the small size of Mali-Sud *bas-fonds*, they offer farmers an opportunity to produce rice if well-watered during the rainy season. While this potential is important, it has not been fully utilized. The study found that *bas-fonds* are highly complex and heterogenous agroecosystems because *bas-fond* fields are generally cultivated by small-scale farmers who also cultivate upland fields.

The study notes that PUs are large with at least two households. Similarly, the households are large and average about 15 people, 46-64 percent of whom are females. Only 66.5 percent of these members significantly contribute to farm production activities.

The study also found that the formal schooling rate in *bas-fond* villages is low (10.6% of the members in each PU), especially among females (4.1%, compared to 9.7% for males). Similarly, adult literacy training is low (7.4% across the entire sample), especially among females (3.5%, compared to 18.0% for males). This low level of education suggests that to be effective, researchers and extension agents must take farmers' education background into account during technology development and extension.

Crop production and animal husbandry are the most important activities in the 12 villages surveyed. With regard to agricultural production, the study found that, when all upland and *bas-fond* fields are combined, the average PU managed seven fields. In seven of the 12 sampled villages, there is a highly significant ($P \leq 0.01$) and strong positive correlation (*i.e.*, $r \geq 0.6$) between the total number of PU members ≥ 15 years old and the total number of fields planted. Upland fields averaged 1.2 ha (with a standard deviation of 1.3) compared to 0.3 ha (with a standard deviation of 0.5) for the *bas-fond* fields.

Based on the total number of farm enterprise fields planted, rice fields were by far the most frequent (43%) of all fields in the entire sample, followed by pure stands of maize (11%), peanut (9%), finger millet (8%), cotton (8%), and sorghum/millet intercrop (8%). However, in terms of area cropped, rice fields accounted for a smaller proportion (16%) of the total area planted than maize (21%), cotton (20%), and sorghum/millet intercrop (17%).

With regard to rice production, the study observed that *bas-fond* rice production systems are influenced by the water regime (deficit, excess or optimum). Because the erratic rainfall has historically contributed to discourage rice farming, a careful management of the water flowing into the Mali-Sud *bas-fond* bed and into the individual plots is essential in order to fully exploit the crop's physical production potential.

This study also reveals that the demographic pattern of rice farmers has been changing, both in terms of age and gender distribution, with (i) more and more young women getting involved in rice production (although the average age is still high), and (ii) rice farming becoming a female-dominated activity. While the study found no correlation between farmers' gender and the adoption of "improved" varieties or herbicide, there is a significant (P=0.01) but weak positive correlation (r=0.2281) between gender and the use of fertilizer, with men (78%) more likely to use fertilizer than women (36%), due to the fact that men tend to control household income.

With regards to production practices, the study observe that animal traction is widely used. However, this equipment are primary used in the cotton fields and other collective upland fields, thereby increasing farmers' availability to work in the *bas-fond* fields. Not surprisingly, PUs in villages involved in cotton production tend to own more equipment than those with no cotton experience. The majority (98%) of the 120 farmers monitored actually plowed their field, only 17 percent cleared the field before plowing. Puddling is rare. About 82 percent of the farmers planted less than two weeks after plowing started. This practice has the effect to (i) expose the seedlings to high concentration of harmful substances generated during the decomposition of the organic material incorporated in the wet soil, and (ii) to limit the plant utilization of the ammonium released by decayed organic matter. As a result, there is a need for research on the timeliness and quality of land preparation.

Similarly, a difficult predominant manual tillage provides an opportunity for herbicide use. Broadcasting on mud is the dominant rice planting method used by farmers (86%). *Bas-fond* rice farmers plant many varieties (60) whose differentiation is not certain. On the average, about seven different varieties were planted in each village. A statistical analysis showed a highly significant association between water control and the type of varieties farmers planted, with a larger proportion of the "improved" varieties (75%) found in the *bas-fonds* with water control infrastructure, while a larger proportion of the "traditional" varieties (62%) found in the *bas-fonds* with no water control infrastructure.

Finally, the study notes that farmers are perfectly aware of the depressive effect of weeds on yield. About 91 percent of the farmers weeded their rice field at least once during the cropping season, only 18 percent weeded twice. Surprisingly, of those who weeded at least once, as much as 48 percent used herbicide. About 90% of the farmers who did not weed at all planted "improved" varieties. The proportion of farmers who applied herbicides is larger among those who planted "improved" varieties (62%) that those with "traditional" varieties (33%). Overwhelmingly, farmers argued that herbicide application could be economically justified, and farmers consistently said they would rather buy herbicide than to buy fertilizer. While farmers have argued that fertilizers are somewhat expensive, as much as 42% of the 120 monitored used chemical fertilizer. The proportion of farmers who used fertilizer is larger among those who planted "improved" varieties (76%) than among those with "traditional" varieties (22%).

CHAPTER FIVE
FACTORS DETERMINING THE ADOPTION OF MODERN INPUTS, AND YIELD LEVELS IN BAS-FOND RICE PRODUCTION SYSTEMS

5.1. Introduction

This chapter focuses on the research question: what determines the current level of production and intensification in *bas-fond* rice production? First, the chapter reviews the theoretical basis for using a logistic model to analyze factors associated with farmers' decisions to adopt modern inputs (*i.e.*, "improved" rice varieties, chemical fertilizer and herbicide), describes the variables used to specify these models, and discusses the estimation results in terms of insights that would help researchers and extension agents prioritize their strategies for achieving wider adoption. Second, it describes the distribution of farmers' rice yields and identifies their determinants, based on econometric estimation. Finally, it discusses the potential contribution of *bas-fond* production systems to the Malian domestic rice supply and reviews constraints to greater production.

5.2. Logistic Models and Adoption Characteristics

A logistic model is used to identify factors associated with varying levels of input (*i.e.*, fertilizer, and herbicide) *bas-fond* rice farmers used during the 1995-96 cropping season, and to predict the likelihood of a farmer using "improved" rice seeds, fertilizer and herbicide, given selected observable attributes.

5.2.1. Justifications for the Use of the Logistic Model

The adoption of an "improved" technology is assumed to be an economic decision based on farmers' expected utility (or expected profitability) of using this new technology, given a set of individual, agroeconomic, institutional, and environmental characteristics. Characteristics hypothesized to be associated with technology adoption in the *bas-fond* include socio-demographic factors (*i.e*,. age, gender, and education), agronomic factors (*i.e.*, management practices and hydrologic features of the field--maximum sustained water depth, rate of increase in the water depth, and length of the flooding period), economic factors (*i.e.*, household and farm sizes, profitability[1]), institutional factors (seed availability and accessibility), and climatic factors (length of the rainy season and intensity of rains).

Identifying the distinctive characteristics of farmers using different technologies and predicting the likelihood of a particular farmer to use a technology is a classification or discrimination problem. Given farmers' observable characteristics, the goal is to classify each of them into one of two categories -- an "adopter" or a "non-adopter" of the "improved" technology-- by identifying factors associated with adoption behavior.

Regression analysis is often used to identify factors (known as regressors or independent variables) that can explain data variability of a particular variable (known

[1] Note that although agronomic factors and profitability are mentioned separately, the study recognizes that the later is a function of the former.

as regressand or dependent variable). In regression analysis, however, the regressand is a continuous variable. But, in this case, the dependent variable being modelled is a dichotomous qualitative variable.

In modeling a qualitative dependent variable, the standard linear regression technique is not appropriate because the limited range of the values of the dependent variable (*e.g.*, between zero and one for binary cases) may result in a misestimation of the magnitude of the effects of the independent variables, especially if the ordinary least square (OLS) procedure is used. In addition, because the disturbances are inherently not normally distributed, no method of estimation that is linear in the dependent variable's observations (Y_is) will be fully efficient[1] (Cox and Snell, 1989). Furthermore, the parameters in the regression model with a dichotomous regressand have limited interpretation, and the condition of constant variance of the disturbances (homoskedasticity) required for the OLS estimation does not hold[2]. Thus, all the standard statistical inferences such as hypothesis testing and construction of the confidence intervals are invalid, even for very large samples. Although Goldberger proposed a two-step, weighted estimator to correct the heteroskedasticity problem

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[1] An estimator is said to be an efficient estimator of ß if it is unbiased (i.e., the mean value of its sampling distribution or expected value of that estimator is ß), and it has the smallest possible sampling variance among all unbiased estimators of ß.

[2] For example, in the case of binary variable where the regressor Y_i takes the value "1" with a probability P_i or "0" with a probability $(1-P_i)$, it follows that:

$$Y_i^2 = Y_i \text{ and}$$
$$E(Y_i) = E(Y_i^2) = 1*P_i + 0*(1-P_i) = P_i. \text{ Thus,}$$
$$Var(Y_i) \equiv E(Y_i^2) - [E(Y_i)]^2 = P_i - P_i^2 = P_i(1 - P_i)$$

This result shows that the variance is heteroskedastic, since its value depends systematically on the probability P_i, except in the rather uninteresting cases where the P_is are the same for all farmers.

(Aldrich and Nelson, 1984), the other problems mentioned earlier remain unsolved because the function is still unbounded.

For these reasons, scientists typically use qualitative response models to model the relationship between a discrete dependent variable and a set of continuous and/or discrete independent variables. The qualitative response models ensure that the regressand P_j is kept within the unit interval. The general form of the qualitative response models is formulated mathematically by relating the probability of an event "Y" (*i.e.*, "using improved technology") occurring conditional on a vector "X" of explanatory variables, to the vector "X", through a cumulative density function F as follows:

$$E[Y_i] \equiv P_j \equiv P(Y_i=j) = F(X_i, \beta) \quad \text{with} \quad i=1,2,...,n \quad j=1,2,...J \tag{1}$$

ß is a vector of unknown parameters, i is a sampled individual, and j is the event's outcome (here, yes or no). For response data, F can be a linear discriminant function, a probit function, or a logit function. The discriminant function is appropriate and justifiable only under (a) multivariate normality of the independent variables, and (b) complete equality of all the underlying covariance matrices (Press and Wilson, 1978). Unfortunately, in practice, the assumption of joint normality of the regressors is difficult to satisfy, and transformations often used to achieve multivariate normality will not typically guarantee equality of covariance matrices (Press and Wilson, 1978).

The probit and logit functions are the most familiar, and in many ways[1] the most useful, analogue to a linear function for normally distributed data (Ameminya, 1981; Aldrich and Nelson, 1984). Both of these models are defined based on the assumption on the distribution of the disturbances over the set of outcomes. The qualitative response models for which F is a logistic distribution function are called logistic regression models, while those for which F is a cumulative normal distribution function are called probit regression models. Although the probit model was the first of the two models to be developed, the choice between these two models is usually made on the basis of practical concerns such as personal preference, experience, and availability and flexibility of computer software (Aldrich and Nelson, 1984; Judge *et al.*, 1988). For this particular study, the logit model was retained based on these considerations.

5.2.2. Mathematical Formulation of the Logistic Model

There are many types of logit models. The more general ones for which there are multiple outcomes for the regressand are known as multinominal logistic models. In cases where there are J+1 possible unordered outcomes, their general form is:

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[1] For example, it can be proven that these functions are continuous, bounded between 0 and 1, monotonically increasing with ß'X, and they approximate the normal distribution (Ameminya, 1981; Judge et al., 1988). In addition, they are easy to use.

Other qualitative response models are models of 'count' data which describe discrete outcomes for which the data, which are enumeration of occurrences of certain events, have some natural ordering and/or their magnitude is meaningful. An example in which only the ordering matters would be cases where preferences (e.g., taste test) are ranked among a set of alternatives. In these cases, the ordered probability models are most appropriate. An example of cases where both the ordering and magnitude matter would be modelling a variable which is an enumeration of the number of occurrences of a certain event such a car accident per year. For such cases, models for count data are the most appropriate.

$$P(Y_i=j) = \frac{\exp(\beta_j'X_i)}{\sum_{j=0}^{J}\exp(\beta_j'X_i)} \qquad with \quad i=1,2,...,n \qquad (2)$$

In other words, for each individual i, the probability of an event's outcome j to occur depends on a single regressor vector of individual or grouped data[1], "X", which describes the individual, and a set of J parameters β_i.

Other types of the multinominal logit models include the nested logit and discrete choice models[2]. In this study, the data used are non-nested individual data. Because, the regressor is binomial and it takes the value "1" if the farmer used the "improved" technology and "0" if he/she did not, this study uses a binomial logit regression model. While there are many specifications of the binomial logistic model, choosing one particular specification is arbitrary (Aldrich and Nelson, 1984). For this study, this choice is imposed by the computer software, LIMDEP and SPSS, available. The LIMDEP and SPSS specifications, which are a model proposed by Chamberlain in 1982, are as follows:

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[1] Individual data are defined as data for which measurements on dependent variable consist of individual responses, while with the grouped data, the regressor consists of proportions.

[2] The discrete choice models are a variant of the multinominal logit models in which the J alternatives (not J+1) are each characterized by a set of K attributes X_{ij}. Respondent i chooses among J such choices. There is a single parameter vector, ß, such that the probability that individual i chooses alternative j is $P(Y_i=j)$, with:

$$P(Y_i=j) = \exp(\beta'X_{ij})/\Sigma_j\exp(\beta'X_{ij}) \qquad i=1,...,I \text{ and } j=1,2,...,J.$$

The nested logit models are models in which the probability are nested at two or more levels. So, instead of:

$$P(Y_i=j) = \exp(\beta'_jX_i)/\Sigma_j\exp(\beta'_jX_i)$$

In the case of two levels nesting, we have: $P(Y_{ij}=j) = \exp(\beta'X_{ij})/\Sigma_i\Sigma_j \exp(\beta'X_{ij})$.

$$P_1 = P(Y_i=1) = \frac{\exp(\beta' X)}{1 + \exp(\beta' X)} \tag{3}$$

The parameters β_is are estimated using the maximum likelihood method (MLE). Unlike the OLS procedure, which chooses those values of the unknown parameters which result in the smallest sum of squared distances between the observed and predicted values of the dependent variable, the MLE chooses those values that make the observed results most "likely". In other words, the MLE method maximizes the probability of obtaining the sample actually observed. For specific values of the independent variables, the corresponding estimated value of P_1 is the probability for the event "adopting the technology" to occur. Therefore, alternative meaningful values of the regressors can be used in the estimated model to predict the likelihood of the event under those conditions.

Each estimated coefficient reflects the effect of a one-unit change in the corresponding independent variable on the logarithm of the odds[1] of the event to occur, *ceteris paribus*. These coefficients are difficult to interpret because the magnitude of the increase in probability depends on the original probability, which is determined by the individual values of all independent variables and their coefficients. However, the effect of individual characteristics can be assessed by estimating the marginal effects δ_1 of the regressors in the logistic model as follows:

where: $P_1 = Prob[y_i=1]$,
X is a vector of the regressors in the logistic function,

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[1] The odds of an event to occur is the ratio of the probability that the event will occur over the probability that it will not occur. This can be expressed mathematically as follows:

$$\text{log of the odds of an event} = \log\left(\frac{Prob(event)}{prob(no\ event)}\right) = \beta_0 + \beta_1 X_1 + .. + \beta_J X_J$$

$$\delta_1 = \frac{\partial P_1}{\partial X} = F(\overline{X}, \beta)\,\beta \qquad (4)$$

β is a vector of the estimated parameters of the logistic function.

These marginal effects δ_1 correspond to changes in the probability of adopting the "improved" technology, given a "unit change" in the characteristics vector **X**. The computer software used for this analysis (LIMDEP) includes a routine to perform all the algebraic computations necessary to estimate δ_1. It is important to note that neither the sign nor the magnitude of δ_1 necessarily have to be similar to those of ß (Greene, 1992). Furthermore, ß and δ_1 do not necessarily have the same statistical significance since the standard error of δ_1 depends on the standard error of ß and F.

5.2.3. Distinctive Characteristics of Adopters of "Improved" Varieties

5.2.3.1. Model Specification

As mentioned earlier, farmers' adoption of "improved" varieties is affected by several socio-demographic, economic, agronomic and institutional factors. Table 5.1 presents the variables used in this study, and the hypothesized direction of the relationship between the identified variables and the probability of farmers' adoption behavior.

Table 5.1: Factors Hypothesized to Affect Farmers' Adoption of "Improved" Rice Varieties for the *Bas-Fond* Production Systems.

Factors	Measurement in the Study	Variable Name	Hypothesized Sign
Socio-Demographic Factors:			
- farmer's age	- years	AGEXPL	-
- farmer's gender	- gender (male/female or 0/1)	GENDER	-
- farmer's education	- schooling rate in the PU (%)	PCTSCOL	+
	- literary rate in the PU (%)	PCTALP	+
	- female schooling rate in the PU (%)	FPCTSCO	+
	- female literary rate in the PU (%)	FPCTALP	+
Economic Factors:			
- farm size	- hectares of rice area planted	SURFACE	+
- size of the PU	- number of people in the PU	UPASIZE	+
Agronomic Factors:			
- maximum sustained water depth	}		
- rate of increase of water depth	- } plant stress during the season (no/yes or 0/1)	STRESS1	-
- length of flooding period	}		
- water control	- water control infrastructure (no/yes or 0/1)	WTCONT	+
Institutional Factors:			
- awareness, availability and access to seeds	} presence of extension service (no/yes or 0/1)	STECHELP	+
	- } village experience in cotton production (years)	HISTCOT	+
	} cotton production in the farmer's PU (no/yes)	COTFIELD	+
- access to markets	- } distance to closest weekly market (km)	WMKTD	-
	} distance to closest urban market (km)	URBMKTD	-

Because the meaning of the identified variables and their hypothesized signs are fairly straightforward, they are not discussed in detail. However, variable STRESS1 warrants further explanation. This variable is used to capture the effect of plots' hydrologic characteristics on farmers' decision to adopt "improved" rice varieties. Theoretically, these characteristics include factors such as the maximum sustained water depth, the rate of increase in water depth, and the length of the flooding period. Because such data do not exit and it was practically impossible to generate them, this analysis uses farmers' perception of the water stress suffered by the rice plant during the critical periods of the crop cycle (*i.e.*, germination, tillering, flowering, and grain filling) as a proxy.

For each farmer, the variable STRESS1 is coded "1" if, from her/his own point of view, she/he observed evidence of significant water stress on the rice plants during any of these periods, and "0" if she/he did not. During the analysis, alternative stress variables were evaluated, which represented combinations of the water stress proxies. However, these results are not reported because none of these combinations was statistically significant. As a result, only the more general proxy was retained.

The hypothesized negative sign for the variable GENDER indicates that it is expected that men are more likely to adopt "improved" varieties than women. The education variable is included as a proxy for farmers' capacity to fully understand the complexity of the technology.

While this study focuses on the variables identified in Table 5.1, it recognizes that other variables can be used in modeling farmers' technology adoption decisions. For example, the extent to which the technology can be tested on a small scale (*i.e.*, trialability and divisibility) and the extent to which it is possible to visualize the change in the resulting outcome (*i.e.*, observability) are potentially important determinants of adoption. Similarly, taste and the processed grain color, as well as the difference in net returns between the "traditional" and "improved" varieties, and the availability of and access to credit are often important determinants.

However, the trialability, divisibility, and observability of the technology being studied (*i.e.*, variety) are not included in the analysis because this technology satisfies these conditions. Varieties taste and color, as well as the access to credit are not considered due to funding and time constraints. Finally, net return differential are not included in this analysis because these farmers are predominantly subsistence farmers[1].

Since, as mentioned earlier, only a fraction of the 334 farmers surveyed were monitored to collect detailed input-output data including yields, the logistics model is estimated with data from this sub-sample. Table 5.2 presents a summary of the descriptive statistics computed from this sub-sample for the variables used in the estimation process. The sub-sample is composed by 221 farmers, 84 percent of which are female, 61 percent from a *bas-fond* with a water control infrastructure, and 48 percent planted "improved" rice varieties.

[1] However, net returns of selected rice production systems are estimated in subsequent chapters.

Table 5.2: Descriptive Statistics of the Variables Hypothesized to Affect Farmers' Adoption of "Improved" Rice Varieties for the *Bas-Fond* Production Systems.

Variables	Unit	Mean Value	Standard deviation	Minimum	Maximum	Sample size
Socio-Demographic:						
GENDER	dummy	0.84	0.37	0	1	221
AGEXPL	years	43.92	12.86	20	81	221
PCTSCOL	%	10.71	17.01	0	100	221
PCTALP	%	7.40	10.62	0	73	221
FPCTSCO	%	3.90	14.88	0	100	221
FPCTALP	%	2.91	11.58	0	100	221
Economic:						
SURFACE	ha	0.42	0.93	0.02	12	221
UPASIZE	persons	16.13	12.42	2	94	221
Agronomic:						
STRESS1	dummy	0.48	0.50	0	1	221
WTCONT	dummy	0.61	0.49	0	1	221
VARIETY	dummy	0.48	0.50	0	1	221
Institutional:						
STECHELP	dummy	0.27	0.45	0	1	221
HISTCOT	dummy	0.52	0.50	0	1	221
COTFIELD	dummy	0.52	0.50	0	1	221
WMKTD	km	3.27	2.61	0	7	221
URBMKTD	km	34.78	26.05	0	80	221

Source: Survey Data.

5.2.3.2. Results, Interpretation, and Implications for Research and Extension

Using the variables identified in Table 5.1 and data for the entire sub-sample of monitored farmers[1], various specifications of the binomial logit model were estimated.

[1] An attempt to evaluate these models at the village-level to determine if there existed some variability in the behavior of the variables from one village to another was abandoned because of limited degrees of freedom within adoption groups in each village.

To take guard against the undesirable[1] effects of correlations between these variables (*i.e.*, multicollinearity), a stepwise regression procedure was used for selecting variables to be included in the model. Variables were excluded or included in the model based on the probability associated with their F-statistics whose cutoff point was set to 0.05 for the inclusion and 0.10 for the exclusion rules. This procedure ensured that when two variables were (statistically) significantly correlated, only one of them was used in a specification.

The estimated model specifications were evaluated based on (i) theoretical consideration, (ii) the significance[2] of the regressors' coefficients and the direction of their effect on the probability of adopting "improved" varieties, (iii) how well the models classify the sampled farmers into their observed adoption category, and (iv) how likely the sample results are, given the parameter estimates. The LIMDEP classification table was used to assess how well each model classifies the observed data. This table compares the model's prediction to the observed outcomes by giving the number of observations that are correctly and incorrectly classified as adopters versus non-adopters. For each farmer, this comparison is based on whether or not the estimated probability

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[1] Appendix 5.1 provides a summary of the two dimensional correlation coefficients between variables considered in estimating the binomial logistic model for farmers' decision to adopt "improved" rice varieties. While there exist many significant correlations between variables in Appendix 5.1, this is not unusual, particularly when many dummy variables are used. Under such circumstances, the analyst is most concerned by perfect or strong correlations. If the model includes variables that are perfectly correlated (i.e., $r=+1$ or -1), it is mechanically impossible to compute the parameters' estimates since the hessian involved would be singular and thus not invertible (i.e., the iterations would not converge). If the model includes variables that are strongly correlated (i.e., r is high), the estimation procedure may produce large standard errors of the coefficients, leading to less precise estimates and making it difficult to reject hypotheses that would otherwise be rejected (i.e., leads to type II error).

[2] The significance of each regressor's estimated coefficient is determined using student test (t-test) to test the null hypothesis that the estimated coefficients are individually equal to zero.

that the farmer used "improved" rice varieties is greater or less than one-half. If for a particular farmer this estimated probability is more than one-half, that farmer is classified as an "adopter" of the "improved" rice variety. Alternatively, if this probability is less than one-half, the farmer is classified as a "non-adopter" of the "improved" rice variety.

To assess how likely the sample results are, the null hypothesis that the explanatory variables other than the intercept have no impact on the choice probability (*i.e.*, the β_is are jointly equal to zero) was tested using the model's chi-square (χ^2) statistics[1].

The results generated by the estimation process showed that three of the specifications are fairly similar, in the sense that the coefficients are fairly similar in magnitude, statistical significance, and the direction of the effects of each regressor on the probability P_1 to adopt "improved" varieties. These three models differ in terms of the education variable used (*i.e.*, literacy rate or schooling rate) and the inclusion or exclusion of the variable "STRESS1" used in an attempt to capture the effect of the hydrological characteristics of each plot on adoption. Ultimately, the model with the literacy rate was retained because of CMDT and ONGs involvement in literacy campaign, and the estimation results are reported in Table 5.3.

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[1] The model's chi-square statistics (χ^2) is computed as the difference between the values of -2LL (i.e., -2 times the value of the log-likelihood function) of the model with only the constant term and the current model. The degrees of freedom for the test is computed as the difference in degrees of freedom between the two models. For each model, the degrees of freedom is the total number of cases (i.e., farmers), minus the number of parameters being estimated. The null hypothesis is rejected if the model's chi-square value is too large.

Table 5.3: Farmers' Adoption of "Improved" Rice Varieties-- Estimated Coefficients (ß), Marginal Effects (δ_1), and Percent Successful Classification for Logit Models in *Bas-Fond* Production Systems, Mali, Cropping Season 1995-96.

Variables	Estimated Coefficient (ß)	Standard Error	Significance	Partial Correlation Coefficient	Marginal Effect (δ_1)[a]
---------- Variables in the Equation ----------					
WTCONT	2.0277	0.4468	0.0000	0.2465	0.5069
GENDER	-2.1526	0.9133	0.0184	-0.1078	-0.5385**
WMKTD	-0.2167	0.0871	0.0128	-0.1170	-0.0542*
SURFACE	-0.3803	0.2655	0.1521	-0.0130	-0.0951*
HISTCOT	0.7544	0.3903	0.0533	0.0753	0.1886
Constant	1.0840	0.9148	0.2360		0.2713
---------- Variables not in the Equation ----------					
<u>Residual χ^2</u>	7.188		0.3038		
UPASIZE	1.4784		0.2240	0.0000	
AGEXPL	1.0000		0.3173	0.0000	
URBMKTD	4.5336		0.0332	0.0910	
STECHELP	0.0048		0.9445	0.0000	
FPCTALP	0.1380		0.7103	0.0000	
STRESS1	0.1073		0.7432	0.0000	
<u>Model's χ^2</u>	92.8730**				
<u>% Correct Prediction</u>:					
non-adopters (n=115)	84.35%				
adopters (n=106)	74.53%				
both (N=221)	79.64%				

(a) "*" is used when P ≤ 0.02 while "**" indicates that P ≤ 0.01 (2-tailed significance). The coefficients with no asterisk are not significantly different from zero for $\alpha \leq 0.05$.

It is important to note that there is a fairly good balance between the size of the sub-sample of adopters (106 farmers) and non-adopters (115 farmers) for the dependent variable[1]. While all variables used in the models were expected to be statistically significant, the estimation results show that only the presence of a water control infrastructure (*i.e.*, WTCONT), farmers' gender (*i.e.*, GENDER), the village distance to the closest market (*i.e.*, both urban and weekly markets, but mostly weekly markets), and the village experience in cotton production (*i.e.*, HISTCOT) are significant.

As hypothesized, the positive signs of the significant estimated coefficients for the presence of water control in the *bas-fond* and the village years of experience in cotton production indicate that each of these two variables increase the probability of adopting "improved" varieties. While the positive effect of water control may be attributed to farmers' perception that "improved" varieties are better suited to the resulting water conditions than "traditional" varieties, the effect of the village cotton production experience is due to the fact that CMDT, a parastatal promoting cotton, makes inputs (including seeds) available on credit to cotton producers.

The negative sign of estimated coefficient of the significant gender and market distance variables indicate that (1) men are more likely than women to adopt "improved" varieties, and (2) the longer the village distance to the closest market, the higher the decrease in probability to adopt the variety, respectively. As argued earlier, the difference in gender behavior with respect to variety adoption can be explained by the

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[1] Note that only 221 of the 334 sampled farmers are included in this analysis because they are cases for which there was no missing data for each variable in the model. The statistical package used to estimate the marginal effects (LIMDEP) could not run the entire data set of 334 cases because some of the variables in the model had missing data. This explanation is also valid for subsequent logistic models.

fact that men are the ones who control the household's income and they tend to be more exposed to extension agents and researchers than women.

Table 5.3 also substantiates the point made earlier that a significant estimated coefficient does not necessarily implies a significant marginal effect[1] of the variable on the regressand because the standard error of marginal effects depends on the standard error of the estimated coefficients and F (see Equation 4). The village experience in cotton production and the presence of water control infrastructure, which have statistically significant estimated coefficients, have non-significant marginal effects. In contrast, farmers' rice plot size which has a non-significant estimated coefficient has a significant marginal effect.

From the estimated values, it appears that farmer's gender has the highest statistically significant marginal effect (absolute value) among the five variables selected in the final equation, followed by farmers' rice plot size, and the village distance to the closest market. These results indicate that moving from male to female farmers tends to decrease the probability for farmers to adopt "improved" varieties by about 54 percent, while the village distance to the closest market and plot size tend to decrease this probability by about five and 10 percent per unit, respectively. While the five percent increase in probability for farmers to adopt the "improved" variety due to the village distance to the closest market may appear to be negligible, it could indeed be important when one keeps in mind that it is estimated on a per kilometer basis.

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[1] The marginal effect of any variable is the change in the probability of adopting the "improved" technology, given a "unit change" in that variable.

The inability of these models to show statistical significance for variables such as plot size (*i.e.*, SURFACE) and farmer's age (*i.e.*, AGEXPL) can be explained by their low variability among the sample of farmers. Almost all rice plots in each of the 12 *bas-fonds* have fairly equal in size and most rice farmers are older members of the PUs. Although the models failed to indicate an expected statistical significance for these other regressors, its goodness of fit is fairly acceptable, based on the (statistically) highly significant chi-square values and the high percent of correct prediction. The models correctly classified 75 percent of the farmers who actually used "improved" varieties, and as much as 84 percent of those who used "traditional" varieties. Overall, 80 percent of the farmers were correctly classified into their actual variety adoption category.

A higher predictive power for adopters of "improved" varieties would have been desirable because the primary goal for this estimation was to identify factors that can be used to promote greater adoption of the "improved" varieties. However, these models do reveal that improving water control, and expanding female farmers' access to credit and seeds could significantly increased the adoption of "improved" varieties.

While not explicitly included as a variable in the estimated models, key informants reported that one of the constraints to a wider adoption of "improved" rice varieties is the absence of a reliable supply of seeds. Currently, CMDT is the only formal source of "improved" seeds, mostly through loans that are later repaid for from cotton sales. However, the role of CMDT as a seed credit source is constrained by the fact that farmers have a credit limit, which is determined by their respective cotton production levels and is limited to no more than 30 percent of their cotton revenues.

Even if CMDT could revise its credit policy on seeds to enable more farmers (including non-cotton farmers) to buy seeds from them, it is likely that CMDT would not be able to meet the potential demand for rice seeds, given that cotton is its main thrust.

Of course, speculation about the need to expand seed availability is contingent to the higher performance of the "improved" varieties, relative to the "traditional" ones. The issue of the performance of the rice varieties is addressed in Section 5.5 of this chapter and in Chapter Six. The important question regarding the extent to which the policy reforms lunched in 1990s would be able to enhance the development of reliable sources of seeds is not addressed in this study[1]. However, we hypothesize that the success of these policies would likely have a some significant effects on *bas-fond* rice production, assuming farmers have the purchasing power or have access to cash.

5.2.4. Distinctive Characteristics of Adopters of Herbicide and Fertilizer

5.2.4.1. Model Specification

As with the use of "improved" varieties, farmers' decision to use herbicides and/or fertilizer in their rice fields is affected by several socio-economic, agronomic and institutional factors. Table 5.4 presents the specific variables used in this study to model herbicide and fertilizer adoption.

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[1] Previous experiences have shown that, to a large extent, the successful development of a seed industry has depended upon governments leadership and investment in launching the seed industry, an effective partnership between the public and private sectors, the development and enforcement of official seed certification labels, and effective rules and regulations dealing with trial of new varieties, variety registration, seed import, intellectual property rights, and access to publicly-developed germplasms, as well as the private sector capability and incentive to commercialize and disseminate high-quality seeds (Rusike, 1995).

Table 5.4: Factors Hypothesized to Affect Farmers' Adoption of Herbicide and Fertilizer in the *Bas-Fond* Rice Production Systems.

Factors	Measurement in the Study	Variable Name	Hypothesized Signs[a]
Socio-Demographic Factors:			
- farmer's age	- years	AGEXPL	-/-
- farmer's gender	- gender (male/female, 0/1)	GENDER	-/-
- farmer's education	- schooling rate in the PU (%)	PCTSCOL	+/+
	- literary rate in the PU (%)	PCTALP	+/+
	- female schooling rate in the PU (%)	FPCTSCO	+/+
	- female literary rate in the PU (%)	FPCTALP	+/+
Economic Factors:			
- farm size	- hectares of rice area planted	SURFACE	+/+
- size of the PU	- number of people in the PU	UPASIZE	-/+
- relative size of the PU (herbicide only)	- UPASIZE/SURFACE	LABOR	-/+
Agronomic Factors:			
- maximum sustained water depth	}		
- rate of increase of water depth	- } plant stress during the season (no/yes or 0/1)	STRESS1	-/-
- length of flooding period	}		
- water control	- water control infrastructure (no/yes or 0/1)	WTCONT	-/+
- rice variety type	- traditional vs improved (0/1)	VARIETY	+/+
Institutional Factors:			
- access to the input	- presence of extension service (no/yes or 0/1)	STECHELP	+/+
	- village experience in cotton production (years)	HISTCOT	+/+
	- cotton production in the farmer's PU (no/yes)	COTFIELD	+/+
	- distance to closest urban market (km)	URBMKTD	-
	- distance to closest weekly market (km)	WMKTD	-

[a] The left hand side signs apply to the herbicide model and the right hand side signs apply to the fertilizer model.

These variables are similar to those used in the variety adoption model, with one exception that the rice variety planted is assumed to be a determinant of herbicide and/or fertilizer use, based on farmers' belief that "improved" varieties require using these inputs. Furthermore, a variable measuring the number of PU labor per hectare of *bas-fond* land cultivated by the PU (*i.e.*, LABOR) is included in the herbicide model as an attempt to improve the value of the variables SURFACE and UPASIZE.

The hypothesized signs on the variables LABOR and UPASIZE indicate that the larger the household or the size of the household per area planted, the less likely are farmers to use herbicide, and the more likely they are to apply fertilizer because they expect to increase their production (yields) to feed their larger household. Farmers age and water stress are expected to have a negative effect on the probability to adopt herbicide or fertilizer. For GENDER, the hypothesized signs indicate that men are more likely to adopt herbicide or fertilizer than women because they control the household's income. In contrast, farmer's education and *bas-fond* area planted are expected to have a positive effect on the probability to adopt herbicide or fertilizer. For VARIETY, the hypothesized signs indicate that farmers who plant "improved" varieties are more likely to adopt herbicide or fertilizer than those who plant "traditional" varieties.

As was the case for variety adoption model, the logistics analysis on herbicide and chemical fertilizer adoption utilizes data from a sub-sample of 334 monitored farmers. The sub-sample includes 115 farmers, 88 percent of whom are female, 50 percent farm in a *bas-fond* with a water control infrastructure, 40 percent planted "improved" rice varieties, 43 percent applied herbicide, and 42 percent applied fertilizer (Table 5.5).

Table 5.5: Descriptive Statistics of the Variables Hypothesized to Affect Farmers' Adoption of Herbicide and Fertilizer for the *Bas-Fond* Rice Production Systems.

Variables	Unit	Mean Value	Standard deviation	Minimum	Maximum	Sample size
Socio-Demographic						
GENDER	dummy	0.88	0.33	0	1	115
AGEXPL	years	43.26	13.61	20	79	115
PCTSCOL	%	12.85	17.63	0	77	114
PCTALP	%	8.86	10.02	0	40	114
FPCTSCO	%	5.41	16.75	0	100	115
FPCTALP	%	2.85	9.85	0	50	115
Economic:						
SURFACE	ha	0.37	1.13	0.2	12	115
UPASIZE	persons	16.52	10.14	3	60	115
Agronomic:						
STRESS1	dummy	0.48	0.50	0	1	115
WTCONT	dummy	0.50	0.50	0	1	115
VARIETY	dummy	0.40	0.49	0	1	115
FERT	dummy	0.42	0.50	0	1	115
HERB	dummy	0.43	0.50	0	1	115
Institutional:						
STECHELP	dummy	0.32	0.47	0	1	115
HISTCOT	dummy	0.50	0.50	0	1	115
COTFIELD	dummy	0.50	0.50	0	1	115
URBMKTD	km	31.47	24.62	0	80	115

Source: Survey data.

5.2.4.2. Results, Interpretation, and Implications for Research and Extension

Using the variables identified in Table 5.4 and data for the entire sub-sample of monitored farmers, various specifications of the binomial logit model for farmers' decision to adopt herbicide and fertilizer application were estimated, using the stepwise procedure to take into account possible correlations between these variables (Appendix

5.2). The estimated model specifications were evaluated using the same tools and standards discussed earlier for the model on the adoption of rice varieties. From the estimation process, one specification was retained for each input. These results are reported in Table 5.6 for herbicide adoption and Table 5.7 for fertilizer adoption.

Table 5.6: Farmers' Adoption of Herbicide Application-- Estimated Coefficients (ß), Marginal Effects (δ_1), and Percent Successful Classification for Logit Models in Farmers' for *Bas-Fond* Production Systems, Mali, Cropping Season 1995-96.

Variables	Estimated Coefficient (ß)	Standard Error	Significance	Partial Correlation Coefficient	Marginal Effect (δ_1)[a]
---------- Variables in the Equation ----------					
VARIETY	1.1008	0.4108	0.0074	0.1814	0.2699**
URBMKTD	0.0207	0.0085	0.0151	0.1576	0.0051**
Constant	-1.3683	0.3705	0.0002		-0.3356**
---------- Variables not in the Equation ----------					
Residual χ^2	9.236		0.3228		
WTCONT	1.3933		0.2379	0.0000	
LABOR	0.1349		0.7134	0.0000	
AGEXPL	0.5098		0.4752	0.0000	
GENDER	0.1577		0.6913	0.0000	
STECHELP	0.0052		0.9427	0.0000	
FPCTALP	1.7668		0.1838	0.0000	
HISTCOT	0.4047		0.5247	0.0000	
STRESS1	3.2058		0.0734	0.0875	
Model's χ^2	15.7533**				
% Correct Prediction:					
non-adopters (n=65)	87.69%				
adopters (n=50)	48.00%				
both (N=115)	70.43%				

(a) "*" is used when P ≤ 0.02 while "**" indicates that P ≤ 0.01 (2-tailed significance). The coefficients with no asterisk are not significantly different from zero for α ≤ 0.05.

Table 5.7: Farmers' Adoption of Fertilizer Application-- Estimated Coefficients (ß), Marginal Effects (δ_1), and Percent Successful Classification for Logit Models on Farmers' in *Bas-Fond* Production Systems, Mali, Cropping Season 1995-96.

Variables	Estimated Coefficient (ß)	Standard Error	Significance	Partial Correlation Coefficient	Marginal Effect (δ_1)[a]
---------- Variables in the Equation ----------					
VARIETY	1.0922	0.5394	0.0429	0.1159	0.2564*
WTCONT	2.0908	0.5264	0.0001	0.2969	0.4913**
HISTCOT	1.5474	0.5157	0.0027	0.2117	0.3636**
Constant	-2.7586	0.4951	0.0000		-0.6482**
---------- Variables not in the Equation ----------					
Residual χ^2	2.664		0.91342		
LABOR	0.4148		0.5195	0.0000	
AGEXPL	0.3574		0.5500	0.0000	
GENDER	1.2590		0.2618	0.0000	
URBMKTD	0.2956		0.5867	0.0000	
STECHELP	0.0925		0.7610	0.0000	
FPCTALP	0.8989		0.3431	0.0000	
STRESS1	0.0046		0.9460	0.0000	
Model's χ^2	56.8574**				
% Correct Prediction:					
non-adopters (n=67)	91.04%				
adopters (n=48)	75.00%				
both (N=115)	84.35%				

(a) "*" is used when P ≤ 0.05 while "**" indicates that P ≤ 0.01 (2-tailed significance). The coefficients with no asterisk are not significantly different from zero for $\alpha \leq 0.05$.

Tables 5.6 and 5.7 reveal that in addition to the type of rice variety planted, which is statistically significant in both cases, different factors significantly affect the probability for farmers to use herbicide versus fertilizer in their rice fields. For herbicide use, the statistically significant independent variables are the type of variety planted and the village distance to the closest urban market. Factors that affect the probability for farmers' to use chemical fertilizers are the type of variety planted, the presence of a water control infrastructure, and the village experience in cotton production.

For the herbicide model (Table 5.6), the positive sign on the estimated coefficient of the type of variety planted indicates that, as expected, farmers using "improved" varieties are more likely to apply herbicide than those who do not. Surprisingly, the estimated output shows that there is a positive correlation between market distance and herbicide use, which suggests that the longer the distance to the closest urban market, the higher the probability that farmers will adopt herbicide application. This result is counter-intuitive and could not be explained.

For the fertilizer model (Table 5.7), the positive sign on the estimated coefficient of the type of variety planted indicates that, as with herbicide, farmers planting "improved" varieties are also more likely to adopt fertilizer application than those who do not. Similarly, the positive sign on the estimated coefficient for water control variable suggests that, as expected, farmers are more likely to use chemical fertilizer in *bas-fonds* with water control infrastructure than in unimproved *bas-fonds*. This is because fertilizer tends to be washed away in fields without water control. Unlike with the herbicide model, there is a positive correlation between village years of experience in cotton production. The positive sign on the estimated coefficient for the variable HISTCOT indicates that, as expected, the longer the village has been growing cotton, the more likely it is that farmers will apply fertilizer. This is because such farmers have easier access to fertilizer through a PU's cotton farmer from CMDT. This parastatal makes fertilizer available to all cotton farmers every cropping season in the form of a loan farmers pay at harvest. Anecdotal evidence suggest that, in cases where the credit limit of the farmer allows him to get fertilizer only for the cotton field, farmers divert some amount of this fertilizer to other non-cotton fields, including rice.

The relative size of the estimated marginal effects clearly shows that variety has the greatest effect on herbicide adoption, and water control most strongly influences fertilizer adoption. From the herbicide model, using "improved" varieties increases the probability that farmers will adopt herbicide by 27 percent (Table 5.6). From the fertilizer model, installing a water control infrastructure in the *bas-fond* increases the probability that farmers will adopt chemical fertilizer by 49 percent, while village experience in cotton production increases this probability by 36 percent, and using "improved" varieties increases this probability by 26 percent (Table 5.7). The significant effect of the village experience in cotton production suggests a credit or input supply constraint in the non-cotton villages.

The non-significance of the other variables considered in the two models can be attributed to the same reason discussed in the variety adoption section, namely the low variability of the data values. But, surprisingly, the size of the PU in absolute or relative terms has no effect on farmers' probability to adopt herbicide. Intuitively, we had expected that larger PUs would be more likely to use herbicide than the smaller ones. The result obtained seems to confirm that PU's labor does not significantly contribute in rice fields. More precisely, it implies that the lack of labor at weeding time is not a binding constraint.

Also, it is surprising that farmers' gender, which is a determinant of the adoption of "improved" varieties (Table 5.3), does not affect farmers' decision to adopt herbicide and fertilizer use. This can be explained by the fact that applying herbicide and chemical fertilizer on rice is a relatively new farm practice. Assuming this is true, one would expect that eventually men would tend to apply these inputs more than women, just as is the case with "improved" varieties. On the other hand, these results may suggest that farmers' variety adoption and herbicide and fertilizer application decisions have different determinants.

Although the fertilizer adoption model revealed some surprising results, its goodness of fit is fairly acceptable, based on the (statistically) highly significant chi-square and the high percent of correct classification. This model correctly classified 75 percent of the farmers who actually used chemical fertilizers, and 91 percent of those who did not. Overall, 84 percent of the farmers were correctly classified into their actual fertilizer adoption category.

In contrast, the goodness of fit of the herbicide adoption model is less satisfactory. Although there is a good balance between the size of the sub-sample of adopters (50 farmers) and non-adopters (65 farmers) for the regressand, and the models' chi-square is highly significant, the percent of correct prediction is low for adopters of herbicide-- only 48 percent of the farmers are correctly classified. This result indicates that farmers' decision to adopt herbicide is more complex than their variety and fertilizer adoption decisions. Thus, the proxy variables used to measure the anticipated effects were inadequate to fully capture all of the factors that influence the adoption of fertilizer.

Finally, from discussions with farmers, it appeared that as with variety adoption, one of the constraints to wider herbicides and chemical fertilizers use is the absence of a reliable source of these inputs. As mentioned earlier, CMDT is the only formal source of "improved" inputs, mostly through limited loans that are repaid for from cotton sales. As with seeds, it is apparent that CMDT alone cannot possibly satisfy the potential demand for fertilizers and herbicide and that the effectiveness of the market liberalization policies of the 1990s could have a significant impact on expanding the availability of and access to chemical fertilizers and herbicides. Because greater input use is also contingent on the higher performance of the "improved" varieties and farmers' access to cash to buy the needed inputs, the profitability of the use of these inputs is addressed in Chapter Six.

5.3. Rice Yield and Its Determinants

Because few studies have been conducted to characterize the *bas-fond* rice production systems, there exists very little information as to its current productivity and the extent to which this system can be improved and extended. This section addresses these questions and assesses the potential contribution of the *bas-fond* production system to Mali's goal of increasing its supply of rice from domestic sources.

5.3.1. Observed Rice Yield Levels

5.3.1.1. The Average Yields Are Relatively Low

Analysis of data collected from 223 rice plots in 11 villages indicates that *bas-fond* rice yields[1] an average of 1,216 kg of rice paddy per hectare, with a standard deviation of 792 kg (Table 5.8). While these yields are less than one-third the level observed in recent years in the intensive *Office du Niger* systems[2], it is important to recognize the other advantages farmers in the *Office du Niger* have over their *bas-fond* counterparts. Not only do these farmers have access to better technologies and a higher quality production environment, but in addition, having participated in the scheme for many years, *Office du Niger* farmers tend to be more market oriented.

However, although average yields appear to be relatively low, *bas-fond* rice makes an important contribution to families' food security and, most of all, to women's self-esteem, pride, and assertiveness in a male-dominated society. Section 5.6.1 provides further evidence of the importance of *bas-fond* rice production.

5.3.1.2. The Average Yields Are Extremely Variable

While farmers' yields are relative low, they tend to be highly variable as well, within each village, from one village to another, and across the entire sample, as indicated by the coefficient of variations (CV) reported in Table 5.8. For example, when

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[1] These yields were determined based on actual measurement of farmers fields and weighing their harvest.

[2] As can be seen in Appendix 2.8, the average rice yield in the *Office du Niger* over the 1994-95 cropping seasons was about 4,600 kg/ha, and 4,900 kg/ha a year earlier.

the entire sample is considered, the CV for the average yield per farmer is four times higher than the national CV for rice (0.165 from Table 2.2), which suggests that the farmers achieving lower yields also face greater production risks. Seven out of the 11 villages have a 25th yield percentile[1] equal to less than one-half the village average.

5.3.1.3. Modern Production Inputs Significantly Affect Yields

The yield variability observed in the sampled *bas-fond* villages can be attributed to numerous factors that are analyzed in section 5.5.2 of this chapter, including water control, type of variety planted (*i.e.*, "traditional" or "improved"), and modern inputs (*i.e.*, chemical fertilizer and herbicide). In an effort to understand better the impact of these factors, yields were arranged by CMDT region, water control status, fertilizer and herbicide use, and the type of rice variety planted by the farmers during the cropping season 1995-96 (Table 5.8). While the difference in average yields was not statistically significant ($P=0.438$) between the two CMDT regions, this analysis indicates that water control, the use of herbicide, fertilizer, and "improved" seeds significantly ($P\leq 0.04$) increased yields by 27, 31, 57, and 22 percent, respectively.

While the average yields in the sampled villages could have varied because they differ in terms of rainfall, this is true only if water control is effective. Thus, because more rainfall makes a difference only if there is good water control, the variable "water control" is a better indication of the effect of location on yield than rainfall.

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[1] Yield percentiles are yield values above or below which certain percentages of the observed yields fall. For example, to say that a yield of 600 kg/ha is the 25th percentile means that about 75 percent of the observed yields are greater than or equal to 600, and 25 percent less than 600. Although the 50th percentiles differ from the means, this difference does not represent a sharp departure from normality.

Table 5.8: Observed Rice Yield Percentiles by Village, Zone, and Input Categories, Mali, Cropping Season 1995-96.

	Sample Size (# farmers)	Average Yield (kg/ha)	CV	Yield (kg/ha) by Percentiles		
				25%	50%	75%
1. Entire sample:	223	1,216	0.651	600	1,050	1,612
2. Village:						
- Banko	29	1,465	0.383	1,176	1,428	1,839
- Diassola*	10	2,989	0.207	2,443	3,000	3,528
- Faradié*	30	1,046	0.571	643	871	1,321
- Sola	30	591	1.008	230	395	777
- Solo	5	1,940	0.460	1,150	2,000	2,700
- Kado*	30	1,099	0.492	599	1,050	1,505
- Kafuziéla	10	886	0.219	673	938	995
- Longorola*	9	1,826	0.381	1,282	1,500	2,250
- Niéna*	30	1,433	0.604	590	1,440	1,980
- Péniasso*	30	1,011	0.612	588	947	1,321
- Sikasso	10	849	0.183	688	867	1,000
CV		0.492		0.652	0.537	0.475
3. CMDT Region:						
- Bougouni	104	1,261	0.718	514	1,099	1,880
- Sikasso	119	1,177	0.577	694	1,000	1,520
4. Water Control:						
- without	139	1,039	0.658	500	938	1,430
- with	84	1,324	0.630	714	1,200	1,875
5. Fertilizer:						
- did not use	54	1,213	0.600	680	945	1,712
- did use	50	1,588	0.576	954	1,280	2,188
6. Herbicide:						
- did not use	58	1,114	0.557	709	980	1,361
- did use	46	1,745	0.543	931	1,606	2,325
7. Variety used:						
- "traditional"	109	1,133	0.609	600	1,000	1,479
- "improved"	87	1,379	0.649	769	1,200	1,920
- both	16	1,204	0.560	696	1,021	1,500

* Indicates that the *bas-fond* in this village has a water control infrastructure.

