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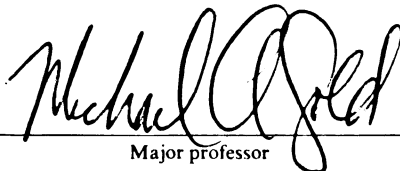
**A Systems Analysis
Of The Status And Potential
Of Acacia Albida (DEL.)
In The North Central Peanut Basin Of Senegal**

presented by

JAMES R. SEYLER

has been accepted towards fulfillment
of the requirements for

Doctoral degree in Forestry


Major professor

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**A SYSTEMS ANALYSIS
OF THE STATUS AND POTENTIAL
OF ACACIA ALBIDA (DEL.)
IN THE NORTH CENTRAL PEANUT BASIN OF SENEGAL**

VOLUME I

By

James R. Seyler

A DISSERTATION

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

DOCTOR OF PHILOSOPHY

Department of Forestry

1993

ABSTRACT

A SYSTEMS ANALYSIS OF THE STATUS AND POTENTIAL OF ACACIA ALBIDA (DEL.) IN THE NORTH CENTRAL PEANUT BASIN OF SENEGAL

By

James R. Seyler

One of the oldest traditional agroforestry systems in the Sahel is the intercropping of the leguminous tree species *Acacia albida* with millet or sorghum, often associated with a livestock component. In the past, this system constituted a form of ecological equilibrium for much of Sahelian agriculture. The system is under stress and breaking down in many areas in spite of government and donor interest in maintaining and expanding it.

The primary purpose of this research was to investigate internal and external biophysical and socio-economic factors related to the decline, maintenance and replication of the *A. albida* system in Senegal's North Central Peanut Basin. A systems model of human ecology was used and implemented through: rapid rural appraisal; formal farm-level socio-economic survey; a farm-level biophysical inventory of on-farm tree and soil resources; and focus group interviews. Regression analysis was used to test the majority of hypotheses. Principal components analysis was employed to identify composite variables and their interactions. A benefit-cost analysis examined the financial returns of the system under different input scenarios.

The research found that the economic incentives are the primary determinant in on-farm natural resource management. Maintenance and wider use of the system and improved natural resource management are influenced more by general agricultural and economic policies than by policies and projects which focus on the system itself. Changes in agricultural policy through structural adjustment had the greatest

positive impact on the system. Internally, a combination of drought, water table depth and cutting for forage had the greatest negative impact. Contrary to conventional wisdom, it was also found that population pressure bears positively on the system through agricultural intensification. The research also found great similarity between Wolof and Serer *A. albida* systems.

This study concludes that increased support for actions that farmers are currently undertaking to better protect and manage their natural resources, is preferable to narrow technical interventions that focus on new methods and technologies. There is a great need for agricultural and forestry/natural resources training to better equip farmers with the skills necessary for improved natural resource management and decision making. Similarly, extension should support existing management systems rather than promote externally conceived systems which seldom conform to local realities. Finally, system-specific and other natural resource policies such as the Forest Code require modification to be brought in line with and supportive of current farmer actions.

ACKNOWLEDGEMENTS

This study is the result of the efforts of a great many individuals at Michigan State University and in Senegal. I would like to offer particular thanks to my major professor Michael A. Gold for his advice, encouragement, and friendship. I would also like to extend thanks to Eric Crawford for his encouragement, support, and tolerance.

The United States Agency for International Development provided both the funding for the field work conducted in Senegal, and the motivation necessary to complete the effort. A special note of thanks to Wayne Nilsestuen and Jane Ellis who supported the idea for this research and helped me overcome many of the hurdles encountered in Senegal.

The in-depth interviews with farmers could not have been done without the assistance of Mohamadu Lamine Diop, El Hady Malik Diouf, Birame Ndiaye, Abdoulaye Sy, Mam Birame Diouf and Awa Diop. Many other people in Senegal also helped me gather information and furthered my understanding of issues surrounding the *Acacia albida* system. Special thanks go to Pape Sall, Samba Ndiaye and Momar Wade and others at the Senegalese Agriculture Research Institute (ISRA) for all their help. I am also grateful for the logistical support provided by the Senegal Agriculture Research II Project; Ann Williams deserves a particular note of thanks for all her help.

The most important contributors to this study were the farmers in the North Central Peanut Basin who willingly participated in a time consuming interview and inventory process. Hopefully, the results of this research will contribute to the design of natural resource policies, programs and projects that better respond to farmers' needs.

Finally, I am most deeply grateful to Linda Kay Seyler, my wife, for her help, understanding, patience, inspiration, and love that made this research possible.

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LIST OF ABBREVIATIONS AND ACRONYMS USED

ABP	Association Producteur de Base
BAME	Bureau d'Analyses Macro-Economiques
CEC	Cation Exchange Capacity
CER	Centre d'Expansion Rural Polyvalent
CNRF	Centre National de Recherches Forestières
CRA/BAMBEY	Centre de Recherches Agricoles de Bambey
CTFT	Centre Technique Forestier Tropical
DCSR	Direction de la Conservation du Sol et du Reboisement
DEFC	Direction des Eaux, Forêts et Chasses
DRPA	Direction des Recherches sur les Productions Animales
DRPF	Direction de Recherche sur les Productions et Forestières
DRPV	Direction des Recherches sur les Productions Végétales
DRSAEA	Direction des Recherches sur les Systèmes Agraires et l'Economie Agricole
FAO	Food and Agriculture Organization
FCFA	CFA Francs
FPP	Foster Parent Plan
GIE	Economic Interest Group
GOS	Government of Senegal
IDA	International Development Association
IMF	International Monetary Fund
ISRA	Senegalese Institute for Agriculture Research
KASA	Knowledge, Attitudes, Skills and Aspirations
MPN	Ministère de la Protection de la Nature
NAP(NPA)	New Agricultural Policy
NCPB	North Central Peanut Basin
NGO(ONG)	Non-Governmental Organization
NPV	Net Present Value
ORSTOM	Office de Recherche Scientifique et Technique de l'Ostre Mer
PA	Programme Agricole
PAGRI	Programme Pilote d'Amelioration des Services d'Appui aux Agriculteurs
PAPEM	Point d'Appui, de Prévulgarisation et d'Expérimentation Multilocal
PARCE	Projet d'Aménagement et Reboisement de Forêts du Centre-Est
PB	Peanut Basin
PNVA	National Agricultural Extension Project (World Bank)
PRECOBA	Projet de Reboisement Communautaires dans le Bassin Arachidier du Sénégal
PREVINOBA	Project du Reboisement Villageois dans le Nord-Ouest du Bassin Arachidier
PROVOBIL	Projet de Boisement Villageois dans la Zone Sahélienne
SODEVA	Société de Développement et de Vulgarisation Agricole
SOM	Soil Organic Matter
SONAR	Société Nationale d'Approvisionnement du Monde Rural
SV	Section Villageoise
UNDP	United Nations Development Program
USAID	U.S. Agency for International Development
WB	World Bank

CHAPTER 1

THE ACACIA ALBIDA HUMAN ECOLOGICAL SYSTEM

"If one mutilates the branch of an *Acacia albida* without reason, his arm will be cut off, and if one cuts down an *Acacia albida* without authorization, his head will be cut off."

Dina Djenne, Sultan of Zinder,
Niger. Ca. 1880, from Giffard (1964)

1.1 Introduction

Many countries in sub-Saharan Africa are now experiencing some of the world's highest population growth rates. As a result, the rise in demand for food and forest products has increased pressure on the natural resource base to the extent that many traditional farming systems are no longer adequate to meet basic family needs (ICRAF 1985). As Africa's human and livestock populations increase, greater and conflicting demands are being placed on a finite land base, thus jeopardizing increased or even sustained agricultural production. Some rural development experts attribute sub-Saharan Africa's declines in agriculture productivity (World Bank 1985) to the widespread deforestation, overgrazing and subsequent increases in soil erosion now present on the continent (Hekstra 1981, Timberlake 1985). Inappropriate agricultural and natural resource policy frameworks have also been implicated in Africa's declining agricultural productivity, not only from a macro-economic perspective, but from their potential negative impacts on natural resources (Berry et al. 1980, Timberlake 1985).

Whatever the reasons for these declines, it is increasingly evident that pressures on the natural resource base in Africa will eventually dictate that food, wood, fodder and other goods be produced by farmers on their own land. This "on-farm" approach maintains that the farm family is a social nucleus around which reforestation programs are planned (Cernea 1985). Thus, soil and water

conservation, achievable through "on-farm" or family forestry and tree planting can play an important role in halting the degradation associated with inadequate land use choices such as uncontrolled shifting cultivation and fuelwood and charcoal harvesting, and overgrazing. This on-farm tree planting is referred to as agroforestry.

Agroforestry has been defined by Bene (1977) and King and Chandler (1978) as a "holistic approach to sustainable land management systems which increases the yield of the land, combines the production of crops (including tree crops) and forest lands and/or animals simultaneously and/or sequentially on the same unit of land, and applies management practices that are compatible with the cultural practices of the local population." In simpler terms, agroforestry is the "culturally appropriate" association of trees and/or shrubs with crops and/or animals either in space or in time.

Agroforestry is an old practice but a new science whose potential for sustaining or increasing crop yields while maintaining ecological stability in farming systems has only recently been recognized by the scientific community¹. One of oldest "traditional" agroforestry systems is the intercropping of the leguminous tree species *Acacia albida* with millet or sorghum, often associated with a livestock component. While the tree species extends across Africa's Sudano-Sahelian zone from Senegal to Israel (Aloni 1972), and south to Namibia, the actual agro-silvo-pastoral system is generally only practiced in the Sahel (including the Sudan) and parts of Ethiopia and Malawi.

The *A. albida* system has many ecological and economic advantages. The trees lose their leaves during the rainy (growing) season so there is no light or nutrient competition with crops (LeBrun

¹The International Center for Research in Agroforestry (ICRAF)-- the primary organization responsible for agroforestry research and development-- is only 16 years old.

1975). *A. albida*'s abundant litterfall, its ability to fix atmospheric nitrogen and recycle nutrients via its deep tap root provides many Sahelian farming systems with their major source of nutrients while helping to maintain or increase soil organic matter content (Jung 1966, Wickens 1969, Charreau 1974). During the dry season, the mosaic of trees makes an effective windbreak thus reducing soil erosion (McGahuey et al. 1977). Economically, it has been determined that this system can increase millet yields by 30-50% while providing an important source of on-farm fuelwood, poles and fodder (Arnold 1985, Miede 1986, Poschen 1986).

The above combination of factors has, in the past, constituted a form of ecological equilibrium² for much of Sahelian agriculture. Swift (1977) provides a concise review of ecological equilibrium or "steady state" in Serer agriculture in Senegal in 1977:

The Serer are peasant farmers inhabiting Western Senegal in the region between Thiès, Diourbel, Kaolack and the coast. The Serer country has soils of mediocre quality, and irregular rainfall with an annual mean of around 760 mm. The high human density (80-100 people per square kilometer) is the result of successful maintenance of soil fertility by systematic use of cattle manure, by conserving useful trees and by crop rotation with regular fallow.

The Serer carefully select useful trees, particularly *Acacia albida*, which returns organic matter to the soil and thus increases the yield and protein composition of millet. Each tree improves 100-300 square meters, and 10-15 per cent of the land is thus fertilized. *Acacia albida* seed pods are valuable forage for livestock and enabled the Serer to keep large herds close to the village. Traditional Serer agriculture concentrated on millet and domestic animals. The fertility of short-cycle millet fields close to the houses was maintained by spreading domestic refuse and by letting cattle pass through and manure them during the dry season; the fertility of the large fields of late millet beyond was maintained by fallows every second year, when they were grazed and manured by village herds.

²However, as Swift (1977) points out, while many African peasant or pastoral cultures show relatively stable forms of ecological adaptation to particular sets of environmental conditions, there is no such thing as a "climax" human society or culture. The subject of ecosystems and social systems as "steady state" or as dynamic systems will be discussed in a later section.

Poncet (1977) describes use of the system in Niger. More recently, Miehé (1986) describes the *A. albida* system as practiced by the sedentary Fur people on the lower slopes and highlands of the Jebel Marra massif in Sudan. He reports that:

The basic agrosilvopastoral system consists of terraced village fields, where semipermanent rainfed cropping of staple millet and other subsistence crops takes place under stands of multi-purpose trees dominated by *Acacia albida*, *Cordia abyssinica* and *Sisiphus spina-christi*. Trees have been retained primarily for food, wood and fodder.....The system has been able to sustain self-sufficiency of a densely settled population over centuries.

Similarly, Poschen (1986) describes the traditional growing of *A. albida* as a permanent tree crop with cereal and vegetable crops and coffee on farmlands in the Hararghe highlands of Ethiopia. He argues that "*A. albida* keeps the promise of the agroforestry concept in the Hararghe highlands of Ethiopia as much as it does in West Africa where it is more popular and extensive".

In spite of *A. albida*'s potential, and in spite of many advocates for an expanded use of the system in the Sahel and other arid and semi-arid areas (Dancette 1968, Catinot 1974, IDRC 1979, Fleury 1982, Wentling 1983), some preliminary studies have indicated that the use of the *Acacia albida* in Sahelian farming systems is declining. Limited research indicates that farmers in some areas of the Sahel are no longer protecting natural regeneration due to increased demographic pressure and the more widespread use of animal traction and cash crops (Wentling 1983, Salle 1988, ISRA 1988, Ndiaye 1989). However, some preliminary studies in Senegal have shown that some farmers are actively protecting *A. albida* natural regeneration (and transplanting seedlings) implying that farmer perception, agronomic practices, national or local incentives or other factors may be playing an important role in the maintenance/expansion of the system (Ndiaye 1989). In short, many questions regarding the *A. albida*-millet system need to be answered particularly as regards constraints to its maintenance and extension. Research conducted

under this study is intended to answer, in part, some of these questions for Senegal's North Central Peanut Basin³ (NCPB).

1.1.1 The research site and its importance in the Senegalese economy

Senegal's Peanut Basin (Bassin Arachidier) was named as a result of the dominant importance of peanuts as a cash crop. Introduced by the French in the late 1880's peanuts quickly gained importance in terms of both area cultivated and economic value in the sandy plains east of Dakar. Extending out from Dakar, the main center for peanut processing and export, the Peanut Basin (PB) soon became a focus for population and economic development and agriculture became settled on a peanut-millet rotation. Today, the Peanut Basin is Senegal's largest and most important agricultural region. It encompasses 64% of the country's arable land, 50% of the total population and 62% of the rural population (Abt Associates 1985). Between 1960 and 1980, the peanut basin produced 82% of Senegal's peanuts and 67% of its millet and sorghum (SODEVA 1983).

Peanuts and millet and sorghum are also the main sources of farm income. From 1983 to 1989, peanuts represented about 43% of farm income and millet and sorghum around 30% of farm income (Rodale 1989). Peanuts are also the main agricultural export⁴ and represent a significant share of foreign exchange earnings. Due to fluctuations in rainfall and international prices, peanuts' contribution to foreign exchange earnings varied between 10% and 25% during the last decade (*op. cit.*). However, since the removal of agricultural subsidies (particularly for fertilizer) in 1984 with Senegal's "Nouvelle Politique Agricole" (New Agricultural Policy or NPA), peanut production has declined both in terms of yields and area planted (Sidibé 1989). However, the relative decline of farm income derived

³It is also expected that findings from this study will have some applicability to other areas of the Sahel where the system is practiced.

⁴Senegal is the main exporter of peanut oil in Africa.

from peanuts appears to have been offset somewhat by crop diversification (cowpeas and cassava), vegetable gardening, animal fattening/small livestock, petty trade and more opportunities for off-season wage employment (Abt Associates 1985).

While the Peanut Basin (and peanut production) has, over time, spread gradually east and south, traditionally, the "original" Peanut Basin (i.e., the older areas of peanut production) was comprised of four of Senegal's eight administrative regions - Diourbel, Louga, Thiès and Sine Saloum. The area chosen for the actual study lies more or less in the center of the old Peanut Basin and was delineated by identifying the ecological zones where *A. albida* is the predominant component of the vegetation⁵. While the old Peanut Basin has an area of approximately 64,000 square kilometers (Rodale 1989), the study area covers only about 2000 square kilometers and includes parts of the administrative districts of Thiès, Diourbel, Fatick and Kaolack.

1.2 Theoretical and conceptual base for the study

The practice of agroforestry and the use of the *A. albida* system respond to Odum's (1984) call for agricultural systems which reverse undesirable trends in agricultural production. However, an underlying factor in the success (or failure) of many agroforestry research and development initiatives is an understanding of both the biological/ecological and socio-economic processes and constraints in a particular ecosystem. Until recently, however, agroforestry and natural resource management in general have been viewed by many Sahelian governments (including the GOS) and donor agencies as an applied natural science primarily concerned with technical and biological aspects. There has been a tendency to ignore human behavior/socio-economic conditions and/or to emphasize society's

⁵Drawing on the vegetation analysis for Senegal conducted by South Dakota State University (Stancioff et al. 1986) the study area was delineated by identifying the geographical/ecological zones where *A. albida* is the predominant component of the vegetation (i.e., either one, two or three in terms of physical presence/numbers). Additional information on site and informant selection is provided in Chapter 2.

impact on the environment⁶. This is particularly true for the *A. albida* system as the vast majority of research and literature on the system have focussed primarily on biophysical or ecosystem components⁷.

Production systems (including those which incorporate *A. albida*) in the NCPB are undergoing continuous social and ecological change. Decision makers and resource managers must adjust to these changes and guide them, where possible, to meet the needs of society. In order to understand these changes and the impact they have on the *A. albida* system, a conceptual framework is needed to organize relationships and

⁶It should be noted that the reverse situation is occasionally true as well; when social scientists are involved the tendency is to ignore the biophysical environment and/or emphasize society's dependence on the environment.

⁷There is a considerable wealth of information on *A. albida*'s: (i) taxonomy (Aubreville 1950, Wickens 1969, Ross 1973, Nongonierma 1977, El Tinay et al. 1979, Ross 1980a, Ross 1980b), phenology (Trochain 1969, Delwaulle et al. 1974, LeBrun 1975, Werger 1983), morphology (Karschon 1967, Guinet et al. 1976, Evans et al. 1977, Brian 1987, DuBoux et al. 1985, Brian 1987, Farooqui 1987, Favre et al. 1987), range (Aloni 1972, Boulous et al. 1976), and ecology (Charney 1975, Kowal et al. 1978, Ward 1983, Miede 1986, Madsen 1986) of the species; (ii) its effect on crop yields (Sarlin 1963, Charreau and Vidal 1965, IHRO 1966, Dancette and Poulain 1969, Felker 1978), soils (Hughes 1957, Giffard 1964, Schoch 1966, Jung 1966, Jung 1967, Radwanski and Wickens 1967, Jung 1969, Jung 1970, Charreau 1974, Felker et al. 1980), ability to nodulate and fix nitrogen (Habish 1968, Habish and Khairi 1970, Habish 1970, Corby 1974, Athar and Mamood 1985) and pesticidal properties (Hussein and Yankov 1987); (iii) its role and importance as a forage crop (Currason 1958, Harvard-Duclos 1967, Boudet and Riviere 1968, Bartha 1970, McCleod 1974, Boudet 1975, Gohl 1975, Van Soest and Robertson 1976, Gallais 1977, Poncet 1977, LeHouerou 1979, LeHouerou 1980a, LeHouerou 1980b, Cisse 1980, Toulain and Piot 1980, Gwynne 1969, Penning and Djiteye 1982, Van Soest 1982, Sherman 1987); (iv) its silvicultural aspects (Giffard 1964, CTFT 1966, Mariaux 1966, Anon. 1968, CTFT 1971, Wickens 1971, FAO 1974, Elamin 1975, Goor and Berney 1976, FAO 1977, Ferlin 1977, McGahuey and Kirmse 1977, Bebawi and Mohamed 1982, Bebawi and Mohamed 1985, Ismail 1986, Ahmed 1987, Babu et al. 1987, Bahuguna et al. 1987); and (v), its role and importance in combatting desertification (Dancette 1968, Lericollais 1970, Brunck 1972, Catinot 1974, Pelissier 1977, von Maydell 1978a, von Maydell 1978b, Pelissier 1979, IDRC 1979, Charreau 1980, Felker 1980, Freeman and Fricke 1980, Edwards 1982, Fleury 1982, Wentling 1983, Duhoux and Davies 1985, Nimbkar 1986).

Published and "fugitive" literature on the socio-economic aspects of the *A. albida* system is numerically at least more limited (Lemaitre 1954, Pelissier 1967, Kerhard and Paccioni 1974, Brokensha and Horowitz 1977, CECET 1977, Delgado 1977 and Pelissier 1979).

interdependencies between inhabitants of the NCPB and their biophysical environment.

1.2.1 The search for a conceptual framework: four assumptions and three perspectives

A conceptual framework is a set of assumptions about how things function in the world. While not a model or a management strategy per se, a conceptual framework does guide thinking in the choice of variables to include in models and in the formulation of management strategies, both by excluding some possibilities and by choosing others. Ultimately human actions (and most research, including this study) are based on the assumptions embedded in a framework even though they may only be implicit and not consciously stated. In short, how one thinks things work governs how one acts to achieve the results or outcomes one desires. As Hall and Day (1977) put it:

One takes the components, interactions and mechanisms that he believes to be operable in the system and considers them within the framework of the whole system and the question he is interested in....To construct a conceptual model one says, 'this is how I think my system is'. (p. 17).

Thus, the ultimate choice of a conceptual framework with which to study the *A. albida* system is based on four key assumptions of how the principal investigator thinks or perceives the *A. albida* system to be. First, it is believed that the *A. albida* system is dynamic and continuously changing, and as such, can never reach an equilibrium or "steady state". Second (and as many NCPB farmers do), the framework should view resources as being finite, requiring certain conditions and inputs for continued or sustained production. Third, if it is assumed that resources are finite, it must also be assumed that it is human activity which needs to be managed in the NCPB rather than human activity managing the ecosystem. Finally, as its name implies, *A. albida* is a system (agroforestry) whose use in NCPB production systems suggests that the conceptual framework be based on a systems approach⁸

⁸A systems approach in general has considerable advantages in the study of the *A. albida* system. Spedding (1984) argues that the systems approach is invaluable for system operators (farmers, decision

which incorporates feedback loops. This assumption automatically excludes linear-causal models (or one way adjustment theories) with only a uni-directional relationship among variables.

In the search for a conceptual framework/model which incorporates the above assumptions, there are essentially three perspectives and models on which one might draw: ecosystem perspectives, environmental management perspectives and perspectives based on human ecology. These three conceptualizations of the relationship between society and the environment in combination with the stated assumptions permit an assessment of the consequences of making decisions about the *A. albida* system on the basis of one perspective or another.

1.2.1.1 Ecosystem perspectives: steady state vs. a dynamic view

Botkin (1990) distinguishes two major schools of thought with regard to the "balance of nature" at the global level⁹. The first sees the biosphere as being in steady state and when perturbed in anyway, seeks to return to equilibrium. This model, generally referred to as the ecosystem model, has been accepted as a framework for studying relationships between nonindustrial societies and their environment. However, it has been criticized for lacking explicit

makers, etc.) in order to identify "points of decision" since these are the "levers" which the manager operates. In addition, the systems approach identifies the information required in order for the operator to make rational decisions. Spedding goes on to observe that the "operation of a system cannot be undertaken without an adequate picture of how the system operates, what is in it and what is not, where its boundary lies, what its main inputs and outputs are, and how these are related via component processes".

Woodmansee (1984) argues along similar lines. He states that "our ability to maintain sustainable agriculture will be dependent largely on our successfully manipulating the interactions of biotic and abiotic factors that operate within ecosystems to produce system nutrient accumulation and persistence". He goes on to add that "our understanding of these interactions is dependent on our ability to produce a consistent concept of ecosystem behavior into which specific knowledge is placed."

⁹The principal investigator also makes the assumption that an understanding of what is happening globally will influence our interpretation of local ecosystem conditions and interactions.

recognition of decision-making and other social processes and its inability to organize society-environment relationships in industrial societies (Bonnicksen 1991).

For these reasons, the ecosystem model gradually emerged into the "agroecosystem" model (Odum 1984). Agroecosystems are defined by Odum (*op. cit.*) as "domesticated ecosystems which are intermediate between natural ecosystems such as grasslands and forests, and fabricated ecosystems such as cities". Odum further argues that the main differences between agroecosystems and natural ecosystems are: (i) the use of auxiliary energy sources; (ii) reduced diversity due to human management; (iii) the fact that the plant and animal species are under artificial selection rather than natural selection; and (iv), that the control in an agroecosystem is external and goal oriented rather than via system feedback as in a natural ecosystem.

As Altieri (1983) observes, the magnitude of these differences depends on the intensity of management and the degree of disturbance of the equilibrium of a particular system. He goes on to stress that an agroecosystem responds to and reflects socio-economic pressures as well as ecological constraints. Thus, the agroecosystem model corrects some of the shortcomings of the ecosystem model as it takes into account both the human and the biological components of the system. However, the model has still been criticized by some for its use of what is essentially a biophysical framework to explain social phenomena and interactions as well as functional relationships between the biophysical and social components (Bonnicksen 1991).

In addition to the criticisms discussed above, both the ecosystem and the agroecosystem models make the assumption that the universe (and all systems encompassing it) tends toward equilibrium and order. However, there is a growing body of literature which suggests that the universe is tending toward disequilibrium and uncertainty. Botkin (1990) refers to this view of the biosphere as "one that is always changing" and that it is this quality that "has

allowed life to persist". Botkin (*op. cit.*) calls this approach a dynamic view of ecosystems. In approaches or models based on this view, change is always occurring but not at a constant rate; change can be slow, almost imperceptible (as in the case of traditional agroforestry systems such as *A. albida*), or cataclysmic.

The contrast between the equilibrium view of an ecosystem and the dynamic view and their consequences for management are presented in Table 1.1.

Table 1.1
Contrasts Between Equilibrium and Dynamic
Views of the Ecosystem

FEATURES	EQUILIBRIUM MODEL	DYNAMIC MODEL
Basic assumptions of model	biosphere in a steady state	biosphere is always changing
Type of management	managed for constancy in terms of uncertainty	managed in terms of uncertainty, change, risk and complexity
View of meaning of sustainability	sustainable harvest obtainable forever at the same rate in every period	long-term time-averaged yield does not decline but rate of harvest may vary from time period to time period; may have to vary in short run to achieve long-term sustainability
Conservation/Utilization	appeared to be different and in general incompatible goals	goals of conservation and utilization part of one approach
Source: Botkin 1990: 155-6.		

A key criterion in choosing a conceptual framework for this study would be the extent to which the framework reflects how farmers in the NCPB tend to view their "universe". Based on Botkin's (*op. cit.*) analysis, the principal investigator believes that the dynamic view best approximates the farmers view. First, because their universe is constantly changing, NCBP farmers, as well most other

subsistence farmers, manage their farms in terms of uncertainty, risk and complexity. The risk-averse nature of subsistence farmers has been well-documented. As Todaro (1977) writes, "the main motivating force in a peasant's life may be the maximization not of income but rather his chances of survival". He goes on to say that peasant farmers are likely to prefer a technology of food production which combines a low mean per hectare yield with fewer fluctuations about the mean, to alternative technologies which may promise a higher mean yield but also present the risk of a greater variance.

From an NCPB farmer's perspective (and contrary to common perception), while there have been considerable variations in yields over the years in the NCPB, the fact remains that long-term time averaged yields have not declined. Rodale (1989), using Ministry of Agriculture data from 1960 to 1989, found that while peanut yields are highly variable from year to year, long term trends are relatively stable, showing only a very slight decline for the Diourbel region. For millet, the main food crop of the NCPB, Rodale (*op. cit.*) found that the annual yield variation was less than that of peanuts and the long-term trend was slightly positive.

Finally, the principal investigator believes that the majority of NCPB farmers do not inherently separate the goals of conservation and utilization as the equilibrium model would suggest. Where this separation does exist, it is primarily a result of external influences by government and donors which has in some instances, lead to the development of maladaptive strategies among some NCPB farmers. The problem is exacerbated by the fact that while these strategies are often recognized as maladaptive, those with the power to take corrective action (government and donors) do not often do so for political or other reasons.

1.2.1.2 Environmental management models: finite vs. infinite resources and managing human activity vs. managing nature

Colby (1990) distinguishes five environmental management models; frontier economics, environmental perception, resource management,

eco-development and deep ecology. Colby's characterization of these approaches is useful in attempting to understand the possible consequences of applying one or another of the models to the *A. albida* system.

The frontier economics model has dominated western civilization's development and expansion, explicitly or implicitly since the beginning of European expansion in the fifteenth century. It has also been the basis for the majority of economic development programs in tropical countries. The model has three key assumptions. First, for all practical purposes, resources are considered as existing in unlimited quantity. Second, the role of humans is viewed as one of ever-increasing domination and control over nature. Finally, technology is seen as the ultimate solution to all problems. These three assumptions together led to the premise that progress can only be equated with unlimited economic growth.

Economic growth itself is not intrinsically bad, but it does use and consume resources. The problem with the frontier growth model is that more often than not, resources are consumed in developing countries at nonrenewable rates and the desired results (or rationale) for these rates of consumption (the alleviation of poverty and greater equity) are almost never achieved.

While there are still many adherents to the frontier growth model or its derivatives (technology will solve all problems¹⁰), much of the ecological devastation in tropical countries has been blamed on the application of this model and its two critical shortcomings: (i) its failure to take into account the enormous population increases these countries have experienced; and (ii) using inappropriate western

¹⁰There are still many who believe that technological innovations will permit growth to continue indefinitely and that technology will save us in the future as it has in the past. While the importance of technology in effective and sustainable natural resource management is not discounted, the principal investigator believes that it is more important to seek solution to resource problems now rather than count on future technological innovations.

technologies to implement the model which often created more environmental and social problems than they solved (Young 1991).

Based on this somewhat cursory analysis, the principal investigator believes that the only relevance the frontier growth model would have in the study of the *A. albida* system would be in examining the impact of the model on the system from an historical perspective. In short, it appears that any analyses and resulting actions based on the use of this model today would produce development that is not sustainable from an economical, ecological or social perspective.

At the other end of Colby's environmental management model continuum, one finds the deep ecology model, also referred to as the "spaceship earth" model (Boulding 1971), which according to Colby (1990) was defined in reaction to the frontier economics model. This model views humans as no different from other organisms in an ecosystem and believes that humans should live in complete harmony with nature. The deep ecology model has not been accepted anywhere as the basis for development planning because its adherents tend to take an extreme conservationist position, often advocate a return to a technologically simpler lifestyle and are avowedly anti-growth (Young 1991). In short, the deep ecology model appears to be a luxury that most developing nations could ill afford.

The other models in Colby's continuum were developed as a result of these two extremes. The environmental protection model was defined by the frontier economics model in reaction to the deep ecology model. Its "dominant imperative" is the tradeoff between ecology and economic growth and considers the dominant threat to the environment as being loss of endangered species and the health impacts of pollution. Major themes in the environmental protection model are remedial and/or defensive actions (e.g., treatment plants and environmental impact statements) and the "legalization" of ecology as an economic

externality. This model appears to have little to contribute to the study of the *A. albida* system.

Moving towards the deep ecology model, one finds what Colby refers to as the Resource Management and Eco-Development models. While Colby draws a distinction between these two models, they appear to be quite similar. For example, according to Colby, the dominant imperative of the Resource Management model is "sustainability" as a necessary condition for "green growth" while the dominant imperative of the Eco-Development model is the co-development of humans and nature and a need to redefine "security". In terms of environmental management technologies, both models tend towards the use of local or "appropriate technologies" and recognize the importance of indigenous knowledge in the management of natural resources.

In terms of finding an appropriate conceptual framework for the study, these models fall short in incorporating two key assumptions. First they are both deterministic/mechanistic (albeit subtly) in the sense that they view equilibrium as the natural state rather than change. As a result, environmental management technologies and strategies under these models tend to focus on better management of the ecosystem and its return to original equilibrium rather than helping the ecosystem reach a new, perhaps different equilibrium. Second, both of these models emphasize management of the ecosystem rather than management of the social system. While there would be much argument to the contrary by proponents of these models, they still support man's dominion over nature, albeit more from a "bottom-up" approach than the frontier economics model's "top-down" approach.

1.2.1.3 Human ecology approaches: linear-causal vs. adaptive dynamics models

Bennett (1976) discusses four major approaches in human (or cultural) ecology since the late nineteenth century: deterministic anthropogeography, possibilism, stewardian cultural ecology and adaptive dynamics. According to Bonnicksen (1991), these approaches or theories used to describe society-environment relationships

developed in two phases; one way adjustment phases characterized the early phase while reciprocal adjustment theories characterize the "second, present phase". The two major one-way adjustment (or linear-causal) theories, "environmental determinism" (anthropogeography) and "cultural determinism" (possibilism) are contradictory in the sense that cultural determinism assumes that society controls its environment more than environment controls society while environmental determinism assumes that the physical environment exerts a controlling influence over society. As Bonnicksen (*op. cit.*) points out, the defect that these theories share is the assumption that society-environment relationships operate in only one direction. As a result, they fail to incorporate the notion of systemic processes or feedback. Neither of these models have any significant numbers of adherents today (Young 1991).

Recognizing this defect, theories describing reciprocal adjustment between a society and its biophysical environment arose from the work of Frey (1960), Geertz (1963), Krader (1970), Kates (1971), DuBos (1978) and others. These authors argue that the relationship between culture and society is reciprocal; neither controls the other but each is produced and maintained by interacting with the other (Krader 1970).

One of the first reciprocal adjustment theories, Stewardian cultural ecology, attempts to determine the extent to which similar cultural adaptations occur in similar environments. Steward viewed environment as limiting but not determining human behavior and was not concerned with other aspects of feedback such as the impact of technology on the natural environment or on the human environment (Young 1991). The cultural ecosystem model (Geertz 1963), also was among the earlier reciprocal adjustment theories. Geertz's model is essentially a biological and physical science-based systems model that sees human activities as either upsetting or maintaining natural phenomena, or creating new balanced environments. Geertz (*op. cit.*)

viewed culture and environment as interdependent and the system as a whole was always tending toward a state of equilibrium. According to Bennett (1976), one of the major drawbacks of Steward's and Geertz's models is that they do not include "the crucial role of human choice (and therefore error)" in their approaches.

Bennett (1976, 1981) introduced the concept of socio-natural systems as a way of referring to the complex interactions between society and nature, including the variable of human choice. He defines socio-natural systems as those systems in which humans individually and collectively interact with other organisms and the physical environment of the ecosystem. Interactions also include those with other socio-natural ecosystems. Bennett uses the term human systems ecology or simply human ecology to refer to the study of these systems and adaptive dynamics as the conceptual framework for pursuing understanding of these systems.

Since the introduction of Bennett's adaptive dynamics model, others from both biological and social science disciplines have also begun to advocate more of a systems approach in studying society-environment interactions (see Smith and Reeves 1989, Bonnicksen 1991). For production systems where trees are (or have been) an integral part of the system, Lovelace (1984a) argues that what is needed is a broader human ecological perspective which would allow planners, researchers and program implementors to see and conceptualize how human and ecosystem interactions are related, and how their efforts (individual or collective) might contribute to a greater understanding of the system as a whole. According to Lovelace (*op. cit.*), the advantages of a systems approach to human ecology are that it: (i) provides for an inter-disciplinary approach; (ii) emphasizes that rural societies do not relate to trees in terms of a separate ecological category, but as part of a larger environmental system; (iii) focusses attention on the interactions and consequences of interactions between components of the system(s); and (iv), provides

considerable flexibility in the types of situations which might be examined.

Rambo (1984), drawing on Bennett's model proposes a "systems model of human ecology" whose primary concern is with the integrated scientific study between two semi-autonomous subsystems, the natural ecosystem and the human social system. It is this model which provides the conceptual framework for the study as it appears to meet all of the stated assumptions: (i) it uses a systems approach; (ii) it views resources as being finite; (iii) it views the ecosystem as being dynamic and not static; and (iv) it reflects human choice (and the eventual management of that choice) as a fundamental variable system evolution.

Figure 1.1 provides an interpretation of Rambo's conceptual model applied to the *A. albida* system in the Sahel. The natural ecosystem is thus composed of a complex of bio-physical factors such as soil, rainfall, radiation, other vegetation, etc., all of which interact with each other. The human social system similarly consists of a number of interacting components, such as knowledge, attitudes, skills, aspirations, economics, and culture, drawn from the socio-economic and cultural realm.

The two sub-systems are connected through exchanges of energy, material and information and Rambo's definitions apply. Energy is considered to be the ability to work. Material flows refers to the transfer of chemical and physical elements between subsystems. Information flows are cues from one subsystem to another which signal current conditions for particular responses and kinds of interaction by the other subsystems. Relationships between the two systems are dialectical--an on-going process of adaptation (or mal-adaptation), selection and co-evolution (Lovelace 1984a). Inputs from other

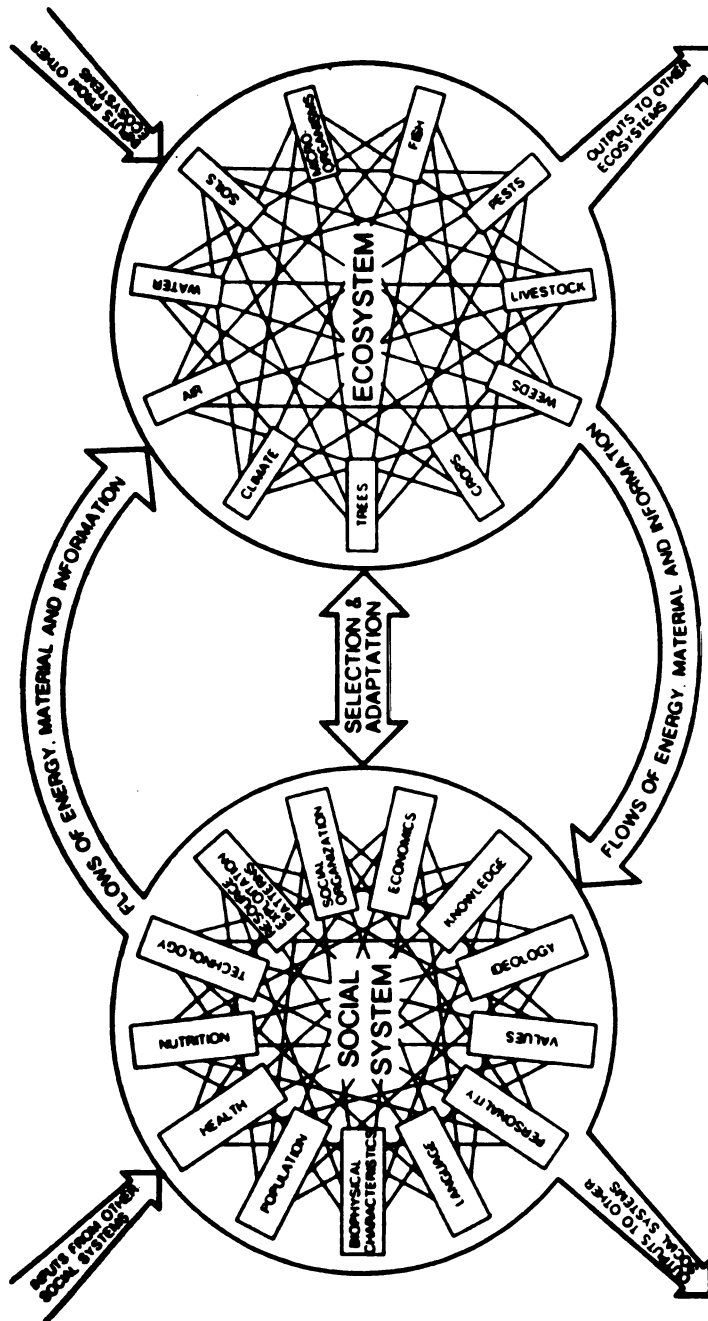


Figure 1.1

The A. albida Human Ecological System -- General Model

Adapted from Rambo (1984).

subsystems, natural as well as social, occur and create perturbations to which the *A. albida* human ecological system must adjust.

1.3 Supporting literature in the context of the *A. albida* human ecological systems framework

Rambo's conceptualization of the relationship between society and environment provides the framework not only for the actual study but for a literature review of some of the internal and external factors which might affect decline, maintenance and/or expansion of the *A. albida* system. However, in reading the following review, two points need to be kept in mind. First, every attempt was made to use Senegal/NCPB-specific information and data whenever possible. However, for certain variables, site-specific information was not available and the principal investigator was obliged to draw on the more relatively abundant literature from the Sahel.

Second, classifying a particular variable as internal or external or as part of the ecosystem or social system is in itself subject to considerable discussion. For example, one might argue that a farmer's decision to place a particular field in fallow is internal; based on an analysis of the ecosystem, the farmer makes a socio-economic decision to give the field a "rest". Others might argue that a farmer's decision to place a field in fallow is a result of input from external social systems (e.g., agriculture policy, lack of inputs, etc.). More than likely, however, a farmer's decision to place a field in fallow is based on both internal and external information. In this context, the objective of the literature review and subsequent study is NOT to "measure" the amount of information (or material or energy) exchanged between system components but to ascertain the impact and relative importance of the information (or material or energy) on the *A. albida* system.

1.3.1 The *A. albida* ecosystem: a combination of internal and external factors

1.3.1.1 Climate, rainfall and drought

The climate of the Peanut Basin is tropical semi-arid, with high temperatures and a pronounced separation of wet and dry seasons. There is one rainy season, occurring approximately between May and October. Rainfall advances from, and retreats to the south; thus rainfall amounts and the length of the rainy season decrease from south to north. Average annual rainfall varies from 400mm in the north with a two and one-half month rainy season to nearly 1000mm in the south with a six-month season. As is common with most areas of the Sahel, the primary characteristic of the rainfall is its variability both between and within seasons; recurrent and periodic drought is the major impediment to agricultural production. Over the last twenty years there has been an isohyetal shift south of about 200mm from the long-term average with the net result that the rains begin later and the season is shorter with these effects increasing toward the north (Rodale 1989).

Temperatures are high, increase from south to north and generally show a bimodal distribution with the highest temperatures occurring just before and just after the rainy season. These high temperatures result in high evapotranspiration rates and rapid desiccation of the soils, particularly those low in organic matter content and clay. The uneven distribution of rainfall within a season can result in times where evapotranspiration exceeds soil storage capacity and crop failure is a frequent occurrence even in good rainfall years.

1.3.1.1.1 The impact of climate

Climatic change has been blamed for many, if not most of the problems in the Sahel including decline of *A. albida* in the NCPB. In short, a continuing problem confronting the maintenance of the *A. albida* system in the NCPB is recurrent and unpredictable drought. While no data are available for Senegal, it is estimated that 40% of the Sahel's *A. albida* trees perished in the great drought of 1968-1973 (Wentling 1983). Moreover, drought also affected tree cover through

its effect on annual and perennial forage grasses. In the absence of grasses, herders were obliged to make greater use of tree browse through lopping and felling in order to keep their animals alive. Some argue that the crowns of *A. albida* were so severely pruned during the 1970's drought that soil fertility was adversely affected in some areas (Louppe 1989).

However, an attempt to understand drought's effect on the *A. albida* ecosystem needs to go beyond an investigation of internal climatological phenomena (which obviously affect regeneration rates as well as tree growth and survival), and address what Berry et al. (1980) refer to as the reasons for the failure of Sahelian social systems to adapt to drought as they have done in the past.

Berry et al. (op. cit.) argue that traditionally, Sahelian societies had taken a defensive attitude toward cultivation; "safeguards against drought played a prominent role in their decisions as to land use practices". One of the best safeguards against drought in the Sahel was the *A. albida* system. But Berry et al. go on to argue that the change in traditional risk-averting social patterns¹¹ led to a decline in the use of risk averting adaptations. In short, while drought no doubt contributes to the physical decline of the *A. albida* system, the effects of drought may be exacerbated by a change in attitude towards cultivation among Sahelian agriculturalists from a defensive one to one that focusses on "high risk and low productive" endeavors (IDRC 1979, LeHouerou 1980).

1.3.1.2 Cash crops

As the above discussion indicates, the introduction of cash crops may have changed the traditionally adaptive social patterns of the Sahelian agriculturalists to what might be considered maladaptive

¹¹Due, according to Berry et al. to: the French colonial administration's emphasis on cash crops; the introduction of taxation; the transformation of the Sahelian zone from the "center to the periphery"; and farmers perceptions of the opportunities to be had in a market economy.

patterns, particularly in the face of poor rainfall years and recurrent drought. The shift from ecologically sound practices such as the use of *A. albida*, to forms of modern industrial agriculture may also have its attendant ecological costs (Dahlberg 1974). As Margalef (1968) writes:

Exploitation of crops means a simplification of the ecosystem in comparison to pre-agricultural stages. The exploited ecosystem is composed of a lower number of species and also has a lower number of biological types....The structure of the soil is simplified and the diversity of soil microorganisms and animals decreases. The importance of the cycle of nutrients outside the bodies of organisms is amplified. Yearly rhythms become more stressed, not only for the cultivated species, but also for species associated with culture such as weeds or pests. The latter are biologically more similar to cultivated species in natural ecosystems. They increase rapidly in numbers, disperse easily and their populations are subjected to strong fluctuations and can be reconstructed after heavy losses. Outbreaks are characteristic of systems of low species diversity.

The introduction of cash crops in the Sahel such as cotton and ground nuts has also been accompanied by new cultivation practices¹² which rely heavily on imported inputs such as fertilizer and pesticides in order to obtain high yields. The environmental dangers of replacing high yielding traditional production systems with ones that depend on costly imported inputs are all too evident as Margalef points out above. From an energy viewpoint, while the agricultural yields per unit area might be higher with industrial agriculture than with traditional systems, the return on the additional energy investment¹³ required for industrial systems might be quite small - the actual conversion of solar energy in both types of systems may remain the same (Holliman 1974). In any event, the "bottom line" in Senegal and elsewhere in the Sahel is that "modern" agriculture has

¹²Including increased use of animal traction which is often cited as a prime culprit in the decline of *A. albida* natural regeneration. According to Ndiaye (1989) the majority of NCPB farmers do not take the time to plow around seedlings.

¹³This is particularly true when the energy input (e.g., fertilizer) is valued at its real cost and not subsidized.

not, as yet, contributed significantly to increasing agriculture yields.

1.3.1.3 Soils

1.3.1.3.1 Soil types¹⁴

The soils of the Peanut Basin are fairly homogenous and reflect the strong zonal influence of climate and a largely uniform parent material. In general, the Peanut Basin consists of a monotonous, gently undulating sandy plain occupied by deep sandy soils of low natural fertility. The apparent monotony is increased by the loss of the natural vegetation cover, and the conversion of almost all these soils to agriculture which leaves the ground bare for most of the year.

The dominant soils in the study area are known as dior¹⁵ soils. These soils occupy most of the Peanut Basin from Louga to Kaolack. The primary variation from north to south in these soils is an increase in organic matter content (a function of rainfall and biomass) and, allegedly, a topsoil texture of finer sand, perhaps due to greater wind erosion in the north (Rodale 1989).

Dior soils show little variation in characteristics either spatially or in terms of depth. Horizon development in the profile is weak. The soil is deep (> 1 m and /or deeper) and color is predominantly brown, varying from yellowish brown to reddish yellow, with little variation below the topsoil. The soils are typically structureless or have a very weak subangular blocky structure. As a function of this weak structure, bulk densities are generally high and total porosity low; the low porosity is generally acknowledged to restrict root development. When dry, these soils tend to harden due

¹⁴The following general description of the four major soil types (locally known as dior, deck, deck-dior and dior noir) draws from Charreau (1974), Aurora Associates (1982), Beye (1977), Stancioff (1986) and Rodale (1989).

¹⁵Known in the French taxonomic system as "sols ferrugineux tropicaux non or peu lessivé", and in the U.S. system as Ustipsamments.

to laterisation and form a continuous crust which occasionally promotes runoff and inhibits seedling emergence. Soil hardness makes deep tillage with horse drawn equipment in the dry season extremely difficult.

Textures of dior soils are sandy or loamy sand; clay content is typically less than 5% throughout the profile. There are few weatherable minerals and the clay is primarily of the weakly reactive Kaolinitic type. Organic matter content is typically less than 1%. The combination of texture, clay type, mineral composition and very low organic matter content provides for a soil of very low natural fertility and moisture holding capacity. Total cation exchange capacity (CEC) is typically less than 3 me/100g with a base saturation of less than 50%. The natural fertility is tied up in the shallow topsoil layer through which nutrients are recycled- released from decaying organic matter, absorbed by the vegetation and returned as litterfall and dead roots. The soils are naturally acidic, with a pH in the range of 4.5 to 6.0.

In the south central portion of the study area, the sands overlie a dissected plateau of sandstone intermittently capped by laterite. On the plateau remnants, soils are typically moderately deep to shallow over laterite; erosion has reduced the depth and laterite exposures are fairly common. On the side slopes and in valley bottoms, soils are again deep. There is a greater variety of soils here but the dominant soils are locally known as "deck"¹⁶. These soils are deep and sandy, and are differentiated from dior soils by their slightly higher clay and organic matter contents and associated higher CEC.

The third type of soil found in the study are what are referred to as deck-dior soils. The differentiating factor is the amount of

¹⁶Known in the French taxonomy as "sols ferrugineux tropicaux peu lessivés" and in the U.S. system as Alfisols.

clay in the soil; deck-dior soils have a slightly higher clay content than dior soils but not as high as a true deck soil.

The remaining soil type in the study area are the heavier soils which are usually found in clay depressions ("bassins" or "bas fonds" in French and "khors" in Wolof) and in and along old water courses. They are known locally as "dior noir"¹⁷. Dior noir soils are thought to be formed by the lateral translocation of clays from the surrounding dior soils (Rodale 1989). Their evolution is dominated by the action of excess water through seasonal fluctuations in the water table; horizons of these soils have alternating phases of oxidation and reduction which in turn determine the precipitation/solubilization of iron and manganese. As a result, these elements often appear as spots in the horizons. Organic matter and clay content are relatively high (3-4% and 8-12% respectively) but are also influenced by water table fluctuations. The texture of these soils is generally sandy and the A horizon can often exceed 40 cm in thickness. While relatively fertile because of a high CEC, they are generally difficult to work because of the high clay content. As a result, where the water table is fairly close to the surface, their only agricultural use is for dry season vegetable gardening (cultures maraichères) and fruit trees. Their pH generally ranges between 5 and 6.

1.3.1.3.2 Soil management in the NCPB

In all three of the major NCPB soil types, organic matter plays a critical role in terms of soil fertility and crop yields. The soils are composed primarily of sand which are considered to be nearly chemically inert (Rodale 1989). The clay content of the soils is not only low but kaolinitic in nature and therefore only weakly reactive. As a result, the structure and productivity of the soil are almost entirely dependent on organic matter content.

¹⁷Known in the French system as "sols hydromorphes moyennement ou peu humifères" and in the U.S. system as Vertisols.

Traditionally, farmers in the NCPB used one or a combination of four methods of incorporating organic matter into the soil. The first of these, animal manure, was usually reserved for continuously cropped fields (usually millet) in the immediate vicinity of a village (toll keur). Household refuse and animal manure were used to maintain soil fertility. Animals grazed on outlying fallow fields during the day but were kept in a village or on a toll keur at night (parcage¹⁸). Since the removal of fertilizer subsidies in 1985 resulting in the general decline in the use of fertilizer among NCPB farmers (Kelly 1988), many farmers are reportedly extending the toll keur practice to more outlying fields although transport costs and reportedly fewer animals remain a critical factor in wider use of animal manure (Rodale 1989, Grosenick et al. 1990).