Source: A Sub-Sample of 223 Farmers from the 334 Farmers Surveyed in 12 *Bas-Fond* Villages in Mali-Sud during the Cropping Season 1995-96.

Although the statistical analysis identifies significant yield differences between input conditions, these results must be interpreted with caution since the analysis does not control for other possible sources of variability. For example, in addition to fertilizer, the significant difference between the average yield of farmers who applied/did not apply fertilizer may be partially due to factors correlated with fertilizer use such as variety or the quality and timing of land preparation.

In an attempt to reduce the effect of these other sources of yield variability, farms were grouped by combinations of input farmers used and the rice yields in each group were computed and summarized in Table 5.9. For example, yield for farmers in *bas-fonds* without water control infrastructure and who used "traditional" varieties, no fertilizer and no herbicide averaged 1,021 kg of rice paddy per hectare of land planted. Similarly, farmers in *bas-fonds* with water control infrastructure and who used "improved" varieties, fertilizer and herbicide averaged 2,326 kg of rice paddy per hectare.

Despite this attempt to control for input conditions, it is still difficult to attribute yield differences to the specific factors noted in Table 5.9. In fact, in a number of cases, the results obtained are counter-intuitive or contradict those reported in Table 5.8. For example, these results suggest that for farmers planting "traditional" varieties in a *bas-fond* with water control infrastructure, fertilizer has no effect on yield when applied alone. However, it is important to recognize that these yield data were not obtained from experimental trials in which it is possible to control non-experimental factors and thereby minimize experimental errors, and the sample sizes involved are small.

Table 5.9: Observed Rice Yield Percentiles Across the Sample by Input Combination, Mali, Cropping Season 1995-96.

Inputs Combination				Sample Size (# farmers)	Average Yield (kg/ha)	Standard Deviation	Yield (kg/ha) by Percentile		
Water control	Variety	Fertilizer	Herbicide				25%	50%	75%
no	no	no	no	19	1,021	633	600	900	1,100
no	no	no	yes	11	1,423	697	640	1,612	2,100
no	no	yes	no	4	923	234	684	968	1,117
no	no	yes	yes	3	1,026	59	960	1,041	nc
no	yes	no	no	4	1,140	845	637	785	2,000
no	yes	no	yes	3	1,305	1,035	211	1,436	nc
no	yes	yes	no	1	1,000	nc	nc	nc	nc
no	yes	yes	yes	nr	nr	nr	nr	nr	nr
yes	no	no	no	13	1,232	872	714	886	1,615
yes	no	no	yes	1	2,300	nc	nc	nc	nc
yes	no	yes	no	5	1,327	428	964	1,280	1,714
yes	no	yes	yes	4	1,192	817	666	884	2,026
yes	yes	no	no	nr	nr	nr	nr	nr	nr
yes	yes	no	yes	nr	nr	nr	nr	nr	nr
yes	yes	yes	no	7	997	483	540	1,120	1,360
yes	yes	yes	yes	18	2,366	923	1,575	2,374	3,074
Others				10	1,078	713	458	1,000	1,470

The symbol "nr" stands for "not represented", and "nc" stands for not computed because the size of the sub-sample is one.
Source: A Sub-Sample of 103 Farmers from the 334 farmers Surveyed in 12 *Bas-Fond* Villages in Mali-Sud during the Cropping Season 1995-96.

5.3.2. Typology of Bas-fond Rice Production Sub-Systems

While Table 5.9 indicates that there exists numerous rice field types in the *bas-fonds* surveyed, based on input combinations, four field types appear to be the most frequent. Each of these field types correspond to a rice production system at increasing levels of intensification[1]:

(1) *Type I fields*, or *purely traditional production system*: the farmer did not benefit from water control and used "traditional" rice varieties, but applied no chemical fertilizer or herbicide;

(2) *Type II fields*, or *macro-semi-intensive production system*: the farmer benefitted from water control and used "traditional" rice varieties, but applied no chemical fertilizer or herbicide;

(3) *Type III fields*, or *micro-semi-intensive production system*: the farmer did not benefit from water control and used "traditional" rice varieties, applied no chemical fertilizer, but applied some herbicide;

(4) *Type IV fields*, or *intensive production system*: the farmer benefitted from water control, used "improved" rice varieties, and applied both chemical fertilizer and herbicide.

Interestingly, Table 5.10 shows that each of these four major field types is found in more than one village and is cultivated by both male and female farmers-- although all systems are predominantly cultivated by women.

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[1] The term intensification characterizes actions undertaken in the bas-fond with the objective to improve yield. Generally, these include agro-hydraulic infrastructure, improved cultural practices, improved varieties and/or some form of farmers' organization aimed at improving their access to inputs and market orientation.

Table 5.10: Village and Gender of the Farmers in the Most Frequent *Bas-fond* Rice Field Types from the Selected Sample of Farmers, Mali, Cropping Season 1995-96.

Field Type	Rice Production system	Farmer's village[(a)]	Farmer's gender
Field I Type	*Purely Traditional*	Sola (4), Solo (4), Kafuziéla (5), and Sikasso (6)	2 males and 17 females
Field II Type	*Macro-semi-intensive*	Faradié (6), Longorola (5) and Péniasso (2)	1 male and 12 females
Field III Type	*Micro-semi-intensive*	Banko (7), Sola (2), and Kafuziéla (2)	11 females
Field IV Type	*Intensive*	Diassola (10), Kado (3) and Niéna (5)	2 males and 16 females

[(a)] The number in the parentheses are the number of sampled farmers from that village engaged in that production system.
Source: A Sub-Sample of 103 Farmers from the 334 farmers Surveyed in 12 *Bas-Fond* Villages in Mali-Sud during the Cropping Season 1995-96.

Given the technological package which is composed of water control and modern inputs (*i.e.*, "improved" varieties, fertilizer, and herbicide), the level of intensification of *bas-fond* rice production systems (Table 5.9) confirms what has long been established in technology adoption literature: (a) all farmers do not adopt new technologies at the same time, and (b) farmers do not necessarily adopt all components of a technological package at the same time. The *purely traditional system* is the most "traditional" of the four most frequent systems observed. Farmers practicing this system do not have access to water control and apply no modern inputs. It is important to note that although 90 percent of these farmers knew about the existence of "improved" varieties, they did not plant them either because of their limited availability, or farmers' believed that the "improved" varieties are late-maturing and require water control. Yet, not all "improved" varieties are late-maturing, and there exists "improved" varieties that suit different water conditions. Clearly, the arguments given by farmers suggest some information gap which, if filled, could promote greater adoption of "improved" varieties. Also, farmers who did not apply fertilizer and herbicide point to financial constraints, limited availability and no water control.

The *semi-intensive systems* are characterized by farmers' adoption of one component of the technological package. The term *macro-semi-intensive* is used to articulate that the factor of intensification (*i.e.*, water control) is introduced in the system on a group basis. As a result, its adoption may have been imposed on the farmer because she happened to have been farming in a *bas-fond* in which CMDT built a water control infrastructure, although there may exist no plot-level control of water. The survey results show that 85 percent of these farmers knew about the existence of "improved" varieties, but did not plant them either because it is only recently that these they got access to the varieties or because they believed that these varieties require fertilizer and water control, which the farmers lacked. The main reasons farmers reported for not using herbicides were financial constraints and limited experience in using them. Similarly, these farmers did not use fertilizer mainly because of financial constraints or because fertilizers had limited yield effect, given poor water control.

The term *micro-semi-intensive* signifies that the factor of intensification (*i.e.*, herbicide) is introduced in the system on a farmer-to-farmer basis. In this case, the farmer has to make a conscious decision to use herbicide, given her/his personal needs and resources. The survey results show that 82 percent of these farmers knew about the existence of "improved" varieties, but did not plant them either because these farmers have only recently (one to two years) seen them performed in a field, or because the farmers believed that these varieties are late maturing, or that these varieties are available in limited amounts. They did not use fertilizer predominantly because of financial constraints or because fertilizers had little yield effect, given poor water control.

The *intensive rice production system* represents the most intensified system identified. Most farmers practicing this system tend to be risk bearers and/or enjoy a financial power great enough to absorb potential losses if the crop fails to yield as expected. These farmers tend to be those with whom other farmers in the village consult before trying the new technology. However, although the extent to which this particular characteristic (*i.e.*, risk bearers and role model) apply to these farmers was not specifically investigated, these *intensive* farmers did mention that they used "improved" varieties because they believed that these varieties have higher yields and are more resistant to diseases.

The distribution of rice fields, based on farmers' combination of inputs, indicates farmers' most frequent strategy for intensifying rice production in the *bas-fond* surveyed involved a combination of water control, "improved" variety, and fertilizer and herbicide use. However, these data suggest that farmers may perceive weed control to be a more important constraint than soil fertility. Indeed, during group discussions, when asked to choose between fertilizer and herbicide, most farmers preferred herbicide.

Finally, although some farmers planted an "improved" variety during the cropping season 1995-96, this does not necessarily imply that they will continue to use this type of variety in subsequent seasons. This study did not analyze the possibility for discontinuance of the technology adoption.

5.3.3. Econometric Models of Yield Determinants

5.3.3.1. Model Specification

Variables Identification

Rice yields are affected by several agricultural practices, as well as environmental and biological factors. This analysis draw from the insights gained in section 5.5.6 to develop a model of factors influencing *bas-fond* yields. Table 5.11 presents the specific variables used in this analysis, and the hypothesized direction of their effect on rice yield.

The water stress variable STRESS# represents the number of critical growth stages during which the farmer reported that the rice plant suffered significant water stress. The critical growth stages taken into account are germination, tillering, flowering, and grain filling. The amount of nitrogen and phosphorous nutrients each farmer applied was determined, based on the nutrient content of the fertilizer she/he used. The three chemical fertilizers farmers used were urea, diammonium phosphate (DAP), and a compound fertilizer (*complexe céréale*). Assuming no quality deterioration, a unit of urea contains 46 percent nitrogen, while a unit of DAP has 10 percent of nitrogen and 20 percent of phosphorous, and compound fertilizer has 15 percent nitrogen, 15 percent phosphorous, and 15 percent potassium.

Table 5.11: Factors Expected to Affect Rice Yields in the *Bas-Fond* Production Systems.

Factors	Measurement in the Study	Variable	Hypothesized Sign
Agricultural Practices:			
- water control	- water control infrastructure (no/yes)	WTCONT	+
- rice variety planted	- type of variety (traditional/improved)	VARIETY	+
- planting date	- date (julian date)	PWEEK	_
- planting method	- actual method (broadcasting/other)	METPLAN T	+
- seeding rate	- kg of seed per hectare	SEED	+
- weeding date	- number of weeks after planting	WEEKW	_
- labor at weeding	- hours of labor at weeding	WEEDLAB	+
- herbicide application	- did not use/use	HERB	+
- fertilizer application	- application rate (nutrients equivalent/ha)	N and P	+
Environmental Factors:			
- water stress	- No. critical growth stages with water stress (0-4)	STRESS#	-
Biological Factors:			
- Insects	- attacks by insects (insignificant/significant)	EFFINSEC	-
- diseases	- disease infestation (insignificant/significant)	EFFDISEA	-
- animal attacks	- attacks by birds (insignificant/significant)	EFFBIRD	-
Farmers' Characteristics			
- technical knowledge	- contact with CMDT (no/yes)	CMDT	+

The hypothesized positive sign on any variable (Table 5.11) indicates that this variable is expected to have a positive effect on yield. In contrast, a hypothesized negative sign indicates that the variable is expected to depress yield. For example, the positive sign on variables WTCONT, HERBICIDE, WEEDLAB, N and P indicates that, individually, each of these inputs are expected to increase yield. The hypothesized positive sign for the variable VARIETY indicates that the "improved" rice varieties are expected to produce higher yields compared to the "traditional" varieties. Similarly, it was expected that late planting and weeding, significant birds and insects attacks, and significant water stress to the rice plant during the growing period decrease yields.

To assess the significance of water stress and birds attacks, each farmer was asked to evaluate the level of water stress and birds attacks in her/his field, if any. The variable STRESS# (*i.e.*, number of critical growth stages during which the rice plant suffered significant water stress) was preferred to STRESS1 (*i.e.*, plant stress during any of the season) because the estimated output using the former was better in terms of the magnitude of the adjusted R^2, and the significant of other regressors.

Although soil type and soil fertility affect rice yield variability, these variables were not included in the study because the necessary data were not available. Finally, the land preparation method was not included in this analysis because most rice farmers surveyed use the same method.

Functional Form

Numerous alternative functional forms can be used to describe the relationship between yield, Y, and vector, X, of regressors. There are essentially two ways in which the relationship between Y and X may be specified. The analyst can postulate one or more functional forms expected to adequately describe the relationship, based on biological concepts, secondary data, and/or past experience. Alternatively, he/she can identify one or more functional forms that are most likely to best fit the data by examining relationships between the regressand and potential regressors using the data, and comparing outputs from the various models. However, in actual practice, these procedures are commonly used jointly.

In this study, four functional forms most commonly used to model biological data were initially considered: high degree polynomial, sigmoid, logarithmic, and exponential forms. However, the choice of functional form was constrained by the desire to include dummy variables as regressors. Because one of the values of a dummy variables is zero, forms like double-logarithmic, semi-logarithmic, log-inverse, and trans-logarithmic were necessarily excluded from the analysis.

A four-stage process was used to determine the functional form for this study's yield equation. First, the scatter diagram technique was used to determine the functional form between the regressand and each of the regressors. When the visual inspection of the scatter diagram revealed no clear pattern, the apparent absence of a relationship was further explored by looking at the magnitude and the statistical significance of the simple linear correlation coefficient between these two variables. Second, variables describing interactions that could exist between the regressors were created (*e.g.*, nitrogen x phosphorous interaction) and then evaluated by visual inspection of the scatter diagram of the interaction variable created.

Third, combinations of the variables identified in the second stage were entered into the model that was estimated using the stepwise linear regression estimation procedure. This procedure first selects the independent variable that contributes most significantly to explaining the variability of Y (entry criterion), and then systematically adds the next one with the highest partial correlation. After the first variable is entered, the first variable is examined to see whether it should be removed based on a set minimum standard for the value of the F-statistics or the significance level P. Then, other variables are examined for entry. This procedure continues until no additional variable met entry or removal criteria. To estimate the quadratic model retained for the study, variables with a quadratic functional form were linearized by creating a new variable which is the product of the original variables. For example, the variable used to represent the quadratic component of nitrogen application (*i.e.*, N2 in Table 5.12) was created by squaring the amount of nitrogen each farmers applied (i.e. N in Table 5.12).

Fourth, the various models estimated were evaluated based on theoretical consistency, empirical validity, and statistical significance. The model retained from these estimations is a quadratic equation. Table 5.12 shows the functional forms of the variables included in this model.

Table 5.12: Functional Forms of the Variables Used in the Estimated Yield Equation.

Variable Code	Variable label	Functional form	Measurement in the study
CMDT	Contact with CMDT	linear	no/yes (0/1)
WTCONT	Bas-fond with water control	linear	without/with (0/1)
VARIETY	Variety farmer planted	linear	Traditional/improved (0/1)
VARREG	Variety x Region interaction	linear	
VARWTC	Variety x water control	linear	
SEED	Amount seeds used	linear	kg/ha
SQSEED	$(\text{seed})^2$ = seed x seed	quadratic	
PWEEK	No. weeks planting started after 1st week of January	linear	weeks
SQPWEEK	$(\text{pweek})^2$ = pweek x pweek	quadratic	
PWEKREG	pweek x region interaction	linear	
PWEK2REG	sqpweek x region interaction	quadratic	
METPLANT	planting method	linear	other/broadcasting (0/1)
WEEKW	No. weeks weeding started after planting	linear	weeks after planting
SQWEEKW	$(\text{wweek})^2$ = wweek x wweek	quadratic	
WEKWREG	wweek x region	linear	
WEKW2REG	sqwweek x region	quadratic	
HERB	Was herbicide applied	linear	no/yes (0/1)
N	Amount of NO_3 applied	linear	kg/ha
N2	N x N = N^2	quadratic	
NREG	N x Region interaction	linear	
N2REG	N^2 x Region interaction	quadratic	
P	Amount of P_2O_3 applied	linear	kg/ha
P2	P x P = P^2	quadratic	
PREG	P x Region interaction	linear	
P2REG	P^2 x Region interaction	quadratic	
NP	N x P interaction	linear	
N2P	N^2 x P interaction	quadratic	
NP2	N x P^2 interaction	quadratic	
N2P2	N^2 x P^2 interaction	quadratic	
NPREG	N x P x Region interaction	linear	
N2PREG	N^2 x P x Region interaction	quadratic	
NP2REG	N x P^2 x Region interaction	quadratic	
N2P2REG	N^2 x P^2 x Region interaction	quadratic	
REGION	CMDT region	linear	Bougouni/Sikasso (0/1)
EFFINSEC	Impact of insect attacks	linear	not significant/significant
EFFDISEA	Impact of disease attacks	linear	not significant/significant
EFFANIM	Impact of animals attacks	linear	not significant/significant
EFFBIRD	Impact of birds attacks	linear	not significant/significant
DISEAREG	EFFDISEA x Region Inter.	linear	
STRESS#	Water stress	linear	0-4

5.3.3.2. Results, Interpretation and Implications for Research and Extension

Using the variables identified in Table 5.12, the linear form of the quadratic function was estimated using a stepwise regression procedure for selecting variables to be included or excluded in the model. Variables were excluded or included based on the probability associated with their F-statistics whose cutoff point was set at 0.05 for the inclusion and 0.10 for the exclusion rules. The estimation output was evaluated based on the model's goodness of fit to the data, the statistical significance of the estimated parameters, and the direction their effect.

The assessment of the model's lack of fit to the data is based on the knowledge that there are two error components involved in modeling relationships: the fixed component and the random component. While the fixed component is attributed to the lack of fit of the functional form to the data, the random component accounts for measurement errors, the effect of relevant variables not included in the model, and natural variability (Weisberg, 1985). The size of the fixed component of the errors (or lack of fit errors) depends on the functional form, and the smaller it is, the better the model's fit. This is assessed from the F-test result of the null hypothesis that the proportion of the variation in the regressand that is explained by the regressors and which is defined by the coefficient of determination R^2 is equal to zero ($R^2=0$). This test is equivalent to testing the hypothesis that there is no linear relationship between the dependent variable and the entire set of explanatory variables other than the intercept (*i.e.*, the β_is are jointly equal to zero).

The statistical significance of the estimated parameters is based on t-test result of the null hypothesis that there is no linear relationship between the dependent variable and each independent variable (*i.e.*, the individual estimated coefficient is equal to zero). To make sure that the tests of hypotheses are valid, violations of the assumptions required for valid OLS estimation results were checked, chiefly that the residuals are mutually uncorrelated, they have a constant variance, and they are normally distributed. The outputs from the estimation process is summarized in Table 5.13.

Table 5.13: Stepwise Regression Output for the Yield Determinants Model.

Variables	Unit	Estimated Coefficient (ß)	Standard Error	Significance
		Variables in the Equation		
STRESS#	0-4	-232.5542	82.0857	0.0061
PWK2REG		-0.8635	0.4066	0.0374
EFFINSEC	sign./insign.	-865.3974	405.3611	0.0365
WTCONT	no/yes	566.4951	207.4824	0.0081
SEED	kg	1.5388	0.4871	0.0024
HERB	no/yes	612.5529	187.7620	0.0018
NREG	kg	-7.7407	3.1267	0.0159
Constant		1,186.7357	289.1140	0.0001
S.E. of the Estimate		681.7652		
F-statistic		9.4536		0.0000
R Square		50.1%		
Adjusted R Square		44.8%		

The estimation output in Table 5.13 shows a highly statistically significant ($P<0.00001$) adjusted coefficient of determination R^2 of 45 percent. This result indicates that the quadratic function used to model the observed *bas-fond* rice yields provides an adequate fit for the data, because the amount of variation in the dependent variable accounted for by this model is reasonably high (45%), given that the study uses survey data.

Looking at the output obtained from the model estimation, it appears that only one of the variables with a quadratic form (PWEK2REG[1]) was statistically significant in explaining the variability in the yield data. In other words, this result indicates that, within the range of yields observed, although the estimated model was a quadratic function, the final output is a linear model for the statistically significant variables and quadratic for the interaction between the square of the number of weeks planting started after the first week of January and the region.

As expected, water stress[2] and insect attacks significantly decreases yield, while water control and herbicide application significantly increased yields. More specifically, the coefficient on the water stress variable indicates that as the yield effect of any additional critical growth period during which the rice plant experiences water stress leads to a reduction in yield of about 233 kg of paddy. Similarly, the impact of significant insect attacks during the cropping season is a reduction of yield (865 kg of

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[1] Variable used to indicate the hypothesized interaction between the square of the number of weeks planting started after the first week of January (PWEEK) and the region (REG).

[2] The coefficient on the water stress variable should be interpreted as the yield effect of an addition critical growth period during which the rice plant experiences water stress.

paddy) which is more than three times that due to water stress. The significance of the variable HERB indicates that herbicide application tends to increase yields by about 613 kg of paddy, compared to no herbicide at all, due to better control of weeds which compete with the rice plant for nutrients, water and solar radiation. Such an increase is realized only if the application rates are similar to those observed by the study. In other words, it is not just enough to apply herbicide at any rate to get this yield effect.

Only the linear portion of farmers' seeding rate (SEED) has a significant and positive effect on yields (*i.e.*, 2 kg of paddy for each additional kg of seed). It is important not to misinterpret this result to infer that the more farmers used seed, the higher the yield (*i.e.*, that this input increases yield indefinitely). Rather, after some amounts, additional amounts of seed will result in increasingly lower yield gains (diminishing marginal effect) until no significant yield effect is observed. However, the quadratic portion of this variable is non-significant because of limited variability in the observed seeding rates. The quadratic portion often appears when scientists use experimental data with seeding rates varying over a wider range.

Interestingly, the estimation results show that while there is a negative significant impact of the interaction nitrogen and CMDT regions (Bougouni and Sikasso), this interaction is not significant with phosphorous. Statistical analysis shows that the yield effect of nitrogen application is significantly higher in Bougouni than in Sikasso[1].

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[1] From the sub-sample of farmers whose yield data were recorded, 193 planted only one of the two rice variety types (i.e., "traditional" or "improved"). From this group, farmers who used "improved" varieties and no fertilizer produced 479 kg/ha more rice paddy in Bougouni than in Sikasso, while the yield difference among those who used "improved" varieties and fertilizer amounted to 1,677 kg more rice paddy in Bougouni than in Sikasso. No significant difference was obtained for farmers who used "traditional" varieties, with or without fertilizer application.

Finally, while the rest of expected important variables were not statistically significant (Appendix 5.4), this can be explained by the presence of significant correlation between variables, some of which could be linear combinations of the regressors which are not revealed by bivariate correlation coefficients. For example, there is a statistically significant positive correlation between the type of rice variety planted and the existence of a water control infrastructure in the *bas-fond*. In such cases, only the most significant of the variable is included in the final output. The variable used to represent these two variables into one single variable (*i.e.*, VARWTC) was not statistically significant.

5.4. Contribution of the Bas-fonds to Mali's Rice Production

5.4.1. Potential Contribution of Bas-fond Production

The potential contribution of *bas-fond* rice production can be assessed in terms of the per capita amount of paddy rice produced from the *bas-fond* in each villages surveyed and what this production level represents in the total domestic rice supply. Table 5.14 below provides a brief summary of the significant of the *bas-fond* rice production based on these standards.

Table 5.14: Contribution of *Bas-fond* Rice Production, Mali, Cropping Season 1995-96.

Location	*Bas-Fond* Area Cultivated (ha)	Village Population	Yield (kg paddy per ha)	Total Paddy Production (kg)	Per Capita Paddy[b] Production (kg)	
Banko	35	806	1,465	51,275	64	(41)
Diassola	3	221	2,989	8,967	41	(26)
Faradié	34	398	1,046	35,564	89	(58)
Sola	300	1,900	591	177,300	93	(61)
Solo	32	1,400	1,940	62,080	44	(29)
Kado	108	3,542	1,099	118,824	34	(22)
Kafuziéla	69	1,625	886	61,418	38	(26)
Longorola	330	540	1,826	602,580	1,116	(725)
Niéna	128	3,457	1,433	183,424	53	(34)
Péniasso	125	840	1,011	126,375	150	(98)
Mali-Sud	48,657[a]	-	1,216	59,166,912	-	

[a] Obtained from a *bas-fond* inventory conducted by CMDT in 1992.
[b] The number in the parentheses are per capita milled rice production computed using a 65 percent milling recover rate.

This table shows that in seven of the 11 villages listed, the per capita level of milled rice production is higher than or equal to that the national average rice consumption per capita (34 kg/person/year[1]). In other words, there exists a real potential for villages with surplus production of rice paddy to sell rice to deficit areas.

At the national level, the importance of this contribution is reflected by comparing *bas-fond* rice production with rice supply from the *Office du Niger*, as well as with commercial imports and food aid to Mali, as summarized in Table 2.

[1] This was estimated by the 1988-89 consumption expenditure survey in Mali.

Table 5.15: *Bas-Fond* Rice Production as a Proportion[(a)] (%) of *Office du Niger* Rice Supply, Commercial Imports or Food aid.

Source	*Bas-Fond*	*Bas-Fond* & Plains
Office du Niger	31	143
Cereal Imports	26	119
Food aid	160	128
Cereal Imports & Food aid	22	102

[(a)] Based on 59,167 tons of rice supply from the *bas-fond*, 210,368 tons from the plains, 189,091 tons from *Office du Niger* annually over the last five years, 226,000 tons of commercial imports and 37,000 tons of food aid in 1991.

Table 5.15 shows that if all Mali-Sud *bas-fonds* (*i.e.*, 48,657 ha) are put into production and assuming the average yield observed in this study, this would produce a total of 59,167 tons of paddy[1] will be produced, which represents about 31 percent of the average quantity of paddy produced in the *Office du Niger* annually over the last five years (189,091 mt). With level equivalent to the 25th percentile yield observed in this study (600 kg/ha), the total *bas-fond* production is 15 percent of the *Office du Niger* average annual production over the last five years. In contrast, a yield level equivalent to the observed 75th percentile yield (1,612 kg/ha) corresponds to a *bas-fond* total production which is 41 percent of the *Office du Niger* average annual production over the last five years. If all Mali-Sud *bas-fonds* (*i.e.*, 48,657 ha) and flooded plains (*i.e.*, 173,000 ha) are put into production and assuming the average yield observed in this

[1] This amount is obtained by multiplying Mali-Sud *bas-fond* area estimated by CMDT in 1992 by the average yield observed in this study (1,216 kg paddy per ha).

study, a total of 269,535 tons of paddy will be produced, which represents about 43 percent more paddy than the average quantity of paddy produced in the *Office du Niger* annually over the last five years.

Similar, the total amount of rice produced from all Mali-Sud *bas-fonds* represents 22 percent of both commercial imports and food aid to Mali. If all rice production from Mali-Sud *bas-fonds* and flooded plains are put together, their production will represent about two percent more paddy than the average quantity of commercial imports and food aid to Mali.

Clearly, such a potential represents a significant contribution in the effort to boost domestic rice production, and thereby a significant saving of foreign exchange to the country. Indeed, this contribution can even be larger if greater attention is given to addressing constraints associated with its extensification and greater intensification. These constraints include factors associated with the unstable production environment, as well as soil fertility, pest, and diseases that prevent rice varieties to fully realize crop potentials.

However, one of the concerns often voiced when promoting technological changes in agriculture is the distribution of the impact of the change in the economy. In other words, does the new technology promote equity or reinforce existing inequity as determined not by the nature of the technology itself but by the pattern of resource ownership and institutional setting. In some cases, technical changes have resulted in concentration of income or polarization due to differences in the speed with which producers adopt technologies as influenced by the size of the farm enterprise, land tenure, and access to inputs and credits. Clearly, in the case of *bas-fond* rice production in Mali such a polarization would be negligible because plot sizes are fairly equal and small, and land tenure guarantees access to rice plots to most farmers interested.

However, because the technical change in rice production leads to higher production, which increases overall economic welfare, an important public policy question is how these gains are distributed between producers and consumers. Currently, because *bas-fond* rice is predominantly consumed in the producers' households, they capture all the welfare gain associated with the technical change. But, with increasing pressure for greater market orientation, some of this gain would be captured by consumers, as farmers sell an increasing share of their rice production. Hence, given that rice in Mali can be characterized as a "necessity" good with a low price elasticity of demand, the share of the welfare gain internalized by market-oriented farmers is inversely related to the proportion of rice production sold by farmers.

In the extreme case where the farmers sell all their rice production in the market place, as rice become a major source of income, all the welfare gain associated with the technical change will be captured by consumers. Thus, one of the impacts of the market liberalization policy in Mali is that, because markets prices are no longer set by the government, technical change may result in price change, and hence, the distribution of benefits accruing to these *bas-fond* rice producers will no longer be directly proportional to farmers sales.

5.4.2. Constraints to Rice Production Intensification

The term constraint is used to characterize biological/technical factors that act on the rice plants to keep production below its maximum level (*i.e.*, physiological potential), and socio-economic factors that limit farmers' ability to exploit the available technical potential including artificially depressed prices or imperfectly functioning markets. Only biological constraints are considered in this analysis of factors affecting yield. Clearly, other biological factors such as diseases and pests, soil conditions, and temperature (rice plants are sensitive to temperature extremes) are also important. For example, we observed disease problems and during group discussions farmers raised the issue of soil fertility and its variability within and across *bas-fond*. However, data on these factors were not collected during the field work due to the limited expertise of the research team on these issues and the lack of resources required to monitor/evaluate these constraints.

5.4.2.1. Lower and Variable Yields

Earlier in this chapter, data was presented indicating that *bas-fond* rice yields (averaging 1,216 kg/ha with a standard deviation of 792 kg/ha) were low and extremely variable, especially when compared to those obtained in the *Office du Niger*. The analysis in the next chapter indicates a negative to low financial return to the *bas-fond* rice enterprise. Clearly, low profitability hinders the adoption of modern inputs such as "improved" seeds, fertilizer, and herbicide. Indeed, during group discussions, many farmers argued that they were reluctant to use modern inputs because they were not certain to recover their investment capital.

While the variety a farmer plants sets the ceiling on production potential, the actual yield potential of a rice variety (*i.e.*, the maximum capacity of the rice plant to produce output given the production environment) is difficult to measure. Furthermore, the degree to which a variety's production potential is realized depends on a wide variety of agronomic and socio-economic factors. Although farm-level yields have increased rapidly in Asia, transforming high on-station experimental yields to the heterogenous *bas-fond* environment represents an enormous challenge for Malian researchers. This is particularly the case in the *bas-fonds* because the "improved" varieties currently being promoted by extension were actually developed for the *Office du Niger* environment which is different from the *bas-fond*.

Recognizing these difficulties, this study argues that to promote greater intensification of the *bas-fond* rice farming system, scientists must develop higher-yielding varieties that are appropriate for the unstable *bas-fond* environments. Often, the call for higher crop yields is associated with the promotion of hybrids[1]. But, for this strategy to be effective, special traits (*e.g.*, responsiveness to fertilizer, sensitivity to day length-photoperiodicity, plant height) must be incorporated into the hybrids that are appropriate to the target growing environment.

Success in developing hybrids will depend on the existence of highly trained staff with the technical skills required to use this technology, a viable hybrid seed production system that guarantees a timely and adequate supply, as well as patience on the part of

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[1] Improved rice varieties are developed by crossing two or more existing cultivars and selecting promising lines from the segregating progeny, resulting in a stable line (F_6). In contrast, hybrid varieties are created by crossing two lines, with farmers planting the F_1 population.

decision-makers and researchers, given the long time horizon involved. For example, Japan-- first country to develop hybrid rice for farm use --, there was a 12-13 year time lag between the initial cross and final distribution of new hybrid varieties (Barker *et al.*, 1985).

However, short-term rapid yield increases can be achieved through traditional plant breeding strategies[1] that rely on selecting appropriate genetic material from a world collection, producing and screening crosses under farmers' environments. For this effort to succeed, a more participatory approach will be required in which researchers combine the experimental knowledge of farmers and their scientific knowledge.

This study suggests three factors which will be important to consider as an integral part of the future breeding program: (1) the yield potential and stability of the material, (2) growth duration of the rice plant (days from planting to harvesting) and its potential for double cropping, and (3) plant characteristics, including height and architecture in relation to the water condition, as well as resistance to diseases and water stress. However, in considering the possibility of reducing growth duration to facilitate double cropping, scientists must consider farmers' preferences, given the tradeoff between shorter growth duration and lower yields.

Finally, as mentioned previously, the yield potential of "improved" varieties will not be realized in farmers fields unless scientists also develop appropriate complementary technologies to relax fertility, pest, disease, and water management constraints. It is important to recognize that currently the most pressing constraint to achieving higher rice

[1] Typically, hybrid varieties are developed in optimal rice growing environments in which all other constraints have been reduced to low levels.

yields is not the physiological potential of the varieties farmers plant, but rather, soil fertility, pests, diseases, and moisture water conditions which have prevented farmers from fully exploiting the plant potential.

Improving the yield level of rice varieties leads to an increase in labor demand, particularly for harvesting, and threshing. While this can be offset by mechanization of these operations, there is no significant gain in output through mechanization. Therefore, promoting mechanization will likely transfer income from labor to owners of machinery. Typically, mechanization represents a straightforward substitution of capital for labor, which under a labor-surplus condition, is socially undesirable.

5.4.2.2. Land and Labor Availability

One possible way to increase *bas-fond* rice production is through area extensification. However, although there exists a large untapped *bas-fond* potential, these areas have remained uncultivated due to poor water control. As a result, the average plot size per farmer is rather small (0.3 ha with a standard deviation of 0.5). Two immediate implications of the small plot size are the subsistence orientation of *bas-fond* rice farming and the inability of the farmers to exploit technologies such as mechanization which have significant scale biases. In addition, the heterogeneity in *bas-fond* area quality raises a question of equity and social justice during plot distribution (*i.e.*, which farmer gets what plot of a particular fertility and water condition status?).

On the other hand, in recent years, most of the increase in Asian rice production resulted from more intensive application of yield-increasing inputs, especially in Eastern

Asia where population pressure was most severe. According to Barker *et al.* (1985), the three factors that had a critical influence on Asian rice productivity growth were: increased fertilizer use, development and adoption of "improved" seeds, and "improved" irrigation and drainage. While Japan had developed the preconditions for agricultural development[1] prior to achieving rapid yield increases in the early 1900s, during early periods, both Japan and China increased rice production by heavily relying on expanding irrigation and increasing multiple cropping, while using traditional technologies on newly developed land.

In other to carry out the research needed to develop appropriate technologies suitable for greater intensification of *bas-fond* rice farming, the Malian agricultural research system must mobilize a political constituency in support of agricultural research. However, as is the case throughout West African, Malian researchers have not been strong advocates for public investment in research. As funding from the government and other donors continue to dwindle, there is an increasing need for researchers to become proactive advocates of the value of agricultural research, especially given the limited political power of the farmers.

5.4.2.3. Inadequate Moisture Condition and Water Control

Mali's climate condition is characterized by erratic rainfall, which significantly affects agricultural production. In the *bas-fond*, the need to control the water flowing

[1] These conditions are: (1) a formal agricultural research system, (2) an industrial sector capable of producing inputs such as fertilizer, and (3) a transportation and communication network to ensure timely supply of quality inputs and information to farmers (Barker *et al.* 1985).

through the river bed during the rainy season has motivated investments in the construction of small dams. However, lacking internal dikes or bunds, this infrastructure does not ensure plot-level water control. As a result, the effectiveness of the existing water control infrastructure is questionable. Supporting this argument is the farmers' contention that weed pressure tends to increase after the construction of the water control infrastructure, while water control should reduce weed competition.

Although, the results reported in Table 5.8 show significant but small yield difference between *bas-fond* with and those without water control (*i.e.*, 1,324 kg/ha versus 1,039 kg/ha), these results do not control for other contributing sources of variation such as soil fertility, variety planted, and timing of farm operations. Given the irregularity of the *bas-fond* topography, there exists a need to carry out research to assess the potential contribution of further infrastructural development (*i.e.*, internal bunding), in order to improve the effectiveness of the water control.

As discussed in Chapter Four, the amount of water and its timeliness are critical to yield growth. Too little or too much water, especially at the critical growth stages, stunts the plants and reduces yield. However, the issue of concern is not just the appropriateness of the amount of water in farmers' individual plots, but also the duration of the flood, the nature of water flow (*i.e.*, stagnant or flowing) and water quality, in relation to the rice variety farmers planted. All of these factors affect the availability of nutrients, and plant competition from weeds (Reinhold, 1991).

Furthermore, rice varieties are adapted to specific water regimes. Because of this, Moorman *et al.* (1977), Masajo and Carsky (1989) and Izaac *et al.* (1990) report that farmers adoption of modern varieties is closely associated with water conditions. In addition, there is a complementarity between irrigation and modern inputs. For example, because of the sensitivity of the rice plant to drought, farmers with an inadequate or unreliable water supply are particularly vulnerable. Typically, they cannot afford the risk of applying fertilizer, if water supply is not assured. Similarly, if there is too much water and/or no plot-level water control, they are not likely to apply fertilizer because it will be washed away.

Improving water control in the *bas-fond* will require addressing both the issues of management/control of the infrastructure and institutional arrangements needed to facilitate greater cooperation between CMDT and local communities. For example, there is a need to design water control infrastructure that takes into account the crop management goals of farmers, so that these two aspects of the water control equation are not treated as separate issues. This could be achieved by creating mechanisms for involving the end user (*i.e.*, the farmer) in the design and management of the infrastructure.

5.4.2.4. Limited Research and Extension of Technological Innovations

While rice research in Mali, which involves collaboration between international (WARDA, IRRI) and national (IER) institutions, has been maturing over the years, most of the financial and technical resources have focused on *Office du Niger*. Although *bas-*

fond rice research was launched in the mid-1980s, only a few rice scientists[1] are assigned to conduct research on this system and they often have many other administrative responsibilities and non-rice research activities. This situation is exacerbated by weak and almost "competitive" horizontal communication among these few scientists. As a result, farm yields in the *bas-fond* are still low, and all "improved" varieties used by farmers were developed for the *Office du Niger* environment, which is ecologically quite different from the *bas-fond*.

In order to expand rice production, the study identifies four principal directions for *bas-fond* research: increasing yield, lowering inputs cost (*e.g.*, fertilizer application and labor content of technologies), reducing growth duration of the plant, and facilitating farmers' adoption of research varieties. To increase rice yield a priority must be given to stabilizing the production environment through more effective water control, and to developing appropriate complementary technologies to relax fertility, pest, diseases constraints in order to fully realize crop potentials.

In order to increase farmers' adoption and the returns to research, investing in *bas-fond* rice research would required strengthening the support to scientists, and the link between research and extension. Strengthening the support to researchers should involve improving their technical skills through training, and their ability to (1) communicate with each other and with researchers abroad (*e.g.*, via email), and (2) process and analyze data (*i.e.*, making computers and their supplies accessible to researchers).

[1] The research staff involved in *bas-fond* rice activities is composed of three agricultural economists, two agronomists, one sociologist, one hydrologist, and one breeder.

5.4.2.5. Limited Access to Modern Inputs and Credit

Modern agricultural technology is typically characterized as including both land-saving (*e.g.*, variety, fertilizer, and irrigation) and labor-saving (*e.g.*, mechanization, and herbicide) elements. Efforts to modernize rice farming in Mali have largely centered on promoting land-saving technologies, primarily the adoption of modern varieties and increased use of fertilizer, all of which require capital. Yet, despite the fact that women play a major role in rice production in the *bas-fond*, institutional and social arrangements do not provide women direct access to information about new rice technologies and other resources such as credit. The main source of "improved" technologies is CMDT, a government agency which gives credit only to cotton farmers. Because all cotton farmers are men, many of whom are not willing to borrow for their wives, very few women farmers have access to modern inputs. This condition is worsened by the patriarchal nature of the social organization which tends not to expect women to generate household income. As a result, women have limited access to household resources for investing in rice inputs.

5.5. Summary

This chapter focused on determining the current level and the determinants of rice production and its intensification in the *bas-fond*. A stepwise logistic regression procedure was used to model farmers decision to adopt "improved" varieties, herbicide, and fertilizer. The estimation results show that only the presence of a water control infrastructure and the village years of experience in cotton production have a significant positive effect on farmers probability to adopt "improved" varieties (*i.e.*, 50.7 and 18.9 %, respectively). In contrast, the village distance to the closest market, and plot size have a negative effect on this probability (*i.e.*, -53.9, -5.4, and -9.5%, respectively).

Statistical analysis reveals that in addition to the fact that farmers who adopt improved varieties are more likely to the use herbicide and chemical fertilizer (*i.e.*, +27% and +26%, respectively), different factors significantly affect this probability for herbicide versus fertilizer. For herbicide use, the model was not very satisfactory as its ability to correctly predict the adoption behavior of adopters of herbicide application was low (48% compared to 88% for non-adopters and 70% overall). For chemical fertilizers, the model's ability to correctly predict farmers' fertilizer adoption behavior was satisfactory (93% for non-adopters, 69% for adopters, and 83% overall). As expected, in addition to variety, the presence of a water control infrastructure and the village years of experience in cotton production increase the likelihood of their use (*i.e.*, +46% and +36%, respectively).

The study observe the rice yields in the *bas-fond* are low and variable, averaging 1,216 kg of rice paddy per hectare, with a standard deviation of 792 kg. However, modern production inputs significantly affect yields, as water control, the use of herbicide, fertilizer, and "improved" seeds significantly ($P \leq 0.04$) increased yields by 27, 31, 57, and 22 percent, respectively.

Grouping yields based on inputs combination farmers used, the study identify four *bas-fond* production systems: the *purely traditional production system*, the *macro-semi-intensive production system*, the *micro-semi-intensive production system*, and the *intensive* *production system*. Farmers using the *purely traditional production system*, which is the most "traditional" of the four systems, did not benefit from water control and used "traditional" rice varieties, but applied no chemical fertilizer or herbicide. Farmers using the *macro-semi-intensive production system* benefitted from water control and used "traditional" rice varieties, but applied no chemical fertilizer or herbicide; Those using the *micro-semi-intensive production system* did not benefit from water control and used "traditional" rice varieties, applied no chemical fertilizer, but applied some herbicide; In contrast, those using the *intensive production system* benefitted from water control, used "improved" rice varieties, and applied both chemical fertilizer and herbicide.

The distribution of rice fields, based on farmers' combination of inputs, indicates farmers' most frequent strategy for intensifying rice production in the *bas-fond* surveyed involved a combination of water control, "improved" variety, and fertilizer and herbicide use. However, these data suggest that farmers may perceive weed control to be a more important constraint than soil fertility.

To identify the determinants of yields, the linear form of a quadratic function was estimated using a stepwise regression procedure. The estimation output shows that, within the range of yields observed, although the estimated model was a quadratic function, the final output is a linear model.

As expected, water stress, insects attacks, herbicide, and nitrogen applications, as well as seeding rate and water control significantly impact yield. The yield effect of any additional critical growth period during which the rice plant experiences water stress leads to a reduction in yield of about 233 kg of paddy. Similarly, the impact of significant insect attacks during the cropping season is a reduction of yield (865 kg of paddy), which is more than three times that due to water stress.

Herbicide application tends to increase yields by about 612 kg of paddy, compared to no herbicide at all. The seeding rate has a significant positive effect on yields (*i.e.*, 2 kg of paddy for each additional kg of seed). In contrast, the yield effect of nitrogen application is significantly higher in the CMDT region of Bougouni than in Sikasso.

The study argues that *bas-fond* rice production can significantly contribute to Mali's domestic production. More specifically, the study found that, in seven of the 11 villages listed, the per capital level of milled rice production is higher than or equal to that the national average rice consumption per capita (34 kg/person/year). In other words, there exists a real potential for villages with surplus production of rice paddy to sell rice to deficit areas.

The study identifies four principal directions for *bas-fond* research in order to expand rice production: increasing yield, lowering inputs cost (*e.g.*, fertilizer application and labor content of technologies), reducing growth duration of the plant, and facilitate farmers' adoption of research varieties. To increase rice yield a priority must be given to stabilizing the production environment through more effective water management, and to developing appropriate complementary technologies to relax fertility, pest, diseases constraints in other to fully realize crop potentials.

Furthermore, in order to increase farmers adoption and the returns to research, investing in *bas-fond* rice research would required strengthening the support to scientists, and the link between researchers and extension agents. To carry out the research needed to develop appropriate technologies suitable for greater intensification of *bas-fond* rice farming, the Malian agricultural research system must mobilize a political constituency in support of agricultural research.

Finally, the study notes that, despite the fact that women play a major role in rice production in the *bas-fond*, institutional and social arrangements do not provide women direct access to information about new rice technologies and other resources such as credit.

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AN ECONOMIC ANALYSIS OF THE COMPETITIVENESS OF ALTERNATIVE RICE PRODUCTION SYSTEMS: THE CASE OF *BAS-FOND RICE PRODUCTION IN MALI-SUD*

Volume II

By

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A DISSERTATION

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Agricultural Economics

1997

CHAPTER SIX
FINANCIAL ANALYSIS OF THE MAJOR RICE PRODUCTION SYSTEMS AND SELECTED UPLAND CROPS IN THE BAS-FOND VILLAGES

6.1. Introduction

The purposes of this chapter are to: (1) estimate and analyze the financial returns associated with the four *bas-fond* rice production systems[1] identified in Chapter Five by computing the costs of production, the net returns per hour of family labor, and the net returns per kilogram of paddy produced, and (2) compare the financial profitability of the *bas-fond* rice enterprise to major alternative upland crops (*i.e.*, cotton, maize and sorghum) competing with rice for the PUs' labor and capital. In these analyses, inputs are valued at the market prices farmers paid for each type of purchased resource, non-purchased resources are valued at their opportunity costs, and outputs are valued at the average farm-gate price received by farmers at harvest. The observed crop yield is also valued by the average consumer price for paddy during the hungry period to account for the possibility that farmers could store part or all their *bas-fond* rice production and use it as a substitute for grains they would have had to purchase later in the season.

[1] The four production systems are: (1) the *purely traditional* system (no water control, "traditional" rice varieties, no chemical fertilizer and no herbicide); (2) the *macro-semi-intensive* system (water control, "traditional" varieties, no chemical fertilizer and no herbicide); (3) the *micro-semi-intensive* system (no water control, "traditional" varieties, no chemical fertilizer, but some herbicide); and (4) the *intensive* system (water control, "improved" varieties, some chemical fertilizer and some herbicide).

The chapter is structured in three sections. First, the base-run rice enterprise budgets for the four rice production systems are presented, based on mean or median values of the technical production coefficients, depending on the skewness of the data. To evaluate the impact of possible measurement and estimation errors on profitability, sensitivity analysis is used to vary some assumptions and/or technical coefficients used in the base-run scenario.

Second, representative enterprise budgets for cotton, maize and millet are presented based on secondary data and following the same principles used in estimating the rice budgets. Finally, the chapter concludes with a comparison of these budgets and their implications for farmers.

At the onset, it is important to caution that budget analysis is based on the assumption that each farmer desires to increase expected income and makes the "best" possible use of the resources available to her or him. However, in interpreting these results, it is important to keep in mind that rice farmers' objectives are typically more complex and may differ from the objective of the household head. For example, as mentioned earlier, the household head, who has the authority over upland productions, may be more concerned about household food security and self-sufficiency based on upland crops. However, for women farmers, the rice enterprise has an important social dimension that is not captured by monetary indicators, especially when measured in financial terms.

6.2. Financial Budgets for the Identified Bas-Fond Rice Production Systems

6.2.1. Budget Items and their Estimation

The four rice enterprises considered in this section[1] are defined by the unique combination of inputs (*i.e.*, seeds, fertilizer, herbicide, and water control) associated with each system. Each enterprise budget is structured in four main components, namely, input use, output, costs, and performance measures.

6.2.1.1. Input Use Level and Valuation

The input section of the rice financial enterprise budgets presents per hectare application rates for seeds, fertilizer, herbicide, and family labor. Estimates for each production system are based on survey data collected from farmers utilizing each of the representative systems. Farmers' input application rates are standardized by dividing plot-level data by the corresponding plot size, and averaging them across all farmers in the representative system.

Seeds

The estimated seeding rates of the four representative production systems are statistically different ($\alpha=5\%$). Both the *purely traditional* and *intensive* production systems have a higher average seeding rate (*i.e.*, 207 and 218 kg/ha, respectively) than the recommended rate of 150 kg/ha, while the two semi-intensive systems have lower rates (*i.e.*, 116 kg/ha for the *macro-semi-intensive* system and 94 kg/ha for the *micro-*

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[1] Only the four major rice production systems used by at least 10 percent of the sampled farmers are considered in this analysis.

semi-intensive system). The observed variation among systems may be explained by various factors specific to each farmer including seed availability, knowledge of the recommended seeding rate, and how careful the farmer is at planting, as well as the germination rates for the different varieties.

In estimating the cost of seeds used in production, "traditional" and "improved" seed varieties are valued differently. Although farmers seldom buy or sell "traditional" rice varieties' seeds, these seeds are valued at their opportunity costs (*i.e.*, market purchase price of 150 CFA.F/kg). In contrast, prices set by CMDT are used to value "improved" varieties' seeds because CMDT is the main source of "improved" seed (*i.e.*, 150 CFA.F/kg).

Fertilizer

Because all farmers did not apply the same combination of fertilizer[1], the cost of this input was estimated by averaging total fertilizer expenditures made by each farmer across all farmers in the representative production system (*i.e.*, 43,344 CFA.F/ha). In other words, if a farmer applied urea and DAP, his/her total expenditure on fertilizer is the monetary value of the amount of urea used plus the value of DAP applied. Because most farmers bought their inputs from CMDT, these inputs are valued using prices set by CMDT.

[1] Farmers used combinations of urea, a compound NPK (15-15-15) cereal fertilizer, and DAP at the rates 100-0-0 kg/ha respectively, or 105-82-0 or 150-0-122.

Herbicide

Unlike with fertilizer and seeds, farmers' herbicide application rates are highly skewed. Therefore, the median values of herbicide application rates are used instead of mean values. While farmers in the *micro-semi-intensive* production system used *Round Up* (82%) and *Gramoxone* (18%), those in the *intensive* system applied *Round Up* (63%) and *Ronstar* (37%). Because the majority of the farmers in these two systems applied *Round Up*, the financial budgets are estimated using *Round Up* application rates. The median application rate used in both systems is 2.5 l/ha, valued at 6,580 CFA.F/l.

Labor

Survey farmers used four types of labor: individual family labor, collective family labor (exchange labor), individual hired labor, and collective hired labor. Of these labor categories, only hired labor (individual and collective) is included in estimating the operating costs of production. However, exchange and individual family labor data are combined into a family labor category, which is used to estimate one of the performance measures (*i.e.*, the return to the rice enterprise for a six-hour day of family labor farm work).

Only the cost of hired labor for plowing, hand weeding, harvest and threshing (*i.e.*, farming operations for which at least 30% of the farmers hired labor) are included in the budgets. These costs are estimated for each production system because they are system-specific. Because hired labor was paid by task, rather than at a daily rate, the corresponding costs were estimated in three steps.

First, for each farmer in the four production systems, his/her total expenditures on hired labor (including both cash and non-cash payments) were computed for each farming operation. The non-cash payments represent in-kind payments or amenities, such as food and drinks provided by the farmer to non-family labor, in addition to the cash payment. The non-cash payments were valued by the farmers themselves at their corresponding market value. Cash labor expenditures include the actual acquisition price of labor hired as individuals plus the cost of labor hired as a group, both converted to a per hectare basis.

Second, for each of the four production systems, the average cost of hired labor for each farming operation was estimated by dividing the system's total expenditures for labor hired by the number of farmers in the sub-sample. Finally, for each system, the total cost of hired labor was derived by summing the corresponding costs for all farm operations considered (*i.e.*, plowing, hand weeding, harvesting and threshing).

Given that hired female labor is rare in the area surveyed, no gender differential was used in valuing hired labor. In addition, as discussed earlier, although differences in gender and age affect individuals' work ability, no adjustment was made to account for these differences because the number of hours of farm labor and the actual work effort each laborer provides depend on several factors in addition to gender and age, such as the farm operations involved, the extent of the effort provided by the farmer in previous commitments, and his/her attitude towards leisure.

Family labor requirements were estimated using recall data provided by farmers. These data were measured in terms of hours of work provided by family members and exchange labor throughout the season (*i.e.*, from cleaning to threshing). In estimating total family labor requirements, two facts were taken into account. First, because the recall family labor data reported by farmers in each farming operation in each system was not normally distributed, the median values were used in the estimation process. Second, the median amounts of family labor used for cleaning, plowing, and planting were estimated by pooling all farmers in the four representative production systems together, because for these generic operations family labor requirements are assumed to be independent of the systems.

Third, the amount of family labor used for weeding, fertilizing, harvesting and threshing was estimated for each of the four production systems, because these operations are clearly system specific. For example, only farmers in the *intensive* system applied fertilizer. Similarly, only farmers in the *intensive* and *micro-semi-intensive* systems applied herbicide. Furthermore, because water control quality affects weed growth, weed pressure in the *traditional* and *micro-semi-intensive* systems (without water control) may be greater than in the *intensive* and *macro-semi-intensive* systems (with water control). However, labor requirements for weeding also differ within systems without water control. For example, although both the *traditional* and *micro-semi-intensive* systems lack water control, farmers in the *traditional* system weeded manually while those in the *micro-semi-intensive* used herbicide. Finally, for each production system, total family labor requirements are estimated by summing median family labor used in each operation (Table 6.1).

6.2.1.2. Output Level and Valuation

The output section of the budget presents gross revenue of each system, by multiplying observed crop yield by the average farm-gate price at harvest, even though very few farmers actually sell their rice crop. The observed crop yield is also valued by the average consumer price for paddy during the hungry period to account for the possibility that farmers may store part or all their *bas-fond* rice production and use it as a substitute for grains they would have had to purchase later in the season. In both cases, the output price is estimated for the whole sample, rather than for each systems because there was no statistical difference ($\alpha=5\%$) between the disaggregated farm-gate paddy prices. The average farm-gate price is estimated using the price data collected between February and March of 1996 in the market closest to each village, and averaging this price over all villages. Although these prices were not adjusted for transportation cost from the farm to the market, the bias associated with the failure to do so is considered negligible. For most villages, weekly markets are situated no further than seven kilometers from the village. In most cases, even for relatively distant villages, farmers walk to the market.

6.2.1.3. Costs

To compute the performance measures, the costs associated with each rice enterprise are classified into operating and fixed costs.

6.2.1.3.1. Operating Costs

Operating costs are defined as costs associated with the use of variable purchased inputs (*i.e.*, seeds, fertilizer, herbicide, hired labor, and in-kind "payments") in addition to the interest cost of working capital. The underlying rationale for including interest on working capital is the recognition that farmers' capital expenditures have an opportunity cost based on the potential rate of return on alternative investments. For simplicity, it is assumed that the money invested by farmers could have earned a rate of return at least equal to the interest on saving in the capital market represented by the banks. As a result, by investing in rice production, farmers forgo the interest they would have earned had this money been placed in a savings bank account. However, while the study recognizes that this rate tends to be higher in the informal sector than in the bank, no data was available for this sector. As a result, the study used interest rate offered in the formal sector.

Two alternative approaches were considered in determining interest cost--calculating interest on only cash transactions (*i.e.*, purchased inputs and hired labor paid in cash), or including all costs (excluding family labor) involved in production. In this study, both cash and non-cash transactions are included since each non-cash transaction also has a corresponding opportunity cost. The interest on capital is computed for each transaction, based on the 12 percent annual interest rate offered by private banks. For each transaction, the corresponding interest cost is obtained by weighting the annual interest costs by when it occurs in the production process. Weighting each transaction by the duration of its occurrence, up to a maximum of six months, which is the length of the farm-level production cycle, captures when the capital is utilized in the production process. To achieve this, the cost of each operation (excluding family labor) was divided by 12 months and then multiplied by 6, 6, 5, 4, 4, 1, 0 months for the cost of cleaning, plowing, planting, weeding, fertilizing, harvesting and threshing, respectively.

6.2.1.3.2. Fixed Costs

Theoretically, fixed costs in rice farming include the cost of land, the annual equivalent value of the cost of land development and farm equipment, as well as water utilization fees. In estimating the financial rice enterprise budgets, no cost is included for depreciation costs associated with the use of harrows, carts, and draft animals because these implements are mainly used in the uplands. Depreciation costs for farm equipment such as hoes and knives are excluded because they are considered negligible--these tools cost about 500 CFA.F each and are used over an extremely long period of time. Finally, the cost of land development and water utilization fees are excluded in the financial analysis because they are borne by CMDT.

With regard to land, its opportunity cost is assumed to be zero, because (a) in these villages land is seldom sold given that it is communally owned (*i.e.*, there is no market purchase price or rental value), and (b) rice is the only crop that can be grown in the *bas-fonds* during the rainy season. Although a token fee of 10 cola nuts is sometimes paid by farmers usually to the village chief, this is of negligible value. Thus, based on all the arguments in this section, no fixed costs are included in the *bas-fond* financial rice budget enterprises.

6.2.1.4. Performance Measures

Six performance measures are used: gross margin, total cost of production per hectare planted, enterprise profit, cost of production per kilogram of paddy produced, net returns per day (6 hours) of family labor used, break even yield change[1], as well as the ratios of fixed, operating, and total cost to the total value of production. The enterprise profit, its cost of production per kilogram of paddy produced, and the associated returns per day of family labor used are alternative indicators of the profitability of the rice enterprise.

The gross margin is the total value of production (*i.e.*, gross revenue) less the total operating costs, excluding family labor. In other words, for each production system, the gross margin is the return over the operating costs. The total production costs include all variable and fixed costs. The enterprise profit, which is computed as the market value of the paddy produced per hectare less total cost of production (including the cost of family labor and land), measures the return to management. A positive enterprise profit indicates a profitable enterprise and a negative profit indicates a non-profitable enterprise.

The cost of production per kg of paddy produced is obtained by dividing the total cost by the yield. It is used in comparison with the farm-gate producer price of paddy to indicate the relative profitability of the enterprise. For example, if the cost of producing one kilogram of paddy is lower than the farm-gate producer price, the rice

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[1] For each production system, the break even yield change indicates by how much (percentage) the system's current yield level would have to change for farmers to earn exactly as much as they invest, *ceteris paribus*.

enterprise is profitable. The return per day of family labor, which is obtained by dividing the net returns to all family labor[1] by the total number of days of family labor used in the rice field during the season, is interpreted in comparison with the opportunity cost of family labor to indicate the relative profitability of the enterprise. For example, a return per day of family labor higher than his/her opportunity cost of family labor indicates a profitable rice enterprise.

The opportunity cost of family labor is assumed to equal the minimum wage (reservation wage) at which a laborer is willing to offer his/her labor services. This reservation wage is assumed to reflect the net returns to the best alternative use of the family laborer, if he/she did not grow rice. This analysis assumes that both hired and family laborers have the same opportunity cost of 500 CFA.F/day. Because hired labor is willing to accept this wage rate, this rate is assumed to reflect his/her reservation wage or its opportunity cost, which is also the opportunity cost of family labor.

Each of the three ratios (*i.e.*, fixed ratio, operating ratio, and gross ratio[2]) indicates the degree to which the total value of production exceeds the corresponding costs in percentage terms. Because fixed costs are zero for the rice enterprise, the fixed ratio is zero, and the operating and gross ratios are equal. However, the operating and gross ratios differ for the upland crops, for which the fixed costs are not zero.

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[1] The net returns to all family labor is computed as the gross margin less fixed costs. In other words, it is the total value of production less all production costs, excluding family labor.

[2] The fixed ratio is the proportion of the total value of production allocated to paying fixed costs. The operating ratio is the proportion of the total value of production allocated to paying operating costs. The gross ratio is the proportion of the total value of production allocated to paying fixed and operating costs.

6.2.2. The Estimated Rice Enterprise Budgets

6.2.2.1. Base-Run Scenario: Average Financial Budgets

The estimated *bas-fond* rice enterprise budgets are presented in Table 6.1. These budgets, which represent "best estimation" scenario, assume no output price differences between rice varieties and an opportunity cost of family labor of 500 CFA.F for a six-hour day of farm work, in addition to the other assumptions discussed in section 6.2.1. An assessment of the degree to which these assumptions affect enterprise profitability is presented in section 6.2.2.2.

Table 6.1: Estimated Average Financial Budget for the *Bas-fond* Rice Enterprise, by Production System, Mali, Rainy Season 1995-96.

Budget Items	Production Systems			
	Purely Traditional	Macro-Semi-Intensive	Micro-Semi-Intensive	Intensive
1. INPUT USE				
Seeding rates (kg/ha):				
"traditional" varieties (@ 85 CFA.F/kg)	207	116	94	0
"improved" varieties (@ 150	0	0	0	218
CFA.F/kg)	0	0	2.5	2.5
Herbicide (l/ha @ 6,580 CFA.F/l)	0	0	0	(a)
Fertilizer				
Family labor use rates (hours/ha):	42	42	42	42
cleaning	48	48	48	48
plowing	41	41	41	41
planting	32	20	2	30
weeding	0	0	0	24
fertilizer application	52	43	64	84
harvesting	41	30	52	72
threshing	256	224	249	341
2. OUTPUT				
Average yield (kg of paddy/ha)	1,021	1,232	1,423	2,366
Market price of paddy (CFA.F/kg of paddy)	115	115	115	115
Gross revenue (CFA.F/ha)	117,415	141,680	163,645	272,090
3. COSTS				
Fixed Costs (CFA.F/ha):	0	0	0	0
Operating Costs (CFA.F/ha):				
Seeds	17,595	9,860	7,990	32,700
Herbicide	0	0	16,450	16,450
Fertilizer	0	0	0	43,344
Hired labor	39,000	56,795	14,000	49,164
Interest on working capital (12%)	2,220	2,837	1,898	5,749
Total operating costs (CFA.F/ha)	58,815	69,492	40,338	147,407
Total non-family labor costs (CFA.F/ha)	58,815	69,492	40,338	147,407
4. PERFORMANCE MEASURES				
Gross margin (CFA.F/ha)	58,600	72,188	123,308	124,683
Net returns to family labor (CFA.F/ha)	58,600	72,188	123,308	124,683
Net returns per day of family labor (CFA.F)	1,374	1,934	2,971	2,194
Opportunity cost of family labor (CFA.F/ha)	21,333	18,667	20,750	28,417
Average total production cost (CFA.F/ha)[(b)]	80,148	88,158	61,088	175,824
Enterprise profit (CFA.F/ha)	37,267	53,522	102,558	96,266
Av. cost per kg of paddy produced (CFA.F)[(b)]	78	72	43	74
Operating ratio (equal to gross ratio)	0.68	0.62	0.37	0.65
Break even yield change (%)	-32	-38	-63	-35

(a) Farmers applied combinations of urea, a compound NPK (15-15-15) cereal fertilizer, and DAP. These fertilizers are applied at the rates 100-0-0 kg/ha respectively, or 105-82-0 or 150-0-122. Urea is valued at 175.0 CFA.F/kg, NPK at 196.0 CFA.F/kg, and DAP at 243.7 CFA.F/kg.

(b) Includes family labor valued at 500 CFA.F for a six-hour day of farm work.

Source: Survey Data.

Gross Revenues

Table 6.1 shows that the gross revenue from *bas-fond* rice production significantly increases with the level of intensification, with the *traditional* production system yielding the lowest revenue (117,415 CFA.F/ha) while the *intensive* system provides the highest revenue (272,090 CFA.F/ha).

Costs

The costs of production associated with these four production systems are estimated with and without family labor. When family labor is excluded, the average cost of production is 40,338 CFA.F/ha for the *micro-semi-intensive* system, 58,815 CFA.F/ha for the *traditional* system, 69,492 CFA.F/ha for the *macro-semi-intensive* system, and 147,407 CFA.F/ha for the *intensive* system. These results show that the production cost in the *intensive* system is more than twice the cost in any of the other three systems.

The relative importance of the structural components of these costs (excluding family labor) differ from one system to another. Hired labor represents the highest share of production costs in the *traditional* system (*i.e.*, 66%), followed by seed (30%). A similar cost structure is observed for the *macro-semi-intensive* system, where hired labor accounts for a greater share of production costs (82%) and seeds account for 14 percent of the costs. For the other two systems, while the cost components are more diverse, hired labor still represents a major share. In the *micro-semi-intensive* system, hired labor represents 35 percent of production costs, while herbicide and seeds account for 41 and

20 percent, respectively. In the *intensive* system, hired labor represents 33 percent of production costs, while herbicide, fertilizer and seeds account for 11, 29 and 22 percent, respectively.

When family labor is included as a cost component and valued at 500 CFA.F/day, the average cost of production under each system increases by 19-51 percent, ranging from 61,088 CFA.F/ha for the *micro-semi-intensive* system, 80,148 CFA.F/ha for the *traditional* system, 88,158 CFA.F/ha for the *macro-semi-intensive* system, to 175,824 CFA.F/ha for the *intensive* system. These estimates are within the range (63,900-126,410 CFA.F/ha) reported by Coulibaly (1995) on Mali Sud's *bas-fonds* (Appendix 6.1), except for the *intensive* system, which here has a higher production cost than estimated by Coulibaly (1995).

Structurally, hired and family labor costs represent the main component in this study's estimates of production cost, accounting for 75 percent of total costs in the *traditional* system, 86 percent in the *macro-semi-intensive* system, 86 percent in the *micro-semi-intensive* system, and 44 percent in the *intensive* system. The estimated total labor used (*i.e.*, combining family and hired labor) is 724, 906, 417, and 931 hours of work per hectare (*i.e.*, 121, 151, 70, and 155 persondays[1]) in the *traditional*, the *macro-semi-intensive*, the *micro-semi-intensive*, and the *intensive* systems, respectively.

Previous studies report greatly varying labor requirements for *bas-fond* rice production, ranging from 93 persondays (Ahmadi in Lavigne Delville, 1994), 100-120 persondays (Séné Conseil in Lavigne Delville, 1994), 131-197 persondays (Coulibaly,

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[1] A personday is defined as equal to six hours of work.

1995), and 1,820 hours (Matlon and Fafchamps, 1988). The variability of these estimates highlights the difficulty in comparing labor data reported in different studies. The differences between these estimates depend in part on the data collection method used (*i.e.*, recall or record keeping), the technology used (*e.g.*, manual or mechanical), individual characteristics of farmers, and the type of statistic reported (*i.e.*, mean or median).

When the measurement method used is "recall interview", as is the case in this study, the accuracy depends in part on when the interview is conducted relative to when the operation was performed. The variability across farmers can be attributed to factors such as farm size, weed type and weed density, farmer's gender, attitude towards leisure, and labor commitment before the operation. With regard to the type of statistic reported, the studies cited earlier in this section may have reported mean values while this study reported median values as the measure of central tendency because of skewed data.

Performance

Because this study assumes no fixed costs for *bas-fond* rice production in Mali-Sud, the gross margin is equal to the returns to family labor and management. When converted to a per day basis, for all systems the returns per day of family labor in the rice field (ranging from 1,374 to 2,971 CFA.F/day) is higher than his/her opportunity cost, estimated to be 500 CFA.F/day. In other words, under the set of assumptions made earlier, all four *bas-fond* rice production systems are financially profitable. The same observation can be made using the associated costs of producing a kilogram of paddy (ranging from 43 to 78 CFA.F/kg), which are lower than the farm-gate producer price of paddy (115 CFA.F), and the corresponding gross ratio[1], which is less than unity. These positive results are consistent with those obtained by Coulibaly (1995) for farmers in Sikasso, but contradict his negative results for farmers in Kadiolo and Bougouni (Appendix 6.1). One possible explanation for this discrepancy is the fact that this study uses both different prices and average inputs and output prices throughout the *bas-fond* area, while Coulibaly used site-specific prices.

Among the four systems studied, the most profitable is the *micro-semi-intensive* system, which has the lowest average production costs per kg of paddy produced (*i.e.*, 43 CFA.F/kg), and the highest return to a day of family labor (*i.e.*, 2,971 CFA.F/day), which is about six times higher than his/her opportunity cost. One reason why this system is so profitable is that this also the system that used the least labor per ha, primarily because of significant herbicide substitution for hired labor in weeding. The estimated gross ratio of 0.37 indicates that, for this system, the total cost of production (family included) is only 37 percent of the total value of production, compared to 62 percent for the *macro-semi-intensive* system, 65 percent for the *intensive* system, and 68 percent for the *traditional* system.

The least profitable of the four production systems is the *traditional* system, which has an average production costs of 78 CFA.F/kg of paddy produced, and a return to a day of family labor amounting to 1,374 CFA.F/day (*i.e.*, about three times higher than his/her opportunity cost). The more intensive of the four production systems (*i.e.*,

[1] The gross ratio is the ratio of total production costs to total value of production.

the *intensive* system) is the farmers' second best alternative, with an average production cost of 74 CFA.F/kg of paddy produced, and a return to a day of family labor of 2,194 CFA.F/day, (*i.e.*, about four times higher than his/her opportunity cost).

Given the costs and output price reported in Table 6.1, under the *traditional* production system, a 32 percent "poor year" yield decrease would be necessary for farmers to break even, *ceteris paribus* (Table 6.1). The same estimate is 38 percent for *macro-semi-intensive*, 63 for *micro-semi-intensive*, and 35 *intensive* systems (Table 6.1).

These results indicate that, as in other places in West Africa[1], *bas-fond* rice production more than covers the opportunity cost of family labor. However, they are based on mean or median values of the items taken into account. While the choice of these central tendencies is theoretically justified, it is also useful to look at the distribution of the net returns per day of family labor among the sampled farmers in each of the four *bas-fond* rice production systems. To achieve this, financial budgets were estimated for each sampled farmer. In this process, revenues were determined by valuing each farmer's specific observed yield by the market price (*i.e.*, 115 CFA.F/kg). In addition, the average cost levels reported in Table 6.1 were maintained. In contrast, for each farmer, family labor requirement at harvest and threshing were adjusted in direct proportion to the corresponding yield difference (*i.e.*, relative to the average yield reported in Table 6.1). Figures 6.1 to 6.4 show the distribution of net returns per day of family labor among the sampled farmers in each of the four production systems.

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[1] For example, Levarsser's (1979) analysis of nine rice production systems in Bénin and Spencer's (1981) analysis of 13 rice production systems in Sierra Leone found that they were highly profitable for farmers.

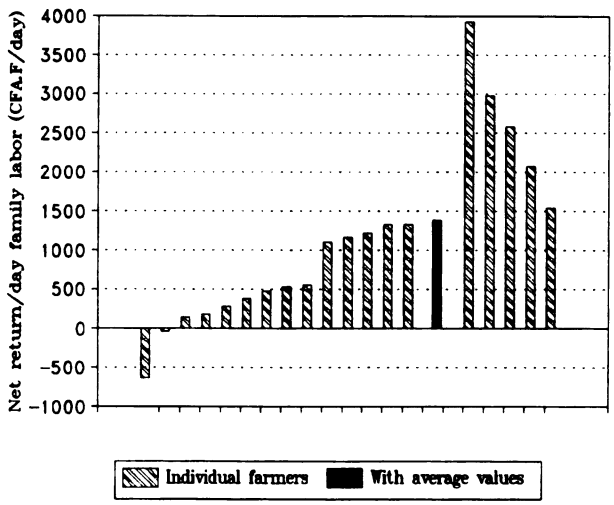

Figure 6.1: Distribution of Net Returns per Day of Family Labor Among Sampled Farmers (N=19) Using the *Bas-Fond Traditional* Rice Production System, Mali, 1996.

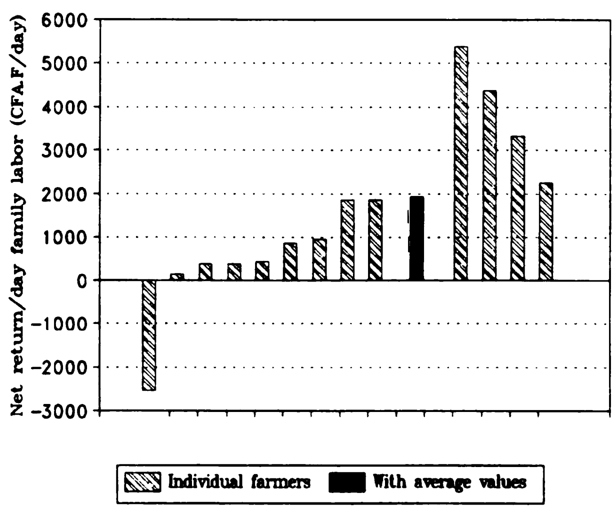

Figure 6.2: Distribution of Net Returns per Day of Family Labor Among Sampled Farmers (N=13) Using the *Bas-Fond Macro-Semi-Intensive* Rice Production System, Mali, 1996.

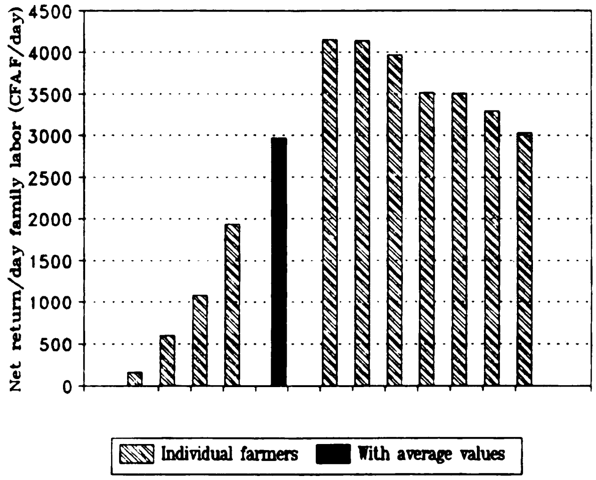

Figure 6.3: Distribution of Net Returns per Day of Family Labor Among Sampled Farmers (N=11) Using the *Bas-Fond Micro-Semi-Intensive* Rice Production System, Mali, 1996.

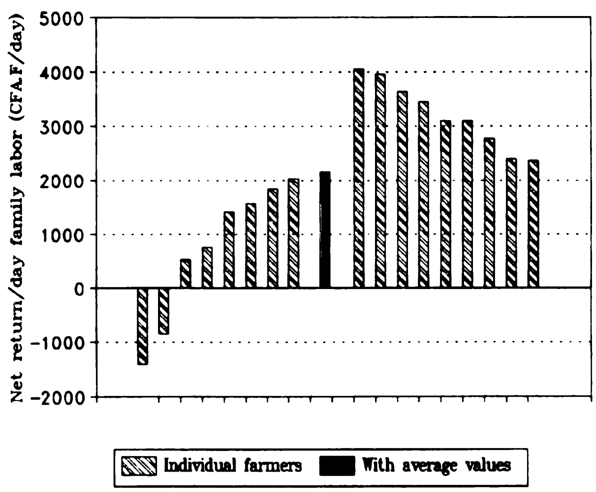

Figure 6.4: Distribution of Net Returns per Day of Family Labor Among Sampled Farmers (N=18) Using the *Bas-Fond Intensive* Rice Production System, Mali, 1996.

Figure 6.1 to 6.4 reveal that, although on the average each of the four *bas-fond* rice production systems was profitable to farmers, this enterprise is not profitable for some farmers. In particular, Figure 6.1 shows that, under the assumptions outlined earlier, the net returns per day of family labor among the sampled farmers using the *traditional* system range between a negative 631 CFA.F/day and a positive 3,936 CFA.F/day. The distribution of these returns is skewed to the left of the average value reported in Table 6.1, as 14 of the 19 farmers (74%) using this system earn less than that average (1,374 CFA.F/day). In addition, two (11%) of the 19 farmers have negative returns, five (26%) earn positive net returns per day which are less than the assumed opportunity cost of family labor (*i.e.*, 500 CFA.F/day), and the rest (63%) earn more than 500 CFA.F/day.

Similarly, Figure 6.2 shows that net returns per day of family labor among the sampled farmers using the *macro-semi-intensive* system range between a negative 2,529 CFA.F/day and a positive 5,368 CFA.F/day. As with in the *traditional* system, the distribution of these returns is skewed to the left of the average value reported in Table 6.1 since nine of the 13 farmers (69%) using this system earn less than that average (1,934 CFA.F/day). In addition, among the 13 farmers using this system, one (8%) has a negative return, four (31%) earn positive net returns per day which are less than the assumed opportunity cost of family labor, and the rest (61%) earn more than 500 CFA.F/day.

For farmers using the *micro-semi-intensive* system, their net returns per day of family labor among the sampled range between positive 161 and 4,142 CFA.F/day

(Figure 6.3). Unlike with in the *traditional* and the *macro-semi-intensive* systems, the distribution of these returns is skewed to the right of the average value reported in Table 6.1 since seven of the 11 farmers (64%) using this system earn more than that average (2,971 CFA.F/day). In addition, among the 11 farmers using this system, none has a negative return, only one (9%) earn positive net returns per day which are less than the assumed opportunity cost of family labor, and the rest (91%) earn more than 500 CFA.F/day.

Finally, Figure 6.4 shows that net returns per day of family labor among the sampled farmers using the *micro-semi-intensive* system range between a negative 1,398 and a positive 4,051 CFA.F/day. These returns are evenly distributed around the average value reported in Table 6.1 (2,194 CFA.F/day). Among the 18 farmers using this system, three (17%) have a negative return, and the rest (83%) earn more than the assumed opportunity cost of family labor.

It is important to recognize that the distribution of net returns per day of family labor among the sampled farmers in each of the four production systems is based on small sample sizes (less than 20). Granted this limitation, however, the results obtained indicate that, even within a given *bas-fond* rice production system, there is some heterogeneity of the profitability of the rice enterprise. Thus, a key question for future research is to find out the factors that account for this variability.

Economic studies on rice production in the major rice producing countries in West Africa (*i.e.*, Côte d'Ivoire, Liberia, Sierra Léone, Sénégal, and Mali) have focused on commercialized production with good water control and under a subsidized environment.

In Mali, the only exception is a study by Coulibaly (1995), who found positive financial returns of 64,170 CFA.F/ha to *bas-fond* rice production in Sikasso, 10,990 CFA.F/ha in Kadiolo, and 9,435 CFA.F/ha in Bougouni, assuming no opportunity cost for family labor (Appendix 6.1). Most of these studies showed that the factors explaining the differences in profitability were country specific[1] (McIntire, 1981).

The Need for Labor-Saving Technologies

The large share of family and hired labor cost (relative to other cost items) in each of these systems (44-86%) suggests that one significant way to increase their profitability is to reduce the labor content of the technologies farmers used without increasing total costs. Interestingly, a distinctive characteristic of the most profitable of the four production systems is that farmers in this system used herbicide as their only modern input. Indeed, group discussions with farmers in all of the systems revealed that weeding is a major constraint in *bas-fond* rice farming. While this study's survey data indicated weeding accounted for 10 percent of total labor used, plowing (22-27%), harvesting (24%), and threshing (21-39%) have the highest labor shares.

Thus, in addition to increasing yields, complementary research is needed to develop relatively low-cost labor-saving technologies. As discussed in Chapter Four,

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[1] These studies show that the profitability of rice production is greatly influenced by not only the availability of improved technology, but also prevailing input and output markets policies, the world market price, the status of the road infrastructure, and the location of consumption centers. Humphreys' (1981) study of improved upland rice in Côte d'Ivoire and McIntire's study (1981) of *bas-fond* rice in Mali reported that animal traction was more profitable than manual land preparation. Humphreys' (1981), Spencer's (1981), and Monke's (1981 in Liberia) found that the use of modern inputs (fertilizer and varieties) increases profitability in the forest areas, but reduces it in the savannah. Finally, Humphreys' (1981), Spencer's (1981) and Tuluy's (1981) results indicated that complete mechanization is less profitable than partial mechanization.

efforts to increase yield should focus on improving land preparation, determining an optimal planting period and better plot-level water control, as well as increasing the rice adaptability and yield potential of "improved" varieties. Efforts to reduce production costs should assess the potential of reducing labor input through the substitution of adapted and economically justifiable labor-saving technologies such as herbicide, mechanical threshing, sickle harvesting, and better water control systems.

There Is a Need to Generate Better Estimates of Family Labor Opportunity Cost

Given the large proportion of labor in total production costs, assessing farmers' labor opportunity cost becomes a central issue in estimating the rice enterprise's profitability. To estimate farmers' labor opportunity cost, four important issues should be kept in mind. First, rural wage labor opportunities in these villages are highly seasonal because farmers only hire labor when family labor is constrained. While households in these villages may have a relative abundance of labor resources in proportion to capital and *bas-fond* land, most of the labor is used in the uplands.

Second, the probability of finding rural employment opportunities is slim, suggesting the market wage is not a good proxy for farmers' reservation wage. As a result, given its limited availability and the thin labor market, wage labor does not represents a viable alternative to rice farming. Indeed, Ryan *et al.* (1980), in a study on labor utilization patterns and labor market behavior in semi-arid tropical rural villages of Peninsular India, found that employment opportunities are not always available as is often assumed. In this context, farmers' labor opportunity cost may be measured in terms of the value of household activities the farmer would have performed had she been at home. Unfortunately, these values are extremely hard to assess.

Third, as discussed earlier, the estimated budgets are based on the assumption that each farmer desires to increase expected income and to make the "best" possible use of available resources. Yet, for women farmers, the rice enterprise has an important social dimension that is not captured by its monetary value, especially when measured in financial terms. As a result, female farmers may attach a utility value to rice self-sufficiency that exceeds its monetary value, and to their own time that may be lower that the assumed opportunity cost of labor. Furthermore, this valuation may differ between male and female farmers, from one farm operation to another, as well as from farmer-to-farmer within the same gender group depending on farmers' wealth, attitude towards leisure, employment opportunities, and the strength of the patriarchal social system[1] in the households with regard to access to entitlements.

Fourth, while the thin seasonal labor market is segmented by gender, men have more chances of obtaining daily wage employment than women. In other words, the 500 CFA.F/day used in this study was the estimated opportunity cost for male labor, and there is no way of knowing how close this estimate is to the intraseasonal opportunity cost of female labor. Whether this estimate overstates or understates the true opportunity cost requires knowledge of the elasticity parameters of demand and supply of female labor.

[1] As mentioned in Chapter Four, in all villages surveyed, a strongly male-dominated social organization influences access to land and decision-making in the households. For example, generally, men decide on how crop production from the uplands is to be used.

At the extreme, under the assumption of zero opportunity cost of family labor, the four systems have a production cost of 58 CFA.F/kg of paddy produced in the *traditional* system, 56 CFA.F/kg in the *macro-semi-intensive* system, 28 CFA.F/kg in the *micro-semi-intensive* system, and 62 CFA.F/kg in the *intensive* system.

These four points indicate that the issue of labor opportunity cost is very much at the heart of the systems' profitability. Thus, a better understanding of seasonal labor market parameters and patterns is required to better assess farm enterprise profitability. Furthermore, such an understanding would provide an opportunity to more explicitly design technologies to capitalize on periods when the opportunity costs are relative high and enhanced the systems' financial profitability and technology adoption.

However, it is important to note that the observed profitability is not the result of a single factor. Rather, it reflects the combined effect of physical, technological, institutional, and managerial factors. For example, while rice is produced predominantly by women, the credit needed to purchase modern production inputs is channeled through CMDT institutional arrangements. Thus, only men who are cotton farmers have access to credit and they are unlikely to borrow for the women.

Farmers' Assessment of Profitability May Very Well Be Higher than Estimated

It is fairly reasonable to assume that farmers grow *bas-fond* rice as a substitute for grain purchases later in the post-season during the hungry period, when prices are high. This assumption is supported by the innovative producer survey research conducted by the MSU Food Security II Cooperative Agreement in 1985/86 in four producing regions of Mali, which revealed in particular that many farmers make cash purchases of food (Dioné, 1989). This result is consistent with the 1988/89 nationwide budget-consumption survey results, which indicated that 41.4 percent of the rice that households consumed in rural areas are purchased in the market. Figure 6.5 depicts increasing returns per day of family labor associated with rising paddy prices, which typically increase by as much as 100 percent during the hungry period.

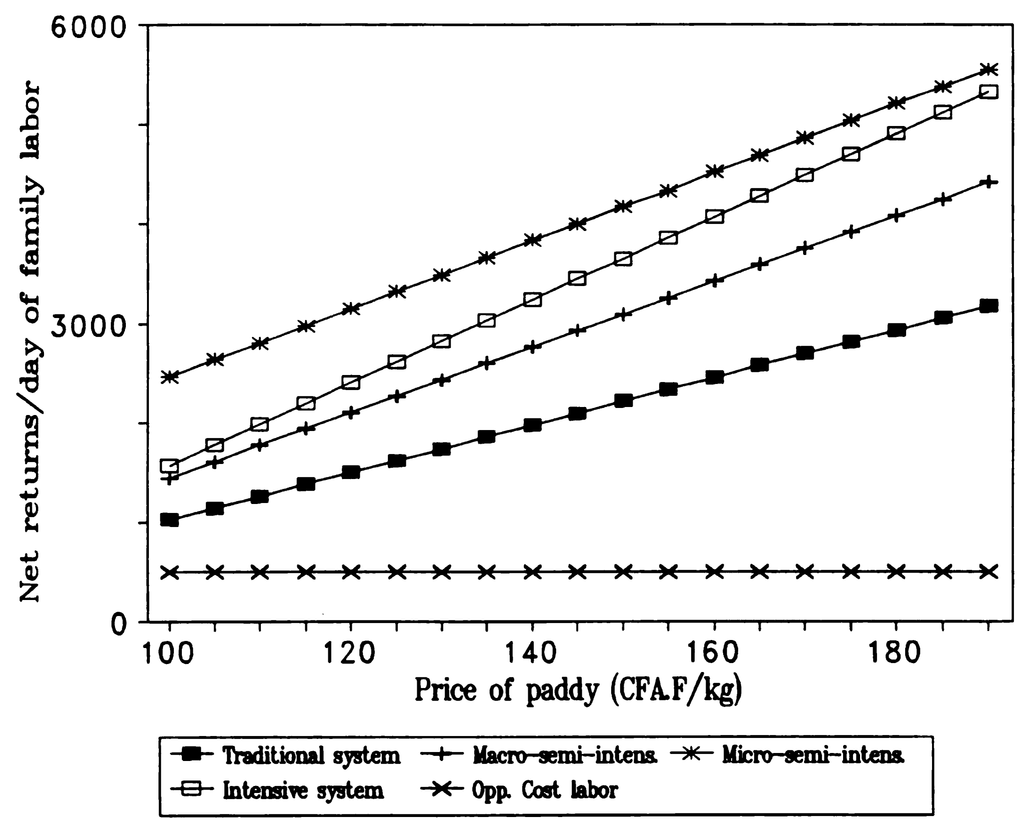

Figure 6.5: Net Returns per Day of Family Labor (CFA.F/day) for Alternative Market Prices and *Bas-Fond* Rice Production Systems, Mali, 1996.

6.2.2.2. Sensitivity Analysis

The rice budgets presented in Table 6.1 are based on average yields and an opportunity cost of family labor of 500 CFA.F for a six-hour farm day. The use of average yields is based on the assumption of an average production year. However, given the erratic nature of rainfall in the area studied, actual yields are fairly unstable, depending in part on the moisture condition in individual plots from one year to another. To assess the degree to which yield variations affect the profitability of the *bas-fond* rice enterprise, this section presents the financial budgets assuming a "poor", and a "good" production years. Under the poor/good year scenario, the study assumes that harvest labor requirements will vary in direct proportion to the yield decline/increase. In each case, the budgets are estimated under the assumption that the resulting supply change would not induce a change in paddy and inputs prices. Then, in each case, the output price changes required for farmers to break even were estimated.

Run 1: Assuming a "poor year" with low yields equal to the 25th percentiles

The scenario of a "poor" production year assumes a low yields equal to the observed 25th percentiles in each production system, a reduction of harvest labor requirements in direct proportion to the yield decline, and an unchanged farmers opportunity cost of labor of 500 CFA.F/day as well as output and inputs prices. This scenario implies a 33 to 55 percent yield decline, depending on the system (Table 6.2), relative to the average values reported in Table 6.1. Table 6.2 presents a summary of these corresponding yield changes, total production costs, and the cost per kg of paddy produce, as well as the output price change required for farmers to break even in a "poor" year.

Table 6.2: Financial Performance Indicators for the *Bas-fond* Rice Enterprise Assuming a Poor Production Year, by Production System, Mali, Rainy Season 1995-96.

Indicators	*Bas-Fond* rice production system			
	Traditional	Macro-semi-intensive	Micro-Semi-intensive	Intensive
Yield Level (kg paddy/ha)	600	714	640	1,575
Yield change[a] (%)	-41	-42	-55	-33
Gross revenues (CFA.F/ha)	69,000	82,110	73,600	181,125
Production cost (CFA.F/ha)[b]	78,361	86,652	58,153	173,484
Return/day of family labor (CFA.F)	220	313	702	548
Cost/kg of paddy (CFA.F/kg)	131	121	91	110
Break-even output price change (%)	+14	+6	-21	-4

[a] For each production system, the change is computed relative to the system's average yield reported in Table 6.1.
[b] Includes family labor valued at 500 CFA.F for a six-hour day of farm work.
Source: Survey Data.

Table 6.2 shows that, with these yield levels and assuming a 500 CFA.F/day of family labor and unchanged output inputs prices, the *micro-semi-intensive* and the *intensive bas-fond* rice production systems are the only systems that remain profitable to farmers. For these two systems, the return to a day of family labor (*i.e.*, 702 and 548 CFA.F/day, respectively) is higher than his/her opportunity cost (500 CFA.F/day), and the associated cost of production per kg of paddy (*i.e.*, 91 and 110 CFA.F/day, respectively) is lower than the output farm-gate price (115 CFA.F/day).

Under the yield decrease assumptions stated in Table 6.2, for the enterprise to break even (*i.e.*, total revenues exactly cover production costs), the farm-gate paddy price would have to increase by 14 percent for farmers utilizing the *traditional* system, and by six percent for those in the *macro-semi-intensive* system. In contrast, for total revenues to cover the production costs and break even, paddy price farm-gate would have to decrease by 21 percent for farmers utilizing the *micro-semi-intensive* system, and four percent for those in the *intensive* system.

Run 2: Assuming a "good year" with high yields equal to the 25th percentiles

This scenario assumes a "good" production year with higher yields equal to the observed 75th percentiles in each production system, an identical opportunity cost of labor (500 CFA.F/day), and an increase in harvest labor requirements in direct proportion to the yield increase. Table 6.3 presents a summary of the corresponding yield change, total production costs, and the cost per kg of paddy, as well as the output price change required for farmers to break even.

Table 6.3: Financial Performance Indicators for the *Bas-fond* Rice Enterprise Assuming a Good Production Year, by Production System, Mali, Rainy Season 1995-96.

Indicators	*Bas-Fond* rice production systems			
	Traditional	Macro-semi-intensive	Micro-semi-intensive	Intensive
Yield level (kg paddy/ha)	1,100	1,615	2,100	3,074
Yield change[(a)] (%)	+8	+31	+47	+30
Gross revenues (CFA.F/ha)	126,500	185,725	241,500	353,510
Production cost (CFA.F/ha)[(b)]	80,483	89,272	63,625	177,919
Return/day family labor (CFA.F)	1,562	2,938	4,319	3,377
Cost/kg of paddy (CFA.F/kg)	73	55	30	58
Break-even output price change (%)	-36	-52	-74	-50

[(a)] For each production system, the change is computed relative to the system's average yield reported in Table 6.1.
[(b)] Includes family labor valued at 500 CFA.F for a six-hour day of farm work.
Source: Survey Data.

Table 6.3 indicates that the "good" production year scenario implies an 8 to 47 percent yield increase, depending on the system, relative to the average values reported in Table 6.1. With these yield levels, when the opportunity cost of family labor is assumed to be 500 CFA.F/day and paddy and inputs prices remain unchanged, all four *bas-fond* rice production systems are profitable to farmers. Their returns to a day of family labor (ranging from 1,562 to 4,319 CFA.F/day) are higher than his/her opportunity cost (500 CFA.F/day) and the associated costs of production per kg of paddy (ranging from 30 to 73 CFA.F/day) are lower than the output farm-gate price (115 CFA.F/day). Under the yield increase assumptions stated in Table 6.3, for total revenues to cover the production costs and break even, farm-gate paddy price would have to decrease by 36 percent for farmers utilizing the *traditional* system, 52 percent for those in the *semi-macro-intensive* system, 74 percent for those in the *semi-micro-intensive* system, and 50 percent for those in the *intensive* system.

6.3. Comparative Financial Analysis of the Rice and Upland Crop Enterprises

So far in this chapter, the profitability of *bas-fond* rice production has been examined without regard to other crops in the farming system, and we have assumed that the next best alternative to a farmer is to seek wage employment. However, as mentioned earlier in Chapter One, interactions with other cropping enterprises are important, especially because *bas-fond* fields are cultivated by small-scale farmers who also cultivate upland fields. Therefore, the interrelationships which link upland and *bas-fond* activities are a particularly important dimension of the *bas-fond* agroecosystems. These interactions are both complementary and competitive. For example, rice may be grown as farmers' income generation in the *bas-fond*, whereas crops grown in the upland fields are used for household food consumption. Alternatively, any of the upland or *bas-fond* crops can be grown as a source of income.

For farmers, one of the major questions is how profitable is the *bas-fond* rice enterprise as an income-generator, relative to other sources of revenues? Indeed, farmers have a variety of revenues opportunities, including crop production and processing, livestock, handicrafts, hunting, and urban remittances. A study conducted in Mali-Sud by Giraudy and Niang (1994)[1] revealed that sources of revenues most cited by farmers are cotton (62% of PU surveyed) and cereals (48% of PU surveyed). Among the cereals, sorghum ranks first (22%), followed by millet (14%), maize (11%), rice (2%), and finger millet (1%).

While this study focuses on rice, this section looks at its profitability relative to cotton, maize and sorghum/millet, the main upland crops grown in the villages surveyed. The financial budgets for these upland crops are presented in Appendix 6.2. Those budgets are based on estimates reported by Giraudy and Niang (1994) and labor data collected in 1988 and 1989 by the farming systems research unit (ESPGRN) based in Sikasso. Giraudy and Niang (1994) estimated average budgets for the cotton, cereals and peanut enterprises for representative PUs using no animal traction, one set of animal traction equipment, and two or more sets of animal traction equipment[2]. Their cereals budget is based on average values from maize and sorghum/millet enterprises. Furthermore, their budgets did not include labor costs and were not standardized to a per hectare basis. This study uses the same estimates with four adjustments.

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[1] This study was conducted by the CMDT monitoring unit (*Suivi-Evaluation*). The unit conducted surveys in 12 Mali-Sud villages with a sample of 625 production units using a cost-route approach.

[2] Giraudy and Niang (1994) found that the financial performance of individual PUs depends in part on their level of mechanization (*i.e.*, animal traction). The main characteristics of the representative enterprises for these budgets are as follows. For PUs with no animal traction: 9 family members, 1 ha of cotton and 3.2 ha of maize (16%) and sorghum/millet (84%) cultivated. For PU with one set of animal traction equipment (i.e., a plow and a pair of oxen): 14 family members, 2.2 ha of cotton and 5.8 ha of maize (15%) and sorghum/millet (85%) cultivated. For PUs with three or more sets of animal traction equipment (i.e., plow, oxen, seeder, cart, multi-purpose plow, and equipment for chemical treatment application): 14 family members, 5.6 ha of cotton and 12.5 ha of maize (16%) and sorghum/millet (84%) cultivated.

First, outputs are valued using 1996 producer prices. Second, the budget item estimates for cereals are partitioned into their maize and sorghum/millet components based on the relative field size of each crop. In doing so, we assumed that farmers apply fertilizer and herbicide only on maize and not on sorghum/millet. Thus, the full costs of fertilizer and herbicide are attributed to the maize enterprise. Third, the resulting budget enterprise estimates, including cotton, were then converted to their per hectare values. Fourth, we added estimates of family labor data valued at the same base-run opportunity cost used earlier with rice (*i.e.*, 500 CFA.F/day), and the interest costs for fixed and operating capital (excluding family labor costs) based on a 12 percent rate.

The labor data obtained from the FSR program were collected on farms using animal traction. To determine the labor requirement for the non-mechanized farms (*i.e.*, manual), a conversion factor was estimated based on a study conducted in Bénin by Gouthon *et al.* (1996) by dividing average labor requirement from non-mechanized farms by that from mechanized farms. The conversion factor, which turned out to be 1.25, indicates that non-mechanized farms use about 25 percent more labor than the mechanized farms. To determine the labor requirement for the non-mechanized farms, the FSR data were adjusted by multiplying them by the estimated conversion factor. Furthermore, this study assumed the same labor requirement per hectare for rice farmers who own one and those who own three or more sets of animal traction equipment. Rather than reducing labor requirements per hectare, the difference in number of equipment owned translates into different farm sizes. Table 6.4 presents a comparative summary of the key budget components estimated for *bas-fond* rice and the upland crops.

Table 6.4: Comparative Financial Budgets for the *Bas-Fond* Rice, and Representative Maize, Sorghum, Cotton Enterprises in the *Bas-fond* Villages, Mali, Rainy Season 1995-96.

Production Systems	Budget Items (CFA.F/ha)					
	Gross Revenues[a]	Total variable Costs	Total fixed costs	Total costs	Net return to family labor	Net ret./day of family labor
Rice Production Systems[b]:						
Purely traditional	117,415	58,815	0	58,815	58,600	1,374
Macro-semi-Intensive	141,680	69,492	0	69,492	72,188	1,934
Micro-semi-Intensive	163,645	40,338	0	40,338	123,308	2,971
Intensive	272,090	147,407	0	147,407	124,683	2,194
Upland Crops:						
"Manual"						
Maize	87,150	1,272	0	1,272	85,878	1,128
Sorghum/millet	62,550	1,272	0	1,272	61,278	823
Cotton	160,580	62,222	0	62,222	98,358	485
"One implement"						
Maize	106,275	34,717	1,123	35,840	70,435	1,157
Sorghum/millet	73,350	3,136	6,359	9,495	63,855	1,072
Cotton	184,140	64,086	24,093	88,179	95,961	591
"> one implement"						
Maize	119,100	34,848	3,962	38,810	80,290	1,318
Sorghum/millet	86,310	4,663	24,343	29,006	57,304	962
Cotton	234,670	65,613	113,705	179,318	55,352	341

[a] Rice is valued at 115 CFA.F/kg, maize at 75 CFA.F/kg, sorghum/millet at 90 CFA.F/kg, and cotton at 115 CFA.F/kg.

[b] These systems are defined as follows: (1) the *purely traditional* system (no water control, "traditional" rice varieties, no chemical fertilizer and no herbicide); (2) the *macro-semi-intensive* system (water control, "traditional" varieties, no chemical fertilizer and no herbicide); (3) the *micro-semi-intensive* system (no water control, "traditional" varieties, no chemical fertilizer, but some herbicide); and (4) *intensive* system (water control, "improved" varieties, some chemical fertilizer and some herbicide).

Source: Adapted from Table 6.4 and Appendix 6.2.