The second method NCPB farmers used was a wooded fallow soil management system. Outlying fields were left in fallow for a period of five to seven years which was sufficient time for the woody vegetation to re-establish itself. Clearing of a wooded fallow began by girdling the trees one year and then in subsequent year(s) burning the resulting brush. The advantage of the wooded fallow system was that it was minimally disruptive to the soil and provided a means of recycling nutrients from lower soil horizons. Additionally, because a wooded fallow produces extensive, large roots as well as large woody surface materials, it took a number of crop years to extract the nutrients accumulated by the fallow (Grosenick et al. 1990).

However, the use of a wooded fallow system in the NCPB has essentially collapsed due to increased population pressure and the increasing use of animal traction (Rodale 1989). Fallow now is

¹⁸Parcage refers to the practice of stationing animals on a particular field for a certain length of time so that the field receives the benefit of the manure. Animals used may belong to the owner of the field or an arrangement can be made with another individual (e.g., a Peul herder) to exchange crop residues and browse on the field for parcage.

usually a result of lack of inputs¹⁹ and is limited to a period of only one or two years (Freeman 1982) which permits only the establishment of grasses. However, as Grosenick et al. (1990) point out, a grass fallow leaves most of the land unprotected most of the time and is not effective for recycling nutrients from deep soil horizons.

In addition to having an impact on soil productivity, reduction of the fallow period also has an impact on the natural regeneration of trees and shrubs which potentially have many economic benefits (fuelwood, medicines, forage, etc.). Fallow lands are also considered for the most part to be common lands and many disadvantaged groups (women and children) help support their families from these areas through the collection, use and or sale of many primary and secondary tree products. It is not known how reduction of the fallow period might affect these groups.

The third method that NCPB farmers have at their disposition for adding organic matter is the incorporation of crop residues into the soil. The benefits of incorporating residues include improvement of soil porosity and water infiltration, reduced wind erosion, assurance of seedbed preparation and plant emergence, improved rooting and weed control (Nicou and Charreau 1979). In spite of these benefits, few farmers in the NCPB use this method as benefits obtained from selling crop residues, particularly peanut hay for forage, appear to outweigh the benefits gained from incorporating crop residues into the soil (Abt Associates 1985, Rodale 1989, Grosenick et al. 1990). The common practice in the NCPB is to rake into piles and burn the few remaining crop residues and surface trash left on the fields prior to plowing.

¹⁹Golan (1989) refers to this as "unplanned" fallow. In a study of two villages in the PB Golan found that out of 108 fields left in fallow, 76 were fallow due to lack of seeds or labor, 6 because they were too far from the compound or were of exceptionally low quality. The ratio of unplanned to planned fallow in Golan's study was on the order of three to one.

While this practice does allow rapid availability of some mineral nutrients, it does reduce overall carbon/organic matter levels.

The fourth method available to NCPB farmers is the use of *A. albida* and other on-farm field trees. Dancette and Poulain (1969) found that outside of *A. albida* cover, the content of mineral colloids plays the determining role in cation exchange capacity (CEC). Under *A. albida*, however, they found that the higher level of organic matter content enables organic matter to play a role at least as important as mineral colloids if not more so. They found that while CEC increases only slightly under *A. albida* (from 2.70 to 2.97), this increase translates into considerably higher levels of exchangeable cations—up to a 42% increase in the case of calcium. Available nitrogen increases under *A. albida* by 0.1% which according to Dancette and Poulain (op. cit.) is equivalent to the addition of 650 kg of urea per hectare.

1.3.1.3.3. Soil microbial activity

Soil microbiology in the Peanut Basin was studied by Jung (1970) who provided baseline studies of seasonal changes in soil microbial populations in dior soils. His study concluded that during the dry season, biological activity in the soil is severely limited by stress from low moisture. With the first heavy rains, there is a rapid increase in soil microbial activity and a concurrent flush of OM decomposition during which declines in soil N, P and pH occur due to intensive leaching. Jung concluded that severe dry season moisture stress limits the soil's biota from efficiently trapping nutrients and making them available to crops over the course of the growing season. However, soils under *A. albida* typically showed significant improvement of soil moisture retention, microbial activity²⁰ and nutrient retention capacity regardless of the season. This suggests that the *A. albida* rhizosphere provides a dry season refuge for soil

²⁰Jung (1966) reports a two- to five-fold increase in microbial activity under *A. albida* vs. soils without tree cover.

biological activity by immobilizing nutrients against leaching losses and enabling their gradual release for plant growth.

1.3.1.3.4 Radiation

There may also be a link between climate, soil degradation and loss of *A. albida* cover in the NCPB. Chase (1986) suggests that drought may trigger soil degradation under human and animal pressure which in turn leads to further drought due to reduced plant evapotranspiration and increased albedo. He describes a possible scenario for the Sahel:

The degeneration of Sahelian forests may be a self-feeding process. Soils that become encrusted exhibit higher rates of runoff and remain drier than non-crusted soils. Dry soils have a lower specific heat than moist soils and, therefore, become hotter than moist soils with similar inputs of solar radiation. This increases temperature which, in turn, decreases relative humidity. The combined result is that hot, drier air from the barren areas passes through the remaining vegetation, increasing the vapor pressure deficit which would accelerate the rate of removal of the soil moisture from these areas. This could accelerate the desiccation and death of trees and other plants during dry periods.

1.3.1.4 Vegetation

1.3.1.4.1 Natural vegetation²¹

The vegetation landscape in the NCPB has undergone a complete transformation since the late 1800's when the cultivation of peanuts was first introduced. Today, an anthropogenic tree or "park" savanna covers this densely populated agricultural area. Nearly 200 years of clearing the land and intensive cultivation have left few traces of natural woodland. It is difficult to reconstruct the previous physiognomy and composition, since even the more wooded areas found today are not relics of the original communities. The present formation and composition can be attributed almost entirely to human activity (Rodale 1989).

At the turn of the century, a pseudo-climax woodland characterized the area and was dominated by *Combretum glutinosum*, with

²¹The description of the vegetation in the NCPB/study area draws from Rodale (1989), Stancioff (1986), Giffard (1974) and Pelissier (1966) as well as the biophysical inventory.

scattered *Anogeissus leiocarpus*, *Cordyla pinnata*, *Khaya senegalensis*, *Bombax costatum*, *Pterocarpus erinaceus* and *Sterculia setigera*. To a certain extent, it resembled the present communities found in the east in the "new lands" of the departments of Kaffrine and Tambacounda. While many of these species have already disappeared or are slowly disappearing from the NCPB, a number of typically Sahelian and Sudanian specimens still survive as individuals in fields and villages, or in clay depressions.

Giffard (1974) reports that the pseudo-climax vegetation which had characterized the Peanut Basin in the early 1800's had disappeared by 1974 due to human activity, primarily overcultivation, uncontrolled bushfires and fire and fuelwood harvesting. Giffard goes on to report that only the departments of Mbour, Tivaouane, Fatick and Gossas had any remnants of the original forest type but this was limited to only about 2500ha. Since 1974, even these small areas have all but disappeared and now the only type of semi-open canopy type of forest cover found in the NCPB are small stands of *Acacia seyal* in clay depressions. However, even many of these stands are now being cleared for dry season vegetable gardens (cultures maraichères).

Now, the characteristic tree and sole dominant of the region is *A. albida* constituting a near monoculture in some areas. However, the species did not belong to the original woodland, but is associated with all the old agrarian civilizations of the Sahel and parts of the Sudan and Ethiopia. Common associates of *A. albida* in the northern part of the NCPB or Sahelo-Sudanian zone include *Balanites aegyptiaca*, *Acacia raddiana*, *Zizyphus mauritiana*, *Piliostigma reticulatum* and *Tamarindus indica*. Farther south toward the Sudanian zone common associates are *Anogeissus leiocarpus*, *Diospyros mespiliformis*, *Ficus gnaphalocarpa*, *Pterocarpus erinaceus*, and *Acacia seyal*, *Prosopis africana* and *Mitragyna inermis* in depressions. *Adansonia digitata* (baobab) is found throughout. *Guiera senegalensis*, a small Sudano-Sahelian shrub which quickly invades the exhausted sandy soils of

fallow fields, predominates the shrub stratum in the north while *Combretum glutinosum* is the shrub species found more in the southern portion of the study area.

Fallow and abandoned fields have been invaded by a heterogeneous mix of Sahelian and Sudanian herbaceous species. The dominants, *Eragrostis tremula* and *Cenchrus biflorus*, are sought out by ruminants. Other common associates are *Aristida adscensionis* and *Schizachyrium exile*. Two ubiquitous invaders are *Mitracarpus scaber* and *Cassia obtusifolia* (formerly *Cassia tora*). These forbs are rarely grazed and grow on the most infertile soils. Other common forbs are *Hibiscus asper*, *Corchorus tridens*, *Alysicarpus ovalifolius* and *Leptadenia hastata*. During the rainy season, the landscape undergoes a striking transformation. The lush, continuous herbaceous cover often exceeds 80 cm in height during years of average or above average rainfall.

The average height of the tree stratum in the northern portion is 6-8 meters with crown cover ranging between one and five percent. Tree height, cover and species diversity increase from north to south in the study area. However, the transition from the Sahelian to the Sudanian vegetation associations in the Peanut Basin is gradual, almost imperceptible. Nevertheless, characteristics of the Sudanian vegetation become more evident as one progresses from the northern to the southern part of the study area. Increasing rainfall, decreasing cover of Quaternary sand deposits and shallower water tables moderate the dry season and prolong the vegetative cycle beyond the last rains.

1.3.1.4.2 Exotic species

While no empirical evidence exists for this hypothesis, the introduction of exotic tree species such as *Eucalyptus spp.* in Sahelian farming systems may also have an impact on the decline of the *A. albida* system and other indigenous species. The question of the use of *Eucalyptus spp.* in the Sahel is one that arouses strong feelings both for and against (Poore and Fries 1985). Proponents see the species as a wonder tree which can bring immediate solutions to

local wood and erosion problems. Opponents see the species as causing adverse impacts on soil (impoverishment and encouraging erosion) and on hydrology (drying up of aquifers). While the impact of this species and other exotics in Sahelian ecosystems is unknown, it is clear that the *Eucalyptus spp.* species planted accelerate soil erosion, are allelopathic, compete vigorously with ground vegetation and crops when water is in short supply, and consume more water and regulate flow less than natural ecosystems (*op cit.*).

In spite of these problems, the use of *Eucalyptus spp.* and other exotics in Sahelian farming systems is becoming more apparent and may in fact, be displacing *A. albida* and other indigenous trees. The reasons for this might be attributed to both internal and external factors. Externally, most Sahelian governments have concentrated their forestry research and development efforts on exotic species such as *Eucalyptus spp.* for fuelwood and poles, and on cash crop species such as *Anacardium occidentale* (cashew nut) and *Acacia senegal* (gum arabic), to the almost total neglect of indigenous trees present in traditional farming systems²². Internally, given the Sahel's wood crisis, wood has gone from essentially a "free good" to a cash crop (Arnold 1984). Given *Eucalyptus spp.* fast growth rates, farmers may in fact prefer it to the more slower growing *A. albida*²³. Additionally, in much of the Sahel, eucalypts are grown and marketed by men for poles rather than fuelwood, raising serious gender issues as regards appropriateness of the species in addressing what is essentially a women's fuelwood crisis.

²²For example, only 5% of Senegal's forestry research budget is devoted to research on agroforestry systems and indigenous species with the majority of the remaining 95% going to cashew nut, eucalyptus and gum arabic research (ISRA/DRPF 1987).

²³Note that considerable genetic improvement of *Eucalyptus spp.* has been done in the Sahel with substantial increases in growth rates provided the proper species/provenance is matched with site. To the author's knowledge, however, there has not been a similar program for *A. albida*.

Finally, from an ecosystem perspective, periodic drought may also have an effect on many of the exotics planted in the NCPB. Exotics may be planted outside of their normal range of tolerance during above average rainfall years and are therefore first to suffer in drought years.

1.3.1.5 Livestock

In analyzing the Peanut Basin's agricultural potential, one tends to underestimate the growing importance of livestock. During the first two decades of independence, the number of cattle in the PB nearly doubled while the number of sheep and goats nearly quadrupled (Abt Associates 1985). While individual livestock holdings were greatly reduced during the drought, livestock numbers appear to be on the rise. The Centre Suivi Ecologique (Marks 1990) estimates dry season animal densities in the Peanut Basin as follows:

Table 1.2
Animal Densities by Department
(Animals per square kilometer)

Department	Cattle	Sheep/ Goats	Horses
Bambey	15.5	33.7	5.0
Diourbel	32.2	43.5	3.5
Mbacké	24.7	24.9	na
Mbour	21.6	17.3	na
Tivaouane	7.2	20.5	2.3
Fatick	33.6	23.9	3.5
Gossas	27.9	25.6	2.2
Thiès	na	na	4.0
Source: Marks (1990). na = data not available.			

With the exception of the departments of Tivaouane and Bambey, dry season animal densities are higher in the Peanut Basin than in what is thought of as the more traditional animal grazing areas of Linguère and other more northern departments (Faye et al. 1989). Unfortunately, it is not known what percentage of these animals are

held permanently in the Peanut Basin. However, it is clear that such animal densities place a burden on a limited dry season forage and fodder supply. In fact in Mbour, Abt Associates (1985) report that during the 1983-84 cropping season, crop residues became a more lucrative source of income than the crops themselves. Farmers planted peanuts closer together than the norm in order to get more hay even though they knew that the weight of the nuts would decline.

Traditionally, the two main sources of cattle in the PB have been the Peul herders in the north and the Serer who have long integrated livestock and agriculture in their production systems. Among the Wolof, however, animal husbandry and agriculture have always been divorced (Pelissier 1966). This pattern appears to have changed in recent years as wealthier Wolof farmers and marabouts (Islamic religious leaders) have been investing in both cattle herds and in animal fattening activities (Abt Associates 1985).

1.3.1.5.1 Impact of livestock on *A. albida*

The effect of livestock on the *A. albida* system also needs to be examined from both an internal and external perspective. Internally, the cultivation of export crops has provided Sahelian farmers with a new source of income which was invested in the "highly valued" traditional manner by acquiring livestock. Livestock not only represents the farmers major asset but also effects his social and cultural status (Wentling 1983). Increasing livestock numbers along with improved animal health services and more numerous water points further imbalance traditional production systems resulting in further degradation of natural forage resources, especially on-farm browse species such as *A. albida*. Unfortunately, as Wentling (op. cit.) points out, *A. albida* is often one of the only sources of feed available in the dry season with adequate nutritional content to satisfy the minimal maintenance requirements of the farmer's ruminant animals.

Externally, the inputs of other subsystems, particularly the traditional pastoralists need to be considered. Swift (1977a) points out that traditional Sahelian pastoral herding strategy was to maximize herd size without regard to immediate environmental consequences. He goes on to add that actual impact on the environment was probably slight as there was a fluctuating relationship between pastures and herds with ecological checks and balances such as drought, animal disease and pasture shortages keeping grazing pressure within bounds. However, the introduction of new water points and improved animal health services resulted in an increase in pastoral livestock numbers and dry season overgrazing is now spread over much larger areas. The net result has been increased pastoral encroachment on the *A. albida* system, particularly during the dry season. Pastoralists often lop off branches of *A. albida* in the dry season or bend them to the ground so the animals might more easily browse. This can lead to reduced growth rates, increased susceptibility to bush fires, and occasionally tree death.

1.3.2 The *A. albida* social system: a combination of internal and external factors

1.3.2.1 Population

Senegal's population has more than doubled over the last 20 years and the Peanut Basin has felt the brunt of an annual population growth rate of over 2.8%. Population densities in the Peanut Basin are among the highest in Senegal varying between 50 and 100 inhabitants per square kilometer in the departments of Kébémér, Thiès, Mbour, Fatick and Diourbel to over 100 inhabitants per square kilometer in the departments of North Fatick, Bambey and Tivaouane (Kone 1986).

While the majority of the population in the Peanut Basin is rural, there is nevertheless a relatively high concentration of urban areas; four of Senegal's 10 regional administrative centers are located there (Thiès, Diourbel, Fatick and Kaolack) along with 12 departmental centers (Kébémér, Tivaouane, Thiès, Mbour, Fatick,

Gossas, Kaolack, Nioro-du-Rip. Kaffrine, Mbacké, Diourbel, and Bambey). The important trading center of Mäckhé and the Mouride Islamic center of Touba-Mbacké are also located in the Peanut Basin.

Three of these towns have populations greater than 50,000 (Kaolack, Thiès and Diourbel), two have populations between 20,000 and 50,000 (Mbacké and Mbour), while four (Fatick, Kaffrine, Touba and Mäckhé) have populations of between 10,000 and 20,000. The remaining towns have populations of under 10,000 habitants (Jeune Afrique 1983).

This high concentration of urban areas, unique to the Peanut Basin, is due primarily to the introduction of peanuts and resulting infrastructure and communications development including a good paved road system and a railroad. However, if the concentration of towns and infrastructure facilitates communications and transport, it also has an impact on the ecological and socio-economic environment of the rural areas; the urban populations require both food and something with which to cook it, primarily wood.

Conventional wisdom would indicate that population growth is perhaps the biggest factor in the decline of the *A. albida* system. Proponents of the population factor argue that the demographic pressure on the system has two facets; overcultivation and fuelwood harvesting. Overcultivation/ agricultural expansion is perhaps the biggest non-climatic factor causing loss of vegetation in the NCPB (Rodale 1989). Overcultivation is caused by two principal factors; (i) the increasing use of animal traction to cultivate larger surfaces at the expense of fallow or previously uncultivated areas (e.g., forests); and (ii) insufficient land in villages to permit fallowing, a consequence of both demographic pressure and the enlargement of the area cropped. Both factors may have a direct bearing on the *A. albida* system. Increased mechanization has been blamed for a reduction in on-field regeneration of *A. albida* and other indigenous species; farmers are reluctant (or do not take the time) to plow around seedlings. The reduction in both use and length of fallow may also be

implicated in reduced natural regeneration of *A. albida* and other species.

Additionally, the primary energy source for the rural inhabitants of the NCPB is fuelwood²⁴. Freeman (1982) estimates that per capita consumption of fuelwood in the PB at 0.6 cubic meters per year. He also estimates that one fourth of rural fuelwood supplies are coming from the remaining forests in the Sine Saloum while three fourths are coming from other areas, mainly trees in the agricultural landscape such as *A. albida*, shrubs cleared from fields (*Gueira senegalensis* and *Combretum spp.*), and from non-woody sources such as crop residues (millet stalks) and manure. If the population pressure continues as expected, the growing pressure on on-farm *A. albida* resources (particularly from urban markets) may raise their value to the point at which economic pressure to cut them may exceed their value as a continuing part of the agricultural system. While the population growth scenario is rather bleak in its implications for woody vegetation in the NCPB, there may be another possible scenario. Boserup (1965) argues that as population increases, there is an intensification of agriculture with increased labor investment in production and increased attention to soil fertility²⁵.

1.3.2.2 Culture, cropping and production systems

Production systems in the Peanut Basin have undergone radical changes with the implementation, two decades ago, of rural modernization. This modernization was achieved to a major extent by the introduction of peanuts as a cash crop (and resulting

²⁴The use of the term fuelwood here refers to both firewood and charcoal.

²⁵Bartlett (1980) provides a concise review of the literature on this aspect which suggests a close relationship between population density, household access to land resources and the intensity of agricultural production. However, Boserup's (1965) sequential argument for agricultural development or adaptation, while perhaps valid for the historical development of traditional agroforestry systems, does not shed much light on why these traditional systems might be declining today.

infrastructure development) and the resulting rapid monetarization of the economy. This modernization process combined with a fairly homogenous biophysical environment has resulted in the development of fairly uniform cropping systems throughout the study area. Peanuts continue to provide the main cash crop while millet, sorghum, cowpeas (niébé) and cassava are the major food crops with cassava becoming an important secondary cash crop in the northern areas of the Peanut Basin (Rodale 1989).

The following is a brief description of a typical cropping system in the NCPB. Land surrounding a village is divided into individual plots on which crops may or may not be rotated depending on the distance from the field to the village. Fields near the households or compounds (*toll keur*) are usually not subject to rotation but are continuously planted with cereals, particularly millet. They are generally able to sustain production (and a certain degree of food security) under normal rainfall conditions as they receive the vast majority of organic matter (animal manure and household litter) produced by a compound. Outlying fields receive far less household organic matter and traditionally, a millet-peanut rotation occasionally combined with cowpeas (intercropped or late overseeding with millet) is used along with *A. albida*, a 2-3 year grass fallow, the burning of crop residues and occasional parcase in order to maintain soil fertility. However, according to most GOS authorities, the use of *A. albida*, planned fallow and parcase have all declined in recent years²⁶. Additionally, the use of mineral fertilizer has essentially ceased in the study area since the

²⁶While the apparent decline in the use of traditional methods to maintain soil fertility, particularly *A. albida*, will be discussed in greater detail in subsequent chapters, as previously stated, the primary reasons cited for the decline in the use of planned fallow is: (i) the increasing use of animal traction to cultivate larger surfaces at the expense of fallow; and (ii) insufficient land in villages to permit fallowing, a consequence of both demographic pressure and the enlargement of the area cropped (Rodale 1989). The use of parcase is thought to have decreased as a result of the reduction in animal populations following the 1970's drought.

inception of the New Agricultural Policy in 1984 which ended fertilizer subsidies and cheap credit for agriculture inputs (Kelly 1988).

In spite of the NCPB's relatively homogenous biophysical environment and cropping systems, it varies considerably in terms of demographic pressure and ethnic composition. As a result, farming or production systems (as opposed to cropping systems) in the Peanut Basin are generally differentiated by the region's two major ethnic groups; the Wolof, with their relatively lower population concentration and more extensive production system, and the Serer, with their higher population concentration and more intensive production system.

In order to understand the differences between these systems some historical perspective is needed. As Stomal-Weigel (1988) observes, throughout their history, the Wolof have been perceived as a society which is politically very structured with a very evident social hierarchy but lacking any sort of agricultural traditions. As Pelissier (1966) writes of the Wolof,

Organisation politique et hiérarchisation sociale sont restées étrangères pour ne pas dire hostiles au développement d'institutions agraires dont on ne trouve aucune trace ni même aucune amorce en pays wolof (p. 110).

The Serer, on the other hand, have been perceived throughout their history as a fundamentally egalitarian society with strong agricultural traditions. Stomal-Weigel (1988) writes that the Serer

apparaissent comme une société véritablement paysanne aux techniques agricoles très perfectionnées dont l'originalité du système de production traditionnel s'exprimait par la place dominante du mil ainsi que par l'intégration de l'élevage à l'agriculture (pp. 21-22).

The *A. albida* tree, as Swift (1977b) observed, was also an integral part of the Serer production system, with Serer farmers "carefully" selecting *A. albida* and other trees for retention in fields in order to provide organic matter to the soil and thus increases the yield and protein composition of millet. In fact,

Felker (1978), citing Pelissier²⁷ (1967), reports that in Serer (Senegal) language, "yaram-sas" - to raise an *A. albida*, is used in the same general context as "yaram o ndiay" which means to raise a child.

Differences between Wolof and Serer production systems became even more pronounced with the spread of Islam²⁸ among the Wolof combined with the introduction of peanuts as a cash crop. The Wolof, looking for new sources of political power following the disappearance of the centralized monarchies converted "en masse" to Islam while the Serer attempted to preserve their egalitarian society (Gastellu 1981). Taking advantage of the new market economy, Mouride "taalibés" (disciples), incited by their "marabout" (quranic teacher/religious leader) quickly expanded peanut production²⁹ by putting more land into peanut cultivation and by clearing new lands usually at the expense of maintaining soil fertility. Peanuts progressively replaced food crops (millet and sorghum) as the dominant factor in Wolof production systems (Stomal-Weigel 1988).

The Serer, by maintaining their egalitarian economy, were able to insert peanuts in their traditional production systems without disrupting their social organization or the ecological benefits derived from their traditional system. Priority was always accorded

²⁷Pelissier (1967) provides, perhaps, the most in-depth information of the cultural aspects of the *A. albida* system in Serer agriculture in Senegal.

²⁸There are three main Islamic brotherhoods in Senegal: the Khadria located in the Moyenne Casamance and composed primarily of the Mandingo ethnic group; the Tidjanes with their center in Tivouane and composed of mainly Toucouleur but with also, about one half of the Wolof population; and the Mourides with their center in Touba-Mbacké and with a practically all Wolof ethnic composition (Jeune Afrique 1983). In terms of agriculture and peanut production in the Peanut Basin, the Mourides exert a much greater influence than the Tidjanes. Of the 120 large-scale landholdings in the Peanut Basin, over 100 belong to the Mouride marabouts (Colvin 1983).

²⁹Some estimates place Mouride (disciples and marabouts) peanut production as high as 75% of total production in 1957-58. More recently, the large-scale Mouride landholdings account for only 5-6% of production but the marabouts' influence in agriculture in the Peanut Basin remains strong (Colvin 1983).

to food production (millet) and soil productivity was maintained by integrating peanuts into the traditional millet-fallow/manure rotation (Gastellu 1981). The net result was that by the early 1960's, the intensive Serer system was capable of maintaining a significantly higher population density than the more extensive Wolof production system.

In 1965, the GOS began its "Programme Agricole" (Agricultural Program) period. The main objective of the Programme Agricole was to increase peanut production and yields by introducing new techniques (improved seed, line seeding, animal traction and mineral fertilizer) and to provide cheap credit in order to facilitate farmer adoption of these new techniques. During the 20 year period of the Programme Agricole, differences between Wolof and Serer production systems became less pronounced. In a study comparing the evolution of production systems in a Serer and Wolof village, Stomal-Weigel (1988) found that the Programme Agricole caused profound changes in both systems which resulted in reduced yields, reduced crop diversity, increased mechanization and a continuous cropping system (reduced fallow) brought about by increased mechanization.

The effects of the GOS's agriculture modernization program were more pronounced in the Wolof village than in the Serer village (*op cit.*). Inhabitants of the Serer village were more concerned with maintaining soil fertility and increasing manual labor productivity which caused them to retain certain elements of their traditional system. In particular, while there was considerable substitution of chemical fertilizer for manure in both systems, Serer farmers continued to maintain *A. albida* trees while the majority of *A. albida* trees on the Wolof farms died³⁰. Additionally, in the Serer village, increased mechanization had not compromised certain cultural

³⁰The cause of death was not specified.

techniques (manual weeding of emerging millet) as it had done in the Wolof village.

With support from the World Bank, the GOS began its agricultural sector reform (structural adjustment) program in 1980. This reform culminated in the development of Senegal's Nouvelle Politique Agricole in 1984 and state disengagement from the agricultural sector began. An emphasis was placed on privatization and subsidies on agricultural inputs (particularly fertilizer) were reduced and eventually eliminated in 1988. Price and marketing controls on cereal grains (except rice) were also eliminated. This structural adjustment program appears to have had a profound effect on both Wolof and Serer production systems and will be discussed in detail in subsequent chapters.

Thus, in the NCPB, cultural differences between the Wolof and Serer may be an important factor in the use of the *A. albida* system. As Lovelace (1984) observes, "the recognition that traditional beliefs contain potentially vast quantities of empirical data related to environmental phenomena, process and historic change carries with it the implication that these traditional systems of knowledge can provide information useful to the planning and process of development". Unfortunately, information on the cultural aspects of the *A. albida* system has been limited mainly to dated ethnographic descriptions (Pageard 1971³¹, Pelissier 1967, Pelissier 1979) and anecdotal information (Felker 1978, LeHouerou 1979³²).

1.3.2.3 Knowledge, Attitudes, Skills and Aspirations (KASA)

As Coughenour (1984) points out, "although farmers' perceptions of environmental resources for agricultural production are shaped by

³¹Pageard (1971) describes sacrifices of chickens and millet made to *A. albida* trees and divine rules promulgated by priests to protect the tree.

³²LeHouerou (1979) observes that in some areas of the Sahel, *A. albida* is the object of "spiritual beliefs and animistic ceremonies" due to its importance and the way it "works against the will of God" via its reverse leaf growing cycle.

the technologies provided by society, the perceptions are also shaped by farmers' goals, interests, capital positions and technical skills". He goes on to point out that neither farmers' perceptions of resources nor the relevant importance of these factors in shaping resource perceptions is well known.

The situation is no different for the *A. albida* system. While an understanding of farmers' "KASA" is critical in relating their perceptions of the *A. albida* system vis a vis the environment, little information is available on the KASA of the various social systems which incorporate the species into their farming practices. Comparative studies of the systems KASA have been limited to anecdotal types of reports and informal farmer interviews³³. To this writer's knowledge, no systematic attempt has been made to equate the presence of on-farm *A. albida* trees with the KASA or other socio-economic aspects of the social system. However, as Coughenour (1984) concludes, "unless the farmer perceives farm resources as exhaustible or nonrenewable, and important to performance of the instrumental system or the long term adaptive strategies of his farm, the incentives to engage in resource conserving practices are limited".

1.3.2.4 Economics

1.3.2.4.1 Financial returns to the use of *A. albida*

In spite of the importance of the *A. albida* system in the Sahel, very little work has been done on its financial aspects. Christopherson (1988), in conducting an analysis of various natural resource management interventions for the Sahel, ranked natural regeneration of *A. albida* fourteenth out of a total of eighteen activities in terms of a financial or farmer perspective. He attributed this low ranking to the assumption that farmers would be required to protect seedlings for the first 3-4 years using individual fences (high labor costs) and the fact that significant benefits from

³³See, for example, Felker (1978).

the trees do not begin to "flow" until the trees are well established, often up to 10 years³⁴. Christopherson goes on to argue that the extension of the *A. albida* system needs to be accompanied by other interventions that generate more immediate returns.

Christopherson's analysis, however, appears faulty from several aspects. First, it is generally recognized that *A. albida* can withstand significant grazing pressure more often resulting in decreased growth rates rather than death, although this relationship remains to be quantified. Thus, alternative measures to control animal browsing need to be considered in the analysis³⁵.

Second, Christopherson uses net present value to rank the interventions. However, as Gittinger (1982) points out, "no ranking of acceptable alternative independent projects is possible with the net present worth criterion because it is an absolute, not a relative measure". According to Gittinger, only the net benefit-investment ratio can be used to rank independent activities.

Finally, Christopherson adds a risk factor to the discount rate in his analyses in order to take into account Sahelian farmers risk averse nature. However, as Todaro (1977) points out, risk-averse farmers more likely prefer a technology of food production which combines a low mean per hectare yield with a low variance (i.e., less fluctuations around the average) to alternative technologies and crops which may promise a higher mean yield but also present the risk of a greater variance. Adding a risk premium to the discount rate does not take into account this variance.

³⁴This would again appear to support the call for an *A. albida* tree improvement program.

³⁵Live fencing appears to hold considerable promise for controlling browsing in Senegal while providing additional economic benefits of increased fuelwood and fodder supplies as well as increased crop yields through reduction of wind erosion and evapotranspiration (Seyler 1988).

Finally, the returns to use of *A. albida* need to be examined in light of changing forestry and agricultural policy and markets in Senegal and elsewhere in the Sahel. For example, did the removal of fertilizer subsidies in Senegal in 1984 have an impact on the use of more traditional systems of maintaining soil fertility; particularly has there been an increase in the use of *A. albida* as a substitute for inorganic fertilizer?

1.3.2.4.2 Crop yields

With the collapse of the wooded-fallow soil management system, the limited use of animal manure combined with little, if any incorporation of crop residues into the soil, and very limited inorganic fertilizer use, one would expect to see a decline in crop yields in the NCPB. Indeed, this is the common perception of many GOS and donor officials. However, this does not appear to be the case. Rodale (1989) presents data collected from Senegal's Ministry of Agriculture which shows that there has not been any significant long-term decline in yields per unit area for millet, sorghum, or peanuts from 1960 through 1988 at three locations in the Peanut Basin; Louga, Diourbel and Sine-Saloum. Lericollais (1990) in a study of three Serer villages in the PB concluded that after thirty years of continuous cropping, there was no decline in per unit area yields. He found that farmers were using shorter season varieties to compensate for the drier weather and improved animal traction techniques to do a better job with planting and cultivating.

Grosenick et al. (1990) attempt to find a reason for this phenomenon. They argue that when the wooded-fallow system collapsed, PB soils quickly degraded to a new equilibrium under continuous cropping and that production levels at this new equilibrium have been steady, albeit low, for years. However, it appears doubtful whether any equilibrium could be maintained without the incorporation of some organic matter in the soils. The question of where this organic

matter is coming from is the subject of analyses presented in Chapter 3.

1.3.2.5 Institutions: Land and Tree Tenure

The importance of land and tree tenure in the promotion of agroforestry initiatives has been well documented³⁶. Where there is no security of land and/or tree tenure, agroforestry systems are bound to fail. However, most governments in the Sahel have prevented individual ownership and management of trees by declaring them state property (Taylor and Soumare 1984, Thompson 1983, Wentling 1983). For example, under Senegal's current forest code, all trees belong to the state and farmers must have permission from the local forestry agent³⁷ to cut them (Seyler 1988). This discourages farmers from providing the care and protection *A. albida* trees need to survive and grow, while allowing nomadic pastoralists (and often friends, relatives and neighbors) to exploit the trees more or less at will as laws regarding harvest of trees are rarely enforced.

In some instances, lack of security of tree tenure has led to the adoption of symbiotic relationships between sedentary agriculturalists and nomads. For example, in northern Burkina Faso, the author has observed situations where pastoralists will pass through a farmer's fields (during the dry season) at night felling trees and lopping branches for animal browse. In the morning, the pastoralists will have departed the field well before the local forestry agent might react. However, the farmer now benefits from the nomads passage as he is now legally entitled to harvest the "dead" wood left by the nomads.

³⁶Fortmann and Riddell (1985) provide a world-wide annotated bibliography on tree and tenure issues in agroforestry. Bruce and Fortmann (1988) provide a detailed analysis of some of the more important issues in land and tree tenure.

³⁷Considered by most farmers to be a policeman rather than an extension agent.

Thus, the link between tenure and state of the ecosystem must be examined in the light of the mediating effect of the particular agroforestry system and the economic use of the land. As economic factors change, tenure patterns typically change with them (Bruce and Fortmann 1988). An example from Senegal can help to illustrate this point. As wood has become more commercialized in Senegal, the government has drafted a new forest code which would provide some transfer of responsibility for tree planting and harvesting from the national to the local level or at least community level³⁸. However, a hypothesis currently being formulated by some Senegalese and expatriate foresters working in Senegal, is that wealthy and/or better educated farmers are planting more trees (or protecting more natural regeneration including *A. albida*) than poorer farmers in order to position themselves for the day when tree establishment and tree tenure may be equated with land tenure. This is consistent with literature on the "tenure enhancing aspects of agroforestry" where a farmer may be able to use tree tenure as a means of securing land tenure³⁹ (Millon 1955, Foster 1966, Bruce and Fortman 1988).

1.3.2.6 Social Organization

Gearing (1958) observes that "human communities typically rearrange themselves to accomplish various tasks". Gearing developed the "structural pose" concept to draw attention to the fact that social structure of a human community is not a single set of roles and organized groups but is rather a series of several sets of roles and groups which "appear and disappear according to the roles at hand".

³⁸However, it is unclear at this time how the code will address private/individual ownership of trees, either those physically planted or those occurring via natural regeneration. As this revised code has been before National Assembly for over two years, chances that it will appear in its original form appear slim to most Senegalese forestry officials (Seyler 1988).

³⁹It is also consistent with the Sahel's past experience in community woodlot establishment. As Bruce and Fortmann (1988) point out, "large number of trees may be planted on communal land for household or community subsistence use but once those trees take on a commercial value, private rights in that land tend to develop".

Evidence is accumulating that many Sahelian rural communities are beginning to strike structural poses vis a vis their environment through wider participation in decision making as well as through participation in local organizations⁴⁰ (Thompson 1983, United Nations 1984).

The importance of local organizations in community forestry activities such as agroforestry has also been well documented⁴¹. Foley and Barnhard (1984) mention several reasons for involvement of NGOs and voluntary organizations in agroforestry: (a) government agencies are completely unsuited to running small-scale tree-growing programs; (b) the flexibility, informality, and low cost approach of NGOs are advantages in small-scale endeavors; and (c) NGOs can bridge the gap between local communities and forest services, acting as an important communication channel both upwards and downwards in the political hierarchy.

While some Sahelian governments (Senegal in particular) have encouraged the development of autonomous local organizations⁴²,

⁴⁰There appears to be some controversy in the literature regarding whether the development of social organizations is an adaptive process or a result of competition or selection. Hannan and Freeman (1977) review the literature on the subject and conclude that strong initial pressure on organizational structure such as internal politics and external environment (public legitimization of organizational activities) require a model of organizational structure which depends on competition and selection, i.e., population growth and carrying capacity. Mialsen (1978) expands on Hannan and Freeman's argument and develops a "competition model of solidarity" to explain collective action.

⁴¹Blair and Olpadwala (1988) provide an excellent review of the importance of rural institutions and local organizations in social forestry projects.

⁴²Senegal, for example, has a number of autonomous farmer organizations. The United Nations (1984) describes them as local clubs with good voluntary work modes at village-specific sites. Their goals are most often of direct benefit to the rural farmer through extension activities and resource dissemination. Membership is exclusively indigenous with limited outside intervention in the form of financial or logistical support. These groups emphasize traditional and informal organizational structures which allow participation of a wide variety of socially diverse people. Although these organizations appear voluntary, they most often appeal to farmers through the financial incentive of increased productivity. Local organizations also have a solid outreach potential to large

others have not which may lend some credence to Hannan and Freeman's argument (1977) that the development of social organizations is based more on competition and selection than adaption. In any event, given the solid outreach potential of these organizations⁴³, they may be one of the best vehicles for extension of the *A. albida* system. It might even be postulated that in some areas, the number of on-farm *A. albida* trees is directly related to a farmer's active membership in local organizations.

1.3.3 External inputs from other social systems

While some biophysical and social inputs from pastoralist and other external social systems have been discussed in preceding sections, the role of Sahelian governments, as an external social system, and how they might affect the maintenance/expansion or decline of the *A. albida* system, deserves closer attention.

1.3.3.1 Research-Extension and Cash Crops

In discussing the links between agrarian subsystems and industrial subsystems, Margalef (1968) argues that the latter:

experiences more predictable changes through time. In so doing, it stores information better and is a more efficient information channel. The first subsystem is subject to a strong energy flow and in fact, the second system feeds on the surplus of such energy. It is a basic property of nature, from the view of cybernetics, that any exchange of information content does not result in a partition or equalizing of the information but increases the difference. The system with more accumulated information becomes still richer from the exchange.

If one considers the Sahelian governments and urban centers to be "industrial" subsystems, then Margalef's analogy might explain how Sahelian governments themselves may be contributing to the decline of the *A. albida* system by focussing research and extension resources on cash crops. It is generally recognized that for the medium term, the

numbers of otherwise inaccessible people.

⁴³For example, the U.N. (1984) reports that the "Amicale des Jeunes Agriculteurs du Walo", a young farmers club in Senegal's river basin area, has a membership of 13,000 and relations with nearly 15,000 farmers.

primary concerns of many countries in sub-Saharan Africa are foreign exchange and foreign debt (Timberlake 1985). Cash crops represent one of the few mechanisms available to many countries to earn foreign exchange. As George (1984) remarks, most developing countries "can't even make the choice between food crops and cash crops". As a result, most research and extension budgets tend to reflect this commodity focus. It is in this context that many agroforestry research and development programs operate. Agroforestry remains detached from the main agricultural research and extension stream both organizationally and institutionally⁴⁴.

The situation in the Sahel is no different. As Taylor and Soumaré (1984) point out, most Sahelian governments emphasize the importance of forestry in their overall strategies but allocate meager resources to the forestry sector. An example from Senegal helps to illustrate this point.

While paying considerable lip service to agroforestry research and development (and to natural resource problems in general), GOS budget allocations for forestry and agroforestry research indicate otherwise. Table 1.3 shows projected GOS expenditures (as a relative percent) on various divisions for Senegal's Agriculture Research Institute (ISRA) for the period 1989-1993.

Clearly, ISRA's Crop Production Department (DRPV) gets the majority of resources. However, while the aim of the DRPV is to conduct research on food crops leading to food self-sufficiency, a closer examination of ISRA's proposed budget indicates that 50% of the funds allotted to the DRPV support research on peanuts (oil for export), rice (primarily for the urban market), irrigated vegetable crops (for export) and cotton (for export). Similarly, of the meager

⁴⁴Although this is now changing, particularly with ICRAF's entry into the Consultative Group for International Agriculture Research (CGIAR) system.

Table 1.3

**GOS Research Expenditures
(As percent of total budget)**

Department	%
Crop Production (DRPV)	33.1
Animal Production (DRSPA)	17.8
Forest Production (DRPF)	7.4
Fisheries Production (DRPH)	21.0
Agrarian Systems and Ag Economy (DSAEA)	20.7
TOTAL	100.0
Source: ISRA (1988)	

funds allocated to the Forest Production Department (DRPF), over 60% goes toward research on *Acacia senegal* (gum arabic for export) and *Anacardium occidentale* (cashew nuts, also an export crop) (ISRA/DRPF 1987). Only a very small percentage of ISRA's budget (in 1989, less than 1%) goes toward research on the *A. albida* system.

Senegal's national extension programs also tend to reflect this commodity focus. Agriculture extension used to be carried out by the Ministry of Rural Development's Region Development Agencies, RDAs, (SRDP--Société Régionale du Développement) which were responsible for rural development activities within a fixed agro-ecological zone. While the RDA's mandate included broad development objectives and activities, their extension actions were generally focussed on a particular commodity or group of commodities⁴⁵.

Senegal's New Agricultural Policy, with its emphasis on privatization, provided for drastic cuts in the size and scope of most of Senegal's RDAs. SODEVA underwent a 75% cut in personnel and

⁴⁵For example, SAED, the Senegalese River Development Authority focussed primarily on irrigated rice and vegetable crops for export. SODEVA (the Peanut Basin's Agriculture Development and Extension Agency) concentrated its efforts on increasing peanut production. SOMIVAC's (the Casamance Development Agency) primary focus was also on the extension of improved rice varieties and cultural techniques. Agroforestry activities (and natural resource activities in general) were low priorities for these agencies unless support was provided by bilateral projects.

funding and is currently only active in very limited types of activities (mainly cowpea and nematocide programs). Since 1987, the World Bank has been working with the GOS to design and implement a program intended to reform and energize government extension services based on the use of the Training and Visitation (T&V) methodology. The pilot program (Programme Pilote d'Amélioration des Services d'Appui aux Agriculteurs--PAGRI) was followed by the Programme Nationale de Vulgarisation Agricole (PNVA) which began in 1990. The PNVA intends to cover 60% of Senegal's rural population in a period of four years.

As the PNVA is just beginning, it is difficult to predict the effect it will have on Senegal's current extension situation. Not the least of its problems will be the issue of sustainability of an extension system which is donor driven and supported. In terms of natural resource activities, however, problems with the T&V system are already more apparent. To date, there is no clear picture of how agroforestry and other natural resource activities will be integrated into the T&V calendar. As agroforestry involves both crops and trees, Senegal's Ministry of Nature Protection's Directorate of Soil Conservation and Reforestation (MPN/DCSR) also has an agroforestry extension mandate but the relationship between DCSR and the PNVA has yet to be defined. Moreover, as Freudenberg (1988) reports, the biggest percentage of MPN/DCSR's extension budget goes towards tree cash crops--the cashew nut and gum arabic programs.

Another problem is that as Eicher and Baker (1982) observe, most sub-Saharan African extension services (including T&V) "are oriented towards technical problems and pay little attention to farm management issues or to the social constraints faced by the rural household". However, farm management and social constraints are critical issues in

the maintenance and extension of the *A. albida* system⁴⁶.

Additionally, as Hoskins (1987) points out, T&V based extension approaches are not tailored to include consideration of the special legal status of trees vis a vis other crops, the different time horizons of annuals and perennials as well as the ever changing availability of tree and tree products.

Additionally, T&V is based on what is referred to as a "non-developmental technical assistance approach" to extension. This approach is defined by Batten (1975) as an approach where the agency decides whatever it thinks people need or ought to do or ought to value for their own good. The agency will then provide whatever staff, equipment, premises and programs it thinks are needed to meet what it perceives as the needs or interests of the people. In short, T&V's top-down and product-oriented approach is not generally suited for the "bottom-up" emphasis required for agroforestry research and development. As a last point, while it is generally recognized that agroforestry programs need to build on and preserve indigenous skills and knowledge rather than causing their extinction (Brokensha et al. 1980), Sahelian government attitudes toward the *A. albida* system may also be contributing to its decline. For example, Ruddle and Rondinelli (1983) argue that the main problem preventing popular participation in rural development occurs both locally (the social subsystem) and within central government bureaucracies. At the local level, they argue that national extension agents consider traditional resource systems to be inefficient, maladaptive and unsophisticated and thus need to be replaced by "modern" systems. At the central

⁴⁶Given the relatively poor performance of national extension agencies in dealing with natural resource problems, non-governmental organizations (NGOs) are becoming increasingly important in the Sahel's natural resource sector (United Nations n.d.). An interesting hypothesis might be that farmer contact with NGO extension services enhances maintenance of the *A. albida* system while farmer contact with "traditional" national extension agencies may be contributing to the decline of the system.

level, planners aim at a total replacement of the "time-honored" resource system "without the planners understanding the system".

1.3.3.2 Projects vs. program support and incentives

1.3.3.2.1 The project approach

To date, the method of choice in dealing with natural resource problems in the Sahel has been the use of a project approach. In Senegal, there are no less than four bilateral and two PVO natural resource-related projects currently operating in the NCPB. Bilateral projects include: (i) the "Projet de Reboisement Communautaire dans le Bassin Arachidier" (PRECOBA), supported by the Germans and based in Fatick; (ii) the "Projet de Reboisement Villageois dans le Nord-ouest du Bassin Arachidier (PRECOBA), supported by the Dutch and based in Thiès; (iii) the Projet de Développement Agroforestier (PDA), supported by FIDA and based in Diourbel; and (iv) the "Senegal Reforestation Project", supported by USAID and based in Dakar⁴⁷. PVO projects include: (i) Foster Parents Plan International (FPPI) forestry activities around Thiès; and (ii) "Cooperazione allo Sviluppo dei Paesi Emergenti" (COSPE) forestry activities around Diourbel.

Problems with a project approach to natural resources in the Sahel have been well documented. Taylor and Soumaré (1983) provide an excellent analysis of some of these problems. Among the more "visible" problems are a lack of coordination and communication between projects, competition for quality personnel between projects and the proliferation of "primes" and other perks, and a "growing web" of special conditions attached by the various funding organizations. Other problems cited by Taylor and Soumaré (*op. cit.*) include a failure to link research and training in projects, too short a commitment/time-frame, too much focus on quantitative aspects (unrealistic project assumptions and targets), and a general neglect

⁴⁷The project has a national rather than a regional focus.

of government absorptive capacity. The project approach in Senegal has experienced many of these same difficulties. Additionally, there appear to be four other concerns directly related to project activities in the NCPB.

First, projects such as PREVINOBA, Foster Parents Plan and PRECOBA assume that "sensibilisation" (or increasing farmer awareness of environmental problems/solutions) is the key to improved natural resource management. However, evidence is accumulating which suggests that when farmer livelihoods/existence are threatened by natural resource degradation (or perhaps changes in policy), they may be more willing to take action to reverse degradation and little sensibilisation is needed. Conversely, it might also be argued that when farmers are not "threatened", they are not particularly interested by messages which stress the importance of "doing something now" to ensure a sustained yield of agriculture and forest products. Thus a key element in the success of these projects may be their ability to identify and work with individual or groups of farmers who are threatened by their environment. Second, projects such as USAID's Senegal Reforestation Project and FIDA's Agroforestry Project in Diourbel and Bambey assume that farmers lack resources for natural resource management activities. Thus, FIDA provides nurseries, fencing, materials and technical assistance, while USAID provides matching grants ("co-investissement") to farmers for undertaking natural resource activities. However, preliminary research suggests that when macro-economic and environmental conditions are such that the farmer's very existence is in jeopardy, sufficient resources (including plant material via natural regeneration) and skills are available at the village/farm level to undertake a number of natural resource activities with little external input.

Third, project assistance may be creating a project mentality among NCPB farmers. Even the most isolated farmer has heard of projects in other villages such as village woodlots, wells, gardening,

etc., and rightfully wants his or her share of the pie. However, the risk is that with this approach, farmers may not equate projects with development but with the resources (particularly money and employment) that accompany them.

Finally, there is the issue of farmer participation in project development. In the agroforestry research and development process, farmer participation in its widest sense can be conceptualized between two extremes. One extreme would be to "stimulate" local farmers to do what "outsiders" have deemed to be in their best interest. In this case, participation becomes a means of obtaining a set of pre-determined objectives. At the other extreme, participation could be viewed as assisting local people to better define their interests and problems and to better allocate resources to address these self-determined priorities. Thus, in this case, participation becomes a way of supporting and instilling individual or group confidence and facilitating the farmer's (or the group's) own ability to mobilize his (or their) own limited resources.

Project activities in the Sahel centered around *A. albidia* have typically found themselves between these two extremes⁴⁸. Given the nature of supporting organizations, project objectives and available resources, effective project participation to the NCPB farmer is most likely to mean:

- Enlisting his/her support in all phases of the agroforestry diagnostic and design process, from project conception to design, implementation, evaluation, and monitoring;
- Assisting him/her in identifying and mobilizing new and existing resources to undertake recommendations resulting from the diagnostic process;
- Development of institutional and/or individual awareness to improve his/her future ability to evolve with and provide for a sustainable income under increasing land pressure. Farmer organization would be a critical part of this awareness.

⁴⁸In addition to being extremes, they rarely occur in pure forms and neither is inherently good or bad; the case specifics, economics, and other socio-cultural factors must be brought into the equation.

- Building on and preserving indigenous skills and knowledge rather than causing their extinction.

However, in spite of the overwhelming evidence indicating the need to involve farmers in both the planning and implementation phases of a community development-type natural resources activities, some projects are still designed in the relative comfort of Dakar with only brief excursions to the countryside where the project will take place. Crouch (1981) states that successful community development projects are ones that "had their origins in the community or which embodied community participation in planning and implementation and not those planned and introduced by some external agency without consultation and involvement of the community". This involvement is critical in *A. albida* projects in Senegal and elsewhere in the Sahel in order for farmers to become competent in and have the authority to operate independent resource management systems. In short, the level of farmer participation in the design and implementation of *A. albida* projects is likely a key factor in the maintenance and extension of the *A. albida* system.

1.3.3.2.2. A program approach

The economic incentives facing the Sahel's rural populations are major determinants of how natural resources are managed. Some of these incentives relate directly to such conservation practices as erosion control, tree planting and forest (natural and plantation) management. Other incentives relate to crop mix, input use, expansion of cultivated area and herd size, all of which can have a positive or negative effect on the maintenance of the *A. albida* system. For example, Shapiro (1988) argues that while low productivity per se is often the cause of cultivation pressing into fragile lands causing rapid loss of vegetative cover (including *A. albida*), there are instances where the process may be enhanced by local laws and policies. He cites the example of the Tahoua in northern Niger where some farmers clear more land than they can harvest. Their "incentive"

is the law that prescribes heavy fines for herders whose cattle trample growing crops.

While a complete analysis of potential incentives⁴⁹ as regards the maintenance of the *A. albida* system is beyond the scope of this study, it is clear that there must be national incentives for sustaining beneficial traditional systems and that maintenance and wider use of the *A. albida* system may derive from more general economic policies than from policies focussed on the system itself. In short, farmers may respond more to macro-economic and policy conditions (a program approach), than a traditional project approach. Thus, improving the agriculture and natural resource economic and policy environment in the NCPB may be a more viable alternative in reversing natural resource degradation than the project approach currently supported by the GOS and many donors.