Table 6.4 shows that the *bas-fond micro-semi-intensive* and *intensive* rice production systems, and the cotton enterprise give the highest gross revenues. However, compared to the rice enterprise, total costs are higher for the cotton enterprise using more than one animal traction implement. The total costs for the cotton enterprise using one animal traction implement is higher than all but the *bas-fond intensive* rice production system, while the same cost for the cotton enterprise using no animal traction is only higher than the *bas-fond intensive* and *macro-semi-intensive* rice production systems.

Overall, the three upland crops and the rice enterprise have positive net returns to family labor. In other words, when the opportunity cost of family labor is assumed to be equal to zero, these four crops are profitable to farmers. However, the estimated returns to a day of family labor show that all four *bas-fond* rice production systems yield higher returns to a day of family labor than the three upland crop enterprises, regardless of their level of mechanization, followed by maize and then sorghum/millet. The cotton enterprise yields the lowest return to a day of family labor among the four crops being compared.

Table 6.4 indicates that, when the opportunity cost of family labor is assumed to be 500 CFA.F/day, the return to a day of family labor from the rice, maize and sorghum/millet enterprises are higher than his/her opportunity cost, regardless of their level of mechanization. In contrast, the return per day of family labor from the cotton enterprise is higher than his/her opportunity only when the farmer uses one animal traction implement. However, it is important to recognize that the magnitude and relative profitability of each of these crops is highly dependent on the corresponding estimated family labor requirement. For the rice enterprises, family labor data were collected during the study's field work. In contrast, for the upland crops, while revenue and costs components are data reported by the cotton development agency (CMDT), the corresponding family labor data are data collected in 1988 and 1989 by the farming system research program based in Sikasso.

Furthermore, one critical reason why the cotton enterprise looks unprofitable is because almost all fixed costs of the upland crops are attributed to cotton production. This allocation pattern is based on the consideration that the cotton enterprise drives household farm enterprises. As a result, because the other household crops free-ride on cotton for farm fixed investments, they tend to be very profitable, compared to cotton.

Clearly, Table 6.4 indicates *bas-fond* rice production represents a significant alternative source of income to farmers. Granted there are some constraints to its extensification and greater intensification, the associated financial profitability and utility value suggest that if given greater attention, it could be a major contribution to achieving household food security. However, given the superior profitability of *bas-fond* rice production relative to cotton and the role and influence of the cotton development agency in the same area in which rice is produced, one critical question for future research is to determine the implications of greater intensification of the rice *bas-fond* rice production on the cotton enterprise. In addition, a key question from the point of view of the economy as a whole is, how significant could be *bas-fond* rice production compared to rice from the *Office du Niger*. This last question is the focus of the next chapter.

6.5. Summary

The purposes of this chapter were to estimate and analyze the financial returns associated with the four *bas-fond* rice production systems identified in Chapter Five, and to compare the financial profitability of the *bas-fond* rice enterprise to major alternative upland crops (*i.e.*, cotton, maize and sorghum) competing with rice for the production units' labor and capital. Using standard budgeting techniques, when family labor is excluded, the average cost of production is 58,815 CFA.F/ha for the *traditional* system, 69,492 CFA.F/ha for the *macro-semi-intensive* system, 40,338 CFA.F/ha for the *micro-semi-intensive* system, and 147,407 CFA.F/ha for the *intensive* system. Hired labor represents the highest share of production costs in all four systems (33-82%).

When family labor in included as a cost component and valued at 500 CFA.F/day, the average cost of production under each system increases by 19-51 percent, ranging from 80,148 CFA.F/ha for the *traditional* system, 88,158 CFA.F/ha for the *macro-semi-intensive* system, 61,088 CFA.F/ha for the *micro-semi-intensive* system, to 175,824 CFA.F/ha for the *intensive* system. Structurally, hired and family labor costs represent the main cost component (44-86%).

In terms of the systems' profitability, the study found that for all systems, the returns per day of family labor in the rice field (ranging from 1,374 to 2,971 CFA.F/day) is higher than his/her opportunity cost (500 CFA.F/day). In addition, for all systems the cost of producing a kilogram of paddy (ranging from 43 to 78 CFA.F/kg), is lower than the output farm-gate producer price (115 CFA.F). These results indicate that, under the set of assumptions made in this study, these systems are financially profitable. However, among the four systems studied, the most profitable is the *micro-semi-intensive* system. The study caution that these results are based on small samples (less than 20). However, even within a given *bas-fond* rice production system, there is some heterogeneity of the profitability of the rice enterprise.

The large share of family and hired labor costs in each of these systems' total production cost suggests that one significant way to increase their profitability is to reduce the labor content of the technologies farmers used without increasing total costs. Thus, in addition to increasing yields, complementary research is needed to assess the potential of reducing labor input through the substitution of adapted and economically justifiable low-cost labor-saving technologies such as herbicide, mechanical threshing, sickle harvesting, and better water control systems. Efforts to increase yield should focus on improving land preparation, determining an optimal planting period, and better plot-level water control, as well as developing new rice varieties that are adapted to the *bas-fond* environment and have a high yield potential.

The large share of family labor cost (relative to other production inputs) in each of these systems' total production cost suggests that the opportunity cost of labor is very much at the heart of the systems' profitability. A better understanding of seasonal labor market parameters and patterns would make it possible to better assess farm enterprise profitability and understand farmers' investment decisions. Furthermore, such an understanding would provide an opportunity to more explicitly design technologies to capitalize on periods when the opportunity costs are relative low and enhanced the systems' financial profitability and technology adoption.

With regards to cotton, maize, and sorghum, the study found that, when the opportunity cost of family labor is assumed to be equal to 500 CFA.F/day, all four *bas-fond* rice production systems yield higher returns to a day of family labor than the three upland crop enterprises, followed by maize and then sorghum/millet. The cotton enterprise yields the lowest return to a day of family labor. Furthermore, the return to a day of family labor from the rice, maize and sorghum/millet enterprises is higher than his/her opportunity cost, regardless of the level of mechanization. However, the return per day of family labor from the cotton enterprise is only higher than his/her opportunity cost when the farmer uses one implement. However, this result is highly dependent on the estimated family labor requirement. Furthermore, one critical reason why the cotton enterprise looks unprofitable is because almost all fixed costs of the upland crops are attributed to cotton production.

These results show that, compared to the upland crops, *bas-fond* rice production represents a significant source of income to farmers. Granted there are some constraints to its extensification and greater intensification, the associated financial profitability and utility value suggest that if given greater attention, it could make an even greater contribution to household food security. However, this result does not imply that *bas-fond* rice production represents a more efficient way for Mali to use domestic resources than to produce upland crops. Addressing this question would require estimation of these crop enterprises' economic budgets, which is beyond the scope of this research.

CHAPTER SEVEN
COMPARATIVE ECONOMIC ANALYSIS OF BAS-FOND AND SELECTED OFFICE DU NIGER RICE PRODUCTION SYSTEMS

7.1. Introduction

In Chapter Six, the main objective was to estimate the profitability of each of the identified rice production systems from the point of view of the farmers (*i.e.*, financial analysis). However, the ranking of farmers profitabilities can sharply diverge from the social ranking due to policy-induced distortions and/or market failures. In this chapter, the purpose is to (1) estimate and analyze the profitability of these *bas-fond* rice production systems from the point of view of the society as a whole (*i.e.*, economic analysis), and evaluate their competitive position at different points of sale, relative to each other and to rice produced in selected intensive production systems with complete water control managed by the *Office du Niger*, and (2) assess the effect of the policy environment (market liberalization and devaluation) on the profitability of *bas-fond* rice production and its incentive structure. This economic analysis helps determine whether or not the contribution of *bas-fond* rice production to the Mali's overall economy is great enough to justify using scarce government resources that are required to further develop these systems.

The first objective of this chapter is achieved in two steps. First, economic budgets for the four *bas-fond* rice production systems identified are estimated by using shadow prices to adjust the financial budget items reported in Chapter Six to reflect their true social values. These budgets are estimated both for subsistence farmers and for market-oriented farmers who sell their paddy either in Bamako, Bougouni, or Sikasso. In this process, the costs of CMDT's investments to control water, which were excluded in the financial analysis, are included. Second, another set of economic budgets are estimated for representative commercial rice production systems in the rehabilitated (Niono) and non-rehabilitated (Macina) perimeters of the *Office du Niger*, based on secondary data.

To achieve the second objective, the financial budget presented in Chapter Six and the economic values estimated to achieve the first objective of this chapter are used to construct policy analysis matrices and compute standard policy analysis ratios such as the DRC and nominal and effective protection coefficients. To provide background for this analysis, the chapter starts with a discussion of the concept of competitiveness and associated performance indicators and determinants.

7.2. The Concept and Measurement of Competitiveness

Before proceeding with the discussion of the concept of competitiveness, it is useful to mention that in this document, the paired expressions "competitiveness" and "comparative advantage", "social value" and "economic value", and "social price" and "economic price" are used interchangeably.

7.2.1. A Definition and Indicators of Competitiveness

Competitiveness for a specific product, at a specific time, in a specific location.

The term competitiveness has been interpreted differently by various authors (Garth *et al.*, 1992). In the literature, it has been used to describe the performance of firms, sectors or industries, and countries. Garth *et al.* (1992) argue that, at the sector level, competitiveness is "the ability of a group of like firms to compete with another group of firms in another sector, or in the same sector in another country". A more pragmatic definition views competitiveness as "... the ability to profitably gain and maintain market share in the domestic and/or export market" (Agriculture Canada, 1990). In addition to recognizing that competitiveness is a dynamic process, the second definition identifies two performance indicators (profits and market shares) and the geographical space of the operation. However, these performance indicators do not necessarily allow unambiguous comparisons because one sector (or firm) may have a larger market share while another may earn higher profits.

Several variations of these measures of competitiveness are found in the literature including factor productivity, costs of production, value added relative to sale, employment, wages, DRC ratio[1], and trade ratios such as export orientation and import penetration[2]. However, factor productivity and costs of production are determinants

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[1] The DRC (domestic resource cost) ratio shows the cost of domestic inputs (including labor, land, and annualized capital values) used in the production of a commodity, compared to the foreign exchange cost of importing that commodity (case of imported good) or the foreign exchange value of exports (case of exported good).

[2] For a given country, the term import penetration refers to the import share of domestic consumption, in contrast to the export share of domestic shipments, which is known as export orientation.

rather than measures of competitiveness, while the DRC ratio and trade ratios are only meaningful if there are no barriers to free trade.

In this study, competitiveness is defined as the ability of a given production system to produce rice of a specific quality, at a given point in time, in a specific market, at a lower unit cost than another rice production system. This definition recognizes that competitiveness is a relative term. For example, a given rice production system can be more competitive than another in the regional market at a specific time in the year, for a given rice quality, while at the same time it is less competitive than the same production system in a local market, given consumer preferences and transportation costs. The immediate implication of this definition is that evaluating the competitiveness of different rice production systems requires that these systems be compared at the farm and at different market levels (or points of sales), for the same rice quality, and during the same time period. In this study, Sikasso, Bougouni, and Bamako are used as market points of sale. *Bas-fond* rice quality is categorized as *45 percent broken rice*, which is comparable in quality to *Thai A1 super*.

Knowledge of the competitive position of alternative production systems is important because the associated potential welfare gains can be used to foster economic growth and improve food security. Over the long-run, additional welfare gains can be assured if research resources are used to strengthen competitive production systems. Indeed, recent developments indicate that agricultural policy makers pay increased attention to competitiveness. Since the 1980s, many countries, including Mali, have implemented policies reforms designed to reduce direct state participation in agriculture, increase productivity, ensure the cost-effectiveness of agricultural research expenditures, liberalize commodity trade, and free market prices to play a greater role in directing economic activities along efficiency lines.

Measures of Competitiveness: Net Social Profit and Domestic Resource Cost Ratio

To assess the competitiveness of alternative production systems, simply comparing production costs is often inconclusive because these costs are frequently influenced by government policies and/or market failures. As a result, a crop can be profitable for farmers to produce (*e.g.*, because of price subsidies), even though its production may not represent an efficient use of resources from the point of view of the country. Conversely, a crop can be unprofitable for farmers to produce (*e.g.*, because of price taxation), even though its production represents an efficient use of the country's resources.

The DRC framework of analysis offers what Michael Morris (1990) calls a way to "see through market distortions" in order to measure competitiveness empirically by generating quantitative indicators of the efficiency of using domestic resources to produce a given crop. In this framework, the measure of efficiency is social profit, defined as the net contribution per hectare of cultivated land of each production system to the national income. At the same time, this framework allows the distortionary effects of policies to be measured.

Measures of relative efficiency of alternatives production systems generated by the DRC framework are the net social profit (NSP) and the domestic resource cost ratio

(DRCR). The NSP indicates the contribution of each rice production system to national income, measured in terms of social net returns to family labor management[1]. The NSP rankings of rice production systems provide a preliminary indication of the systems' competitiveness. Because social prices reflect the true economic scarcity value of inputs and output, the rice production systems with the largest positive NSP represent the most profitable production alternative in terms of contributing to national income. Furthermore, because in estimating the NSP, social prices are set to reflect values in alternative uses, the NSPs automatically indicate relative efficiency in production and thus provide an empirical measure of competitiveness (Morris, 1990). However, the NSP provides no explicit information about the use of tradables (and hence of foreign exchange) in production.

In contrast, the DRCR indicates the efficiency of each alternative in using domestic resources to earn or save one unit of foreign exchange. Indeed, the DRCR is a restatement of the NSR, expressed not in terms of domestic currency, but rather as a unitless ratio. Although it provides an explicit indication of the efficiency with which each production alternative uses domestic resources to generate or save foreign exchange, both indicators lead to the same conclusions.

The DRC ratio is computed for each rice production system as the ratio of domestic factor cost to value added measured in social prices, where value added is the

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[1] This implies that the opportunity costs of family labor and land are included as cost components in the estimated NSP. Many DRC studies do not include the opportunity cost of land and assume zero opportunity cost of family labor management (Morris, 1990; Barry, 1994). In such cases, the resulting NSPs indicate the contribution of each rice production system to national income, measured in terms of social net returns to land and labor.

value of total production less the cost of tradable inputs[1]. For any of the production systems, a DRC ratio between zero and one indicates that the value of domestic resources used in this system is less than the value of foreign exchange saved (import substitute). Consequently, the country has a comparative advantage in producing rice with that production system. For an efficiency-minded society, the higher the social profitability, the better. Minimizing the DRC ratio is equivalent to maximizing social profit. Thus, one can compare the different production systems based on their DRC ratios.

In contrast, a DRC ratio greater than one indicates that the value of domestic resources used in the production system exceeds the value of foreign exchange earned or saved. As a result, the country has no comparative advantage in producing rice under that specific system. Finally, a DRC ratio of less than zero indicates a negative value added domestically. As a result, foreign exchange is being wasted because more foreign exchange is being used in producing the commodity locally than would be spent by importing it.

7.2.2. Policy Determinants of Competitiveness

A production system's ability to produce rice of a specific quality, at a given point in time, in a specific market, at a lower unit cost than another rice production system is determined by the associated potential technological efficiency and the incentives farmers have to be efficient. In other words, there are two sides to the

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[1] Tradable inputs are inputs that are traded internationally (traded tradables) or potentially could be traded (non-traded tradables). Tradable inputs are defined in contrast to domestic factors (sometimes refer to as primary factors in standard DRC analyses), which are factors that are not normally traded internationally and include chiefly land and labor.

determinants of competitiveness: a technological side and a policy side. While recognizing the importance of the technological side of competitiveness, this chapter focuses on the policy determinants of competitiveness.

Subsequent analyses in this chapter are based on the assertion that government policies and institutional arrangements that provide incentives to farmers and induce them to produce more rice influence the relative competitiveness of the rice production systems. To examine the extent to which the agricultural policy environment in Mali has affected *bas-fond* rice competitiveness, this analysis compares the difference between production systems in terms of the static overall effect of (distorting or efficient) policy initiatives, the incentive effects associated with the systems, and the extent of policy transfers.

The static overall effect of policy initiatives is examined by comparing financial and social profitability. A positive value for the difference between financial and social net profitability (NNP-NSP) indicates that, on the whole, the policy increases financial profitability while a negative value reveals the opposite effect.

To compare the incentive effects associated with the four rice production systems, four ratios are computed: the nominal protection coefficient (NPC), the effective protection coefficient (EPC), the profitability coefficient (PC), and the subsidy ratio to producers (SRP). The NPC is the ratio of the financial price of the output (NPCO), or a tradable input (NPCI), or a domestic factor (NPCF) to its corresponding social price. This ratio indicates the extent of the policy effect reflected by the divergence between the financial and social prices. The EPC is the ratio of value added estimated in financial terms (*i.e.*, under market prices) to value added measured in economic terms (*i.e.*, under world prices). It measures the degree of policy transfer due to policies affecting product and input markets (output and tradables).

The profitability coefficient (PC), an extension of the EPC, is the ratio of financial to social profits and serves as a proxy for net policy transfers (*i.e.*, incentive effects of all policies). The subsidy ratio to producers (SRP) measures the net policy transfer, as a proportion of total social value. It shows the proportion of revenues in world prices that would be required if a single subsidy or tax were substituted for the entire set of commodity and macroeconomic policies, and thereby allows one to estimate the extent to which all policy subsidizes a production system. The SRP can be computed for output (SRPO), input (SRPI), and factors (SRPF).

7.3. Social Profitability of the Selected Rice Production Systems

Having discussed the concept of competitiveness, we now turn our attention to the economic budgets for subsistence and commercial *bas-fond* and *Office du Niger* rice production systems. These economic budgets include the depreciation costs of water control infrastructure and farm equipment, as well as the economic value of land, which were ignored in the financial analysis (Chapter Six). Normally, the value of a water control investment depends on the age of the investment. For new investments, the total investment cost is used. For old investments, only the cost of rehabilitation is used.

This section is structured in three parts. The first part presents the economic budgets for the four *bas-fond* rice production systems, while the second part focuses on selected rice production systems managed by *Office du Niger*. These first two parts include a detailed discussion of how the shadow prices of paddy, fertilizer, labor, and land were estimated. These prices are then used to determine the social profitability of the alternative rice production systems. The third part analyzes the NSP of the *bas-fond* compared to *Office du Niger* rice production.

7.3.1. Bas-Fond Rice Production Systems

7.3.1.1. Estimation of Shadow Prices

The financial budgets estimated in Chapter Six are based on prices farmers actually pay. However, Mali's domestic market prices for paddy and fertilizer do not reflect the scarcity value (*i.e.*, social opportunity cost) of these inputs because the domestic market environment is distorted, in part, by direct government intervention. For non-tradables such as labor, their social value is found by estimating their social opportunity cost (*i.e.*, the net income foregone because the factor is not employed in its best alternative use).

In contrast, for tradable goods such as fertilizers (*i.e.*, urea, DAP and NPK) or paddy, the appropriate social values are based on world prices (expressed in domestic currency) because these prices represent the society's choice to permit consumers and producers to either import or produce those goods domestically. As a result, the social value of the imported fertilizer and herbicide is equal to the value of the foreign exchange required to import them. Similarly, the social value of domestically produced paddy is equal to the foreign exchange saved by not importing it. In both cases (*i.e.*, fertilizers and paddy), the actual computation of shadow prices depends on the point of sale under consideration, and on whether farmers consume or sell their harvest.

For simplicity, in this economic analysis, only the market prices for paddy and fertilizers, as well as the assumed rate of return to capital[1], are adjusted. The market prices for paddy and fertilizers are adjusted based on world prices to reflect the true costs to the economy as a whole. Because of global output fluctuations, distorting policies abroad, and the long-term perspective of the analyses, the appropriate world price is not necessarily the prevailing price. Rather, the world price is the expected long-run value obtained from models of the world market estimated by international institutions such as the World Bank. In principle, such a price is the current world price adjusted for expected future changes in the rice demand and supply balance.

However, unless a given year was extremely unusual with extraordinary demand and supply shifts that created abnormally high or low prices, long-run demand and supply shifts in the world cereals market usually result in only small changes in commodity prices because the world commodity market is large. As a result, in a given year, the observed world market price of cereals will generally be close or equal to the long-run price. But, the world rice market is thin and more volatile than other cereal markets.

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[1] For economic analysis, the cost of capital is estimated using the social rate of return on investment capital. This is computed by adjusting the observed (nominal) interest rate used earlier to correct for inflation and divergences such as tax on capital. In this study, the nominal interest rate (12%) is adjusted for inflation, assumed to be three percent in Mali, using the formula:

$$\frac{1 + \textit{nominal interest rate}}{1 + \textit{inflation rate}} - 1 = 8.7\ \%$$

Although world prices are influenced by subsidies and trade policies of foreign countries, from an efficiency perspective, economists agree that their price effect can be disregarded, unless future price changes are expected to alter world prices (Monke and Pearson, 1995). Furthermore, because the timing, magnitude, and price effects of such changes are usually impossible to predict, most estimates of expected future prices assume constant agricultural policies (Monke and Pearson, 1995).

For the reasons discussed above, this study uses current world prices. However, because world prices are quoted in foreign currency, an exchange rate is used to convert world prices into domestic equivalents. This is achieved using the equilibrium or shadow exchange rate[2] (also called social exchange rate) which reflects the shadow price or opportunity cost of foreign exchange.

In Mali, like in all CFA.F countries[3], the equilibrium exchange rate exceeded the official exchange rate since the 1980s. According to Salinger and Stryker (1991) unsustainable current account deficits and trade policy distortions created an excess demand for foreign exchange, which led to extra borrowing and excessive drawing down of foreign exchange reserves. The corresponding overvalued exchange rate made imports, such as agricultural inputs, cheaper (*i.e.*, less domestic currency paid out for imports) and the price of exports and non-tradables domestic items (particularly labor),

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[2] The equilibrium exchange rate is the official exchange rate times one plus the foreign exchange premium.

[3] CFA.F countries have maintained a fixed rate of exchange with the French currency (FF) since 1948 (at initially a 50:1 rate and now 100:1 rate since January 1994). These countries are former French colonies in West and Central Africa. The West African group (Sénégal, Guinée Bisau, Mali, Niger, Burkina Fasso, Côte d'Ivoire, Togo, and Benin) belongs to the regional monetary group UEMOA and their trade policy is implemented by the BCEAO. The Central African group (Chad, Cameroon, Central Africa Republic, Gabon, and Congo) belongs to the regional monetary group BEAC.

more expensive (*i.e.*, less domestic currency earned by exports). In other words, Malians have paid a premium on non-traded goods over what they paid for traded goods. Thus, because the CFA.F was overvalued, it is necessary to use an adjusted exchange rate to convert the price of goods traded in foreign currency into a domestic equivalent. Failure to correct the distorted exchange rate would bias comparative advantage rankings in favor of the import-intensive rice production systems.

However, because the CFA.F was devalued in January 1994, this study assumes that the official exchange rate now reflects the social value of the currency. Thus, no further adjustment of the 1996 official exchange rate (*i.e.*, 530 CFA.F/$US) was made. Had the study been conducted prior to devaluation, a foreign exchange premium of 48.9 percent (Salinger and Stryker, 1991) would have been used to adjust the official exchange rate to its equilibrium value.

Because farm-level economic prices vary depending on the point of sale, the *bas-fond* rice production systems are first compared under two scenarios. The first scenario is based on the assumption that farmers consume their paddy harvest. The second scenario assumes that farmers sell their paddy harvest in three central output markets: Sikasso, Bougouni, and Bamako. Given that *bas-fonds* are geographically scattered around each point of sale at variable distances, the estimated shadow prices for paddy and fertilizer are also estimated by varying the distance between the point of sale and the farm in order to determine the distance beyond which each system's competitiveness changes.

7.3.1.1.1. Farm-Level Shadow Price of Paddy

Appendix 7.1 outlines cost items used to estimate the farm-level economic price of paddy produced in the *bas-fond* for a commercial purpose. This price represents the social value of paddy at the farm necessary in order to be competitive with imports at the point of sale. The cost items are estimated using the price for imported milled rice offloaded at Dakar, transported by train to Kidira (*i.e.*, Sénégal-Mali border) and then to Bamako, and transported on road from Bamako to the point of sale and then to village. Thus, social paddy prices were determined by first estimating the social price of milled rice at the point of sale, and then at the farm. Because the study assumes that the milling of paddy takes place in the village, the social prices of milled rice are converted into paddy price equivalents at the village-level. In addition, the study assumes that rice is traded at wholesale first in Bamako, and then at the point of sale. Furthermore, in the village, rice is traded first at wholesale, and then at retail. The estimated marketing margins (*i.e.*, 5% for wholesale and 15% for retail) are based on observed price differences using SIM data.

To determine the shadow price of milled rice at the point of sale, the FOB price of milled rice on the world market, plus freight and insurance costs, was converted into domestic currency (*i.e.*, CFA.F) using the real exchange rate. This CFA.F price was adjusted by adding port charges in Dakar, transportation cost[4] in Sénégal (*i.e.*, Dakar-Kidira), custom services and charges at the border, and domestic transportation costs

[4] For simplicity, for all transportation costs, indirect taxes such as subsidies on railroad or tax on gasoline are not included in these estimates.

between Kidira and Bamako[5], as well as a five percent wholesale marketing margin in Bamako. Then, the wholesale economic price of milled rice at Bamako was adjusted by adding domestic transportation costs between Bamako and the point of sale, and another five percent wholesale marketing margin at the point of sale.

To determine the social farm-gate paddy price, the wholesale price of milled rice at each point of sale was adjusted by (1) subtracting the transportation cost from this point to a hypothetical village[6], (2) subtracting a five percent wholesale and a 15 percent retail marketing margin, (3) converting the village-level retail price of milled rice into its paddy equivalent, based on a 65 percent milling recovery factor, and then (4) subtracting the milling cost of paddy (12 CFA.F/kg of paddy). Thus, for commercial farms, the social farm-gate paddy price is the social value of a kg of paddy at the farm necessary in order to sell it as milled rice at the point of sale at the same price as the imported milled rice of the same quality.

The domestic transportation costs are estimated by adjusting rates prevailing before the 1994 devaluation (*i.e.*, 18 CFA.F/mt.km on urban roads and 23 CFA.F/mt.km on rural roads) to account for a 32 percent transport cost increase on the road and 65 percent on the train that occurred after devaluation. In addition, at the village level, the

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[5] *Ad valorem* import taxes and duties totaling 46 percent of the border price, as well as a four percent license stamp and taxes such as subsidies on railroad or tax on gasoline which affect transportation costs are not included because they represent transfer payments.

[6] Usually, an import parity price of a product is estimated for a specific production site (*e.g.*, a project site), relative to a particular point of sale. When there is more than one production site, as is the case with the sampled villages, the product will have a different economic price at each of these sites, due to differences in distance to the market point. For simplicity, a hypothetical village situated at a village-market distance equivalent to the average of the distances from the point of comparison to each of the sampled villages is used in this study. Graphs are presented showing the economic price over space.

price of milled rice is converted into the price of paddy using a 65 percent milling recovery rate and a milling cost of 12,000 CFA.F/mt of paddy. The results obtained from this process outlined above are summarized in Table 7.1:

Table 7.1: Farm-Level Financial and Economic Price (CFA.F/kg) of Paddy, by Output Market, Mali, 1996.

Output Market	Price	
	Financial[a]	Economic[b]
Bamako	115	104
Bougouni	115	115
Sikasso	115	118

[a] Average market price throughout the sampled *bas-fond* area.
[b] Estimated for hypothetical *bas-fond* villages assumed to be 307, 144 and 144 km away from Bamako, Bougouni, and Sikasso, respectively. They represent the social value of paddy at the farm necessary in order to be competitive with imports at these markets.
Source: Appendix 7.1 for economic prices.

Table 7.1 shows that, if farmers sell their *bas-fond* milled rice in Bamako at its social value, the corresponding social paddy price at the farm is 104 CFA.F/kg. Similarly, the farm-level social price of paddy sold as milled rice in Bougouni is 115 CFA.F/kg, and 118 CFA.F/kg when Sikasso is the output market. These prices, which represent the foreign exchange Mali saves for each kg of paddy produced in these sites, were estimated for a hypothetical *bas-fond* village situated 307, 144, and 144 km away from Bamako, Bougouni, and Sikasso, respectively[7]. Figure 7.1 shows that this price

[7] These distances are the average of the distances from each sampled village the point of sale.

decreases over space as the distance between the production site and the output market increases. Later in the chapter, the shadow prices of paddy are discussed in the context of policies' influence on production incentives. Normally, these price lines should be straight lines. The nonlinearity observed in these figures are due to rounding errors.

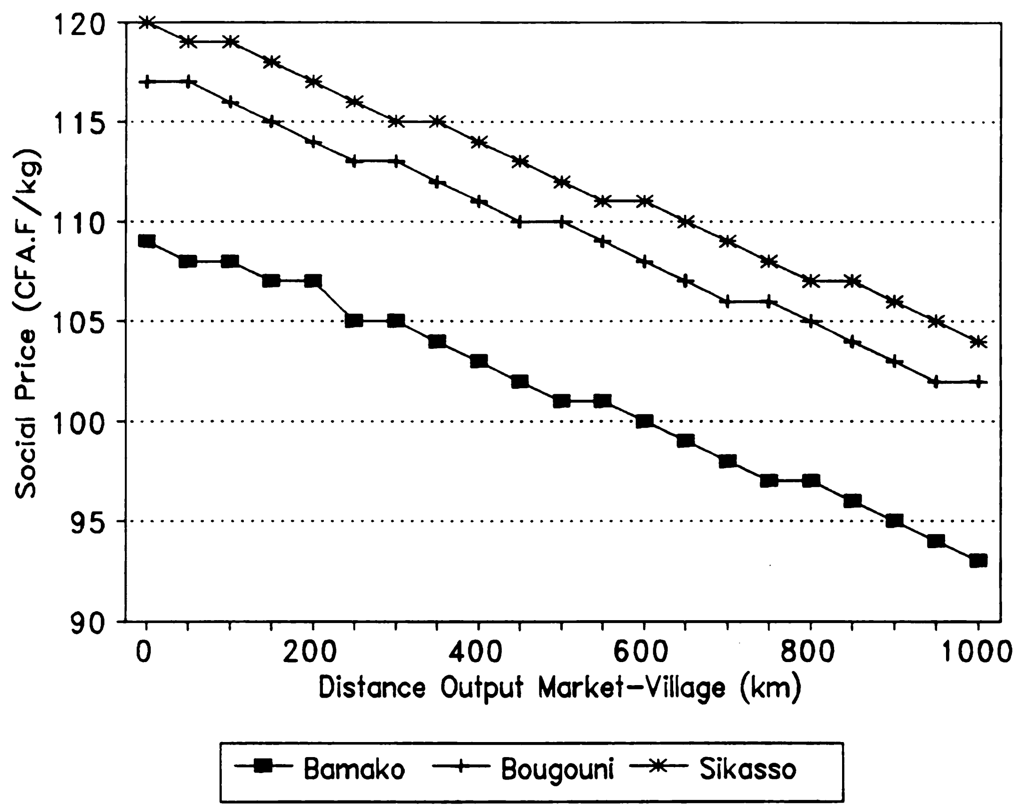

Figure 7.1: Farm-Level Social Price of Paddy over Space for Commercial *Bas-Fond* Rice Farming If they Are to Be Competitive with Imports in each of the Three Central Output Markets, Mali, 1996.

7.3.1.1.2. Farm-Level Social Cost of Seeds

Unlike the financial analysis, which used the market price to value seeds, in the economic analysis, seeds are valued by the social price of paddy. Thus, this price is determined using the same principles and procedure outlined for paddy. However, because seeds are used in the farms, they are valued at the social price of paddy consumed in the farm. This price is equivalent to the farm-level undistorted price of imported rice (expressed in paddy equivalent). As a result, to determine the social price of paddy consumed at the farm (*i.e.*, the farm-level undistorted price of imported rice expressed in paddy equivalent), all cost items taken into account to determine the social price of rice from the border to the village are added up along the import route "border-Bamako-village".

In the hypothetical village under consideration, the social price of paddy used at the farm as seeds is different from its social price at the same farm necessary in order to be competitive in Bamako. Earlier, it was outlined that to determine the farm-level social price of rice (expressed in paddy equivalent) at the same farm necessary in order to be competitive with imports in Bamako, the costs items from the border to the central market point of comparison (Bamako) are added up along the route selected, and the resulting shadow price at the point of sale is further adjusted by subtracting the cost identified between this market point and the farm. Thus, when the distance between the market point and the farm is zero (*i.e.*, if the farm is in Bamako), the social price of paddy used at the farm as seeds and its social price at the same farm necessary in order to be competitive with imports in Bamako are identical.

The social cost of seeds is estimated to be 201 CFA.F/kg (Appendix 7.2). Figure 7.2 shows that this price increases over space as the distance between the production site and Bamako increases.

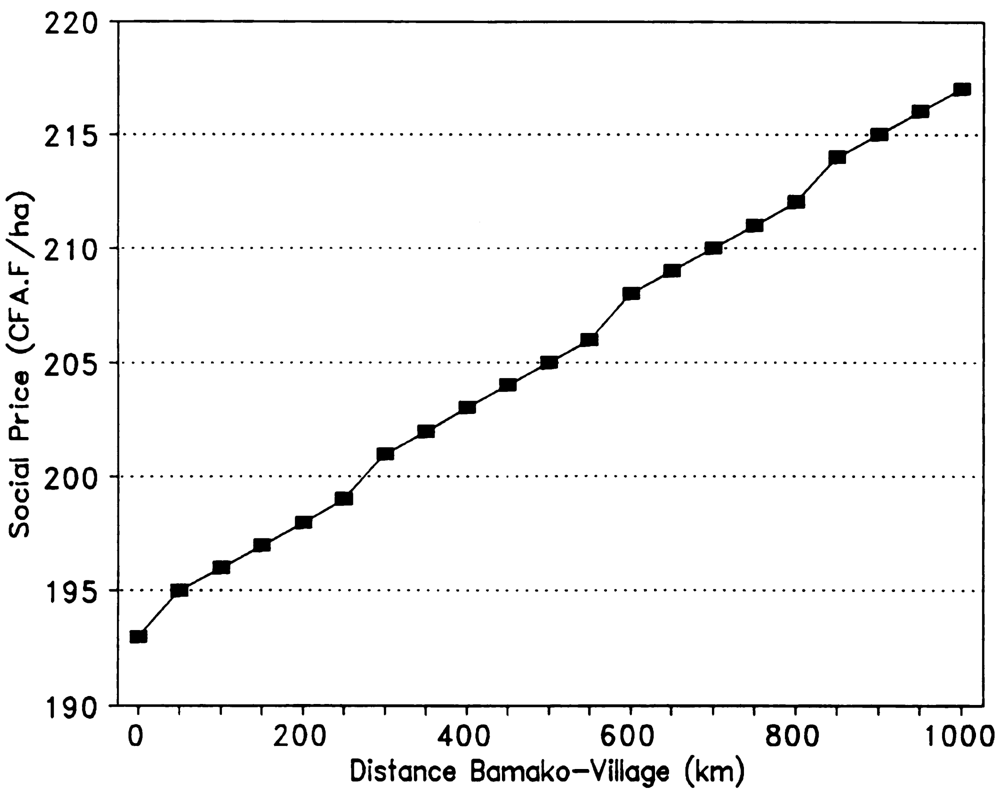

Figure 7.2: Farm-Level Social Price of Seed over Space in *Bas-Fond* Rice Farming, Mali, 1996.

7.3.1.1.3. Farm-Level Shadow Price of Fertilizers

Rice farmers used three types of fertilizers: urea, diammonium phosphate (DAP), and a compound fertilizer (NPK). Malian traders import the bulk of NPK and DAP from the Sénégal's *Industrie Chimique du Sénégal* (ICS) or from *Hydrochem-CI* in Côte d'Ivoire. In contrast, they import urea from outside the continent. While the bulk of Mali's imported fertilizer is transported from Dakar to Bamako by train, or from Abidjan to Ségou by truck, a small proportion comes from Nigeria and Niger.

The farm-level shadow price of fertilizers is estimated using the same principles and procedure outlined for paddy. However, because fertilizers are imported from abroad, they are valued by their corresponding undistorted farm-level price of imported fertilizer. To determine this price, all costs from the border to the village are added up along the import route selected. Appendix 7.3 shows that the main cost items are international and domestic transportation costs, transit costs, handling, and insurance costs. *Ad valorem* import taxes and duties, which are limited to an 11 percent *taxe conjoncturelle* and a four percent license stamp, were not included because they are transfer payments. In addition, these import price estimates include a five percent wholesale marketing margin between the border and Bamako, Bamako and the output market, and the point of sale and the village. A 15 percent retail marketing margin is included at the village.

Transportation costs used in this study are estimated using data reported by Salinger and Stryker (1991). While prior to the 1994 devaluation, traders preferred the train route because of it had a lower unit cost (20 CFA.F/mt.km compared to 25 CFA.F/mt.km on the road), since devaluation, traders prefer the road route primarily due to a smaller increase in its unit cost (32% compared to 62.5% on the train), a shorter distance[8], train delays, and the additional cost of 500 CFA.F/mt charged for offloading the train and loading the trucks. However, since data required to estimate the cost of using the road route were not available, the cost of shipping by train from Dakar to Bamako is used to estimate the farm-level fertilizer import price in 1996.

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[8] The Abidjan-Ségou road distance is 1,156 km, compared to 1,290 km on the train between Dakar and Bamako, and 240 km on the road between Bamako and Ségou.

Domestic transportation costs are estimated based on unit costs of 33 CFA.F/mt.km on tarred roads and 66 CFA.F/mt.km on rural roads. For simplicity, storage costs (506 CFA.F/mt/month before devaluation and 460 CFA.F/mt/month after devaluation), and overtime transit costs (12,500 CFA.F/truck) are ignored. Table 7.2 summarizes the estimated social price for these fertilizers in 1996. Later in the chapter, these estimated shadow prices of fertilizers are discussed in assessing the influence of government policies on production incentives.

Table 7.2: Farm-Level Financial and Economic Prices (CFA.F/kg) of Urea, DAP, and NPK Cereal Fertilizer Used by *Bas-Fond* Farmers on Rice, Mali, 1996.

Fertilizer	Price	
	Financial[(a)]	Economic[(b)]
Urea	175.0	232
DAP	243.7	260
NPK for Cereals	196.0	242

[(a)] Average price throughout the sampled *bas-fond* area.
[(b)] Estimated for a hypothetical village assumed to be 307 km away from Bamako.
Source: Appendix 7.3 for economic prices.

As for paddy, the prices reported in Table 7.2 are estimates for a hypothetical village situated 307 km away from Bamako. Figure 7.3 shows that these prices increase over space as the distance between the production site and Bamako increases.

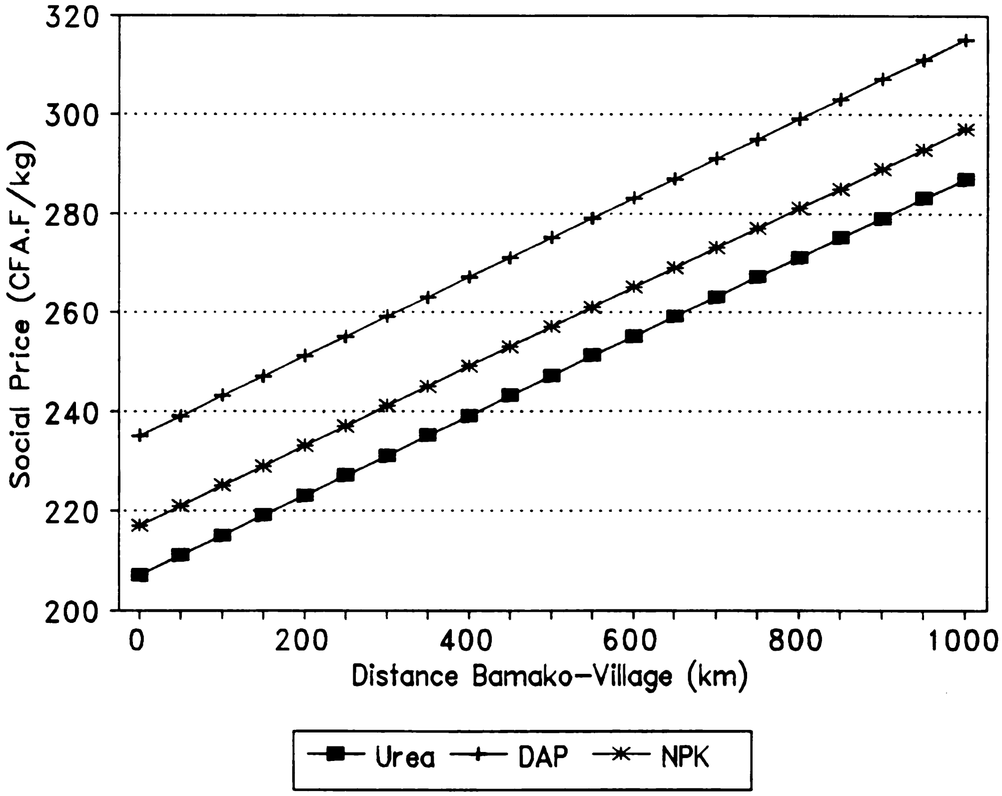

Figure 7.3: Farm-Level Social Prices of Urea, DAP, and NPK Cereal Fertilizer (15-15-15) over Space in *Bas-Fond* Rice Farming, Mali, 1996.

7.3.1.1.4. The Social Cost of Hired Labor

Typically, family labor is valued at its opportunity cost, defined as the wage foregone by the laborer by engaging in the rice activity instead of in his/her next best alternative. In a perfectly competitive labor market, this wage reflects the marginal value product of labor. While the labor market in rural *bas-fond* villages is far from being perfectly competitive, one could assume that because farmers are willing to pay the prevailing wage rate, additional labor increases output value by at least as much as its costs, and this rate reflects his/her reservation wage or opportunity cost.

Given that agricultural wages are fairly stable, these assumptions are reasonable. If a laborer could produce significantly more than the amount he/she costs, some farmers in the village would have bid up the wage rate and labor would have been attracted to the new offer. While the absence of such labor reallocations does not necessarily imply a perfect labor market, the wage rate paid to individually hired labor is assumed to be equal to the shadow wage rate, given the lack of information on off-farm earnings opportunities, and considering that available labor is largely unskilled. Thus, the financial family labor cost of 500 CFA.F/day was not adjusted, as it is assumed that it reflects the social cost of labor.

7.3.1.1.5. The Opportunity Cost of Land

In the financial analysis, land is valued at the price farmers actually paid for the land they used to produce rice. Theoretically, this price is either the purchase price or its rental cost. But, because the *bas-fond* land farmers used to produce rice is seldom sold or rented, in the financial analysis, the study imputed no cost to land. In the economic analysis, however, land is typically valued at its opportunity cost (*i.e.*, economic cost), which is estimated as the residual claimant on the profit from farming. This residual value represents the return to land after the farmer has paid for all resources used in production (valued in social terms), including family labor and management, operating capital, and amortization. In the *bas-fond*, the economic cost of land was also assumed to be zero, because in these villages land is seldom sold, and rice is the only crop that can be grown in the *bas-fonds* during the rainy season.

7.3.1.2. Synthetic Economic Budgets of Bas-Fond Rice Production Systems

The economic budgets for the *bas-fond* production systems use the shadow prices estimated earlier to adjust the financial budget items. In addition, the cost of water control infrastructure (550,000 CFA.F/ha)[9] borne by CMDT is included in the economic budgets. This investment is rehabilitated every 15 years with no salvage value (Dème, 1993). However, because it has a useful life of many years, only part of this cost (*i.e.*, its annual equivalent value) is attributed to 1996. Since in economic analysis investment costs earn an economic rate of return, the annual equivalent investment value of water control is determined by multiplying its full cost by the corresponding capital recovery factor. The capital recovery factor is estimated using the formula:

$$\frac{(1 + i)^n}{(1 + i)^n - 1}$$

where "n" is the useful life of the infrastructure, and "i" the real interest rate. As defined, the annual equivalent investment value is the annual payment that will repay infrastructure cost over its useful life and earn an economic rate of return equal to "i".

The economic budgets for the *bas-fond* production systems are estimated both for commercial and subsistence enterprises. Commercial rice enterprises are production systems in which farmers sell part or all their harvest in a market. However, for simplicity, the study assumes that the entire harvest is sold. In contrast, subsistence enterprises are production systems in which farmers consume their harvest in their household. Table 7.3 summarizes the economic budgets for commercial enterprises.

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[9] Estimate reported by Dème (1993).

Table 7.3: Synthetic Economic Budgets[a] for Commercial *Bas-fond* Rice Production Systems, by Output Market, Mali, 1996.

Output Market/Budget Items	*Bas-Fond* Production Systems			
	Traditional	Macro Semi Intensive	Micro Semi Intensive	Intensive
Yield (kg of paddy per ha)	1,021	1,232	1,423	2,366
Bamako				
Gross value of production (CFA.F/ha)	106,583	128,609	148,548	246,988
Total fixed costs (CFA.F/ha)	0	54,965	0	54,965
Total operating costs[b] (CFA.F/ha)	83,028	82,628	51,091	165,820
Total costs[b] (CFA.F/ha)	83,028	137,593	51,091	220,786
Net social returns[b] (CFA.F/ha)	23,555	-8,984	97,457	26,203
Enterprise social profit[c] (CFA.F/ha)	2,221	-27,650	76,707	-2,214
Net return/day family labor (CFA.F/day)	552	-241	2,348	461
Bougouni				
Gross value of production (CFA.F/ha)	117,606	141,910	163,911	272,532
Total fixed costs (CFA.F/ha)	0	54,965	0	54,965
Total operating costs[b] (CFA.F/ha)	83,028	82,628	51,091	165,820
Total costs[b] (CFA.F/ha)	83,028	137,593	51,091	220,786
Net social returns[b] (CFA.F/ha)	34,577	4,317	112,819	51,746
Enterprise social profit[c] (CFA.F/ha)	13,244	-14,244	92,069	23,329
Net return/day family labor (CFA.F/day)	810	116	2,719	911
Sikasso				
Gross value of production (CFA.F/ha)	120,373	145,249	167,768	278,945
Total fixed costs (CFA.F/ha)	0	54,965	0	54,965
Total operating costs[b] (CFA.F/ha)	83,028	82,628	51,091	165,820
Total costs[b] (CFA.F/ha)	83,028	137,593	51,091	220,786
Net social returns[b] (CFA.F/ha)	37,345	7,656	116,677	58,159
Enterprise social profit[c] (CFA.F/ha)	16,012	-11,010	95,927	29,742
Net return/day family labor (CFA.F/day)	875	205	2,811	1,023

[a] Estimated for hypothetical *bas-fond* villages assumed to be 307, 144 and 144 km away from Bamako, Bougouni, and Sikasso, respectively.
[b] Estimated not including family labor.
[c] Net social return less opportunity cost of family labor.
Source: Appendix 7.4.

Table 7.3 shows that for each *bas-fond* rice production system, social profitabilities differ between points of sale because the transportation cost between each of these points and the village differ. If *bas-fond* farmers produce rice to sell the output in Bamako, all but the *macro-semi-intensive bas-fond* rice production systems have positive net social returns (NSR). In other words, when the opportunity cost of family labor is assumed to be zero, all but the *macro-semi-intensive bas-fond* rice production systems are profitable to the society. However, when family labor is valued at 500 CFA.F/day and farmers sell their output in Bamako, the estimated net returns per day family labor indicate that only farmers using the *micro-semi-intensive* and the *traditional bas-fond* rice production systems earn more than their opportunity costs. Thus, only these two systems (*i.e.*, *micro-semi-intensive* and the *traditional*) are socially profitable.

In contrast, if *bas-fond* rice farmers sell their paddy harvest in either Bougouni or Sikasso, all four *bas-fond* rice production systems have positive net social returns (NSR). Thus, when the opportunity cost of family labor is assumed to be zero, all these four rice production systems are profitable to the society. However, when family labor is valued at 500 CFA.F/day and farmers sell their paddy in either Bougouni or Sikasso, all but the *macro-semi-intensive bas-fond* rice production system are socially profitable.

The results presented in the synthetic economic budgets (Table 7.3) and the financial budgets (Table 6.1) show that the rankings of the four *bas-fond* rice production based on their financial and social profitabilities are not always identical. The net returns per day of social labor indicate that, if farmers produce paddy to sell in any of the three markets, the *micro-semi-intensive* rice production system, which was the farmers' best option in the financial analysis (Table 6.1), is also the most profitable to society. It yields a net return per day of family labor at least two times higher than the net returns from any of the other three production systems, regardless of the point of sale. Also, it yields a net return per day of family labor four to five times higher than its opportunity cost (*i.e.*, 500 CFA.F/day), regardless of the point of sale.

Unlike in the financial analysis, the ranking of the remaining three *bas-fond* rice production systems diverges from social ranking across output markets. For example, if farmers sell their rice in Bamako, the *traditional bas-fond* production system is the second most (socially) profitable system. In contrast, if they sell their rice in either Bougouni and Sikasso, the *intensive bas-fond* rice production system is the second most (socially) profitable production system. The *macro-semi-intensive* system, which is the least profitable of all four *bas-fond* rice production systems, is not profitable to the society, regardless of the output market.

The above discussion suggests that the level of social profitability of the four *bas-fond* rice production systems depends in part on the social prices used to value output and inputs. These social prices in turn depends on the distance between the central point of sale and the farm. In the previous budgets, we have assumed market-oriented farmers who sell their harvest in markets situated at specific distances from the farm. Later in this chapter we examine how social profitability, measured by DRCRs, varies as the distance between the central market point and the farm increases.

Another important policy question is the profitability of these *bas-fond* production systems when farmers consume their production in their households. Table 7.4 presents synthetic economic for such subsistence *bas-fond* rice production systems. These budgets are estimated for a *bas-fond* village assumed to be 307 km away from Bamako. In estimating these budgets, the study assumes that the commercial (Table 7.3) and subsistence (Table 7.4) *bas-fond* rice enterprises have identical costs.

Table 7.4: Synthetic Economic Budgets for Subsistence *Bas-fond* Rice Production Systems[a], Mali, 1996.

Budget Items	Production Systems			
	Purely Traditional	Macro-Semi-Intensive	Micro-Semi-Intensive	Intensive
Output:				
Average yield (kg/ha)	1,021	1,232	1,423	2,366
Social price (CFA.F/kg)	201	201	201	201
Gross value of production (CFA.F/ha)	204,891	247,233	285,563	474,800
Total costs (CFA.F/ha)	83,028	137,593	51,091	220,786
Net social return (CFA.F/ha)	121,862	109,640	234,471	254,015
Opportunity cost family labor (CFA.F/ha)	21,333	18,667	20,750	28,417
Enterprise profit (CFA.F/ha)	100,529	90,974	213,721	225,598
Net return/day family labor (CFA.F/day)	2,856	2,937	5,650	4,470

[a] Estimated for a *bas-fond* village assumed to be 307 km away from Bamako.
Source: Survey Data.

Table 7.4 shows that, under subsistence farming, all four *bas-fond* rice production systems have positive net social returns. In other words, when the opportunity cost of family labor is assumed to be zero, all four subsistence *bas-fond* rice production systems are profitable to the society. When family labor is valued at 500 CFA.F/day and farmers consume all their paddy, these systems yield a net return per day of family labor five to 11 times higher than its opportunity cost. Furthermore, the *micro-semi-intensive bas-fond* rice production system remains the most (socially) profitable of the four systems, followed by the *intensive* system. The *traditional* system is the least (socially) profitable of the four production systems.

A comparison of Tables 7.3 and 7.4 reveals that, from the point of view of society, subsistence *bas-fond* rice farms are two to ten times more profitable than profitable commercial farms, depending on the production system and the output market. This extremely higher profitability of subsistence *bas-fond* rice farming relative to commercial farming is attributable to the output price difference (201 versus 104 CFA.F/kg of paddy, respectively), which in turn is due to the assumption that farmers' alternative to producing their own rice is to buy imported rice.

As mentioned earlier, because the NSR reveals the relative efficiency of the *bas-fond* systems in producing rice, these results provide an empirical indication that the *micro-semi-intensive* rice production system is the most competitive of the four systems. However, in using the social profit results for guiding policy decisions, it is important to recognize the limitations of the results and the scale bias of this indicator. First, the levels of social profitability reported in Tables 7.3 and 7.4 are based on the assumption of hypothetical *bas-fond* villages assumed to be situated 307, 144 and 144 km away from Bamako, Bougouni, and Sikasso, respectively. Second, the analysis does not take into account the relative importance of the various systems, measured in terms of total area cultivated. Furthermore, this research does not address how likely farmers are to change from one system to another, and what needs to be done to achieve such changes. As a practical matter, it could be more reasonable to promote the second best economic option rather than the first one, if farmers are more likely to adopt this option.

Finally, social profit does not explicitly indicate which system uses domestic resources best. Later in the chapter, these budget items are restructured in a PAM and the relative competitiveness of these systems is examined using DRC ratios, which provides an explicit answer to this question.

7.3.2. Selected Rice Production Systems from the Office du Niger

For the purpose of comparison with the commercial *bas-fond* rice production systems, this section provides the economic budgets (Appendix 7.11) of a representative commercial farm from the rehabilitated and non-rehabilitated perimeters of the *Office du Niger*[10] for the 1995-96 rainy season. The non-rehabilitated area considered is the *Office du Niger* zone of Macina and the rehabilitated area is the Niono zone. This section presents the data and economic principles used to estimate and compare the revenues and costs for these two systems. The analysis of these budgets focuses on assessing the competitiveness of the commercial *bas-fond* rice production systems relative to the selected commercial *Office du Niger* systems.

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[10] *Office du Niger* production area extends over a total of 53,300 ha of cultivated land distributed into five zones: Macina (15,000 ha), Molodo (7,100 ha), Niono (10,500 ha), N'Débougou (10,300 ha), and Kouroumani (10,400 ha). The rehabilitation of the degrading infrastructure began in 1982 with assistance from the Dutch (12,000 ha), the French CFD (2,800 ha), the World Bank (3,000 ha), and the European Development Fund (3,000 ha).

7.3.2.1. Estimation of Shadow Prices

7.3.2.1.1. Shadow Prices of Paddy, Urea and DAP

Appendices 7.6 to 7.10 outline cost items used to estimate the economic price of paddy, urea, and DAP in the *Office du Niger* rice production. These estimates are obtained using the same import route and cost items up to Bamako, as previously discussed for *bas-fond* rice production, as well as the same central market points of sale. The only difference between these two sets of prices (*i.e.*, in *Bas-fond* and *Office du Niger*) is the cost of transportation between the central market points of sale and the production site, since different distances are involved.

For the two *Office du Niger* systems, when farmers produce rice to sell it in Bamako, the shadow prices are estimated following the "Bamako-Ségou" (240 km), "Ségou-Niono" (103 km), and "Niono-Macina" (95 km) route. When Bougouni is their point of sale, these prices are estimated following the "Bamako-Bougouni" (163 km), "Bougouni-Sikasso" (207 km), "Sikasso-Ségou" (255 km), "Ségou-Niono" (103 km), and "Niono-Macina" (95 km) route. Finally, when Sikasso is the point of sale, the shadow prices are estimated following the "Bamako-Sikasso" (370 km), "Sikasso-Ségou" (255 km), "Ségou-Niono" (103 km), and "Niono-Macina" (95 km) route.

As for *bas-fond*, for the *Office du Niger*, seeds and fertilizers are valued by the farm-level undistorted price of imported rice and fertilizer, respectively. Similarly, the enterprise output (paddy) is valued by its corresponding farm-level import parity price and assuming commercial farmers who sell their production in Bamako, Bougouni. and Sikasso. Tables 7.5 and 7.6 report the estimated *Office du Niger* social prices for paddy rice and fertilizers. Later in the chapter, the estimated shadow prices are discussed in assessing the influence of government policies on production incentives.

Table 7.5: Farm-level Financial and Economic Prices (CFA.F/kg) of Rice Seeds and Paddy, by *Office du Niger* Production Site and by Output Market, Mali, 1996.

	Non-rehabilitated Perimeter		Rehabilitated perimeter	
	Financial	Economic[a]	Financial	Economic[a]
Rice seeds	100	203	122	201
Paddy[b]:				
Bamako	110	102	110	103
Bougouni	110	107	110	109
Sikasso	110	114	110	116

[a] Estimated for a hypothetical village assumed to be 307 km away from Bamako. The economic seed prices are the farm-level undistorted price of imported rice. In contrast, the economic paddy prices represent the social value of paddy at the farm necessary in order to be competitive with import at these markets.
Source: Appendices 7.6 to 7.8 for economic prices.

Table 7.6: Farm-Level Financial and Economic Prices (CFA.F/kg) of Urea and DAP Used by *Office du Niger* Farmers on Rice, Mali, 1996.

Fertilizer	Non-rehabilitated Perimeter		Rehabilitated perimeter	
	Financial	Economic[a]	Financial	Economic[a]
Urea	204	242	193	234
DAP	216	270	205	262

[a] Estimated for a hypothetical village assumed to be 307 km away from Bamako. The economic prices of fertilizers are the farm-level undistorted price of imported fertilizers.
Source: Appendices 7.9 and 7.10 for economic prices.

7.3.2.1.2. Shadow Prices of Labor and Land

For the *Office du Niger*, both labor and land costs were estimated using the same principles as for *bas-fond* rice production. The financial labor cost, which is the ongoing wage rate in the *Office du Niger*, is 650 CFA.F/day of family labor. This cost was not adjusted in the economic budget, as it is assumed that it reflects the social cost of labor.

For land, which was valued at zero opportunity cost in the financial budgets of the *Office du Niger* (as was the case in the *bas-fond*), a cost of 96,260 CFA.F/ha was included in the economic budgets. This cost is based on the consideration that, unlike in the *bas-fond*, farmers in the *Office du Niger* can use agricultural land to grow crops other than rice. Although *Office du Niger* requires farmers to grow rice in the irrigated areas, their alternative farming activity is vegetable production. Thus, producing rice results in foregone income, which is used to value land.

In principle, economic theory suggests that the economic value of land in the *Office du Niger* should be the residual value of the return from vegetable production after the farmer has paid for family labor and management, operating capital, and amortization. Because data on vegetable production does not exist, this study uses a proxy used by Barry (1994), which is the return to land from recessional maize production (*i.e.*, 96,260 CFA.F/ha). This value corresponds to the net incremental value of maize production foregone by changing land use to rice production[11].

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[11] In an earlier study, Kamuanga (1982) used sugar cane production as the alternative use of land to estimate its economic value.

7.3.2.2. Estimation of Financial and Social Values of Production

Financial budgets for the two *Office du Niger* rice production systems are based on yield and price data reported by A. Coulibaly (1996). These budgets include a producer rebate which *Office du Niger* pays to rice farmers each cropping season in both the non-rehabilitated (24,000 CFA.F/ha) and the rehabilitated (32,000 CFA.F/ha) perimeters. Farmers' gross value of production in each of the perimeters is computed by valuing paddy based on the corresponding economic price reported in Table 7.5.

7.4.2.3. Estimation of Financial and Social Costs

As with the *bas-fond* budgets, rice production costs in the *Office du Niger* perimeters are grouped into fixed and variable costs per hectare. Fixed costs include the one-season annualized cost of harrows, plows, oxen, and carts, as well as the cost of land development and gross maintenance. The operating costs include purchased inputs (*i.e.*, seeds, urea, and DAP), hired labor, irrigation fees, costs associated with the use of animal traction (*i.e.*, veterinary care, and animal feed), and the interest cost of capital.

For each of these fixed costs, the one-season annualized values are estimated using the corresponding capital recovery factor, taking into account the investments' salvage values. As the opportunity cost of investment capital, these estimations use the nominal interest rate in the financial budgets (Appendix 7.5), and the real interest rate in the economic budgets (Appendix 7.11). For operating costs, the opportunity cost of capital (interest rate) is estimated using the same method as was for the *bas-fond* budgets. The data used in all these estimations are based on the following facts:

a) In the Non-Rehabilitated Perimeter

In the non-rehabilitated perimeter, all farm operations are done by hand using small tools (*i.e.*, daba and harvesting knifes), except land preparation, which is done with animal traction. Although nearly all threshing is handled by mechanized services from village associations (AVs), increasingly private operators are providing this service due to the AV's inability to finance replacement of its aging threshers.

Fixed-cost data are based on the assumptions that households in this perimeter own two oxen, a plow, and a harrow. This equipment is valued based on data reported by A. Coulibaly (1996)[12]. In addition, *Office du Niger* manages the principal irrigation infrastructure, and carries out periodic heavy maintenance (without extensive leveling), every 10 years. However, because the non-rehabilitated infrastructure is degraded, no investment cost is included in the budgets estimated for this perimeter.

Operating-cost data are based on the following assumptions. Seed come from farmers' own stock. Farmers broadcast seed (104 kg/ha) of semi-improved tall varieties due to poor water control, especially drainage. Farmers use moderate amounts of fertilizer (139 kg of urea, and 74 kg of DAP per ha), with a market value of 204 and 216 CFA.F/kg, respectively. In the economic budget, the market value of seeds and fertilizers are adjusted to reflect their economic prices. As a result, they are valued at their corresponding farm-level undistorted import price (Appendices 7.6 and 7.8 to 7.10).

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[12] According to A. Coulibaly (1996), an ox is priced at 100,000 CFA.F and is usually amortized over 8 years for 25% of its initial value, leaving a 75% salvage value. A plow, which is assumed to have a service life of 10 years with no salvage value, is sold at 20,000 CFA.F. A harrow is assumed to have a service life of 8 years with no salvage and is sold at 20,000 CFA.F. Finally, a cart is priced at 80,300 CFA.F. and is assumed to have a service life of 8 years with no salvage value.

In addition, farmers pay a water utilization fee of 21,000-24,000 CFA.F/ha for the two seasons. Finally, although no cost was included for land development and gross maintenance, an operating cost estimated to be about 87,500 CFA.F per year for the two cropping seasons is included in the economic budgets. Only one-half of these annual costs is allocated to the rainy season budgets.

b) In the Rehabilitated Perimeter

The rehabilitated perimeter includes ARPON (13,861 ha), RETAIL (2,820 ha), DAF/SAF (3,075 ha), FED (3,331 ha), and KFW (2,173 ha). In these perimeters, farmers have increasingly adopted intensive rice production techniques. Farmers are required to double-crop at least 20 percent of their allocated land in a rice-rice crop sequence. Farm operations are similar to those followed in the non-rehabilitated perimeters, in terms of the level of mechanization. Similarly, threshing is handled by mechanized services from AVs, but increasingly private operators are providing this service. Most households in this perimeter own two oxen, a plow, an harrow, and a cart, which are all valued as in the non-rehabilitated perimeter.

Farmers transplant seeds (80 kg/ha) of semi-dwarf varieties (*eg.*, BG-90-2) obtained from their own stock, which are valued at the corresponding farm-level undistorted import price of rice (Appendices 7.7 to 7.10). Farmers use higher amounts of fertilizers (215 kg of urea, and 130 kg of DAP per ha), with a market value of 193 and 205 CFA.F/kg, respectively. Farmers purchase fertilizer directly from the AVs and pay a higher price than for the subsidized *Office du Niger* supplies. DAP is incorporated at transplanting and urea is used in split applications at booting and at flowering. Although farmers in the rehabilitated perimeter use small amounts of herbicide, its cost is not included in this analysis because data on application rates were not available.

As in the non-rehabilitated perimeters, canals and diversion dams were originally constructed in 1932-47. However, in the rehabilitated perimeter, this infrastructure underwent extensive rehabilitation in the 1980s. The cost of the rehabilitation is estimated to be around 2,600,000 CFA.F/ha. As discussed in the case of the non-rehabilitated perimeter, the annualized equivalent value of the rehabilitation cost is estimated assuming no salvage value, using its capital recovery factor, and taking into account land use intensity (two seasons). In addition, farmers pay an irrigation fee of 600 kg per ha of paddy for the rainy season and 500 kg per ha for the dry season. Additional costs include the cost of hired labor, the operating costs associated with the use of animal traction (*i.e.*, veterinary care, animal feed), and the opportunity cost of operating capital.

7.4.2.4. Synthetic Economic Budgets of Selected Rice Enterprises

Employing the same economic principles and points of sale used to estimate the economic budgets for the four *bas-fond* production systems, economic budgets were developed for the two *Office du Niger* systems (Appendix 7.11). These budgets, which assume market-oriented *Office du Niger* farmers, are summarized in Table 7.7. In addition, the opportunity cost of a family labor is estimated to be 650 CFA.F/day.

Table 7.7: Synthetic Economic Budgets for Selected Commercial *Office du Niger* Rice Enterprises[a], by Output Market, Mali, 1996.

Output Market/Budget Items	Production Perimeter	
	Non-Rehabilitated	Rehabilitated
Yield (kg of paddy per ha)	2,546	4,877
Bamako		
Gross value of production (CFA.F/ha)	283,411	536,300
Total fixed costs (CFA.F/ha)	60,243	238,069
Total operating costs[b] (CFA.F/ha)	155,369	239,459
Total costs[b] (CFA.F/ha)	215,613	477,529
Opportunity cost of land (CFA.F/ha)	96,260	96,260
Net social returns[c] (CFA.F/ha)	-28,491	-37,489
Enterprise social profit[d] (CFA.F/ha)	-71,361	-138,889
Bougouni		
Gross value of production (CFA.F/ha)	297,339	562,978
Total fixed costs (CFA.F/ha)	60,243	238,069
Total operating costs[b] (CFA.F/ha)	155,369	243,028
Total costs[b] (CFA.F/ha)	215,613	481,098
Opportunity cost of land (CFA.F/ha)	96,260	96,260
Net social returns[c] (CFA.F/ha)	-14,534	-14,379
Enterprise social profit[d] (CFA.F/ha)	-57,434	-115,779
Sikasso		
Gross value of production (CFA.F/ha)	315,322	597,426
Total fixed costs (CFA.F/ha)	60,243	238,069
Total operating costs[b] (CFA.F/ha)	155,369	247,636
Total costs[b] (CFA.F/ha)	215,613	485,706
Opportunity cost of land (CFA.F/ha)	96,260	96,260
Net social returns[c] (CFA.F/ha)	3,449	15,460
Enterprise social profit[d] (CFA.F/ha)	-39,451	-85,940
Net return/day family labor (CFA.F/day)	52	99

[a] The non-rehabilitated perimeter is in the CMDT zone of Macina and the rehabilitated perimeter is in Niono Zone.
[b] Estimated not including family labor.
[c] Gross value of production less total costs and opportunity cost of land.
[d] Net social return less opportunity cost of family labor.
Source: Appendix 7.11.

Table 7.7 indicates that, given the assumptions made to estimate costs and revenues, including zero opportunity cost of family labor, the two *Office du Niger* rice production systems under consideration have negative net social returns (NSR) when Bamako and Bougouni are considered as point of sale, and positive NSR when Sikasso is the central market point. However, when family labor is valued at 650 CFA.F/day, for both *Office du Niger* systems, the return per day of family labor is lower than its opportunity cost, regardless of the central output market. In other words, from the point of view of society, these *Office du Niger* production systems are not profitable. Furthermore, for these two systems, social profitability (Table 7.7 or Appendix 7.11) is lower than the financial profitability (Appendix 7.5) because farmers do not have to pay for any of the infrastructure development costs.

7.3.3. Comparative Analysis of NSPs of Bas-Fond and ON Rice Production Systems

A comparison of the social profitability of the selected commercial *bas-fond* (Appendix 7.4 or Table 7.3) and that of the commercial *Office du Niger* (Appendix 7.11 or Table 7.7) rice production systems shows that, while the *Office du Niger* production systems give the highest gross values of production, the level of investment in the *Office du Niger* is so high that any of the *Bas-fond* rice production systems is more socially profitable than the two *Office du Niger* systems, regardless of the point of sale. In other words, all four *bas-fond* production systems are more competitive than the *Office du Niger* systems. The remaining part of this chapter, which uses a policy analysis framework to assess competitiveness, confirms this conclusion.

However, for policy decisions, it is important to note that this result does not take into account the lower production risk associated with the *Office du Niger* perimeters, due to better water control. Furthermore, in terms of the nation's food security, this result does not take into account the relative size of these two production schemes. Nonetheless, this result suggests that the *bas-fonds* can make a lower-cost contribution to supplying the country's rice requirements than does the *Office du Niger*.

7.4. Competitiveness of the Rice Production Systems: A PAM Framework

7.4.1. Budget Concepts and Policy Analysis Matrices

The policy analysis matrix (PAM) was developed by Pearson *et al.* (Nelson and Panggabean, 1991) to quantify the magnitude of policy distortions, by measuring the difference between financial and economic prices that arise because of government policies (*e.g.*, subsidies and government set prices) or because of the public-good nature of the good or service under consideration. Compared to the standard economic budget, the main advantages of the PAM approach is that it allows varying levels of disaggregation, makes the analysis of policy-induced distortion straightforward, and makes it possible to identify the net effects of those policies. Its main weakness is the underlying assumption of fixed technical input-output coefficients.

Appendices 7.12 to 7.14 present the PAM constructed for *bas-fond* and *Office du Niger* rice production systems. As shown in these tables, the PAM approach is a system of double-entry bookkeeping that consists of two accounting identities. The first identity holds that profit equals revenues minus costs, measured either in financial or economic terms. The second identity measures the divergence between financial and economic values. The main empirical task involved in developing the PAM presented in Appendices 7.12 to 7.14 was to construct accounting matrices of revenues, costs and profits for each enterprise, based on the financial and economic budgets presented earlier.

In the PAM matrix, inputs are partitioned into tradables and domestic factors. As mentioned earlier, tradable inputs are inputs that are traded internationally (traded tradables) or potentially could be traded (non traded tradables). Domestic factors (sometimes refer to as primary factors in DRC analyses) are factors that are not normally traded internationally and include chiefly land and labor. While labor might be considered tradable in cases where seasonal migration results in remittances of foreign exchange, in Mali labor is treated as a domestic factor.

Ideally, intermediate inputs such as fertilizer, seed, and transportation should be disaggregated into cost components until all costs items are traced back to tradable inputs, domestic factors, and transfers. However, this process, which is referred to in benefit/costs analysis by Little and Mirrless (OECD) as complete border pricing, was not used because the necessary information was not available[13]. In this study, the full costs of seed and fertilizer are classified as tradable input costs.

Appendices 7.12 to 7.14 report data used to estimate the DRC ratio, the effective protection coefficient (EPC), the profitability coefficient (PC), and the subsidy ratio to producers (SRP) associated with each of the rice production systems under consideration.

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[13] In practice, researchers have used several versions of the border pricing approach (Ward, 1977). Probably the most commonly used version is the partial border pricing approach developed by Squire and Van der Tak. Here, all costs items are selectively traced back to their tradable and domestic components, depending on the analyst's assessment of the need to increasingly break minor items into costs components.

7.4.2. DRC Ratios of the Selected Rice Production Systems

This section examines the DRC ratios for subsistence and commercial *bas-fond* rice farming, estimated with and without including the cost of family labor. These ratios measure the efficiency of each production system in using domestic resources to save one unit of foreign exchange.

7.4.2.1. DRC Ratios for Subsistence Rice Farming

As a reminder, the term subsistence rice farming refers to rice production systems in which farmers consume their harvest in their own households. The study assumes that these farmers buy fertilizers that are imported through the route "Mali border-Bamako-village". In other words, in the economic budgets, urea, DAP, and the NPK cereal fertilizer are valued by their corresponding undistorted farm-level import price following the import route "border-Bamako-village". Similarly, seeds and paddy are valued by the same undistorted farm-level import price following the import route "border-Bamako-village". Table 7.8 reports the DRC ratios of the four *bas-fond* production systems in a hypothetical village assumed to be 307 km away from Bamako, which is the average of the distances between the sampled villages to Bamako.

Table 7.8: DRC Ratios[a] for Subsistence *Bas-Fond* Rice Production Systems[b], Mali, 1996.

Production Systems	500 cfa/day of family labor	Zero cost for family labor
Traditional	0.385	0.254
Macro-semi-intensive	0.594	0.510
Micro-semi-intensive	0.146	0.063
Intensive	0.378	0.300

[a] Computed as the ratio of domestic factor cost to value added measured in social prices, where value added is the value of total production less the cost of tradable inputs.
[b] For a hypothetical village assumed to be 307 km away from Bamako.
Source: Computed from Appendix 7.12.

Table 7.8 indicates that, for a village situated 307 km away from Bamako, all four subsistence *bas-fond* rice production systems have DRC ratios which are between zero and one, with and without including family labor. In other words, if farmers in these villages produce rice for their own home consumption, the value of domestic resources used in each of the *bas-fond* systems is less than the foreign exchange cost of importing more rice. Therefore, these systems are competitive, and the *bas-fond micro-semi-intensive* production system is the most competitive of the four systems.

While this result is significant from a policy point of view, it holds only for the specific geographic location for which it is derived. A more important information for policy makers is the distance at which the identified *bas-fond* rice production systems are no longer competitive, assuming farmers consume the harvest. To address this question, the study estimated DRC ratios for these systems over space. Figure 7.4 depicts how these DRC ratios vary as the distance between the production/consumption point and Bamako increases.

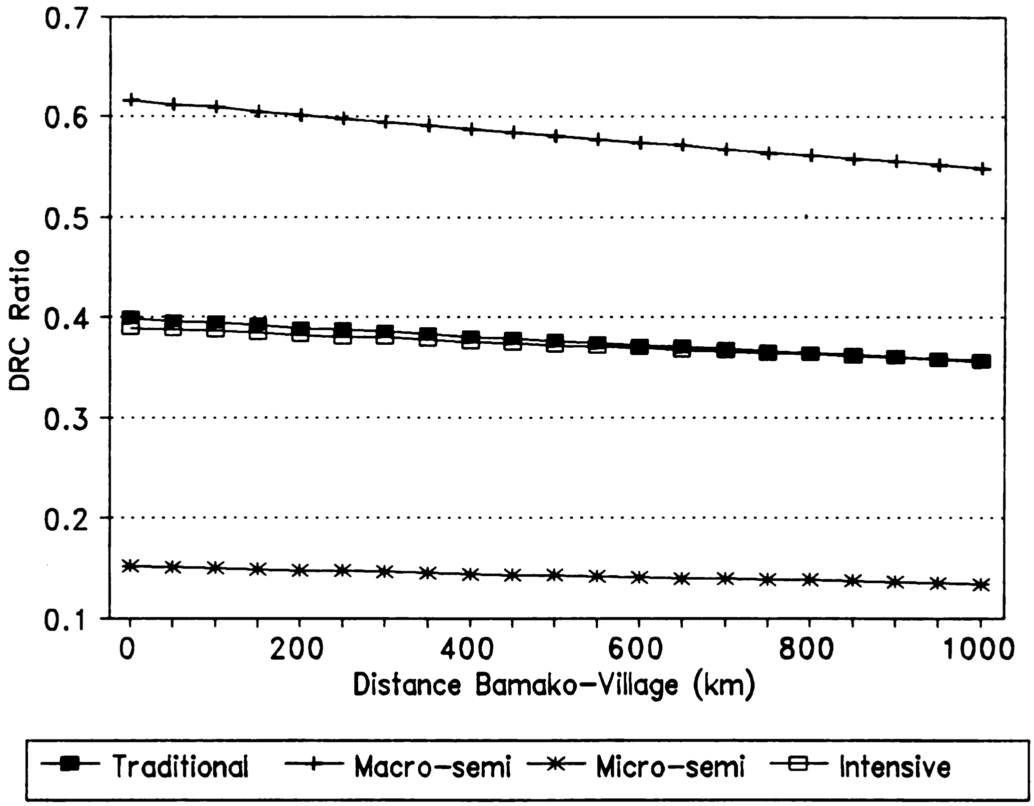

Figure 7.4: DRC Ratios for Subsistence *Bas-Fond* Rice Production Systems over Space, Mali, 1997.

Figure 7.4 shows that the four subsistence *bas-fond* rice production systems have DRC ratios which are less than 0.7, regardless of the distance between the production/consumption point and Bamako. In other words, under any of the production systems being considered in this study, producing rice for home consumption in any of the Mali-Sud *bas-fonds* is a better use of domestic resources than importing rice to feed farmers. The DRCs are so low because of the high opportunity cost of rice. However, it is important to recognize that this result does not take into account the production risks associated with the prevailing erratic rainfall and poor water control in these *bas-fonds*.

7.4.2.2. DRC Ratios for Commercial Rice Farming

Table 7.9 reports the DRC ratios of the *bas-fond* and *Office du Niger* rice production systems, assuming that farmers sell their paddy either in Bamako, Bougouni, or Sikasso. The social prices for paddy, seeds, and fertilizer used to determine these DRC ratios were estimated based on the principles discussed earlier and assuming the import route "Mali border-Bamako-Output market-village".

Table 7.9: DRC Ratios[a] for Selected Commercial *Bas-Fond* and *Office du Niger* Rice Production Systems, by Output Market, Mali, 1996.

Production Systems	Assuming 500 cfa/day for family labor			Assuming zero opportunity cost for family labor		
	Bamako	Bougouni	Sikasso	Bamako	Bougouni	Sikasso
Bas-Fond[b]						
Traditional	0.966	0.826	0.797	0.638	0.545	0.526
Macro-semi-intensive	1.263	1.121	1.090	1.085	0.964	0.937
Micro-semi-intensive	0.323	0.284	0.276	0.139	0.123	0.119
Intensive	1.016	0.855	0.822	0.806	0.678	0.652
Office du Niger						
Rehab. perimeter	1.319	1.250	1.173	1.086	1.031	0.969
Non-rehab. perimeter	1.342	1.258	1.164	1.136	1.065	0.986

[a] Computed as the ratio of domestic factor cost to value added measured in social prices, where value added is the value of total production less the cost of tradable inputs.
[b] In a hypothetical village assumed to be 307, 144 and 144 km away from Bamako, Bougouni and Sikasso, respectively.
Source: Computed from Appendices 7.13 and 7.14.

The results summarized in Table 7.9 suggest several significant conclusions. As expected, the competitiveness of the commercial *bas-fond* rice production systems relative to each other depends on the central market point at which they are compared. When family labor is valued at 500 CFA.F/day, the *traditional* and the *micro-semi-intensive bas-fond* rice production systems have DRC ratios between zero and one, for all points of sale. In other words, the value of domestic resources used in each of these two *bas-fond* systems is less than the foreign exchange cost of importing more rice. Consequently, Mali has a comparative advantage in producing rice with those *bas-fond* production systems. However, the magnitude of the estimated DRC ratios indicates that the *micro-semi-intensive bas-fond* rice production system is more competitive than the *traditional* system in any of the three markets.

Farmers utilizing the *intensive bas-fond* rice production system are efficient in the use of domestic resources when they sell their production in either Bougouni or Sikasso, and they are not competitive in Bamako. In contrast, farmers utilizing the *macro-semi-intensive bas-fond* rice production system are not efficient in the use of domestic resources when they sell their production in any of the three output markets.

When the opportunity cost of family labor is assumed to be zero, output from the *traditional*, the *micro-semi-intensive*, and the *intensive bas-fond* rice production systems are competitive in any of the three markets. In contrast, output from the *macro-semi-intensive bas-fond* rice production system is competitive in either Bougouni or Sikasso, and it is not competitive in Bamako.

These results are consistent with the one obtained using the NSPs in the economic budgets. Because minimizing the DRC ratio is equivalent to maximizing social profit, the estimated DRC values establish that the contribution of the competitive *bas-fond* rice production systems to Mali's economy justifies the use of scarce government resources to develop these production system further. In particular, the results confirm that, for the country, it does not pay if the government simply builds a dam and does nothing else. It is necessary to pay attention to providing the complementary inputs, particularly herbicide.

When contrasted with the *Office du Niger* systems, it appears that all four commercial *bas-fond* rice production systems have lower DRC ratios than the two *Office du Niger* systems, regardless of the point of sale. In other words, if farmers in the Macina and Niono perimeters sell their paddy production in either Bamako, Bougouni, or Sikasso, the *bas-fond* rice production systems are more efficient in the use of domestic resources than the two *Office du Niger* systems. Differences in labor use and tradables may largely explain the differences in efficiency in the use of domestic resources between the *bas-fond* and *Office du Niger* rice production systems. In particular, the *bas-fond* systems are disproportionately more labor-intensive than the *Office du Niger* systems.

The fact that the *bas-fond*'s *micro-semi-intensive* production system is the most competitive of all systems under consideration (*i.e.*, *bas-fond* and *Office du Niger*) suggests that minor changes such as herbicide application result in better use of domestic resources than greater levels of intensification, at least in the short-run. However, over time, as farmers become more familiar using modern technologies (learning curve), they may improve their efficiency in the use of domestic resources in the intensive *bas-fond* rice production systems.

The significance of the DRC analysis results is limited by the standard criticisms of all DRCs. Furthermore, this study assumed constant market prices for paddy and fertilizer throughout the *bas-fond* area. However, earlier in this chapter it was shown that, for each point of sale, the shadow prices estimated for *bas-fond* rice production vary over space. As a result, the corresponding DRC ratios also vary over space. As was the case for subsistence rice farming, it is useful to determine the distance between the central output market and the village at which the competitiveness of each of the *bas-fond* rice production changes. To achieve this, DRC ratios for sale in each market were estimated by varying the distance between each of the three central output markets under consideration and the village. The results obtained show how the DRCs in each output market vary depending on how far away the domestic rice is produced (Figures 7.5 to 7.7).

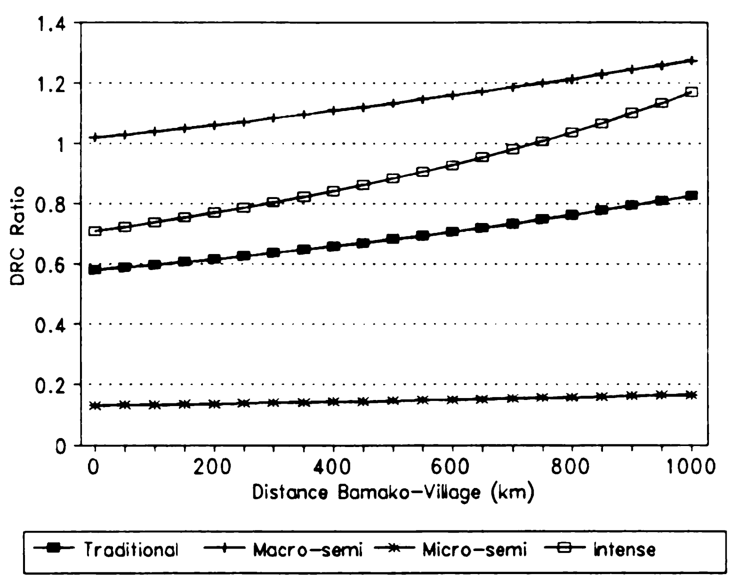

Figure 7.5: DRC Ratios for Commercial *Bas-Fond* Rice Production Systems over Space, Using Bamako as Output Market, Mali, 1996.

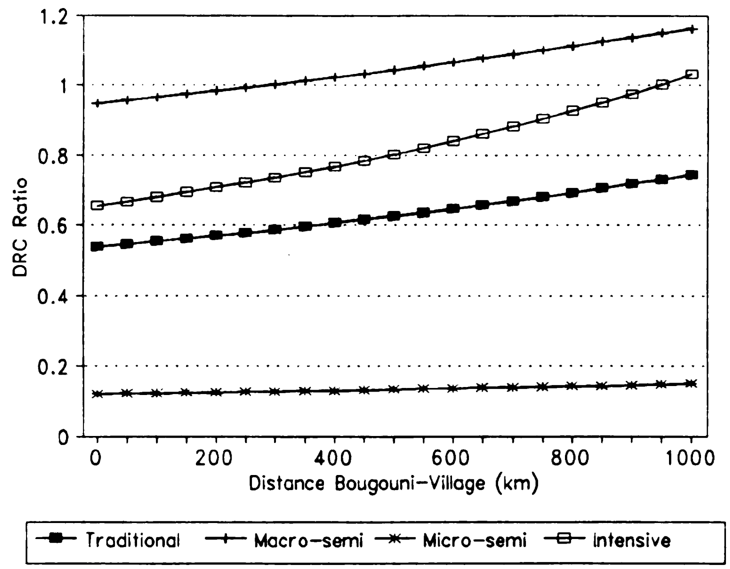

Figure 7.6: DRC Ratios for Commercial *Bas-Fond* Rice Production Systems over Space, Using Bougouni as Output Market, Mali, 1996.

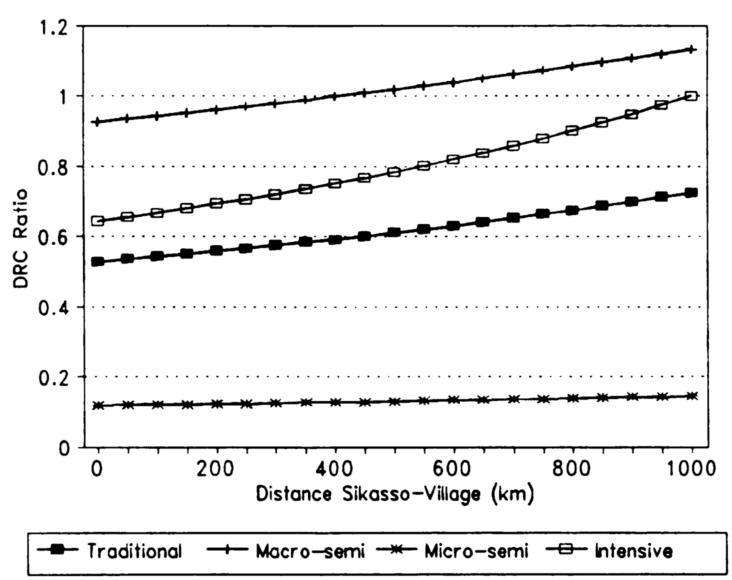

Figure 7.7: DRC Ratios for Commercial *Bas-Fond* Rice Production Systems Over Space, Using Sikasso as Output Market, Mali, 1996.

Figures 7.5 to 7.7 show that the competitiveness of each of the commercial *bas-fond* rice production systems under consideration varies over space depending on the market in which farmers sell their rice harvest. The more transportation cost farmers have to pay to reach the output market, the less competitive their rice is.

For example, Figure 7.5 shows that, if *bas-fond* farmers sell their rice harvest in Bamako, the *micro-semi-intensive* production system is not competitive in this market, regardless of the distance between Bamako and their production site. In contrast, the *intensive* system is competitive in the Bamako market only for distances "Bamako-production site" ranging between zero and 740 km. At a distance of 740 km from Bamako, the system's DRC becomes equal to one and the system is no longer competitive. Rice harvest from both the *traditional* and the *micro-semi-intensive bas-fond* production systems are competitive in the Bamako market for farms located within zero and 1,000 km away from Bamako. In fact, the results show that these two systems (*traditional* and *micro-semi-intensive*) cease to be competitive in Bamako at 1,408 and 4,206 km away from Bamako, respectively. In other words, rice harvested from these two systems in any of the Mali-Sud *bas-fond* would be competitive in Bamako.

Figure 7.6 shows that, unlike when Bamako is the output market (Figure 7.5), the *micro-semi-intensive* production system is competitive in Bougouni for distances "Bougouni-production site" ranging between zero and 288 km, if *bas-fond* farmers sell their rice harvest in that market. Similarly, the *intensive* system is competitive in the Bamako market only for distances "Bougouni-production site" ranging between zero and 945 km. As when Bamako is the output market, rice harvest from both the *traditional* and the *micro-semi-intensive bas-fond* rice productions are competitive in the Bougouni market for farms located within zero and 1,000 km away from Bougouni. Indeed, they cease to be competitive in Bougouni at 1,666 and 4,620 km away from Bougouni.

Finally, Figure 7.7 shows that, the *micro-semi-intensive* production system is competitive in the Sikasso market for distances "Sikasso-production site" ranging between zero and 408 km, if *bas-fond* farmers sell their rice harvest in that market. Similarly, the *intensive* system is competitive in the Bamako market only for distances "Sikasso-production site" ranging between zero and 998 km. As when either Bamako or Bougouni is the output market, rice harvest from both the *traditional* and the *micro-semi-intensive bas-fond* rice productions are competitive in the Sikasso market for farms located within zero and 1,000 km away from Bougouni. Indeed, they cease to be competitive in Sikasso at 1,743 and 4,754 km away from Sikasso.

When Figures 7.5 to 7.7 are contrasted with the estimated DRC ratios for the *Office du Niger* systems (Table 7.9), it appears that, within a distance ranging between zero and 1,000 km, paddy harvested from the *bas-fond* systems would be more competitive than rice of the same quality harvested from any of the *Office du Niger* systems if sold either in Bougouni (Figure 7.6) or Sikasso (Figure 7.7). The same conclusion holds if farmers sell their rice harvest in Bamako, with the exception in this case that the superior competitiveness of the *bas-fond macro-semi-intensive* systems is limited to the range zero to 700 km. Clearly, this result reinforces the conclusion made earlier that the *bas-fonds* can make a lower-cost contribution to supplying Mali's rice requirements than does the *Office du Niger*.

7.5. Influence of Government Policies on Farm-Level Incentives

This section looks at how government policies have affected the incentives associated with commercial rice production, both for *bas-fond* and *Office du Niger* farmers. To achieve this objective, the study uses quantitative indicators showing the extent to which financial paddy market prices, value added, gross revenues, and profit diverge from their corresponding social values. For *bas-fond*, unlike with DRC estimation, this analysis focuses only on the hypothetical village situated 307 km away from Bamako, which is the average of the distances between the sampled villages to Bamako. Also, it is based constant financial prices for paddy and fertilizer throughout the *bas-fond* area. Finally, the study assumes that the effect of government policies on *bas-fond* rice farming is identical in all *bas-fond* villages, relative to each output market.

7.5.1. Policy-Induced Protection

7.5.1.1. Policy-Induced Protection in the Output Markets

The estimated shadow prices of paddy indicate that, as a result of government policies, average paddy's farm-gate financial price (115 CFA.F/kg) departs from its economic value by about +11, 0, and -3 CFA.F/kg when Bamako, Bougouni, and Sikasso are used as points of sale, respectively. In other words, while the policy environment distorted output market prices when Bamako and Sikasso are the points of sale, it had no effect on prices when Bougouni is the output market. These output price divergences correspond to nominal protection coefficients (NPC) on paddy of 1.11, 0.0 and 0.97, respectively (Table 7.10).

Table 7.10: Nominal Protection Coefficients[a] on Paddy in the *Bas-Fond* and *Office du Niger*, by Output Market, Mali, 1996.

Production Area	Bamako	Bougouni	Sikasso
Bas-Fond[b]	1.11	0.00	0.97
ON Rehabilitated perimeter	1.07	1.01	0.95
ON Non-rehab. perimeter	1.08	1.03	0.96

[a] Computed as the ratio of financial price of output to its corresponding social price.
[b] For a hypothetical village assumed to be 307 km away from Bamako.
Source: Computed from Table 7.1 for *bas-fond*, and Table 7.5 for *Office du Niger*.

In the *bas-fond*, the magnitude of the estimated NPCs on paddy indicates that the degree to which these prices diverge ranges between zero and 11 percent. In other words, for reasons not fully investigated in this study (in addition to the taxes in Appendix 7.1), the paddy farm-gate price is 11 percent higher than its world price equivalent when Bamako is the central output market, while the same farm-gate price is three percent lower than its world price equivalent when Sikasso is the central output market. In contrast, when Bougouni is the central output market, the financial farm-gate price of paddy approximately reflects its economic value.

The significance of this result depends on whether a farmer is a net seller or net buyer of grain. For example, when Bamako is considered as the central output market, the policy environment is such that *bas-fond* rice producers who are net sellers of paddy receive more money for every kilogram of paddy they sell than they would have gotten if the market price of paddy was aligned with world price. As a result, they are implicitly subsidized in the output market. In contrast, those who are net buyers pay more money for each kilogram of paddy they buy than they would have had to spend if the market price of paddy was aligned with world price. Thus, they are implicitly are taxed in the output market. In contrast, when Sikasso is considered as the central output market, *bas-fond* rice producers who are net sellers of paddy are implicitly taxed in the output market, and those who are net buyers are implicitly subsidized. When Bougouni is the central market point, *bas-fond* rice farmers are neither subsidized nor are they taxed as a result of government policies.

A comparison of the level of paddy market price protection (*i.e.*, {1-NPC}*100) in the *bas-fond* versus the *Office du Niger* shows that, when Bamako is considered as central output market, the degree to which the financial and social prices diverge is higher in the *bas-fond* than in the *Office du Niger*. Thus, the level of protection is lower in the *bas-fond* than in the *Office du Niger*. In contrast, when Bougouni or Sikasso is the point of sale, the level of protection is lower in the *bas-fond* than in the *Office du Niger*. This analysis of the level of protection in the paddy market is based on the assumption of a constant average farm-gate financial price over the sampled villages. In reality, however, market prices vary over space due in part to differences in transportation costs. Thus, given the quality of the data and the small difference in NPC between the *bas-fond* and *Office du Niger*, these NPCs are roughly equal.

7.5.1.2. Policy-Induced Protection in the Input Markets

Table 7.11 reports the NPC associated with each type of fertilizer farmers used in the *bas-fond* rice production systems.

Table 7.11: Nominal Protection Coefficients[a] on Urea, DAP and NPK Cereal Fertilizer Used by *Bas-Fond* Rice Farmers, by Output Market, Mali, 1996.

Fertilizer	Price		NPC
	Financial	Economic[b]	
Urea	175.0	232	0.75
DAP	243.7	260	0.94
NPK for Cereals	196.0	242	0.81

[a] Computed as the ratio of financial to social prices.
[b] For a hypothetical *bas-fond* village assumed to be 307 km away from Bamako.
Source: Appendix 7.3 for economic prices.

Given the assumption of constant financial price of fertilizers throughout the *bas-fond* area, Table 7.11 shows that all three fertilizers are sold at a price lower than their equivalent social value. In other words, producers who use fertilizer are implicitly subsidized. The level of subsidy is 25 percent for urea, 6 percent for DAP, and 19 percent for NPK. As was the case for paddy, this analysis is limited by the assumption of constant market price of fertilizer throughout the *bas-fond* area.

7.5.1.3. Effective Protection Coefficients on Paddy

The separate influences of government policies in the output and inputs markets can be combined in one single indicator, called the effective protection coefficient (EPC), to show the extent of incentives or disincentives that each of the rice production systems under consideration receive. Table 7.12 presents the estimated EPCs for each point of sale under consideration.

Table 7.12: Effective Protection Coefficients[a] for Commercial *Bas-Fond*[b] and *Office du Niger* Rice Production Systems, by Output Market, Mali, 1996.

Production Systems	Bamako	Bougouni	Sikasso
Traditional	1.54	1.31	1.27
Macro-semi-intensive	1.25	1.11	1.08
Micro-semi-intensive	1.23	1.08	1.05
Intensive	1.33	1.12	1.06
ON Rehabilitated perimeter	1.13	1.06	0.99
ON Non-rehab. perimeter	1.20	1.12	1.04

[a] Computed as the ratio of value added in financial terms to value added in social terms, where value added is the value of total production less the cost of tradable inputs.
[b] For a hypothetical *bas-fond* village assumed to be 307 km away from Bamako.
Source: Computed from Appendices 7.13 and 7.14.

Table 7.12 indicates that, in general, the net impact of government policies influencing output and tradable input markets results in a 0-54 percent increase in value added measured in financial prices, depending on the specific *bas-fond* and *Office du Niger* production systems considered, compared to what it would have been had domestic prices been set by the world market. In other words, the net impact of policies in the output market translates into a net incentive effect for farmers who are net sellers.

For each of the four *bas-fond* and *Office du Niger* production systems, the highest increase or incentives are observed when Bamako is chosen as a central market point, while the highest disincentives are observed when Sikasso is chosen as a central market point. Similarly, for each market point, the highest incentive is associated with the *traditional* production system, followed by the *micro-semi-intensive* system. This can be attributed to the low content in tradables in the *traditional* system, compared to the more intensive ones. Finally, *bas-fond* rice production systems are associated with higher incentive than the systems in the *Office du Niger*. This last result is influenced by the constant price assumption for fertilizers throughout the *bas-fond* area.

7.5.2. Net Policy-Induced Transfers

7.5.2.1. Monetary Value of the Net Policy-Induced Transfers

Appendix 7.13 and 7.14 show divergences in the inputs and output markets for all four *bas-fond* and *Office du Niger* production systems at the three points of sale. These divergences are attributable to the rice production policy environment. The positive (negative) divergences in the output market indicate higher financial values of paddy, compared to its corresponding social values. This implies positive (negative) net transfers to farmers in the output market. In contrast, positive (negative) divergences in the input markets indicate negative (positive) net transfers to farmers in the these markets. Table 7.13 summarizes the estimated net transfers in the output and input markets.

Table 7.13: Summary of the Policy-Induced Net Transfers to Producers (CFA.F/ha) in the *Bas-fond*[a] and *Office du Niger* Areas, by Production System and Output Market, Mali, 1996.

	Via Paddy Market	Via Market for		Overall[b]
		Tradable Factors	Domestic Factors	
Bamako				
Traditional	10,832	23,945	-268	35,045
Macro-semi-intensive	13,071	13,418	54,683	81,172
Micro-semi-intensive	15,097	10,874	-120	25,851
Intensive	25,102	19,332	54,046	98,480
ON Non-rehabilitated	20,649	20,011	184,626	225,285
ON Rehabilitated	32,170	22,689	348,989	403,848
Bougouni				
Traditional	-191	23,945	-268	24,023
Macro-semi-intensive	-230	13,418	54,683	67,871
Micro-semi-intensive	-266	10,874	-120	10,488
Intensive	-442	19,332	54,046	72,937
ON Non-rehabilitated	6,721	20,011	184,626	211,357
ON Rehabilitated	5,492	22,689	352,558	380,738
Sikasso				
Traditional	-2,958	23,945	-268	21,255
Macro-semi-intensive	-3,569	13,418	54,683	64,532
Micro-semi-intensive	-4,123	10,874	-120	6,631
Intensive	-6,855	19,332	54,046	66,524
ON Non-rehabilitated	-11,262	20,011	184,626	193,374
ON Rehabilitated	-28,956	22,689	357,166	350,899

[a] For a hypothetical *bas-fond* village assumed to be 307 km away from Bamako.
[b] Computed as the transfers in the paddy market plus transfers in the markets for tradables and domestic factors.
Source: Adapted from Appendices 7.13 and 7.14.

Table 7.13 shows that, overall, the net effect of all distortions results in positive net transfers in the *bas-fond* and in the *Office du Niger*, regardless of the production system and the point of sale. These net transfers are two to 15 times larger in the *Office* than in the *bas-fond* mainly because of higher land development costs. When one looks at the absolute values of the estimated divergences in the *bas-fond*, it appears that, when Bamako is the central output market, the *intensive* system has the highest net transfer (98,480 CFA.F/ha of private earnings in excess of social values). The *macro-semi-intensive* system has the second highest net transfer (81,172 CFA.F/ha), followed by the *traditional* system (35,045 CFA.F/ha). The *micro-semi-intensive* system has the lowest net transfer (25,851 CFA.F/ha), indicating that market price distortions are smaller than for the other systems.

When either Bougouni or Sikasso is the central output market, the *intensive* system has the highest net transfer, followed by the *macro-semi-intensive* system, and then the *traditional* system. The *micro-semi-intensive* system has the lowest net transfer, indicating that market price distortions are smaller, compared to their magnitude in the other systems. In both cases, these distortions are still larger (2-52 times) in the *Office du Niger* than in the *bas-fond* market environments.

From a normative perspective, negative divergences in the output market favor rice producers who are net buyers of grains because they indicate that those farmers buy paddy whose market value is lower than its social equivalent. However, during the hungry period, the market price of paddy is much higher and closer to its social value. The remaining parts of this chapter look at the divergences in relative terms.