1.4 Organization of the dissertation

Drawing on the conceptual framework described above, the rest of the dissertation is divided into nine chapters. Chapter 2 describes the research problem, strategy and methodologies used to achieve research objectives. Chapter 3 examines the contribution of *A. albida* and other woody perennials to soils in the NCPB as well as an analysis of farmer perception of soil problems and actions undertaken to correct them. A historical review of dior soils analyses is also

⁴⁹Shaikh et al. (1988) provide a detailed description of "successful" socio-economic and policy incentives which have been used in the Sahel to foster improved natural resource management. Socio-economic incentives include: direct payments for tree planting or protection; upgrading village infrastructure; free distribution of seedlings, nursery equipment and extension advice; farmer visits to model sites; long term non-governmental organization commitment; food for work, extension supported diffusion; market incentives; productivity sustaining incentives; reinforcement of local institutions, performance prizes and public awards and honors.

Policy incentives include: renegotiating multi-sector resource management legislation; enlisting local values in natural resource management; transferring tenure of planted trees to the planter; increases in woodcutting permit fees; and permitting local organizations to form non-governmental institutional structures.

provided in order to shed some light on the degree of soil degradation currently taking place in the NCPB.

Chapter 4 focusses on inputs from external social systems and uses time series analysis to attempt to quantify the impact of Senegal's changing agricultural policy on the *A. albida* system and the use of other woody perennials. Chapter 5 examines other external variables such as education, training, extension and the impact of development projects on the system.

Chapter 6 looks at potential financial returns of the *A. albida* system to NCPB farmers under various input/subsidy scenarios. Chapter 7 continues the internal focus and examines farmer perceptions of the *A. albida* system, focusing on the evolution of tree cover, the role of trees, communal and private tree planting, unexploited land, and the role of associations and village groups. Chapter 7 also looks at the influence of land and tree tenure on the system, and the potential impact of Senegal's proposed new Forestry Code.

Chapter 8 examines the interaction between biophysical and socio-economic variables, and uses the method of principal components analysis to identify the sets of variables that have the most significant impact on the use of the *A. albida* system and on *A. albida* regeneration rates. Using some of the same variables as the principal components analysis, Chapter 9 examines differences between the Wolof and Serer production systems as they affect the role and use of *A. albida*.

Chapter 10 summarizes the principal findings of Chapter 3 through 9, and discusses their implications for policy and program guidelines. Appendices include, inter alia, survey questionnaires and additional detail on the data and methods used, and on the statistical and graphical results.

CHAPTER 2

RESEARCH PROBLEM AND METHODOLOGY

"People who write about methodology often forget that it is a matter of strategy, not of morals. There are neither good nor bad methods, but only methods that are more or less effective under particular circumstances."

G. C. Homans (1949)

2.1 Problem Statement

One of oldest "traditional" agroforestry systems in sub-Saharan Africa is the inter-cropping of the leguminous tree species *Acacia albida* (known in Senegal as "cad" in Wolof or "njas" in Serer) with millet or sorghum, often associated with a livestock component. While the species itself extends across Africa's Sahelo-Sudanian zone from Senegal to Israel (Aloni 1972), and south to Namibia, the actual agro-silvo-pastoral system is generally only practiced in the Sahel (including the Sudan) and parts of Ethiopia and Malawi.

The *A. albida* system has many ecological and economic advantages. The trees lose their leaves during the growing season so there is no light or nutrient competition with crops (LeBrun 1975). *A. albida*'s abundant litterfall, its ability to fix atmospheric nitrogen and recycle nutrients via its deep tap root provides Sahelian farming systems with their major source of nutrients while helping to maintain or increase soil organic matter content (Charreau and Vidal 1965, Radwanski and Wickens 1967, Charreau 1974). During the dry season, the mosaic of trees makes an effective windbreak thus reducing soil erosion (McGahuey and Kirmse 1977). Economically, it has been determined that this system can increase millet yields by 30-50% (Charreau and Vidal 1965, Dancette and Poulain 1969, Felker 1978), while providing an important source of on-farm fuelwood, poles and fodder (Arnold 1984, Miede 1986, Poschen 1986, Miede 1988).

The above combination of factors has, in the past, constituted a form of ecological equilibrium for much of Sahelian agriculture. Swift (1977) and Pelissier (1966), Poncet (1977), Miede (1986, 1988)

and Poschen (1986) provide descriptions of this equilibrium or "steady state" in traditional agriculture in Senegal, Niger, Sudan and Ethiopia respectively.

In spite of the system's potential and many advocates for an expanded use of the system in the Sahel and other arid and semi-arid areas (Catinot 1974, Dancette 1968, Fleury 1982, Wentling 1983, Dancette and Sarr 1985), some preliminary studies have indicated that the use of the *A. albida* in Sahelian farming systems is declining. Limited research suggests that farmers in some areas of the Sahel are no longer protecting natural regeneration due to increased demographic pressure and the widespread use of animal traction and cash crops (Wentling 1983, ISRA 1988, Salle 1988). Research in other areas has shown that farmers are actively protecting natural *A. albida* regeneration implying that farmer socio-economic status, perception, cultural practices and financial returns may play important roles in the maintenance and or expansion of the system, or alternatively, its decline (Ndiaye 1988a, 1988b). In short, many questions regarding the *A. albida*-millet-livestock system need to be answered particularly as regards constraints and incentives in its more widespread use.

Research conducted under this study was intended to answer, in part, some of these questions for Senegal's North Central Peanut Basin⁵⁰ (NCPB), in order to provide the Government of Senegal (GOS) with better information for decision making purposes.

Research on the system was carried out from September 1989 through August 1990. Its primary purpose was to investigate certain internal and external biophysical and socio-economic factors relating to the decline, maintenance and/or expansion of the *A. albida* system in the area. The key research question asked was whether the *A. albida* social systems (internal and/or external) were driving the *A.*

⁵⁰It is also expected that findings from this study will have some applicability to other areas of the Sahel where the system is practiced.

albida ecological system or vice versa. In this context, additional research questions included:

- (i) What is the status of the system (declining, increasing or static)? If the system is changing, what are the causes of the change?
- (ii) What do farmers know about the *A. albida* system and its management? Are there any differences between ethnic and other social groups in terms of knowledge and use of the system?
- (iii) What are the stated perceptions about cultivation, use, preference, and management of tree resources (including *A. albida*)? What actions, if any, are taken by people and social groups to manage and/or protect tree resources?
- (iv) What socio-economic and biophysical variables influence system use and management, and what is the nature of the relationships among these variables?
- (v) Does the system need to be modified/adapted to reflect current socio-economic and ecological conditions and needs, and what actions might the Government of Senegal undertake to promote a wider use of the system?

Addressing these questions and developing an understanding of the use and management of the *A. albida* system and other tree resources in the NCPB required the use of four primary research methods: (i) an inter-disciplinary "rapid rural appraisal" (RRA) of the Peanut Basin; (ii) a formal farm-level socio-economic survey; (iii) a farm-level biophysical inventory of on-farm tree and soil resources; and (iv) the use of focus group interviews/discussions.

The combination of an inventory of farmer biophysical resources and a household level survey to collect system-related socio-economic data allowed a determination of relationships that exist between certain socio-economic variables (both internal and external) and the decline/maintenance of the *A. albida* system.

An understanding of farmer perception and valuation of the *A. albida* system in relationship to his/her goals, perceived needs and expected benefits is considered critical in understanding wider system maintenance and replication issues. While the socio-economic survey instrument incorporates pertinent questions regarding farmer knowledge, skills and aspirations, an assessment of farmer perception of the *A. albida* system may be difficult to obtain through a single

interview socio-economic survey. Therefore, field research also draws considerably on focus group interviews to assess environmental perception/social attitudes of different groups of residents of the NCPB as both a complement and supplement to the more formal survey.

Additionally, throughout the course of the study, an attempt was made to incorporate daily observations of farm life with informal opportunistic discussions with residents of the NCPB. While the principal investigator does not consider this to be "participant observation" *per se*⁵¹, it did afford the team the opportunity to experience the daily routine of village and farm life, and helped in general to learn first-hand some farmer techniques for natural resource utilization and management.

This multi-method approach facilitated the collection of different types of data and information which were considered essential in achieving research goals and objectives. It also helped overcome at least some of the problems inherent in cross-cultural research. Although each of these methods was applied individually, they were developed and used in an integrated and systematic manner and the resulting data were analyzed both individually and collectively.

2.2 Research Strategy and Tactics

This research sought two types of information: information about the agroecosystem(s) in the NCPB and information about the purpose or functional role of *A. albida* within the system(s). Odum (1984) defines agroecosystems as domesticated ecosystems which fall between "natural" ecosystems such as forests and grasslands, and "fabricated" ecosystems such as cities. He further argues that the

⁵¹"Observations" and "participation" were considerably more informal and "opportunistic" and done over shorter time periods than is required by "true" participant observation. Whyte (1977) describes this latter as a research method where direct observations, asking questions and listening are systematically blended together by the researcher as he/she takes part in the life and actions of the people he/she is studying.

main differences between agroecosystems and natural ecosystems are:

(i) the use of auxiliary energy sources; (ii) reduced diversity due to human management; (iii) the fact that the plant and animal species are under artificial selection rather than natural selection; and (iv), that the control in an agroecosystem is external and goal oriented rather than via system feedback as in a natural ecosystem.

By definition then, the concept of an agroecosystem implies the existence of a "user" or "manager" who exerts a controlling influence on the system. As Altieri (1983) points out, the magnitude of differences between natural and agroecosystems depends on the intensity of management and the degree of disturbance of the equilibrium of a particular system. He goes on to stress that an agroecosystem responds to and reflects socio-economic pressures as well as ecological constraints. However, as Raintree (1984) argues, in the study of land use systems, there is a tendency to focus on the environmental and biophysical parameters of the system to the neglect of the socio-economic processes, constraints and interactions in the system.

The nature of this research required an approach or strategy which would not require an elaborate and separate treatment of agroecosystem social factors but would rather seek to address these aspects as an integral dimension of system organization along with the biophysical factors. The strategy which appeared to best meet this need is referred to by Lovelace (1984a) as a "human ecological systems approach". According to Lovelace, the advantages of such an approach are that it: (i) is discipline neutral and interdisciplinary; (ii) emphasizes that rural societies do not relate to trees in terms of a separate ecological category, but as part of a larger environmental system; (iii) focusses attention on the interactions and consequences of interactions between components of the system(s); and (iv), provides considerable flexibility in the types of situations which might be examined.

As the nature of the data and information collected draws from both the natural and social sciences, the tactics used to achieve the above strategy draw on a combination of: (i) scientific hypothesis testing and subject-oriented research; and (ii) informant-oriented research⁵². The rationale behind the use of two different tactics is twofold. First, much research in both the natural and social sciences is designed around the "received view," which, according to Agar (1986) "centers on the systematic test of explicit hypotheses." This rigorous process has proven successful for many research problems, especially those that emphasize scientific hypothesis testing. Thus, it lends itself particularly well to hypotheses and questions concerning biophysical data (e.g., the relationship between *A. albida* and soil fertility) as well as the relationship between certain socio-economic variables and biophysical variables (e.g., private tree planting initiatives as a function of previous training in forestry). Moreover, the principal investigator's previous experience in the study area via the rapid rural appraisal exercise mentioned above yielded a considerable amount of information on which to formulate specific questions and research hypotheses.

However, for some socio-economic and cultural factors, subject-oriented research and the formulation of specific hypotheses may prove less satisfactory (Glaser and Strauss, 1967; Spradley, 1979; Agar, 1986; Turner, 1982). As Schatzman and Strauss (1973) write:

⁵²Spradley (1979) provides some basic differences between subject-oriented and informant-oriented research. He argues that social science research that uses subjects usually has the specific goal of testing hypotheses. He maintains that the investigator is not really interested in discovering the cultural knowledge of the subjects but only seeks to confirm or disconfirm a specific hypothesis by studying the subjects' responses. Informant-oriented research, on the otherhand, seeks to discover this cultural knowledge by using informants to gain an understanding of indigenous knowledge, concepts and folk theory about a particular topic. As Spradley puts it, "work with subjects begins with preconceived ideas; work with informants begins with naive ignorance".

The automatic use of formally stated hypotheses, and statements of "the problem" may make it easier to program action, but it will also limit the kinds of experience that [the researcher] will tolerate and deal with. In original research there is less likely to be a conceptual closure to inquiry, for as the work of discovery continues and new kinds of data are conceptualized, new problems and hypotheses quite naturally will emerge. (pp. 12-13)

Thus a more informant-oriented research approach was used to obtain additional socio-economic and cultural information, particularly for questions two and three above. Rather than articulate these questions as formal hypotheses before going into the field, aspects of these broad questions were gradually refined via RRA and group discussions into more specific questions and hypotheses as research and learning progressed. Additionally, other aspects of the research methodology, specifically the socio-economic survey and biophysical inventory also benefitted from this gradual development of hypotheses and research questions.

2.2.1 Research Hypotheses

The following section presents the research hypotheses that were ultimately formulated. These hypotheses were determined, to a great extent, by the character and structure of the socio-economic survey and biophysical inventory. Although most of the data used to test these hypotheses came from these two instruments, information gathered from the other research methods was also applied.

Two remarks regarding the research hypotheses are in order. The first concerns their number. Many would argue that thirty hypotheses violates one of the unwritten rules for dissertations--keep the number of working hypotheses under ten. However, by consciously choosing a systems approach to the problem and examining all of the components of the *A. albida* human ecological system (both biological/ecological and socio-economic processes, constraints and interactions), the principal investigator thought it necessary to at least state all pertinent hypotheses. The ultimate goal in using a systems approach is to strengthen the understanding of both the biological and socio-economic components of the *A. albida* system in order to help GOS decision

makers choose a better course of action through "discovery" of what those better actions might be. This goal could not be achieved by consciously limiting the number of hypotheses.

It should be kept in mind, however, that principal components analysis will be used to reduce much of the data collected (the set of explanatory variables) to a new and reduced set of independent variables expressing the underlying similarities of the original variables. As a result, many of the hypotheses noted below will be eventually reduced, combined and/or reformulated in subsequent chapters.

The second remark concerns the occasionally arbitrary (or perhaps artificial) assignment of a hypothesis to a particular subcomponent of the system. For example, one might argue that a farmer's decision to place a particular field in fallow is internal. Based on an analysis of the ecosystem, the farmer makes a socio-economic decision to give the field a "rest". Others might argue that a farmer's decision to place a field in fallow is a result of input from external social systems (e.g., agriculture policy, lack of inputs, etc.). More than likely, however, a farmer's decision to place a field in fallow is based on both internal and external information. In this context, the objective of the study is NOT to "measure" the amount of information (or material or energy) exchanged between system components but to ascertain the impact of the information (or material or energy) on the *A. albida* system itself.

2.2.1.1 Hypothesis set #1: inputs from other social systems

Inputs from external social systems will have an impact on the *A. albida* system. These include, inter alia; frequency and type of extension contact, previous agriculture and forestry training, presence or absence of national/local incentives, contact with forestry/natural resource-related projects, degree of pastoral encroachment, and changes in macro-economic policy (both forestry and agricultural).

- (1) $H_{(r)}$: There is a significant positive correlation between the number of *A. albida* trees/tree density and frequency and/or type of extension service contact.
- (2) $H_{(r)}$: There is a significant positive correlation between the number of *A. albida* trees/tree density and frequency/type of agriculture and/or forestry training.
- (3) $H_{(r)}$: There is a significant positive correlation between number of *A. albida* trees/tree density and locally available incentives for tree planting.
- (4) $H_{(r)}$: There is a significant positive correlation between number of *A. albida* trees/tree density and security (perceived or real) of land/tree tenure.
- (5) $H_{(r)}$: There is a significant negative correlation between number of *A. albida* trees/tree density and degree of pastoral encroachment.

With regard to agricultural policy, the recent removal of agricultural subsidies has had an impact on farm management decisions over the past years including factors such as crop mix, amount of landholding in fallow and relative proportion of income obtained off farm. In turn, these factors are expected to have an impact on the *A. albida* system.

- (6) $H_{(r)}$: There is a significant negative correlation between agricultural subsidies, particularly for fertilizer, and the number of *A. albida* trees/tree density.
- (7) $H_{(r)}$: There is a significant positive correlation between the area of the landholding in fallow and the number of *A. albida* trees/tree density.
- (8) $H_{(r)}$: There is a significant negative correlation between the areas of landholding in cash crops (peanuts) and the number of *A. albida* trees/tree density.
- (9) $H_{(r)}$: There is a significant negative correlation between the relative proportion of income obtained off-farm and the number of *A. albida* trees/tree density.
- (10) $H_{(r)}$: The financial returns in using *A. albida* in maintaining soil fertility are comparable to the use of unsubsidized fertilizer.

2.2.1.2 Hypothesis set #2: inputs from other ecosystems

Two major inputs from other ecosystems are considered. The first is the role of nomadic (Peular) livestock in *A. albida* propagation.

- (11) $H_{(r)}$: Farmers who have benefitted from arrangements from Peular herders for parage have higher *A. albida* regeneration rates than those who have not.

The second input concerns the role of exotic tree species in NCPB farming systems. Given the GOS's research and development emphasis on exotic tree species, the introduction of exotics such as *Eucalyptus spp.* and *Acacia holosericea* in NCPB farming systems may be displacing the use of indigenous tree species such as *A. albida*. Questions to ask are whether private exotic tree planting practices are random, (i.e., are certain species cultivated in association with different planting areas within a farming system), and are there associations between the cultivation of different exotic tree species with different cultivated crops?

(12) $H_{(r)}$: The cultivation of exotic trees (i.e., where they are grown) on private land is not random.

(13) $H_{(r)}$: The number of exotic trees that are "planted" each year per household has increased in recent years.

2.2.1.3 Hypothesis set #3: outputs to other social and ecosystems

The export of *A. albida* pods, wood and forage to other social/eco- systems (in particular, urban areas) is expected to have an impact on the sustainability of the system.

(14) $H_{(r)}$: There is a significant negative correlation between sale of *A. albida* pods and other products and natural regeneration rate.

2.2.1.4 Hypothesis set #4: the *A. albida* social system

It is expected that size and quality of landholding, family size, numbers of livestock/draft animals (fodder/forage demand), access to common lands, population pressure, agronomic practices, etc., will influence the cultivation and management of *A. albida* trees on private land. Hypotheses include:

(15) $H_{(r)}$: There is a significant positive correlation between size of landholding and the number of *A. albida* trees/tree density.

(16) $H_{(r)}$: There is a significant positive correlation between the quality/fertility of the landholding and the number of *A. albida* trees.

(17) $H_{(r)}$: There is a significant positive correlation between the number of household members and the number of *A. albida* trees.

(18) $H_{(r)}$: There is a significant negative correlation between population pressure as measured by village

population and the number of *A. albida* trees/trees density.

- (19) $H_{(r)}$: There is a significant negative correlation between farmer access to common lands and the number of *A. albida* trees/tree density.

Farmer perception and knowledge of environmental problems as well as farmer perception and knowledge of the *A. albida* system's potential to address these problems suggests additional internal hypotheses:

- (20) $H_{(r)}$: There is a positive correlation between farmer perceived need for "environmental action" and the number of *A. albida* trees/tree density.
- (21) $H_{(r)}$: There will be a difference between the domains of knowledge of men and women regarding *A. albida* cultivation and management.
- (22) $H_{(r)}$: There will be a difference in the perception of benefits of the *A. albida* system between men and women.
- (23) $H_{(r)}$: There will be a difference between the domains of knowledge of Wolof and Serer farmers regarding *A. albida* cultivation and management.
- (24) $H_{(r)}$: There will be a difference in the perception of benefits of the *A. albida* system between Wolof and Serer farmers.
- (25) $H_{(r)}$: Fields that have been consecutively cropped with peanuts have a significantly lower *A. albida* regeneration rate than fields where crop rotations are practiced.
- (26) $H_{(r)}$: Farmers who stall feed *A. albida* pods and subsequently spread the resulting manure on field have a significantly higher *A. albida* regeneration rate on those fields.
- (27) $H_{(r)}$: Fields on which farmers have practiced "parcage" in the past two years have a significantly higher *A. albida* regeneration rate than fields where parcage was not practiced.

2.2.1.5 Hypothesis set #5: the *A. albida* ecosystem

From an internal ecosystem perspective, agronomic practices, rainfall/water table depth, competition with other vegetation and soil type all appear to be major determinants of system maintenance and viability. Hypotheses include:

- (28) $H_{(r)}$: There is a significant negative correlation between water table depth and *A. albida* natural regeneration rate.

- (29) $H_{(r)}$: Fields that have been in fallow for two or more consecutive years have a significantly lower *A. albida* regeneration rate.
- (30) $H_{(r)}$: *A. albida* natural regeneration rates and tree densities are significantly higher on "dior" soils than on "deck", "deck-dior" or "khor" soils.
- (31) $H_{(r)}$: *A. albida* makes its major contribution to soil fertility in the NCPB through the provision of organic matter deposited by litterfall.

2.2.2 Sampling procedure

2.2.2.1 Study area delineation

Drawing on the vegetation analysis for Senegal conducted by South Dakota State University (Stancioff et al. 1986) the study area was delineated by identifying the ecological zones where *A. albida* is the predominant component of the vegetation (i.e., either one, two or three in terms of physical presence/numbers). The area thus defined was then transferred to a 1:200,000 administrative map. The study area covers about 2000 square kilometers and includes parts of the administrative districts of Thiès, Diourbel, Fatick and Kaolack. The location of the study area is provided in Figure 2.1.

2.2.2.2 Village selection

Two approaches were considered in village/informant selection; (i) a large sample of villages with fewer informants per village or (ii) a smaller village sample with more informants per village (i.e., an in-depth study of one or two villages). Given the relatively large study area, it was decided that the first approach best met the needs of the study.

Moreover, based on the principal investigator's experience in the NCPB, there are large differences between villages within the study area and even greater differences within villages when it comes to farmer awareness of, and willingness to take action on natural

Figure 2.1
Location of the Study Area

resource problems. As a result, it is doubtful whether the findings from a study of only one or two villages would be applicable or relevant for other villages⁵³. A larger geographic focus also permits the use some geographical analytical techniques (mapping residuals from regression/principal components analysis) to determine whether there may be sub-regional biophysical or socio-economic differences in terms of presence or absence of *A. albida*. Given this rationale as well as time and resource limitations, it was decided that the study would include a total of 36 villages with two informants selected per village.

Villages were chosen entirely at random using a stratified sampling technique. Having delineated the study area per the above, the area was then overlaid with 7cm X 7cm grids and random numbers were used to determine the geographic coordinates of one point within each grid/square. The village closest to this point was selected to participate in the study. It should be noted that with the population density in the Peanut Basin, villages selected were never more than one kilometer from the randomly selected geographic coordinate. Using this system, 36 villages and two alternates were identified. The names of the villages and their relative location within the study area are presented in Figure 2.2.

2.2.2.3 Initial village visits

Initial visits were made to all 36 villages during October, November and December 1989. The purpose of these visits was to: (i) ascertain whether a particular village actually existed⁵⁴; (ii) explain the purpose of the research and seek village and individual farmer consent for the study; and (iii) obtain a general "feel" for

⁵³This hypothesis is supported by others conducting research/studies in the North Central Peanut Basin, including Pim Wisser (Wisser 1989) from the PREVINOBA project in Thiès, and André Lericollais (Lericollais 1989) from ORSTOM.

⁵⁴The administrative map used dates from 1978-79. Since this time, some villages may have either disappeared or were relocated.

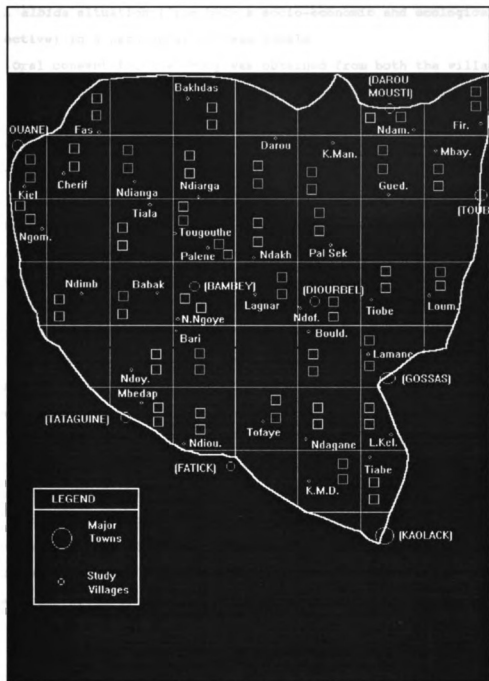


Figure 2.2
Location of Study Villages

the *A. albida* situation (from both a socio-economic and ecological perspective) in a particular village/locale.

Oral consent for the study was obtained from both the village chief (as the GOS administrative representative), and by consensus among farmers present in the village during the visit⁵⁵. The consent script for both village and informant participation in the study was essentially the same.

Following the explanation of the study's purpose/requirements via the consent script, a general discussion was held in each village at which time issues were discussed in detail with the villagers and any questions were answered. A tentative time period/schedule for the study was also discussed. At this juncture, the village chief's concurrence for participation in the study was sought along with the concurrence of other members of the village who might be present. In this manner, all 36 villages originally identified agreed to participate in the study.

It should be noted that the initial village visits may have contributed to survey leakage as the process did stimulate thought and conversation about the survey in particular and natural resources in general before the actual interviews. However, such losses in survey quality were likely offset by gains brought about by informants being more relaxed and less fearful during the actual study. This introduction process, combined with the knowledge that village

⁵⁵The standard procedure during the initial village visits was to hold a meeting with the village chief and those farmers (and others) in the village who were present. Usually, 10-15 heads of households plus 3 or 4 women participated in these meetings. While not a true democratic process (as not all of the chefs de carrés/exploitation from the village were present), it is believed that the concurrence given by the chief and those farmers present was, in most instances, representative of the entire village.

leaders⁵⁶ supported the study, hopefully contributed to the fidelity of research results.

2.2.2.4 Major characteristics of villages

The village selection process described above yielded a wide cross section of villages which captured at least part of the diversity apparent in the NCPB. As Table 2.1 indicates, villages ultimately selected for the study have considerable differences in terms of population, number of concessions, water table depth, number of years established and distances to administrative and social services.

2.2.2.5 Informant selection

As previously mentioned, two informants were selected per village for a total of 72 households. Informant selection procedures were adapted from procedures used by SODEVA. On arrival of the research team in a village, another village meeting was held to once again go over the consent script noted above. The rural tax list, which includes all heads of households in the village (i.e., the basic production units--chefs de carrés/concessions, chefs d'exploitation and chefs de ménage dépendent), was then obtained from the village chief.

From this list, it was determined which heads of households were actually present in the village and explained that with their permission, the names of these individuals would be put on a piece of paper and placed in a hat. Two names were then drawn from the hat and these individuals would be selected to participate in the study (and

⁵⁶It is not uncommon for local leaders of rural communities to be distrusted by community residents. While difficult to substantiate, we felt that the local leaders, particularly the village chiefs, were generally well respected by the communities. There was only one apparent exception to this observation. In one village, there was both an administrative "chef" and a locally important religious leader or "marabout". As a result, there was considerable conflict between the two leaders and members of the village had drawn lines in terms of their support. Given this conflict, we chose not to conduct the study in this village and an alternate village was selected.

Table 2.1

Major Characteristics of Study Villages

Variable	Max.	Min.	Avg.	St.D.
Village population	1412	34	454.0	352.0
No. carrés/village	126	4	46.3	27.9
Dist. near. market (km)	25	0	6.3	4.7
Dist. near. paved road (km)	21	0	7.2	5.3
Dist. near. SODEVA (km)	29	1	8.9	5.4
Dist. near. Eaux & For. (km)	30	2	11.8	6.7
Dist. near. CER (km)	30	2	12.7	7.2
Water table/well (m)	90	7	37.4	22.3
Village established (yrs)	767	38	192.1	164.7
Source: Survey data.				

to a certain extent, represent the village). All heads of households were given the option of not placing their names in the hat but this was never an issue; everyone wanted his/her name to be included. Once informants were selected in this fashion, the consent script was again reviewed and oral permission was obtained individually from each informant.

While it is believed that this procedure yielded a fairly representative sample of farmers, it has some obvious shortcomings. First, farmers from the NCPB frequently travel during the dry season (the period in which the study took place) usually either for commerce or religious purposes. In several villages, nearly 20% of the heads of households were absent, some for the entire dry season⁵⁷. Thus, the sample might be biased towards individuals who remain in the village during the dry season for one reason or another (e.g., health, age, off-farm employment opportunities, etc.).

A second shortcoming of the sample is that as the study's purpose was primarily to examine land management decisions vis-a-vis the use of the *A. albida* system, it included only those individuals

⁵⁷As a general observation, we noted that villages which had other means of making money during the dry season such as animal fattening or vegetable gardening, tended to have a higher percentage of heads of household present than villages who relied solely on rainfed agriculture.

who owned or had access to land. Thus, women and older children in the household were not included in the "official" survey sample. However, other methods, particularly focus group discussions, were used to obtain critical input from these individuals.

Finally, two very minor problems were noted in using this sampling technique. In two villages, the village chief wanted to select the farmers to participate in the survey. It appears as though these chiefs, being concerned that this study would eventually bring a "project" to the village (in spite of repeatedly stating that this would not be the case), wanted the "best" farmers in the village to participate. They were concerned that the random procedure might select individuals who were not "representative" of what the village was capable of doing. However, after explaining: (i) that the study required both "good" and other types of farmers; (ii) the importance of a random sample; and (iii) there would definitely be no "project" after the study, both chiefs agreed and everybody's names were put into the hat.

The other minor problem was that there appears to be a certain degree of prestige associated with participating in the study. In three other villages, more farmers wanted to participate in the survey than time and resources would permit. For the most part, these were farmers who were particularly proud of their farms in terms of numbers of *A. albida*, other species and/or tree planting/natural resource activities. In two instances, the principal investigator was obliged to conduct "mini" socio-economic surveys and biophysical inventories with several farmers from these villages. While the data from these surveys are not included in the sample or the analyses, this technique succeeded in alleviating the tension between those who were eventually selected to participate and those who were not.

Table 2.2 provides descriptive statistics on the 72 farmers retained for the survey. As with the village selection process, it is believed that the actual survey sample, while relatively small and

with the caveats discussed above, contained a fairly good representation of the types of farms, farmers and socio-economic conditions present in the NCPB⁵⁸. There is considerable variation in the sample in terms of informant age, amount of off-farm income, age on becoming chef and length of time as a chef, and total area farmed. Only the number of households per concession is relatively uniform for the sample.

In terms of ethnic groups, 39 of the informants are Wolof while 33 are Serer. This approximates the relative distribution of the two major ethnic groups in the study area. In terms of their status as heads of household, 50 (69.4%) informants were "chefs de concession", 20 (27.8%) were "chefs d'exploitation" and 2 (2.8%) were "chefs de ménage dépendent"⁵⁹. What appears to be a disproportionately high number of chefs de concession is due primarily to the fact Serer farmers tend to establish their own independent household compounds on becoming a "chef". As a result, the majority of Serer households in the sample are single family units with only one head of household, the chef de concession.

⁵⁸There is considerable argument over the proper sample size for studies such as this one. The only general agreement is that sample size is more a function of time and resources than anything else (Clark and Hosking 1986, Shaner et al. 1982). However, our sample size of 72 farmers is not without some statistical validity. We considered the key variable in the study to be the number of *A. albida* trees per hectare per farm. Based on the RRA exercise and Ndiaye (1989a), we found that there was considerable variation in the number of trees per hectare and estimated the standard deviation to be + or - 40 trees/hectare and an error margin per farm of + or - ten trees. With a confidence interval of 95% and a z value of 1.96, our estimate of the minimum sample size required was $n = (40 \times 1.96 / 10)^2 = 61$.

⁵⁹Golan (1990) provides a concise description of these classifications. The "concession" or compound consists of one or more households. The head of the compound (chef de concession) is typically one male who has the "right of hatchet" (literally the right to clear fields passed on from father to son) and his household. Other households may also be in the compound and are headed by brothers, sons or cousins of the household head. These secondary households are broken into two categories; independent (chef d'exploitation) and dependent (chef de ménage dépendent). According to Golan, the primary distinction between these two types of households is that independent households prepare their own meals and are responsible for meeting their own millet needs.

Table 2.2

Some Respondent Characteristics

Variable	Max.	Min.	Avg.	St.Dv.
Age of respondent (yrs.)	86.0	30.0	52.7	13.8
Households/concession (no.)	5.0	1.0	1.5	0.9
Off farm income (fcfa/year)	200000.0	0.0	33428.0	53354.0
Age became chef (yrs.)	60.0	17.0	31.6	9.9
Time in village (yrs.)	73.0	3.0	47.2	14.0
Total farm area (ha)	24.8	0.8	6.5	4.3
Source: Survey data.				

Table 2.3 indicates that the majority (52.8%) of informants became a chef through the death of the existing chef, or by taking over responsibilities from an older chef (22.2%). Only 12.5% of informants asked to become a chef or became a chef on the proposition of the existing chef (9.7%). Conflict does not appear to be a major determinant in becoming a chef. Only two informants sought to become a chef as a result of a conflict with the existing chef while none reported conflicts with other individuals as a factor.

Table 2.3

How Informants Became Chef

(Number and Percent of Responses)

Method	No.	Per.
Asked to become chef	9	12.5
Proposition of existing chef	7	9.7
Deceased chef	38	52.8
Take over for older chef	16	22.2
Conflict with existing chef	2	2.8
Conflict w/someone in con.	0	0.0
Conflict w/someone else	0	0.0
Source: Survey data.		

Family composition by age and by individual household is provided in Table 2.4. Results suggest that there is considerable variation between households in terms of numbers of adult men and women and to a lesser extent, in terms of numbers of male and female youth.

Table 2.5 provides a summary of household composition by status for all households in the sample. Approximately 92% of all household adults were considered to be active. Note that the absence of "navetanes" and "noranes" is not unexpected as these are primarily seasonal (rainy season) workers⁶⁰. However, many informants and other farmers from the study area reported that the use of noranes and navetanes is becoming rare given problems in the agriculture sector.

Table 2.4
Household Composition
(Number of Family Members by Household)

Category	Max.	Min.	Avg.	St.Dv.	Total
Adult men ⁶¹	7	1	2.26	1.29	163
Adult women ⁶²	9	1	2.43	1.45	175
Male youth ⁶³	6	0	1.43	1.29	103
Female youth	4	0	1.04	1.01	75
Male children	4	0	.96	1.05	69
Female children	4	0	.94	1.09	68
Source: Survey data.					

⁶⁰Navetanes are "hired" labor who work for a farmer in return for the loan of seed and a parcel of land. Noranes are hired labor who travel around the Peanut Basin providing supplemental labor as needed usually during the rainy/cropping season. They are generally paid in cash and given food and lodging for the duration of their contract.

⁶¹Adults have at least 15 years of age. Adult men include chefs de concession, d'exploitation, male heads of dependent and independent households and sourgas (unmarried dependents) in the concession.

⁶²Includes married, unmarried and widowed women.

⁶³Youth are considered to be between 6 and 15 years old.

Table 2.5

Sample Household Composition

Status	No.	% of Adults	Avg./ Hous.
Chefs de concession	53	15.7	0.7
Chefs d'exploitation	23	6.8	0.3
Navetanes (hired labor)	0	0.0	0.0
Chefs dependent households	9	2.7	0.1
Sourgas familiales (family labor)	78	23.1	1.1
Noranes (hired labor)	0	0.0	0.0
Married women	150	44.4	2.1
Unmarried women/widows	25	7.4	0.3
Source: Survey data.			

One area where there appears to be considerable variation between households is in livestock holdings. While the majority of informants reported possessing both sheep and goats (58% and 56% of informants respectively), and to a lesser extent cattle (29%) the differences in numbers of livestock per household are quite high as Table 2.6 indicates. This may, in fact, be the case, or is a reflection of an informant's hesitancy in accurately reporting actual numbers of livestock⁶⁴. This issue will be discussed in greater detail in the section on survey implementation.

A small fraction of the respondents are fattening cattle (7%) and sheep (11%) to supplement their farm incomes, although the number of animals fattened is relatively low. The principal investigator feels relatively comfortable with the accuracy of these figures as the team was usually able to see/count the animals in the compound as they were all stall fed.

⁶⁴A "touchy" question, particularly among the Serer, is asking how many animals a farmer has. Farmers are generally hesitant to provide exact numbers considering that numbers given to the local sous-prefecture for tax purposes are usually below actual holdings.

Table 2.6
Livestock Per Household
(Number of Animals)

Type	Max.	Min.	Avg.	St.Dv.	Total
Cows fattened	4	0	0.1	0.6	9
Other cows	40	0	2.0	5.4	143
Sheep fattened	2	0	0.2	0.5	12
Other sheep	27	0	3.3	4.6	234
Goats	16	0	2.7	3.3	196
Chickens	30	0	6.6	7.8	472
Source: Survey data.					

There was considerably less variation in the sample with regard to traction animals used. As Table 2.7 indicates, the most common traction animal is the horse with an average of 1.25 horses per farm. The second most common traction animal was the donkey with an average of 0.64 animals per farm. Only two farmers in the sample had oxen but did not own any of the heavier traction implements normally used with oxen such as deep plows and polyculteurs.

Table 2.7
Traction Animals By Household
(Number of Animals)

Type	Max.	Min.	Avg.	Std.	Total
Oxen	4	0	0.08	0.52	6
Donkeys	4	0	0.64	0.95	46
Horses	4	0	1.25	0.81	90
Source: Survey data.					

Finally, the distribution of tools and other agricultural implements per household is also fairly uniform as Table 2.8 indicates.

2.3 Research methods

To accomplish the objectives of the study to address the above hypotheses, a multi-method research approach, consisting of four

Table 2.8
Tools And Equipment Per Household
(Number of Implements)

Item	Max.	Min.	Avg.	St.Dv.	Total
Seeders	3	0	1.26	0.71	91
Houes sine ⁶⁵	2	0	0.28	0.53	20
Houes occidentale ¹⁶	3	0	1.06	0.72	76
Other cultivators	1	0	0.04	0.20	3
Araras ¹⁶	2	0	0.10	0.34	7
Horse carts	2	0	0.36	0.51	26
Donkey carts	1	0	0.01	0.12	1
Ox carts	0	0	0.00	0.00	0
Plows	0	0	0.00	0.00	0
Polyculteurs ⁶⁶	0	0	0.00	0.00	0
Bati ariana ⁶⁷	2	0	0.21	0.50	15
Souleveuses ¹⁸	2	0	0.71	0.65	51
Source: Survey data.					

distinct methods, was used to gather different, but related, types of data and information. This approach helped overcome many of the problems endemic to cross-cultural research. Perhaps more importantly, it helped provide a more holistic view of the *A. albida* human ecological system in Senegal's North Central Peanut Basin. Each of the research methods is discussed individually in the following sections of this chapter. However, it should be emphasized that even though each method was applied individually they were selected and developed to function in an integrated fashion. Data and information from each method provided important pieces to this research puzzle.

⁶⁵Houe sine, houes occidentale and ariana are all generally considered as cultivators. A houes sine is a cultivator with generally one blade, either artisanal ("iler", local fabrication) or purchased from a dealer. Houes occidentale and ariana are multi-purpose cultivators with more than one blade and can be used for various tasks.

⁶⁶Multi-purpose implements capable of plowing, cultivation, seeding and harvest generally used with oxen traction.

⁶⁷Souleveuses are peanut harvesters, while bati ariana is a particular brand of harvester.

2.3.1 Rapid rural appraisal

Rapid appraisal has been defined by Grandstaff and Grandstaff (1985) as any systematic activity designed to draw inferences, conclusions, hypotheses, or assessments, including the acquisition of new information, in a limited period of time. Rapid rural appraisal focuses on the management of rural resources. While there is some concern about the confidence that can be placed in the results of RRA (Gibbs 1987) there is general agreement that RRA can be used to improve the design and execution of any formal survey or more in depth investigation that follows RRA (Beebe 1985).

As a precursor but integral part of this research, the principal investigator participated in a interdisciplinary study of soil degradation in the Peanut Basin in June 1989. This study, entitled "Soil Degradation and Prospects for Sustainable Agriculture in the Peanut Basin of Senegal" (Rodale 1989), was essentially a "rapid rural appraisal" (RRA) of soil productivity constraints in the Peanut Basin (PB) and the potential of "regenerative agriculture" to address these constraints. A major focus of the study was the use of woody perennials, particularly *A. albida*, in restoring or maintaining soil fertility.

The study loosely followed the International Council for Research on Agroforestry's (ICRAF) Diagnostic and Design (D&D) Methodology (ICRAF 1983a and 1983b) prediagnostic and diagnostic stage guidelines. The prediagnostic stage consisted of (i) a background description of the Peanut Basin including relevant aspects of both the biophysical and socioeconomic environment; and (ii) a differentiation of land use systems within the PB. The diagnostic stage included: (i) a diagnostic survey of major land use systems in the PB and relevant aspects of the environmental setting; and (ii) a diagnostic analysis and identification of major land use problems and potentials of selected systems. Specific methods included an in-depth literature review for the PB, the use of key informants (ministry and donor

officials, local authorities) and semi-structured group and individual interviews with PB farmers. "Triangulation" was used to bring together the observations of individual team members from different disciplinary perspectives to address the problem--soil degradation.

The net result of the principal investigator's participation in the study was that it provided a solid foundation on which to base a more detailed study of one of the major land use systems in the PB, the *A. albida* system. Specifically, it laid the groundwork for this study by increasing the principal investigator's awareness of the target group thus helping him better define research questions and hypotheses.

2.3.2 Socio-economic survey

A formal household survey questionnaire was developed and used to gather information on socio-economic variables from farmers in the sample. The complete questionnaire is found in Appendix A. A variety of questionnaire techniques were used including close-ended questions (where answer categories are discrete, distinct and relatively few in number), and open-ended questions to elicit informant views, philosophy and goals relative to the *A. albida* system. Repertory grids were also used to help organize information about farmer's perceptions of the relative advantages and disadvantages of *A. albida* and other farming practices. Under this broad category of information, eleven specific classes of quantitative and qualitative data were gathered:

- (i) general information, e.g., distances from villages to nearest roads and change agents, village population, number of active farmers, etc. in order to ascertain whether these variables might have an impact on the *A. albida* system;
- (ii) village history, e.g., how old is the village, has the location ever changed and why, conflict with other villages over land/natural resources, and past, current and future perception of the availability of natural resources/extent of degradation around the village;
- (iii) farm (household) characteristics, including demographics, migration, importance of off-farm employment, numbers/types of animals and tools, etc., and how these variables might influence *A. albida*. (e.g., does level/type of education have an impact? relative wealth? numbers/types of animals, etc);

(iv) participation in farmers groups or associations, including types of associations and level of participation. Are farmers who are members of organizations more environmentally aware than those who are not? What is the potential role of farmers associations in extending/maintaining the *A. albida* system?

(v) land availability, tenure and segmentation. How do these factors influence the *A. albida* system and to what extent?

(vi) farm performance. How and why have yields varied over the years? What is the relative importance of "parcage"⁶⁸, fallow and *A. albida* in maintaining soil fertility?

(vii) formal agricultural training received, including type and relevance to the farmer. Does formal agricultural training have an impact on farmer perception of the environment/*A. albida* system?

(viii) formal forestry training received, including type and relevance to the farmer's needs. Does formal forestry/natural resources training have an impact on farmer's perception of the environment/*A. albida* system?

(ix) knowledge, attitudes practices (KAP) of farmer vis a vis *A. albida*/natural resources. How does KAP vary in the study area and what is its relevance in maintaining/increasing use of the *A. albida* system? What is the farmer's private tree planting history? What are his/her species preferences? What is the relative importance (social and economic) of *A. albida* in the farming system?

(x) level, type and importance of contact with development agencies. What has been the role/importance of government and non-governmental agencies in promoting awareness of *A. albida*/natural resource problems and solutions?

(xi) questions concerning common land or "domaine nationale", e.g., has there been any privatization of common land due to tree planting? What is the role and importance of woodlots/collective plantations in the village and what are the implications for the *A. albida* system.

These question areas, and the entire survey, focused on the importance of trees, specifically *A. albida*, within the farming system. Information gathered from this survey was also used with data gathered from the biophysical inventory and other methods, to evaluate the formal hypotheses.

Problems associated with cross-cultural survey research are well documented, and the accuracy and validity of data collected using

⁶⁸Parcage is an arrangement made between a farmer and a herdsman (often from the same village but occasionally a Peul) to exchange crop residues (and occasionally *A. albida* and other forage species) on a particular field for several days (up to a month) of manuring.

surveys with rural populations in low income countries is open to debate (Whyte, 1977). One major problem with formal surveys is that the meanings ascribed to terms and concepts in survey questions often differ widely between researchers and informants. Additionally, questions are usually framed within the researcher's world view, and this may diverge significantly from that of members of the target group. Finally, the cultural inclination to "tell people what they want to hear" obviously colors the results of qualitative surveys dealing with perceptions, attitudes and practices of a particular target group. This inclination is more than likely manifested in responses to questions dealing with extension, participation in private and collective reforestation initiatives, and the priority accorded to natural resource problems.

These general problems are compounded by a certain distrust or suspicion of forestry agents in the NCPB. Senegal's Forest Service (Direction des Eaux et Forêts) is mandated to provide both extension services and enforcement of the national forestry code. Farmers often view DEF agents with considerable suspicion and apprehension. While every effort was made to explain that the principal investigator and his assistants were not affiliated with the DEF in any fashion, farmer perception of forestry agents in general may color responses to questions dealing with sensitive issues such as pruning/harvesting trees and the sale of fuelwood and other tree products.

In recognition of these potential problems, a rigorous preparation process was used in the development of the survey instrument. Great care was taken to use terms and concepts throughout the survey that were thought to be appropriate for farmers in the NCPB. Development of questions for this component drew from: (i) the rapid rural appraisal conducted in the Peanut Basin by the principal investigator as discussed above; (ii) a number of other agriculture and natural resource surveys already pre-tested and conducted in

Senegal by other researchers and projects⁶⁹; and (iii) related surveys which have been conducted in other sub-Saharan African countries.

Questions were first written in French and reviewed/critiqued by colleagues in ISRA/DRPF, ISRA/DSAEF and others with experience in conducting surveys in rural Senegal. Based on input from these individuals, the questionnaire was revised and reorganized. Questions were then reviewed (in French) by the research assistants both to gain from their experience in implementing rural surveys and to make sure that they understood the context and meaning of each question--i.e., the information that each question was seeking to obtain. Following this exercise, each question was translated into Wolof and Serer by the research assistants as a group⁷⁰. The purpose of this exercise was for the group to reach a consensus on each question in order to ensure that each assistant would ask the question in the same manner using the same translation. This would hopefully eliminate, to the extent possible, biases and errors resulting from using six different people to implement the survey.

This version of the survey instrument was then pre-tested with three farmers (two Wolof and one Serer) from the Thienaba area⁷¹ in December 1989. The approach for the pre-test consisted of dividing the research assistants into three teams and administering the questionnaire in a team rather than an individual fashion. Over the

⁶⁹Numerous surveys on natural resources and agriculture have been conducted in Senegal. The principal investigator owes a particular debt of thanks to Desiré Sarr, a sociologist at ISRA/DSAEA, for providing copies of the questionnaires for the majority of these surveys in addition to his own guidelines on the structure and use of rural surveys in Senegal.

⁷⁰Two of the six research assistants hired by the principal investigator had taught in SODEVA's adult literacy program; one in Wolof and the other in Serer.

⁷¹Farmers chosen for the pre-test were identified by Momar Wad, ISRA/DRPF forest technician working in the Thienaba area. Farmer selection criteria was based mainly on availability and willingness to participate in the survey.

two day period, the author spent approximately 5-6 hours with each team in order to: (i) identify particular problems vis-a-vis the questionnaire; (ii) clarify particular questions/issues for the assistants; (iii) observe farmer reactions to different questions; and (iv) observe assistant interaction with farmers.

At the end of the pre-test, a series of meetings were held with the assistants in Dakar to once again go over the questionnaire and make necessary corrections/modifications. This version was then orally back-translated from Wolof and Serer into French by the assistants in order to ensure that the original intent and purpose of the question had not been lost.

Even though a significant effort was expended in the development of the survey instrument, problems with informant's "cultural inclination" and a general distrust of forestry agents could still persist. However, it is felt that this problem was circumvented to a certain extent by spending considerably more time with informants than is usually the norm for "one shot" socio-economic surveys. In practice, the socio-economic questionnaire is rather lengthy and required about 8 hours to complete. However, it was designed to be administered by section in 1-2 hour sessions chosen entirely at the convenience of the informant and spread over the 7-10 day period required to complete the biophysical inventory. Farmers find this approach convenient as it does not detract significantly from their other activities. Moreover, experience has shown that if an informant has a problem with a particular question or topic, the question/topic can be postponed for several days giving the informant the opportunity to get to know the principal investigator and research assistants better, and have more confidence and trust in them.

An example can help illustrate this point. Farmers are generally hesitant to provide the exact number of animals they own, considering that the figures they provide to the local sous-prefecture for tax purposes are usually well below actual holdings. A concern

among some informants was that if they provided more accurate numbers during the survey, they might be reported to the local authorities for rural tax evasion in spite of any assurances given by the assistants or the principal investigator to the contrary.

During the course of survey implementation, however, it was discovered that as farmers gained confidence and trust in the research team (i.e., the team was not affiliated with the Forestry Department, and/or informants were not going to be reported to the local authorities), they would come to the team toward the end of the visit to state that some of the information they had given about animal numbers in might have been "faulty" and would revise their total animal holdings upward. While the "revised" figures are still probably on the low side, the principal investigator feels that they better reflect reality than data which would be obtained from a one or two hour interview. Similar experiences happened for other "touchy" subjects including tree pruning and harvesting and the sale of tree products. In general, we found that as informant confidence in the research team grew, so did informant openness in answering questions.

Finally, as a result of the biophysical inventory, the research team was actually able to verify/cross reference/compare some questions which are notorious for generating questionable responses. These include, inter alia, questions concerning size of landholdings, private tree planting initiatives or other natural resource-related practices, pruning rates and care and management practices of *A. albida*.

2.3.3 Biophysical inventory

Much of a person's and community's indigenous knowledge is tacit, not easily verbalized and often not obvious to outside observers. As a result, verbal statements often differ from actual behavior. It was therefore necessary to seek out other, more objective indicators of farmer behavior vis-a-vis the *A. albida* system and other natural resource management practices. Thus, in addition to

the farm level socio-economic survey, a biophysical inventory of tree and other on-farm resources was carried out on each informant's landholdings. The complete biophysical inventory questionnaire is found in Appendix B.

Given the shortage of arable land in the NCPB combined with increasing population pressure, it was reasoned that the majority of trees (including *A. albida*), bushes and shrubs growing (either planted or naturally regenerated) on informant landholdings were at the most, purposely cultivated and managed⁷², or at least, permitted to live because they served a particular purpose.

Based on this reasoning, and the general research goals, an extensive inventory of private trees cultivated on all informant landholdings was carried out. Data collected include:

- Number, base diameter and crown diameter of all on-field *A. albida* trees greater than 1 cm in base diameter;
- An estimate of the degree of severity of *A. albida* pruning/lopping (i.e., none- 0% of crown removed, light- 5-20%, moderate- 20-40%, and severe >40%);
- An indication of *A. albida* natural regeneration. Three 10 m X 10 m plots were selected at random on each field. *A. albida* trees with less than 1 cm base diameter were counted in each plot and the natural regeneration per field and per hectare were then estimated;
- Number, base diameter, crown diameter and severity of pruning/lopping for all other on-field trees greater than 1 cm in base diameter;

In addition to on-farm tree information, the following data were also collected:

- Field⁷³ ("parcelle") area. Field circumference was obtained by using a 30 m tape and a handheld compass. The outline of the field was sketched to scale on the sheet provided on the

⁷²The terms management and cultivation are used here to convey the idea of woody vegetation being maintained on household land with varying degrees of farmer involvement. This might be simply plowing around naturally regenerated seedlings or may involve more intense management practices such as staking young trees to support them.