7.5.2.2. The Profitability Coefficient

This sections looks at by how much private profits in the selected rice production systems depart from their corresponding social values. To achieve this objective, ratios of private to social profits were computed and they presented in Table 7.14. These ratios, which quantify the impact of the policy environment on the systems' profitability, are computed only for production systems with positive financial and social profits.

Table 7.14: The Profitability Coefficients[a] for *Bas-Fond* Rice Production Systems, by Output Market, Mali, 1996.

Production System	500 cfa/day family labor			Zero cost for family labor		
	Bamako	Bougouni	Sikasso	Bamako	Bougouni	Sikasso
Traditional	16.776	2.814	2.327	2.488	1.695	1.569
Macro-semi-intensive	-	-	-	-	16.722	9.429
Micro-semi-intensive	1.337	1.194	1.069	1.265	1.093	1.054
Intensive	-	4.126	3.237	4.758	2.410	2.144

[a] Computed as the ratio of profit measured in financial terms to profit measured in social terms.
"-" indicates that the corresponding social profit is negative. As a result, the profitability coefficient was not computed.
Source: Computed from Appendices 7.13 and 7.14.

Table 7.14 shows that, when family labor is valued at 500 CFA.F/day, private profits from the *bas-fond traditional* rice production system are 2-17 times higher than the corresponding social profits, but only 1-1.3 times higher for the *micro-semi-intensive* systems, and 3-4 times higher for the *intensive* system. When the opportunity cost of family labor is assumed to be zero, private profits from the *bas-fond traditional* rice production system are 2-3 times higher than the corresponding social profits, but only 1-1.3 times higher for the *micro-semi-intensive* systems, and 2-5 times higher for the *intensive* system.

7.6. Summary

The focus of this chapter was to (1) estimate and analyze the social profitability of subsistence and commercial *bas-fond* rice production systems, (2) evaluate their competitive position in the domestic market, relative to each other and to rice produced in the two intensive production systems in the *Office du Niger*, and (3) assess the effect of the government policies on the profitability of *bas-fond* rice production and its incentive structure.

With regard to the social profitability of commercial *bas-fond* rice production situated 307 km away from Bamako, the study found that, when family labor is valued at 500 CFA.F/day, all but the *macro-semi-intensive* production systems are socially profitable, if farmers sell their paddy harvest in Bougouni or Sikasso. In contrast, when farmers sell their paddy harvest in Bamako, only the *traditional* and the *micro-semi-intensive* systems are socially profitable.

However, the *micro-semi-intensive* rice production system is the most profitable for society at all points of sale, as shown by the estimated enterprise net return per day of family labor. It yields a net return per day of family labor at least two times higher than the net returns from any of the other three production systems, regardless of the point of sale. Also, it yields a net return per day of family labor four to five times higher than its opportunity cost (*i.e.*, 500 CFA.F/day), regardless of the point of sale. The *traditional* system is the second most profitable *bas-fond* rice production system from the point of view of society when Bamako is the point of sale, or the *intensive* system when Bougouni or Sikasso are the point of sale.

For subsistence *bas-fond* rice farming 307 km away from Bamako, the study found that, if farmers consume all their paddy, the four rice production systems under consideration yield a net return per day of family labor five to 11 times higher than its opportunity cost (*i.e.*, 500 CFA.F/day). Furthermore, the *micro-semi-intensive bas-fond* rice production system remains the most (socially) profitable of the four systems, followed by the *intensive* system. The *traditional* system is the least (socially) profitable of the four production systems.

A comparison of the social profitability of commercial *bas-fond* versus *Office du Niger* rice production systems shows that all *bas-fond* systems yield higher returns per day of family labor day than the two *Office du Niger* systems. However, due to better water control, production risk is lower in the *Office du Niger* systems, which is not accounted for in this analysis. This result suggests that the *bas-fonds* can make a lower-cost contribution to supplying the country's rice requirements than does the *Office du Niger*.

The results obtained both in the *bas-fond* and in the *Office du Niger* show that financial and social profitabilities diverge due to government policies, including the fact that farmers do not have to pay the land development costs. These divergences are such that, while farmers' ranking of the profitability of the four *bas-fond* rice production systems are only identical to social ranking for the best alternative, it different from social ranking for the second, third, and fourth alternatives.

The positive performance of the *bas-fond* rice production systems is confirmed using DRC ratios. The study found that, if farmers produce rice for their own home consumption, the value of domestic resources used in each of the *bas-fond* systems is less than the foreign exchange cost of importing more rice, regardless of the distance between the production site and Bamako. Therefore, these subsistence systems are competitive, and the *bas-fond micro-semi-intensive* production system is the most competitive of the four systems.

For commercial *bas-fond* rice production, the study shows that the competitiveness of each of the commercial *bas-fond* rice production systems under consideration varies over space depending on the market in which farmers sell their rice harvest. Similarly, their competitiveness relative to the two *Office du Niger* rice production systems also varies over space depending on the market in which farmers sell their rice harvest. For example, paddy harvested from both the *traditional* and the *micro-semi-intensive bas-fond* rice productions are competitive in either Bamako, Bougouni or Sikasso market for farms located within zero and 1,000 km away from these markets.

In addition, within a distance ranging between zero and 1,000 km, paddy harvested from the *bas-fond* systems would be more competitive than paddy of the same quality harvested from any of the *Office du Niger* systems if sold either in Bougouni or Sikasso. The same conclusion holds if farmers sell their rice in Bamako, with the exception in this case that the superiority of the competitiveness of the *bas-fond macro-semi-intensive* systems is limited to the range zero to 700 km. Clearly, this result reinforces the conclusion that the *bas-fonds* can make a lower-cost contribution to supplying the country's rice requirements than does the *Office du Niger*. However, for the country, it does not pay if the government simply builds a dam and does nothing else. It is necessary to pay attention to providing the complementary inputs, particularly herbicide.

Finally, analysis of the effect of the policy environment on the profitability of *bas-fond* rice production and its incentive structure show that the significance of this effect depends on whether a farmer is a net seller or net buyer of grain. For example, when Bamako is considered as the central output market, *bas-fond* rice producers who are net sellers of paddy are implicitly subsidized in the output market. In contrast, net buyers are implicitly taxed in the output market. When Sikasso is considered as the central output market, *bas-fond* rice producers who are net sellers of paddy are implicitly taxed in the output market, and net buyers are implicitly subsidized. When Bougouni is the central market point, *bas-fond* rice farmers are neither subsidized in the output market, nor are they taxed.

CHAPTER EIGHT
SUMMARY, RECOMMENDATIONS, AND FURTHER RESEARCH

8.1. Summary

This study was initiated to guide the Malian government's interest in considering further investments to boost domestic production of rice in order to improve the country's food security. While the government and researchers increasingly consider the untapped production potential from the largely underdeveloped *bas-fond* areas as an alternative to expanding the costly government-managed irrigation schemes which have always been the main focus of Mali's rice policy, very little is known about their production potential and profitability.

The main objective of the study was to fill this information gap by: (1) providing a better understanding of the characteristics of *bas-fond* rice production systems and factors that determine their level of intensification, (2) analyze the competitiveness of various types of *bas-fond* rice production systems, and (3) derive implications for public and private investments as well as agricultural research.

The study relies on primary data collected from a random sample of 334 production units selected from a purposive sample of 12 *bas-fond* villages in Mali-Sud, during the rainy season 1996-97. In each production unit, one rice farmer was monitored throughout the cropping season.

This concluding chapter summarizes the major findings of the dissertation and their policy implications, and suggests issues that need further investigation.

8.1.1. Rice Is an Important Consumption Good in Mali's Food System

Because Mali's climate is marked by irregular rainfall, the country's agricultural production is characterized a high degree of production variation that often leads to food deficits. Still, in 1993 Mali's agriculture accounted for the major share of country's GDP (42%), foreign exchange (75%), and employment (83%).

Mali's agricultural sector is also characterized by both a low crop diversity. The dominant crops are cotton, cereals (sorghum, millet, rice and maize), and groundnuts. Compared to other cereals, rice has important distinctive advantages. First, because rice is the only cereal grown under irrigation in this drought-prone country. Second, rice is of paramount political importance. Adequate supply of rice and relatively low rice prices benefit the politically powerful urban consumers. Thus, supply shortage or rising prices produce inflationary pressure on wages and have a potential of creating political instability.

Rice is a major consumption good in the Mali's food system. It represents about 16.7% of total per capita cereal consumption, and 6.4% of the total expenses of the Malian households. National rice consumption per capita averages about 34 kg per annum, which in absolute terms is third among the cereals after millet and sorghum. However, this average is higher in urban areas (58.0 kg) than in rural areas (24.3 kg).

8.1.2. Bas-fond Rice Production Represents a Significant Untapped Potential

Mali rice production is concentrated in the Niger Valley and Delta, especially in the Ségou and Mopti regions. The government has focused its efforts to increase rice production on both expanding the intensive irrigated areas and increasing productivity (yield) in these intensive schemes, primarily because these environments are well-watered by the Niger river. In contrast, *bas-fonds* are narrow inland valley swamps that used to be permanent rivers which have dried up due to declining rainfall. During the rainy season, the water table in these swamps rises as overflow from small rivers, seepage and slope surface runoffs from adjacent upland flood the low-lying areas. Because the cost of expanding and maintaining the irrigation systems in the North is extremely high, the government and researchers are increasingly exploring the potential of expanding the *bas-fonds* to supplement the national rice supply from these large public schemes.

The *bas-fonds* are particularly important because, as the gap between national food production and demand widened in the late 1980s-- largely because of recurrent droughts, rural-urban migration, and low agricultural productivity-- Mali has become increasingly dependant on commercial imports and food aid, much of which has been as rice. While average *bas-fond* yields (*i.e.*, 1,216 kg of rice paddy per hectare) are less than one-third the level observed in recent years in the intensive *Office du Niger* systems, in seven of the 11 villages surveyed, per capita milled rice production was higher than or equal to Mali's average rice consumption per capita (34 kg/person/year). This suggests that there exists a real potential for villages with surplus production of rice paddy to sell rice to deficit areas. If all Mali-Sud *bas-fonds* (*i.e.*, 48,657 ha) are put into production and assuming the average yield observed in this study, this would represent about 31 percent of the average quantity of paddy produced in the *Office du Niger* annually over the last five years (189,091 mt), and 22 percent of both commercial imports and food aid to Mali.

If all of Mali-Sud *bas-fonds* area (*i.e.*, 458,817 ha) were put into production, this would produce a total of 557,921 metric tons of paddy, which represents about three times the average quantity of paddy produced in the *Office du Niger* annually over the last five years (189,091 mt) and about two percent more paddy than the average quantity of commercial imports and food aid to Mali. Clearly, if this potential could be exploited, the *bas-fonds* would make a significant contribution to Mali's effort to boost domestic rice production and improve food security.

8.1.3. Yet, Limited Research/Extension Efforts Have Been Directed to the Bas-Fonds

Bas-fond rice research in Mali was launched by the *Institut d'Economie Rurale* (IER) in the 1987 by the Farming Systems Research program. This program's research activities, which is directly related to *bas-fond* rice production, focused on varietal, planting method, and herbicides trials, as well as demonstration plots between 1987 and 1989. However, these research trials were not only limited in number, but also site specific. Currently, *bas-fond* rice research is implemented primarily by the Sikasso-based Farming Systems Research Program (ESPGRN) and the *Bas-Fond* Rice projects, as well as the Bamako-based Subsector Economics Program (ECOFIL).

Until 1994, rice breeding activities of IER were limited to on-station varietal screening with minimal interaction with the FSR research program. The *sativa* rice varieties tested by scientists were originally selected for the much drier northern part of the country. As a result, the bulk of the "improved" varieties released to farmers performed poorly in the more humid *bas-fond* environments due to their susceptibility to diseases and insects. Recognizing these problems, in 1994 the breeding program refocused its efforts to develop varieties adapted to *bas-fond* water environments.

The most recent significant research effort on *bas-fonds* rice production is being carried out by the Subsector Economic Program (ECOFIL), which is characterizing and assessing the economic performance of different rice production systems in Mali. This study was carried out as part of ECOFIL program.

While CMDT[1] provides *bas-fond* rice production extension services, this support is predominantly directed at constructing and maintaining water control infrastructure in those *bas-fonds* whose feasibility study justifies the appropriateness of the investment.

8.1.4. Bas-Fond Villages Are Dispersed, Non-nucleated and Heterogeneous

The study found that *bas-fond* villages exhibit dispersed and non-nucleated settlement patterns that constitute hamlets. In general, each village, which often cuts across official boundaries, has a dominant founding lineage (clan) and one or more affinal lineages created by matrilocal marriages or the relocation of migrant settlers.

[1] CMDT is a semi-autonomous industrial and commercial enterprise to which the State has assigned the missions to promote an integrated development of the cotton subsector, and to provide public services for rural development activities.

While the dominant lineage has had superior rights over land, these rights tend to be weakening. However, these "tribal" villages are far from being homogeneous units. As a result, researchers and extension agents need to understand the existing social organization if they are to work effectively and promote broad-based participation.

8.1.5. Agriculture Is the Dominant Activity in the Bas-Fond Villages

Crop production and animal husbandry are the most important activities in the 12 villages surveyed, both in terms of PUs'[1] labor allocation and these activities contribution as sources of food and income. Ten of the 12 villages surveyed have a history of cotton production. These villages benefit from the presence the cotton extension service which provides cotton farmers greater access to production inputs.

8.1.6. Production Units Are Large and their Members Have Limited Education

The study found that PUs are large with at least two households. The PUs average about 15 people, 46-64 percent of whom are females. However, only 66.5 percent of PU members significantly contribute to farm production activities. The formal schooling rate is low (only 10.6% of the members in each PU attended or attend school), especially among females (4.1%, compared to 9.7% for males). Similarly, participating in adult literacy programs is low (7.4% across the entire sample), especially among females (3.5%, compared to 18.0% for males). Overall, about 76.0 percent of

[1] PU refers to production unit, which is defined here to include individuals involved, on a medium to long-term basis, in the household's production activities (they form the production unit) and are fed from the household's production. It can be a single nuclear family or a group of nuclear families.

the PU heads have no education at all. The low rates of formal schooling and adult literacy suggest that to be effective, researchers and extension agents must take it into account farmers' limited education background in their daily interactions with farmers.

8.1.7. Erratic Rainfall and Poor Water Control Deter Bas-fond Rice Production

The study found that *Bas-fond*s are highly complex and heterogenous agroecosystems which are cultivated by small-scale farmers who also cultivate upland fields. Since *Bas-fond* rice production systems are influenced by the erratic rainfall which has historically contributed to discourage rice farming, a careful management of the water flowing into the Mali-Sud *bas-fond* bed and into the individual plots is essential in order to fully exploit the crop's physical production potential.

Investing in water control is important to improving *bas-fond* rice production, not only because it lessens weed competition and increases the presence of critical growth and productivity factors (*i.e.*, water and nutrients), but also because it: (1) makes it possible to expand the command area, (2) allows the rice crop to escape late-season drought, (3) increases the rate of adoption of new technologies, and thus the returns to research and extension, (4) releases labor for other activities, and (5) provides an opportunity to increase land-use intensity. However, because the extent to which these benefits are captured depends on the effectiveness of the water control, the absence of effective plot-level water control in Mali-Sud *bas-fonds* limits the effectiveness of the existing infrastructure.

8.1.8. Rice Farming Is a Female-Dominated Activity

This study reveals that the composition of *bas-fond* rice farmers has been changing, both in terms of age and gender distribution. More younger women are getting involved in rice production and rice production is becoming a female-dominated activity. While the study found no correlation between farmers' gender and the adoption of "improved" varieties or herbicide, there is a significant (P=0.01) but weak positive correlation (r=0.2281) between gender and the use of fertilizer, with men (78%) more likely to use fertilizer than women (36%). The observed male propensity to use fertilizer may be explained by the fact that men tend to control household income and gain access to inputs through their cotton farming enterprise. In contrast, correlation analysis failed to indicates a significant relationship between age and adoption.

In general, PUs plant three types of fields: collective fields, men's individual fields, and women's individual fields. Most production decisions are made by the head of the PU, who gives the highest priority to collective fields in the allocation of available labor and farm implements. Rice production is dominated by women's individual fields, both in terms of total rice area planted and number of rice fields. For example, while male farmers plant rice as a source of income, female farmers attach a utility value to it attributable to the discretionary power they have over the use of their rice production. The study observed that male and female rice farmers have gender-specific concerns. This result suggests that research and extension strategies should be sensitive to gender-centered perspectives.

8.1.9. Production Practices

The study found that animal traction is widely used in Mali-Sud. While this equipment is primary used in the cotton fields and other collective upland fields, its use increases farmers' (especially women) availability to work in the *bas-fond* fields. Villages involved in cotton production tend to own more equipment than those with no cotton experience.

The study found that only 17 percent of the PUs cleared the rice field before plowing. The majority (98%) of the 120 farmers monitored prepared their field manually before planting. About 82 percent of the farmers planted less than two weeks after starting plowing, a practice which (i) exposes the seedlings to the effect of high concentration of harmful substances generated during the decomposition of the organic material incorporated in the wet soil, and (ii) limits the ability of the plant to utilize the ammonium released by decayed organic matter.

The study also found that farmers till their land manually, which provides an opportunity for herbicide use. Few farmers puddle their field before broadcasting seeds on mud, the dominant rice planting method followed by 86 percent of the farmers. Although this practice has the advantage of being easier and quicker and thus to lower labor requirements of the operation, it tends to make weeding difficult and result in significant seed waste.

The surveyed *bas-fond* rice farmers reported planting many varieties (60), although it was impossible to determine if all of the varieties were actually unique. On the average, about seven different varieties were planted in each village. The study found a highly significant association between water control and the type of varieties farmers planted, with a larger proportion of the "improved" varieties (75%) found in the *bas-fonds* with water control infrastructure, while a larger proportion of the "traditional" varieties (62%) were planted in the *bas-fonds* with no water control infrastructure.

Farmers are very aware of the depressive effect of weeds on yield. About 91 percent of the farmers weeded their rice field at least once during the cropping season, but only 18 percent weeded twice. Surprisingly, of those who weeded at least once, as much as 48 percent used herbicide (*Round up* or *Ronstar*). About 90% of the farmers who did not weed at all planted "improved" varieties. The proportion of farmers who applied herbicides is larger among those who planted "improved" varieties (62%) that those planting "traditional" varieties (33%).

Overwhelmingly, farmers argued that herbicide application could be economically justified, and farmers consistently said they would rather buy herbicide than fertilizer. Although farmers argued that fertilizers are somewhat expensive, as much as 42% of the 120 monitored farmers used chemical fertilizer in combination of urea, DAP and NPK. The proportion of farmers who used fertilizer is larger among those who planted "improved" varieties (76%) than among those planting "traditional" varieties (22%).

8.1.10. Factors Influencing Farmers' Adoption of Rice Varieties and Fertilizer

A stepwise logistic regression procedure was used to model farmers' decision to adopt "improved" varieties, herbicide, and fertilizer. The estimation results show that only the presence of a water control infrastructure and the village's years of experience in cotton production have a significant positive effect on farmers' probability to adopt "improved" varieties (*i.e.*, +50.7% and 18.9%, respectively). In contrast, female farmers, the village distance to the closest market, and plot size have a negative effect on this probability (*i.e.*, -53.9, -5.4, and -9.5%, respectively).

Statistical analysis reveals that in addition to the fact that farmers who adopt "improved" varieties are more likely to the use herbicide and chemical fertilizer (*i.e.*, +27% and +26%, respectively), different factors significantly affect this probability for herbicide versus fertilizer. The only additional factor influencing herbicide adoption was the village's distance to the closest urban market. For chemical fertilizers, the presence of a water control infrastructure and the village experience in cotton production increase the likelihood to use them (*i.e.*, +46% and +36%, respectively).

8.1.11. Factors Determining Farmers' Rice Yield

Using the linear form of a quadratic yield function, a stepwise OLS regression procedure revealed that, as expected, water stress, insects attacks, herbicide and nitrogen applications, as well as seeding rate, weeding date after planting, and water control significantly impact yield. The yield effect of water stress during a critical growth period reduces yield by 233 kg of paddy. Similarly, a significant insect attacks during the cropping season reduces yield by 865 kg of paddy, which is more than three times the yield loss due to water stress.

Herbicide application, which provides better control of weeds that compete with the rice plant for nutrients, water and solar radiation, tends to increase yields by 612 kg of paddy, compared to no herbicide at all. The seeding rate has a significant positive effect on yields (*i.e.*, 2 kg of paddy for each additional kg of seed). In contrast, the yield effect of nitrogen application is significantly higher in the CMDT region of Bougouni than in Sikasso. The yield difference among farmers who used "improved" varieties and fertilizer amounted to 1,677 kg more rice paddy in Bougouni than in Sikasso. No significant difference was obtained for farmers who used "traditional" varieties, with or without fertilizer application.

8.1.12. Bas-fond Rice Production Systems

To identify the main rice production systems in the *bas-fonds*, yields were grouped by input combinations that farmers used. The result obtained indicates that farmers' most frequent strategy for intensifying rice production in the *bas-fond* surveyed involved a combination of water control, "improved" variety, and fertilizer and herbicide use. The most frequent production systems are: the *purely traditional production system* (N=19), the *macro-semi-intensive* production system (N=13), the *micro-semi-intensive* production system (N=11), and the *intensive* production system (N=18).

Farmers using the *purely traditional* production system, the most "traditional" of the four systems, did not have access to water control, planted "traditional" rice varieties, and applied no chemical fertilizer or herbicide. Those using the *macro-semi-intensive* production system had access to water control, used "traditional" rice varieties, but applied no chemical fertilizer or herbicide; Those using the *micro-semi-intensive* production system did not had access to water control, planted "traditional" rice varieties, applied no chemical fertilizer, but applied some herbicide; In contrast, those using the *intensive* production system benefitted from water control, used "improved" rice varieties, and applied both chemical fertilizer and herbicide.

8.1.13. Bas-Fond Rice Production Profitability Depends on the Cost of Family Labor

Using standard budgeting techniques, the study found that when family labor is excluded, the average cost of production is 40,338 CFA.F/ha for the *micro-semi-intensive* system, 58,815 CFA.F/ha for the *traditional* system, 69,492 CFA.F/ha for the *macro-semi-intensive* system, and 147,407 CFA.F/ha for the *intensive* system. When family labor is included as a cost component and valued at 500 CFA.F/day, the average cost of production under each system increases by 19-51 percent, ranging from 61,088 CFA.F/ha for the *micro-semi-intensive* system, 80,148 CFA.F/ha for the *traditional* system, 88,158 CFA.F/ha for the *macro-semi-intensive* system, to 175,824 CFA.F/ha for the *intensive* system. In both cases (*i.e.*, including or excluding family labor), labor represents the highest share of production costs in all four systems.

The study stresses that, to a large extent, the estimated level of *bas-fond* rice production profitability depends upon the assumed opportunity costs of family labor. Using an opportunity costs of family labor of 500 CFA.F, the study shows that these systems are financially profitable. For all systems, the returns per hour of family labor in the rice field (1,374-2,971 CFA.F/hr) is higher than its opportunity cost (*i.e.*, 500 CFA.F/hr). The same observation is made for the cost of producing a kg of paddy (43-78 CFA.F/kg), which is lower than the output farm-gate price of 115 CFA.F.

Among the four systems studied, the most profitable is the *micro-semi-intensive* system, which has the lowest average production costs per kg of paddy produced (*i.e.*, 43 CFA.F/kg), and the highest return to a day of family labor (*i.e.*, 2,971 CFA.F/day). This system is so profitable in part because it is also the system that used the least labor per ha, primarily because of significant herbicide substitution for hired labor in weeding. The least profitable of the four production systems is the *traditional* system, which has an average production costs of 78 CFA.F/kg of paddy produced, and a return to a day of family labor amounting to 1,374 CFA.F/day.

Given the estimated costs and output price, under the *traditional* production system, a 32 percent "poor year" yield decrease would be necessary for farmers to break even, *ceteris paribus*. The same estimate is 38 percent for *macro-semi-intensive*, 63 for *micro-semi-intensive*, and 35 *intensive* systems.

8.1.14. Bas-Fond Rice Production Is More Profitable than Cotton and Cereals

The study found that the three upland crops (cotton, maize, and sorghum/millet) and the rice enterprise have positive net returns to family labor. In other words, when the opportunity cost of family labor is assumed to be equal to zero, these four crops are profitable to farmers. However, the estimated returns to a day of family labor show that all four *bas-fond* rice production systems yield higher returns to a day of family labor than the three upland crop enterprises, regardless of their level of mechanization, followed by maize and then sorghum/millet. The cotton enterprise yields the lowest return to a day of family labor among the four crops being compared.

When the opportunity cost of family labor is assumed to be 500 CFA.F/day, the return to a day of family labor from the rice, maize and sorghum/millet enterprises are higher than his/her opportunity cost, regardless of their level of mechanization. In contrast, the return per day of family labor from the cotton enterprise is higher than his/her opportunity only when the farmer uses one animal traction implement. One critical reason why the cotton enterprise looks unprofitable is because almost all fixed costs of the upland crops are attributed to cotton production.

8.1.15. The Financial and Social Profitability Bas-Fond Rice Production Diverge

Because inputs costs and paddy price are distorted by Mali's agricultural and trade polices, it was necessary to estimate the profitability of the four *bas-fond* production systems from the point of view of the society. To achieve this, input costs and output prices were adjusted to reflect their true social values if farmers were to sell their rice production in either of three market points, namely Bamako, Bougouni and Sikasso. The study found that financial and social profitabilities diverge. The results obtained show that the rankings of the four *bas-fond* rice production based on their financial and social profitabilities are not always identical. While farmers' ranking of the profitability of the four *bas-fond* rice production systems are only identical to social ranking for the best alternative, it diverges from social ranking across output markets for the other ranks.

If *bas-fond* farmers produce rice to sell the output in Bamako and the opportunity cost of family labor is assumed to be zero, all but the *macro-semi-intensive bas-fond* rice production systems are profitable to the society. However, when family labor is valued at 500 CFA.F/day, the estimated net returns per day family labor indicate that only farmers using the *micro-semi-intensive* and the *traditional bas-fond* rice production systems earn more than their opportunity costs. Thus, only these two systems (*i.e.*, *micro-semi-intensive* and the *traditional*) are socially profitable.

In contrast, if *bas-fond* rice farmers sell their paddy harvest in either Bougouni or Sikasso and the opportunity cost of family labor is assumed to be zero, all four *bas-fond* rice production systems are profitable to the society. However, when family labor is valued at 500 CFA.F/day, all but the *macro-semi-intensive bas-fond* rice production system are socially profitable.

The study fund that, the *micro-semi-intensive* rice production system, which was the farmers' best option in the financial analysis, is also the most profitable to society. It yields a net return per day of family labor at least two times higher than the net returns from any of the other three production systems, regardless of the point of sale. Also, it yields a net return per day of family labor four to five times higher than its opportunity cost (*i.e.*, 500 CFA.F/day), regardless of the point of sale.

Under subsistence farming and assuming a zero opportunity cost of family labor, all four *bas-fond* rice production systems are profitable to the society. When family labor is valued at 500 CFA.F/day and farmers consume all their paddy, these systems yield a net return per day of family labor five to 11 times higher than its opportunity cost. Furthermore, the *micro-semi-intensive bas-fond* rice production system remains the most (socially) profitable of the four systems, followed by the *intensive* system. The *traditional* system is the least (socially) profitable of the four production systems. These results provide an empirical indication that the *micro-semi-intensive* rice production system is the most competitive of the four systems.

However, it is important to recognize the limitations of the results and the scale bias of this indicator. First, the levels of social profitability reported are based on the assumption of hypothetical *bas-fond* villages assumed to be situated 307, 144 and 144 km away from Bamako, Bougouni, and Sikasso, respectively. Second, the analysis does not take into account the relative importance of the various systems, measured in terms of total area cultivated. Furthermore, this research does not address how likely farmers are to change from one system to another, and what needs to be done to achieve such changes.

A comparison of the social profitability of commercial *bas-fond* versus the *Office du Niger* shows that when family labor is valued at 500 CFA.F/day, all *bas-fond* production systems yield higher returns to the society than the two *Office du Niger* systems, regardless of the point of sale. Indeed, none of the *Office du Niger* is socially profitable. However, due to better water control, production risk is lower in the *Office du Niger* production systems, which is not accounted for in this analysis. Nonetheless, this result suggests that the *bas-fonds* can make a lower-cost contribution to supplying the country's rice requirements than does the *Office du Niger*.

8.1.16. Bas-Fond Systems Are Competitive and Office du Niger Systems Are Not

To explicitly reinforce the finding that the contribution of *bas-fond* rice production to the overall Mali's economy is great enough to justify using scarce resources that are required to further develop these systems, they were compared with the representative rice production systems from the *Office du Niger*'s rehabilitated and non-rehabilitated perimeters, in terms of social profitability and efficiency in the use of domestic resources. The results obtained from DRC estimation indicate that, under subsistence farming, the four *bas-fond* rice production systems have DRC ratios which are less than 0.7, regardless of the distance between the production/consumption point and Bamako. In other words, producing rice for home consumption in any of the Mali-Sud *bas-fonds* is a better use of domestic resources than importing rice to feed farmers.

For commercial production, the results obtained suggest that, as expected, the competitiveness of the commercial *bas-fond* rice production systems relative to each other depends on the central market point at which they are compared. For example, if *bas-fond* farmers sell their rice harvest in Bamako, the *micro-semi-intensive* production system is not competitive in this market, regardless of the distance between Bamako and their production site. In contrast, the *intensive* system is competitive in the Bamako market only for distances "Bamako-production site" ranging between zero and 740 km. At a distance of 740 km from Bamako, the system's DRC becomes equal to one and the system is no longer competitive. Rice harvest from both the *traditional* and the *micro-semi-intensive bas-fond* production systems are competitive in the Bamako market for farms located within zero and 1,408 and 4,206 km away from Bamako, respectively.

Finally, analysis of the effect of the policy environment on the profitability of *bas-fond* rice production and its incentive structure show that the significance of this effect depends on whether a farmer is a net seller or net buyer of grain. For example, when Bamako is considered as the central market point of comparison, *bas-fond* rice producers who are net sellers of paddy are implicitly subsidized in the output market. In contrast, net buyers are implicitly taxed in the output market. When Sikasso is considered as the central market point of comparison, *bas-fond* rice producers who are net sellers of paddy are implicitly taxed in the output market, and net buyers are implicitly subsidized. When Bougouni is the central market point, *bas-fond* rice farmers are neither subsidized in the output market, nor are they taxed.

8.2. Policy Implications for Research and Extension

The yield analysis showed that *bas-fond* rice production makes a significant contribution to Mali's domestic supply of rice. The study argued that this contribution can be improved if the *bas-fond* potential is fully exploited. Financial and economic analysis showed that producing rice in the *bas-fond* is economically justified for the farmers and for the country. However, the study observe that given the complexity and heterogeneity of the *bas-fond* production environment, transforming high on-station experimental yields into farmers' fields represents an enormous challenge for Malian researchers, as scientists must develop higher-yielding varieties that are appropriate for the unstable heterogeneous *bas-fond* environments. In order to expand rice production, the study identifies four principal directions for *bas-fond* research: increasing yield, lowering inputs cost (*e.g.*, fertilizer application and labor content of technologies), reducing growth duration of the plant, and facilitate farmers' adoption of research-generated varieties.

To increase rice yield, priority must be given to stabilizing the production environment through more effective water control/management, and to developing appropriate complementary technologies to relax fertility, pest, and diseases constraints.

In order to increase farmers' adoption and the returns to research, women --who play a major role in rice production in the *bas-fond*-- should be given greater and direct access to credit and information about new rice technologies and other resources.

Furthermore, investing in *bas-fond* rice research will require strengthening the support to scientists, and the link between researchers and extension agents. Also, the study found that farmers' education is low and that male and female rice farmers have gender-specific concerns. These results suggest that to be effective, researchers and extension agents must take into account farmers' limited education background in their daily interactions with farmers, both in terms of the complexity of the technology being tested or promoted, and the communication strategies used to promote technology adoption.

Finally, to gain political support to carry out the research needed to develop appropriate technologies suitable for greater intensification of *bas-fond* rice farming, the Malian agricultural research scientists will have become proactive advocates of the value of agricultural research, especially given the limited political power of the farmers.

8.3. Recommendations and Priorities for Further Studies

Discussions of this study's findings, which show the significant potential contribution of *bas-fond* rice production to achieving greater food security in Mali, have suggested additional research efforts are needed to fully exploit this potential. In particular, the study recommends that research be carried out:

a. to assess the potential contribution of further infrastructural development (*i.e.*, internal bunding), in order to improve the effectiveness of water control;

b. on the timeliness and quality of land preparation in order to fully realize the crop yield potential;

c. to estimate the opportunity cost of family labor, including the elasticity parameters of demand and supply of labor categories (*eg.*: female versus male labor) in order to improve profitability analysis.

d. to inventory and describe rice varieties planted by farmers, in terms of their morphological, physiological, and genetic characteristics;

Finally, this research focused on farm-level activities and did not look at post-harvest issues. In particular, a significant research issue is the extent to which the rice production contribute to PUs' food security throughout the post-harvest period. The study therefore recommends that further studies be carried out to determine what distinguishes between farmers who are net buyers of grain and those who are net sellers of grain over time.

8.4. Limitations

This study was a pioneer research effort extending over more than one *bas-fond* village. While the factors used to select the sample villages may describe diversity in *bas-fonds* in Mali-Sud, their relative importance in terms of factors such as the area each factor represents was not fully taken into account because the necessary data were not available. Thus, generalizing the inferences that are drawn from this sample to the Mali-Sud area should be done cautiously.

Furthermore, because the data used in the analysis were collected in one season, the findings reported in this dissertation are specific to the particular conditions that prevailed at the time the data were collected, especially for rainfall. Finally, a good deal of the data collected for this study is recall data, which are typically associated with the concern for reliability.

APPENDICES

APPENDICES

Appendix 2.1: Population Distribution (%) by Annual Expenditure Level and by Administrative Region, Mali, 1988-89.

Per capita Expenditure Level	Percent Population								National	
('000 cfa.F/year)	Kayes	Koulikoro	Sikasso	Segou	Mopti	Toumbouctou	Gao	Bamako District	Percent Total Expenditures	Percent Total Population
0-25	0.0	0.6	0.1	1.6	5.9	0.9	2.6	0.8	0.2	1.6
25-50	4.3	1.7	11.4	15.7	32.9	14.5	14.2	0.1	4.2	12.5
50-75	10.2	16.9	34.8	25.6	24.6	18.7	19.1	5.1	11.0	21.3
75-100	22.1	19.8	21.5	23.7	16.7	18.6	14.3	10.3	14.2	19.5
100-125	13.9	18.0	12.2	14.2	7.5	15.2	8.3	9.0	11.7	12.7
125-150	15.5	9.7	8.4	5.7	4.4	11.6	14.7	15.3	10.3	9.1
150-175	9.6	11.1	3.4	5.1	3.3	6.9	2.5	9.9	8.7	6.5
175-200	4.5	4.1	4.6	2.5	0.8	4.8	5.6	8.8	6.2	4.0
200-225	4.4	6.9	0.7	0.4	1.5	0.5	6.2	9.2	5.7	3.2
225-250	2.8	2.7	0.8	0.7	0.7	0.7	5.1	8.8	4.4	2.3
250-275	2.2	1.6	0.8	0.5	0.2	2.6	0.5	5.0	3.1	1.4
275-300	3.1	1.0	0.5	0.0	0.3	1.3	0.0	4.1	2.7	1.2
300-325	1.2	0.9	0.0	2.3	0.1	1.5	1.9	3.9	3.3	1.2
325-350	0.9	0.7	0.1	0.5	0.3	0.1	0.7	2.2	1.7	0.6
350-400	1.3	1.2	0.3	0.6	0.4	0.4	1.0	2.5	2.7	0.9
400-450	1.2	0.6	0.4	0.3	0.2	1.6	0.6	0.6	2.1	0.6
> 450	2.8	2.6	0.2	0.6	0.0	0.1	2.5	4.4	7.8	1.5

Source: Adapted from DNSI 1988-89 Expenditure/Consumption Survey.

Appendix 2.2: Per Capita Average Annual Cereals Consumption (kg/year/individual), Mali, 1988/89.

Year	Domestic Milled[a] Rice Production		Population		Annual Per Capita Milled[a] Rice Requirement[b] (kg/person)	Estimated National Milled Rice Demand (kg)	% National Milled Rice Demand Met by Domestic Production
	Amount (mt)	Annual Growth Rate (%)	Number (inhabitants)	Annual Growth Rate (%)			
1987-88	153,769	5.08	7,728,011	-	22.4	173,107.45	88.83
1988-89	187,068	21.66	7,849,992	1.58	22.3	175,054.82	106.86
1989-90	219,537	17.36	7,983,588	1.70	27.4	218,750.31	100.36
1990-91	183,538	-16.40	8,129,569	1.83	33.2	269,901.69	68.00
1991-92	295,327	60.91	8,289,210	1.96	34.3	284,319.90	103.87
1992-93	266,512	-9.76	8,464,282	2.11	34.3	290,324.87	91.80
1993-94	277,946	4.29	8,648,599	2.18	34.3	296,646.95	93.70
1994-95	304,932	9.71	8,831,713	2.12	34.3	302,927.76	100.66

[a] Milled rice production is obtained by using a milling recovery factor of 65 percent.

[b] There has been no study conducted to estimate national milled rice requirement. Like most studies and policy makers, annual per capita consumption of milled rice is used as a proxy for milled rice requirement. It is assumed here that the requirement level did not change between 1991 and 1995.

Source: DNSI/Bureau Central du Recencement (1992) for population data, DNSI for domestic rice production and annual per capita milled rice requirement.

Appendix 2.3: Relative Contribution of Cotton, Livestock, Rice and Maize to Foreign Earnings, Mali, 1970-94.

Year	Share of Agricultural Export Value (%)		Share of Agricultural Import Value (%)			Share of Cereal Import Value (%)	
	Cotton	Bovines, Ovines & Caprins	Cereals	Rice	Maize	Rice	Maize
1970	20.9	2.1	17.5	9.0	0.0	51.7	0.0
1971	24.4	2.2	26.6	9.2	0.9	34.6	3.4
1972	3.8	2.0	32.2	18.8	0.0	58.3	0.0
1973	2.9	1.7	38.0	16.3	6.4	42.8	16.8
1974	2.8	1.9	49.8	26.2	7.0	52.6	14.1
1975	2.1	1.3	53.8	7.8	7.4	14.5	13.7
1976	33.3	16.1	15.2	0.1	0.0	0.6	0.1
1977	39.6	13.5	11.0	0.0	0.0	0.0	0.0
1978	41.9	18.4	48.4	25.4	9.3	52.5	19.2
1979	42.8	37.3	36.0	26.9	0.0	74.7	0.0
1970-79	28.3	11.3	39.1	16.3	4.7	41.7	12.0
1980	43.8	51.7	52.2	39.9	2.0	76.5	3.8
1981	29.6	55.2	48.5	20.3	10.9	41.8	22.4
1982	23.9	60.6	50.5	34.8	6.8	68.8	13.4
1983	39.4	73.2	66.5	27.6	12.7	41.5	19.1
1984	43.5	54.0	69.7	52.9	7.6	75.9	10.9
1985	34.4	46.5	62.8	27.3	17.2	43.5	27.4
1986	25.2	50.5	29.9	23.0	2.2	76.7	7.4
1987	47.0	32.7	18.8	11.9	0.0	63.3	0.0
1988	46.5	41.4	28.1	21.4	0.9	76.4	3.3
1989	52.1	35.9	20.8	14.4	0.0	69.6	0.0
1980-90	37.3	40.3	47.6	30.2	6.5	63.5	13.6
1990	66.9	38.9	12.4	5.5	0.0	44.3	0.0
1991	65.0	29.8	42.1	30.7	0.6	72.9	1.4
1992	61.0	34.0	23.3	13.3	0.3	57.3	1.2
1993	62.1	33.5	19.4	10.5	0.1	54.3	0.7
1990-93	61.6	25.8	24.4	15.7	0.2	64.2	0.9
1970-93	43.3	29.2	38.4	22.5	4.1	58.6	10.7

Source: Adapted from FAO Trade Yearbooks for 1975 to 1993.

Appendix 2.4: Average Annual Per Capita Food Consumption (kg/person/year) in Mali, 1988/89.

Food Type	Rural Areas	Urban Areas	National
Cereals	245.90	168.90	212.43
Oil	2.89	4.81	3.28
Meat	4.85	10.90	6.10
Fish	9.09	11.68	9.62
Legumes	0.24	0.11	0.21
Fruits	1.02	7.83	2.41
Sugar and sugar products	3.25	14.83	5.63
Tuber crop	2.66	5.23	3.19
Milk and milk products	9.75	4.81	8.74
Green leaves	0.55	2.86	1.02
Legumes/Canned	0.51	1.33	0.68
Legumes	6.72	17.11	8.85
Bread and pastry	3.58	5.37	3.24

Source: Ministère de l'Agriculture, de l'Elévage et de l'Environnement (1992) citing the 1988/89 consumption/expenditure survey data.

Appendix 2.5: Rice Import and Domestic Production in Mali, 1970-94.

Years	Milled[a] Rice Imports ('00 mt)[b]	Rice Import Value (US $ '0,000)	National Production of Milled[a] Rice ('00 mt)	Total Milled[a] Supply ('00 mt)
1970-71	145 (10.6)	140	893	1,038
1971-72	150 (9.6)	195	1,021	1,171
1972-73	305 (26.3)	434	753	1,058
1973-74	457 (34.9)	1,068	850	1,307
1974-75	653 (36.5)	2,758	1,161	1,814
1975-76	151 (7.7)	530	1,274	1,425
1976-77	1 (0.0)	3	1,938	1,939
1977-78	0 (0.0)	0	1,029	1,029
1978-79	205 (13.0)	930	1,561	1,766
1979-80	244 (10.2)	975	1,561	1,805
1980-81	531 (43.5)	2,991	790	1,321
1981-82	235 (17.4)	1,400	876	1,111
1982-83	711 (46.5)	3,550	992	1,703
1983-84	648 (30.0)	1,674	1,404	2,052
1984-85	2,566 (235.4)	7,631	711	3,277
1985-86	1,140 (53.3)	2,780	1,390	2,530
1986-87	1,291 (57.2)	2,800	1,463	2,754
1987-88	500 (21.1)	1,000	1,538	2,038
1988-89	703 (24.4)	2,200	1,871	2,574
1989-90	505 (14.9)	1,800	2,195	2,700
1990-91	200 (7.1)	640	1,835	2,035
1991-92	1,284 (28.3)	4,300	2,953	4,237
1992-93	400 (9.8)	1,400	2,665	3,065
1993-94	315 (7.4)	1,040	2,779	3,094

[a] Milled Rice equivalent is obtained by converting the paddy value at the rate of 100 kg of paddy equals 65 kg of milled rice.

[b] Each of the numbers in the parentheses represents the import share of total national supply of rice for that particular year.

Source: Adapted from FAO Trade Yearbooks for 1975 to 1993 for the trade variables, and the DNA/DNSI statistics for national production.

Appendix 2.6: Percentage Distribution of the Main Sources of Rice Consumption by Administrative Region, Mali

Administrative Region	Consumption Per Capita (kg/year)	Origin of Total Rice Consumed in the Region[a]		(%) Total Population
		Purchases (%)	Own Production (%)	
Gao	68.81	63.2	31.2	4.1
Kayes	21.24	92.8	6.1	13.5
Segou	34.36	45.7	49.8	18.5
Mopti	47.57	43.3	47.8	16.1
Sikasso	12.00	59.0	39.0	18.0
Koulikoro	19.70	93.1	5.3	15.4
Tombouctou	69.87	53.8	41.4	5.1
Bamako District	59.69	99.4	0.2	9.3
National	34.00	65.3	30.5	100.0
- urban	58.02	92.3	6.2	27.5
- rural	24.91	41.4	52.0	72.5

[a] Other origins are gifts and donation, exchange, marriages, and traditional ceremonies.

Source: 1988/89 National Budget-Consumption Survey.

Appendix 2.7: Per Capita Average Annual Cereals Consumption (kg/year/individual), Mali, 1988/89.

Region	Absolute values				Percentage within the Region[a]			
	Millet	Sorghum	Maize	Milled Rice	Millet	Sorghum	Maize	Milled Rice
Kayes	22.7	107.7	34.7	21.2	12.18	57.81	18.63	11.38
Koulikoro	99.2	92.7	20.2	19.7	42.80	39.99	8.71	8.50
Sikasso	82.7	50.7	73.7	12.0	37.75	23.14	33.64	5.48
Segou	114.3	27.3	17.3	34.4	59.13	14.12	8.95	17.80
Mopti	147.9	24.9	5.6	47.6	65.44	11.02	2.48	21.06
Tombouctou	69.2	49.2	7.1	69.9	35.41	25.18	3.63	35.77
Gao	42.4	15.4	21.6	68.8	28.61	10.39	14.57	46.42
Bamako	22.4	42.1	7.8	59.7	16.97	31.89	5.91	45.23
National	85.6	53.7	27.1	34.0	42.71	26.80	13.52	16.97
urban	44.5	37.8	13.6	58.0	NA	NA	NA	NA
rural	101.1	60.0	32.2	24.3	NA	NA	NA	NA

[a] Each of these numbers represents the crop share of per capita average annual consumption of millet, sorghum, maize and milled rice.

"NA" stands for "Not Applicable".

Source: DNSI, 1988-1989 National Budget-Consumption Survey.

Appendix 2.8: Rice Area, Yield and Total Production in the *Office du Niger*, 1973/74- 1994/95, Mali.

YEAR	AREA (ha)	AVERAGE YIELD (t/ha)	TOTAL PRODUCTION[(a)] (t)	PADDY SALE BY *OFFICE DU NIGER* (t)
1973/74	40,139	2.071	83,128 (63.1)	54,862
1974/75	40,774	2.109	86,000 (48.0)	65,000
1975/76	39,916	2.254	90,000 (45.9)	63,880
1976/77	39,567	2.385	94,400 (31.7)	65,500
1977/78	37,946	2.662	101,000 (33.3)	58,044
1978/79	36,557	2.599	95,000 (60.1)	52,297
1979/80	35,104	1.775	62,314 (26.0)	50,756
1980/81	35,589	1.977	69,290 (56.8)	50,668
1981/82	34,802	1.780	62,801 (46.5)	47,450
1982/83	35,181	1.607	56,524 (36.9)	43,796
1983/84	36,920	1.751	64,663 (30.0)	43,148
1984/85	38,154	1.680	64,086 (58.8)	45,562
1985/86	39,433	2.100	82,957 (38.8)	54,111
1986/87	39,910	2.205	88,011 (39.1)	49,672
1987/88	42,125	2.346	98,194 (41.4)	47,522
1988/89	43,352	2.253	97,796 (34.0)	64,939
1989/90	44,251	2.411	106,593 (31.5)	50,794
1990/91	43,872	3.280	143,938 (51.1)	18,158
1991/92	44,435	4.071	180,909 (39.8)	41,521
1992/93	43,700	4.300	187,910 (45.8)	25,000
1993/94	45,600	4.900	223,400 (52.2)	10,000
1994/95	45,500	4.600	209,300 (44.6)	2,000

[(a)] Each of the numbers in the parentheses represents the share of *Office du Niger* rice production in the Mali's domestic rice production for that particular year.

Source: *Office du Niger* (1993).

Appendix 2.9: Inventory of Size, Investment Year and Costs of *Bas-Fonds* with Water Control Investments in the CMDT Regions in 1982, Mali.

Perimeter	Area (ha)	Year	Costs	Funding Source
CMDT REGION OF SIKASSO				
Kléla	1,200	1975-79	536,224	FED
Toubouroumadie	90	1982-83	17,475	FED
Doumanaba	190	1982-83	16,209	FED
Samogossoni	180	1982-83	49,519	FED
Bambadougou	200	1974	2,500	FED
Longorola	50	1981-82	22,490	FED
Kargouan	160	1980-82	40,957	FED
Kado	200	1979-80	20,000	FED
Gouene	65	1958	2,700	TD
Siou	100	1981	na	FED
Lole	180	1981	na	FED
Loulouni	800	1974	7,500	BIRD
Nieana east	110	1986-87	222,000	WORLD BANK
Niena west	30	1982	8,356	FED
Kobi (valley)	180	1978	na	FED
Zaniena	1,000	1979	na	FED/TD
CMDT REGION OF KOUTIALA				
Kouniana	830	1958	na	FED
Sourbasso	490	1958	na	FED
Sinkolo	760	1962	na	TD
CMDT REGION OF SAN				
San west	3,500	1976	1,000,000	FED
San east	-	na	na	na
Bougoura	5,000	1958	na	FED
CMDT REGION OF BOUGOUNI				
Yoroba	60	1976	2,500	FED
Faboulako	60	1976	2,500	FED
Dalabani	70	1976	15,000	FED
Beguela	325	1981	na	FED
Diaban	650	na	na	na
CMDT REGION OF MANA				
Zena	150	1976	4,000	FED
TOTAL AREA MALI-SUD	16,630			

"na" stands for "not available".
Source: CMDT/Projet Riz, Sikasso Riziculture en Zone Mali-Sud, pp.2-3.

Appendix 4.1: Estimated Correlation Coefficients Between the Total Area Planted (upland and the *Bas-Fond*) by a PU and Farm Equipment, by Farm Equipment and by Village, Mali-Sud, Rainy Season 1995-96.

	Total Area Planted (upland and *bas-fond* combined)						
	PLOW	CARTS	SEEDERS	HARROW	P. TILLER	OXENS	DONKEYS
Banko	0.7683**	0.5308*	0.7393**	0.5890**	0.1464	0.7282**	0.5002*
Diassola	0.7090**	0.4289	0.4622	.	0.8473**	0.5559*	0.4811
Faradjélé	0.4283	0.4716*	0.5329*	.	0.5408*	0.6356**	0.3263
Faradié	0.7065**	0.5358*	0.3370	.	0.6237**	0.5944**	0.6160**
Sola	0.5309*	0.4264*	0.3559	.	0.3353	0.4062	0.2914
Solo	0.6379**	0.5636**	0.3896	0.6759**	0.3125	0.6240**	0.3931
Kado	0.7972**	0.5740**	0.6931**	0.7634**	0.6490**	0.7922**	0.5568**
Kafuziéla	0.3006	0.5393*	0.5404*	.	0.1665	0.6695**	0.4320*
Longorola	0.3840	0.5002*	.	.	0.4093	0.5682**	0.3715
Niéna	0.5823**	0.5721**	0.7420**	0.5157**	0.4381*	0.7327**	0.5311*
Péniasso	0.4760*	0.3626	0.6701**	0.2947	0.7585**	0.7173**	0.1749
Sikasso	-0.20291	0.3459	.	.	.	.	0.2881

The symbol "." is used when the correlation coefficient could not be computed due to small sample size.
The symbol "*" is used when $P \leq 0.05$ while "**" indicates that $P \leq 0.01$ (2-tailed significance). The correlation coefficients with no asterisk are not statistically significantly different from zero at $\alpha \leq 0.05$.
Source: Survey of 334 Households in 12 *Bas-Fond* Villages in Mali-Sud.

Appendix 4.2: Estimated Correlation Coefficients Between the Total Area Planted in the Upland by a PU and Farm Equipment, by Farm Equipment and by Village, Mali-Sud, Rainy Season 1995-96.

	Total Area Planted (upland only)						
	PLOW	CARTS	SEEDERS	HARROW	POWER TILLER	OXEN	DONKEYS
Banko	0.7486**	0.5413**	0.7299**	0.5676**	0.1698	0.7016**	0.5169*
Diassola	0.6969**	0.3936	0.3989	.	0.8271**	0.5516*	0.4300
Faradjélé	0.4117	0.5208*	0.5733*	.	0.5325*	0.6470**	0.3634
Faradié	0.6931**	0.5477**	0.3319	.	0.6363**	0.5867	0.6283**
Sola	0.5184*	0.4231*	0.3519	.	0.3291	0.3991	0.3014
Solo	0.6258**	0.5457	0.3689	0.6765**	0.2364	0.6193**	0.3365
Kado	0.6333*	0.2443	0.5770*	0.5804*	0.3619	0.6731*	0.4397
Kafuziéla	0.2660	0.5308*	0.4777*	.	0.0557	0.6018**	0.5147*
Longorola	0.3523	0.4793*	.	.	0.3420	0.5105*	0.2954
Niéna	0.5067*	0.5772**	0.6606*	0.4715*	0.3296	0.6360**	0.5392*
Péniasso	0.4974*	0.3773	0.7069*	0.3479	0.7763**	0.7318**	0.2344
Sikasso	-0.0648	0.2288	.	.	.	.	0.2882

The symbol "." is used when the correlation coefficient could not be computed due to small sample size.
The symbol "*" is used when $P \leq 0.05$ while "**" indicates that $P \leq 0.01$ (2-tailed significance). The correlation coefficients with no asterisk are not statistically significantly different from zero at $\alpha \leq 0.05$.
Source: Survey of 334 Households in 12 *Bas-Fond* Villages in Mali-Sud.

Appendix 4.3: Estimated Correlation Coefficients Between the Total Area Planted in the *Bas-Fond* by a PU and Farm Equipment, by Farm Equipment and by Village, Mali-Sud, Rainy Season 1995-96.

	Total Area Planted (*bas-fond* only)						
	PLOW	CARTS	SEEDERS	HARROW	P. TILLER	OXENS	DONKEYS
Banko	0.6440**	0.1835	0.5166*	0.5596**	-0.1730	0.6974**	0.0990
Diassola	0.5520*	0.5730*	0.8511**	.	0.6872**	0.4122	0.7501**
Faradjélé	0.4687	0.1161	0.1185	.	0.5076*	0.3699	0.0749
Faradié	0.5768**	0.1490	0.2591	.	0.1893	0.4380*	0.1892
Sola	0.4919*	0.3314	0.2885	.	0.2943	0.3535	0.1105
Solo	0.1728	0.1849	0.0314	0.1235	0.3975	0.1370	0.3254
Kado	0.3790	0.4386*	0.3542	0.5687	0.4194	0.2499	0.1156
Kafuziéla	0.2259	0.2904	0.4066	.	0.3208	0.4826*	0.0416
Longorola	0.3601	0.4154	.	.	0.4726*	0.5616**	0.4686*
Niéna	0.7596*	0.5599	0.8413*	0.7407	0.7069	0.9041**	0.5599
Péniasso	0.3407	0.2635	0.4641*	0.1150	0.5823**	0.5564**	0.0012
Sikasso	-0.0721	0.2976	.	.	.	.	0.0769

The symbol "." is used when the correlation coefficient could not be computed due to small sample size.
The symbol "*" is used when $P \leq 0.05$ while "**" indicates that $P \leq 0.01$ (2-tailed significance). The correlation coefficients with no asterisk are not statistically significantly different from zero at $\alpha \leq 0.05$.
Source: Survey of 334 Households in 12 *Bas-Fond* Villages in Mali-Sud.

Appendix 4.4: Estimated Correlation Coefficients Between the Number of Fields Planted in the Upland and the *Bas-Fond* and the Number of Working People in a PU, by Village, Mali-Sud, Rainy Season 1995-96.

	Total Number of Fields			
	female workers	male workers	both genders age ≥ 15	both genders age ≥ 6
Banko	0.7014**	0.7104**	0.7585**	0.7340**
Diassola	0.5207*	0.4027	0.4714	0.5227*
Faradjélé	0.7632**	0.6127**	0.7739**	0.7643**
Faradié	0.8323**	0.7493**	0.8629**	0.8749**
Sola	0.1756	0.4269*	0.3324	0.3905*
Solo	0.1340	0.4133*	0.2955	0.3098
Kado	0.3300	0.3935*	0.3839	0.2699
Kafuziéla	0.6263**	0.6860**	0.7029**	0.6072**
Longorola	0.6798**	0.7537**	0.7828**	0.7733**
Niéna	-0.1936	-0.0828	-0.1502	-0.1428
Péniasso	0.6756**	0.7697**	0.7695**	0.7662**
Sikasso	0.5212*	0.3851	0.5761**	0.5991**

The symbol "*" is used when $P \leq 0.05$ while "**" indicates that $P \leq 0.01$ (2-tailed significance). The correlation coefficients with no asterisk are not statistically significantly different from zero at $\alpha \leq 0.05$.

Source: Survey of 334 Households in 12 *Bas-Fond* Villages in Mali-Sud.

Appendix 4.5: Estimated Correlation Coefficients Between the Total Area Planted in the Upland and the *Bas-Fond* by a PU and the Number of Working People in a PU, by Village, Mali-Sud, Rainy Season 1995-96.

	Bas-Fond	Upland		
	female workers only	both genders age ≥ 15	female workers only	male workers only
Banko	0.6489**	0.6995**	0.6611**	0.6381**
Diassola	0.3668	0.9234**	0.8912**	0.8393**
Faradjélé	0.4084*	0.7485**	0.6072**	0.6672*
Faradié	0.4073*	0.8111**	0.7055**	0.7659**
Sola	0.4187*	0.3812	0.1978	0.4051*
Solo	0.1815	0.0930	0.0723	0.0702
Kado	-0.2075	0.7234**	0.5438*	0.5296*
Kafuziéla	0.2927	0.6496**	0.5399**	0.6100**
Longorola	0.6403**	0.6647**	0.5421**	0.6217**
Niéna	.	0.2444	-0.0612	0.2750
Péniasso	0.4056*	0.7515**	0.7210**	0.7234**
Sikasso	-0.2804	0.1320	0.0154	0.1992

The symbol "." is used when the correlation coefficient could not be computed due to small sample size.

The symbol "*" is used when $P \leq 0.05$ while "**" indicates that $P \leq 0.01$ (2-tailed significance). The correlation coefficients with no asterisk are not statistically significantly different from zero at $\alpha \leq 0.05$.

Source: Survey of 334 Households in 12 *Bas-Fond* Villages in Mali-Sud.

Appendix 4.6: Distribution (%) of the Number and Size of All Fields Planted by All Sampled Production Units, by CMDT Regions (Bougouni and Sikasso), Mali, Rainy Season 1995-96.

Field[a]	Entire Sample			Bougouni			Sikasso		
	Fields		Area	Fields		Area	Fields		Area
	No.	%	%	No.	%	%	No.	%	%
Maize	263	11	21	97	7	13	166	17	28
Cotton	171	8	20	85	6	14	86	9	25
Millet/Sorghum	182	8	17	87	7	21	95	9	13
Rice	991	43	16	439	34	9	552	55	23
Finger millet	179	8	5	179	13	9	0	0	0
Peanut	204	9	6	175	13	10	29	3	2
Millet	30	1	3	20	2	4	10	1	2
Sorghum	56	2	5	39	3	8	17	2	3
Finger millet/dah	35	2	1	35	3	1	0	0	0
Sweat potatoes	54	2	1	19	2	1	35	3	2
Sorghum/cowpea	27	1	2	27	2	5	0	0	0
Other	106	5	3	93	8	5	13	1	2
Total	2,298	100	100	1,295	100	100	1,003	100	100

[a] Rows with only one crop correspond to are single crop fields while those with more than one crops are intercrops.
Source: Survey of 334 Production Units in 12 *Bas-Fonds* Villages in Mali-Sud.

Appendix 4.7: Distribution (%) of the Number and Size of Fields Planted by All Sampled Production Units, by Field Types, Mali, Rainy Season 1995-96.

Field[a]	Number of Fields	% Number of Fields, (by field)			% Area Planted, (by field)		
		Collective	Individual		Collective	Individual	
			Men	Women		Men	Women
Cotton	171	100.0	0.0	0.0	100.0	0.0	0.0
Rice	991	10.7	3.1	86.1	28.3	8.0	63.8
Maize	263	92.0	3.0	4.9	97.8	1.3	0.9
Finger millet	179	41.0	2.8	56.2	62.2	1.6	36.2
Peanut	204	70.1	8.3	21.6	84.6	4.7	10.7
Millet	30	96.7	0.0	3.3	99.6	0.0	0.4
Sorghum	56	89.3	10.7	0.0	97.1	2.9	0.0
Fing. millet/dah	35	0.0	0.0	100.0	0.0	0.0	100.0
Millet/Sorghum	182	97.2	2.2	0.6	98.0	1.9	0.2
Sweat potatoes	54	90.7	9.3	0.0	95.5	4.5	0.0
Sorghum/cowpea	27	88.9	3.7	7.4	96.6	2.3	0.1

[a] Rows with only one crop correspond to are single crop fields while those with more than one crops are intercrops.

Source: Survey of 334 Production Units in 12 *Bas-Fond* Villages in Mali-Sud.

Appendix 4.8: Distribution (%) of the Number and Size of Fields Planted by All Sampled Production Units, by Field Types, Mali, Rainy Season 1995-96.

Field[a]	Number of Fields	% Number of Fields, (all fields included)			% Area Planted, (all fields included)		
		Collective	Individual		Collective	Individual	
			Men	Women		Men	Women
Cotton	171	7.4	0.0	0.0	19.7	0.0	0.0
Rice	991	4.6	1.4	37.2	4.6	1.3	10.4
Maize	263	10.6	0.3	0.6	20.4	0.3	0.2
Finger millet	179	3.2	0.2	4.4	2.8	0.1	1.6
Peanut	204	6.2	0.7	1.9	5.1	0.3	0.7
Millet	30	1.3	0.0	0.0	3.0	0.0	0.0
Sorghum	56	2.2	0.3	0.0	5.3	0.2	0.0
Fing. millet/dah	35	0.0	0.0	1.5	0.0	0.0	0.5
Millet/Sorghum	182	7.7	0.2	0.0	16.7	0.3	0.0
Sweat potatoes	54	2.1	0.2	0.0	1.0	0.0	0.0
Sorghum/cowpea	27	1.0	1.0	0.1	2.2	0.1	0.0
Other	106	3.1	0.6	1.0	2.9	0.2	0.2

[a] Rows with only one crop correspond to are single crop fields while those with more than one crops are intercrops.

Source: Survey of 334 Households in 12 *Bas-Fond* Villages in Mali-Sud.

Appendix 4.9: Average Monthly and Annual Rainfall[a] (mm) Distribution and Variability in Mali-Sud, Mali, 1980-95.

Year	January	February	March	April	May	June	July	August	September	October	November	December	Total
1980	0	6	0	22	134	153	256	314	180	71	9	9	1,157
1981	0	11	18	47	126	111	268	304	163	52	0	0	1,103
1982	0	3	33	92	87	121	207	217	117	64	1	0	947
1983	0	12	0	37	69	95	135	165	174	31	3	0	725
1984	0	0	18	32	84	104	136	198	178	55	18	0	827
1985	0	0	17	43	81	151	247	211	197	45	11	0	1,006
1986	0	13	4	54	133	131	188	295	239	30	3	0	1,095
1987	0	6	1	1	56	146	173	258	195	81	0	0	920
1988	0	0	7	63	39	190	202	269	151	59	2	0	985
1989	0	0	23	14	47	178	172	378	169	52	0	5	1,043
1990	0	0	0	76	120	158	268	245	184	76	3	0	1,135
1991	0	5	23	31	184	145	260	299	178	93	10	0	1,234
1992	3	0	0	30	170	118	294	286	183	58	13	0	1,158
1993	0	3	26	65	61	113	239	257	182	57	8	1	1,080
Average	0	4	12	43	99	137	217	264	178	59	6	1	1,025
CV		1.103	0.926	0.554	0.442	0.198	0.228	0.201	0.144	0.289	0.953	2.362	0.130

[a] These data are averages across the Bougouni, Kadiolo and Sikasso Meteorological Stations.
Source:

Appendix 5.1: Correlation Matrix of the Variables Used in the Logistics Models for Farmers' Adoption of "Improved" Rice Varieties. Mali, Cropping Season 1995-96.

Correlations:	GENDER	AGEXPL	PCTSCOL	PCTALP	FPCTSCO	FPCTALP
GENDER	1.0000	-.3956**	-.2568**	-.0142	-.2722**	-.0816
AGEXPL	-.3956**	1.0000	.2574**	-.0388	.2313**	-.0221
PCTSCOL	-.2568**	.2574**	1.0000	-.1056	.6684**	-.0496
PCTALP	-.0142	-.0388	-.1056	1.0000	-.0419	.5671**
FPCTSCO	-.2722**	.2313**	.6684**	-.0419	1.0000	.0994
FPCTALP	-.0816	-.0221	-.0496	.5671**	.0994	1.0000
SURFACE	-.5132**	.1736*	.0666	-.0450	.0747	-.0129
UPASIZE	-.0024	-.0534	.0409	-.0479	-.0432	-.0706
STRESS1	.0404	-.2160**	-.2377**	.2184**	-.1201	.1188
WTCONT	-.2734**	.0464	.0458	-.1621*	-.0886	-.0769
STECHELP	.1533	-.0764	.0676	-.1160	-.1374	-.0631
HISTCOT	-.3459**	.0697	.1702*	-.0579	.0117	.0096
COTFIELD	.2037*	-.2034*	-.1156	-.1013	-.2175**	-.1308
WMKTD	.4597**	-.4177**	-.3776**	.0659	-.2423**	-.0248
URBMKTD	.5546**	-.1183	-.1336	-.1008	-.2388**	-.0197
VARIETY	-.3774**	.1208	.1257	-.0753	.0159	-.0310

Correlations:	SURFACE	UPASIZE	STRESS1	WTCONT	STECHELP	HISTCOT
GENDER	-.5132**	-.0024	.0404	-.2734**	.1533	-.3459**
AGEXPL	.1736*	-.0534	-.2160**	.0464	-.0764	.0697
PCTSCOL	.0666	.0409	-.2377**	.0458	.0676	.1702*
PCTALP	-.0450	-.0479	.2184**	-.1621*	-.1160	-.0579
FPCTSCO	.0747	-.0432	-.1201	-.0886	-.1374	.0117
FPCTALP	-.0129	-.0706	.1188	-.0769	-.0631	.0096
SURFACE	1.0000	.0988	-.0604	.1376	-.0769	.2010*
UPASIZE	.0988	1.0000	.0594	.0975	-.1083	.2499**
STRESS1	-.0604	.0594	1.0000	-.1607*	-.3159**	-.1299
WTCONT	.1376	.0975	-.1607*	1.0000	.1587*	.4796**
STECHELP	-.0769	-.1083	-.3159**	.1587*	1.0000	.2453**
HISTCOT	.2010*	.2499**	-.1299	.4796**	.2453**	1.0000
COTFIELD	-.0591	.3347**	.0973	.1348	.1584*	.2117**
WMKTD	-.1868*	.1185	.2351**	.1197	-.2945**	-.4001**
URBMKTD	-.2902**	-.1840*	-.1501	.1438	.2549**	-.0386
VARIETY	.1082	-.0255	-.1517	.4584**	.1471	.4589**

Correlations:	COTFIELD	WMKTD	URBMKTD	VARIETY
GENDER	.2037*	.4597**	.5546**	-.3774**
AGEXPL	-.2034*	-.4177**	-.1183	.1208
PCTSCOL	-.1156	-.3776**	-.1336	.1257
PCTALP	-.1013	.0659	-.1008	-.0753
FPCTSCO	-.2175**	-.2423**	-.2388**	.0159
FPCTALP	-.1308	-.0248	-.0197	-.0310
SURFACE	-.0591	-.1868*	-.2902**	.1082
UPASIZE	.3347**	.1185	-.1840*	-.0255
STRESS1	.0973	.2351**	-.1501	-.1517
WTCONT	.1348	.1197	.1438	.4584**
STECHELP	.1584*	-.2945**	.2549**	.1471
HISTCOT	.2117**	-.4001**	-.0386	.4589**
COTFIELD	1.0000	.1629*	.1740*	.0515
WMKTD	.1629*	1.0000	.0776	-.2882**
URBMKTD	.1740*	.0776	1.0000	.0639
VARIETY	.0515	-.2882**	.0639	1.0000

N of cases: 221   1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Appendix 5.2: Correlation Matrix of the Variables Used in the Logistics Models for Farmers' Adoption of Fertilizer and Herbicide Applications. Mali, Cropping Season 1995-96.

Correlations:	GENDER	AGEXPL	PCTSCOL	PCTALP	FPCTSCO	FPCTALP
GENDER	1.0000	-.3509**	-.2353*	.1143	-.2939**	.1091
AGEXPL	-.3509**	1.0000	.3909**	-.0080	.2654*	-.0266
PCTSCOL	-.2353*	.3909**	1.0000	-.1420	.6671**	.0187
PCTALP	.1143	-.0080	-.1420	1.0000	-.0409	.5284**
FPCTSCO	-.2939**	.2654*	.6671**	-.0409	1.0000	.2384*
FPCTALP	.1091	-.0266	.0187	.5284**	.2384*	1.0000
SURFACE	-.4271**	.1252	.0265	-.0585	.0302	-.0779
UPASIZE	-.1334	.0595	.0465	-.0799	-.0792	-.1241
STRESS1	.0873	-.2127	-.3159**	.3048**	-.1254	.2495*
WTCONT	-.2073	-.0087	-.1149	-.1637	-.1839	-.0905
STECHELP	.2594*	-.1538	-.0701	-.1850	-.1885	-.1546
HISTCOT	-.2138	.0019	-.0181	-.0228	-.0909	.0037
COTFIELD	.0000	-.2507*	-.2259*	.0478	-.2690*	-.0943
WMKTD	.3547**	-.4580**	-.4449**	.0631	-.3104**	.0972
URBMKTD	.4387**	-.0511	-.1870	.0091	-.2265*	.1901
VARIETY	-.2915**	.1591	.0437	-.0263	-.0209	-.0750
HERB	.0549	-.0346	-.2145	-.0491	-.1814	-.0898
FERT	-.2839*	.0758	.1266	-.0821	-.0355	-.1252

Correlations:	SURFACE	UPASIZE	STRESS1	WTCONT	STECHELP	HISTCOT
GENDER	-.4271**	-.1334	.0873	-.2073	.2594*	-.2138
AGEXPL	.1252	.0595	-.2127	-.0087	-.1538	.0019
PCTSCOL	.0265	.0465	-.3159**	-.1149	-.0701	-.0181
PCTALP	-.0585	-.0799	.3048**	-.1637	-.1850	-.0228
FPCTSCO	.0302	-.0792	-.1254	-.1839	-.1885	-.0909
FPCTALP	-.0779	-.1241	.2495*	-.0905	-.1546	.0037
SURFACE	1.0000	.2138	-.1047	.1182	-.0905	.1209
UPASIZE	.2138	1.0000	-.1947	.0527	-.0858	.2318*
STRESS1	-.1047	-.1947	1.0000	-.2978**	-.2449*	-.2460*
WTCONT	.1182	.0527	-.2978**	1.0000	.0815	.3158**
STECHELP	-.0905	-.0858	-.2449*	.0815	1.0000	.0937
HISTCOT	.1209	.2318*	-.2460*	.3158**	.0937	1.0000
COTFIELD	.0763	.3338**	.1054	.1404	.0562	.1930
WMKTD	-.0322	-.0582	.1170	.3267**	-.0661	-.3157**
URBMKTD	-.1758	-.0625	.0124	.2270*	.0569	.1995
VARIETY	-.0128	.1072	-.1715	.4148**	-.0355	.3576**
HERB	-.0648	.1261	.0990	.0734	.0037	.1949
FERT	-.0046	.2341*	-.2235*	.5735**	.0664	.4811**

Correlations:	COTFIELD	WMKTD	URBMKTD	VARIETY	HERB	FERT
GENDER	.0000	.3547**	.4387**	-.2915**	.0549	-.2839*
AGEXPL	-.2507*	-.4580**	-.0511	.1591	-.0346	.0758
PCTSCOL	-.2259*	-.4449**	-.1870	.0437	-.2145	.1266
PCTALP	.0478	.0631	.0091	-.0263	-.0491	-.0821
FPCTSCO	-.2690*	-.3104**	-.2265*	-.0209	-.1814	-.0355
FPCTALP	-.0943	.0972	.1901	-.0750	-.0898	-.1252
SURFACE	.0763	-.0322	-.1758	-.0128	-.0648	-.0046
UPASIZE	.3338**	-.0582	-.0625	.1072	.1261	.2341*
STRESS1	.1054	.1170	.0124	-.1715	.0990	-.2235*
WTCONT	.1404	.3267**	.2270*	.4148**	.0734	.5735**
STECHELP	.0562	-.0661	.0569	-.0355	.0037	.0664
HISTCOT	.1930	-.3157**	.1995	.3576**	.1949	.4811**
COTFIELD	1.0000	.1628	.0926	.0000	.1949	.2317*
WMKTD	.1628	1.0000	.1446	-.1053	.0294	-.1749
URBMKTD	.0926	.1446	1.0000	.1662	.2681*	.1284
VARIETY	.0000	-.1053	.1662	1.0000	.2972**	.4735**
HERB	.1949	.0294	.2681*	.2972**	1.0000	.2807*
FERT	.2317*	-.1749	.1284	.4735**	.2807*	1.0000

N of cases: 114 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed.

Appendix 5.3: Descriptive Statistics of the Variables Used in the Rice Yield Response Model in the Bas-fond. Mali, Cropping Season 1995-96.

Variable	Mean	Std Dev	Minimum	Maximum	N	Label
GENDER	.83	.37	0	1	223	Farmer's gender (male/ female or 0/1)
AGEXPL	44.81	13.28	20.00	85.00	222	Farmer's age
SEED	149.04	134.08	25.00	1000.00	154	Amount of seeds used (kg/ha)
SQSEED	40072.29	115032.16	625.00	1000000	154	Square amount seed used
WTCONT	.62	.49	0	1	223	This Bas-fond has water (no/yes or 0/1)
HERB	.44	.50	0	1	120	Did farmer used herbicide (no/yes or 0/1)
VARWTC	.50	.63	.00	2	212	Interaction amount variety/water control
N	17.70	32.08	.00	220.00	122	Amount nitrogen applied (kg/ha)
N2	1333.72	4847.78	.00	48400.00	122	Square amount nitrogen applied
NREG	14.39	31.63	.00	220.00	104	Interaction amount nitrogen/region
N2REG	1197.97	5174.25	.00	48400.00	104	Interaction square amount nitrogen/region
P	3.51	8.35	.00	40.00	122	Amount phosphorous applied (kg/ha)
P2	81.38	292.44	.00	1600.00	122	Square amount phosphorous applied
PREG	2.81	8.47	.00	40.00	104	Interaction amount phosph./region
P2REG	79.01	313.62	.00	1600.00	104	Interaction square amount phosph./region
K	1.17	3.61	.00	20.45	122	Amount potassium applied (kg/ha)
K2	14.27	53.91	.00	418.39	122	Square amount potassium applied
KREG	.07	.53	.00	4.50	104	Interaction amount potassium/region
K2REG	.28	2.17	.00	20.25	104	Interaction square amount potassium/region
NP	279.40	1046.30	.00	8800.00	122	Interaction nitrogen/phosphorous
NPREG	258.61	1122.97	.00	8800.00	104	Interaction nitrogen/phosphorous/region
N2P	32909.92	189744.53	.00	1936000	122	Interaction square nitrogen/phosphorous
N2PREG	34559.57	205416.05	.00	1936000	104	Interaction square nitrog./phosph./region
N2P2	1163834.0	7583429.89	.00	77440000	122	Interaction square nitrog./square phosph.
N2P2REG	1315813.0	8208944.58	.00	77440000	104	Interaction sq. nitrog./sq. phosph./region
NP2	8435.10	41181.80	.00	352000.0	122	Interaction nitrogen/square phosphorous
NP2REG	9018.87	44554.02	.00	352000.0	104	Interaction nitrogen/square phosph./region
METPLANT	.86	.35	.00	1.00	246	Planting method
ROWPLANT	.03	.18	0	1	245	row planting (no/yes or 0/1)
PWEEK	22.07	3.25	15.00	33.00	122	# weeks planting done after Jan. 1st, 1995
SQPWEEK	497.70	150.73	225.00	1089.00	122	sq. # weeks planting done after Jan. 1st
PWEKREG	13.37	11.96	.00	33.00	104	Interaction planting date/region
PWEK2REG	320.23	304.04	.00	1089.00	104	Interaction square planting date/region
WEEKW	2.72	9.56	-29.00	15.00	115	# weeks weeding done after planting
SQWEEKW	98.01	185.18	.00	841.00	115	square # weeks weeding done after planting
WEKWREG	.35	8.34	-29.00	11.00	97	Interaction weeding date/region
WEKW2REG	68.89	193.23	.00	841.00	97	Interaction square weeding date/region
REGION	.53	.50	0	1	223	CMDT Region
CMDT	.27	.44	0	1	226	Contact with CMDT (no/yes or 0/1)
EFFANIM	.08	.27	0	1	326	Impact animal (no/yes)
EFFBIRD	.08	.27	0	1	330	Impact birds (no/yes)
EFFINSEC	.05	.21	0	1	328	Impact insects (no/yes)
EFFDISEA	.05	.22	0	1	326	Impact disease (no/yes)
DISEAREG	.07	.26	.00	1.00	210	Interaction disease/region
STRESS11	.93	1.08	.00	4.00	203	water stress, critical period (no/yes)
VARIETY	.43	.60	0	2	331	Variety farmer plant (trad./imp. or 0/1)
VARREG	.40	.58	.00	2.00	212	Interaction variety/region
YIELD	1216.47	791.64	.00	3863.64	223	Yield (kg/ha)

Appendix 5.4: Estimation Statistics for the Variables Excluded in the Rice Yield Response Model in the Bas-fond. Mali, Cropping Season 1995-96.

* * * * M U L T I P L E   R E G R E S S I O N * * * *

Equation Number 1   Dependent Variable.. YIELD   Yield (kg/ha)

------------- Variables not in the Equation -------------

Variable	Beta In	Partial	Min Toler	T	Sig T
SQSEED	-.469797	-.162063	.059421	-1.324	.1901
VARWTC	-.059536	-.065659	.476343	-.531	.5976
N	.434362	.223470	.132169	1.848	.0691
N2	.280221	.161260	.119304	1.317	.1923
N2REG	.210937	.103893	.083552	.842	.4028
P	.251560	.214190	.318587	1.768	.0818
P2	.132041	.105161	.226459	.853	.3970
PREG	.110355	.085325	.219425	.690	.4924
P2REG	.060937	.047291	.205255	.382	.7039
NP	.353109	.201460	.115678	1.658	.1021
NPREG	.262738	.133368	.087147	1.085	.2820
N2P	.210548	.130733	.127560	1.063	.2917
N2PREG	.185649	.112337	.120038	.911	.3654
N2P2	.174103	.109970	.130525	.892	.3757
N2P2REG	.165598	.103904	.128491	.842	.4027
NP2	.224051	.127718	.109113	1.038	.3030
NP2REG	.184213	.102330	.102421	.829	.4099
METPLANT	-.082981	-.113365	.495945	-.920	.3610
PWEEK	.001918	.001937	.300280	.016	.9876
SQPWEEK	-3.841E-04	-.000388	.299439	-.003	.9975
PWEKREG	.021538	.004279	.019710	.034	.9726
WEEKW	.159144	.209193	.488454	1.725	.0893
SQWEEKW	-.119651	-.162188	.485938	-1.325	.1898
WEKWREG	.145422	.183778	.489024	1.507	.1366
WEKW2REG	-.096740	-.124755	.476481	-1.014	.3145
REGION	-.001396	-.000533	.072633	-.004	.9966
EFFANIM	-.085868	-.107069	.467183	-.868	.3885
EFFBIRD	-.124732	-.170576	.487191	-1.396	.1676
EFFDISEA	-.160560	-.216625	.464509	-1.789	.0783
DISEAREG	-.160560	-.216625	.464509	-1.789	.0783
VARIETY	-.046873	-.057501	.486595	-.464	.6439
VARREG	-.161586	-.177991	.419255	-1.458	.1496

End Block Number 1   PIN =   .050 Limits reached.

Appendix 5.5: Correlation Matrix of the Variables Used in the Rice Yield Response Model in the Bas-fond. Mali, Cropping Season 1995-96.

Correlations:	GENDER	AGEXPL	SEED	SQSEED	WTCONT	HERB
GENDER	1.0000	-.1505	.1204	.0960	-.1649	-.0549
AGEXPL	-.1505	1.0000	.0189	.0526	.0524	.1917
SEED	.1204	.0189	1.0000	.9614**	-.0925	-.0943
SQSEED	.0960	.0526	.9614**	1.0000	-.1978	-.1466
WTCONT	-.1649	.0524	-.0925	-.1978	1.0000	.0060
HERB	-.0549	.1917	-.0943	-.1466	.0060	1.0000
VARWTC	-.2364	-.0009	.0263	-.0776	.5562**	.2113
N	-.1572	.1677	.0480	-.0474	.4847**	.4627**
N2	-.0510	.1718	.0113	-.0302	.2295	.2611
NREG	-.2419	.1280	-.0412	-.0982	.3501*	.2923*
N2REG	-.0751	.1596	-.0212	-.0484	.1730	.1893
P	-.2332	.3421*	.0225	-.0366	.3490*	.3822**
P2	-.2647	.2953*	-.0155	-.0432	.2153	.2595
PREG	-.3138*	.2985*	-.0482	-.0708	.2340	.2388
P2REG	-.2853*	.2679	-.0401	-.0536	.1686	.2025
K	.0849	.1153	.1347	.0565	.2797*	.3411*
K2	.0993	.1519	.1336	.0552	.2624	.3197*
KREG	-.3621**	-.2035	-.0344	-.0342	.0940	.1202
K2REG	-.3621**	-.2035	-.0344	-.0342	.0940	.1202
NP	-.1291	.2508	-.0028	-.0345	.2110	.2548
NPREG	-.1520	.2273	-.0317	-.0485	.1581	.1868
N2P	-.0329	.1795	-.0099	-.0307	.1337	.1681
N2PREG	-.0393	.1733	-.0179	-.0347	.1176	.1475
N2P2	-.0242	.1701	-.0130	-.0314	.1156	.1473
N2P2REG	-.0261	.1677	-.0153	-.0324	.1109	.1413
NP2	-.1167	.2210	-.0169	-.0376	.1515	.1907
NP2REG	-.1232	.2112	-.0255	-.0413	.1348	.1694
METPLANT	.0732	-.1201	.0252	.0025	-.0356	-.1071
ROWPLANT	.	.	.	.	.	.
PWEEK	-.3551**	.0487	.0724	.0865	-.0114	-.1292
SQPWEEK	-.3832**	.0603	.0848	.0923	.0018	-.1365
PWEKREG	-.3743**	-.1102	-.2008	-.2414	.3961**	-.0977
PWEK2REG	-.4179**	-.0959	-.1933	-.2334	.3916**	-.1114
WEEKW	.3183*	-.1452	-.1804	-.2770*	.1401	.1143
SQWEEKW	-.2690	.2217	.0232	.1528	-.1294	-.1697
WEKWREG	.3345*	-.1364	.0153	-.0567	.3047*	.1084
WEKW2REG	-.5159**	.1788	-.1407	-.0977	.0386	-.1743
REGION	-.3321*	-.1201	-.2030	-.2440	.3937**	-.0819
CMDT	.2171	-.1358	-.0420	-.0613	.1802	-.1863
EFFANIM	.1045	.0509	.0420	.0795	.0703	-.3146*
EFFBIRD	-.0970	-.1286	-.0909	-.0767	-.0045	-.1543
EFFINSEC	.0773	-.0686	-.0778	-.0687	.1919	-.2327
EFFDISEA	-.3621**	.0781	-.0344	-.0342	.0940	.1202
DISEAREG	-.3621**	.0781	-.0344	-.0342	.0940	.1202
STRESS11	.1457	-.0697	-.1190	-.0777	-.4764**	-.0454
VARIETY	-.1999	-.0037	.0498	-.0400	.4142**	.2153
VARREG	-.3146*	-.0066	-.0359	-.1099	.4232**	.0954
YIELD	.2632	.1408	.3566**	.2788*	.1855	.3232*

N of cases: 74 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Correlations:	VARWTC	N	N2	NREG	N2REG	P
GENDER	-.2364	-.1572	-.0510	-.2419	-.0751	-.2332
AGEXPL	-.0009	.1677	.1718	.1280	.1596	.3421*
SEED	.0263	.0480	.0113	-.0412	-.0212	.0225
SQSEED	-.0776	-.0474	-.0302	-.0982	-.0484	-.0366
WTCONT	.5562**	.4847**	.2295	.3501*	.1730	.3490*
HERB	.2113	.4627**	.2611	.2923*	.1893	.3822**
VARWTC	1.0000	.4087**	.1977	.3010*	.1472	.3218*
N	.4087**	1.0000	.8542**	.8360**	.7737**	.8174**
N2	.1977	.8542**	1.0000	.8408**	.9773**	.7223**
NREG	.3010*	.8360**	.8408**	1.0000	.8798**	.6739**
N2REG	.1472	.7737**	.9773**	.8798**	1.0000	.6581**
P	.3218*	.8174**	.7223**	.6739**	.6581**	1.0000
P2	.1952	.7310**	.7805**	.7401**	.7709**	.9145**
PREG	.2321	.6967**	.7252**	.8141**	.7516**	.8749**
P2REG	.1554	.6733**	.7664**	.7705**	.7871**	.8472**
K	.2421	.3550**	.1014	-.1601	-.0798	.3874**
K2	.2273	.3323*	.0942	-.1485	-.0718	.3877**
KREG	.2523	.0304	-.0145	.0591	-.0061	-.0069
K2REG	.2523	.0304	-.0145	.0591	-.0061	-.0069
NP	.1956	.8260**	.9636**	.8197**	.9461**	.8450**
NPREG	.1480	.7552**	.9456**	.8556**	.9666**	.7748**
N2P	.1224	.7428**	.9791**	.7975**	.9849**	.6736**
N2PREG	.1078	.7191**	.9705**	.8054**	.9880**	.6515**
N2P2	.1053	.7156**	.9694**	.7903**	.9830**	.6466**
N2P2REG	.1010	.7088**	.9668**	.7924**	.9836**	.6395**
NP2	.1383	.7549**	.9530**	.8156**	.9608**	.7713**
NP2REG	.1232	.7316**	.9449**	.8237**	.9638**	.7458**
METPLANT	-.0762	-.1975	-.0702	.0491	.0379	-.0847
ROWPLANT	.	.	.	.	.	.
PWEEK	.1033	-.0464	-.0578	.1531	.0112	-.1523
SQPWEEK	.1092	-.0329	-.0558	.1553	.0088	-.1437
PWEKREG	.3310*	.2137	.1287	.4475**	.2004	.0712
PWEK2REG	.3300*	.2000	.1072	.4260**	.1766	.0428
WEEKW	.1422	.1480	.1040	.1097	.0884	.1247
SQWEEKW	-.2183	-.1716	-.0524	-.1365	-.0368	-.1052
WEKWREG	.3042*	.2788*	.2063	.3674**	.2298	.2095
WEKW2REG	-.0413	-.0196	.0380	.0511	.0617	-.0021
REGION	.3268*	.2276	.1497	.4644**	.2222	.1039
CMDT	.1585	.0766	.1322	.1674	.1552	.0442
EFFANIM	-.0924	-.1687	-.0902	-.1461	-.0699	-.1450
EFFBIRD	-.1865	-.0798	-.0464	-.0248	-.0269	-.1208
EFFINSEC	.0046	-.1169	-.0665	-.1081	-.0517	-.0573
EFFDISEA	.2523	.0045	-.0229	.0313	-.0144	-.0525
DISEAREG	.2523	.0045	-.0229	.0313	-.0144	-.0525
STRESS11	-.3191*	-.2776*	-.1637	-.1318	-.1067	-.2529
VARIETY	.9241**	.3373*	.1652	.2499	.1228	.2712*
VARREG	.8476**	.2697	.1592	.4088**	.1990	.1874
YIELD	.1406	.2056	.0154	-.1274	-.1060	.2282

N of cases: 74   1-tailed Signif: * - .01 ** - .001

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Correlations:	P2	PREG	P2REG	K	K2	KREG
GENDER	-.2647	-.3138*	-.2853*	.0849	.0993	-.3621**
AGEXPL	.2953*	.2985*	.2679	.1153	.1519	-.2035
SEED	-.0155	-.0482	-.0401	.1347	.1336	-.0344
SQSEED	-.0432	-.0708	-.0536	.0565	.0552	-.0342
WTCONT	.2153	.2340	.1686	.2797*	.2624	.0940
HERB	.2595	.2388	.2025	.3411*	.3197*	.1202
VARWTC	.1952	.2321	.1554	.2421	.2273	.2523
N	.7310**	.6967**	.6733**	.3550**	.3323*	.0304
N2	.7805**	.7252**	.7664**	.1014	.0942	-.0145
NREG	.7401**	.8141**	.7705**	-.1601	-.1485	.0591
N2REG	.7709**	.7516**	.7871**	-.0798	-.0718	-.0061
P	.9145**	.8749**	.8472**	.3874**	.3877**	-.0069
P2	1.0000	.9330**	.9833**	.0994	.1126	-.0276
PREG	.9330**	1.0000	.9544**	-.1054	-.0963	.0151
P2REG	.9833**	.9544**	1.0000	-.0788	-.0700	-.0206
K	.0994	-.1054	-.0788	1.0000	.9771**	.0495
K2	.1126	-.0963	-.0700	.9771**	1.0000	-.0172
KREG	-.0276	.0151	-.0206	.0495	-.0172	1.0000
K2REG	-.0276	.0151	-.0206	.0495	-.0172	1.0000**
NP	.9086**	.8488**	.8896**	.1176	.1233	-.0211
NPREG	.8938**	.8738**	.9093**	-.0734	-.0655	-.0132
N2P	.7843**	.7262**	.7867**	-.0008	.0040	-.0180
N2PREG	.7778**	.7311**	.7898**	-.0551	-.0489	-.0157
N2P2	.7752**	.7152**	.7836**	-.0352	-.0290	-.0167
N2P2REG	.7728**	.7165**	.7843**	-.0521	-.0461	-.0161
NP2	.8979**	.8322**	.9002**	-.0021	.0066	-.0214
NP2REG	.8895**	.8370**	.9032**	-.0633	-.0560	-.0189
METPLANT	.0242	.0172	.0435	-.2032	-.1043	.0348
ROWPLANT	.	.	.	.	.	.
PWEEK	-.1418	-.0194	-.1001	-.2662	-.2285	.1025
SQPWEEK	-.1353	-.0164	-.0949	-.2547	-.2217	.0976
PWEKREG	.1111	.2624	.1700	-.3411*	-.3165*	.1298
PWEK2REG	.0714	.2262	.1283	-.3299*	-.3067*	.1342
WEEKW	.0994	.1020	.0908	.0606	.0489	-.0138
SQWEEKW	-.0510	-.0680	-.0357	-.0927	-.0858	-.0655
WEKWREG	.2115	.2840*	.2306	-.1073	-.0990	.0316
WEKW2REG	.0404	.0592	.0599	-.1194	-.1063	-.0262
REGION	.1561	.2995*	.2157	-.3454*	-.3199*	.1202
CMDT	.0489	.1351	.0782	-.1736	-.1606	-.0786
EFFANIM	-.0871	-.0942	-.0679	-.1219	-.1079	-.0378
EFFBIRD	-.0726	-.0785	-.0565	-.1015	-.0899	-.0315
EFFINSEC	-.0551	-.0697	-.0502	.0124	-.0284	-.0280
EFFDISEA	-.0315	-.0341	-.0246	-.0441	-.0391	-.0137
DISEAREG	-.0315	-.0341	-.0246	-.0441	-.0391	-.0137
STRESS11	-.1825	-.1375	-.1369	-.2660	-.2548	-.0943
VARIETY	.1648	.1993	.1317	.1995	.1896	.2398
VARREG	.1736	.3037*	.2063	-.1664	-.1684	.2895*
YIELD	.0381	-.0534	-.0645	.5627**	.5594**	-.0753

N of cases: 74 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Correlations:	K2REG	NP	NPREG	N2P	N2PREG	N2P2
GENDER	-.3621**	-.1291	-.1520	-.0329	-.0393	-.0242
AGEXPL	-.2035	.2508	.2273	.1795	.1733	.1701
SEED	-.0344	-.0028	-.0317	-.0099	-.0179	-.0130
SQSEED	-.0342	-.0345	-.0485	-.0307	-.0347	-.0314
WTCONT	.0940	.2110	.1581	.1337	.1176	.1156
HERB	.1202	.2548	.1868	.1681	.1475	.1473
VARWTC	.2523	.1956	.1480	.1224	.1078	.1053
N	.0304	.8260**	.7552**	.7428**	.7191**	.7156**
N2	-.0145	.9636**	.9456**	.9791**	.9705**	.9694**
NREG	.0591	.8197**	.8556**	.7975**	.8054**	.7903**
N2REG	-.0061	.9461**	.9666**	.9849**	.9880**	.9830**
P	-.0069	.8450**	.7748**	.6736**	.6515**	.6466**
P2	-.0276	.9086**	.8938**	.7843**	.7778**	.7752**
PREG	.0151	.8488**	.8738**	.7262**	.7311**	.7152**
P2REG	-.0206	.8896**	.9093**	.7867**	.7898**	.7836**
K	.0495	.1176	-.0734	-.0008	-.0551	-.0352
K2	-.0172	.1233	-.0655	.0040	-.0489	-.0290
KREG	1.0000**	-.0211	-.0132	-.0180	-.0157	-.0167
K2REG	1.0000	-.0211	-.0132	-.0180	-.0157	-.0167
NP	-.0211	1.0000	.9807**	.9614**	.9529**	.9506**
NPREG	-.0132	.9807**	1.0000	.9659**	.9686**	.9623**
N2P	-.0180	.9614**	.9659**	1.0000	.9983**	.9984**
N2PREG	-.0157	.9529**	.9686**	.9983**	1.0000	.9989**
N2P2	-.0167	.9506**	.9623**	.9984**	.9989**	1.0000
N2P2REG	-.0161	.9477**	.9628**	.9977**	.9991**	.9998**
NP2	-.0214	.9858**	.9909**	.9756**	.9743**	.9738**
NP2REG	-.0189	.9762**	.9935**	.9737**	.9759**	.9742**
METPLANT	.0348	-.0225	.0336	.0164	.0369	.0356
ROWPLANT	.	.	.	.	.	.
PWEEK	.1025	-.0968	-.0442	-.0579	-.0419	-.0552
SQPWEEK	.0976	-.0951	-.0448	-.0604	-.0451	-.0582
PWEKREG	.1298	.1037	.1705	.1058	.1248	.1095
PWEK2REG	.1342	.0742	.1388	.0799	.0983	.0824
WEEKW	-.0138	.1021	.0915	.0853	.0818	.0818
SQWEEKW	-.0655	-.0434	-.0265	-.0124	-.0074	-.0053
WEKWREG	.0316	.2040	.2258	.1829	.1886	.1820
WEKW2REG	-.0262	.0433	.0654	.0584	.0647	.0634
REGION	.1202	.1348	.2024	.1314	.1505	.1363
CMDT	-.0786	.1154	.1423	.1534	.1595	.1580
EFFANIM	-.0378	-.0853	-.0637	-.0538	-.0474	-.0465
EFFBIRD	-.0315	-.0711	-.0530	-.0448	-.0394	-.0388
EFFINSEC	-.0280	-.0609	-.0471	-.0397	-.0350	-.0344
EFFDISEA	-.0137	-.0309	-.0231	-.0195	-.0172	-.0169
DISEAREG	-.0137	-.0309	-.0231	-.0195	-.0172	-.0169
STRESS11	-.0943	-.1769	-.1239	-.1232	-.1071	-.1115
VARIETY	.2398	.1658	.1258	.1036	.0913	.0891
VARREG	.2895*	.1588	.1959	.1330	.1433	.1315
YIELD	-.0753	.0317	-.0854	-.0564	-.0902	-.0791

N of cases: 74 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Correlations:	N2P2REG	NP2	NP2REG	METPLANT	ROWPLANT	PWEEK
GENDER	-.0261	-.1167	-.1232	.0732	.	-.3551**
AGEXPL	.1677	.2210	.2112	-.1201	.	.0487
SEED	-.0153	-.0169	-.0255	.0252	.	.0724
SQSEED	-.0324	-.0376	-.0413	.0025	.	.0865
WTCONT	.1109	.1515	.1348	-.0356	.	-.0114
HERB	.1413	.1907	.1694	-.1071	.	-.1292
VARWTC	.1010	.1383	.1232	-.0762	.	.1033
N	.7088**	.7549**	.7316**	-.1975	.	-.0464
N2	.9668**	.9530**	.9449**	-.0702	.	-.0578
NREG	.7924**	.8156**	.8237**	.0491	.	.1531
N2REG	.9836**	.9608**	.9638**	.0379	.	.0112
P	.6395**	.7713**	.7458**	-.0847	.	-.1523
P2	.7728**	.8979**	.8895**	.0242	.	-.1418
PREG	.7165**	.8322**	.8370**	.0172	.	-.0194
P2REG	.7843**	.9002**	.9032**	.0435	.	-.1001
K	-.0521	-.0021	-.0633	-.2032	.	-.2662
K2	-.0461	.0066	-.0560	-.1043	.	-.2285
KREG	-.0161	-.0214	-.0189	.0348	.	.1025
K2REG	-.0161	-.0214	-.0189	.0348	.	.1025
NP	.9477**	.9858**	.9762**	-.0225	.	-.0968
NPREG	.9628**	.9909**	.9935**	.0336	.	-.0442
N2P	.9977**	.9756**	.9737**	.0164	.	-.0579
N2PREG	.9991**	.9743**	.9759**	.0369	.	-.0419
N2P2	.9998**	.9738**	.9742**	.0356	.	-.0552
N2P2REG	1.0000	.9731**	.9745**	.0394	.	-.0510
NP2	.9731**	1.0000	.9980**	.0336	.	-.0880
NP2REG	.9745**	.9980**	1.0000	.0436	.	-.0735
METPLANT	.0394	.0336	.0436	1.0000	.	.0298
ROWPLANT	.	.	.	.	1.0000	.
PWEEK	-.0510	-.0880	-.0735	.0298	.	1.0000
SQPWEEK	-.0542	-.0877	-.0737	.0148	.	.9954**
PWEKREG	.1151	.1177	.1374	-.0300	.	.5334**
PWEK2REG	.0878	.0844	.1035	-.0490	.	.6074**
WEEKW	.0810	.0908	.0878	.0976	.	-.2415
SQWEEKW	-.0037	-.0201	-.0145	-.1724	.	-.0434
WEKWREG	.1837	.2014	.2074	.2024	.	.0517
WEKW2REG	.0652	.0598	.0663	-.2840*	.	.1970
REGION	.1419	.1527	.1726	-.0080	.	.4513**
CMDT	.1599	.1256	.1342	.0925	.	.2233
EFFANIM	-.0446	-.0610	-.0543	.0960	.	-.0594
EFFBIRD	-.0372	-.0508	-.0452	-.1173	.	.1096
EFFINSEC	-.0330	-.0448	-.0401	.0710	.	-.2572
EFFDISEA	-.0162	-.0221	-.0197	.0348	.	.1939
DISEAREG	-.0162	-.0221	-.0197	.0348	.	.1939
STRESS11	-.1067	-.1393	-.1226	.1983	.	-.1113
VARIETY	.0855	.1170	.1043	-.0421	.	.1375
VARREG	.1345	.1532	.1638	.0823	.	.2796*
YIELD	-.0892	-.0498	-.0859	-.1934	.	-.1354