⁷³Fields include all land currently owned, rented, leased borrowed or otherwise held or used by the respondent, including fallow areas.

inventory form and the field area (in ha) derived by using a planimeter;

- Distance to village. The distance from the village to a particular field was also estimated. (Initial observations gained from the RRA and the initial village visits suggested that distance may be a critical factor in terms of *A. albida* density. Fields furthest from the village appeared to have more trees than fields located near the village. This may be due to the more intense grazing pressure on fields in close proximity to the village);
- Evidence of any on-field tree planting activities and or other soil conservation measures;
- Soil samples. A total of three soil samples were taken from each field; one at 2 m from the trunk of a randomly selected *A. albida* tree, one at the drip line (edge of the crown) of the same tree, and one 20 m from the drip line. (In fields where there were no *A. albida* trees, three samples were taken at random.)

The procedure for taking the sample was to dig a hole approximately 15 cm in depth and to mix the soil from all horizons in the hole. From this mixture, a sample of about one kilogram was drawn, placed into a plastic bag and coded. In this manner, 915 samples were taken (3 samples per field times 305 fields).

The original intention was to analyze all samples but costs involved in doing this were prohibitive. As a result, a subsample of 36 of the original 915 samples were drawn at random (12 samples per location) for analysis. Each subsample weighed approximately 150g.

Soil samples were analyzed for pH, phosphorus, potassium, calcium, magnesium, nitrogen and percent organic matter at Michigan State University's Department of Crop and Soil Science. Analytical procedures used followed "Recommended Chemical Soil Test Procedures for the North Central Region" as described in North Central Regional Publication 221 (Revised) of October 1980.

A history of each field was obtained from informants which included: (i) the means of field acquisition (whether inherited, allocated, cleared by self or rented); (ii) cropping history for the past five years (crops and yield estimates, fallow periods, use of manure, chemical fertilizers, compost and parcase); and (iii) the informant's impression of the quality of the field.

2.3.4 Focus group interviews

Beebe (1985) points out that group interviews with farmers can be extremely useful in collecting information on natural resources, local histories and certain sensitive information such as land quality, where an individual may be penalized if he or she replies truthfully to a particular question. As an RRA technique, combining group interviews with more formal survey methods serves two main purposes in this study. First, it provides a means of cross-referencing some of the information and data obtained through the formal socio-economic survey as well as a means of checking sampling error. Second, it seeks to complement data and information gained through other methods by involving a wider number of participants, particularly women and youth, in the research process. Focus group interviews can be used to systematically gather in-depth information on the behavior and attitudes of a particular target group (Molnar 1987). According to Krunar (1987) target groups should be small (6-12 people) and homogenous (sex, social status, occupation, etc.). Discussion on selected topics is stimulated by the interviewer making extensive use of "what if?" questions to develop a logical sequence and focus group attention on different contingencies.

Based on Krunar's guidelines, information was sought from three major focus groups; women, youth (predominantly male) and other heads of households (chefs) not selected for participation in the actual survey. The procedure for identifying/selecting groups in a particular village would be for the principal investigator and/or his assistants to explain to the local leaders (the chef de village and a few "notables") the purpose and goals of the method and seek his concurrence to hold a meeting with a particular focus group. (We chose only one focus group per village but sought an approximately equal distribution of all three target groups across the 36 villages.) On receiving the chef's concurrence, the research team would inform members of a particular focus group that there would be a

meeting with the research team on a particular day, time and place and all members of the group were free to attend.

Focus group discussions centered, for the most part, around seven major topics including:

- (i) privatization of common land/demise of the village collective field;
- (ii) the role of marabouts in natural resource conservation and or destruction;
- (iii) the role of women in natural resource management;
- (iv) private vs. collective tree planting;
- (v) the role of farmers organizations in natural resource management;
- (vi) project vs. program/policy support for natural resource endeavors;
- (vii) re-establishing *A. albida* via natural regeneration vs. planting seedlings.

In order to provide the "triangulation" necessary for this method, individuals with different disciplines and interests were invited to accompany the principal investigator. In this regard, the research team was fortunate to have the participation of a wide variety of individuals including social foresters, agriculture economists, Peace Corps Volunteers as well as colleagues from ISRA, DEF and USAID.

It was anticipated that there might be problems with this method, particularly in terms of women's participation. However, this was not the case and women participated freely and very vocally in all the group discussions. However, a major problem encountered was keeping the groups homogenous, particularly in Wolof villages. As one Wolof farmer put it, "we (i.e., the Wolof) are very social and outgoing and like to know what's going on". Therefore, it would not be uncommon for passersby or other members of the village to stop by the meeting place to, in fact, see what was going on. Sometimes these individuals would participate in discussions and other times they would not but no attempt was made to exclude them from the meeting or

the discussions. The net result is that in some villages, there was what Gow (1987) refers to as a "distorted picture" of the local situation; either the local leaders dominated the discussions, the "ideal" was discussed rather than the "real", or simply the discussions presented an opportunity for participants to air their grievances and problems along with a "wish list" of solutions.

However, in other villages, there was open and free discussion among all participants and much was learned even if the homogeneity of the groups was occasionally violated. In fact, some of the more insightful discussions involved interactions between men and women and men and male youth. Discussions between different focus groups were often quite vocal and occasionally became quite heated and difficult to control. In these instances where participants freely corrected each other and spoke openly on often sensitive topics, the variability which make up an NCPB village became very apparent and much was learned.

2.4 Study implementation

2.4.1 Selection and training of research assistants

In order to adequately cover the area and the scope of work within the timeframe allowed, six research assistants (five men and one woman) were hired to assist in study implementation. These individuals are all ex-SODEVA employees⁷⁴ each with 10-15 years experience in conducting rural surveys⁷⁵ and in living and working in rural Senegal. They are all able to read, write and speak French, and in addition to speaking and writing Wolof, three of the six speak fluent Serer. Most importantly, they all appeared to enjoy working with farmers in often very difficult living conditions.

⁷⁴Recommended by M. Diop, ex-deputy director of SODEVA, currently working for CIDA.

⁷⁵Including the "filière engrais" study and the evaluation of USAID's Cereals II agroforestry component.

A two week training session for the assistants was held in Dakar in December 1989. The objectives of this training were to:

- Discuss the purpose/objectives of the study and review the consent procedures outlined above;
- Discuss various approaches in survey implementation;
- Review the socio-economic survey questionnaire per the above discussion;
- Review the requirements of the biophysical inventory. Research assistants were given hands-on training in: (i) how to measure trees (base and crown diameters); (ii) how to determine field area; (iii) how to take soil samples; (iv) how to determine the extent of *A. albida* natural regeneration; (v) how to estimate pruning rate; and (vi) how to enter/code this information on the inventory sheets.

2.4.2 Implementation strategy

In order to complete the study within the timeframe and budget allotted, the study area was divided into three "administrative" (geographic) zones composed of 12 villages each. One team composed of two assistants was assigned to each zone and under the direct supervision of the principal investigator, was responsible for implementing the socio-economic survey and biophysical inventory in the 12 villages (24 households) within that zone. All teams worked concurrently. After selection of the two study participants/ households per village per the procedures outlined above, each team member worked individually with his/her farmer in administering the socio-economic questionnaire. However, the team regrouped in order to facilitate implementation of the biophysical inventory. For this latter, the informant or a member of his household (an older son) would accompany the team to the fields in order to determine their location and boundaries. The teams were given a considerable amount of assistance in conducting the biophysical inventory by the informants themselves as well as from other members of the village. It would not be uncommon to have 5-10 men/male youth and several children assist the research team in locating/identifying trees and in taking measurements. Often, these sessions would turn into forestry

"field days" complete with food and water brought from the village for all the "workers".

As previously stated, completing the surveys in one village required between 7-10 days, the exact time depending on the number of fields per farmer. During this time, the team would live with someone from the village (usually the village chief and occasionally one of the informants or someone else from the village who had extra room. So as not to be a drain on these households, research assistants were given sufficient funds (per diem) in order to be able to purchase commodities (rice, dried fish, tea and sugar) for contribution to household meals. It should be noted, however, that informants were never paid for participating in the survey. The principal investigator spent 1-2 days per week with each team in each village. This time is spent in: (i) reviewing survey results with the assistants; (ii) conducting the focus group interviews; and (iii) generally participating in village life.

CHAPTER 3

SOIL DEGRADATION IN THE PEANUT BASIN: THE TREE FACTOR

"The sandy upland soils of the Peanut Basin are resilient but, because of the harsh climate, they are not responsive to management. Consequently, low yields are easily maintained and improved yields are hard to achieve."

(Grosenick et al. 1990:54)

3.1 Introduction

There is a common consensus among many GOS and expatriate scientists and development personnel that soil fertility in the Peanut Basin has declined significantly and continues to decline since the collapse of the bush fallow system in the early 1950's. Put simply, soil degradation has been cited as a problem in the Peanut Basin for at least 40 years. Dancette and Sarr (1985) review literature and research on soil degradation and regeneration in the Peanut Basin from 1952. They found that early research focussed on regenerating and conserving soil fertility and research programs during this period centered on crop rotations, soil preparation techniques (animal traction) and restitution of soil organic matter through a better integration of livestock into farming systems. Additionally, as Dancette and Sarr (*op. cit.*) point out, much of the original research on *A. albida* was also conducted during this period.

Dancette and Sarr (*op. cit.*) go on to argue that the late 1960's and early 1970's saw a shift in emphasis from essentially organic and cultural-based (improved techniques) research programs to ones that focussed on the use of mineral fertilizers and improved crop varieties as a means of resolving problems stemming from intensification of agricultural systems and the effects of continuous cropping/declining fallows. This shift in emphasis combined with GOS personnel and financial constraints caused much of the early research on soil degradation problems and regeneration techniques to be abandoned.

The late 1970's and early 1980's saw somewhat of a renewed interest in soil degradation, and soil conservation once again became a "hot" topic among some researchers and donors. In 1977, Beye discussed the causes and effects of soil degradation in Senegal (wind and water erosion, acidification, and changes in soil physical structure) and concluded that "all forms of soil degradation are evident in Senegal, sometimes to such a degree that if urgent conservation measures are not undertaken, the results could be catastrophic". In 1980, the National Research Council, financed by USAID, carried out a brief review of soil degradation in the Peanut Basin. In 1982, USAID also sponsored two additional studies on soil degradation in the Peanut Basin. Freeman (1982) proposed a "multi-donor reclamation operation" in the Peanut Basin whose objective would be to "develop sustainable land management systems and increase the productivity of soils". Aurora Associates (1982) stressed the need for increased attention to soil conservation and management in its master plan for the Peanut Basin (Bassin Arachidier: Schema Directeur. USAID 685-0235).

In 1984, SODEVA reviewed efforts to date which addressed the problems of soil degradation and concluded that the effects of many interventions had been limited. SODEVA stressed the need for integrated development programs which placed an accent on soil and water conservation (in French, "défense et restauration des sols"-DRS) without which "desertification" in the Peanut Basin would reach such a level that it would be "difficult to reverse". SODEVA's report was followed by the previously mentioned Dancette and Sarr (1985) study which reviewed the causes and effects of soil degradation and research conducted on the subject in the Peanut Basin since the early 1950's.

The mid- 1980's saw GOS's attitude begin to shift from one which focussed primarily on mineral fertilizer research and improved varieties to one that included natural resource based agricultural

research programs such as agroforestry and soil conservation. It was during this period that evidence was accumulating that mineral fertilizer use on-farm was generally low due to removal of subsidies. Moreover, researchers were concluding that the impact of mineral fertilizer in soils of low organic matter content on crop yields, particularly during poor rainfall years, was minimal. Additionally, many of ISRA's crop breeders began to recognize that improved varieties of crop seed alone may not be effective in increasing agricultural production without improvements to the natural resource base. A new governmental department--the Direction de la Conservation des Sols et du Reboisement--under the Ministry of Nature Protection was established in the late 1980's with a special responsibility for soil conservation⁷⁶. In 1989, the Direction de l'agriculture prepared a "Programme de régénération et de réhabilitation des sols". 1989 also saw the publication of the Senagrosol report which attempted to evaluate the degradation of soil fertility in the Peanut Basin.

Concurrent with the GOS's shift in emphasis, USAID and other donor activity in the soil conservation and related activities also began to increase in the 1980's. From 1985 to 1987, USAID implemented the "Projet de l'Agroforesterie et du Conservation des Sols et des Eaux" (PAFOCSE) whose aim was to conduct: (i) soil conservation and agroforestry activities in 60 villages; (ii) adaptive research on agroforestry techniques; and (iii) studies of environmental degradation, inter-agency coordination, and technical and financial feasibility of various interventions. In 1986 South Dakota State University, also financed by USAID, conducted a resource inventory of Senegal which also included an analysis of soil degradation (see Stancioff et al. 1986).

In 1989, the Rodale Institute, conducted a study entitled "Soil Degradation and Prospects for Sustainable Agriculture in the Peanut

⁷⁶However, its activities to date have been primarily limited to reforestation.

Basin of Senegal". Rodale's conclusion was that agricultural systems in the Peanut Basin are "undergoing a process which is spiralling downward...left alone, a complete system collapse may be predicted". Rodale's study led in part to the development of USAID's "Natural Resources-Based Agricultural Research Project" which began in early 1991. The project will be housed in ISRA and its purpose will be to generate technologies based on improved natural resources management practices which increase the productivity and sustainability of cereals based-cropping systems above the 400mm rainfall isohyet. In the Project Identification Document (PID) for this activity, USAID states that soil productivity in the Peanut Basin is declining at a rate of 3-5% per year.

The above is by no means intended to be a complete review of all the literature on soil degradation in the Peanut Basin. Its purpose is to simply illustrate the long standing concern the GOS and donors, particularly USAID, have had with soil degradation in the region. It should also be pointed out that documentation of the situation and conclusions reached vary considerably between documents. However, in all of the literature, the principal investigator believes that there is one critical shortcoming and one key question which have not been addressed. First, there has been no quantification of the soil degradation problem. Permanent soil sample points have never been established in the Peanut Basin (PB), and while everyone talks about degradation, its extent and rate have never been actually measured.

Second, if soil degradation is a critical problem in the PB, one would expect to see it reflected in terms of declining crop yields. While the common perception is that yields are declining in the PB, Rodale (1989), analyzing MOA data from 1960 to 1988 concluded that while peanut yields were highly variable from year to year, long term trends are relatively stable. For millet, Rodale (op. cit.) found that the long term trend was slightly positive and the annual variation in yields was less than that of peanuts. Similarly,

Lericollais (as cited in Grosenick et al. 1990) in a study of three Serer villages in the Peanut Basin, found that in thirty years of continuous cropping there had not been any decline in yields. Lericollais's conclusion was that farmers were able to maintain their yields on a per unit area basis by using short season varieties to compensate for lower rainfall and animal traction to do a better job with planting and cultivation.

Given the lack of quantification of the soil degradation problem in the NCPB combined with the fact that there has been no long term decline in crop yields, it is the principal investigator's contention that when the wooded fallow soil management system collapsed, the soils did degrade quickly but reached a new equilibrium under more or less continuous cropping. Moreover, as production levels at this new equilibrium have been steady for years, it is further maintain that in addition to new varieties and better planting and cultivation techniques, on-farm trees and shrubs including *A. albida* play a critical role in maintaining this new, albeit lower, equilibrium.

In the context of the conceptual framework presented in Chapter 1, the principal investigator contends that there are both internal and external factors which are influencing farmer soil management decisions in the *A. albida* human ecological system. From an internal social and ecosystem perspective, as Pieri (1989) observes, the sandy soils of the Peanut Basin are "poor but forgiving" and that productivity in these soils is almost entirely dependent on organic matter content. It is therefore postulated that there is a direct relationship between on-farm tree cover and organic matter content and that farmers consciously manage certain trees and shrubs for the express purpose of adding organic matter and nutrients to the soil. This action, combined with an increased use of manure among many farmers (an extension of the toll keur practice to outlying fields), permits low but stable yields in average rainfall years. These will be the main hypotheses addressed in this chapter.

Externally, it is maintained that changing agriculture policy has had a significant impact on farmer use of trees and shrubs and other soil conservation techniques in the NCPB and that there is a direct economic link between maintenance of soil fertility/soil conservation activities undertaken by farmers and the prevailing agriculture and natural resource policies. By implication, it is maintained that improved yields will require policies which serve to strengthen this link and will be the subject of analysis and discussion in Chapter 4.

3.2 Major soil types

The soils of the study area are fairly homogenous and reflect the strong zonal influence of climate and a largely uniform parent material. In general, the Peanut Basin consists of a monotonous, gently undulating sandy plain occupied by deep sandy soils of low natural fertility. The apparent monotony is increased by the loss of the natural vegetation cover, and the conversion of almost all these soils to agriculture which leaves the ground bare for most of the year. Within the study area, four main soil types can be distinguished; dior, deck-dior, deck and dior noir. Table 3.1 shows the distribution of these soil types among the 305 fields in the Biophysical Inventory.

Table 3.1
Distribution of Sample Soil Types

Soil type	No. of Fields	Area (ha)	Percent Fields	Percent Area
Dior	198	276.8	64.9	60.6
Deck-dior	70	131.8	23.0	28.9
Deck	21	28.9	6.9	6.3
Dior noir	16	19.2	5.2	4.2
Total	305	456.7	100.0	100.0
Source: Survey data.				

The following general description of the four major soil types draws from Charreau (1974), Aurora Associates (1982), Baye (1977), Stancioff (1986) and Rodale (1989).

3.2.1 Dior soils

The dominant soils in the study area are known as "dior"⁷⁷ soils. These soils occupy most of the Peanut Basin from Louga to Kaolack and comprise the majority of soils in the study area (64.8% of fields surveyed). The primary variation from north to south in these soils is an increase in organic matter content (a function of rainfall and biomass) and, allegedly, a topsoil texture of finer sand, perhaps due to greater wind erosion in the north (Rodale 1989).

Dior soils show little variation in characteristics either spatially or in terms of depth. Horizon development in the profile is weak. The soil is deep (> 1 m or deeper) and color is predominantly brown, varying to yellowish brown and reddish yellow, with little variation below the topsoil. The soils are typically structureless or have a very weak subangular blocky structure. As a function of this weak structure, bulk densities are generally high and total porosity low; the low porosity is generally acknowledged to restrict root development. When dry, the clay content albeit small, tends to harden these soils and leads to the formation of a continuous crust which occasionally promote runoff and inhibits seedling emergence. Soil hardness makes deep tillage with horse drawn equipment in the dry season extremely difficult.

Textures of dior soils are sandy or loamy sand; clay content is typically less than 5% throughout the profile. There are few weatherable minerals and the clay is primarily of the weakly reactive Kaolinitic type. Organic matter content is typically less than 1%. The combination of texture, clay type, mineral composition and very

⁷⁷Known in the French taxonomic system as "sols ferrugineux tropicaux non or peu lessivés", and in the U.S. system as Ustipsamments.

low organic matter content provides for a soil of very low natural fertility and moisture holding capacity. Total cation exchange capacity (CEC) is typically less than 3 me/100g with a base saturation of less than 50%. The natural fertility is tied up in the shallow topsoil layer through which nutrients are recycled--released from decaying organic matter, absorbed by the vegetation and returned as litterfall and dead roots. The soils are naturally acidic, with a pH in the range of 4.5 to 6.0.

3.2.2 Deck soils

In the south central portion of the study area, the sands overlie a dissected plateau of sandstone intermittently capped by laterite. On the plateau remnants, soils are typically moderately deep to shallow over laterite; erosion has reduced the depth and laterite exposures are fairly common. On the side slopes and in valley bottoms, soils are again deep. There is a greater variety of soils here but the dominant soils are locally known as "deck"⁷⁸. These soils are deep and sandy, and are differentiated from the dior soils by slightly higher clay and organic matter contents and associated higher CEC. They accounted for 6.8% of fields and 6.3% of total area.

3.2.3 Deck-dior soils

The third type of soil found in the study is referred to locally as deck-dior soils. The differentiating factor is the amount of clay in the soil; deck-dior soils have a slightly higher clay content than dior soils but not as high as a true deck soil. This type of soil accounted for 32.1% of fields and 28.9% of area in the study.

3.2.4 Dior noir soils

The remaining soil type in the study area is the heavier soils which are usually found in basins (clay depressions, in French "bas fonds" or in Wolof, khors) and in and along old water courses. These

⁷⁸Known in the French taxonomy as "sols ferrugineux tropicaux peu lessivés" and in the U.S. system as Alfisols.

soils are known locally as "dior noir"⁷⁹ and comprise about 5.2% of fields surveyed and roughly 4.2% of total area. Dior noir soils are thought to be formed by the lateral translocation of clays from the surrounding dior soils (Rodale 1989). Their evolution is dominated by the action of excess water through seasonal fluctuations in the water table; horizons of these soils have alternating phases of oxidation and reduction which in turn determine the precipitation/solubilization of iron and manganese. As a result, these elements often appear as spots in the horizons. Organic matter and clay content are relatively high (3-4% and 8-12% respectively) but are also influenced by water table fluctuations. The texture of these soils is generally sandy and the A horizon can often exceed 40 cm in thickness. While relatively fertile because of a high CEC, they are generally difficult to work for traditional NCPB crops because of the high clay content. As a result, where the water table is fairly close to the surface, they are often used for vegetable gardening and fruit trees. Their Ph generally ranges between 5 and 6.

3.3 Soil degradation

3.3.1 A comparison of past and present soil analyses

As previously stated, most GOS and expatriate personnel consider soil degradation to be a serious problem in the Peanut Basin. Rodale (1989) presents a concise review of what they feel are the causes of resource degradation in the Peanut Basin and their impact on the soils of the region. These causes, discussed in detail in Chapter 1, include climatic change (a progressive decline in precipitation with consequent biomass reductions), increasing population pressure (loss of fallow, overcultivation, fuelwood harvesting), and poor tillage practices (little incorporation of crop residues and deep plowing). This in turn lead to soil degradation which takes the form of loss of organic matter content (loss of structural resistance to erosion, loss

⁷⁹Known in the French system as "sols hydromorphes moyennement ou peu humifères" and in the U.S. system as Vertisols.

of soil productivity), reduced soil microbial activity, soil acidification and increased soil erosion⁸⁰. However, with no permanent soil sample plots the rates and extent of soil degradation have never been quantified⁸¹. Given the absence of permanent sample plots, it was believed that a historical review of soil analyses conducted in the study area might shed some light on longer-term soil degradation trends, if only for illustrative purposes. A review of published soil analyses available from ISRA/Bambey indicated that the majority of early work was conducted on dior soils. As this soil type comprises the majority of soils in the study area, the review is limited to analyses of only dior soils. From historical records at Bambey and from more recent analyses (Senagrosol 1987 and from the Biophysical Inventory), analyses of dior soils appear to fall into three distinct time periods: (i) the mid-to late 1950's (Boujer et al. 1954, Bonfils et al. 1956, Mainguy et al. 1957-58, and Busson et al. 1958-59); (ii) the mid 1970's (Pieri 1973, Nicou 1974, Nicou 1975 and Pieri 1977); and (iii) the late 1980's (Senagrosol 1987 and analyses conducted under this study).

In the review, only analyses from the top horizon (0-20cm) was used and included, when available, data on granulometry (percent organic matter content, clay, fine silt, coarse silt, fine sand and coarse sand) and on chemical composition (pH, calcium, magnesium, potassium--all in meq/100g of soil, phosphorus--either as ppm P_2O_5 or as percent of total, nitrogen--as percent of total, and cation exchange capacity). In the majority of cases, information on techniques used to conduct the analyses, particularly for chemical composition, were not available and are therefore not specified. In

⁸⁰Rodale (1989) cites wind erosion as the predominant problem in the northern Peanut Basin--including the study area--and water erosion as the major problem in the southern reaches of the Peanut Basin.

⁸¹There is one exception to this. ISRA/ORSTOM are conducting erosion/runoff studies in the Southern Peanut Basin (Nioro du Rip) but the data have not as yet been fully analyzed and no published results are available.

some instances, it was necessary to convert some of the data (e.g., from lbs/acre to meq/100g, meq/1000g to meq/100g) in order to permit a more uniform comparison. The complete results of these individual analyses are presented in Appendix C.

While no statistical analysis (e.g., ANOVA) can be conducted on the data nor can any real conclusions be drawn, the review does suggest that there has at least been no "downward spiral" of soil degradation in dior soils over the past 40 years. In terms of Rodale's (1989) key indicators of soil degradation (organic matter, clay content and acidification), there appears to be little change as means, maximums, minimums and standard deviations are all more or less within the same range as Figures 3.1 through 3.3 indicate. For organic matter, the analysis would even suggest that there has been a slight increase over the past years. In short, the annual 3-5% decline in soil fertility that some consider to be occurring in the Peanut Basin appears too high for dior soils; rates of decline as high as this should have been at least partially reflected in the analysis.

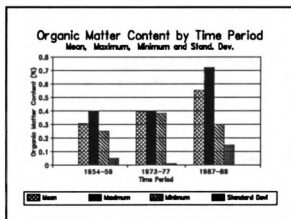


Figure 3.1
Organic Matter Content by Time Period

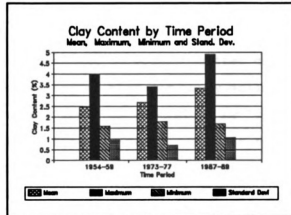


Figure 3.2
Clay Content by Time Period

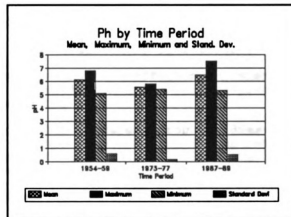


Figure 3.3
pH by Time Period

3.4 The role of organic matter

The case of soil organic matter content deserves particular attention as both Rodale (1989), Pieri (1989) and many others argue that other than rainfall, organic matter content is the most limiting factor in increasing agricultural productivity in the NCPB. In all of the major soil types described above, organic matter plays a critical role in terms of soil fertility and crop yields. The soils are composed primarily of sand which are considered to be nearly chemically inert (Rodale 1989). The clay content of the soils is not

only low but kaolinitic in nature and therefore only weakly reactive (Pieri 1989). As a result, the structure and productivity of the soil are almost entirely dependent on organic matter content.

Pieri (*op. cit.*) argues that for sandy soils such as dior soils, organic matter loss per year, as determined by " k^{82} ", is about 4% per year just by placing a field in crops. At this rate, after 17 years of continuous cropping, organic matter in dior soils would be reduced by one-half. While this high rate of loss would appear to be valid for soils that had never been cropped (e.g., forested areas), or after a cleared wooded fallow, it does not appear to be valid for continuously cropped fields⁸³. Again, it was expected that declining organic matter rates this high would have been reflected in the above review of past and present soil analyses. However, as Pieri goes on to argue, k needs to be modified by coefficients which reflect:

- (i) tillage practices- coefficient α , where α would normally be 1, but could be >1 for tillage practices which increase soil erosion;
- (ii) incorporation of cereal crop residues- coefficient γ , where γ would be >1 if cereal crop residues are incorporated into the soil resulting in increased mineralization of organic carbon;
- (iii) use of mineral fertilizer (NPK)- coefficient q , where q would be <1 where mineral fertilizer is used, or $= 1$ otherwise;
- (iv) crop rotations- coefficient p , where p is <1 where crop rotations are followed and equal to 1 otherwise;
- (vi) mineral nitrogen ("fumure minerale azoté)- coefficient β , where β is >1 when mineral nitrogen is used (e.g.,

⁸²Pieri (1989) defines " k " as the annual rate of loss of organic matter due to mineralization and other causes (erosion). $k(\%) = (1 - (\log C_0 - \log C_n/n)) \times 100$, where C_0 is the initial amount of organic carbon and C_n is the amount remaining after time n .

⁸³In reality, organic matter loss over time is an exponential function with high rates of loss after initial forest clearing, but decreasing over time. Siband (1974) in a study of soils in southern Senegal (Casamance) found the following relationship between organic matter loss (y) and number of years of continuous cropping: $y = 0.58 + 1.6e^{-0.021x}$ with $R = 0.972$. Using Siband's formula, after 15 years of continuous cropping, the rate of loss is 1.75% but after 40 years, the rate is reduced to 1.27%. While there has been no study done on rates of organic matter loss for dior soils, it is assumed that the relationship is also exponential.

intensive cereals cropping) resulting in rapid mineralization of OM, and = 1 otherwise.

- (v) organic matter input- Pieri uses "h" (%) to reflect the contribution of inputs such as manure, compost and root decomposition to organic matter replenishment ("taux d'enrichissement"). The term k_h will be used to reflect actual rate of replenishment where;

$$k_h = ((h - 100) \cdot T_I) \quad T_{OM} \cdot 3.2 \cdot 10^6)$$

and T_I is the amount of manure or compost applied in tons, and T_{OM} is the initial stock of organic matter, also in tons⁸⁴.

Thus, the following formula, adapted from Pieri, could be used to determine annual rate of organic matter loss or gain:

$$k_s = k_h - k_o \cdot \alpha \cdot \gamma \cdot q \cdot \rho \cdot \beta$$

where k_s is the annual rate of loss (or gain) and k_o is the initial estimated annual soil loss (4% for dior soils) as modified by the various coefficients. But as Pieri points out, the major problem in the application of this formula is that there has been very little work done on the coefficients for the Sahel's major soil types. However, for dior soils in the NCPB, the influence of at least some of the coefficients could be eliminated or estimated and these are discussed below.

3.4.1 Tillage practices/soil conservation actions (coefficient α)

The estimation of α is perhaps the most difficult of all of Pieri's coefficients. Rodale (1989) argues that the common practice of shallow tillage (5-10 cm) combined with the removal of crop residues can increase surface runoff and sediment erosion while deep tillage and residue incorporation improve, inter alia, soil porosity and moisture infiltration while reducing wind erosion. However, none of the 72 informants practiced deep tillage as evidenced by both observations in the field and the absence of equipment (plows and oxen) required for deep tillage.

⁸⁴ T_{OM} is determined by taking the initial stock of organic matter in percent, dividing it by 100 and multiplying it by $3.2 \cdot 10^6$ kg/ha which is the estimated weight of soil of the 0-20 cm horizon.

Practices such as contour field preparation, strip cropping, tied ridges and intercropping can also help to minimize the erosive effects of wind and water thereby reducing α . However, the only one of these practices observed during the course of the study was intercropping. A total of five informants reported practicing the late overseeding of millet with cowpeas.

While Pieri (1989) does not explicitly discuss the impact tree planting for conservation purposes (e.g., windbreaks and live fences) might have on k_0 , it is assumed that this practice would have a reducing effect on α . However, tree planting for conservation purposes among informants was very limited. According to the results of the biophysical inventory, summarized in Table 3.2, the most common soil conservation activity observed in terms of fields and informants was live fences, almost always with *Euphorbia tirucalli* or *E. balsamifera*⁸⁵. Twenty-two fields (7.2%) were observed with at least remnants of live fences distributed among 15 informants (20.8%). With one exception, all the fences observed were established in the distant past. Only one informant had attempted any "new" fence establishment by planting *E. balsamifera* cuttings to fill in holes in an existing fence.

General tree planting was the next most common activity observed with six respondents (8.3%) planting trees on 7 fields (2.3%). The most common species planted were neem (*Azadirachta indica*), mangos (*Mangifera indica*) and ronier palm (*Borassus aethiopum*) planted on the borders of fields or located in fields in close proximity to the family compound. However, it is doubtful whether any of these plantings were done intentionally for soil conservation purposes and their impact on α would be negligible.

⁸⁵The only exception was in small gardens and/or orchards near villages and compounds where we observed a number of farmers using *Ziziphus mauritiana* in a live fence configuration.

Four informants (5.6%) had what could be considered to be an attempt at windbreak establishment in a total of four fields. These plantings as differentiated from the general tree plantings described above, were usually composed of a single row of *Eucalyptus spp.* or *Prosopis juliflora* with 10-12 trees in a row at a three to five meter spacing and oriented against prevailing winds.

Table 3.2
Conservation Actions Undertaken By Farmers

Action	No. of Fields	No. of Farmers	Percent Fields	Percent Farmers
Windbreaks	4	4	1.3	5.6
Live fences	22	15	7.2	20.8
Tree planting	7	6	2.3	8.3
Total	33	29	11.8	34.7
Source: Survey data.				

Based on the above, it would appear that the value of α among the majority of farmers in the NCPB would be greater than one and that tree planting for conservation purposes would have no effect on the majority of fields surveyed. In the absence of a site specific value, research at Nioro du Rip (ISRA/Senegal) on deck soils (on considerably steeper slopes) determined an α of 1.37 (Pieri 1989). The principal investigator assumes that for the sandier dior soils in the study area (where the terrain is less accentuated), α would be slightly lower and estimates it at 1.2.

3.4.2 Incorporation of cereal crop residues (coefficient γ)

Currently in the NCPB, the economic incentive to use crop residues for forage or other purposes exceeds the incentive to incorporate them into the soil (Magnison 1985, Rodale 1989). In terms of cereal crop residues (millet and sorghum stalks), they are used for a wide variety of purposes including fencing, fuel and forage. Stalks are almost never plowed under. Even the stubble that remains after the stalks are removed (and/or grazed) is usually raked into piles and

burned⁸⁶. It is thus estimated that γ for the majority of farmers in the NCPB would be 1.

3.4.3 Fertilizer use (coefficients γ and β)

As Table 3.3 indicates, reported fertilizer use among informants from 1985 to 1989 was very limited. In 1985, seven informants reported using fertilizer on 11 fields (17.2 ha) while in 1989, only one informant reported using fertilizer one field (2.3 ha). According to informants, the amount of fertilizer used (Table 3.4) has also decreased from an average of 86 kg/ha in 1985 to an average of 20 kg/ha in 1989 (only one informant). According to discussions with informants and other farmers, the decline in fertilizer use is due mainly to the removal of subsidies under the Nouvelle Politique Agricole and the lack of sale points in closer proximity to the villages. These issues will be the subject of additional analysis in Chapter 4.

Table 3.3
Reported Fertilizer Use
1985-1989

Variable	1985	1986	1987	1988	1989
Number of fields	11	10	3	0	1
Area	17.2	20.2	9.7	0.0	2.3
Number of farmers	7	7	3	0	1
Percent of fields (n=305)	4.3	3.7	1.1	0.0	0.3
Percent area (n=456.7)	4.1	4.7	2.2	0.0	0.5
Percent of farmers (n=72)	9.7	9.7	4.2	0.0	1.4
Source: Survey data.					

Based on these findings, it could be safely estimated that the coefficients for γ and β would be very close to one for the majority of farmers/fields in the study area.

⁸⁶While this practice does serve a useful purpose by mineralizing nutrients, destroying pests and making field work easier, it has been widely criticized by many in Senegal given the loss of organic matter and nitrogen to the system.

Table 3.4
Quantity Fertilizer Used, 1985-1989
(Kilograms per Hectare)

Variable	1985	1986	1987	1988	1989 ⁸⁷
Maximum	107	113	102	0	20
Minimum	20	7	20	0	20
Average	86	83	73	0	20
Total fert. use (kg)	1050	1000	375	0	50
Total per study area (kg/ha)	2.3	2.2	.8	0	0.2
Source: Survey data.					

3.4.4 Crop rotations

Informants reported that they followed crop rotations (millet-peanuts and occasionally cowpeas) on 197 fields (64.6%) during the 1985 to 1989 period. Of the remaining fields, 32 (10.5%) benefitted from rotation at least one time during the five year period. However, according to informants, 61 fields (20.0%) never had crop rotations during the above period. For the most part, these latter are fields close to the compound ("toll keur") and are reserved primarily for millet production. They also tend to receive more manure than other fields and are able to better sustain continuous millet cropping (Rodale 1989). Information was not available for 15 fields as respondents had only recently acquired them and/or were not familiar with the cropping history.

Given these results, it is assumed that ρ has a reducing influence on k_0 for the majority of farmers/fields in the study area. In the absence of site specific information, Pieri (1989) citing research in Chad found that a simple rotation with sorghum instead of a cotton monoculture yielded a ρ of 0.86. While a millet-peanut

⁸⁷Only one respondent reported having used fertilizer in 1989 (one 50 kg sack).

rotation would probably be more beneficial than a cotton-sorghum rotation, the value of ρ as 0.86 will be retained.

3.4.5 Organic matter input--determination of " k_p ".

Farmers in the NCPB currently have one or a combination of four conventional methods of incorporating additional organic matter into the soil; use of peanut/cowpea crop residue; a wooded fallow system, the use of animal manure (by "parcage" or by spreading), and composting.

3.4.5.1 Use of peanut/cowpea residues

The first means that NCPB farmers have at their disposition in terms of increasing organic matter content is the incorporation of peanut and/or cowpea residues into the soil. The benefits of incorporating these residues include improvement of soil porosity and water infiltration, reduced wind erosion, assurance of seedbed preparation and plant emergence, improved rooting and weed control (Nicou and Charreau 1979). In spite of these benefits, few farmers in the NCPB chose this option as benefits obtained from selling crop residues, particularly peanut hay for forage, appear to outweigh the benefits gained from incorporating crop residues into the soil (Abt Associates 1985, Rodale 1989, Grosenick 1991).

The common practice in the NCPB is to rake into piles and burn the few remaining crop residues and surface trash left on the fields prior to plowing. While this practice does allow rapid availability of some mineral nutrients, it does reduce overall carbon/organic matter levels. In this context, it is estimated that organic matter input from residue incorporation would be negligible for the majority of farmers/fields.

3.4.5.2 Wooded fallow

In the NCPB's traditional wooded fallow system, outlying fields were left in fallow for a period of five to seven years which was sufficient time for the woody vegetation to re-establish itself. Clearing of this fallow began by girdling the trees one year and then

in subsequent year(s) burning the resulting brush. The advantage of the wooded fallow system was that it was minimally disruptive to the soil and provided a means of recycling nutrients from lower soil horizons. Additionally, because a wooded fallow produces extensive, large roots as well as large woody surface materials, it took a number of crop years to extract the nutrients accumulated by the fallow (Grosenick et al. 1990).

In order to obtain an idea of the fallow history of the fields surveyed in the study, informants were asked (for each field in their possession) the last time that the field had been in fallow (including periods prior to 1985) and for how long. Informants were able to provide what was thought of as fairly accurate information for about one third (103) of the fields surveyed. Of these fields, informants reported that to their knowledge, 31.1% (32 fields) had never been in fallow⁸⁸. For those fields where informants recalled a fallow period prior to 1985, the average number of years since fallow was 16.9. During 1985 to 1989, the reported average length of fallow of was 1.7 years with a maximum of 5 years and a minimum of one.

The primary reason given by respondents for putting a field in fallow was to "give the land a rest" which accounted for 45.7% of responses. This was closely followed by seed unavailability (either not available or unwilling to purchase at current price) which accounted for 42.9% of responses. Insufficient labor, lack of fertilizer (again, either not available or not willing to availability or funds to purchase), and a lack of traction equipment accounted for 5.4%, 4.3% and 1.6% of responses respectively. In total, however, lack of inputs⁸⁹ appears to be the major factor in informants'

⁸⁸For the most part, these are the fields located close to the compound and used almost exclusively for millet production. Being close to the compound, they tend to receive the most manure and in good rainfall years, can support continuous monocropping.

⁸⁹This is consistent with Golan's (1989) findings. Golan refers to this as "unplanned" fallow. In a study of two villages in the PB Golan found that out of 108 fields left in fallow, 76 were fallow due

decisions to leave land in fallow. Perceived reasons for placing fields in fallow are summarized in Table 3.5.

Table 3.5
Reasons For Fallow
(Number and Percent of Farmers)

Reason	No.	Per.
Give land a rest	84	45.7
No seed ⁹⁰ (pur./avail.)	79	42.9
No labor	10	5.4
No traction equipment	3	1.6
No fertilizer ¹⁶ (pur./avail.)	8	4.3
Source: Survey data.		

Per the above, and as many have argued (Freeman 1982, Rodale 1989 and Grosenick et al. 1990 among others), the use of a wooded fallow system in the NCPB has essentially collapsed⁹¹. The collapse which began in the 1950's with the introduction of peanuts, reached its end probably sometime in the early 1970's. The reasons for the collapse are more than likely twofold. First, as discussed in Chapter 1, the introduction of peanuts combined with increasing use of animal traction is implicated in the cultivation of larger areas at the expense of fallow or previously uncultivated areas (mainly forests).

to lack of seeds or labor, 6 because they were too far from the compound or were of exceptionally low quality. The ratio of unplanned to planned fallow in Golan's study was on the order of three to one.

⁹⁰In the Biophysical Inventory, we did not attempt to make a distinction between an informant's ability (or reluctance) to purchase seed and fertilizer at current NPA prices, and actual seed and fertilizer availability.

⁹¹In addition to having an impact on soil productivity, reduction of the fallow period also has an impact on the natural regeneration of trees and shrubs which potentially have many economic benefits (fuelwood, medicines, forage, etc.). Fallow lands are also considered for the most part to be common lands and many disadvantaged groups (women and children) help support their families from these areas through the collection, use and or sale of many primary and secondary tree products. It is not known how the reduction of the fallow period and woody vegetation might have affected these groups.

Second, there is now insufficient land in villages to permit fallowing, a consequence of both demographic pressure and enlargement of the area cropped.

According to informants, the majority of fallow now is usually a result of lack of inputs and is limited to a period of only one or two years which permits only the establishment of some perennial grasses. However, as Grosenick et al. (1990) point out, a grass fallow leaves most of the land unprotected most of the time and is not effective for recycling nutrients from deep soil horizons. Also, it does not have the vigorous root system required to improve the physical characteristics of sandy soils (Charreau 1974). Finally, Pieri (1989) argues that a natural fallow on degraded soils only begins to add organic matter after a period of 10 years. It is therefore thought that the current grass fallow makes little if any contribution to k_h .

3.4.5.3 Animal manure

Animal manure can be applied to fields in two different fashions; through the spreading of manure resulting from animals kept in the compound at night and through the practice of "parcage". Parcage refers to the stationing ("parking") of animals on a particular field for a certain length of time so that the field receives the benefit of the manure and the animals receive the benefit of crop residues and other forage. Animals used may belong to the actual owner of the field or a relative from the same or a neighboring village⁹² or an arrangement can be made with another individual (e.g., a Peul herder) to exchange crop residues and browse on the field for manure⁹³.

⁹²In which case, the animals are kept on the field at night but are usually returned to the compound in the evening. Animals owned by different individuals may often be "pooled" for purposes of parcage. Using one's own animals or a relative's is the typical Serer method.

⁹³This is typically the Wolof method, as the Wolof generally have fewer animals and/or access to fewer animals than the Serer.

3.4.5.3.1 Manure spreading

Spreading of manure (and household refuse) is usually reserved for continuously cropped fields (usually millet) in the immediate vicinity of a village or compound (i.e., toll keur fields). When manure is transported to the field, it is usually dumped in piles and then spread evenly over an area with a radius of about 5 to 6 meters. Manure is not spread at random, but placed on areas of the field which the farmer deems as particularly infertile. As a rule, the more fertile areas in a particular field such as those under or around an *A. albida* tree and certain other tree species would not receive any manure.

The results of the biophysical inventory, presented in Table 3.6, suggest that the use of manure among informants increased slightly during the 1985 to 1989 period. In 1985, 27 farmers use manure on 43 fields (69.4 ha) compared with 45 farmers and 72 fields (118.5 ha) in 1989. Average manure use, however, appears to remain fairly constant at about 5.6 charrettes per hectare as Table 3.7 indicates.

From these observations, it is concluded that the decline in the use of fertilizer noted above appears to have been compensated to a certain extent by increased use of manure among respondents. The relationship between the various soil fertility measures used by informants in terms of percent of fields inventoried and as a percent of informants are presented graphically in Figures 3.4 and 3.5, respectively.

Table 3.6

**Perceived Manure Use
1985-1989**

Variable	1985	1986	1987	1988	1989
Number of fields	43	54	66	64	72
Hectares	69.4	83.2	110.1	94.7	118.5
Farmers using man.	27	34	39	42	45
Percent of fields (n=305)	16.6	19.7	23.2	21.8	23.4
Percent of area (n=456.7)	16.7	19.3	24.4	20.7	25.5
Percent of farmers (n=72)	37.5	47.2	54.2	58.3	62.5
Source: Survey data.					

Table 3.7

**Perceived Quantities of Manure Used
(Charrettes per Hectare)**

Variable	1985	1986	1987	1988	1989
Maximum	17.9	58.8	17.9	19.2	30.8
Minimum	0.2	0.9	0.4	0.9	0.4
Average	5.0	6.6	5.2	5.2	5.8
Total manure (char.)	220.5	343.8	343.0	339.0	431.5
Manure/study area (char./ha)	0.5	0.8	0.8	0.7	0.9
Source: Survey data.					

Additionally, since the removal of fertilizer subsidies in 1985 resulting in the general decline in the use of fertilizer among NCPB farmers (Kelly 1988), discussions with informants and other NCPB farmers indicated that some farmers are extending the toll keur practice to more outlying fields although transport costs and reportedly fewer animals remain a critical factor in wider use of animal manure.

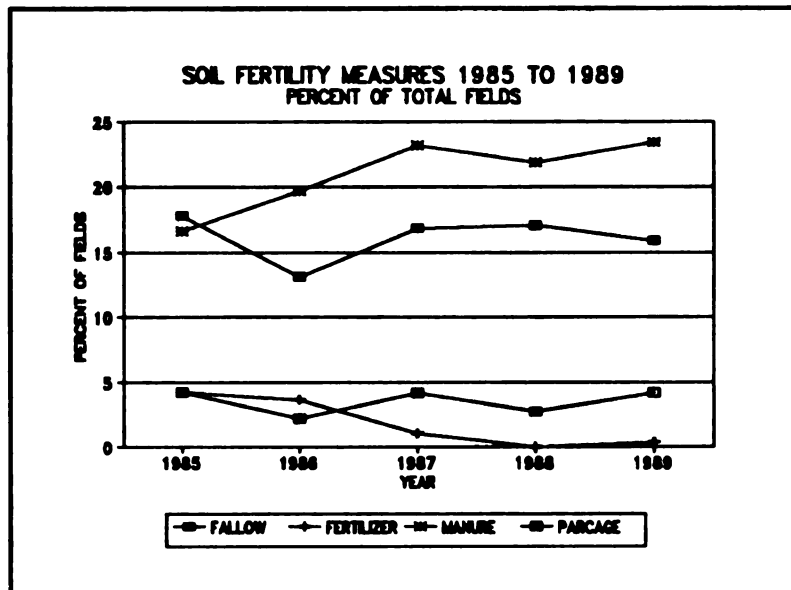


Figure 3.4

Soil Fertility Measures 1985 to 1989 (Fields)

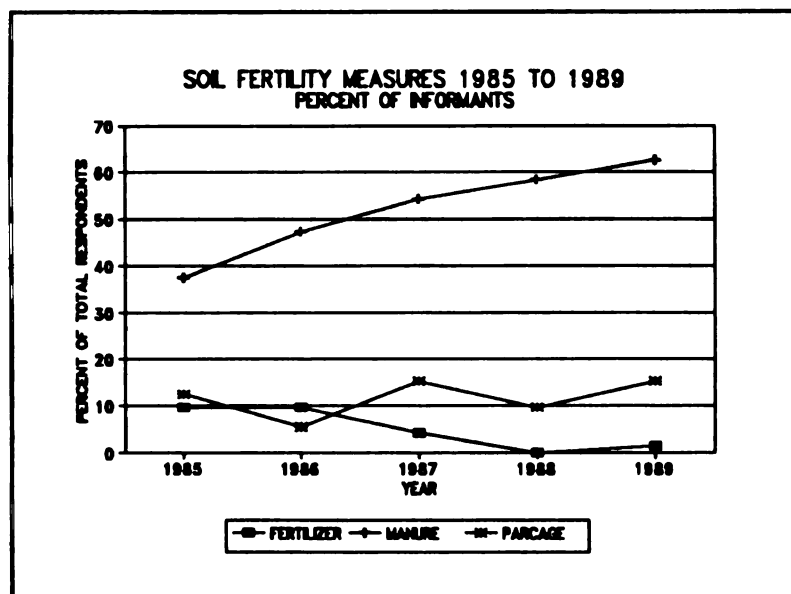


Figure 3.5

Soil Fertility Measures 1985 to 1989 (Informants)

Given this argument, distances from the 307 fields in the biophysical inventory to the village were compared with average reported manure use per hectare on those fields from 1985 to 1989.

Using regression analysis, the following hypothesis was tested:

Hypothesis 3.1

$H_{(0)}$: There is no relationship between distance from a field to a village (DISVIL) and average manure use on that field (MAHA).

$H_{(1)}$: On-field manure use (MAHA) decreases with increasing distance from the field to the village (DISVIL).

DEP VAR: MAHA N: 299 MULTIPLE R: .143 SQUARED MULTIPLE R: .020						
ADJUSTED SQUARED MULTIPLE R: .017 STANDARD ERROR OF ESTIMATE: 2.318						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	1.373	0.176	0.000	.	7.820	0.000
DISVIL	-0.409	0.164	-0.143	1.000	-2.486	0.013
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	33.203	1	33.203	6.180	0.013	
RESIDUAL	1595.754	297	5.373	.		

The results of the regression suggest that there is a weak but highly significant (99% confidence level one-tailed) inverse relationship between average manure use and distance from a field to a village. Its predictive power, however, is quite low which does lend some credence to the argument of certain farmers that the toll keur practice is being extended to outlying fields.

3.4.5.3.2 Parcage

A total of 29 informants (40.3%) reported practicing parcage, either currently (13 or 15.3%) or in the past (16 or 22.2%). Nine of the 29 farmers who reported practicing (or having practiced) parcage indicated that they made such arrangements with Peul herders. These were all Wolof farmers. The remainder (all Serer farmers) used their own cattle or the herds of a relative in the village or from a neighboring village. Among current users, parcage, as with fallow,

appears to have remained fairly constant from 1985 to 1989 as Table 3.8 indicates.

Yearly fluctuations, reflected in Figures 3.4 and 3.5 above, suggest that farmers practice parcage on a particular field every other year. Usually this is a millet field as evidenced by the fact that when informants were asked if there was a particular crop which benefitted from parcage, 27 informants said millet while only 2 said peanuts.

Table 3.8
Use Of Parcage

Variable	1985	1986	1987	1988	1989
Number of fields	11	6	12	8	13
Hectares	22.6	6.1	9.3	18.2	17.5
Number of farmers	9	4	11	7	11
Percent of fields (n=305)	4.2	2.2	4.2	2.7	4.2
Percent of area (n=456.7)	5.4	1.4	2.1	4.0	3.8
Percent of farmers (n=72)	12.5	5.6	15.3	9.7	15.3
Source: Survey data.					

Of those farmers practicing parcage, the average length of time the herd stays on the field is about four weeks (a maximum of seven and a minimum of one--see Table 3.9) and the average herd size is about 37 animals representing a density of about 35 animals per hectare (Tables 3.10 and 3.11).

Over the longer term, however, the use of parcage appears to be declining. Sixteen informants reported having practiced parcage on a total of 24 fields (44.3 ha) but have discontinued primarily due to a lack of animals and reduced presence of Peul herders in the area as Table 3.12 indicates.

Among these individuals the average number of years since parcage for these 24 fields was 15.8 with a maximum of thirty and a minimum of six (Table 3.13).

Table 3.9
Length Of Parcage
(Weeks)

Length of parcage	1985	1986	1987	1988	1989
Maximum	5	6	6	7	6
Minimum	1	3	1	3	1.5
Average	3.0	4.2	3.7	5.6	3.6
Source: Survey data.					

Table 3.10
Parcage Herd Size
(Number of Animals)

No. of animals	1985	1986	1987	1988	1989
Maximum	120	100	100	100	100
Minimum	18	20	10	10	15
Average	50.3	40	25.9	29.6	37.2
Source: Survey data.					

Table 3.11
Parcage Herd Size
(Animals per hectare)

Animals per hectare	1985	1986	1987	1988	1989
Maximum	88.5	88.5	113.6	88.5	88.5
Minimum	5.2	16.4	7.8	3.9	9.8
Average	37.6	40.9	39.7	23.5	35.2
Source: Survey data.					

Table 3.12

Reasons for Discontinuing Parcage

Reason	No.	%
Conflicts with rotations ⁹⁴	1	6.3
Peuls don't come anymore	4	25.0
Peuls too expensive ⁹⁵	1	6.3
No more/too few animals	8	50.0
Peuls too destructive ⁹⁶	1	6.3
No response	1	6.3
Source: Survey data.		

Table 3.13

Parcage Before 1985

Variable	< 1985
Number of fields	24
Number of farmers	16
Total area (ha)	44.3
Percent of fields (n=305)	7.9
Percent of farmers (n=72)	22.2
Percent of area (n=456.7)	9.6
Source: Survey data.	

3.4.5.4 Composting

The composting of manure and crop residues in the NCPB is a relatively new technique. None of the 72 informants practiced composting and the majority of these did not even know what it was. However, several informants reported hearing about the benefits of composting on the radio and during group discussions, some farmers expressed an interest in learning more about the subject. It is

⁹⁴This informant said it was not worthwhile to use parcage with a peanut-millet rotation. Parcage was wasted on peanuts.

⁹⁵This informant stated that instead of the customary exchange of crop residues and forage for manure, Peul herders now wanted tea and soap.

⁹⁶This informant reported that the Peul were too destructive of his cad trees and he felt that the cad were more important to maintaining soil fertility than the parcage. While not apparent in this study, Kone (1986) reports that some farmers go as far as to sell the right to prune the cad trees of their neighbors to passing herders.

assumed that composting makes no contribution to SOM (soil organic matter) in the NCPB.

3.4.5.5 Estimation of k_h

An estimate can now be made of k_h . As there appears to be little if any organic matter resulting from the short grass fallows, the incorporation of peanut or cowpea residues and composting, it is assumed that organic matter is coming primarily from spreading manure and parcase. However, these two practices are mutually exclusive in that a field which receives spread manure one year would not be placed in parcase the same year, or even the following year. Thus, in 1989, a total of 85 fields (27.9%) received manure either from spreading (72 or 23.6%) or by parcase (13 or 4.3%). Additionally, as the study was not able to estimate the amount of manure resulting from parcase, it is assumed that it is more or less equivalent to spreading, although in reality, it is probably higher.

An average spread manure use of 5.6 charrettes/ha translates into approximately 1.1 tons of manure per hectare per year⁹⁷. According to Pieri (1989), one ton of manure adds the equivalent of about 100 kg of organic matter to the soil (i.e., "h" is about 10%). Thus,

$$k_h = ((10 \text{ } 100) \cdot 1100T) \quad 0.55/100 \cdot 3.2 \cdot 10^6)$$

$$k_h = 110/17600 = 0.63\%.$$

We can now determine k_s , recalling that

$$k_s = k_h - k_o \cdot \alpha \cdot \gamma \cdot q \cdot \rho \cdot \beta,$$

and $k_h = 0.63\%$, $k_o = 4.0\%$, $\alpha = 1.2$, $\gamma = 1$, $q = 1$,

$$\rho = 0.86 \text{ and } \beta = 1.$$

$$k_s = 0.63 - (4.0 \cdot 1.2 \cdot 1 \cdot 1 \cdot 0.86 \cdot 1),$$

$$k_s = 3.5\%$$

⁹⁷While there is considerable variation in the amount of manure that can be carried in a charrette, we assumed a range of about 150-250 kg of manure per charrette load. 5.6 charrettes/ha times an average of about 200 kg equals about 1.1 tons of manure applied annually.

Based on this analysis, organic matter content in study area dior soils would be decreasing (or have been decreasing) at an annual rate of 3.5%. This would mean that organic matter content would be halved in 18 years instead of the 17 years predicted above. Again, however, the review of past dior soil analyses and crop yield information in the study area does not seem to support such a high rate of decrease.

As a result, the principal investigator believes that one factor that has been neglected in Pieri's formula is the role of *A. albida* and other indigenous woody perennials in providing organic matter to dior soils and thus enabling some farmers to maintain at least low but steady levels of continuous production for most major crops. In the following section, it is suggested that what is needed is the addition of a "tree factor" to Pieri's formula, which would reflect the fifth and more traditional source of organic matter for many NCPB farmers.

3.5 The tree factor

3.5.1 The role of *A. albida*

A. albida's contribution to soils and soil productivity has in the past been well-documented. Comparisons of soil samples taken from under the crowns of *A. albida* and from outside the influence of the crowns indicate that almost every soil characteristic is improved by the presence of the tree. A summary of past research findings⁹⁸ for selected soil characteristics is found in Table 3.14.

⁹⁸Charreau and Vidal (1965) and Jung's (1966 and 1969) research design and results, according to Felker (1978), are probably the most statistically valid.

Table 3.14

Past Research Comparing Differences Between Selected Characteristics of Soil Samples Collected Under the Crown of *A. albida* and from Adjacent Open Spaces

Characteristic	Authority							
	Charreau and Vidal 1965		Jung 1966 and 1969		Dugain 1960		Dancette and Poulain 1969	
	%	prob.	%	prob.	%	prob.	%	prob.
pH	4%	NS	6%	.01				
OM (%)	42%	.010	91%	.01	269%	NSA	40%	NSA
N (%)	94%	.001	115%	.01	231%	NSA	33%	NSA
P ₂ O ₅ (assim.)	134%	NS	108%	.01				
K (meq/kg)	43%	.050	45%	NSA				
Ca (meq/kg)	100%	.001	101%	NSA				
Mg (meq/kg)	58%	.010	53%	NSA				

NS = not significant; NSA = no statistical analysis available

The research design for comparing the effects of *A. albida* on soil characteristics was slightly different from the ones used by Charreau and Vidal (1965) and Jung (1966). In terms of similarities, a total of three soil samples were taken from each field; one at 1 m from the trunk of a randomly selected *A. albida* tree, one at the drip line (edge of the crown) of the same tree, and one 20 m from the drip line in the open field. The procedure for taking the sample was to dig a hole approximately 20 cm in depth and to mix the soil from all horizons in the hole. From this mixture, a sample of about one kilogram was drawn, placed into a plastic bag and coded. In this manner, 915 samples were taken (3 samples per field times 305 fields).

The original intention was to analyze all samples but costs involved in doing this were prohibitive. As a result, a subsample of 13 samples per location vis-a-vis the tree (39 samples total--27 from dior soils, 5 from deck-dior soils, 4 from deck soils and 3 from dior noir soils) was drawn at random from the original 915 samples. Each subsample selected in this manner weighed approximately 150g. Rather than taking 3 samples from around the same tree as did Charreau and Vidal, the principal investigator believes that this random selection

procedure provides a better indication of the global impact of *A. albida* in the study area by adding more sites and increasing statistical validity.

Soil samples were analyzed for pH, phosphorus, potassium, calcium, magnesium, nitrogen and percent organic matter at Michigan State University's Department of Crop and Soil Science Soil Testing Laboratory. Analytical procedures used followed "Recommended Chemical Soil Test Procedures for the North Central Region" as described in North Central Regional Publication 221 (Revised) of October 1980. For the comparative ANOVA, only samples from dior soils were used to eliminate the effect of soil type⁹⁹. The results of the ANOVA are presented in Table 3.15.

Table 3.15

A Comparison of Selected Characteristics of Dior Soils Taken from Under the Crown of *A. albida*, at the Drip Line and from Adjacent Open Spaces

Characteristic	(A) 1 m from base of tree	(B) at the drip line	(C) 20 m from dripline	AOV Between Groups	
				F-value	Prob.
Sample size (n)	9	9	9		
pH	6.067	6.189	6.311	0.553	0.583
OM (%)	0.839	0.708	0.608	4.601	0.020**
N (%)	0.024	0.021	0.015	4.655	0.020**
P (lbs/acre)	40.444	27.556	25.444	1.006	0.381
K (lbs/acre)	101.444	67.111	43.556	6.139	0.007**
Ca (lbs/acre)	541.889	457.333	423.333	1.058	0.363
Mg (lbs/acre)	111.889	36.048	82.444	1.198	0.319
Source: Survey data.					

As the analyses indicate, levels of organic matter, nitrogen, phosphorus, potassium and calcium all decrease with increasing distance from the base of the tree. However, the difference is only statistically significant in the case of organic matter (95% confidence level), nitrogen (95% confidence level) and potassium (99%

⁹⁹Additionally, although found on other soil types, *A. albida* is most frequently associated with dior soils.

confidence level. It is suspected that differences would have been more pronounced had all three samples been taken from the same tree, but as previously stated, the objective in selecting random samples was to ascertain the global impact of *A. albida* in the region.

As Table 3.16 indicates, differences were only statistically significant between the samples taken from under the crown and from samples taken from adjacent open spaces; organic matter content increased by 38%, nitrogen by 60% and potassium by 133%. While levels of OM, N and K were higher at the drip line than those from adjacent spaces the difference was not statistically significant.

Table 3.16
Results of Statistical Analyses

Character- istic	Percent increase over C			Significance		
	A	B	C	A/C	A/B	B/C
OM (%)	138	116	100	.016	.220	.404
N (%)	160	140	100	.017	.607	.127
K (lbs/acre)	233	154	100	.005	.118	.345
Source: Survey data.						

The increase in organic matter content under *A. albida* trees is particularly important. Dancette and Poulain (1969) found that outside of *A. albida* cover, the content of mineral colloids plays the determining role in cation exchange capacity (CEC). Under *A. albida*, however, they found that the higher level of organic matter content enables it to play a role at least as important as mineral colloids if not more so. They found that while CEC increases only slightly under *A. albida* (from 2.70 to 2.97), this increase translates into considerably higher levels of exchangeable cations.

The increases in organic matter due to *A. albida* have also been found to improve soil microbial activity. Soil microbiology in the Peanut Basin was studied by Jung (1970) who provided baseline studies

of seasonal changes in soil microbial populations in dior soils. His study concluded that during the dry season, biological activity in the soil is severely limited by stress from low moisture. With the first heavy rains, there is a rapid increase in soil microbial activity and a concurrent flush of OM decomposition during which declines in soil N, P and pH occur due to intensive leaching. Jung concluded that severe dry season moisture stress limits the soil's biological community from efficiently trapping nutrients and making them available to crops over the course of the growing season. However, soils under *A. albida* typically showed significant improvement of soil moisture, microbial activity¹⁰⁰ and nutrient retention capacity regardless of the season. This suggests that *A. albida* provides a dry season refuge for soil biological activity by immobilizing nutrients against leaching losses and enabling their gradual release for plant growth.

Based on the above, it is suggested that Pieri's formula be modified by a factor called " Φ " to account for the influence of *A. albida* in providing organic matter to dior soils. Assuming that *A. albida* only has an influence on OM directly under the crown, for the sample, Φ could be determined as follows:

$$\Phi = ((T_{OM} \times R \times C) / T_{OM}) \times 100, \text{ where}$$

$$T_{OM} = .55 \times 3.2 \times 10^6 = 17600 \text{ kg}$$

$$R = \text{rate of increase of OM due to } A. \text{ albida (38\%)}$$

$$C = \text{average } A. \text{ albida crown cover for the sample (2.3\% for the 305 fields)}$$

$$\Phi = ((17600 \times 0.38 \times 0.023) / 17600) \times 100$$

$$\Phi = 0.87\%$$

Thus k_p would be reduced by 0.87% to 2.63% due to the influence of *A. albida*. The range of Φ for the 305 field sample would be a minimum of 0 (no *A. albida* present) to a maximum of 7.8% (crown cover of 20.6%) which would indicate that fields with a relatively high *A.*

¹⁰⁰Jung (1966) reports a two- to five-fold increase in microbial activity under *A. albida*.

albida crown cover could actually have a net gain in SOM content. From a total farm perspective, only 32 informants had a total farm *A. albida* crown cover greater than the mean of 2.3%, so for the majority of informants, annual OM loss would be greater than 2.6%.

Additionally, *A. albida*'s contribution to soil fertility in NCPB farming systems is probably greater than that reflected in the estimation of Φ . The mosaic of on-field trees would no doubt have an influence on α in terms of soil conservation in general by reducing soil loss and evapotranspiration due to wind erosion.

3.5.2 The influence of other woody perennials

Other tree and shrub species in the NCPB also appear to play an important role in agriculture. Informants were asked if they thought there was a positive relationship between certain trees on a particular field and soil productivity. All 72 survey participants responded in the affirmative which indicates there is a wide understanding of the relationship between trees and soil fertility. Moreover, informants appear to have at least a rudimentary understanding of how a particular tree species contributes to soil fertility and conservation as the discussion below indicates.

Informants were then asked to choose and rank, in order of importance to them, three of the six roles of trees (medicinal, soil conservation/fertility, food, forage/fodder, fuelwood and service wood). Choices were summed in order and results are presented in Table 3.17.

Table 3.17

Role Of Trees According to Men
(Choices by Number and Percent)

Role	First Choice		Second Choice		Third Choice		Total	
	No.	Percent	No.	Percent	No.	Percent	No.	Percent
Medicinal	27	37.50	9	12.50	9	12.50	45	20.83
Soil conservation	15	20.83	15	20.83	12	16.67	42	19.44
Human food	16	22.22	22	30.56	11	15.28	49	22.69
Service wood	8	11.11	9	12.50	13	18.06	30	13.89
Firewood	3	4.17	7	9.72	9	12.50	19	8.80
Forage/fodder	3	4.17	10	13.89	18	25.00	31	14.35

Source: Survey data

According to informants, the most important role of trees was in providing human food which accounted for 22.7% of total responses. Food was closely followed by medicinal uses (20.8%) and soil conservation/fertility (19.4%). Service wood and forage fodder were considered to be about equal in importance accounting for 13.9 and 14.4 percent of responses respectively. Fuelwood was considered by respondents to be the least important role of trees accounting for only 8.8% of total responses¹⁰¹.

Thus, a total of 42 informants chose soil conservation (either first, second or third choice) as one of the most important roles of trees. These informants were then asked to name three species, in order of preference, which contributed in a significant way to enhancing soil fertility and/or soil conservation and explain why they felt the species did so. Results, presented in Table 3.18, indicate that the contribution of *A. albida* is widely recognized. It was cited by all 42 informants. According to informants *A. albida*'s major contribution is that it improves the soil and increases yields. However, several informants also mentioned factors such as attracting animals/manure underneath the crowns, its role as a windbreak/soil conservation species and its role in improving fallow. Four

¹⁰¹There is obviously some gender bias in responding to this question as all of the informants were men. This issue will be discussed further in Chapter 4.

informants specifically cited *A. albida*'s role in providing organic matter via leaf fall.

The second most frequently cited conservation species was *Balanites aegyptiaca* (19 informants). According to informants, its major role was in improving soil/increasing yields and as a windbreak. Soil conservation, fallow improvement and provision of organic matter were also cited as contributing factors.

The third most frequently cited conservation species was *Guiera senegalensis* (niger in Wolof) and according to informants, it makes its contribution by improving the soil/increasing yields, acting as a windbreak and helping promote soil conservation. *Acacia nilotica*, *Eucalyptus spp.*, *Tamarindus indica*, *Piliostigma reticulata*, *Antiaris africana* and *Cordyla pinnata* were also cited as good soil conservation species by at least three informants.

Based on informant perceptions of the role of woody perennials in soil conservation and soil productivity in the NCPB, the presence of other on-field woody perennials, in addition to *A. albida*, also appears to make a major contribution to SOM and soil stability in the NCPB. In section 3.5.1 above, it was determined that *A. albida*'s major influence in terms of organic matter appears to be directly under the tree canopy. However, it is believed that *A. albida*, along with other woody perennials also exerts an influence on the SOM of soils outside the influence of the canopy through movement of litterfall by the wind. Using only samples taken from outside the influence of the influence of the *A. albida* crowns, but from all soil types, regression analysis was used to examine the relationship between woody perennial crown cover per hectare and soil organic matter content. Original data and summary statistics for the following hypotheses are found in Appendices D and E.

Table 3.18

**Recognition of the Contribution of
Various Tree Species to Soil Fertility/Conservation**

(Number of Responses and Perceived Contribution)

Species	Total No. Resp.	Contribution					
		Improves soil/ yields	Ani- mals under	Wind- break	Soil cons.	Im- proves fallow	Org. mat- ter
<i>Acacia albida</i>	42	40	2	11	7	2	4
<i>Acacia nilotica</i>	4	4	0	1	1	0	0
<i>Acacia raddianna</i>	2	2	0	0	0	0	0
<i>Anacardium occidentale</i>	1	0	0	1	0	0	0
<i>Anogeissus leiocarpus</i>	2	2	0	0	1	0	0
<i>Antiaris africana</i>	3	3	0	0	1	0	0
<i>Azadirachta indica</i>	1	0	0	1	0	0	0
<i>Balanites aegyptiaca</i>	19	15	0	5	5	1	1
<i>Celtis integrifolia</i>	1	1	0	0	0	0	0
<i>Combretum glutinosum</i>	2	2	0	1	2	0	0
<i>Cordyla pinnata</i>	3	2	0	1	0	0	0
<i>Diospyros mespiliformis</i>	2	1	0	1	0	0	0
<i>Eucalyptus spp.</i>	6	0	0	6	1	0	0
<i>Euphorbia spp.</i>	2	0	0	2	0	0	0
<i>Guiera senegalensis</i>	12	10	0	3	4	1	1
<i>Maytenus senegalensis</i>	1	0	0	1	0	0	0
<i>Parinari macrophylla</i>	1	0	0	0	1	0	0
<i>Parkia biglobosa</i>	1	1	0	0	0	0	0
<i>Piliostigma reticulata</i>	3	3	0	2	1	0	0
<i>Prosopis africana</i>	1	1	0	0	0	0	0
<i>Prosopis spp.</i>	2	0	0	2	1	0	0
<i>Tamarindus indica</i>	9	5	0	2	1	0	1
<i>Zizyphus mauritiana</i>	2	0	1	1	2	0	1

Source: Survey data.

Hypothesis 3.2

H_0 : There is no relationship between *A. albida* crown cover per hectare (CRNCAD - %) and soil organic matter content (ORG - %) of soil samples taken from outside the influence of the tree canopy.

H_1 : Soil organic matter content from outside the *A. albida* canopy, is in part, a function of the percent crown cover per hectare of *A. albida*.

DEP VAR: ORG N: 13 MULTIPLE R: .278 SQUARED MULTIPLE R: .077 ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 0.331						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.712	0.120	0.000	.	5.945	0.000
CRNCAD	0.040	0.042	0.278	1.000	0.959	0.358
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.101	1	0.101	0.919	0.358	
RESIDUAL	1.203	11	0.109			

The results of the regression suggest that *A. albida* has no influence on SOM outside of its canopy and the null hypothesis must be accepted. However, as discussed above, other woody perennials may have an influence on SOM. The hypothesis is:

Hypothesis 3.3

- H_0 : There is no relationship between the crown cover per hectare of other woody perennials (CRNOTH - %) and soil organic matter content (ORG - %) of soil samples taken from outside the influence of the tree canopy.
- H_1 : Soil organic matter content from outside the tree canopy, is in part, a positive function of the percent crown cover per hectare of other woody perennials.

DEP VAR: ORG N: 13 MULTIPLE R: .443 SQUARED MULTIPLE R: .196 ADJUSTED SQUARED MULTIPLE R: .123 STANDARD ERROR OF ESTIMATE: 0.309						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.706	0.099	0.000	.	7.156	0.000
CRNOTH	0.068	0.042	0.443	1.000	1.640	0.129
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.256	1	0.256	2.690	0.129	
RESIDUAL	1.047	11	0.095			

The results of the regression do not suggest a positive relationship between crown cover of other woody perennials and SOM.

In order to ascertain whether the relationship between crown cover and SOM is could be strengthened, the relationship between total crown cover (*A. albida* plus other woody perennials- CRNCAD + CRNOTH) and SOM was examined. The hypothesis is:

Hypothesis 3.4

H_0 : There is no relationship between total crown cover per hectare (TOTCRN - %) and soil organic matter content (ORG - %) of soil samples taken from outside the influence of the tree canopy.

H_1 : Soil organic matter content from outside the tree canopy, is in part, a positive function of the percent total crown cover per hectare of all woody perennials.

DEP VAR: ORG N: 13 MULTIPLE R: .467 SQUARED MULTIPLE R: .218						
ADJUSTED SQUARED MULTIPLE R: .147 STANDARD ERROR OF ESTIMATE: 0.304						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.649	0.115	0.000	.	5.628	0.000
TOTCRN	0.045	0.026	0.467	1.000	1.752	0.107
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.285	1	0.285	3.071	0.107	
RESIDUAL	1.019	11	0.093			

The results of the analysis suggest that the relationship between crown cover is only slightly strengthened when total crown cover is used as the independent variable instead of just other species crown cover. From this it might be concluded that *A. albida* has very little, if any effect on SOM outside of its crown area, but that other woody perennials might have some limited effect in increasing SOM.

While the variable CRNOTH accounts for all on-field woody vegetation over one centimeter in diameter, it does not taken into account the presence or absence of *Guiera senegalensis*. Nger is a shrub of the Combretaceae family which is very abundant on cultivated and fallow fields in the study area. It is usually found in small clumps and can represent a major percentage of tree/shrub crown cover in some fields. Nger is a major source of fuelwood and is cut during field preparation in May and June. It sprouts prolifically and the sprouts are usually cut during the cropping season and it is only after crops are harvested that it is permitted to grow. Most growth thus occurs during the dry season and nger becomes a characteristic

element of the countryside at this time. It is thought that the shrub plays both a major role in soil conservation by reducing wind erosion¹⁰² and by providing additional organic matter through litterfall (Louppe 1989).

While it was not possible to count and measure all the nger clumps on all of the fields, the presence or absence of the shrub in all of the fields was noted during the course of the biophysical inventory. A strong presence (covering roughly 15-20% of the field) was noted with a one while a weak presence was noted with a 0. Thus, using the presence or absence of nger as a dummy variable in combination with other species crown cover, an attempt was made to ascertain whether nger has an impact on SOM. The hypothesis is:

Hypothesis 3.5

- H_0 : There is no relationship between crown cover per hectare of species other than *A. albida* (CRNOTH), the presence or absence of nger (GUER) and soil organic matter content (ORG) of soil samples taken from outside the influence of the tree canopy.
- H_1 : Soil organic matter content from outside the tree canopy, is in part, a positive function of the percent total crown cover per hectare of all woody perennials, including nger.

DEP VAR: ORG N: 13 MULTIPLE R: .640 SQUARED MULTIPLE R: .410						
ADJUSTED SQUARED MULTIPLE R: .292 STANDARD ERROR OF ESTIMATE: 0.277						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.782	0.097	0.000	.	8.039	0.000
CRNOTH	0.091	0.039	0.588	0.910	2.311	0.043
GUER	-0.332	0.175	-0.484	0.910	-1.901	0.086

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.534	2	0.267	3.471	0.072
RESIDUAL	0.769	10	0.077		

¹⁰²The elevation of the nger clumps is always slightly higher (mounds) than the surrounding area which suggests that it is effective as a windbreak and in trapping and depositing fine soil elements (probably silts and fine sand). According to farmers in the area as well as our personal observation, millet and peanut production is higher on these mounds than on surrounding areas.

While the relationship between the presence or absence of nger is significant (at the 95% confidence level, one-tailed), the directionality is not as predicted. The results of the regression suggest that in fields where nger is present at levels higher than 15-20% crown cover, SOM is generally lower than in fields where nger is not a significant part of the vegetation.

There may be at least a partial explanation for these results. *G. senegalensis* may be an indicator of a "poor" site. Rodale (1989) refers to the species as one which "quickly invades the exhausted sandy soils of fallow fields". Von Maydell (1983) considers the species to be an indication of overgrazing and reports that it is most frequently associated with poorer sites (excessively leached, sandy and/or dry sites).

Additionally, while *G. senegalensis* can produce abundant dry matter, up to 600 kg/ha/year according to Louppe (1989), the composition of the litter/debris may not make much of a contribution to soil fertility. Jung (1966), in a comparison of litter nutrient release from *A. albida* and *G. senegalensis*, found that *A. albida* and *G. senegalensis* had a C/N ratio of 16.5 and 44, respectively. The lower rate of nitrification with nger suggests that very little if any nitrogen is being made available to higher plants. The C/N ratio needs to be reduced to about 20 for any significant amount of N become available to plants through mineralization (op cit.). Jung also found mineral and nitrifiable N content to be three times higher with *A. albida*.

In spite of the above, it is clear from observation and discussions with farmers that nger does have a positive impact on crop yields. More than likely, this impact is not due to the addition of OM but through its role in intercepting soil elements transported by wind and water erosion, thus increasing CEC and water retention capacity. Research comparing the soil composition/granulometry and water retention capacity of soils under nger and outside of nger

appears to warranted particularly given the importance of nger as a firewood species.

Finally, one additional hypothesis remains to be tested. As noted in the above description of soil types, soil type is also a major determinant of SOM. In order to reflect soil type in the determination of the role of other species in adding OM to the soil, an additional dummy variable was used in the analysis. This variable, named TYPE, indicates 0 for dior 1 for all other soil types. The hypothesis is:

Hypothesis 3.6

- H_0 : There is no relationship between crown cover per hectare of species other than *A. albida* (CRNOTH), the soil type (TYPE) and soil organic matter content (ORG) of soil samples taken from outside the influence of the tree canopy.
- H_1 : Soil organic matter content from outside the tree canopy, is in part, a function of the percent total crown cover per hectare of all woody perennials, and soil type.

DEP VAR:	ORG	N: 13	MULTIPLE R: .836	SQUARED MULTIPLE R: .699		
ADJUSTED	SQUARED MULTIPLE R: .639	STANDARD ERROR OF ESTIMATE: 0.198				
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.612	0.067	0.000	.	9.081	0.000
CRNOTH	0.040	0.028	0.262	0.939	1.465	0.174
TYPE	0.550	0.135	0.732	0.939	4.087	0.002
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.911	2	0.456	11.618	0.002	
RESIDUAL	0.392	10	0.039			

The results of the regression are as expected; the sandier dior soils tend to have a lower SOM than the deck and dior noir soils and the relationship is significant at a confidence interval of 99% (one-tailed). The two variables CRNOTH and TYPE also account for 64% of OM variance in the sample, significant at the 99% confidence level (one-tailed).

While the number of samples is relatively small ($n=13$), in order to determine the contribution of other species crown cover to SOM,

organic matter (ORG) was then modeled as a function of other species crown cover (CRNOTH), presence or absence of nger (GUER) and soil type (TYPE)¹⁰³. The results of the model, presented below suggest that these three variables, all highly significant (99% confidence level one-tailed), explain 84% of the variance in SOM in the sample. Additionally, the tolerance values of the variables suggest that there is little interrelationship between the variables. Finally, the model itself is highly significant (99% confidence interval, one-tailed).

DEP VAR: ORG N: 13 MULTIPLE R: .940 SQUARED MULTIPLE R: .883						
ADJUSTED SQUARED MULTIPLE R: .844 STANDARD ERROR OF ESTIMATE: 0.130						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.685	0.048	0.000	.	14.161	0.000
CRNOTH	0.062	0.019	0.402	0.853	3.261	0.010
TYPE	0.534	0.089	0.711	0.937	6.033	0.000
GUER	-0.309	0.082	-0.450	0.908	-3.761	0.004
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	1.151	3	0.384	22.641	0.000	
RESIDUAL	0.153	9	0.017			

Results of this model suggest that Pieri's formula be modified by another tree factor "Θ" to account for the influence of other woody perennials in providing organic matter to dior soils. The model yields the following formula:

$$\text{ORG} = 0.062(\text{CRNOTH}) + 0.534(\text{TYPE}) - 0.309(\text{GUER}) + 0.685,$$

where $\Theta = 0.062 (\text{CRNOTH})$.

Thus, a field with no trees (CRNOTH = 0) but with nger (GUER = 1) would have a SOM content of 0.376%. With CRNOTH at 1.3%, the average of the 305 field biophysical inventory sample, SOM increases

¹⁰³An attempt was made to include in the model several other variables including charrettes of manure used per hectare in 1988 and 1989 (MAN8889), presence or absence of parcase in 1988 or 1989 (PARCAGE as a dummy variable), as well as distance from the field to the village as an indicator of the relative ease of transport of manure from the compound to the field. The results, presented in Appendix F, suggest that there is no relationship between any of these variables and SOM.

by 21.5% to 0.457%. This would represent an annual input of organic matter from other woody perennials of 0.081% ($0.062 \times 1.3\%$) and the value of k_p would be reduced from 2.6% to approximately 2.5%.

Based on the 305-field inventory, Θ would range from a minimum of 0 (0% crown cover on some fields) to a maximum of 2.20% (maximum crown cover of 35.5% on one field). From a total farm perspective, however, only 23 informants had an average "total farm other species crown cover" higher than the mean; the majority of farms in the survey do not tend to benefit from the presence of other on-field woody perennials.

While the contribution of other species to SOM appears relatively low compared to *A. albida*, it should be kept in mind that the above analysis only involved soil samples taken from outside the influence of the crowns of any woody perennial species. It is expected the actual value of Θ to be higher if SOM levels under the canopy of these other species were taken into account. Additionally, as in the case of *A. albida*, the contribution of other woody perennials to soil maintenance in NCPB farming systems is probably greater than that reflected in the estimation of Θ . The mosaic of on-field trees would no doubt also have an influence on α (tillage practices) in terms of soil conservation in general by reducing soil loss due to wind erosion.

3.6 Conclusions and recommendations

The preceding analysis suggests that degradation of dior soils in the NCPB, while still a problem, may not be as serious as many believe. Dior soils are in fact poor but resilient. A major contributing factor to this resiliency is the role of *A. albida* and other on-field woody perennials in providing and/or maintaining organic matter content.

Organic matter plays a critical role in terms of soil fertility and crop yields on dior soils. The soils are composed primarily of sand which are considered to be nearly chemically inert. The clay

content of the soils is not only low but kaolinitic in nature and therefore only weakly reactive. As a result, the structure and productivity of the soil are almost entirely dependent on organic matter content. Loss of organic matter content would appear to be an excellent indicator of the rate of degradation of NCPB soils.

Pieri (1989) argues that for sandy soils such as dior soils, organic matter loss per year is about 4% just by placing a field in crops. He goes on to suggest that this rate needs to be modified by coefficients which reflect tillage practices, use of cereal crop residues, mineral fertilizer and crop rotations, as well as organic matter inputs from manure. However, what appears to be missing from Pieri's formula is the role of woody perennials in providing organic matter.

We therefore suggest that Pieri's formula be modified by two "tree factors", Φ to reflect organic matter input from *A. albida*, and Θ to reflect organic matter input from other woody perennials. Using data from the biophysical inventory, it was found that the mean value for Φ in the sample to be 0.87% and Θ to be 0.08%. Thus, instead of a 4% annual decline in SOM, the rate is estimated to be closer to 2.5%.

In reality, the contribution of woody perennials (including *A. albida*) to NCPB farming systems is probably greater than that reflected in the estimation of Φ and Θ as the mosaic of on-field trees would no doubt also have an influence α by reducing soil loss due to wind erosion. For example, if the presence on on-field trees reduced Pieri's α from 1.2 to 1.1, the annual rate of organic matter loss would be reduced by 0.4% to 2.1%. Thus, the presence of on-field trees would nearly halve the estimated annual rate of organic matter loss.

Sustainable agriculture in the NCPB requires continuous soil maintenance to continue the productive capacity of the land indefinitely. In turn, soil maintenance, particularly for dior soils,

requires organic matter input, establishing production demands consistent with the soil and water resources available and managing the land accordingly. It will also require a mental shift among many GOS personnel from production/commodity-based research and development programs to programs which focus on conserving and enhancing the natural resource base and its contribution to soil maintenance. While soil maintenance does not exclude inorganic soil amendments or production increases resulting from varietal research, it does require a better balance between commodities programs and natural resource-based agricultural research.

To maximize the sustainable production potential of most NCPB farming systems, the productive capacity of the soil must be restored. This requires a two-step approach. First, the existing resource must be stabilized; that is, the soil and water must be retained within the farming systems through erosion control and water conservation. As the preceding analysis suggests, some farmers in the NCPB appear to be doing just this through the use of indigenous on-farm trees and shrubs which maintain levels of organic matter sufficient for low but stable crop yields in average rainfall years.

Secondly, and for the majority of NCPB farmers, the soil must be rebuilt and enhanced to its maximum productive capacity. In turn, this will promote soil and water conservation. With the exception of traditional techniques such as *A. albida*, manure and parcase, other techniques for rebuilding the soil such as composting, green manure crops and improved agronomic practices are not well known in Senegal, or if known, have not been adopted. While some of these newer techniques require little cash expenditure, many will require a significant investment of labor. This means that the benefits of a particular soil building technology need to exceed costs. In turn, this requires more stringent research designs where benefits can actually be demonstrated/proven rather than assumed. Moreover, costs

and benefits of these "new" technologies need to be compared with the traditional technologies; new is not always better.

Once this is achieved, a third stage would be to establish land use and land management practices and production expectations that can be sustained while maintaining the restored resource. It is at this stage that the use of inorganic fertilizer and improved varieties can begin to make significant increases in crop yields.

As with many countries in sub-Saharan Africa, Senegal has, in the past, tended to focus on the third stage (commodities and fertilizer) to the neglect of the first two stages. While the new USAID/ISRA Natural Resource-Based Agricultural Research Project will be a first step in reaching a better balance between commodities/variety research and soil maintenance, the following recommendations are offered in the context of this new activity:

(1) Soil degradation problems and solutions in the NCPB and the Peanut Basin in general need to be disaggregated by soil type. While the above analysis focuses on dior soils, the results would not be applicable to deck soils where erosion problems and woody species are considerably different;

(2) Permanent soil sampling monitoring points on each soil type need to be established in order to better quantify both the rate and the extent of soil degradation.

(3) In the context of items (1) and (2), more work needs to be done on Pieri's coefficients. In particular, the impact of on-field trees on α (tillage practices) needs to be determined.

(4) More research attention needs to be accorded to traditional methods of maintaining soil fertility in the NCPB, including the role of indigenous trees and shrubs. There is a tendency among many GOS and expatriate personnel in Senegal to equate development and increased yields with new, imported technologies and exotic species to the neglect of traditional methods of maintaining the soil base. A key research question to ask would be how these traditional methods might be better adapted to meet current ecological and socio-economic conditions.

(5) In terms of indigenous tree and shrub species, the role of *Balanites aegyptiaca*, *Piliostigma reticulata*, *Guiera senegalensis* and *Cordyla pinnata*, according to informants, deserves particular research attention. Specifically for nger, its action on the soil whether as a windbreak or as a provider of SOM needs to be determined.

(6) Finally, one cautionary note is in order. Many farmers, researchers and development workers in Senegal give considerable attention to agroforestry as a means of addressing many soil fertility problems in the NCPB. However, agroforestry should

not be looked on as a panacea for the agricultural ills of the region. Gains in crop yields from agroforestry technologies are likely to be small. However, agroforestry's major contribution to agriculture in the NCPB will be to reverse the resource degradation currently taking place and restore soil fertility and organic matter to levels where the use of fertilizer and improved crop varieties can begin to make significant gains in crop yields.

Chapter 4

External Influences: the Impact of Changing Agriculture Policy

"Un cad égal au moins un sac d'engrais"¹⁰⁴

Mbaye Gueye, NCPB farmer
(Ndimb Diol)

4.1 Introduction

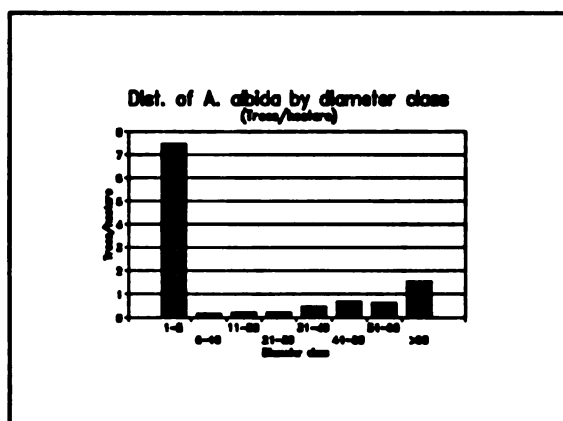
The analyses and conclusions presented in Chapter 3 suggest that soil degradation in the NCPB, since the collapse of the bush fallow system, may not be as severe as previously thought due to the mediating presence of on-field trees, particularly *A. albida*. In this context, one of the original but formally unstated hypotheses of this research was that the *A. albida* system was in serious decline thus jeopardizing soil fertility in the NCPB. This assumption was based on discussions with GOS and expatriate personnel familiar with natural resource problems in Senegal, on literature reviews, and on a brief visit by the principal investigator to Senegal in 1988 to examine ISRA/DRPF's agroforestry research and development program¹⁰⁵.

However, during the course of the rapid rural appraisal and in the initial village visits conducted by the principal investigator, it became apparent that the system was experiencing a "renaissance" among many farmers. This was later substantiated by the results of the Biophysical Inventory which showed a relatively strong cad density in the 1-5cm diameter class, as well as high rates of cad regeneration for many informants. Figure 4.1 shows this dramatic increase in the number of *A. albida* trees in the 1-5cm diameter class. Depending on the nature of the tree (whether a root/stump sprout or a seedling) and

¹⁰⁴Meaning that one *A. albida* tree is at least equivalent to one sack of fertilizer.

¹⁰⁵See Seyler (1988).

the site, this represents an age class of approximately 1 to 6 years¹⁰⁶.



Source: Biophysical Inventory.

Figure 4.1

Distribution of *A. albida*
by Diameter Class

Results of the Biophysical Inventory also suggest that regeneration rates¹⁰⁷ for cad, while varying considerably from field to field, also appear to be satisfactory. The mean regeneration rate was 0.8 seedlings or sprouts per 100m² with a minimum of 0 and a maximum of 10. Over one-half of the 305 fields surveyed had some cad regeneration. If it is assumed that a minimum regeneration rate required to sustain a population of cad of about 40 trees/ha would be 0.5 (the equivalent of 50 seedlings or suckers/ha), then 43% of the

¹⁰⁶In the field, it is virtually impossible to distinguish between root suckers and seedlings. Cad is a prolific "sprouter" and root sprouts are thought to have higher growth rates than seedlings (Giffard 1971)), although this difference has not been quantified. For seedlings, however, annual diameter growth rates are reported by Mariaux (1966) to range from 0.61 to 2.9 cm, by Wickens (1966) to be 1.59 ± 0.59 cm, and by Anon (1966) to range from 0.31 to 2.9 cm. The wide variation in growth rates is due to both site differences and genetic variability (Felker 1978).

¹⁰⁷The regeneration rate per field is the average number of seedlings or sprouts less than one centimeter in diameter taken from three randomly selected 10m X 10m sample plots. The field regeneration rate is the mean number of seedlings/sprouts of all three plots, or the rate per 100m².

fields surveyed could be said to have an adequate regeneration rate. The overall distribution of regeneration rates by field is presented in Table 4.1.

Table 4.1
Distribution of Cad Regeneration Rates by Field
(Number and percent of fields)

Rate	No. Fields	% Fields
Rate = 0	136	44.6
0<Rate<0.5	37	12.1
0.5<Rate<1	26	8.5
1<Rate<2	60	19.7
2<Rate<3	28	9.2
Rate > 3	18	5.9
Total	305	100.0
Source: Biophysical Inventory		

If one aggregates the field regeneration rates up to the total farm level (the average of all fields), then nearly 23% of the informants could be considered to have an adequate regeneration rate while 30% have what would appear to be an excellent regeneration rate as Table 4.2 indicates.

Table 4.2
Distribution of Cad Regeneration Rates by Farm
(Number and percent of Farms/Informants)

Rate	No. Farms	% Farms
Rate = 0.0	8	11.1
0<Rate<0.5	25	34.7
0.5<Rate<1	15	23.6
1<Rate<2	14	19.4
2<Rate<3	7	9.7
Rate > 3	1	1.4
Total	72	100.0
Source: Biophysical Inventory		

Another "mystery" which surfaced during the course of the rapid rural appraisal study and initial village visits and subsequently confirmed by the Biophysical Inventory, was the relative scarcity of

trees in the middle age/diameter classes. While there appeared to be quite a few old trees and lots of younger trees and regeneration, trees in the middle diameter/age class were few and far between. Figure 4.1 above shows that on a per hectare basis, there are fewer trees in the 6-10cm, 11-20cm and 21-30cm diameter class than in the other classes. If one again assumes an average growth rate for cad of between 1cm and 1.5cm per year, this suggests that something rather drastic happened to the NCPB's cad trees from roughly 1959 to 1986.

It was originally thought that at least part of the reason for the absence of middle diameter class trees was due to the great drought of the late 1960's early 1970's which more than likely would have had an impact on regeneration and on system trends as a whole. Forage/fodder scarcity during the drought would have also probably contributed to the decline of the system during these years. However, an analysis of the internal factors which might affect the system as presented later in Chapter 7 suggests that while water table depth and fluctuations have an impact on cad, there is no apparent relationship between cad and rainfall per se.

During the initial village visits and in subsequent group discussions with farmers it became clear that certain external factors, particularly the removal of fertilizer subsidies under the GOS's structural adjustment/New Agricultural Policy program, were having a positive impact on the system. Comments like the ones at the beginning of this chapter were heard from both informants and other farmers in the NCPB. Unable or unwilling to purchase fertilizer at the unsubsidized market price, many farmers appeared to be returning to the traditional *A. albida* system for nutrient input and soil stabilization.

At the same time, other external factors such as land and tree tenure, formal education, agriculture and forestry training, and extension contact, while deemed important at the proposal writing phase of the study, appeared to have little impact on the system. The

purpose of this chapter, therefore, is to further explore and attempt to quantify the impact that certain external inputs or influences from other social systems may be having on the *A. albida* system.

4.2 Changing agricultural policy and the *A. albida* system

4.2.1 Perceived long and short-term production trends, problems and solutions

The first step in exploring the impact of changes in agricultural policy on the *A. albida* system was to attempt to differentiate between longer-term production trends and problems (over the past ten years) and shorter-term trends and problems (over the past two cropping seasons) in order to ascertain the relative importance of soil degradation/*A. albida* in terms of informants' planning/time horizons.

4.2.1.1 Perceived longer-term production trends and problems

Informants were asked to describe their production trends over the past 10 years by major crop. If informants perceived yields for a particular crop to be declining over the longer term, they were then asked to specify the reason for the decline. Results are summarized in Table 4.3.

Table 4.3
Perceived Longer-Term Production Trends
(Number and Percent of Responses)

Production Trends	Millet		Cowpeas		Peanuts	
	No.	Per.	No.	Per.	No.	Per.
Increase	4	5.6	1	1.4	0	0.0
Decrease	68	94.4	67	93.0	72	100.0
No change	0	0.0	2	2.8	0	0.0
No response	0	0.0	2	2.8	0	0.0
Total	72	100.0	72	100.0	72	100.0
Source: Survey data.						

The overwhelming perception of decreased yields for millet, cowpeas and peanuts is shared by nearly all informants. Only four informants (5.6%) felt that millet yield have increased while only one

farmer believed that cowpea yields have increased. All informants considered peanut yields to have decreased over the longer term.

According to those informants who perceived a decrease in yields, the most significant factor affecting agricultural productivity over the long term was declining soil fertility. Soil related problems (declining soil fertility, increased wind and water erosion, reduced fallow periods and reduced tree cover) accounted for nearly 50% of responses. Poor rainfall and lack of agricultural inputs accounted for 20.2% and 24.3% of responses respectively, followed by pest-related problems (8.0%). Results are summarized in Table 4.4.

Table 4.4
Perceived Reasons For Decline In Yields
Over The Longer-Term
(Number and Percent of Responses)

Reason	Millet		Peanuts		Cowpeas		All Crops	
	No.	Per.	No.	Per.	No.	Per.	No.	Per.
Poor rainfall	39	21.2	35	18.8	32	20.5	106	20.2
More wind erosion	20	10.9	24	12.9	19	12.2	63	12.0
More water erosion	3	1.6	4	2.2	3	1.9	10	1.9
Declining fertility	58	31.5	59	31.7	51	32.7	168	31.9
Lack of inputs	45	24.5	48	25.1	35	22.4	128	24.3
Pests	16	8.7	13	7.0	13	8.3	42	8.0
Reduced fallow	2	1.1	2	1.1	2	1.3	6	1.1
No tree cover	1	0.5	1	0.5	1	0.7	3	0.6
Total responses	184	100.0	186	100.0	156	100.0	526	100.0
Source: Survey data.								

4.2.1.1.1 Perception of field quality compared with perceived long-term problems

As a means of cross checking informant perceptions of soil fertility, informants were also asked to describe the "quality" of their fields during the biophysical inventory. It was believed that fertility problems and soil quality become much more apparent (and responses more "honest") when actually walking in the fields.

Responses are presented in Table 4.5. Results suggest that perceived reasons for declines in yields are roughly matched by informant perceptions of field quality. Nearly one half of the fields (49.6%) surveyed were considered by informants to be "fair" or fairly fertile. Some fields were considered to be fairly good but were subjected to some wind erosion (11.5%) and water erosion (0.7%). In sum, fields considered to be good or fairly good accounted for over 60% of the total fields surveyed.

The remaining fields were considered by informants to be "poor" or infertile due to: wind erosion (20%), no fertilizer trees or fallow (8.5%), a combination of water and wind erosion (5.6%), water erosion only (1.3%), gravel on the surface (1%) and gravel combined with water erosion (1%). Wind erosion and "soil infertility" caused by lack of fertilizer, fallow or trees were the main soil problems according to informants.

Table 4.5
Informant Perception Of Field Quality
(Number and Percent of Fields)

Quality	No.	Percent
Fertile-fair	151	49.6
Poor-gravel	3	1.0
Poor-eroded-rain	4	1.3
Poor-eroded-wind	64	20.0
Fairly good-rain eros.	2	0.7
Fairly good-wind eros.	35	11.5
Poor-rain and wind eros.	17	5.6
Poor (no fert./trees/fallow)	26	8.5
Poor gravel-wind eros.	3	1.0
Total responses	305	100.0
Source: Survey data.		

4.2.1.2 Short-term production trends and problems

Informants were asked whether they felt their crop production over the past two years (cropping seasons 1988 and 1989) was

sufficient to cover family needs¹⁰⁸. The results are presented in Table 4.6. The majority of informants indicated that production of all major crops (millet, peanuts, cowpeas and peanut and cowpea hay) was not adequate to meet household needs for both years. However, according to informants, needs were better met in 1989 than in 1988. This difference is due primarily to: (i) higher rainfall in 1989 (an average of 645mm in 1989 compared with 547mm in 1988); and (ii) locust attacks in 1988.

More informants perceived millet and peanut hay production to be sufficient in both years compared with peanut, cowpea and cowpea hay production. This makes sense in terms of millet as it is the staple food crop of the region and more effort and resources go into its production than for other crops. Similarly, the difference for cowpeas is probably due to the fact that cowpeas are a relatively new crop in the NCPB and only a small percentage of informants actually had any experience growing them. As an example, informants who did not even grow cowpeas tended to say that their cowpea production was insufficient.

Perceived differences between peanut and peanut hay production are more difficult to explain. Both are considered to be cash crops in the sense that the majority of peanut hay from the NCPB is sold/exported from the system (Rodale 1989). This being the case, it would be expected that informants who perceive peanut pod production to be insufficient in a given year, would also perceive peanut hay production to be inadequate. This discrepancy may in part be related

¹⁰⁸This is obviously a very leading question. To ask any farmer whether he/she produced enough to meet his family needs depends a great deal on what the farmer's needs and aspirations actually are. The original purpose behind asking the question was to attempt to determine if there was a difference in cad density between informants who perceive crop yields to be sufficient and those who did not. The hypothesis was that farmers who perceive their production to be sufficient would tend to have more cad and other trees on their farms. Unfortunately, there were too few informants who perceived crop production to be sufficient to make a meaningful comparison between the two groups.

to two factors. First, little fertilizer (particularly phosphorous¹⁰⁹) is used on peanuts or any other crop since the inception of the NAP. As will be discussed later in this chapter, farmers now tend to rely on *A. albida* and other trees and shrubs for organic matter and nutrient input. The higher N levels under cad trees tend to favor peanut green matter rather than pod production (Louppe 1989) and this may account for the perceived difference.

Second, as above ground peanut biomass develops first and only much later in the season do the peanuts put on much growth and development, it may be that in years of poor peanut yield (e.g., drought conditions), the farmer might still be able to have a harvestable and saleable peanut biomass crop.

Table 4.6
Perceived Production Trends 1988-1989
(Number and Percent of Responses)

Crop/Year	Sufficient		Insufficient	
	No.	Per.	No.	Per.
Millet 1989	18	25.0	54	75.0
Millet 1988	11	15.3	61	84.7
Cowpeas 1989	15	20.8	57	79.2
Cowpeas 1988	3	4.2	69	95.8
Peanuts 1989	7	9.7	65	90.3
Peanuts 1988	3	4.2	69	95.8
Peanut hay 1989	16	22.2	56	77.8
Peanut hay 1988	13	18.1	59	81.9
Cowpea hay 1989	5	6.9	67	93.1
Cowpea hay 1988	3	4.2	69	95.8
Source: Survey data, n=72.				

Perceived short-term production problems by major crop for 1988 and 1989 are presented in Tables 4.7 and 4.8 below. For millet in 1989, pest/weed problems, poor quality land and lack of fertilizer accounted for 33.0%, 21.7% and 16.5% of responses respectively. Poor rainfall and shortage of labor accounted for only 8.3% of responses each. Major perceived production problems for cowpeas were seed

¹⁰⁹The fertilizer recommendation for peanuts in the NCPB is 150 kg/ha of 6-20-10 (Kelly 1988).

availability (22.7%), poor quality land (18.7%), lack of fertilizer (13.3%) and pest and weed problems (13.3%).

For peanuts in 1989, the majority of farmers indicated that seed availability was the major production problem accounting for over 44% of responses¹¹⁰. Poor quality land, lack of fertilizer and pest/weed problems accounted for 14.4%, 15.3% and 8.5% of the remaining responses respectively.

Table 4.7

Perceived Production Problems For Major Crops in 1989
(Number and Percent of Responses)

Problem	Millet		Cowpeas		Peanuts	
	No.	Per.	No.	Per.	No.	Per
Seed availability	3	3.1	17	22.7	52	44.1
Poor rainfall	8	8.3	7	9.3	6	5.1
Insufficient land	5	5.2	7	9.3	7	5.9
Insufficient labor	8	8.3	7	9.3	7	5.9
Poor land	21	21.7	14	18.7	17	14.4
Lack of fertilizer	16	16.5	10	13.3	18	15.3
Lack of trac.anim.	3	3.1	0	0.0	0	0.0
Poor variety seed	0	0.0	0	0.0	0	0.0
Late planting	1	1.0	3	4.0	1	0.9
Pests/weeds	32	33.0	10	13.3	10	8.5
Total responses	97	100.0	75	100.0	118	100.0
Source: Survey data						

Perceived production problems by major crop in 1988 were similar to those in 1989 with two exceptions; poor rainfall and pest/weed problems accounted for a higher frequency of responses for reasons as previously mentioned.

¹¹⁰Unfortunately, no attempt was made to differentiate between seed availability and reluctance to purchase peanut seed because of its (now unsubsidized) price.