N of cases: 74 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Correlations:	SQPWEEK	PWEKREG	PWEK2REG	WEEKW	SQWEEKW	WEKWREG
GENDER	-.3832**	-.3743**	-.4179**	.3183*	-.2690	.3345*
AGEXPL	.0603	-.1102	-.0959	-.1452	.2217	-.1364
SEED	.0848	-.2008	-.1933	-.1804	.0232	.0153
SQSEED	.0923	-.2414	-.2334	-.2770*	.1528	-.0567
WTCONT	.0018	.3961**	.3916**	.1401	-.1294	.3047*
HERB	-.1365	-.0977	-.1114	.1143	-.1697	.1084
VARWTC	.1092	.3310*	.3300*	.1422	-.2183	.3042*
N	-.0329	.2137	.2000	.1480	-.1716	.2788*
N2	-.0558	.1287	.1072	.1040	-.0524	.2063
NREG	.1553	.4475**	.4260**	.1097	-.1365	.3674**
N2REG	.0088	.2004	.1766	.0884	-.0368	.2298
P	-.1437	.0712	.0428	.1247	-.1052	.2095
P2	-.1353	.1111	.0714	.0994	-.0510	.2115
PREG	-.0164	.2624	.2262	.1020	-.0680	.2840*
P2REG	-.0949	.1700	.1283	.0908	-.0357	.2306
K	-.2547	-.3411*	-.3299*	.0606	-.0927	-.1073
K2	-.2217	-.3165*	-.3067*	.0489	-.0858	-.0990
KREG	.0976	.1298	.1342	-.0138	-.0655	.0316
K2REG	.0976	.1298	.1342	-.0138	-.0655	.0316
NP	-.0951	.1037	.0742	.1021	-.0434	.2040
NPREG	-.0448	.1705	.1388	.0915	-.0265	.2258
N2P	-.0604	.1058	.0799	.0853	-.0124	.1829
N2PREG	-.0451	.1248	.0983	.0818	-.0074	.1886
N2P2	-.0582	.1095	.0824	.0818	-.0053	.1820
N2P2REG	-.0542	.1151	.0878	.0810	-.0037	.1837
NP2	-.0877	.1177	.0844	.0908	-.0201	.2014
NP2REG	-.0737	.1374	.1035	.0878	-.0145	.2074
METPLANT	.0148	-.0300	-.0490	.0976	-.1724	.2024
ROWPLANT	.	.	.	.	.	.
PWEEK	.9954**	.5334**	.6074**	-.2415	-.0434	.0517
SQPWEEK	1.0000	.5257**	.6077**	-.2309	-.0510	.0453
PWEKREG	.5257**	1.0000	.9894**	-.0961	-.1177	.2867*
PWEK2REG	.6077**	.9894**	1.0000	-.1055	-.1082	.2593
WEEKW	-.2309	-.0961	-.1055	1.0000	-.7512**	.5750**
SQWEEKW	-.0510	-.1177	-.1082	-.7512**	1.0000	-.6166**
WEKWREG	.0453	.2867*	.2593	.5750**	-.6166**	1.0000
WEKW2REG	.1873	.3357*	.3332*	-.5291**	.6407**	-.6535**
REGION	.4374**	.9904**	.9601**	-.0840	-.1272	.3091*
CMDT	.1975	.5504**	.5117**	.0796	-.2430	.3924**
EFFANIM	-.0539	-.2199	-.2138	-.0439	.0875	-.0709
EFFBIRD	.0973	.1683	.1616	-.0794	.1666	-.0707
EFFINSEC	-.2456	-.2304	-.2234	.1607	.0159	-.0719
EFFDISEA	.1991	.1500	.1765	.0306	-.0399	.0984
DISEAREG	.1991	.1500	.1765	.0306	-.0399	.0984
STRESS11	-.1121	-.3862**	-.3814**	.1328	-.0419	-.0507
VARIETY	.1411	.2207	.2231	.1853	-.2426	.2707*
VARREG	.2781*	.5442**	.5372**	.0968	-.1885	.3816**
YIELD	-.1343	-.1851	-.1892	.0864	-.1242	.1128

N of cases: 74 1-tailed Signif: * - .01 ** - .001

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Correlations:	WEKW2REG	REGION	CMDT	EFFANIM	EFFBIRD	EFFINSEC
GENDER	-.5159**	-.3321*	.2171	.1045	-.0970	.0773
AGEXPL	.1788	-.1201	-.1358	.0509	-.1286	-.0686
SEED	-.1407	-.2030	-.0420	.0420	-.0909	-.0778
SQSEED	-.0977	-.2440	-.0613	.0795	-.0767	-.0687
WTCONT	.0386	.3937**	.1802	.0703	-.0045	.1919
HERB	-.1743	-.0819	-.1863	-.3146*	-.1543	-.2327
VARWTC	-.0413	.3268*	.1585	-.0924	-.1865	.0046
N	-.0196	.2276	.0766	-.1687	-.0798	-.1169
N2	.0380	.1497	.1322	-.0902	-.0464	-.0665
NREG	.0511	.4644**	.1674	-.1461	-.0248	-.1081
N2REG	.0617	.2222	.1552	-.0699	-.0269	-.0517
P	-.0021	.1039	.0442	-.1450	-.1208	-.0573
P2	.0404	.1561	.0489	-.0871	-.0726	-.0551
PREG	.0592	.2995*	.1351	-.0942	-.0785	-.0697
P2REG	.0599	.2157	.0782	-.0679	-.0565	-.0502
K	-.1194	-.3454*	-.1736	-.1219	-.1015	.0124
K2	-.1063	-.3199*	-.1606	-.1079	-.0899	-.0284
KREG	-.0262	.1202	-.0786	-.0378	-.0315	-.0280
K2REG	-.0262	.1202	-.0786	-.0378	-.0315	-.0280
NP	.0433	.1348	.1154	-.0853	-.0711	-.0609
NPREG	.0654	.2024	.1423	-.0637	-.0530	-.0471
N2P	.0584	.1314	.1534	-.0538	-.0448	-.0397
N2PREG	.0647	.1505	.1595	-.0474	-.0394	-.0350
N2P2	.0634	.1363	.1580	-.0465	-.0388	-.0344
N2P2REG	.0652	.1419	.1599	-.0446	-.0372	-.0330
NP2	.0598	.1527	.1256	-.0610	-.0508	-.0448
NP2REG	.0663	.1726	.1342	-.0543	-.0452	-.0401
METPLANT	-.2840*	-.0080	.0925	.0960	-.1173	.0710
ROWPLANT	.	.	.	.	.	.
PWEEK	.1970	.4513**	.2233	-.0594	.1096	-.2572
SQPWEEK	.1873	.4374**	.1975	-.0539	.0973	-.2456
PWEKREG	.3357*	.9904**	.5504**	-.2199	.1683	-.2304
PWEK2REG	.3332*	.9601**	.5117**	-.2138	.1616	-.2234
WEEKW	-.5291**	-.0840	.0796	-.0439	-.0794	.1607
SQWEEKW	.6407**	-.1272	-.2430	.0875	.1666	.0159
WEKWREG	-.6535**	.3091*	.3924**	-.0709	-.0707	-.0719
WEKW2REG	1.0000	.3280*	.0180	-.0988	.3266*	-.0763
REGION	.3280*	1.0000	.5731**	-.2222	.1689	-.2327
CMDT	.0180	.5731**	1.0000	-.1173	-.0645	-.1605
EFFANIM	-.0988	-.2222	-.1173	1.0000	-.0870	.3311*
EFFBIRD	.3266*	.1689	-.0645	-.0870	1.0000	-.0643
EFFINSEC	-.0763	-.2327	-.1605	.3311*	-.0643	1.0000
EFFDISEA	.0073	.1202	-.0786	-.0378	-.0315	-.0280
DISEAREG	.0073	.1202	-.0786	-.0378	-.0315	-.0280
STRESS11	-.1784	-.3812**	-.3234*	.0072	.0506	-.0441
VARIETY	-.0785	.2153	.0813	-.0643	-.1415	-.0231
VARREG	.0212	.5417**	.2593	-.1704	-.1419	-.1260
YIELD	-.1994	-.1798	.0944	-.1160	-.2345	-.1566

N of cases: 74 1-tailed Signif: * - .01 ** - .001

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Correlations:	EFFDISEA	DISEAREG	STRESS11	VARIETY	VARREG	YIELD
GENDER	-.3621**	-.3621**	.1457	-.1999	-.3146*	.2632
AGEXPL	.0781	.0781	-.0697	-.0037	-.0066	.1408
SEED	-.0344	-.0344	-.1190	.0498	-.0359	.3566**
SQSEED	-.0342	-.0342	-.0777	-.0400	-.1099	.2788*
WTCONT	.0940	.0940	-.4764**	.4142**	.4232**	.1855
HERB	.1202	.1202	-.0454	.2153	.0954	.3232*
VARWTC	.2523	.2523	-.3191*	.9241**	.8476**	.1406
N	.0045	.0045	-.2776*	.3373*	.2697	.2056
N2	-.0229	-.0229	-.1637	.1652	.1592	.0154
NREG	.0313	.0313	-.1318	.2499	.4088**	-.1274
N2REG	-.0144	-.0144	-.1067	.1228	.1990	-.1060
P	-.0525	-.0525	-.2529	.2712*	.1874	.2282
P2	-.0315	-.0315	-.1825	.1648	.1736	.0381
PREG	-.0341	-.0341	-.1375	.1993	.3037*	-.0534
P2REG	-.0246	-.0246	-.1369	.1317	.2063	-.0645
K	-.0441	-.0441	-.2660	.1995	-.1664	.5627**
K2	-.0391	-.0391	-.2548	.1896	-.1684	.5594**
KREG	-.0137	-.0137	-.0943	.2398	.2895*	-.0753
K2REG	-.0137	-.0137	-.0943	.2398	.2895*	-.0753
NP	-.0309	-.0309	-.1769	.1658	.1588	.0317
NPREG	-.0231	-.0231	-.1239	.1258	.1959	-.0854
N2P	-.0195	-.0195	-.1232	.1036	.1330	-.0564
N2PREG	-.0172	-.0172	-.1071	.0913	.1433	-.0902
N2P2	-.0169	-.0169	-.1115	.0891	.1315	-.0791
N2P2REG	-.0162	-.0162	-.1067	.0855	.1345	-.0892
NP2	-.0221	-.0221	-.1393	.1170	.1532	-.0498
NP2REG	-.0197	-.0197	-.1226	.1043	.1638	-.0859
METPLANT	.0348	.0348	.1983	-.0421	.0823	-.1934
ROWPLANT	.	.	.	.	.	.
PWEEK	.1939	.1939	-.1113	.1375	.2796*	-.1354
SQPWEEK	.1991	.1991	-.1121	.1411	.2781*	-.1343
PWEKREG	.1500	.1500	-.3862**	.2207	.5442**	-.1851
PWEK2REG	.1765	.1765	-.3814**	.2231	.5372**	-.1892
WEEKW	.0306	.0306	.1328	.1853	.0968	.0864
SQWEEKW	-.0399	-.0399	-.0419	-.2426	-.1885	-.1242
WEKWREG	.0984	.0984	-.0507	.2707*	.3816**	.1128
WEKW2REG	.0073	.0073	-.1784	-.0785	.0212	-.1994
REGION	.1202	.1202	-.3812**	.2153	.5417**	-.1798
CMDT	-.0786	-.0786	-.3234*	.0813	.2593	.0944
EFFANIM	-.0378	-.0378	.0072	-.0643	-.1704	-.1160
EFFBIRD	-.0315	-.0315	.0506	-.1415	-.1419	-.2345
EFFINSEC	-.0280	-.0280	-.0441	-.0231	-.1260	-.1566
EFFDISEA	1.0000	1.0000**	.0026	.2398	.2895*	-.1369
DISEAREG	1.0000**	1.0000	.0026	.2398	.2895*	-.1369
STRESS11	.0026	.0026	1.0000	-.1899	-.2065	-.3586**
VARIETY	.2398	.2398	-.1899	1.0000	.7903**	.1149
VARREG	.2895*	.2895*	-.2065	.7903**	1.0000	-.1094
YIELD	-.1369	-.1369	-.3586**	.1149	-.1094	1.0000

N of cases: 74 1-tailed Signif: * - .01 ** - .001

" . " is printed if a coefficient cannot be computed

Appendix 6.1: Alternative *Bas-fond* Rice Financial Budgets, by location, Mali, Rainy Season 1994-95.

	Location		
	Sikasso	Kadiolo	Bougouni
Inputs application rates:			
seed (kg/ha)	76	114	90
urea (kg/ha)	40	0	0
DAP (kg/ha)	39	0	0
Herbicide (l/ha)	5	0	0
Family labor (personday/ha)	160	131	197
Inputs prices:			
seed (cfa.F/kg)	100	80	50
urea (cfa.F/kg/ha)	175		
DAP (cfa.F/kg)	140		
Herbicide (cfa.F/l)	3,700		
Revenues			
Yield (kg paddy/ha)	1,971	1,230	889
Price (cfa.F/kg)	80	55	55
Gross revenues	157,680	67,650	48,895
Operating Costs (cfa.F/ha):			
Seeds	7,600	9,160	4,500
Urea	7,000	0	0
DAP	5,460	0	0
Herbicide	18,500	0	0
Hired labor	49,450	19,000	33,400
equipment rental	0	25,000	0
Total operating costs	88,010	53,160	37,900
Fixed costs (cfa.F/ha):			
Equipment depreciation	5,000	3,000	1,000
Small equipment	500	500	500
Total fixed cost	5,500	3,500	1,500
Opportunity cost of family labor (cfa.F/ha)	32,900	31,500	24,500
Total production cost (cfa.F/ha)	126,410	88,160	63,900
Net Margin including family labor (cfa.F/ha)	31,270	-20,510	-15,005
Net Margin not including family labor (cfa.F/ha)	64,170	10,990	9,495

Source: Adapted from Coulibaly (1995).

Appendix 6.2: Financial Budgets for Maize, Sorghum/Millet, and Cotton Enterprises in the *Bas-fond* Villages, Mali, Rainy Season 1995-96.

	Manual			1 set of implements			3 sets of implements or more		
	Cotton	Maize	Sorg./Millet	Cotton	Maize	Sorg./Millet	Cotton	Maize	Sorg./Millet
1. Revenues									
Yield (kg/ha)	1,036	1,162	695	1,188	1,417	815	1,514	1,588	959
Market price (cfa.F/kg)	155	75	90	155	75	90	155	75	90
Gross Revenues (kg/ha)	160,580	87,150	62,550	184,140	106,275	73,350	234,670	119,100	86,310
2. Costs (cfa.F/ha)									
Variable Costs	3,200	1,200	1,200	3,200	1,200	1,200	3,200	1,200	1,200
seeds	1,965	0	0	1,965	6,661	0	1,965	6,844	0
fungicide/herbicide	18,832	0	0	18,832	3,520	0	18,832	3,143	0
compound cotton fert.	0	0	0	0	9,900	0	0	6,860	0
compound cereal fert.	7,748	0	0	7,748	9,933	0	7,748	11,836	0
urea	0	0	0	1,759	1,759	1,759	3,199	3,199	3,199
maint. animal traction	27,729	0	0	27,729	0	0	27,729	0	0
insecticide treatment	2,748	72	72	2,854	1,745	178	2,940	1,767	264
interest costs	62,222	1,272	1,272	64,086	34,717	3,136	65,613	34,848	4,663
Total variables costs									
Fixed costs (cfa.F/ha):	0	0	0	22,729	1,059	5,999	107,269	3,738	22,965
depreciation	0	0	0	1,364	64	360	6,436	224	1,378
interest costs	0	0	0	24,093	1,123	6,359	113,705	3,962	24,343
Total fixed costs	62,222	1,272	1,272	88,179	35,840	9,495	179,318	38,810	29,006
Total cost (cfa.F/ha)									
Net Returns family labor (cfa.F/ha)	98,358	85,878	61,278	95,961	70,435	63,855	55,352	80,290	57,304
Op. cost fam. lab. (500 cfa.F/day)	101,490	38,062	37,230	81,192	30,450	29,784	81,192	30,450	29,784
3. Performance Indicators									
Gross Margin (cfa.F/ha)	98,358	85,878	61,278	120,054	71,558	70,214	169,057	84,252	81,647
Total production cost (cfa.F/ha)	163,712	39,334	38,502	169,371	66,290	39,279	260,510	69,260	58,790
Profit (cfa.F/ha)	-3,132	47,816	24,048	14,769	39,985	34,071	-25,840	49,840	27,520
Net ret./hr family labor (cfa.F/ha)	485	1,128	823	591	1,157	1,072	341	1,318	962
Prod. cost/kg of output (cfa.F/ha)	158	34	55	143	47	48	172	44	617

Source: Giraudy *et al.* (1994) for variable and fixed costs estimates as well as cotton yields, ESPGRN (1989) for labor data, and survey data for yield and market prices.

Appendix 7.1: Farm-Level[a] Import Parity Price of *Bas-Fond* Paddy Rice, by Point of Sale, Mali, 1996.

Item	Point of Sale		
	Bamako	Bougouni	Sikasso
World price-- FOB (cfa.F/mt milled rice)	270	270	270
Freight and handling (cfa.F/mt milled rice)	30	30	30
CIF Dakar (cfa.F/mt milled rice)	300	300	300
Real exchange rate (cfa.F/$)	530	530	530
CIF price (cfa.F/mt milled rice)	159,000	159,000	159,000
Domestic cost (cfa.F/mt milled rice)			
Port charges	7,370	7,370	7,370
Transport Dakar-Kidira	19,435	19,435	19,435
Before tax border price (cfa.F/mt milled rice)	185,805	185,805	185,805
Total *ad valorem* Import Taxes[b] (% on CIF)	0	0	0
After tax Price (cfa.F/mt milled rice)	185,885	185,805	185,805
Custom Operations Charges:			
Transit interventions (%)	1.3	1.3	1.3
Insurance (%)	3.3	3.3	3.3
Financial fees (%)	1.8	1.8	1.8
Stamp on import licenses	0.0	0.0	0.0
After tax border price--Kidira (cfa.F/mt milled rice)	197,697	197,697	197,697
Border to Bamako:			
Distance (km)	640	640	640
Transport cost (cfa.F/mtkm milled rice)	33.00	33.00	33.00
Transport (cfa.F/mt milled rice)	21,120	21,120	21,120
Handling (cfa.F/mt milled rice)	1,250	1,250	1,250
Bamako gate price (cfa.F/mt milled rice)	220,067	220,067	220,067
Importer marketing margin (%)	5	5	5
Wholesale price in Bamako (cfa.F/mt milled rice)	231,070	231,070	231,070
Bamako to the point of sale:			
Distance (km)	0	163	370
Transport cost (cfa.F/mtkm milled rice)	23.76	23.76	23.76
Transport (cfa.F/mt milled rice)	0	3,873	8,791
Point gate price (cfa.F/mt milled rice)	231,070	234,943	239,861
Wholesale marketing margin (%)	0.0	5	5
Wholesale price in the Region (cfa.F/mt milled rice)	231,070	246,690	251,854
Point of sale to Village:			
Distance (km)	307	144	144
Transport cost (cfa.F/mtkm milled rice)	30.36	30.36	30.36
Transport (cfa.F/mt milled rice)	9,321	4,372	4,372
Village gate price (cfa.F/mt milled rice)	221,749	242,318	247,482
Semi-wholesale marketing margin (%)	5	5	5
Semi-wholesale price (cfa.F/mt milled rice)	210,662	230,202	235,108
Retail marketing margin (%)	15	15	15
Retail price in the village (cfa.F/kg milled rice)	179	196	200
Milling rate (% kg milled rice/kg paddy)	65	65	65
Milling costs of paddy (cfa.F/kg of paddy)	12	12	12
Import parity price in the village (cfa.F/kg paddy)	104	115	118

[a] Computed for a Hypothetical village assumed to be 307, 144, and 144 km away from Bamako, Bougouni, and Sikasso, respectively.

[b] Includes: 5% custom duties, 25% fiscal tax, 5% services charges, 1% solidarity fund, and 10% value added tax.

Source: Survey data.

Appendix 7.2: Farm-Level[a] Social Price of Imported Paddy Rice, Mali, 1996.

Item	Value
World price-- FOB (cfa.F/mt milled rice)	270
Freight and handling (cfa.F/mt milled rice)	30
CIF Dakar (cfa.F/mt milled rice)	300
Real exchange rate (cfa.F/$)	530
CIF price (cfa.F/mt milled rice)	159,000
Domestic cost (cfa.F/mt milled rice)	
Port charges	7,370
Transport Dakar-Kidira	19,435
Before tax border price (cfa.F/mt milled rice)	185,805
Total *ad valorem* Import Taxes[b] (% on CIF)	0
After tax Price (cfa.F/mt milled rice)	185,885
Custom Operations Charges:	
Transit interventions (%)	1.3
Insurance (%)	3.3
Financial fees (%)	1.8
Stamp on import licenses	0.0
After tax border price--Kidira (cfa.F/mt milled rice)	197,697
Border to Bamako:	
Distance (km)	640
Transport cost (cfa.F/mtkm milled rice)	33.00
Transport (cfa.F/mt milled rice)	21,120
Handling (cfa.F/mt milled rice)	1,250
Bamako gate price (cfa.F/mt milled rice)	220,067
Importer marketing margin (%)	5
Wholesale price in Bamako (cfa.F/mt milled rice)	231,070
Bamako to Village:	
Distance (km)	307
Transport cost (cfa.F/mtkm milled rice)	30.36
Transport (cfa.F/mt milled rice)	9,321
Village gate price (cfa.F/mt milled rice)	240,390
Semi-wholesale marketing margin (%)	5
Semi-wholesale price (cfa.F/mt milled rice)	252,410
Retail marketing margin (%)	15
Retail price in the village (cfa.F/kg milled rice)	290
Milling rate (% kg milled rice/kg paddy)	65
Milling costs of paddy (cfa.F/kg of paddy)	12
Import parity price in the village (cfa.F/kg paddy)	201

[a] Computed for a Hypothetical farm assumed to be 307 km away from Bamako.

[b] Normally includes: 5% custom duties, 25% fiscal tax, 5% services charges, 1% solidarity fund, and 10% value added tax.

Source: Survey data.

Appendix 7.3: Farm-Level[a] Social Prices of Imported Urea, DAP, and NPK Cereal Fertilizer Used by Farmers in *Bas-Fond* Rice Production, Mali, 1996.

Item	Fertilizer		
	Urea	DAP	NPK
World price-- FOB ($US/mt fertilizer)	169.60	211.18	184.64
Freight and handling ($US/mt fertilizer)	30	30	30
CIF Dakar ($US/mt fertilizer)	199.60	241.18	214.64
Real exchange rate (cfa.F/$)	530	530	530
CIF price (cfa.F/mt fertilizer)	105,788	127,825	113,759
Domestic cost (cfa.F/mt fertilizer)			
Port charges	7,370	7,370	7,370
Transport Dakar-Kidira	21,125	21,125	21,125
Before tax border price (cfa.F/mt fertilizer)	134,283	156,320	142,254
Import Tax (% on CIF):			
Conjunctural import	0	0	0
Total ad valorem taxes (%):	0	0	0
After tax Price (cfa.F/mt fertilizer)	134,283	156,320	142,254
Custom Operations Charges:			
Transit interventions (cfa.F/mt fertilizer)	7,000	7,000	7,000
Insurance (cfa.F/mt fertilizer)	460	460	460
Financial fees (cfa.F/mt fertilizer)	0	0	0
Stamp on import licenses	0	0	0
After tax border price--Kidira (cfa.F/mt fertilizer)	141,743	180,975	149,714
Border to Bamako:			
Distance (km)	640	640	640
Transport cost (cfa.F/mtkm fertilizer)	33.00	33.00	33.00
Transport (cfa.F/mt fertilizer)	21,120	21,120	21,120
Handling (cfa.F/mt fertilizer)	500	500	500
Bamako gate price (cfa.F/mt fertilizer)	163,363	185,400	171,334
Importer marketing margin (%)	5	5	5
Wholesale price in Bamako (cfa.F/mt fertilizer)	171,531	194,670	179,901
Bamako to the Village:			
Distance (km)	307	307	307
Transport cost (cfa.F/mtkm fertilizer)	66.00	66.00	66.00
Transport (cfa.F/mt fertilizer)	20,262	20,262	20,262
Village gate price (cfa.F/mt fertilizer)	191,793	214,932	200,163
Semi-wholesale marketing margin (%)	5	5	5
Semi-wholesale price (cfa.F/mt fertilizer)	201,383	225,679	210,171
Retail marketing margin (%)	15	15	15
Retail price in the village (cfa.F/kg fertilizer)	232	260	242
Import parity price in the village (cfa.F/kg fertilizer)	232	260	242

[a] Computed for a Hypothetical farm assumed to be 307 km away from Bamako.
Source: Survey data.

Appendix 7.4: Farm-Level[a] Economic Budgets for Commercial *Bas-fond* Rice Enterprises, by Point of Sale and Production System, Mali, 1996.

Budget Items	Bamako				Bougouni				Sikasso			
	Purely Trad.	Macro-Semi-Intensive	Micro-Semi-Intensive	Intensive	Purely Trad.	Macro-Semi-Intensive	Micro-Semi-Intensive	Intensive	Purely Trad.	Macro-Semi-Intensive	Micro-Semi-Intensive	Intensive
A. OUTPUT												
Gross Revenue (cfa.F/ha)	106,583	128,609	148,548	246,988	117,606	141,910	163,911	272,532	120,373	145,249	167,768	278,945
B. COSTS												
Fixed Costs (cfa.F/ha):												
water utilization fee	0	54,965	0	54,965	0	54,965	0	54,965	0	54,965	0	54,965
Total fixed costs (cfa.F/ha)	0	54,965	0	54,965	0	54,965	0	54,965	0	54,965	0	54,965
Operating Costs (cfa.F/ha):												
Seeds	41,540	23,278	18,864	43,747	41,540	23,278	18,864	43,747	41,540	23,278	18,864	43,747
Fertilizer	0	0	0	51,629	0	0	0	51,629	0	0	0	51,629
Herbicide	0	0	16,450	16,450	0	0	16,450	16,450	0	0	16,450	16,450
Hired labor	39,000	56,795	14,000	49,164	39,000	56,795	14,000	49,164	39,000	56,795	14,000	49,164
Interest cost (8.7%)	2,488	2,554	1,778	4,830	2,488	2,554	1,778	4,830	2,488	2,554	1,778	4,830
Total operating costs (cfa.F/ha)	83,028	82,628	51,091	165,820	83,028	82,628	51,091	165,820	83,028	82,628	51,091	165,820
Total costs (cfa.F/ha)	83,028	137,593	51,091	220,786	83,028	137,593	51,091	220,786	83,028	137,593	51,091	220,786
C. NET SOCIAL RETURNS (cfa.F/HA)	23,555	-8,984	97,457	26,203	34,577	4,317	112,819	51,746	37,345	7,656	116,677	58,159
Opportunity cost family labor (cfa.F/ha)	21,333	18,667	20,750	28,417	21,333	18,667	20,750	28,417	21,333	18,667	20,750	28,417
D. ENTERPRISE PROFIT (cfa.F/HA)	2,221	-27,650	76,707	-2,214	13,244	-14,350	92,069	23,329	16,012	-11,010	95,927	29,742

[a] Estimated for a *bas-fond* village assumed to be 307, 144 and 144 km away from Bamako, Bougouni, and Sikasso, respectively.

Source: Survey Data.

Appendix 7.5: Farm-Level Financial Budgets for Commercial *Office du Niger* Rice Enterprises, by Point of Sale and Production Perimeter[a], Mali, 1996.

Budget Items	Production Parameter	
	Non-Rehabilitated	Rehabilitated
A. INPUT USE RATES		
Oxen (No. for 8 years)	2	2
Plow (No.for 10 years)	1	1
Harrow (No.for 8 years)	1	1
Cart (No.for 10 years)	0	1
Seeds (kg/ha)	104	80
Urea (kg/ha)	139	215
DAP (kg/ha)	74	130
B. INPUT PRICES		
Oxen (cfa.F/unit)	100,000	100,000
Plow (cfa.F/unit)	20,000	20,000
Harrow (cfa.F/unit)	20,000	20,000
Cart (cfa.F/unit)	80,300	80,300
Seeds (cfa.F/kg)	100	122
Urea (cfa.F/kg)	204	193
DAP (cfa.F/kg)	216	205
C. OUTPUT		
Average Yield (kg of paddy/ha)	2,546	4,877
Market price of paddy (cfa.F/kg of paddy)	110	110
Rebate	24,000	32,000
Gross Revenue (cfa.F/ha)	304,060	568,470
D. COSTS		
Fixed Costs (cfa.F.ha):		
Land Development	0	0
Gross maintenance	0	0
Depreciation costs:		
Oxen	15,098	15,098
Plow	1,770	1,770
Harrow	2,013	2,013
Carts	0	7,106
Total fixed costs (cfa.F/ha)	18,881	25,986
Operating Costs (cfa.F/ha):		
Seeds	10,400	9,760
Urea	28,356	41,495
DAP	15,984	26,650
Herbicide	0	0
Irrigation	0	0
Hired labor	14,000	16,500
Animal traction:		
maintenance	1,000	1,000
anim. feed	2,000	2,000
vet. care	3,300	3,300
Irrigation fees (cfa.F/ha)	11,500	66,000
Interest on working capital (12%)	4,816	12,419
Total operating costs (cfa.F/ha)	88,356	176,124
Total costs (cfa.F/ha)	107,236	202,111
E. NET RETURNS (cfa.F/HA)	196,824	366,359

[a] The non-rehabilitated perimeter is the CMDT zone of Macina and the rehabilitated perimeter is the Niono Zone.
Source: Survey Data.

Appendix 7.6: Farm-Level Import Parity Price for Paddy Rice Produced in the Non-Rehabilitated *Office du Niger* Perimeter (Macina), by Point of Sale, Mali, 1996.

Item	Point of Sale		
	Bamako	Bougouni	Sikasso
CIF Dakar	300.00	300.00	300.00
Real exchange rate (cfa.F/$)	530	530	530
CIF price (cfa.F/mt milled rice)	159,000	159,000	159,000
Domestic cost (cfa.F/mt milled rice)			
Port charges	7,370	7,370	7,370
Transport Dakar-Kidira	19,435	19,435	19,435
Before tax border price (cfa.F/mt milled rice)	185,805	185,805	185,805
Import Tax (% on CIF):			
Total ad valorem taxes (%):	0	0	0
After tax Price (cfa.F/mt milled rice)	185,805	185,805	185,805
Custom Operations Charges:			
Transit interventions (%)	1.3	1.3	1.3
Insurance (%)	3.3	3.3	3.3
Financial fees (%)	1.8	1.8	1.8
Stamp on import licenses (%)	0.0	0.0	0.0
After tax border price--Kidira (cfa.F/mt milled rice)	197,697	197,697	197,697
Border to Bamako:			
Distance (km)	640	640	640
Transport cost (cfa.F/mtkm milled rice)	33.00	33.00	33.00
Transport (cfa.F/mt milled rice)	21,120	21,120	21,120
Handling (cfa.F/mt milled rice)	500	500	500
Bamako gate price (cfa.F/mt milled rice)	219,317	219,317	219,317
Importer marketing margin (%)	5	5	5
Wholesale price in Bamako (cfa.F/mt milled rice)	230,282	230,282	230,282
Bamako to the point of sale:			
Distance (km)	0	163	370
Transport cost (cfa.F/mtkm milled rice)	33.00	33.00	33.00
Transport (cfa.F/mt milled rice)	0	5,379	12,210
Point gate price (cfa.F/mt milled rice)	230,282	235,661	242,492
Wholesale marketing margin (%)	0	5	5
Wholesale price in the Region (cfa.F/mt milled rice)	230,282	247,444	254,617
Point of sale to Village:			
Distance (km)	438	660	453
Transport cost (cfa.F/mtkm milled rice)	30.36	30.36	30.36
Transport (cfa.F/mt milled rice)	13,298	20,038	13,753
Village gate price (cfa.F/mt milled rice)	216,985	227,407	240,864
Semi-wholesale marketing margin (%)	5	5	5
Semi-wholesale price (cfa.F/mt milled rice)	206,135	216,036	228,821
Retail marketing margin (%)	15	15	15
Retail price in the village (cfa.F/mt milled rice)	175	184	194
Milling rate (%)	65	65	65
Milling cost of paddy (cfa.F/kg milled rice)	12	12	12
Import parity price in the village (cfa.F/kg paddy)	102	107	114

Source: Survey data.

Appendix 7.7: Farm-Level Import Parity Price for Paddy Rice Produced in the Rehabilitated *Office du Niger* Perimeter (Niono), by Point of Sale, Mali, 1996.

Item	Point of Sale		
	Bamako	Bougouni	Sikasso
CIF Dakar	300.00	300.00	300.00
Real exchange rate (cfa.F/$)	530	530	530
CIF price (cfa.F/mt milled rice)	159,000	159,000	159,000
Domestic cost (cfa.F/mt milled rice)			
Port charges	7,370	7,370	7,370
Transport Dakar-Kidira	19,435	19,435	19,435
Before tax border price (cfa.F/mt milled rice)	185,805	185,805	185,805
Import Tax (% on CIF):			
Total ad valorem taxes (%):	0	0	0
After tax Price (cfa.F/mt milled rice)	185,805	185,805	185,805
Custom Operations Charges (%):			
Transit interventions	1.3	1.3	1.3
Insurance	3.3	3.3	3.3
Financial fees	1.8	1.8	1.8
Stamp on import licenses	0.0	0.0	0.0
After tax border price--Kidira (cfa.F/mt milled rice)	197,697	197,697	205,129
Border to Bamako:			
Distance (km)	640	640	640
Transport cost (cfa.F/mtkm milled rice)	33.00	33.00	33.00
Transport (cfa.F/mt milled rice)	21,120	21,120	21,120
Handling (cfa.F/mt milled rice)	500	500	500
Bamako gate price (cfa.F/mt milled rice)	219,317	219,317	219,317
Importer marketing margin (%)	5	5	5
Wholesale price in Bamako (cfa.F/mt milled rice)	230,282	230,282	230,282
Bamako to the point of sale:			
Distance (km)	0	163	370
Transport cost (cfa.F/mtkm milled rice)	33.00	33.00	33.00
Transport (cfa.F/mt milled rice)	0	5,379	12,210
Point gate price (cfa.F/mt milled rice)	230,282	235,661	242,492
Wholesale marketing margin (%)	0	5	5
Wholesale price in the Region (cfa.F/mt milled rice)	230,282	247,444	254,617
Point of sale to Village:			
Distance (km)	343	565	358
Transport cost (cfa.F/mtkm milled rice)	30.36	30.36	30.36
Transport (cfa.F/mt milled rice)	10,413	17,153	10,869
Village gate price (cfa.F/mt milled rice)	219,869	230,291	243,748
Semi-wholesale marketing margin (%)	5	5	5
Semi-wholesale price (cfa.F/mt milled rice)	208,875	218,776	231,561
Retail marketing margin (%)	15	15	15
Retail price in the village (cfa.F/mt milled rice)	178	186	197
Milling rate (%)	65	65	65
Milling cost of paddy (cfa.F/kg milled rice)	12	12	12
Import parity price in the village (cfa.F/kg paddy)	103	109	116

Source: Survey data.

Appendix 7.8: Farm-Level Social Prices for Imported Paddy Rice in the Non-Rehabilitated and Rehabilitated *Office du Niger* Perimeters, Mali, 1996.

Item	Perimeter	
	Non-Rehabilitated (Macina)	Rehabilitated (Niono)
CIF Dakar	300.00	300.00
Real exchange rate (cfa.F/$)	530	530
CIF price (cfa.F/mt milled rice)	159,000	159,000
Domestic cost (cfa.F/mt milled rice)		
Port charges	7,370	7,370
Transport Dakar-Kidira	19,435	19,435
Before tax border price (cfa.F/mt milled rice)	185,805	185,805
Import Tax (% on CIF):		
Total ad valorem taxes (%):	0	0
After tax Price (cfa.F/mt milled rice)	185,805	185,805
Custom Operations Charges:		
Transit interventions (%)	1.3	1.3
Insurance (%)	3.3	3.3
Financial fees (%)	1.8	1.8
Stamp on import licenses (%)	0.0	0.0
After tax border price--Kidira (cfa.F/mt milled rice)	197,697	197,697
Border to Bamako:		
Distance (km)	640	640
Transport cost (cfa.F/mtkm milled rice)	33.00	33.00
Transport (cfa.F/mt milled rice)	21,120	21,120
Handling (cfa.F/mt milled rice)	500	500
Bamako gate price (cfa.F/mt milled rice)	219,317	219,317
Importer marketing margin (%)	5	5
Wholesale price in Bamako (cfa.F/mt milled rice)	230,282	230,282
Bamako to perimeter:		
Distance (km)	438	343
Transport cost (cfa.F/mtkm milled rice)	30.36	30.36
Transport (cfa.F/mt milled rice)	13,298	10,413
Village gate price (cfa.F/mt milled rice)	243,580	240,696
Semi-wholesale marketing margin (%)	5	5
Semi-wholesale price (cfa.F/mt milled rice)	255,759	252,731
Retail marketing margin (%)	15	15
Retail price in the village (cfa.F/mt milled rice)	294	291
Milling rate (%)	65	65
Milling cost of paddy (cfa.F/kg milled rice)	12	12
Import parity price in the village (cfa.F/kg paddy)	203	201

Source: Survey data.

Appendix 7.9: Farm-Level Social Prices for Imported Urea Used by Farmers in the Non-Rehabilitated and Rehabilitated *Office du Niger* Perimeters, Mali, 1996.

Item	Perimeter	
	Non-Rehabilitated (Macina)	Rehabilitated (Niono)
CIF Dakar ($US/mt urea)	199.60	199.60
Real exchange rate (cfa.F/$)	530	530
CIF price (cfa.F/mt urea)	105,788	105,788
Domestic cost (cfa.F/mt urea)		
Port charges	7,370	7,370
Transport Dakar-Kidira	21,125	21,125
Before tax border price (cfa.F/mt urea)	134,283	134,283
Import Tax (% on CIF):		
Conjunctural import	0	0
Total ad valorem taxes (%):	0	0
After tax Price (cfa.F/mt urea)	134,283	134,283
Custom Operations Charges:		
Transit interventions (cfa.F/mt urea)	7,000	7,000
Insurance (cfa.F/mt urea)	460	460
Financial fees (cfa.F/mt urea)	0	0
Stamp on import licenses	0	0
After tax border price--Kidira (cfa.F/mt urea)	141,743	141,743
Border to Bamako:		
Distance (km)	640	640
Transport cost (cfa.F/mtkm urea)	33.00	33.00
Transport (cfa.F/mt urea)	21,120	21,120
Handling (cfa.F/mt urea)	500	500
Bamako gate price (cfa.F/mt urea)	163,363	163,363
Importer marketing margin (%)	5	5
Wholesale price in Bamako (cfa.F/mt urea)	171,531	171,531
Bamako to perimeter:		
Distance (km)	438	343
Transport cost (cfa.F/mtkm urea)	66.00	66.00
Transport (cfa.F/mt urea)	28,908	22,638
Village gate price (cfa.F/mt urea)	200,439	194,169
Semi-wholesale marketing margin (%)	5	5
Semi-wholesale price (cfa.F/mt urea)	210,461	203,878
Retail marketing margin (%)	15	15
Retail price in the village (cfa.F/kg urea)	242	234
Import parity price in the village (cfa.F/kg urea)	242	234

Source: Survey data.

Appendix 7.10: Farm-Level Social Prices for Imported DAP Used by Farmers in the Non-Rehabilitated and Rehabilitated *Office du Niger* Perimeters, Mali, 1996.

Item	Perimeter: Non-Rehabilitated (Macina)	Perimeter: Rehabilitated (Niono)
CIF Dakar ($US/mt DAP)	241.18	241.18
Real exchange rate (cfa.F/$)	530	530
CIF price (cfa.F/mt DAP)	127,825	127,825
Domestic cost (cfa.F/mt DAP)		
Port charges	7,370	7,370
Transport Dakar-Kidira	21,125	21,125
Before tax border price (cfa.F/mt DAP)	156,320	156,320
Import Tax (% on CIF):		
Conjunctural import	0	0
Total ad valorem taxes (%):	0	0
After tax Price (cfa.F/mt DAP)	156,320	156,320
Custom Operations Charges:		
Transit interventions	7,000	7,000
Insurance (cfa.F/mt DAP)	460	460
Financial fees (cfa.F/mt DAP)	0	0
Stamp on import licenses (cfa.F/mt DAP)	0	0
After tax border price--Kidira (cfa.F/mt DAP)	163,780	163,780
Border to Bamako:		
Distance (km)	640	640
Transport cost (cfa.F/mtkm DAP)	33.00	33.00
Transport (cfa.F/mt DAP)	21,120	21,120
Handling (cfa.F/mt DAP)	500	500
Bamako gate price (cfa.F/mt DAP)	185,400	185,400
Importer marketing margin (%)	5	5
Wholesale price in Bamako (cfa.F/mt DAP)	194,670	194,670
Bamako to perimeter:		
Distance (km)	438	343
Transport cost (cfa.F/mtkm DAP)	66.00	66.00
Transport (cfa.F/mt DAP)	28,908	22,638
Village gate price (cfa.F/mt DAP)	223,578	217,308
Semi-wholesale marketing margin (%)	5	5
Semi-wholesale price (cfa.F/mt DAP)	234,757	228,173
Retail marketing margin (%)	15	15
Retail price in the village (cfa.F/kg DAP)	270	262
Import parity price in the village (cfa.F/kg DAP)	270	262

Source: Survey data.

by Point of Sale and Production Perimeter[a], Mali, 1996.

Appendix 7.11: Farm-Level Economic Budgets for Commercial *Office du Niger* Rice Enterprises, by Point of Sale and Production Perimeter[a], Mali, 1996.

Budget Items		Bamako		Bougouni		Sikasso	
		Non-Rehab.	Rehabilitated	Non-Rehab.	Rehabilitated	Non-Rehab.	Rehabilitated
A. OUTPUT							
Average Yield (kg of paddy/ha)		2,546	4,877	2,546	4,877	2,546	4,877
Market price of paddy (cfa.F/kg of paddy)		102	103	107	109	114	116
Rebate		24,000	32,000	24,000	32,000	24,000	32,000
Gross Revenue (cfa.F/ha)		283,411	536,303	297,339	562,978	315,322	597,426
D. COSTS							
Fixed Costs (cfa.F.ha):							
Land Development		0	200,235	0	200,235	0	200,235
Gross maintenance		43,495	14,902	43,495	14,902	43,495	14,902
Depreciation costs:	Oxen	13,419	13,419	13,419	13,419	13,419	13,419
	Plow	1,540	1,540	1,540	1,540	1,540	1,540
	Harrow	1,789	1,789	1,789	1,789	1,789	1,789
	Carts	0	6,184	0	6,184	0	6,184
Total fixed costs (cfa.F/ha)		60,243	238,069	60,243	238,069	60,243	238,069
Operating Costs (cfa.F/ha):							
Seeds		21,131	16,073	21,131	16,073	21,131	16,073
Urea		33,642	50,409	38,489	57,905	37,400	56,221
DAP		19,978	34,112	22,661	38,826	22,082	37,808
Hired labor		14,000	16,500	14,000	16,500	14,000	16,500
Animal traction:	maintenance	1,000	1,000	1,000	1,000	1,000	1,000
	anim. feed	2,000	2,000	2,000	2,000	2,000	2,000
	vet. care	300	300	300	300	300	300
Irrigation fees (cfa.F/ha)		55,250	105,792	55,250	109,074	55,250	113,312
Interest on working capital (12%)		8,068	13,273	8,068	13,560	8,068	13,930
Total operating costs (cfa.F/ha)		155,369	239,459	155,369	243,028	155,369	247,636
Total costs (cfa.F/ha)		215,613	477,529	215,613	481,098	215,613	485,706
E. RETURNS to land, family labor (cfa.F/ha)		67,799	58,771	81,726	81,881	99,709	111,720
F. Opportunity cost of land (cfa.F/ha)		96,260	96,260	96,260	96,260	96,260	96,260
G. RETURNS family labor (cfa.F/ha)		-28,491	-37,489	-14,534	-14,379	3,449	15,460
H. Opportunity cost of family labor (cfa.F/ha)		42,900	101,400	42,900	101,400	42,900	101,400
I. Social profit (cfa.F/ha)		-71,361	-138,889	-57,434	-115,779	-39,451	-85,940

[a] The non-rehabilitated perimeter is the CMDT zone of Macina and the rehabilitated perimeter is the Niono Zone.

Appendix 7.12: Policy Analysis Matrices for Subsistence *Bas-Fond* Rice Production Systems[a], Mali, 1996.

	Assuming 500 cfa/day for family labor				Assuming zero opportunity cost for family labor			
	Revenues	Costs		Profits	Revenues	Costs		Profits
		Tradable inputs	Domestic factors			Tradable inputs	Domestic factors	
Purely Traditional								
Financial prices	117,415	17,595	62,553	37,267	117,415	17,595	62,553	37,267
Social prices	204,891	41,540	62,821	46,017	204,891	41,540	41,488	121,862
Divergences	-87,476	-23,945	268	63,262	-87,476	-23,945	268	-63,262
Macro-semi-intensive								
Financial prices	141,680	9,860	78,298	53,522	141,680	9,860	78,298	53,522
Social prices	247,233	23,278	132,981	90,974	247,233	23,278	114,315	109,640
Divergences	-105,553	-13,418	-54,683	-37,452	-105,553	-13,418	-54,683	-37,452
Micro-semi-intensive								
Financial prices	163,645	24,440	36,648	102,558	163,645	24,440	36,648	102,558
Social prices	285,563	35,314	36,528	213,721	285,563	35,314	15,778	234,471
Divergences	-121,918	-10,874	120	111,164	-121,918	-10,874	120	-111,164
Intensive								
Financial prices	272,090	92,494	83,329	96,266	272,090	92,494	83,329	96,266
Social prices	474,800	111,827	137,376	225,598	474,800	111,827	108,959	254,015
Divergences	-202,710	-19,332	-54,046	-129,332	-202,710	-19,332	-54,046	-129,332

[a] The non-rehabilitated perimeter is in the CMDT zone of Macina and the rehabilitated perimeter is Niono Zone.
Source: Computed from Appendices 7.6 and 7.11.

Appendix 7.13: Policy Analysis Matrices[a] for Commercial *Bas-fond* Rice Production Systems[b], by Point of Sale, Mali, 1996.

	Bamako				Bougouni				Sikasso			
	Revenues	Costs		Profits	Revenues	Costs		Profits	Revenues	Costs		Profits
		Tradable inputs	Domestic factors			Tradable inputs	Domestic factors			Tradable inputs	Domestic factors	
Purely Traditional												
Financial prices	117,415	17,595	62,553	37,267	117,415	17,595	62,553	37,267	117,415	17,595	62,553	37,267
Social prices	106,583	41,540	62,821	2,221	117,606	41,540	62,821	13,244	120,373	41,540	62,821	16,012
Divergences	10,832	-23,945	268	35,045	-191	-23,945	268	24,023	-2,958	-23,945	268	21,255
Macro-semi-intensive												
Financial prices	141,680	9,860	78,298	53,522	141,680	9,860	78,298	53,522	141,680	9,860	78,298	53,522
Social prices	128,609	23,278	132,981	-27,650	141,910	23,278	132,981	-14,350	145,249	23,278	132,981	-11,010
Divergences	13,071	-13,418	-54,683	81,172	-230	-13,418	-54,683	67,871	-3,569	-13,418	-54,683	64,532
Micro-semi-intensive												
Financial prices	163,645	24,440	36,648	102,558	163,645	24,440	36,648	102,558	163,645	24,440	36,648	102,558
Social prices	148,548	35,314	36,528	76,707	163,911	35,314	36,528	92,069	167,768	35,314	36,528	95,927
Divergences	15,097	-10,874	120	25,851	-266	-10,874	120	10,488	-4,123	-10,874	120	6,631
Intensive												
Financial prices	272,090	92,494	83,329	96,266	272,090	92,494	83,329	96,266	272,090	92,494	83,329	96,266
Social prices	246,988	111,827	137,376	-2,214	272,532	111,827	137,376	23,329	278,945	111,827	137,376	29,742
Divergences	25,102	-19,332	-54,046	98,480	-442	-19,332	-54,046	72,937	-6,855	-19,332	-54,046	66,524

[a] Assumes a 500 cfa/day for family labor.
[b] Estimated for a *bas-fond* village assumed to be 307, 144 and 144 km away from Bamako, Bougouni, and Sikasso, respectively.
Source: Computed from Table 6.1 and Appendix 7.4.

Appendix 7.14: Policy Analysis Matrices[a] for Representative Commercial *Office du Niger* Rice Production Systems, by Point of Sale and Production Perimeter[b], Mali, 1996.

	Bamako				Bougouni				Sikasso			
	Revenues	Costs		Profits	Revenues	Costs		Profits	Revenues	Costs		Profits
		Tradable inputs	Domestic factors			Tradable inputs	Domestic factors			Tradable inputs	Domestic factors	
Non-Rehab. Perimeter												
Financial prices	304,060	54,740	95,396	153,924	304,060	54,740	95,396	153,924	304,060	54,740	95,396	153,924
Social prices	283,411	74,751	280,022	-71,361	297,339	74,751	280,022	-57,434	315,322	74,751	280,022	-39,451
Divergences	20,649	-20,011	-184,626	225,285	6,721	-20,011	-184,626	211,357	-11,262	-20,011	-184,626	193,374
Rehabilitated Perimeter												
Financial prices	568,470	77,905	225,606	264,959	568,470	77,905	225,606	264,959	568,470	77,905	225,606	264,959
Social prices	536,300	100,594	574,595	-138,889	562,978	100,594	578,164	-115,779	597,426	100,594	582,772	-85,940
Divergences	32,170	-22,689	-348,989	403,848	5,492	-22,689	-352,558	380,738	-28,956	-22,689	-357,166	350,899

[a] Assumes a 500 cfa/day for family labor.
[b] The non-rehabilitated perimeter is in the CMDT zone of Macina and the rehabilitated perimeter is Niono Zone.
Source: Computed from Appendices 7.6 and 7.11.

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