Table 4.8

**Perceived Production Problems For
Major Crops in 1988**

(Number and Percent of Responses)

Problem	Millet		Cowpeas		Peanuts	
	No.	Per.	No.	Per.	No.	Per.
Seed availability	4	3.2	17	17.7	48	31.8
Poor rainfall	23	18.1	16	16.7	21	13.9
Insufficient land	5	3.9	5	5.2	5	3.3
Insufficient labor	7	5.5	4	4.2	4	2.7
Poor land	22	17.3	15	15.6	19	12.6
Lack of fertilizer	22	17.3	8	8.3	18	11.9
Lack of trac.anim.	2	1.6	1	1.0	1	0.7
Poor variety seed	0	0.0	0	0.0	0	0.0
Late planting	1	0.8	1	1.0	3	2.0
Pests/weeds	41	32.3	29	30.2	32	21.2
Total responses	127	100.0	96	100.0	151	100.0
Source: Survey data.						

As short-term production problems vary from year to year, perceived problems were combined for 1988 and 1989 and the results are summarized in Table 4.9. At the farm level (all major crops), the most important problems cited by informants are pest/weed problems (23.2% of responses), followed by seed availability (21.2%), poor quality/infertile land (16.3%) and lack of fertilizer (13.9% of total responses).

4.2.1.3 Farmer-based solutions to maintaining soil fertility and increasing crop yields

Responses to the preceding questions suggest that in terms of declining soil fertility, many informants make a distinction between the long term and the short term. In the longer term, soil-related problems (declining soil fertility, increased wind and water erosion, reduced fallow periods and reduced tree cover) accounted for nearly 50% of responses. In the shorter term, soil-related problems (poor quality land and lack of fertilizer) accounted for only 30.2% of responses. Of more immediate concern to informants in the short-term were problems related to seed availability and pests and weeds.

Table 4.9

**Combined Perceived Production Problems For
Major Crops in 1988 and 1989**

(Number and Percent of Responses)

Problem	Millet		Cowpeas		Peanuts		All Crops	
	No.	Per.	No.	Per.	No.	Per.	No.	Per.
Seed availability	7	3.1	34	19.9	100	37.2	141	21.2
Poor rainfall	31	13.8	23	13.5	27	10.0	81	12.2
Insufficient land	10	4.5	12	7.0	12	4.5	34	5.1
Insufficient labor	15	6.7	11	6.4	11	4.4	37	5.6
Poor land	43	19.2	29	17.0	36	13.4	108	16.3
Lack of fertilizer	38	17.0	18	10.5	36	13.4	92	13.9
Lack of trac.anim.	5	2.2	1	0.6	1	0.4	7	1.1
Poor variety seed	0	0.0	0	0.0	0	0.0	0	0.0
Late planting	2	0.9	4	2.3	4	1.5	10	1.5
Pests/weeds	73	32.6	39	22.8	42	15.6	154	23.2
Total responses	224	100.0	171	100.0	269	100.0	664	100.0
Source: Survey data.								

This distinction between long and short term is also apparent in perceived farmer solutions to soil infertility and decreasing yields. In an open-ended question, informants were asked to imagine themselves as President of Senegal and indicate how, as President, they would ensure that farmers in the NCPB: (i) could maintain soil fertility; and (ii) could increase crop yields.

As was expected, this question generated a considerable amount of discussion as well as a wide variety of responses. However, for both questions, responses could be grouped into several broad categories. For the question concerning maintenance of soil fertility, groups included solutions based on: (i) the use of inorganic fertilizer; (ii) the use of manure; (iii) the use of trees; (iv) cropping practices; and (v) "miscellaneous" (Table 4.10). Of particular interest is the fact that the overwhelming majority of proposed soil fertility/maintenance solutions were based on the use of manure, trees and improved cropping practices. These three categories alone accounted for over 75% of total responses (24.5% for manure,

39.7% for trees and 11.3% for improved cropping practices). Moreover, direct reference to *A. albida* accounted for 29.5% of total responses.

Somewhat surprisingly, the use of inorganic fertilizer accounted for only 20.5% of soil fertility solutions. This suggests that the majority of informants equate the maintenance of soil fertility more with traditional practices than with the use of inorganic fertilizer.

While some responses to this question were probably clouded by informants' desire to provide the "correct" response (this was afterall a study on *A. albida*), group discussions with informants and other farmers regarding fertilizer (e.g., high price, difficult access) suggest that farmers are more or less required to return to traditional practices.

Contrary to solutions proposed for the maintenance of soil fertility, informant solutions proposed for increasing yields centered around the provision of seed and fertilizer in addition to general changes in agriculture policy. These three categories accounted for nearly 93% of responses while improved cropping techniques and the use of trees accounted for only 5.9% and 1.2% of responses respectively. Results are summarized in Table 4.11.

4.2.2 Changing agriculture policy: a brief history

Responses to the above series of questions suggest that the majority of informants make a distinction between maintaining soil fertility and increasing yields. Proposed solutions to the former center around the use of traditional technologies (i.e., the use of manure, cad and other on-farm trees), while proposed solutions to the latter tend to center around policy (credit/pricing) and more modern technologies (fertilizer).

Unfortunately, this distinction has, until recently, not been taken into consideration by the GOS. Since the 1970's (when much of the original research on the cad system and other traditional methods of maintaining soil fertility were abandoned), the GOS and donors have

Table 4.10

**Proposed Solutions To Maintaining Soil Fertility
(Frequency and Percent of Responses)**

Proposed solution	No.	Per.
Solutions based on fertilizer		
Lower the price of fertilizer	18	11.9
Provide fertilizer free of charge	9	6.0
Have closer sale points for fertilizer	4	2.6
Subtotal	31	20.5
Solutions based on manure		
Encourage farmers to use more manure	22	14.6
Give cows to farmers to increase manure	1	0.7
Increase livestock numbers for manure	6	4.0
Use more "parcage"	7	4.6
Provide credit to purchase animals	1	0.7
Subtotal	37	24.5
Solutions based on cropping practice		
Encourage farmers to respect fallow	10	6.6
Encourage farmers to follow crop rotations	2	1.3
Follow advice of extension agents	1	0.7
Develop new soil regeneration techniques	1	0.7
Have CERPS rent tractors to farmers	1	0.7
Encourage deep plowing	2	1.3
Subtotal	17	11.3
Solutions based on trees		
Provide cad seed to farmers	1	0.7
Protect existing field trees	1	0.7
Increase number of good field trees	3	2.0
Provide a village nursery for cad	3	2.0
Protect cad and other species regeneration	26	17.2
Plant cad and other "soil fertility" trees	13	8.6
Adopt agroforestry techniques	1	0.7
Provide plants for windbreaks	5	3.3
Provide village nurseries	7	4.6
Subtotal	60	39.7
Miscellaneous		
More equal distribution of land	2	1.3
Have a "soil fertility" project	2	1.3
Have a better weed control program	1	0.7
Create a national soil conservation service	1	0.7
Subtotal	6	4.0
Source: Survey data.		

tended to focus agriculture research and development programs on "modern" technologies (fertilizer response, animal traction and improved varieties), and on macro-economic issues (generally to facilitate adoption of these techniques), to the neglect of

traditional methods of maintaining the soil base. In turn, these R&D programs were a major determinant of agricultural policy.

The underlying premise of these policies, whether based on heavily subsidized inputs or a more free market approach, was accelerated agricultural development. In either case, however, little attention was accorded to the impact of changing agricultural policy on the natural resource base. However, as Kyle (1989) points out, the micro-economic adjustments made by individual farmers to these policy changes not only drive macro-outcomes but simultaneously influence environmental impact through changes in natural resource use patterns. While changes to the environment are unavoidable if accelerated agricultural development is to be achieved, the issue becomes one of whether changes are sustainable, particularly in terms of soil and water use, or if they alter the ecological balance to the extent that soil, water and other assets cannot be maintained over the long term.

In order to understand the impact of changing agricultural policy on natural resources in general and the *A. albida* system in particular, a brief history of major agricultural policy changes in Senegal is required. The following description of these changes draws primarily from Abt Associates (1985) and USAID (1991).

Prior to independence in 1960 and the end of 1989, Senegal's economy passed through five major economic policy and/or program changes related to the agricultural sector (USAID 1991). The first of these phases, the colonial period, was geared to developing and sustaining a colonial export economy based on peanuts produced by traditional peasant agricultural methods (Abt 1985). An expanding peanut trade provided the main source of foreign exchange for the economy, revenues for the state and cash income for the rural populations. The phase was characterized, *inter alia*, by a high

degree of state intervention to stimulate and maintain peanut production, including distribution of seeds and other inputs, setting producer and export prices and the dates for the opening and closing for the peanut trade and food loans to tide farmers over the hungry season (the "période de soudure"¹¹¹).

Table 4.11

**Proposed Solutions To Increasing Crop Yields
(Frequency and Percent of Responses)**

Perceived solution	No.	Per.
Solutions based on fertilizer		
Provide free fertilizer	22	12.9
Lower fertilizer prices	25	14.7
Have closer sale points for fertilizer	10	5.9
Subtotal	57	33.5
Solutions based on seed		
Provide more and better quality seed	10	5.9
Provide free seed	35	20.6
Lower price of seed	27	15.9
Provide for free sale of seed	2	1.2
Subtotal	74	43.5
Solutions based on cropping techniques		
Respect cropping techniques	4	2.4
Farm less land better	1	0.6
Better weed/pest control techniques	2	1.2
Develop better ag techniques and follow-up	1	0.6
Develop better implements	1	0.6
More use of manure and fallow	1	0.6
Subtotal	10	5.9
Solutions based on credit/policy		
Provide cheaper agriculture credit	14	8.2
Rethink NAP (return to SODEVA)	2	1.2
Reduce price of tools/implements	7	4.1
Give food (soudure)	3	1.8
More equal distribution of land	1	0.6
Subtotal	27	15.9
Solutions based on trees		
Encourage use of cad	1	0.6
Develop a better field tree policy (agroforestry)	1	0.6
Subtotal	2	1.2
Source: Survey data.		

¹¹¹The "période de soudure" is from the end of the dry season through the rainy season and until crops are harvested. Foodstocks have been depleted or are low during this time.

The second period, from 1960 to 1966, began with independence and was characterized by good weather, the initiation of the 20-year "Programme Agricole" and preferential treatment for exports (especially peanuts) by the French. Senegal was one of the African states which opted for "African Socialism" and the over-riding philosophy was that the state, and especially an enlightened bureaucracy would manage the economy for the benefit of all of its citizens. This philosophy translated into extensive price controls, subsidies and state owned and managed industry. An extensive cooperative system was created, almost exclusively concentrated on providing credit and inputs to the peanut producing regions and peanut marketing. By 1963, about 80% of the cooperatives had been established and were controlled and managed by state agents. Even at the outset, loan repayment rates were low (68%). In 1965, the GOS began its "Programme Agricole" (Agricultural Program) whose main objective was to increase peanut production and yields by introducing new techniques (improved seed, line seeding, animal traction and mineral fertilizer) and by providing cheap credit in order to facilitate farmer adoption of these new techniques.

The third period, from 1967 to 1980, is characterized by thirteen years of fluctuating output and increasing agriculture sector deficits. This period begins with the loss of French preferential treatment for peanut exports in 1967 and ends with the termination of the "Programme Agricole" in 1980. It encompasses the creation, growth and eventual dissolution of ONCAD (Office Nationale de la Coopération et d'Assistance pour le Développement), the creation of 83 regional development authorities and other state-owned and operated agencies, Senegalisation of the economy, several bad weather years resulting in the forgiveness of agricultural credit, growth and eventual discrediting of state controlled cooperatives, and the worldwide commodity crisis. The cooperatives were under the control of ONCAD, which was also responsible for the sale of agricultural commodities,

determination of cooperative credit and their input needs. By 1970, there were 1870 cooperatives with 1060 specific to peanuts. ONCAD staff increased from an initial level of about 450 to over 2900 in 1979, when personnel costs accounted for about one half of the ONCAD budget. Credit repayment rates decreased to 48% in 1979 but agricultural credit was forgiven three times in the 1970's and again in 1980 when ONCAD was dissolved.

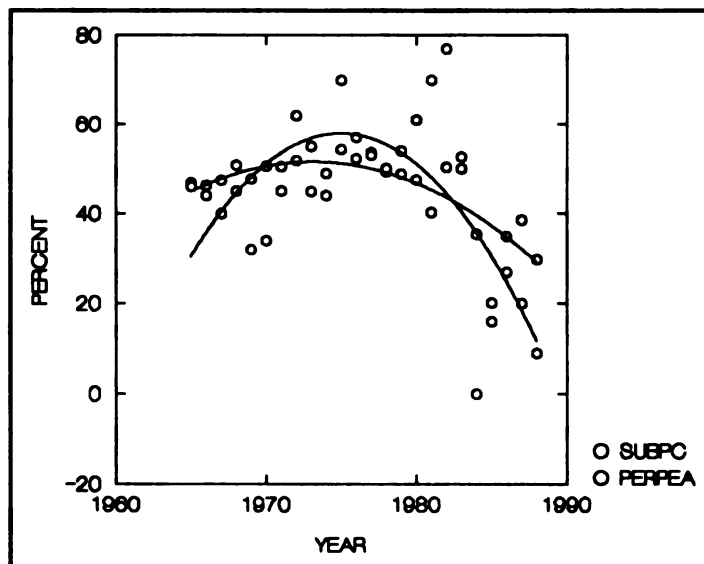
The fourth period, from 1981 to 1983, is considered to be a transitory stage and the beginning of stabilization (USAID 1991). SONAR (Société Nationale pour l'Approvisionnement du Monde Rural) was created to replace ONCAD and all agricultural credit was suspended. Deficits, partly from ONCAD and now from SONAR, built to crisis levels and SONAR was dissolved. SONAR's main function was the provision of seed and fertilizer to the peanut sector. The World Bank's first structural adjustment loan (SAL-1) was approved in December 1980. The SAL-1 program was aimed at improving parastatal efficiency, increasing producer and exporter incentives, raising productivity of investments, containing urban consumption and a wide range of institutional and policy reforms in the agricultural sector. SAL-1 was considered a failure as a result of: (i) two bad weather years (1979/80 and 1980/81); (ii) its use of inaccurate and incomplete information (debt and arrears were much higher than originally thought); (iii) excessively optimistic forecasts; and (iv) GOS inaction. As a result, virtually no progress was made on policy reform. High world peanut prices led the GOS to increase the producer price by 43% in 1981, and when world prices fell in 1982, the deficit exploded. The second phase of SAL-1 was postponed and the outstanding balance was canceled in June 1983.

The fifth period, from 1984 to 1989 could be considered as the stabilization and structural adjustment period. The "Nouvelle Politique Agricole" (New Agricultural Policy--NAP) was formulated in 1986 and state disengagement from the agricultural sector began. The

NAP aims to diversify agricultural production away from reliance on peanuts and reduce government involvement in the agriculture sector through restructuring of rural development agencies and privatization of input distribution, credit and marketing services previously performed by parastatals. Subsidies on agricultural inputs (particularly fertilizer) were reduced and eventually eliminated in 1988. Price and marketing controls on cereal grains (except rice) were also eliminated.

4.2.2.1 Indicators of changing agriculture policy: fertilizer subsidies and area in peanuts

Perhaps the best way to visualize these periods and their impact on farmer decision making is examine two key indicators of changing policy; fertilizer subsidies and crop area in peanuts. Figure 4.2 shows the relationship between the percent fertilizer subsidy and percent of total arable area in peanuts from 1965 to 1989 for the Departments of Thiès and Diourbel¹¹².



Source: Data are from USAID (1991).

Figure 4.2
Relationship Between Percent of Fertilizer Subsidy
and Percent of Crop Area in Peanuts

¹¹²Data from these two departments were used in the analysis as the majority of study villages fall within their domain.

From the graph, it is obvious that there is a direct relationship between fertilizer subsidies and area in peanuts. In order to quantify this relationship, regression analysis was used to test the following hypothesis:

Hypothesis 4.1

H_0 : There is no relationship between the amount of fertilizer subsidy (SUBPC in percent) and percent of total arable area in peanuts for the departments of Thiès and Diourbel (PERPEA).

H_1 : Cropping area in peanuts (PERPEA) is a positive function of the amount of the fertilizer subsidy.

DEP VAR: PERPEA N: 24 MULTIPLE R: .703 SQUARED MULTIPLE R: .494 ADJUSTED SQUARED MULTIPLE R: .471 STANDARD ERROR OF ESTIMATE: 6.090						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	32.167	3.147	0.000	.	10.221	0.000
SUBPC	0.303	0.065	0.703	1.000	4.634	0.000
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	796.309	1	796.309	21.471	0.000	
RESIDUAL	815.914	22	37.087			

The results of the regression suggest that the relationship between fertilizer subsidy and area in peanuts is highly significant (at the 99% confidence level); as fertilizer subsidies increase farmers tend to plant more of their land in peanuts. However, the model has only a weak predictive power (an adjusted R squared of only .474). Obviously other factors, particularly the price of peanut seed (or subsidy) would enter into the equation. As time-series data on peanut seed prices were unavailable, this hypothesis could not be tested¹¹³.

4.2.2.2 The MAP and informant decision making

Clearly agriculture policy has an impact at farm-level decision making. While informants were not asked specific questions about the

¹¹³Additionally, no attempt was made to "lag" the data to determine if the model could be strengthened.

impact of the NAP, results from the Biophysical inventory suggest that there is indeed an impact in terms of both cropping patterns and soil management methods.

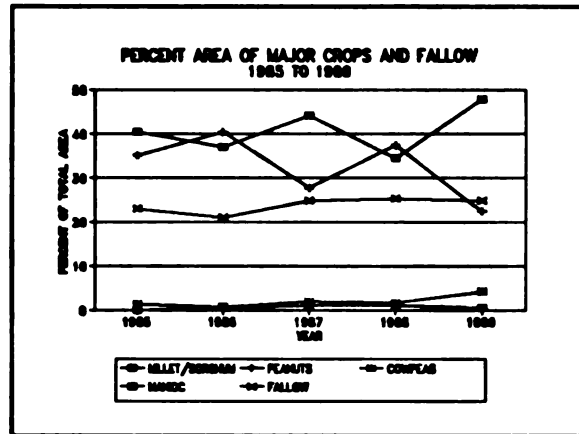
During the course of the Biophysical Inventory, informants were asked to provide the cropping history for each field in their possession from 1985 to 1989. The results, summarized in Figure 4.3, suggest that the percent of the total study area¹¹⁴ in peanuts decreased during this time period while the area in cowpeas and millet increased¹¹⁵. As the percent of total area in fallow and manioc during this period remained relatively constant, informants appear to be shifting production from peanuts to millet and cowpeas. These trends are also supported by DA/DISA data¹¹⁶.

In terms of soil conservation/fertility measures, results of the Biophysical Inventory, presented in Figure 4.4, suggest that while perceived fertilizer use among informants was practically non-existent and the use of parcase and fallow were fairly constant for the 1985 to 1989 period, there was a significant increase in the use of manure. Moreover, if one assumes a 1 cm annual growth rate for *A. albida*, the distribution of cad trees/ha by age class for the total study area has increased dramatically since 1985. This suggests that as fertilizer use is declining in the study area due to the impact of the NAP, the use of more traditional practices of maintaining soil fertility such as manure and *A. albida* is increasing.

¹¹⁴The total hectareage of all fields inventoried.

¹¹⁵As Figure 4.3 indicates, the area in millet fluctuates considerably from year to year. This is primarily a function of rainfall; if rainfall is poor one year and millet yields are low, farmers tend to plant more of their farm area in millet the next year to compensate for losses. If rainfall is high one year and millet yields good, farmers tend to devote more of their cropping area to peanuts and/or other cash crops the next year.

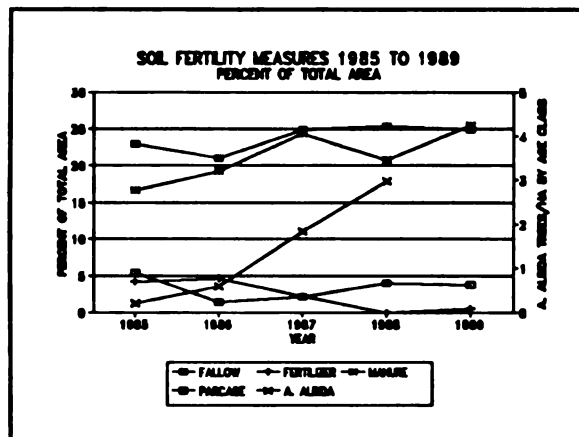
¹¹⁶See USAID (1991).



Source: Biophysical Inventory.

Figure 4.3

Percent Area of Major Crops and Fallow
1986 to 1989



Source: Biophysical Inventory.

Figure 4.4

Soil Fertility Measures 1985 to 1989

4.2.2.3 The relationship between *A. albida* and fertilizer subsidies and area in peanuts

The above analysis suggests that structural adjustment/NAP has had at least two impacts on agriculture in the NCPB. First, it has led to a decrease in the area in peanuts and a concurrent shift from peanuts to millet and cowpeas. Second, it has decreased the use of

fertilizer, obliging farmers to return to more traditional methods of maintaining soil fertility. In turn, these tentative conclusions led to the formulation of two general hypotheses with regard to the relationship between the *A. albida* and changing agricultural policy. The first is that when fertilizer is cheap (i.e., highly subsidized and/or credit is forgiven as during the Programme Agricole period), farmers, being economically rational individuals, find it easier and cheaper to use fertilizer to maintain soil fertility rather than to take care of their cad trees¹¹⁷.

The second general hypothesis is that peanut culture has had a negative impact on the cad population in general. One of the difficulties often cited by farmers during group discussions is that it is easier to cultivate around cad seedlings/sprouts in millet fields where the spacing between plants is fairly large (1.0m to 1.2m) than in peanut fields where spacing between plants is much narrower (0.30m to 0.60m). This problem is exacerbated by the fact that the majority of the farmers follow crop rotations.

The plant spacing problem also has significant implications during crop harvest. While millet heads stalks are harvested by hand, peanuts are harvested using a horse or donkey drawn "lame souleveuse"¹¹⁸ whose 0.30m to 0.40m blade leaves little between row room for manoeuvring around seedlings. This would suggest that an overall decrease in the area in peanut culture in the NCPB would have a positive impact on the cad population.

In order to test these hypotheses, the first step was to estimate the age class of the cad trees inventoried. Growth rates of cad are highly variable and depend both on site and a considerable amount of genetic variation (Felker 1978). Moreover, in the field, it

¹¹⁷As will be discussed in Chapter 5, use of the cad system does entail certain costs to the farmer, particularly an increased labor input.

¹¹⁸Literally, "lifting blade".

is virtually impossible to distinguish between root suckers and seedlings. Cad is a prolific sprouter and root sprouts tend to have higher growth rates than seedlings (Giffard 1971)) although this difference has not been quantified. For seedlings, however, annual diameter growth rates are reported by Mariaux (1966) to range from 0.61 to 2.9 cm, by Wickens (1966) to be 1.59 ± 0.59 cm, and by Anon (1966) to range from 0.31 to 2.9 cm.

Based on the above research and on discussions with farmers about the age of certain trees¹¹⁹, it was decided to retain for analytical purposes a growth rate of 1.2 cm/year¹²⁰. Figure 4.5 shows the relationship between total cad trees/ha by year/age class (LOGTOT), fertilizer subsidy (LOGSUB), and percent area in peanuts for the Departments of Thiès and Diourbel (LOGPEA). In order for the values for each variable to be on a similar scale, a natural log transformation was used¹²¹. SYSTAT's quadratic smoothing function was used to estimate the linear trend given the quadratic nature of the original data.

As was expected, the ebb of cad population coincides closely with the GOS's "Programme Agricole" period where fertilizer subsidies and area in peanuts were at their peak. In order to quantify these relationships, regression analysis was used to test the following hypotheses:

¹¹⁹In several instances, informants knew the exact age of a particular tree. Diameters for these trees were taken at ground level and the mean diameter growth rate for these individual trees was estimated at 1.2cm/year.

¹²⁰In reality, it did not make a real difference in terms of the analyses which growth rate was ultimately used. The shape of the curve remained essentially the same in all cases and only expanded or contracted over time. Regression analyses on the different growth rates all yielded similar results.

¹²¹The logarithmic values for each of the variables were retained for the analysis as this transformation contributed to better linearity as indicated by a probability plot test.

Hypothesis 4.2

$H_{(0)}$: There is no relationship between the distribution of *A. albida*/ha by year/age class (LOGTOT) and the percent fertilizer subsidy (LOGSUB).

$H_{(1)}$: The distribution of *A. albida*/ha by year/age class (LOGTOT) is a negative function of the percent of fertilizer subsidy (LOGSUB).

Hypothesis 4.3

$H_{(0)}$: There is no relationship between the distribution of *A. albida*/ha by year/age class (LOGTOT) and the percent of total area in peanuts in the Departments of Thiès and Diourbel (LOGPEA).

$H_{(1)}$: The distribution of *A. albida*/ha by year/age class (LOGTOT) is a negative function of the percent of total area in peanuts in the Departments of Thiès and Diourbel (LOGPEA).

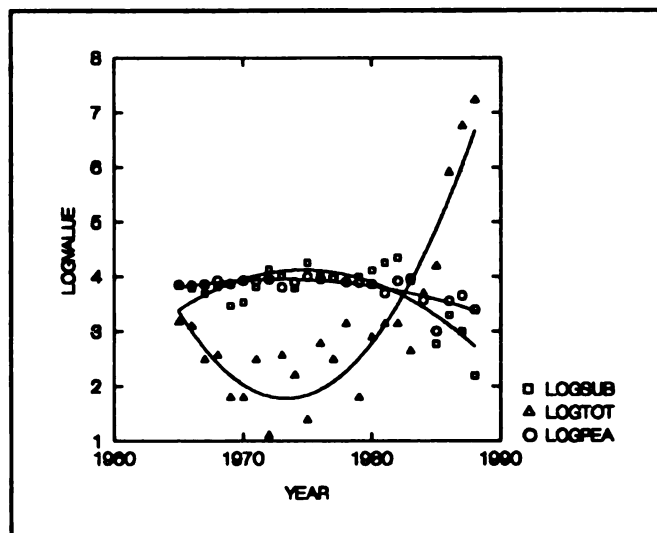
The results of the both regressions suggest that there is indeed a relationship between *A. albida* and changing agricultural policy. For the first hypothesis, the directionality is as predicted and the relationship between the distribution of cad by age class and rate of fertilizer subsidy is highly significant (99% confidence level one-tailed). Moreover, the predictive power of the model is good with an adjusted R-squared of .548. In short, the null hypothesis must be rejected. The distribution of cad over time is inversely related to the amount of fertilizer subsidy.

DEP VAR: LOGTOT N: 23 MULTIPLE R: .754 SQUARED MULTIPLE R: .569
ADJUSTED SQUARED MULTIPLE R: .548 STANDARD ERROR OF ESTIMATE: 1.057

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	11.759	1.664	0.000	.	7.065	0.000
LOGSUB	-2.327	0.442	-0.754	1.000	-5.265	0.000

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	30.946	1	30.946	27.717	0.000
RESIDUAL	23.447	21	1.117		



Source: LOGPEA and LOGSUB are from USAID (1991) and LOGTOT is from the Biophysical Inventory.

Figure 4.5
Relationship Between *A. albida* Density,
Fertilizer Subsidy and Area in Peanuts from 1965 to 1989

Similarly, the relationship between the distribution of cad by age class and total area in peanuts is also as predicted and the null hypothesis must be rejected. The relationship is highly significant (at the 99% confidence level one-tailed) but the model's predictive power is slightly less than the relationship between cad and fertilizer, with an adjusted R squared of .423.

DEP VAR: LOGTOT N: 24 MULTIPLE R: .669 SQUARED MULTIPLE R: .448						
ADJUSTED SQUARED MULTIPLE R: .423 STANDARD ERROR OF ESTIMATE: 1.172						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	20.326	4.085	0.000	.	4.976	0.000
LOGPEA	-4.536	1.074	-0.669	1.000	-4.224	0.000
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	24.524	1	24.524	17.846	0.000	
RESIDUAL	30.232	22	1.374			

Data used and summary statistics for variables used in the preceding analysis are found in Appendix G.

4.2.2.4 The NAP and other species

The above analysis suggests that changing agricultural policy has a direct impact on the cad system. While evidence is only circumstantial or at best anecdotal, the NAP also appears to be having a positive impact on other woody perennial species. One farmer (not an informant) reported that given the difficulty and cost in obtaining inputs for peanuts combined with the low producer price, he was now taking better care of (and excluding others from use of) his on-farm *Siszyphus mauritiana* trees. For the past two years he had been harvesting his "jujube" (*Siszyphus* berries) for sale in both the local market and in Thiès and Dakar¹²².

Two informants reported that due to the impact of the NAP, they intentionally left one field each in fallow for the past two years to regenerate in *Balanites aegyptiaca*¹²³. Their intention is to harvest *Balanites* fruit for sale to artisanal oil pressers in Tilmakha and Mékhé.

In general, there appears to be quite a trade in both primary and secondary forest/tree products in the NCPB. Tables 4.12 through 4.16 provide information from the socio-economic survey on the number of informants buying and/or selling, the price per unit and the species for fodder/forage, food, medicinal, fuelwood and service wood species.

¹²²Jujubes (either fresh or dried) are a very common snack available at almost every roadside stands in both rural and urban areas throughout Senegal.

¹²³Both fields had a substantial presence of older *B. aegyptiaca* trees and literally hundreds of seedlings.

Table 4.12

**Fodder/Forage Species
Species Bought And Sold**

Species	Buying			Selling		
	No. resp.	Price (cfa)	Unit	No. resp.	Price (cfa)	Unit
<i>Acacia albida</i>	4	200	basin	9	200	basin
<i>Acacia raddiana</i>	1	150	basin	1	100	basin
<i>Balanites aegyptiaca</i>	0	n/a	n/a	1	250	pot
<i>Celtis integrifolia</i>	1	50	pile	0	n/a	n/a
Source: Survey data.						

When this information is compared with tree densities from the Biophysical Inventory (see Appendix K), the results suggest that for many of the above species, regeneration rates are relatively stable as evidenced by the high proportion of trees in the 1-5cm diameter class. In particular, such "high value" multi-purpose species such as *A. albida*, *A. raddiana*, *B. aegyptiaca*, *Borassus aethiopum*, *Prosopis africana* and *S. mauritiana* all have relatively high densities in the 1-5cm diameter class.

Species such as *Adansonia digitata*, *Cassia sieberiana*, *Grewia bicolor* and *Parinari macrophylla*, while showing no regeneration, are nevertheless relatively well represented in the other diameter classes. This suggests that there is more than likely some regeneration of these species occurring which was not identified during the Biophysical Inventory¹²⁴.

4.2.2.5 The NAP and investment in agriculture/natural resources

During group discussions, many farmers remarked (rather emphatically on occasion) that agriculture (particularly peanut culture) under the NAP was no longer "rentable", i.e., no profit could be made on growing peanuts given the cost of the inputs and the low

¹²⁴Cad seedlings and seedlings of certain other species (e.g., *B. aethiopum* and *B. aegyptiaca*) are easy to spot in the dry season as they do not lose their leaves. However, seedlings of species such as *A. digitata* and *P. macrophylla* are much more difficult to spot given their deciduous nature. It is assumed that quite a number of deciduous species seedlings in the 1-2cm range were missed during the course of the Biophysical Inventory.

Table 4.13
Food Species
Species Bought and Sold
(cfa)

Species	Sell (cfa)/unit						Buy (cfa)/unit					
	No. Inf.	Pile	Bowl	Kg	Basin	Sack	No. Inf.	Pile	Bowl	Kg.	Basin	Sack
<i>Adansonia digitata</i>	5	25/POD	n/a	75	500/1500	n/a	8	15/25/30/POD	n/a	100/150	1000	n/a
<i>Anacardium occidentale</i>	2	10/25	50	n/a	n/a	n/a	4	10/25	50	70	n/a	n/a
<i>Balanites aegyptiaca</i>	0	n/a	n/a	n/a	n/a	n/a	3	n/a	n/a	25 (OIL)	800	n/a
<i>Citrus sinensis</i>	0	n/a	n/a	n/a	n/a	n/a	5	n/a	n/a	75/100	n/a	n/a
<i>Detarium microcarpum</i>	0	n/a	n/a	n/a	n/a	n/a	1	n/a	n/a	n/a	n/a	n/a
<i>Detarium senegalensis</i>	1	n/a	n/a	n/a	3000	n/a	1	100	n/a	n/a	n/a	n/a
<i>Diospyros mespiliformis</i>	1	n/a	n/a	n/a	n/a	n/a	1	10	n/a	n/a	n/a	n/a
<i>Ficus gnaphalocarpa</i>	0	n/a	n/a	n/a	n/a	n/a	1	n/a	n/a	50	n/a	n/a
<i>Mangifera indica</i>	4	25	n/a	n/a	n/a	1500/2000	16	25/50	50/100	n/a	500/750	2000
<i>Parinari macrophylla</i>	2	n/a	n/a	25 (OIL)	900	n/a	1	n/a	n/a	n/a	250	n/a
<i>Partia biglobosa</i>	0	n/a	n/a	n/a	n/a	n/a	2	10/15	n/a	n/a	n/a	n/a
<i>Phoenix spp.</i>	0	n/a	n/a	n/a	n/a	n/a	1	n/a	n/a	800	n/a	n/a
<i>Psidium spp.</i>	1	100	n/a	n/a	n/a	n/a	3	25/50	200	n/a	n/a	n/a
<i>Tamarindus indica</i>	2	n/a	n/a	250/400	n/a	n/a	2	n/a	n/a	200/300	n/a	n/a
<i>Zizyphus mauritiana</i>	0	n/a	n/a	n/a	n/a	n/a	1	50	n/a	n/a	n/a	n/a
Source: Survey data.												

Source: Survey data.

Table 4.14

**Fuelwood Species: Species Bought and Sold
(cfa)**

Species	Sell			Buy		
	No.	Price	Unit	No.	Price	Unit
<i>Balanites aegyptiaca</i>	0	0	0	2	1500	charette
<i>Parinari macrophylla</i>	0	0	0	1	1000	charette
<i>Pterocarpus erinaceus</i>	0	0	0	1	1000	charette
Source: Survey data.						

Table 4.15

Service Wood Species: Species Bought and Sold
(cfa)

Species	Sell			Buy		
	No. inf.	Price (cfa)	Unit	No. inf.	Price (cfa)	Unit
<i>Acacia albida</i>	1	600	4m	2	150/300	3m
<i>Azadirachta indica</i>	1	1500/2000	4m	0	n/a	n/a
<i>Borassus aethiopum</i>	0	n/a	n/a	1	500	3m
<i>Eucalyptus spp.</i>	1	600	4m	0	n/a	n/a
<i>Prosopis africana</i>	0	n/a	n/a	2	750/1000	3m
<i>Pterocarpus erinaceus</i>	0	n/a	n/a	2	300/500	3m
Source: Survey data.						

Table 4.16

**Medicinal Species: Species Bought And Sold
(Frequency of Responses)**

[illegible]

producer prices. As a result, many farmers were seeking to expand their extra-agriculture activities (discussed in Chapter 5) to compensate for loss of income from peanuts and the absence of any alternative cash crops.

In order to gauge if and how informants might reinvest money in agriculture and/or natural resources, they were asked what they would do if they won one million cfa (approximately \$4000). Responses to this open-ended question suggest that the majority of informants (43 or 59.7%) would not invest in agriculture at all should surplus funds be available while 29 informants (40.3%) indicated that they would invest at least a portion of these funds in agriculture. (In the case of this study, agricultural activities are considered to be investments directly related to cropping; livestock, other than traction animals are not included.)

The results of what informants would do with this money are presented in Table 4.17. For non-agricultural activities, the most frequent responses were for building or rebuilding a house "en dur" (cement--22.6%) followed by assuring the supply of family food through purchasing reserves (14.3%).

Agricultural activities accounted for 24.4% of all responses and the most frequently cited investment possibilities were the purchase or new tools and equipment (9.7%), seed (8.8%) and traction animals (5.1%). One informant indicated that he would use the funds to rent more land while another informant indicated he would like to establish a fruit tree (mango) orchard with the money. Frequency of responses for the purchase of livestock for extensive grazing and/or fattening accounted for 18.9% of responses while religious activities (related to the marabouts) and assistance to children or parents accounted for 6.0% and 6.9% of responses respectively.

No informant said that he would invest a portion of these excess funds in any sort of land stewardship/natural resource management activities for his farm. In spite of this finding, during the course

of the study, it became apparent that some were farmers were meant to be farmers (as evidenced by their knowledge of agriculture, soils, the condition of their farms, etc.), while others were farmers simply for lack of alternate employment opportunities. The preceding question afforded the opportunity to explore the difference between these two groups of farmers by testing the following hypothesis:

Hypothesis 4.4

- $H_{(0)}$: There is no difference in the cad regeneration rate between informants who would invest in agriculture and those who would not.
- $H_{(1)}$: Informants who would invest all or part of the "extra" money described above in agriculture activities would be more likely to have a higher cad regeneration rate (AALB1).

Table 4.17

**Actions Taken On Winning One Million CFA
(Frequency and Percent of Responses)**

Action	No.	Per.
MISCELLANEOUS		
Build/rebuild house	49	22.6
Assure family food supply (purchase food)	31	14.3
Purchase clothes	2	0.9
Take a second wife	4	1.8
Pay off debts	2	0.9
Invest in commerce	6	2.8
Purchase medicine	1	0.5
TOTAL MISC.	95	43.8
AGRICULTURE		
Purchase seed	19	8.8
Purchase new ag material (tools/equip.)	21	9.7
Establish a fruit tree orchard	1	0.5
Acquire more land	1	0.5
Purchase traction animals	11	5.1
TOTAL AGRICULTURE	53	24.4
ANIMALS		
Purchase animals ("de rente")	27	12.4
Purchase animals (fattening)	14	6.5
TOTAL ANIMALS	41	18.9
RELIGION		
Purchase house in Touba	3	1.4
Purchase a prayer mat	1	0.5
Give to marabouts	6	2.8
Go to mecca	3	1.4
TOTAL RELIGION	13	6.0
AID/ASSISTANCE		
Help parents	11	5.1
Help children	4	1.8
TOTAL AID	15	6.9
Source: Survey data.		

Tukey's HSD test was used (which accounts for unequal n's) to test this hypothesis. The results, presented below, indicate that there is a significant difference (at the 90% confidence level one-tailed) in cad regeneration rates between farmers who would invest in agriculture and farmers who would not. Those farmers who indicated that they would invest in agriculture had a mean regeneration rate of 1.0 while informants who indicated they would not invest in agriculture had a mean regeneration rate of 0.70. The results suggest

in part that informants who are likely to invest in agriculture are also more likely to be protecting cad regeneration.

SUMMARY STATISTICS FOR AALB1

BARTLETT TEST FOR HOMOGENEITY OF GROUP VARIANCES

CHI-SQUARE = 4.282 DF= 1 PROBABILITY = .039

OVERALL MEAN = 0.829 STANDARD DEVIATION = 0.846

POOLED WITHIN GROUPS STANDARD DEVIATION = 0.837

T STATISTIC = -1.572 PROBABILITY = .120

4.3 Conclusions and recommendations

The preceding analyses suggest that the majority of informants make a distinction between maintaining soil fertility and increasing yields. Farmer-based solutions to the former center around the use of traditional technologies (i.e., the use of manure, cad and other on-farm trees), while solutions to the latter tend to center around policy (credit/pricing) and more modern technologies (fertilizer).

Unfortunately, this distinction has not been taken into consideration by the GOS and donors. Since the 1970's (when much of the original research on the cad system and other traditional methods of maintaining soil fertility were abandoned), the GOS and donors have tended to focus agriculture research and development programs on "modern" technologies (fertilizer response, animal traction and improved varieties), and on macro-economic issues (generally to facilitate adoption of these techniques), to the neglect of traditional methods of maintaining the soil base. In turn, these R&D programs were a major determinant of agricultural policy.

The underlying premise of these policies, whether based on heavily subsidized inputs or a more free market approach, was accelerated agricultural development. In either case, little attention was given to the relationship between natural resources and agriculture in general, and the impact of changing agricultural policy on the natural resource base in particular. However, the micro-

economic adjustments made by individual farmers to these policy changes not only drive macro-outcomes but simultaneously influence environmental impact through changes in natural resource use patterns. The analyses presented in this chapter suggest that these micro-adjustments to policy changes made by farmers in the NCPB have had a significant impact on the *A. albida* system.

Among the external variables examined including those in Chapter 6, changing agricultural policy appears to have had the biggest impact on the *A. albida* system. Structural adjustment/NAP has resulted in a decrease in use of fertilizer among informants obliging them to return to more traditional methods of maintaining soil fertility. It has also led to a decrease in the area in peanuts and a concurrent shift from peanut culture to millet and cowpeas. In turn, these two actions have had a positive impact on the *A. albida* system.

Using the percent fertilizer subsidy and percent of arable land in peanut culture from 1965 to 1989 as indicators of changing agricultural policy, it was determined that since 1965, there is a highly significant inverse relationship between the amount of fertilizer subsidy and area in peanuts, and the distribution of *A. albida* by age class. This leads to two general conclusions. First, when fertilizer was cheap (i.e., highly subsidized and/or credit is easily forgiven as during the Programme Agricole period), farmers, being economically rational individuals, found it easier and cheaper to use fertilizer to maintain soil fertility rather than take care of their cad trees. Conversely, the removal/reduction of fertilizer subsidies under the NAP since 1986, has led to a return to more traditional methods of maintaining soil fertility, including a significant increase in the use of *A. albida*. Results of the biophysical inventory suggest that nearly one half of the fields surveyed have an adequate cad regeneration rate. When aggregated to the farm level, 23% of informants have an adequate regeneration rate

while 30% have an excellent regeneration rate, with an on-farm average of 100 seedlings/sprouts per hectare.

Second, while there is also a highly significant relationship between fertilizer subsidies and area in peanuts, it is also felt that the reduction in area in peanuts and a shift to cowpea and millet production has also had a positive impact on the *A. albida* system. Many informants argued that it is difficult to associate cad with peanuts due to the close between row spacing required for peanuts which makes cultivating around cad seedlings difficult. Additionally, mechanical peanut harvesting, according to informants, also causes considerable destruction of cad seedlings. The results of the analyses tend to support informant observations.

Additionally, while evidence was only anecdotal, changing agricultural policy in the form of the NAP also appears to have had a positive impact on other woody perennial species. Several informants reported that due to the increased price of inputs for peanut culture (particularly seed and fertilizer), certain on-farm tree resources such as *Z. mauritiana* and *B. aegyptiaca*, represented a means of replacing the income lost from peanuts. Results of the Biophysical Inventory suggest that regeneration rates for certain of these high value multi-purpose species are indeed quite high.

Chapter 5

OTHER EXTERNAL FACTORS

"Ca fait au moins six ou sept ans que les gens des Eaux et Forêts viennent au village¹²⁵."

Mohktar Gueye
NCPB Farmer (Bahkdas II)

5.1 Introduction

Chapter 4 examined the impact of changing agricultural policy on the *A. albida* system. However, other external variables such as level and type of informant formal education, level and type of agriculture or forestry training, and contact with extension agencies involved in forestry, natural resources and/or agriculture, might also have a direct bearing on the use of the *A. albida* system. Similarly, it is thought that the many forestry/natural resource-related projects currently operating in the NCPB would also have some influence. The general hypothesis here is that these types of variables would have a positive impact on the system

Drawing on the both the Socio-economic survey and the Biophysical Inventory, the purpose of this chapter is to explore the relationship between some of these variables and the *A. albida* system.

5.2 Education, Training and Extension¹²⁶

5.2.1 Formal education and the *A. albida* system

Responses to the series of education-related questions in the Socio-economic survey yielded a number of variables¹²⁷ which could be used to explore the relationship between formal education and the

¹²⁵It's been at least six or seven years since a forestry agent has been to the village.

¹²⁶Description of variables, data and summary statistics for all variables used in Chapter 5 analyses are found in Appendices L and M.

¹²⁷These variables include percent of adult and youth household members who are literate in French, Arabic and/or a local language.

A. albida system. While all of these variables will ultimately be used in the principal components analysis in Chapter 8, as a preliminary indication of the importance of formal education, only one variable - ATOTLIT (the percent of adults in a household who are at least partially literate in one or a combination of French, Arabic, Wolof or Serer) will be used at this level of analysis. Two hypotheses will be tested. The first is:

Hypothesis 5.1

$H_{(0)}$: There is no relationship between farm/household literacy rate (ATOTLIT) and average farm *A. albida* density/ha (TOTCAD).

$H_{(1)}$: Average farm *A. albida* density/ha (TOTCAD) is a positive function of household adult literacy rate (ATOTLIT).

DEP VAR: TOTCAD N: 72 MULTIPLE R: .056 SQUARED MULTIPLE R: .003						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 11.634						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	10.806	1.827	0.000	.	5.914	0.000
ATOTLIT	0.034	0.073	0.056	1.000	0.467	0.642
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	29.474	1	29.474	0.218	0.642	
RESIDUAL	9473.781	70	135.340			

The results of the regression suggest that there is no relationship between household literacy level and average cad density per hectare per farm. The null hypothesis must be accepted.

The second hypothesis concerns regeneration rates of *A. albida*. Given recent changes in agricultural policy and the NAP, it is expected that households with a higher literacy rate would be more cognizant of changing policies and are perhaps more inclined to begin to protect cad regeneration in the absence of fertilizer subsidies. The hypothesis is:

Hypothesis 5.2

$H_{(0)}$: There is no relationship between farm/household literacy rate (ATOTLIT) and average farm *A. albida* regeneration rate (AALB1).

$H_{(1)}$: Average farm *A. albida* regeneration rate (AALB1) is a positive function of household adult literacy (ATOTLIT).

DEP VAR: AALB1 N: 72 MULTIPLE R: .187 SQUARED MULTIPLE R: .035 ADJUSTED SQUARED MULTIPLE R: .021 STANDARD ERROR OF ESTIMATE: 0.837						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.691	0.131	0.000	.	5.258	0.000
ATOTLIT	0.008	0.005	0.187	1.000	1.593	0.116
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	1.776	1	1.776	2.537	0.116	
RESIDUAL	49.021	70	0.700			

The results of the regression again suggest that there is no relationship between household literacy rate and cad regeneration.

5.2.2 Agricultural training and the *A. albida* system

In terms of the possible influence of agricultural training on the *A. albida* system, the dependent variables of TOTCAD and AALB1 will again be used with the independent variable of AGCOEF¹²⁸. The assumption is that contact with external systems such as agricultural training would have a positive impact on the cad system. The hypotheses are:

Hypothesis 5.4

$H_{(0)}$: There is no relationship between formal agricultural training (AGCOEF) and average per farm cad density per hectare (TOTCAD).

$H_{(1)}$: Average per farm cad density (TOTCAD) is a positive function of formal agricultural training (AGCOEF).

Hypothesis 5.5

$H_{(0)}$: There is no relationship between formal agricultural training (AGCOEF) and average farm *A. albida* regeneration rate (AALB1).

$H_{(1)}$: Average per farm regeneration rate (AALB1) is a positive function of formal agricultural training (AGCOEF).

¹²⁸AGCOEF--"agriculture training coefficient." This is a composite variable which represents the number of agriculture training sessions in which a farmer participated plus the number of those sessions which discussed trees in agriculture and/or soil conservation. AGCOEF was weighted by a factor of two.

DEP VAR: TOTCAD N: 72 MULTIPLE R: .079 SQUARED MULTIPLE R: .006						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 11.616						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	10.935	1.519	0.000	.	7.198	0.000
AGCOEF	0.521	0.790	0.079	1.000	0.660	0.512
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	58.696	1	58.696	0.435	0.512	
RESIDUAL	9444.559	70	134.922			

DEP VAR: AALB1 N: 72 MULTIPLE R: .039 SQUARED MULTIPLE R: .001						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 0.851						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.814	0.111	0.000	.	7.309	0.000
AGCOEF	0.019	0.058	0.039	1.000	0.324	0.747
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.076	1	0.076	0.105	0.747	
RESIDUAL	50.721	70	0.725			

The results of the regression suggest that there is no relationship between formal agricultural training and either average cad density per hectare per farm or cad regeneration rate. The null hypothesis must be accepted for both of the above hypotheses. In sum, agricultural training appears to have little if any impact on use of the *A. albida* system among informants.

5.2.3 Forestry training and the *A. albida* system

In terms of the possible influence of formal forestry training on the *A. albida* system, TOTCAD and AALB1 are once again used as the dependent variables with FORCOEF¹²⁹ as the independent variable. The assumption is once again that contact with external "systems"

¹²⁹FORCOEF--"forestry training coefficient"--this is a composite variable which represents the number of forestry-related training sessions in which a farmer participates plus the number of those sessions which discussed trees in agriculture and/or soil conservation.

providing forestry training would have a positive impact on the cad system. The hypotheses are:

Hypothesis 5.7

$H_{(0)}$: There is no relationship between formal forestry training (FORCOEF) and average per farm cad density per hectare (TOTCAD).

$H_{(1)}$: Average per farm cad density (TOTCAD) is a positive function of formal forestry training (FORCOEF).

Hypothesis 5.8

$H_{(0)}$: There is no relationship between formal forestry training (FORCOEF) and average farm *A. albida* regeneration rate (AALB1).

$H_{(1)}$: Average per farm regeneration rate (AALB1) is a positive function of formal agricultural training (FORCOEF).

DEP VAR: TOTCAD N: 72 MULTIPLE R: .065 SQUARED MULTIPLE R: .004
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 11.627

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	11.673	1.478	0.000	.	7.898	0.000
FORCOEF	-0.706	1.287	-0.065	1.000	-0.549	0.585

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	40.709	1	40.709	0.301	0.585
RESIDUAL	9462.545	70	135.179		

DEP VAR: AALB1 N: 72 MULTIPLE R: .091 SQUARED MULTIPLE R: .008
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 0.848

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.799	0.108	0.000	.	7.405	0.000
FORCOEF	0.071	0.094	0.091	1.000	0.761	0.449

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.417	1	0.417	0.579	0.449
RESIDUAL	50.380	70	0.720		

The results of the regression suggest that as in the case of agricultural training, there is no relationship between formal forestry training and either average cad density per hectare per farm or cad regeneration ration. The null hypothesis must again be

accepted; forestry training appears to have little if any impact on use of the *A. albida* system.

5.2.4 Extension contact

5.2.4.1 Background

Another variable which may have a positive impact on the *A. albida* system is contact with the various extension services and projects currently operating in the NCPB. In the past, Senegal's national extension programs had primarily a commodity focus. Agriculture extension used to be carried out by the Ministry of Rural Development's Regional Development Agencies--RDAs (SRDP--Société Regionale du Développement) which were responsible for rural development activities within a fixed agro-ecological zone. While the RDAs' mandate included broad development objectives and activities, their extension actions were generally focussed on a particular commodity or group of commodities. SODEVA was the RDA for the Peanut Basin and peanuts were its primary focus.

Senegal's New Agricultural Policy, with its emphasis on privatization, provided for drastic cuts in the size and scope of most of Senegal's RDAs. SODEVA underwent a 75% cut in personnel and funding (USAID 1991) and is currently only active in very limited types of activities (mainly cowpea and nematocide programs). Since 1987, the World Bank has been working with the GOS to design and implement a program intended to reform and reanimate government extension services based on the use of the Training and Visitation (T&V) methodology. The pilot program (Programme Pilote d'Amélioration des Services d'Appui aux Agriculteurs--PAGRI) was followed by the Programme Nationale de Vulgarisation Agricole (PNVA) which began in 1990. The PNVA intends to cover 60% of Senegal's rural population in a period of four years.

As the PNVA is just beginning, it is difficult to predict the effect it will have on Senegal's current extension situation. Not the least of its problems will be the issue of sustainability of an

extension system which is donor driven and supported. In terms of natural resource activities, however, problems with the T&V system are already more apparent. To date, there is not a clear picture of how agroforestry and other natural resource activities will be integrated into the T&V calendar. As agroforestry involves both crops and trees, Senegal's Ministry of Nature Protection's Directorate of Soil Conservation and Reforestation (MPN/DCSR) also has an agroforestry extension mandate but the relationship between DCSR and the PNVA has yet to be defined.

While some criticisms of the T&V approach were presented in Chapter 1, they seem rather moot after implementation of the socio-economic survey. There is little agriculture or forestry/natural resources extension taking place among informants and the PNVA has yet to make its presence known. A total of 21 informants (29.17%) received extension visits in 1989 for a total of 66 visits distributed among four organizations (SODEVA, DEF, MOA, and MOH) and two projects (PRECOBA and FIDA). Perceived extension visits among informants for 1989 are summarized in Table 5.1.

In terms of natural resource-related extension visits, only two extension visits dealt directly with cad. One was a visit to a village by a DEF agent to discuss the role and importance of cad. The other was by an agent from the FIDA *A. albida*/agroforestry project¹³⁰ to discuss goals and objectives of the project. However, informants from this particular village along with discussions with other members of the village indicated that on the whole, they were not satisfied with the project. The general feeling was that one did not need to plant cad trees as there was an abundance of regeneration in the area. What they wanted was assistance to protect the tree

¹³⁰This project hopes to rehabilitate the cad system by providing seedlings to farmers (free of charge) and by encouraging planting, care and maintenance of the seedlings in exchange for providing the village with items such as grain mills, peanut shellers and other equipment.

resources that they already had. To them (a Serer village), this meant an increased role for DEF agents in protection and control rather than extension.

Only two out of five DEF visits dealt with tree planting, the remainder were protection/control (policing) related visits. Informants in general found the majority of forestry related extension visits to be very useful with only the informants from the village visited by the FIDA cited above, indicating that the visit was only somewhat useful.

5.2.4.2 Extension contact and the *A. albida* system

Extension - as measured by the variable EXTRATE¹³¹ - is also expected to have a positive impact on the *A. albida* system (TOTCAD and AALB1). However, while farmers were asked to provide information on previous agriculture and forestry training, they were not asked to specify extension contacts prior to 1989 other than an indication of whether they had been visited by a DEF/SODEVA agent or not. As a result, the effects of previous extension contacts on the system would be unknown and impossible to quantify. For purposes of this analysis, however, it is assumed that informants who had extension contact in 1989 are probably the ones that also had more frequent contact in previous years. Thus, the hypotheses are:

Hypothesis 5.11

$H_{(0)}$: There is no relationship between extension contacts (EXTRATE) and average per farm cad density per hectare (TOTCAD).

$H_{(1)}$: Average per farm cad density (TOTCAD) is a positive function of extension contacts (EXTRATE).

¹³¹"Extension rate"--a composite variable which represents the total number of visits made by extension agencies during the last campaign times the total number of different agencies.

Table 5.1
Extension Activity 1989

Organization	Theme	No. Resp.	Number of visits	Spoke with		Month												Utility				
				Men	Women	VIL	J	F	M	A	M	J	J	A	S	O	N	D	Very	Some	Ltd.	No. new
SODEVA	Extension -- improved millet (Souss III)	1	2	1	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	2	
	Improved cowpea/ millet seed	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	
SODEVA	Nematocides	8	33	8	0	14	0	0	0	2	5	3	9	6	1	1	0	2	10	6	6	
SODEVA	Socio-economic study	1	12	1	0	0	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	
DEF	Tree planting	2	2	2	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	
DEF	Protection/ control of natural re- sources	3	4	3	1	0	1	1	2	0	0	0	0	0	0	0	0	3	1	0	0	
FIDA	Reestablishment of A. albidia	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	
MOH	Vaccination of children & pregnant women	9	9	3	3	1	3	2	2	0	0	0	0	0	0	0	0	9	0	0	0	
MOA	Creation of a locust association	1	1	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	
PRECOBA	Improved stoves "baa ak saaf"	1	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	0	
TOTAL		28 ¹³²	66	22	6	16	5	4	8	5	7	6	11	7	7	3	2	1	18	12	6	8

Source: Survey data.

Source: Survey data.

¹³²This total is higher than the number of respondents actually visited due to the fact that some respondents were visited by more than one organization.

Hypothesis 5.12

$H_{(0)}$: There is no relationship between extension contacts (EXTRATE) and average farm *A. albida* regeneration rate (AALB1).

$H_{(1)}$: Average per farm regeneration rate (AALB1) is a positive function of extension contacts (EXTRATE).

DEP VAR: TOTCAD N: 72 MULTIPLE R: .031 SQUARED MULTIPLE R: .001						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 11.646						
VARIABLE TAIL)	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2
CONSTANT	11.502	1.464	0.000	.	7.857	0.000
EXTRATE	-0.100	0.382	-0.031	1.000	-0.261	0.795
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	9.210	1	9.210	0.068	0.795	
RESIDUAL	9494.045	70	135.629			

DEP VAR: AALBI N: 72 MULTIPLE R: .047 SQUARED MULTIPLE R: .002						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 0.851						
VARIABLE TAIL)	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2
CONSTANT	0.844	0.107	0.000	.	7.892	0.000
EXTRATE	-0.011	0.028	-0.047	1.000	-0.397	0.693
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.114	1	0.114	0.157	0.693	
RESIDUAL	50.683	70	0.724			

The results of the regression suggest if the assumption about previous extension contacts is correct, extension contacts appear to have little, if any influence on the *A. albida* system. In both cases, the null hypothesis must be accepted.

5.3 The impact of projects

To date, the method of choice in dealing with natural resource problems in Senegal has been the use of a "projectized" approach. There are no less than four bilateral and two PVO natural resource-related projects currently operating in the NCPB. Bilateral projects include: (i) the "Projet de Reboisement Communautaire dans le Bassin

Arachidier" (PRECOBA), supported by the Germans and based in Fatick; (ii) the "Projet de Reboisement Villageois dans le Nord-ouest du Bassin Arachidier (PRECOBA), supported by the Dutch and based in Thiès; (iii) the Projet de Développement Agroforestier (PDA), supported by FIDA and based in Diourbel; and (iv) the "Senegal Reforestation Project", supported by USAID and based in Dakar¹³³. FVO projects include: (i) Foster Parents Plan International (FPPI) forestry activities around Thiès; and (ii) "Cooperazione allo Sviluppo dei Paesi Emergenti" (COSPE) forestry activities around Diourbel.

In addition to having a limited impact (only two villages had contact with any of the current projects), the problems with a project approach to natural resources in the Sahel have been well documented. Taylor and Soumaré (1983) provide an excellent analysis of some of these problems. Among the more "visible" problems are a lack of coordination and communication between projects, competition for quality personnel between projects and the proliferation of "primes" and other perks, and a growing web of special conditions attached by the various funding organizations. Other problems cited by Taylor and Soumaré (*op. cit.*) include a failure to link research and training in projects, too short a commitment/time frame, too much focus on quantitative aspects (unrealistic project assumptions and targets), and a general neglect of government absorptive capacity. The project approach in Senegal has experienced many of these same difficulties.

While an evaluation of the impact of these projects is well beyond the scope of this study, some commentary appears necessary, particularly in the context of research findings discussed above. First, projects such as PREVINOA, Foster Parents Plan and PRECOBA assume that "sensibilisation" (or increasing farmer awareness of environmental problems/solutions) is the key to improved natural

¹³³The project has a national rather than a regional focus.

resource management. However, results of the study suggest that when farmer livelihoods/existence are threatened by natural resource degradation combined with changes in agriculture policy, they may be more willing to take action to reverse degradation, so that little sensibilisation is needed.

Second, projects such as USAID's Senegal Reforestation Project and FIDA's Agroforestry Project in Diourbel and Bambey assume that farmers lack resources for natural resource management activities. Thus, FIDA provides nurseries, fencing, materials and technical assistance, while USAID provides matching grants ("co-investissement") to farmers to undertake natural resource activities. However, the results of the study suggest that when macro-economic and environmental conditions are such that the farmer's very existence is in jeopardy, sufficient resources (including plant material via natural regeneration) and skills are available at the village/farm level to undertake a number of natural resource activities with little external input.

Finally, project assistance may be creating a project mentality among many NCPB farmers. Even the most isolated farmer has heard of projects in other villages such as village woodlots, wells, gardening, etc., and rightfully wants his or her share of the pie. However, group discussions with informants and other farmers suggest that in general, they do not equate projects with development but with the resources (particularly money and employment) that accompany them. More often than not, the village/farmers have little interest in the specific goals and objectives of the project itself.

A village's desire to have a woodlot may be a case in point. In one of the study villages (unnamed), a past development project (unnamed) wanted to assist a village in establishing a village nursery and woodlot. The village was eager to participate in this activity not because of the expected benefits from the trees, but because the village well would have to be upgraded in order to provide sufficient

water for the nursery. When this was accomplished, the village soon forgot about the nursery and woodlot; the former ceased operation after the first year while the latter has suffered due to lack of maintenance and protection.

5.4 Conclusions and recommendations

Based on the analyses presented above and in Chapter 4, the following general recommendations are offered with regard to the *A. albida* system and improved natural resource management in the NCPB. First, the economic incentives facing the NCPB's rural populations are major determinants of how natural resources are managed. Maintenance and wider use of the *A. albida* system and improved natural resource management may depend more on general agricultural and economic policies than on policies and projects which focus on the system itself. In short, farmers appear to respond more to a program approach than to the traditional project approach supported by the GOS and many donors.

Second, the fact that external variables related to education, training and extension were found to have little impact on the cad system, needs to be tempered with one observation; since the demise of the Programme Agricole, few informants have had the opportunity to participate in agriculture and forestry training sessions or have been visited by agriculture and/or forestry extension agents. Only 19 informants had ever participated in an agriculture training session, the majority of which were conducted in the distant past. Similarly, only 14 informants had ever received any formal forestry training, again the majority of which took before 1980. The situation for extension visits is much the same. In 1989 only 11 informants reported having had any ag-related extension contact while only two informants reported any forestry/natural resource related extension contact. Only one of these visits had to do with *A. albida*.

Given this situation, the conclusion is NOT that extension and training do not have an impact on the *A. albida* system, but that too

few informants have received training and extension advice on the system or other natural resource conservation and management techniques to make a difference. The majority of NCPB farmers have essentially been forgotten since the Programme Agricole period, and neither the plethora of projects nor the proposed PNVA has moved in to fill what appears to be a glaring gap.

Finally, as anyone familiar with the NCPB will note, there is one glaring omission in terms of external variables examined. The role of the marabouts and the Islamic brotherhoods in natural resource management (or in some cases destruction), was intentionally omitted from the study. It was considered to be far too complicated (as well as perhaps too important) to be addressed adequately in the context of this study, and merits being treated as a separate research endeavor.

Two of the three main Islamic brotherhoods are located in the NCPB: (i) the Tidjanes with their center in Tivouane and composed of mainly Toucouleur but also including about one-half of the Wolof population; and (ii) the Mourides with their center in Touba-Mbacké and with a practically all Wolof ethnic composition (Jeune Afrique 1983). In terms of agriculture and peanut production in the Peanut Basin, the Mourides exert a much greater influence than the Tidjanes. Of the 120 large-scale landholdings in the Peanut Basin, over 100 belong to the Mouride marabouts (Colvin 1983).

The Mourides have been and continue to be responsible for much of the ecological devastation that has occurred both in the "old" Peanut Basin, and in the expanded Peanut Basin. In the past, with the introduction of peanuts as a cash crop, mouride "taalibés" (disciples), taking advantage of the new market economy and incited by their "marabout" (quranic teacher/religious leader) quickly expanded peanut production by putting more land into peanut cultivation and by clearing new lands usually at the expense of maintaining soil fertility.

Some estimates placed Mouride (disciples and marabouts) peanut production as high as 75% of total production in 1957-58. More recently, the large-scale Mouride landholdings account for only 5-6% of production (Colvin 1983). However, in 1990 the Mouride marabout succeeded in getting several hundred square miles of classified (and protected) silvo-pastoral zone declassified, and clearing for peanut production began shortly thereafter.

Clearly, the role of the marabouts and brotherhoods in natural resources management in the NCPB cannot be neglected and the subject surfaced many times during group discussions. Jokingly, and with farmers and colleagues alike, the principal investigator suggested that with only two actions he could have the entire Peanut Basin green with trees in two years. The first action would be to reduce the amount of rural tax paid by farmers who maintained a certain level/number of cad trees on their fields. The second would be to make a "contribution" to both the Mouride and Tidjane marabouts "inspirational" fund in exchange for encouraging their respective disciples to plant trees and conserve natural regeneration. However, instead of a joke, the majority of farmers thought that this was the best course of action.

CHAPTER 6

FINANCIAL RETURNS TO *A. ALBIDA*

"Il faut vraiment le dire; le sol est arrivé
à un stade de dégradation sévère et je pense
que c'est seul le cad qui peut nous aider au
moins à le restaurer et à le défendre."

Souleye Diokhané, NCPB farmer
(Tiala)

6.1 Introduction

The micro-economic adjustments made by individual farmers to agriculture policy changes in Senegal not only drive macro-outcomes but simultaneously influence environmental impact through changes in natural resource use patterns. The analyses presented in Chapter 4 suggest that these micro-adjustments to policy changes made by farmers in the NCPB have had a significant impact on the *A. albida* system.

Among the external variables examined in Chapter 4, changing agricultural policy appears to have had the biggest impact on the *A. albida* system. Structural adjustment/NAP has resulted in a decrease in use of fertilizer among informants, apparently obliging them to return to more traditional methods of maintaining soil fertility. It has also led to a decrease in the area in peanuts and a concurrent shift from peanut culture to millet and cowpeas. In turn, these two actions appear to have had a positive impact on the *A. albida* system.

In this context, a key premise is that the use of *A. albida* makes financial sense to the farmer in the current agriculture policy/price environment. The purpose of this section is to conduct a financial analysis of some possible agricultural "interventions" for Senegal's North Central Peanut Basin. These interventions include: (i) doing nothing (the base case scenario); (ii) a moderate intensification of agriculture through the use of chemical fertilizer; (iii) a "high input" (fertilizer and mechanization) scenario; and (iv) increasing yields/farmer income through the introduction of *A. albida* via natural regeneration with benefits of maintenance of soil

fertility, increased crop yields, and increased wood and forage supplies.

In order to explore the impact that fertilizer subsidies might have (or have had) on the use of the *A. albida* system, three additional scenarios are examined: (i) a moderate intensification of agriculture through the use of chemical fertilizer subsidized at 50%; (ii) a "high input" (fertilizer and mechanization) scenario with fertilizer subsidized at 50%; and (iii) increasing yields/maintaining soil fertility through the introduction of *A. albida* via natural regeneration. The additional cad benefits of increased wood (fuelwood and construction wood) and forage supplies were not included in this last model for two reasons. First, group discussions with farmers suggested that wood and forage supplies were more plentiful during the Program Agricole period and came not only from cad but from other species which are currently not as plentiful. Second, excluding these benefits helps to not "overstate" the financial returns to the *A. albida* system and facilitates comparisons between models.

6.2 General assumptions

The following are the general assumptions used in the analysis:

- (i) **Farm size/rotations:** all scenarios/models assume that a farmer possesses a minimum of two hectares on which he plants one hectare of millet/sorghum and one hectare of peanuts and practices crop rotations. This mix remains constant over the period of analysis, 20 years;
- (ii) **Crop costs and revenues:** Costs and benefits for millet and peanut production are based on crop budgets developed by Martin (1988) for the Central Peanut Basin, as updated by Sidibé (1990).
- (iii) **Rainfall:** rainfall is not constant over the period of analysis. Rainfall is perhaps the most limiting factor in terms of NCPB crop yields. However, it is

not so much total rainfall as rainfall distribution throughout the growing season. Using average total rainfall for the Departments of Thiès and Diourbel as the independent variable, and average millet and peanut yields/ha for the same two Departments as the dependent variables, regression analysis suggests that there is indeed no significant relationship between total rainfall and crop yields.

However, when the average number of days of rainfall (AVDAY) is used as the independent variable, the relationship is highly significant for both millet (YLDMIL) and peanuts (YLDPEA) as indicated below.

DEP VAR: YLDMIL N: 24 MULTIPLE R: .538 SQUARED MULTIPLE R: .289 ADJUSTED SQUARED MULTIPLE R: .257 STANDARD ERROR OF ESTIMATE: 151.736						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	54.643	145.159	0.000	.	0.376	0.710
AVDAY	11.283	3.772	0.538	1.000	2.991	0.007
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	206010.634	1	206010.634	8.948	0.007	
RESIDUAL	506524.105	22	23023.823			

DEP VAR: YLDPEA N: 24 MULTIPLE R: .462 SQUARED MULTIPLE R: .214 ADJUSTED SQUARED MULTIPLE R: .178 STANDARD ERROR OF ESTIMATE: 240.767						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	157.141	230.331	0.000	.	0.682	0.502
AVDAY	14.633	5.985	0.462	1.000	2.445	0.023
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	346488.869	1	346488.869	5.977	0.023	
RESIDUAL	1275315.089	22	57968.868			

In order to incorporate these findings into the analysis and therefore make it more realistic from a farmer's perspective, 20 random numbers were

generated based on the maximum and minimum average of rain days from Thiès and Diourbel data. The standard deviation for these numbers was calculated and the type of rainfall year (i.e., "good", "average" and "poor" was determined based on the standard deviation. Drawing on the above models and the randomly generated rainfall days, a "rainfall factor" was developed to adjust Martin's millet and peanut yields and production costs¹³⁴ over the 20-year period of the financial analysis. A more detailed explanation of the calculation of rainfall and soil factors is found in Appendix H.

- (iv) **Inorganic fertilizer:** chemical fertilizer has a positive impact on yields only in average and good rainfall years. This assumption has some scientific basis (Kelly 1988) and is supported by discussions with informants and other farmers in the study area. The analyses therefore assume that in poor rainfall years, millet and peanut yields will not increase but will remain at levels equivalent to scenarios based on the use of no fertilizer.
- (v) **Loss of organic matter content/declining yields:** the absence of on-field trees translates into loss of organic matter content and subsequent decline in crop yields. As Chapter 3 points out, organic matter plays a critical role in terms of soil fertility and crop yields on the sandy soils of the NCPB; the structure and productivity of the soil are almost entirely dependent on organic matter content.

¹³⁴Crop yields and prices would vary by rainfall year; in above average rainfall years yields would be higher and prices would be lower. The only production costs to vary by rainfall year would be harvest labor.

Rates of loss of organic matter content from NCPB soils are estimated to be as high as 4% per year, although as Chapter 3 again points out, the presence of on-field trees can reduce this loss by nearly one-half.

For purposes of this analysis (the base case), it is assumed that the farmer initially has few if any *A. albida* trees (or other species) on his two fields and is therefore losing organic matter at the 4% annual rate. Translating organic matter loss into declines in crop yields becomes more problematic; there are few empirical studies which show the relationship between organic matter loss and declines in crop yields. Thus, a conservative estimate of a 0.5% annual reduction in average (over the 20-year period) millet and peanut yields is used for all models¹³⁵. This figure is consistent with available literature (Pieri 1989) and is used to estimate a "soil factor" (decline in yields due to decline in organic matter content) for each model/scenario. Crop yield declines due to this soil factor are provided in Appendix H.

- (vi) All interventions are mutually exclusive: The analysis assumes that all of the interventions/models are mutually exclusive, i.e.,

¹³⁵While this 0.5% rate is somewhat arbitrary, it is based on analyses presented in Chapter 3 with regard to declines in SOM content and on evidence which suggests that trends in crop yields in the NCPB have remained constant over the past 20 years. However, a key issue is the relationship between decreasing organic matter content and crop yields - no site specific information was found on this relationship. Thus, a 0.5% rate of yield decrease for millet and sorghum was retained so as not to overstate the gains from introducing *A. albida*. For individual farmers, this rate could vary from 0.0% to as high as 4% depending on the relationship between organic matter loss and crop yields.

choosing one activity necessarily precludes implementing another. For example, it is assumed that the farmer would use either natural regeneration of cad or planting but not a combination of both. This convention permits the use of Net Present Value (NPV) to determine whether the investments are financially viable. To the extent that they are similar investments, NPV can also be used to compare the various alternatives and select the best intervention among alternatives.

- (vii) **Discount rate:** while the analysis includes a sensitivity analysis of the models at various discount rates, a 20% real discount rate is used to compare models. This rate is substantially higher than the 10-12% more commonly used in financial analyses because of the farmer's propensity to be a risk averter. The farmer's intuitive discount rate would typically be much higher than bank lending rates, indices or other benchmark statistics or alternative investment opportunities more commonly used to determine discount rates¹³⁶.
- (viii) **Family/hired labor wage rate and availability:** All analyses use Martin's (1987) opportunity cost of labor, valued at 500 fcfa per 7 hour workday for both family and hired labor. The analysis makes no distinction between rainy season and dry season wage

¹³⁶Hoekstra (1983) argues that a more accurate discount rate than the society equivalent commonly used is one that combines a farmer's "risk discount rate" (a reflection of production trends), with a "consumption discount rate" which should reflect current and future consumption. For the case of farmers in the Peanut Basin, Hoekstra would argue that their personal discount rates would be significantly higher than society's discount rate given their downward or static trends in production combined with few resources or opportunities available for increasing consumption.

rates, although in practice, rainy season wage rates appear to be slightly higher as demand for labor increases for planting, weeding and harvesting activities.

Additionally, the analysis perhaps unrealistically assumes that there is no labor shortage in the North Central Peanut Basin and that all interventions can be implemented with family or hired labor. However, preliminary interviews with farmers in the Peanut Basin indicate that labor availability may be a constraint in agricultural activities due to migration/seasonal employment and other off-farm activities during both seasons.

6.3 Detailed description of models

6.3.1 The base case, or the cost of doing nothing (Model 3):

This model assumes that the farmer possesses a minimum of two hectares on which he plants one hectare of millet/sorghum and one hectare of peanuts. Crop rotations are practiced and the crop mix is constant over the 20-year period of analysis. Costs and revenues are based on crop budgets developed by Martin (1988) for the Central Peanut Basin as updated by Sidibé (1990). In the case of millet/sorghum and peanuts, the analysis uses "Module Number 3: intensification faible"¹³⁷.

The base case scenario assumes that yields are highly dependent on rainfall and costs and crop prices are adjusted for poor, average and good rainfall years as discussed above. Additionally, it is assumed that the farmer has few if any trees at the beginning of the analysis and per assumption (v) above, mean yields for millet/sorghum

¹³⁷"Intensification faible" appears to best approximate the current practice of the majority of farmers in the North Central Peanut Basin based on the results of the Biophysical Inventory and Socio-economic surveys as discussed in Chapters 3, 4, and 6. Martin (op.cit.) describes this practice as one which includes: mechanical seeding; no use of fertilizer; two mechanical weeding; and in the case of millet/sorghum, one "démariage rapide" (cursory thinning of plants), and for peanuts, a mechanical harvest.

and peanuts will decline at an annual rate of 0.5% per year over the period of analysis due to declining soil fertility and the loss of soil organic matter content.

6.3.2 Moderate intensification:

This scenario draws on Martin's "Module 2: intensification moyenne"¹³⁸ crop budgets for all crops for an average year with prices updated from Sidibé (1990). Increased costs for this scenario include fertilizer purchase, increased labor and traction inputs, and some additional fixed costs (equipment purchase and upkeep).

Increased benefits under this scenario are again drawn from Martin, and are estimated to be: a 150 kg/ha increase in millet/sorghum production; a 50 kg/ha increase in peanut production; and a 80 kg/ha increase in peanut hay production. However, these increases are dependent on rainfall and will only occur in good and average rainfall years.

This scenario again assumes that due to declining soil organic matter content, increased fertilizer use will not be sufficient to maintain yields at a constant level independent of rainfall. Thus, this model assumes that mean average yield (over the 20 year period) will still decline at the 0.5% rate, but the use of moderate amounts of chemical fertilizer will nevertheless result in increases in yields in good and average rainfall years. In poor rainfall years, however, fertilizer will have no impact and yields will be equivalent to the base case scenario.

6.3.3 High intensification:

This scenario is based on Martin's "Module 1: intensification élevée" for both crops¹³⁹. As for the moderate intensification

¹³⁸Differences from the base case scenario include: the use of 100 kg/ha of NPK (14-7-7) for millet/sorghum and 80 kg/ha of NPK (6-20-10) for peanuts; better plant thinning in the case of millet/sorghum; and better site preparation (radou mécanique) for peanuts.

¹³⁹For millet, differences from the base case scenario include the use of 100 kg/ha of NPK (14-7-7) and 50 kg/ha of urea accompanied by better plant thinning. For peanuts, the difference is in the use of

scenario above, increased costs are due to additional fertilizer and insecticide purchase, increased labor and traction inputs and some additional fixed costs.

Under this scenario, Martin estimates that: millet sorghum yields will increase by 300 kg/ha over the base case scenario; peanut yields will increase by 150 kg/ha; and peanut hay yields will increase by 240 kg/ha over the base case scenario. However, these increases are adjusted by the rainfall factor. Moreover, it is again assumed that due to declining soil organic matter content and cation exchange capacity, high input agriculture in NCPB will result in increased yields only in good and average rainfall years and that average mean yield for both millet/sorghum and peanuts will continue to decline at the 0.5% rate.

6.3.4 *A. albida* natural regeneration¹⁴⁰ (Model 4):

In this scenario using Model 3 as the base case, the costs and benefits of introducing *A.albida* on the farmer's two hectares (i.e., in association with both crops) via natural regeneration are examined. All costs and benefits associated with cad establishment are assumed to be mutually exclusive to avoid double counting. Costs of this intervention are estimated as follows:

6.3.4.1 Costs

- Variable costs/ha (materials): This scenario assumes that no or only a few *A. albida* seed trees are currently on the farmer's fields and that it will be necessary to purchase 10 kg of seed

120 kg/ha of NPK (6-20-10).

¹⁴⁰The option of introducing cad via seedlings was not considered as an option as this practice has not as yet been perfected and usually results in high seedling mortality rates and significantly higher costs. Moreover, as many farmers in the NCPB stall feed pods to their animals and the subsequent spreading of the resulting manure on fields significantly increases regeneration rates, it was felt that natural regeneration best approximates reality and possibilities in the NCPB.

Pods in years one and two at a cost of 50 fcfa/kg¹⁴¹. Due to erratic rainfall, it is expected that seed will need to be purchased for two years in order to assure a minimum density of young plants which can be eventually thinned to 40 mature trees per hectare.

- **Variable costs/ha (labor):**

Seeding: It is assumed that the seeds will be given to the farmer's domestic animals (sheep and goats) for concession feeding and for eventual dispersion in the fields via manure spreading¹⁴². Therefore, there are no labor costs for site preparation/sowing.

Staking: The normal practice in the North Central Peanut Basin (particularly among the Serer--see Pelissier 1967) is to make a phenotypic selection of young plants for form and growth and to stake these plants with "tuteurs" in order to enhance growth rates. The cost of this activity is estimated at about 4 person-days/ha and needs to be done for about 5 years, beginning in year 2.

Pruning: Pruning costs are divided into establishment costs in the initial years (initial pruning) and harvesting costs (service pruning, forage pruning and pod harvest) in later years. Initial pruning is usually carried out with the above staking and involves removal of lower branches to improve form and increase height growth rates. The cost of this activity is estimated at about 4 person-days/ha over a five year period beginning in year 2. Service pruning costs are estimated to be about 10 person-days/ha beginning in year 17 and continuing at that

¹⁴¹Costs estimated from discussions with women selling pods along the Thies-Diourbel road.

¹⁴²Concession feeding of pods and subsequent manure spreading significantly increases cad regeneration rates.

rate through year 20. Forage pruning costs begin in year 10 and are estimated to be about 4 person-days/ha through year 12, increasing to 8 person-days/ha in years 13 through 15, and 10 person-days/ha in years 16 through 20. Pod harvest costs begin in year 13 at 4 person-days/ha through year 17, 8 person-days/ha in years 17 through 19, and reach maximum costs of 10 person-days/ha in year 20. The model assumes no costs for harvesting fuelwood as this is considered to be an ancillary activity of pruning for service wood and forage.

Protection: During the first three years of growth, the trees will require some protection from grazing animals, particularly sheep and goats¹⁴³. This cost is estimated to be about 8 person days/ha during years 1 through 3. During the remaining period of analysis, some additional protection costs will be incurred given the necessity to patrol fields, control illicit harvesting, etc. Often, as discussed in Chapter 5, this is done on a group basis, but the costs to the individual farmer are estimated to be 2 person-days/ha for years 4 through 20.

- **Fixed costs:**

Fixed costs for the introduction of cad are assumed to be negligible. However, drawing on Martin's analysis for peanuts, fixed costs for small equipment are estimated to be fcfa 231 per year for years 1 through 6, 0 for years 6 and 7, and increasing to 2071 per year in years 8 through 20 to reflect repairs on traction equipment and additional use of traction animals.

¹⁴³Discussions with farmers suggest that sheep and goats are more a threat to young *A. albida* plants than cattle, as former are better adapted at removing the foliage without getting pricked by the thorns.

6.3.4.2 Benefits

Benefits from the introduction of *A. albida* include maintenance of soil fertility, increased crop yields, increased fuelwood and service wood (poles) supplies and increased forage/fodder supplies (from both leaves and pods). This scenario assumes that beginning in year 10, the farmer will have 40 young *A. albida* trees on each 1 ha field and that these trees will be managed in such a way as to increase wood and fodder supplies without jeopardizing crop yields. For example, in any one year, one-fourth of the trees could be pruned for poles, dry season forage and firewood. The remaining trees would be sufficient to insure an increased supply of pods/fodder while maintaining/increasing crop yields. Specific benefits include:

- **Maintenance of soil fertility:** Analyses conducted in Chapter 3 suggest that cad makes a significant contribution to soil organic matter directly under its crown. Given these results it is assumed that the 0.5% decline in soil fertility could be stopped by the introduction of cad. The net result is that millet/sorghum and peanut yields foregone by declining soil fertility in Model 3 would become a benefit under the cad natural regeneration model. It is estimated that for all crops, this benefit will begin to flow in year 6 when one-half of the yield loss to declining soil fertility might be recovered, and continue at this rate of recovery through year 15. From years 15 to 20, it is assumed that the crowns have reached a stage where 100% of yields lost to declining soil fertility could be recovered.

- **Increased crop yields:**

Millet/sorghum: The effect of *A. albida* on millet and sorghum yields has been well documented. For example, Charreau and Vidal (1965) compared millet yields under and outside the crown and found a 250% increase in millet yield under the tree. However, as pointed out in Chapter

3, increased yields occur mainly under the crowns of cad and thus total crop yields/ha are highly dependent on the percent cad crown cover per hectare. For purposes of this analysis, however, a conservative estimate of 40% has been used to reflect the impact of cad on increasing millet/sorghum yields. However, this figure is multiplied by the percent cad crown cover. Cad crown cover is expected to increase from 1% in year 0 to 60% in year 20. Thus in year 20, the net benefit of cad in terms of increased millet production would be 24% of the base yield for year 0.

Peanuts: The effect of *A. albida* on peanut yields is less well documented and generally more controversial. Some research indicates a positive effect on both peanut and hay yields (increases of 15-20%) while others report a slight decrease in peanut yields but a 15% increase in hay yields (Louppe 1988). Discussions/interviews with farmers indicate that Louppe's analysis is perhaps closer to the truth. They feel that *A. albida* may decrease peanut yields slightly but that increases in peanut hay yields are worth the cost. For purposes of this analysis and in view of the assumption of declining CEC, this intervention assumes that cad will not contribute either positively or negatively to peanut pod yields.

Peanut hay yields, on the other hand are expected to increase by 20%. However, as in the case of millet/sorghum, this rate is assumed to be highly dependent on the percent cad crown cover and the overall contribution of cad to increased peanut hay production is adjusted accordingly.

- **Increased wood supplies (poles and fuelwood):**

Poles: As stated above, it is assumed that the farmer could, in any one year after the trees mature, harvest service poles (for fencing, house construction) on one-fourth of the trees without affecting crop yield benefits (severe pruning). This intervention assumes that the farmer could begin harvesting poles in year 17 on 10 trees/ha (one-fourth of total) and that each tree harvested would yield 10, 10-15 cm base diameter poles (for a total of 100 poles per hectare per year). The 1987 adjusted price for such poles in the Peanut Basin is about 200 fcfa each (Livingston 1990).

Fuelwood: Freeman (1982) estimates that 40 mature *A. albida* trees per hectare, if properly managed, can provide 1 cubic meter of fuelwood annually without jeopardizing crop yields. In this scenario, fuelwood is assumed to result from branches left after pole harvest (severe pruning) and fodder harvest (light pruning). Fuelwood yields are estimated to be 0.2 cubic meters per hectare in years 10-12 and 0.5 cubic meters/ha in years 13 through 20. Christopherson (1988) estimates the price of fuelwood to be 2500 fcfa/cubic meter.

- **Increased fodder/forage yields:**

Forage: During the end of the dry season, *A. albida* is often the sole source of forage for the NCPB's many cattle, goats and sheep. Customarily, farmers prune *A. albida* trees for this purpose during the months of April and May and sometimes into June. It is estimated that one mature tree produces 50 to 150 kg of dry matter/year (forage) but that pruned trees produce about one-fifth of that (Le Houerou 1980). The quality of browse is similar to that of peanut hay. In this analysis, the value of *A. albida* forage is taken to be the same as that of peanut

hay, i.e., 30 fcfa/kg in an average rainfall year, increasing to 35 fcfa/kg in poor rainfall years and decreasing to 25 fcfa/kg in good rainfall years. It is further assumed that 10 trees/ha will be managed (lightly pruned) in any one year for browse production. Forage yields from harvesting poles and pruning for forage are estimated to be: 200 kg/ha/year for years 10-12; 400 kg/year for years 13-15; and 600 kg/ha for years 16-20 (or about 30 kg/tree per year).

Pods: Piot (1980) notes that mature, unpruned *A. albida* trees produce 50-150 kg of pods/year. Assuming that the remaining 20 trees/ha are managed for pod production (or are only very lightly pruned), pod yields are assumed to be 200 kg/ha in years 10-12, and 400 kg/ha in years 13 through 15, reaching 600 kg/ha in years 16 through 20 (or approximately 30 kg/tree/year. Charreau and Niceau maintain that the fodder quality of *A. albida* pods is twice that of peanut hay and three times that of the local grass species. Pods are also greatly appreciated by farmers in the NCPB and there is now a market for them with prices often exceeding 75 fcfa/kg. For purposes of this analysis, however, the revenue from pods is assumed to be the pod/seed base price of 50 fcfa/kg.

6.3.5 High intensification with the cost of fertilizer subsidized at 50% (Model 1.50)

This model is exactly the same as Model 1 described in Section 6.2.3 above except that the cost of fertilizer is reduced by one-half (from 82 fcfa/kg to 41 fcfa/kg for 6-20-10 peanut fertilizer, and from 82 fcfa/kg to 41 fcfa/kg for 14-7-7 millet for peanuts, and from 92 fcfa/kg to 46 fcfa/kg for urea) to reflect a 50% subsidy.

6.3.6 Moderate intensification with the cost of fertilizer subsidized at 50% (Model 2.50)

This model is exactly the same as Model 2 described in Section 6.2.2. above except that the cost of chemical fertilizer inputs (NPK and urea) is reduced by 50% to reflect a 50% subsidy.

6.3.7 *A. albida* natural regeneration: soil maintenance and increased yield benefits only (Model 5)

This model is the same as Model 4 described in Section 6.2.4 above but only cad benefits of maintenance of soil fertility and increased yields are retained for the analysis. As previously discussed, cad benefits of increased wood and forage fodder supplies are not included in order to: (i) better approximate resource conditions during the Programme Agricole period; (ii) not over state the benefits of cad; and (iii) facilitate comparison between the three models as all benefits are similar in nature.

Detailed crop and cad budgets for each of the above models over the 20-year period of analysis are presented in Appendix I.

6.4 Results

Net Present Values at discount rates of 5%, 10%, 15%, 20% and 25% were calculated for all of the above models using QuattroPro¹⁴⁴. The results comparing Models 1, 2, 3, 4 and 5 are presented in Table 6.1.

Table 6.1
Net Present Value (fcfa - 1 US\$= 250fcfa)
(Models 1 through 5)

Discount Rate	High Intensification (Model 1)	Moderate Intensification (Model 2)	Base Case (Model 3)	All cad benefits (Model 4)	Cad soil/ yield benefits (Model 5)
5%	670886	604586	742605	1513990	826366
10%	492577	439412	528596	983313	563022
15%	384297	339870	401989	696949	413749
20%	313352	275192	321202	528967	322154
25%	263883	230466	266261	422736	261959
Source: Data from Appendix I.					

¹⁴⁴Borland International, Inc.

Using the decision criterion that all activities with an NPV greater than 0 are acceptable, then the results indicate that all of the above interventions would be acceptable to the farmer. However, the analysis suggests clear differences between the models. While model 4 appears to be sensitive to changes in discount rates¹⁴⁵, at a 20% discount rate Model 4's NPV is over 40% higher than Model 1's, 48% higher than Model 2's and 39% higher than Model 3's NPV. Providing the initial assumptions are correct, this clearly demonstrates the advantages of maintaining a viable population of on-farm cad trees to NCPB farmers.

Even more interesting is the fact that at a 20% discount rate, the NPV of no intervention (Model 3) is higher than the NPVs of both the high and moderate intensification scenarios (Models 1 and 2). This suggests that at current fertilizer prices, farmers in the NCPB might find it more attractive financially to continue with their traditional practices rather than purchase the inputs required for the high intensification model. In fact, based on the results of the Biophysical Inventory and Socio-economic survey, the results of the analysis appear to approximate current practices in the NCPB today; little if any fertilizer use and an increased use of manure and cad.

Table 6.2 compares the NPVs at varying discount rates for scenarios where the cost of fertilizer is subsidized at 50% (Models 1.5 and 2.5), with the soil fertility maintenance and increased yield benefits derived by introducing cad via natural regeneration.

Again, using the decision criterion that all activities with an NPV greater than 0 are acceptable, the results suggest that all of the above interventions would be acceptable to the farmer. However, there is a fairly significant difference between the high and moderate intensification models. This suggests that the returns to larger

¹⁴⁵Due more than likely to the increased labor costs associated with cad harvesting in the later years of the project.

quantities of "cheap" fertilizer are greater than returns associated with using less fertilizer.

Table 6.2
Net Present Value (fcfa)
(Models 1.5, 2.5 and 5)

Discount Rate	High Intensification 50% fert. Sub. (Model 1.50)	Moderate Intensification 50% fert. sub. (Model 2.50)	Cad soil/ yield benefits (Model 5)
5%	883341	786285	826366
10%	639522	563539	563022
15%	493599	431131	413749
20%	399262	346191	322154
25%	334243	288114	261959
Source: Data from Appendix I.			

Additionally, the NPV for Model 1.50 is 25% higher than the NPV for Model 5 at the 20% discount rate. This difference needs to be analyzed in the context of past agriculture policies in the NCPB. One of the principal reasons why the subsidized models were chosen for the analysis was to attempt to reflect farmer actions during Senegal's Programme Agricole period, where the price of inputs for agriculture, particularly fertilizer, was highly subsidized. As is discussed in Chapter 4, between 1965 and 1983 the percent subsidy for fertilizer ranged from a low of 32% to a high of 70%. Moreover, agricultural credit was extremely cheap during this period and the majority of loans were never repaid¹⁴⁶. In this context, fertilizer subsidies probably amounted closer to 90% of the purchase price, which would increase NPV for Model 1.5 to fcfa 443867¹⁴⁷. This represents a 38% increase over model 5. Moreover the NPV for Model 1.50 would likely be higher if one considered that many of the other high intensity agriculture inputs (e.g., pesticides) were also subsidized. This lends additional credence to the hypothesis and analyses presented in

¹⁴⁶See USAID (1991) and Chapter 4, Section 4.4.2.

¹⁴⁷See Annex 5.2 Model 1.10 for the complete analysis.

Chapter 4 which argue that it is easier and more cost effective for NCPB farmers to spread cheap/subsidized fertilizer than to take care of their cad trees.

6.5 Discussion and conclusions

It should be kept in mind that financial analysis is only one of many tools to be used in the technology appraisal process. It is deterministic by nature and analyses conducted need to be considered as a preliminary assessment of some agricultural technologies currently available in the NCPB. Much more work needs to be done.

For example, additional research and sensitivity analyses need to be conducted on one of this Chapter's key premises: a 0.5% decline in crop yields as a result of organic matter decreasing at an annual rate of between 2 and 4%. The relationship between organic matter loss and declines in crop yields requires additional research. As the Rodale Study (1989) points out, there is little hard data on the extent, rate or seriousness of soil degradation in the Peanut Basin. While Chapter 3 suggests that soil degradation may not be as serious as previously thought, the rate of decline of the base case scenario needs to be varied and alternative interventions examined under the context of different rates of decline. Interventions such as windbreaks, living fences, micro water catchments and particularly those concerned with increasing organic matter content of the soil (e.g., composting, organic manure), need to be examined both separately and in combination with other interventions.

In spite of the above shortcomings, the analyses presented in this Chapter help explain why Senegal's structural adjustment program/New Agriculture Policy has resulted in a decrease in use of fertilizer among informants obliging them to return to more traditional methods of maintaining soil fertility including a significant increase in the use of *A. albida*. Results of the Biophysical inventory suggest that nearly one-half of the fields surveyed have an adequate cad regeneration rate. When aggregated to

the farm level, 23% of informants have an adequate regeneration rate while 30% have an excellent regeneration rate, with an on-farm average of 100 seedlings/sprouts per hectare.

The analyses suggesting that the introduction of cad via natural regeneration has a 40% higher NPV than the fertilizer/high input model lend additional credence to the above conclusion. Similarly, when fertilizer is highly subsidized, the use of cad becomes less attractive financially to farmers given its lower NPV. Both of these findings tend to support one of the key premises presented in Chapter 4; micro-economic adjustments made by individual farmers to agriculture policy changes not only drive macro-outcomes but simultaneously influence environmental impact through changes in natural resource use patterns. In short, when fertilizer is inexpensive or highly subsidized, it is easier for farmers to spread cheap fertilizer on their fields than to maintain their population of cad trees. Conversely, when fertilizer prices reflect market prices, the tendency is for informants to rely on cad and other more traditional methods of maintaining soil fertility. The policy implication here is obvious; careful thought needs to be given to agriculture input pricing policies and other macro-economic policies to ensure sustainable agriculture production.

Finally and perhaps most importantly, the analysis shows that in addition to trying to increase per hectare yield of basic food and cash crops, those concerned with rural development and policy formulation in Senegal must also devote increased attention to building on peasant subsistence farming systems in order to increase farmer resilience against soil degradation and for poor rainfall years. As Todaro (1977) writes, "the main motivating force in a peasant's life may be the maximization not of income, but of survival." Thus, risk-avoiding peasants such as those in the Peanut Basin are likely to prefer a technology of food production which combines a low mean per hectare yield with a low variance (less

fluctuation about the mean) to alternative technologies which may promise a higher mean yield but also present the risk of greater variance. If properly conceived and implemented, the re-introduction of *A. albida* via natural regeneration may be one of the most historically tried and accessible technologies available today to aid in creating this resilience.



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**A SYSTEMS ANALYSIS
OF THE STATUS AND POTENTIAL
OF ACACIA ALBIDA (DEL.)
IN THE NORTH CENTRAL PEANUT BASIN OF SENEGAL**

VOLUME II

By

James R. Seyler

A DISSERTATION

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

DOCTOR OF PHILOSOPHY

Department of Forestry

1993

1.1 Introduction

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CHAPTER 7

OTHER INTERNAL FACTORS: INFORMANT PERCEPTIONS OF THE *A. ALBIDA* SYSTEM AND NATURAL RESOURCES IN GENERAL

"Il y a deux sortes de gens qui savent:
- Celui qui sait et qui sait qu'il sait.
- Celui qui sait et qui ne sait pas qu'il
sait¹⁴⁸."

Wolof proverb (Cribier et al. 1986)

7.1 Introduction

The need to understand interactions between humans and their environment has become increasingly important over the past years as many of the world's traditional but resilient agricultural systems experience the effects of modernization. This need has been especially evident in Senegal's Peanut Basin where changes in population, technology, economics, politics and values have had significant consequences for the ways in which farmers and other inhabitants of the region use their resources and interact with each other and their natural environment. As the *A. albida* system makes up a large part of that environment, the impact of the above changes on the system has been considerable.

A key step in assessing this impact is to gain a better understanding of perceptions as well as knowledge, attitudes and practices of farmers in the NCPB with regard to the *A. albida* system and related environmental concerns.

This chapter examines four interrelated themes with regard to the *A. albida* system: (i) the evolution of tree cover; (ii) the role of *A. albida*; (iii) land tenure; and (iv) the role of associations and village groups, including the relationship between tree tenure and these groups.

¹⁴⁸Meaning literally that there are two types of people who "know"; those that know and know they know, and those that know and don't know they know.

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7.2 Theme 1: Informant perceptions on the evolution of tree cover

Informants were asked to describe the evolution of tree cover over the past 10 years differentiating between *A. albida* and other species. Table 7.1 summarizes the findings.

Table 7.1

Informant Perception of the Evolution of Tree Cover
(Number and Percent of Informants)

Response	<i>A. albida</i>		Other species	
	No.	Per.	No.	Per.
Increase	16	22.2	2	2.8
Decrease	55	76.4	70	97.2
No change	1	1.4	0	0.0
Source: Survey data, n=72.				

The results suggest that while the majority of informants perceive tree cover for both *A. albida* and other species to be decreasing, many more informants believe *A. albida* tree cover to be increasing relative to other species. This perception is supported by the results of the Biophysical Inventory. Figure 7.1 shows a dramatic increase in the number of *A. albida* trees in the 1-5cm diameter class. Depending on the nature of the tree (whether a root/stump sprout or a seedling) and the site, this represents an age class of approximately 1 to 6 years¹⁴⁹.

Regeneration rates¹⁵⁰ for cad, while varying considerably from field to field also appear to be increasing. The mean regeneration rate was 0.8 seedlings or suckers per 100 square meters with a minimum of 0 and a maximum of 10. Over one-half of the 305 fields surveyed had some cad regeneration. If one assumes that the minimum

¹⁴⁹The methods used to estimate cad age classes are discussed in Chapter 4.

¹⁵⁰The regeneration rate per field is the average number of seedlings or sprouts less than one centimeter in diameter taken from three randomly selected sample plots, each 10m by 10m square; rate = number of seedlings/100 square meters.

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regeneration rate required to sustain a population of cad/ha of about 40 trees would be 0.5 (50 seedlings/suckers/ha), then 43% (131) of the fields surveyed could be said to have an adequate regeneration rate. The overall distribution of regeneration rates is presented in Table 7.2.

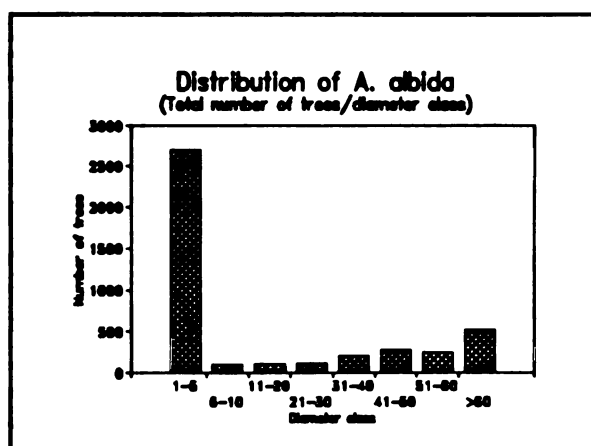


Figure 7.1

Distribution of *A. albida*

Table 7.2
Distribution of Cad Regeneration Rates by Field
(Number and percent of fields)

Rate	No. Fields	% Fields
Rate = 0	136	44.6
0<Rate<0.5	37	12.1
0.5<Rate<1	26	8.5
1<Rate<2	60	19.7
2<Rate<3	28	9.2
Rate > 3	18	5.9
Source: Biophysical Inventory, n=305		

If one aggregates the field regeneration rates up to the total farm level (the average of all fields), then nearly 23% (15) of the informants could be considered to have an adequate regeneration rate while 30% (22) have what would appear to be an excellent regeneration rate as Table 7.3 indicates.

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Table 7.3

Distribution of Cad Regeneration Rates by Farms
(Number and percent of Farms/Informants)

Rate	No. Farms	% Farms
Rate = 0.0	8	11.1
0<Rate<0.5	25	34.7
0.5<Rate<1	15	23.6
1<Rate<2	14	19.4
2<Rate<3	7	9.7
Rate > 3	1	1.4
Source: Biophysical Inventory, n=72.		

For the majority of other species, however, tree cover indeed appears to be decreasing. Of the 69 woody perennial species identified and counted in the Biophysical Inventory, only *A. nilotica* v. *adansonii*, *A. raddiana*, *Balanites aegyptiaca*, *Bauhinia rufescens*, *Borassus aethiopum*, *Combretum glutinosum*, *Cordyla pinnata*, *Piliostigma reticulatum* and *Ziziphus mauritiana* appear to have relatively high stocking levels in all diameter classes as well as relatively high numbers of younger trees. Total study area species distribution by diameter class, and by occurrence per 100 ha are found in Appendix J. Tree occurrence per 100 ha for all woody perennial species inventoried are represented graphically in Appendix K.

Informants were also asked how they felt about the adequacy of current forest product supplies and what future supplies may be like. As Table 7.4 indicates, informants appear to be particularly concerned about service wood and forage supplies¹⁵¹. However, they are also more optimistic that supplies for these products will increase in the future.

¹⁵¹The fact that fuelwood appears to be less critical could perhaps be due to a gender bias, as fuelwood collection is a women's task and the majority of respondents were men. However, from group discussions, the fuelwood problem is local in nature and 3 out of the 36 villages were selling firewood to urban centers (Bambey and Diourbel). Moreover, the firewood problem seems directly associated with the absence of *Guiera senegalensis*.

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Table 7.4

**Perceived Current and Future
Forest Product Supplies
(Number and Percent of Responses)**

Product Supply	Sufficient		Insufficient		Don't know	
	No.	Per.	No.	Per.	No.	Per.
Current fuelwood	18	25.0	54	75.0	0	0.0
Future fuelwood	13	18.1	49	68.1	10	13.9
Current service wood	5	6.9	67	93.1	0	0.0
Future service wood	9	12.5	54	75.0	9	12.5
Current forage	7	9.7	65	90.3	0	0.0
Future forage	11	15.3	51	70.8	10	13.9
Source: Survey data, n=72.						

7.2.1 Perceived reasons for decreasing tree cover

Informants who perceived a decrease in tree cover over the past years (55% or 40 informants for *A. albida* and 70% or 50 informants for other species) were then asked to specify the reasons for the decrease. Responses are summarized in Table 7.5 and discussed in detail below.

Table 7.5

**Perceived Reasons for Decrease in
Tree Cover
(Number and Percent of Responses)**

Reason	A. albida		Other species	
	No.	Per.	No.	Per.
Bush fires	1	0.8	4	2.0
Drought	51	39.2	66	33.3
Cutting for firewood	5	3.8	25	12.6
Cutting for forage	24	18.5	24	12.1
Cutting for service wood	22	16.9	31	15.7
Cutting for charcoal	3	2.3	14	7.1
Clearing for agriculture	0	0.0	7	3.5
Field preparation	14	10.8	14	7.1
Browsing by animals	8	6.2	13	6.6
Told to clear	1	0.8	0	0.0
Decreasing water table	1	0.8	0	0.0
Total responses	130	100.0	198	100.0
Source: Survey data.				

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7.2.1.1 Drought/decreasing water table

Over the past several decades, substantial evidence has implicated drought as an initiator or important contributor to forest declines (Smith 1990). Wentling (1983) estimates that over 40% of the Sahel's *A. albida* trees perished in the great drought of 1968-1973. Trees in chronic drought areas such as the NCPB typically allocate an abnormally large carbon component to their roots (Waring 1987). Sustained drought halts photosynthesis, depletes carbohydrate reserves, attenuates defensive compound synthesis, and ultimately reduces canopy mass (Pook 1984, Waring 1983). Enhanced pathogen and insect stress is also linked to drought-stressed plants (Smith 1990).

Informants perceive drought/decreasing water table to be the main cause for the decline in both cad and other species tree cover, accounting for 40.0% and 33.3% of total responses respectively. However, as one informant observed, there appear to be a need to distinguish between the impact of drought versus drought's effect on the water table.

A. albida has a fast-growing tap root (5m after only one year's growth-Giffard 1971) capable of reaching depths of over 40 meters (CTFT 1986) to the water table. Surface lateral root development is rare and usually only occurs after years of frequent pruning (Bonkougou 1987). Thus, given *A. albida*'s reverse deciduous cycle, the actual amount of rainfall (or surface retention) does not appear to be as important in older tree survival as fluctuations in the water table might be.

In order to explore this hypothesis further, an attempt was made to examine the relationship between the distribution of cad by age class/year and rainfall patterns over the past years. The first step in the analysis was to estimate the age class of the cad trees inventoried. Growth rates of cad are highly variable, depending on both site and a considerable amount of genetic variation (Felker 1978). Cad is a prolific sprouter and root sprouts tend to have

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higher growth rates than seedlings (Giffard 1971)), although this difference has not been quantified. For seedlings, however, annual diameter growth rates are reported by Mariaux (1966) to range from 0.61 to 2.9 cm, by Wickens (1966) to be 1.59 ± 0.59 cm, and by Anon (1966) to range from 0.31 to 2.9 cm. The wide variation in growth rates is due to both site differences and genetic variability (Felker 1978).

Based on the above research and on discussions with farmers about the age of certain trees¹⁵², five different growth rates were chosen; 1.0, 1.1, 1.2, 1.3, 1.4 and 1.5cm per year. Regression analysis was then used to model the distribution of cad by age class using these different growth rates, as a positive function of the average rainfall in the districts of Thiès and Diourbel since 1965. Time series analysis was also used in order to lag tree distribution by one and two years to determine if a better "fit" or relationship could be established. The general hypothesis is:

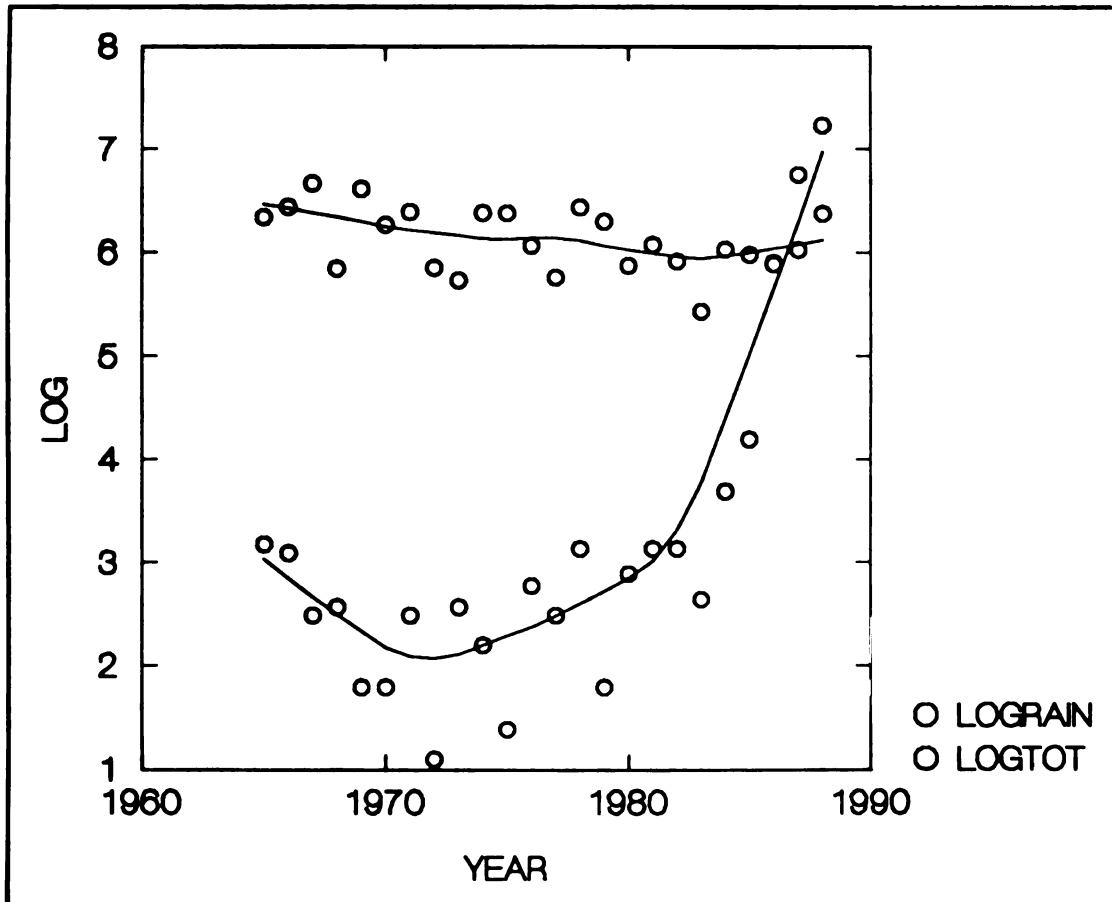
Hypothesis 7.1

$H_{(0)}$: There is no relationship between the distribution of *A. albida* by age class and average rainfall.

$H_{(1)}$: Distribution of *A. albida* by age class is a positive function of average rainfall.

Using all of the diameter growth rates noted above, each one lagged by one and two years, the regression analyses suggested that there is no relationship between average rainfall and the distribution of cad by age class. For illustrative purposes, the relationship between rainfall and cad age class distribution at a diameter growth rate of 1.2cm per year is presented graphically in Figure 7.2. The natural logarithm of both total trees/ha/age class (LOGTOT) and rainfall (LOGRAIN) were used in order to put both variables on a similar scale.

¹⁵²On several occasions, informants knew the exact age of a particular tree and an average diameter growth rate for these individual trees was estimated at 1.2cm/year.



Source: Rainfall data (average of the districts of Thiès and Diourbel) are from DA/DISA reports. Tree distribution data are from the Biophysical Inventory.

Figure 7.2

Relationship Between Distribution of
A. albida by Age Class and Rainfall

The results of the regression analysis on the above data (natural log of total trees/age class at an annual diameter growth rate of 1.2cm/year - LOGTOT, as a positive function of the natural log of average rainfall - LOGRAIN) suggest that there is no relationship between tree cover by age class and rainfall.

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VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	5.551	6.443	0.000	.	0.861	0.398
LOGRAIN	-0.400	1.050	-0.081	1.000	-0.381	0.707

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	0.359	1	0.359	0.145	0.707
RESIDUAL	54.397	22	2.473		

In terms of the influence of water table depth on the distribution of cad, it was expected that there would be a inverse relationship between tree density and water table depth. The hypotheses are:

Hypothesis 7.2:

$H_{(0)}$: There is no relationship between average *A. albida* tree density per hectare per farm (TOTCAD) and water table depth (WELL) as estimated by the depth of the village well.

$H_{(1)}$: Average *A. albida* tree density per hectare per farm (TOTCAD) is a negative function of water table depth (WELL) as estimated by the depth of the village well.

Hypothesis 7.3:

$H_{(0)}$: There is no relationship between average *A. albida* regeneration rate per hectare per farm (AALB1) and water table depth (WELL) as estimated by the depth of the village well.

$H_{(1)}$: Average *A. albida* regeneration rate per hectare per farm (AALB1) is a negative function of water table depth (WELL) as estimated by the depth of the village well.

The results of the regression are presented below. As predicted, the relationship between water table depth as measured by depth of the village well and cad tree density and regeneration rate are highly significant (99% confidence interval one-tailed).

DEP VAR: TOTCAD N: 66 MULTIPLE R: .321 SQUARED MULTIPLE R: .103 ADJUSTED SQUARED MULTIPLE R: .089 STANDARD ERROR OF ESTIMATE: 11.256						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	17.938	2.703	0.000	.	6.638	0.000
WELL	-0.168	0.062	-0.321	1.000	-2.707	0.009
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	928.678	1	928.678	7.329	0.009	
RESIDUAL	8109.131	64	126.705			

DEP VAR: AALB1 N: 66 MULTIPLE R: .322 SQUARED MULTIPLE R: .104 ADJUSTED SQUARED MULTIPLE R: .090 STANDARD ERROR OF ESTIMATE: 0.825						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	1.326	0.198	0.000	.	6.697	0.000
WELL	-0.012	0.005	-0.322	1.000	-2.724	0.008
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	5.051	1	5.051	7.421	0.008	
RESIDUAL	43.559	64	0.681			

During the course of the study, the impact of a declining water table on the cad survival was observed first-hand near the study village of Mbayene Missirah, located about 10 kilometers north of Touba. The water table in the area is at about 70 m, but nevertheless supports a fairly good population of mature cad trees (about 10 trees/ha) with little evidence of any severe pruning. However, the area has a number of small hills which rise about 10 to 15 meters above the rest of the landscape. These hills had a number of dead cad trees (about 2 per hectare), while the trees of the lower elevations were not apparently affected. Farmers from the village reported that these trees died in 1986 which coincides with the drought the area experienced the same year. This would suggest that where the water table is deep, even relatively small fluctuations in its depth due to even a short drought can have an impact on tree survival.

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7.2.1.2 Pruning (émondage)

One of the more visible actions taken by farmers in the NCPB vis-a-vis cad is "émondage" or the lopping/pruning of branches. Even a casual observer to the area will notice that the vast majority of cad trees have been pruned to one degree or another. Pruning of cad and other species is done for a variety of goals including the provision of forage, service wood and fuelwood. Most often, these goals are interrelated and are difficult to distinguish. Based on the results of the Biophysical Inventory, it is estimated that an average of 13.4% of *A. albidia* crown cover per farm¹⁵³ has been removed by pruning (a minimum of 0 to a maximum of 50% by farm), and 12.2% of other species (a minimum of 0 to a maximum of 50% by farm).

Pruning for forage: Lopping branches for dry season animal forage was, according to informants, an important factor in the decline of both cad and other species. Twenty-nine informants (40.28%) indicated that they practiced émondage of cad in order to obtain animal forage. Of those who reported not pruning cad, the reasons most often cited are interdiction by Eaux et Forêts (13 informants or 25.5%), absence of animals (13 or 25.5%), or they prefer not to prune for various reasons including fear of reducing crop yields (23 or 45.1%). Only two informants reported having sufficient "other" forage resources and only practiced émondage in particularly bad (drought) years.

In order to gauge the relative impact of pruning for forage on cad, survey participants were asked what actions they took if sufficient animal feed (crop residues, peanut/cowpea hay) was not produced on-farm. The frequency of responses provided in Table 7.7 below generally reflects the order of actions taken by farmers to secure adequate supplies of animal feed. Once on-farm forage fodder supplies are depleted, the most common action is to look for straw in

¹⁵³Note that 100% of the crown of individual tree is often pruned for both cad and other species.

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unexploited areas (khors, bas fonds, forest remnants, fallow areas, etc.) The most common species gathered is *Pennisetum pedicellatum* (bop or mbop in Wolof). When hay/straw from these areas are depleted, farmers turn to the pruning of forage trees. After forage tree resources have been depleted, farmers will then purchase feed concentrate, peanut hay, son de blé or millet and occasionally torteaux d'arachide. Five informants reported selling an animal and one informant reported selling millet in order to obtain the cash required for feed purchase.

Table 7.6
Reasons Given For Not Pruning *A. albida*
(Number and Percent of Responses)

Reason	No.	Per.
Sufficient other forage	2	3.9
Interdiction by DEF	13	25.5
Just don't cut	23	45.1
No animals	13	25.5
Total responses	51	100.0
Source: Survey data.		

Table 7.7
Actions Taken By Informants When On-Farm
Forage Resources Are Depleted
(Frequency and Percent of Responses)

Action	No.	Per.
Look for straw "en brousse"	46	42.6
Prune forage trees	27	25.0
Purchase peanut hay	14	13.0
Purchase feed concentrate	6	5.6
"Confiage" to a herder	1	0.9
Borrow peanut hay	1	0.9
Sell millet, purchase feed	1	0.9
Purchase peanut torteaux	3	2.8
Purchase son de blé/millet	4	3.7
Sell animals, purchase feed	5	4.6
Total responses	108	100.0
Source: Survey data		

Group discussions with farmers who practice émondage suggest that trees to be pruned for forage are not selected at random, but selected according to three general criteria including: (i) quantity

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and quality of pods; (ii) quantity of leaves; and (iii), number of thorns. In terms of frequency of pruning, there appears to be no fixed rule other than aspect of the tree and need for a particular product. When the need is for forage, the tendency is to prune every year. When the need is for service wood, the tendency is to prune every two years or more. In turn, both the criteria for tree selection as well as the frequency of pruning/appear to depend on four factors:

- **genetic variability-** Considerable variability was noted¹⁵⁴ with regard to cad leaf, pod and thorn production. Given that the majority of sites/fields are fairly uniform, it is assumed that much of this difference is due genetic variability¹⁵⁵. Many farmers appear to take advantage of this variability when selecting young trees to protect, stake and prune;
- **age-** Farmers usually begin pruning cad between 8-12 years of age, or generally when the crown is well developed. Kone (1986) found that the most frequently pruned age class is between 10 and 30 years. Older trees appear to be pruned less frequently as farmers consider them to be generally less productive;
- **rainfall-** After a poor rainy season, informants and other farmers remarked that cad leaf and pod production often decrease;
- **previous pruning-** Farmers report that trees which are severely pruned one year are considerably less productive the next, and if possible are given a chance to recover.

Time of pruning generally depends on the availability of other forage resources as suggested above. As Table 7.8 indicates, the majority of pruning for forage takes place from April to June - at the end of the dry season and/or when other sources of animal food (crop residues, grasses, etc.) have been depleted. Farmers who prune earlier have generally depleted all other forage or have very limited forage resources. However, only ten informants (34% of those who

¹⁵⁴In fact, it appears possible to distinguish at least three varieties of cad in Senegal: the typical cad of the NCPB, the cad around Thiès which is smaller and has a more yellow cast, and the cad which grows in the rice paddies of Casamance, whose aspect is completely different from the previous two.

¹⁵⁵Felker (1978) also argues along similar lines.

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prune) indicated that they prune early (in January and February). Length of pruning varies according to rainfall and availability of other forage resources but some informants reported pruning for a five month period, while others pruned for only a month. The average was 2.3 months.

Leaves vs. pods: A distinction needs to be made between branches pruned and pods pruned (or more frequently knocked down) as the former results in considerably more damage to the tree. Originally, it was assumed that the majority of pods used were simply foraged by animals from the ground. However, 63 or 87.5% of informants indicated that they (or more frequently their children and wives) intentionally harvested pods for concession feeding of animals. The primary reason for harvesting pods is to ensure that their own livestock will receive the benefits from what they consider to be their trees. Pods are harvested by either knocking them off the tree with a long pole, or actually cutting them off with a hooked blade attached to a pole.

Table 7.8

Pruning Periods (Number of Informants)

Month	No.
January	1
January/February	2
February/March	2
February/May	2
February/June	1
March/May	1
March/June	2
April	1
April/May	3
April/June	2
May/June	9
June	3
Source: Survey data.	

In addition to concession use of pods, ten informants (16%) indicated that either themselves or someone in their household (usually women and/or children) harvested pods for selling. The average price was 215 fcfa per basin (2-3 kilos) with a maximum of 400

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fcfa and a minimum of 125 fcfa per basin reported. While the impact this practice on cad regeneration could not be quantified, it is suspected that the export of seed from the NCPB may be seriously compromising regeneration of cad in certain areas. During the months of March and April, it is not uncommon to see 30-40 women along the Thiès-Tivaouane and the Thiès-Diourbel roads each with one or two basins of pods for sale. Discussions with these women indicate that the majority of pods are sold to residents of Dakar, Thiès or Diourbel to be used primarily for appears to be "urban" concession feeding of animals.

Finally, informants were also asked to specify if there were any particular animals which benefitted from cad forage (both pods and leaves). As Table 7.9 indicates, sheep and goats are the primary beneficiaries of cad forage (both pods and leaves) with cattle ranking third. However, in terms of frequency of responses, sheep and goats tend to benefit more from pods than leaves while cattle benefit equally from both. One informant reported giving pods to "skinny cattle" to "fatten them up" while one informant gave pods to donkeys as "they have to work hard".

Table 7.9

Animals Fed *A. albida* Pods And Leaves
(Number and Percent of Responses)

Animal	Leaves		Pods	
	No.	Per.	No.	Per.
Beef	15	23.8	16	14.2
Sheep	24	38.1	49	43.4
Goats	24	38.1	48	42.5
Donkeys	0	0.0	1	0.01
Total	63	100.0	114	100.0
Source: Survey data.				

Nomadic herders: Peular herders are also responsible for émondage in the NCPB although the amount of degradation they actually cause is not clear. The principal investigator was informed of and

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able to verify disputes between farmers and herders in two survey villages¹⁵⁶. These conflicts led one village to create a "protection" committee to patrol fields in the afternoon hours¹⁵⁷, and the other village to begin marking cad trees with pieces of bark or cloth as a sign of ownership. These methods of farmer adaptation to current socio-economic and ecological conditions are discussed in Section 7.5. In other villages, the Peular were often blamed for the amount and severity of pruning taking place around the villages. However, it is suspected -- considering the absence of large herds -- that most of the damage was done by the villagers themselves. In fact, during group discussions, informants and other farmers from these villages admitted (with much laughter) that this was in indeed the case. In short, Peular herders often appear to make convenient scapegoats given their mobility and the difficulty DEF agents have in verifying village claims of infractions.

In other instances, the relationship between farmers and pastoralists may be more symbiotic. The practice of "parcage" involves a pastoralist stationing his herd on a farmer's field or fields for 2-3 months. In exchange for his crop residues and cad forage or browse, the farmer receives the benefit of the manure. Nine of the 38 farmers (24%) who reported practicing parcage indicated that they made such arrangements with Peular herders¹⁵⁸. Occasionally even this arrangement may result in some conflict. Kone (1986) reports that some farmers go as far as to sell the right to prune the cad trees of their neighbors to passing herders.

¹⁵⁶The herders were still camped close to the villages and were able to corroborate the villagers stories.

¹⁵⁷Between the hours of 2:00 to 5:00 pm. the majority of farmers and their families return to the concession from their fields for the noon meal and a rest. As a result, this is the favorite time for Peular tree poaching.

¹⁵⁸The remainder used their own cattle or the herds of someone from the village.

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Additionally, the recent conflict between Senegal and Mauritania may also have had an impact on the *A. albida* and other species regeneration. Traditionally, Mauritanian herders brought large herds of camels, cattle, sheep and goats into the Peanut Basin (reportedly as far south as Kaolack) for dry season grazing. However, since the border conflict in 1988, this practice has stopped and the subsequent reduction in grazing pressure has undoubtedly had an impact on tree populations. Additionally, the indigenous animal populations in the area have generally decreased over the past few years (Centre Suivi Ecologique 1989) which has also contributed to reduced grazing pressure.

The effects of pruning: One of the major concerns in the NCPB today is what effect the more or less continuous pruning of cad for forage and other purposes is having on crop yields in particular and on the cad population in general. Of those farmers that actively prune cad, 11 (38%) felt that crop yields decreased with severe pruning (over 75% of crown removed) while 18 (62%) noticed no impact or had no opinion. Those that perceived a decrease in yields maintain that it was either prune the cads for forage or lose their animals--they said they had no choice as all other supplies of feed were exhausted. Moreover, a majority of the farmers who actively prune indicated that trees that were periodically pruned tend to produce more pods and leaves than those that are not. In particular, they noted when older trees are pruned (over 40 years old), they tend to produce more foliage the following year while producing more pods the second year after the operation.

While the practice of pruning cad obviously has some silvicultural advantages as it does for a number of other species, the impact of severe pruning on the cad population in general is undoubtedly important but difficult to gauge as it appears to be directly linked with rainfall. A poor rainfall year results in fewer crop residues and grasses and resulting increased pressure on cad. If

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rainfall is adequate and water tables stable the following year, cad appears to be able to recover and can sustain some light pruning. If rainfall is poor, the cad may or may not recover but if it is pruned severely yet again as livestock conditions may warrant, its chances of recovering are considerably reduced. In fact, one informant remarked that two consecutive drought years combined with two years of severe pruning more often than not results in the death of the tree.

Browsing: A distinction also needs to be made between pruning for forage and general browsing of woody perennials by animals. If animals are indispensable for the propagation of cad, many argue that browsing also results in considerable damage. According to informants, however, browsing by animals has more impact on other species than on cad. This reasoning may have some biological basis as well. While the leaves of young cad trees are preferred by animals, seedlings are armed with two-inch thorns which appear to protect them from the majority of animals. Literally hundreds of young cad trees (less than 5cm in diameter) were counted -- quite often the only green vegetation around at the end of the dry season -- and very little browse damage was noted.

Again, the conflict between Senegal and Mauritania may also be at play here as well. Farmers report that camels are notoriously "good" browsers of cad and are able to circumvent the thorns with their mouths. However, given the absence of camels in the study area, there was no means of verifying this hypothesis.

7.2.1.3 Pruning for service wood

In the past, species such as *Prosopis africana*, *Anogeissus leiocarpus*, *Borassus aethiopum* and *Diospyros mespiliformis* provided the majority of wood used house construction, fence posts, roof supports, etc. As these species have now become quite rare in the NCPB¹⁵⁹, farmers are obliged to turn to the more plentiful cad to

¹⁵⁹See Appendix K for the actual distribution.

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supply these needs placing additional strain on an already scarce resource. The situation is exacerbated by the fact that according to farmers, species such as *P. africana* and *A. leiocarpus* would last between 30 and 40 years before requiring replacement. Cad, on the other hand lasts only about 10 years and thus requires much more frequent replacement.

In terms of wood quality and duration, farmers equate cad with *Asadirachta indica* (neem). Neem grows in many of the villages in the MCPB and actions undertaken to increase its presence may have a positive impact on cad.

Pruning cad for service wood involves selecting a particular branch on a particular tree which meets a farmer's particular requirements. All undesirable secondary branches which might disturb development are removed and growth and development of the branch is monitored for two or three years depending on rainfall, soils, etc. When the branch has attained the length and diameter desired, the farmer then harvests it.

7.2.1.4 Pruning for fuelwood

The distinction between pruning cad and pruning other species for fuelwood is particularly important as many consider fuelwood harvesting to be a major contributor to cad's decline. For example, the Plan Directeur de Développement Forestier (1981) estimates that one-half to three-quarters or more of the rural fuel in the Peanut Basin is from sources other than forest areas, namely trees on fields such as *A. albida*, *Guiera senegalensis*, plus crop residues and manure. Similarly, some argue that demographic pressure on the *A. albida* system (particularly from urban markets) raises the species value to the point at which economic pressure to cut it and use it exceed its value as a continuing part of the agricultural system (Arnold 1984).

Survey results suggest that contrary to this conventional wisdom, fuelwood harvesting may not play much of a role in cad's

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decline. Livewood from cad is seldom harvested for fuelwood and rarely are whole trees cut, even by passing nomads. While women have major responsibility for the collection of fuelwood, Kone (1986) reports that they rarely participate directly in pruning cad for firewood. Kone (op cit.) as well as group discussions with farmers suggest that there are three common practices with regard to cad: (i) women collect branches pruned by the pastoralists or others after the leaves have been removed; (ii) women may hire a boy from the village to climb a tree and cut dead and occasionally living branches. According to the particular arrangement, the boy might be paid in cash for dead branches or by the pods and leaves in the case of living branches; and (iii) women will occasionally use a pole to knock or pull down dead branches themselves.

The exception to these practices appears to be when women own animals. In two villages the principal investigator observed women actively pruning cad branches for their herds of sheep and goats anxiously awaiting underneath. Discussions with these women indicated that they were the proprietors of the animals, that this was a millet field that they held in common (*champs collectif*) and that they considered the cad trees in this field to be their property to do with as they desired. They further indicated that they would share the fuelwood among members of the group.

Two additional factors suggest that pruning of cad for fuelwood has little impact on overall population. First, while cad is an important firewood species, it ranks behind *Guiera senegalensis* and *Balanites aegyptiaca* in terms of preference as Table 7.10 indicates.

While cad is considered by informants to be a "hardy, economical and plentiful" species, its other benefits are considered by informants to be more important.

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Table 7.10

Fuelwood Species
Species Preferences and Perceived Benefits
(Frequency of Responses)

Species	Total No. Resp.	Perceived benefits				
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<i>Acacia albida</i>	7	3	0	0	0	5
<i>Acacia nilotica</i>	1	1	0	0	0	0
<i>Acacia raddiana</i>	1	0	0	0	1	0
<i>Acacia seyal</i>	2	1	1	1	0	0
<i>Anogeissus leiocarpus</i>	2	2	0	0	0	0
<i>Antiaris africana</i>	3	2	0	1	2	0
<i>Balanites aegyptiaca</i>	9	0	4	0	1	2
<i>Bauhinia rufescens</i>	1	0	1	1	0	0
<i>Combretum glutinosum</i>	5	1	1	0	0	2
<i>Combretum micranthum</i>	2	1	1	1	0	1
<i>Cordyla pinnata</i>	2	2	0	0	0	0
<i>Dalbergia melanoxylon</i>	2	0	1	0	1	0
<i>Diospyros mespiliformis</i>	1	1	0	0	0	0
<i>Guiera senegalensis</i>	10	1	2	1	0	9
<i>Mitragyna inermis</i>	2	1	0	0	0	0
<i>Parinari macrophylla</i>	1	0	1	0	0	0
<i>Prosopis spp.</i>	1	1	0	0	0	0
<i>Pterocarpus erinaceus</i>	3	1	2	0	1	1
<i>Tamarindus indica</i>	1	1	0	0	1	0
Source: Survey data.						

Informants were also asked to list the benefits they felt they derived from cad. Results are summarized in Table 7.11.

Table 7.11

Perceived Benefits of *A. albida*
(Number and Percent of Responses)

Benefit	No.	Per.
Fuelwood	16	4.6
Forage (leaves)	60	17.1
Forage (pods)	67	19.1
Crop yields	66	18.8
Selling pods	14	4.0
Erosion control (wind)	22	6.3
Shade	29	8.3
Soil conservation	34	9.7
Service wood	43	12.3
Total responses	351	100.0
Source: Survey data.		

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The frequency of responses suggests that forage (leaves and pods combined), and increased crop yields are all accorded approximately equal importance (17.1%, 19.1% and 18.8% of total responses respectively). This is followed by service wood (12.3%), soil conservation (9.7%), erosion control (6.3%) and shade (8.3%). Cad as fuelwood ranks next to last as a benefit, only slightly more important than selling pods.

Having identified benefits, informants were then asked to rank them in order of importance. Responses for first, second and third choices were summed and the percent of total responses provides an indication of the relative importance of benefits. Table 7.12 suggests that informants consider increased crop yields to be cad's most important contribution followed by pod forage, service wood and soil conservation. In terms of cad's perceived importance as a fuelwood species, it is again next to last following leaf forage but before shade.

Table 7.12

Order Of Importance of *A. albida* Benefits
(Number and Percent of Responses)

Benefit	First Choice	Second Choice	Third Choice	Total	Percent
Increases yields	9	12	44	65	29.6
Soil conservation	13	4	7	24	10.9
Service wood	10	14	12	36	16.4
Shade	7	1	2	10	4.6
Forage (leaves)	4	14	3	21	9.6
Forage (pods)	20	26	3	49	22.3
Firewood	11	3	1	15	6.8
Total responses				220	100.0
Source: Survey data.					

The second factor which suggests that pruning for fuelwood has little impact on the cad system is simply that if growth of urban and rural populations is having an impact on fuelwood demand as some believe, one would expect that there would be evidence that *A. albida* was being bought and sold in the study area. However, survey results

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indicate that no informants were selling firewood in the study area¹⁶⁰ and only three reported purchasing it. As Table 7.13 indicates, only three species- *B. aegyptiaca*, *P. macrophylla* and *P. erinaceus*- were purchased. No informants reported marketing cad fuelwood and a occasional spot check at two weekly markets (Ndangalma and Thilmakha) showed no cad but mainly *B. aegyptiaca* and *G. senegalensis* being sold.

7.2.1.5 Field clearing

Informants perceive that clearing new fields has a bigger impact on other species than on cad. This reasoning has both a biological and sociological basis. From a sociological point of view, practically the only land in the NCPB which has not been exploited at one time or another is the bas-fonds or khor areas (clay depressions). However, more and more of these areas are being cleared for vegetable gardens if water table depth permits.

Table 7.13

Fuelwood Species
Species Bought And Sold
(fcfa)

Species	Sell			Buy		
	No.	Price	Unit	No.	Price	Unit
<i>Balanites aegyptiaca</i>	0	0	0	2	1500	charrette
<i>Parinari macrophylla</i>	0	0	0	1	1000	charrette
<i>Pterocarpus erinaceus</i>	0	0	0	1	1000	charrette
Source: Survey data.						

Biologically or ecologically, *A. albida* does not generally grow on these areas (preferring the sandier dior soils) and species such *Balanites aegyptiaca* and *Acacia nilotica* generally predominate. As a

¹⁶⁰While no informants reported (or admitted) selling firewood, farmers from three survey villages (Kiel, Pal Seck and Tougouthé) were selling *G. senegalensis* to Tivaouane, Diourbel and Bambey respectively.

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result, clearing these areas for agriculture probably has little impact on cad.

Only one informant reported that he was told to remove trees from his fields under the auspices of SODEVA's "ten commandments". He indicated that he was required to conform to certain agricultural practices which included the complete removal of trees from fields (*A. albida* and others) in order to obtain traction animals and other inputs from SODEVA.

7.2.1.6 Field preparation, cultivation and harvesting

The impact of field preparation, cultivation and harvesting on cad and other species regeneration is another area cited by informants as a problem. Field preparation begins 2-3 months before the rainy season and is aimed at removing crop residues and bushes (primarily coppicing species such as *G. senegalensis* and *Combretum spp.*) to facilitate passage of the grain drill. There is generally no deep plowing per se, but the field is prepared for planting by shallow plowing with a horse or donkey drawn "houe sine" or by hand with an "iler". Discussions with both informants and other farmers suggest that the major problem affecting cad regeneration at this stage is youth. The task of field preparation is generally delegated to a farmer's sons or "sourga familial", who, according to informants, neither take the time to differentiate between species when removing bushes nor plow around seedlings during plowing and cultivation.

Additionally, one of the difficulties cited by farmers in terms of cultivation is that it is easier to cultivate around seedlings in millet fields where the spacing between millet plants is fairly large (1.0m to 1.2m) than in peanut fields where spacing between plants is much narrower (0.30m to 0.60m). The regeneration problem is exacerbated by the fact that the majority of the farmers follow crop rotations.

The plant spacing problem also has significant implications during crop harvest. While millet heads stalks are harvested by hand,

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peanuts are harvested using a horse or donkey drawn "lame souleveuse"¹⁶¹ whose 0.30m to 0.40m blade leaves little between-row room for manoeuvring around seedlings.

7.2.1.7 Charcoal making

On three occasions, informants reported that there was illicit charcoal making taking place around their villages, supposedly by "charcoal makers from Dakar". While the principal investigator was unable to confirm the origin of these charcoal makers, it was noted that two (live) cad's and one *Tamarindus indica* had been felled and converted to charcoal¹⁶². According to farmers there is a considerable amount of illicit charcoal making taking place, which in a tree-poor area such as the NCPB, seems somewhat surprising but reasonable given transport costs from the southern/wood rich areas of Senegal. However, in terms of making a significant contribution to the decline of cad, it appears doubtful whether charcoal making has much of an impact.

7.2.2 Perceived reasons for increasing tree cover

Those farmers who believe that both *A. albida* and other species tree cover are increasing were asked to specify the reasons for the increase.

¹⁶¹Literally, "lifting blade".

¹⁶²In all three cases, the perpetrators were reported to the local DEF agent by the village. In one case, the culprit was apprehended and forced to pay a fine of 25,000 fcfa. On several other occasions, the practice of making charcoal from dead cad trees was observed and is permitted providing a permit is obtained from the DEF.

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Table 7.14

Perceived Reasons for Increase in Tree Cover
(Number and Percent of Responses)

Reason	<i>A. albida</i>		Other species	
	No. resp.	Per.	No. resp.	Per.
Development project	0	0.0	1	25.0
Increased planting	1	5.0	1	25.0
Increased protection	13	65.0	2	50.0
Increased regeneration	5	25.0	0	0.0
Increased fallow	1	5.0	0	0.0
Total responses	20	100.0	4	100.0
Source: Survey data.				

Results indicate that informants perceive increased protection of natural regeneration by individuals to be the main reason for the increase in tree cover for both *A. albida* and other species. Increased regeneration during the past two years (due primarily to higher rainfall) and increased fallow have also contributed to increased cad cover according to informants. Only one informant felt that a development project contributed to increased tree cover and this only for species other than cad¹⁶³. Informant perceptions on increasing cad regeneration rates appear to reflect reality.

7.2.2.1 Increased rainfall and increased natural regeneration

As discussed above, there is a highly significant relationship between water table depth and the natural regeneration rate of *A. albida*. However, the analyses also suggested that there was no relationship between total rainfall and cad stocking density for a particular year. Admittedly this analysis and resulting conclusion has several shortcomings, not the least of which is the estimation of the age class and the relationship between the number of trees in that age class and rainfall for a particular year.

¹⁶³Considering that there are no less than seven forestry or forestry related projects currently operating in the study area, the implications of the current "projectized" approach to natural resources are discussed in Chapter 4.

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Additionally, it would be expected that total rainfall, number of days of rainfall and residual dry season soil moisture content in particular would have an impact on regeneration rates as well as on younger tree growth rates and survival. Unfortunately, the above analyses was not able to capture these relationships. Thus, while no real conclusions about rainfall/drought and cad regeneration rates can be drawn, the analysis does tend to support von Maydell's (1983:89) contention that the species is more or less independent from precipitation due to its tap root.

7.2.2.2 Increased fallow and increased natural regeneration

Informants also attributed an increase in the amount of fallow as a factor in increasing regeneration/cad cover. However, as Figure 7.3 indicates, the percent of fields in fallow among informants remained fairly constant from 1985 to 1989; there was no dramatic increase in fallow which would account for the high regeneration rates observed in some fields. Moreover, cad is usually associated with cultivated areas and has its highest grow rates when grown in combination with crops. It is therefore suspected that contrary to farmer perceptions, fallow has little influence on cad regeneration rates.

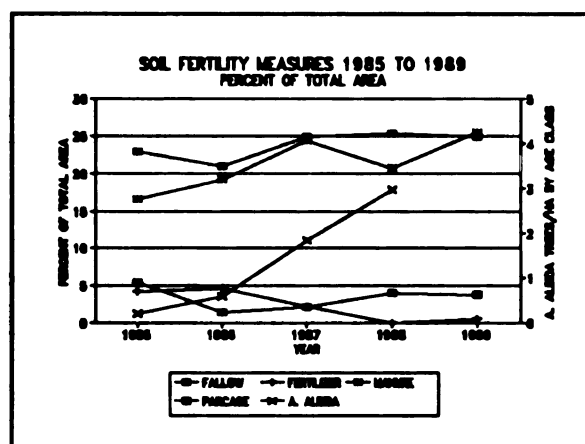


Figure 7.3

Soil Fertility Measures 1985 to 1989

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In order to test this hypothesis, informants were asked (for each field in their possession) the last time that a field had been in fallow since 1985, and for how long. Using the total number of years a field was in fallow from 1985 to 1989 (TOTFAL) as the independent variable, and the cad field regeneration rate (AALB1) as the dependent variable, regression analysis was used to test the following hypothesis:

Hypothesis 7.4:

$H_{(0)}$: There is no relationship between average *A. albida* field regeneration rate per hectare (AALB1) and number of years a field has been in fallow from 1985 to 1989 (TOTFAL).

$H_{(1)}$: Average *A. albida* regeneration rate per field (AALB1) is a positive function of length of fallow (TOTFAL).

The results of the regression, presented below, suggest that there is no relationship between fallow and cad regeneration rate; the null hypothesis must be accepted.

DEP VAR: AALB1 N: 305 MULTIPLE R: .064 SQUARED MULTIPLE R: .004						
ADJUSTED SQUARED MULTIPLE R: .001 STANDARD ERROR OF ESTIMATE: 1.256						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.878	0.088	0.000	.	10.011	0.000
TOTFAL	-0.074	0.067	-0.064	1.000	-1.113	0.267
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	1.955	1	1.955	1.239	0.267	
RESIDUAL	478.127	303	1.578			

In addition to regeneration rate, the relationship between the number of cad trees/ha in the 1-5cm diameter class (AALB15HA) and total years fallow from 1985 to 1989 was also examined. The assumption is that fallow would not only have an impact on regeneration rate but on the younger on-field cad trees as indicated by the diameter class. The hypothesis is:

Hypothesis 7.5:

$H_{(0)}$: There is no relationship between the number of *A. albida* trees/ha in the 1-5cm diameter class (AALB15HA) and the

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number of years a field has been in fallow from 1985 to 1989 (TOTFAL).

$H_{(1)}$: The number of *A. albida* trees/ha in the 1-5cm diameter class (AALB15HA) is a positive function of total fallow (TOTFAL).

Again, the results of the regression suggest that there is no relationship between fallow and density of younger cad trees.

DEP VAR: AALB15HA N: 305 MULTIPLE R: .068 SQUARED MULTIPLE R: .005 ADJUSTED SQUARED MULTIPLE R: .001 STANDARD ERROR OF ESTIMATE: 15.748						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	8.551	1.100	0.000	.	7.776	0.000
TOTFAL	-1.000	0.838	-0.068	1.000	-1.193	0.234
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	353.012	1	353.012	1.424	0.234	
RESIDUAL	75140.075	303	247.987			

7.2.2.3 The impact of manure and parcentage on cad regeneration

There are at least two additional factors which may be contributing to cad regeneration in the NCPB but which were not considered by informants.

Manure: The first of these is an increased use of manure. As Table 7.15 indicates, manure use appears to be increasing both in terms of the number of informants as well as number of fields receiving manure.

Table 7.15

Perceived Manure Use Among Informants
1985-1989

Variable	1985	1986	1987	1988	1989
Number of fields (n=305)	43	54	66	64	72
Hectares (n=variable)	69.4	83.2	110.1	94.7	118.5
Inf. using man. (n=72)	27	34	39	42	45
Percent of fields	16.6	19.7	23.2	21.8	23.4
Percent of area	16.7	19.3	24.4	20.7	25.5
Percent of farmers	37.5	47.2	54.2	58.3	62.5
Source: Survey data.					

This apparent increase in the use of manure combined with the fact that the majority of informants (63 or 87.5%) reported stall (or concession) feeding pods to their livestock, has undoubtedly had a positive impact on cad regeneration¹⁶⁴. In fact, on several occasions extremely high regeneration rates (literally 100's of seedlings/ha) were noted on fields where manure had been spread the previous year and the informant reported stall feeding pods to his animals. Using the total number of years a field received manure from 1985 to 1989 (TOTMAN) as the independent variable and cad field regeneration rate (AALB1) as the dependent variable, the hypothesis is:

Hypothesis 7.6:

$H_{(0)}$: There is no relationship between the *A. albida* regeneration rate (AALB1) and the number of years a particular field received manure from 1985 to 1989 (TOTMAN).

$H_{(1)}$: Cad regeneration (AALB1) is a positive function of manure use (TOTMAN).

The results of the regression suggest that there is indeed a highly significant relationship (at the 99% confidence level one-tailed) between manure use among informants and cad regeneration rates; the null hypothesis is rejected. However, the regression's predictive power is very low which indicates that there are other factors which come into play. Not the least of these factors would be depth of the water table, as discussed above.

¹⁶⁴Passing the pods through the digestive tracts of animals is one of the best methods to soften an extremely hard seedcoat thus increasing germination.

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DEP VAR: AALB1 N: 305 MULTIPLE R: .171 SQUARED MULTIPLE R: .029
ADJUSTED SQUARED MULTIPLE R: .026 STANDARD ERROR OF ESTIMATE: 1.240

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.686	0.084	0.000	.	8.170	0.000
TOTMAN	0.138	0.046	0.171	1.000	3.029	0.003

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	14.108	1	14.108	9.174	0.003
RESIDUAL	465.974	303	1.538		

As with fallow, we also examined the relationship between the density/ha of younger cad trees (the 1-5cm diameter class representing and age class of between 1 and 6 years), and informant use of manure.

The hypothesis is:

Hypothesis 7.7:

$H_{(0)}$: There is no relationship between younger *A. albida* trees (as represented by the 1-5cm diameter class - AALB15HA) and the number of years a particular field received manure from 1985 to 1989 (TOTMAN).

$H_{(1)}$: The density/ha of younger cad trees (AALB15HA) is a positive function of positive function of manure use (TOTMAN).

The results of the regression suggest that there is no relationship between younger cad trees and previous manure use and the null hypothesis must be accepted.

DEP VAR: AALB15HA N: 305 MULTIPLE R: .010 SQUARED MULTIPLE R: .000
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 15.784

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	7.903	1.069	0.000	.	7.392	0.000
TOTMAN	-0.105	0.581	-0.010	1.000	-0.181	0.856

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	8.178	1	8.178	0.033	0.856
RESIDUAL	75484.908	303	249.125		

Parcage: Parcage is another mechanism which is thought to enhance both the natural regeneration of cad and other species. A

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total of 29 informants (40.3%) reported practicing parcage, either currently (13 or 15.3%) or in the past (16 or 22.2%). Of these 29, 21 informants thought that there was a definite increase in the regeneration of certain species, particularly cad, after parcage. The remainder noticed no difference. The hypotheses are therefore:

Hypothesis 7.8:

$H_{(0)}$: There is no relationship between the *A. albida* regeneration rate (AALB1) and the number of years a particular field received parcage from 1985 to 1989 (TOTPAR).

$H_{(1)}$: Cad regeneration (AALB1) is a positive function of parcage (TOTPAR).

Hypothesis 7.9:

$H_{(0)}$: There is no relationship between younger *A. albida* trees (as represented by the 1-5cm diameter class - AALB15HA) and the number of years a particular field received parcage from 1985 to 1989 (TOTPAR).

$H_{(1)}$: The density/ha of younger cad trees (AALB15HA) is a positive function of positive function of parcage (TOTPAR).

DEP VAR: AALB1 N: 305 MULTIPLE R: .019 SQUARED MULTIPLE R: .000 ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 1.259						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.831	0.076	0.000	.	10.886	0.000
TOTPAR	-0.051	0.153	-0.019	1.000	-0.332	0.740
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.175	1	0.175	0.110	0.740	
RESIDUAL	479.908	303	1.584			

DEP VAR: AALB15HA N: 305 MULTIPLE R: .058 SQUARED MULTIPLE R: .003 ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 15.758						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	8.115	0.955	0.000	.	8.495	0.000
TOTPAR	-1.923	1.914	-0.058	1.000	-1.005	0.316
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	250.810	1	250.810	1.010	0.316	
RESIDUAL	75242.276	303	248.324			

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The results of both regressions suggest that there is no relationship between parcage and natural regeneration of cad. However, it should be noted that over the longer term, the use of parcage appears to be declining. Only a total of 20 fields out of the 305 sampled had had parcage from 1985 to 1989. Thus, while parcage may have contributed to cad regeneration in the past, its current contribution, as reflected by only 24 fields out of the 305 sampled, may not be sufficient to accurately test the hypothesis.

7.3 Theme 2: Informant perceptions on the role of *A. albida*

Informants were asked how they learned of cad's benefits. As multiple responses were permitted, Table 7.16 indicates that the majority of informants (67 or 75%) learned of cad's benefits through personal experience. However, it is interesting to note that a number of informants (11 or 12%) learned about (or at least heard about) cad by radio. This would suggest that a wider use of radio as a media for transmission of information on forestry and natural resources may be appropriate. However, the Senegal Reforestation Baseline study (1989) found that only 1% of informants actually followed advice diffused by the radio.

A still smaller percentage of informants learned of cad through experience combined with training (4 or 4%), and through extension agents (7 or 8%). Training alone and project-related advice were not cited as a means of acquiring skills/knowledge about cad.

In order to estimate informant knowledge about cad, they were asked to identify the reasons why they felt that cad had an impact on agricultural productivity. The frequency of responses suggests that the majority of informants are familiar with how cad works. Nearly all informants (71) cited litterfall as a contributing factor while 40 mentioned livestock underneath the trees providing manure and 54 cited soil conservation/wind erosion control as a contributing factor.

Table 7.16

Ways In Which Farmers Learned
Of *A. albida* Benefits
(Number and Percent of Responses)

Method	No.	Per.
Experience only	67	75.3
Training only	0	0.0
Experience and training	4	4.5
Radio	11	12.4
From a project	0	0.0
Extension agent	7	7.9
Total responses	89	100.0
Source: Survey data.		

Table 7.17

Reasons For Impact Of *A. albida*
(Number and Percent of Responses)

Reason	No.	Per.
Livestock underneath	40	24.2
Litterfall	71	43.0
Soil cons./erosion control	54	32.7
Total responses	165	100.0
Source: Survey data.		

The majority of informants (63 or 87.50%) indicated that they take specific actions to protect/enhance cad regeneration on their fields. However, this contrasts with 46% of informants who were actually observed (or showed evidence of) undertaking specific actions in their fields. This discrepancy is more than likely due to informants' desire to cite the "correct" answer, as this was after all, a study on cad. Nevertheless nearly half of the informants were actually taking measures to protect/enhance cad.

According to informants, the most frequent action undertaken to enhance cad development was during field preparation and harvest; sixty-three (88%) informants indicated that they attempted to plow/cultivate around seedlings. This was followed by: (i) selecting and pruning individual trees with desired morphological characteristics in order to enhance growth (28 or 39%); and (ii) the

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use of tutors to stake and support selected young trees (23 or 28%). According to informants, the most difficult action to undertake was the protection of young seedlings from animal browsing or indiscriminate cutting by youth. Only 16 informants (22%) indicated that they attempted some form of protection.

Table 7.18

Actions Taken By Informants To
Enhance *A. albida* Development
(Number and Percent of Responses)

Technique	No.	Per.
Flow around seedlings	63	87.5
Make a phenotypic selection/prune	28	38.9
Use tutors	23	31.9
Protect regeneration	16	22.2
Source: Survey data, n=72.		

For the six informants (8%) who indicated that they took no actions to enhance cad development, the most often cited reasons were that it was: (i) too difficult (50% of responses); (ii) that youth cut the seedlings (17%); and (iii) that there was no cad regeneration on their fields with which to take any action (33%). Three informants chose not to answer this question.

Table 7.19

Reasons Given For Taking No Action
To Enhance *A. albida* Development
(Number and Percent of Responses)

Reason	No.	Per.
Takes too much time	0	0.0
See no advantage	0	0.0
Too difficult	3	50.0
Youth cut	1	16.7
No regeneration	2	33.3
Total responses	6	100.0
Source: Survey data.		

Practically all of the informants (70) indicated that cad had a positive effect on crop yields, while two did not respond to this

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question. Informant perceptions of the effect of cad on major crop is summarized in Table 7.20. For millet, 86% (62) of informants indicated that cad raised yields considerably while only 11% (8) indicated that yields increased only slightly.

The situation for peanuts is somewhat different. While the majority of farmers (48 or 67%) believed that cad increased peanut yields significantly, nearly 30% of informants (21) indicated that cad's effect on peanuts was only slightly positive. One informant even felt that cad's effect on peanuts was negative; his experience was that peanut yields actually decreased under cad cover. However, 75% of informants (54) indicated that peanut hay yields increased significantly under cad.

The distinction between peanut pod and hay yields under cad has some scientific basis. Louppe (1989) found that in the more fertile peanut plots grown under cad, peanut yields were reduced by 30% within the first three meters around the trunk of the tree. After three meters, yields increased somewhat but remained inferior to the control. Between 8 and 10 meters from the trunk, a further decline in production was experienced. Louppe's conclusion was that the increased N under the tree from cad litterfall (and possibly animal manure) combined with a legume crop such as peanuts increased N levels to the extent that vegetative growth was enhanced at the expense of pod production. While farmer experience tends to support Louppe's conclusion, the principal investigator believes that in extremely poor fields with very low N levels, peanut production will nevertheless increase under cad¹⁶⁵. This should be the subject of additional research.

¹⁶⁵CTFT's work in Senegal (CTFT 1988) tends to support this hypothesis as well. They found in some cases that peanut yields increased under cad and in other cases yields decreased, but no soil analyses were conducted. However, in one plot peanut yields decreased and peanut hay yields increased significantly under cad when additional fertilizer was added.

Additionally, when informants were asked if they could only associate cad with only one crop 24% of the informants indicated they would choose peanuts over millet because increased peanut yields means more money. Informants choosing millet stated either that cad's impact on millet was greater than its impact on peanuts or that as millet was the most important food crop, it was better to associate cad with millet.

As was expected, farmer perception of the effect of cad on cowpeas is similar to that for of peanuts. Fifty informants (69%) informants believe that cad has a significant effect on cowpea yields while 52 informants (72%) believe that cad has a significant effect on cowpea hay yields. While the distinction is not as great as that with peanuts, these results need to be tempered by the fact that farmer experience with cowpeas in the NCPB is fairly limited. Cowpeas are a relatively "new" crop and only 40% (28) of the informants have actually grown them. Moreover, cad's effect on cowpeas is less well documented than its effect on peanuts and millet/sorghum.

Table 7.20

Perceived Effect Of *A. albida* On Crop Yields
(Number and Percent of Responses)

Crop	Increase +		Increase -		Decrease		No change		No resp.	
	No.	Per.	No.	Per.	No.	Per.	No.	Per.	No.	Per.
Millet/sorghum	62	86.1	8	11.1	0	0.0	0	0.0	2	2.8
Peanuts	48	66.7	21	29.2	1	1.4	0	0.0	2	2.8
Cowpeas	50	69.4	17	23.6	0	0.0	2	2.8	3	4.2
Peanut hay	54	75.0	3	4.2	0	0.0	0	0.0	15	20.8
Cowpea hay	52	72.2	4	5.6	0	0.0	0	0.0	16	22.2

Source: Survey data, n=72.

Only one informant was satisfied with the number of cad trees he had on his farm. All other informants indicated that they would like to have a higher cad density. When asked what spacing they would prefer, the average was about 14m between trees. Responses ranged from a minimum of 4 meters to a maximum of 50. The average distance desired by farmers corresponds to what many people consider to be the best tree spacing, 12-14m.

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Seven (10%) informants indicated there was nothing hindering them from re-establishing/maintaining cad on their fields and were actively doing just that. However the majority of informants (90% or 65) desiring additional cad indicated that they were hampered in doing this by several factors. As Table 7.21 shows, informants had numerous reasons for not re-establishing cad. Chief among these were lack of seedlings/regeneration and lack of technical skills. These two factors alone accounted for more than 84% of responses. Other factors perceived by informants as problems include difficulty in protecting trees from browsing and the fact that many seedlings are intentionally or inadvertently removed by youth during cultivation and peanut harvesting as previously mentioned. However, three informants noted that they accompany their sons into the fields prior to preparation and designate certain young cad seedlings and other seedlings to be specifically protected.

Table 7.21

Reasons For Not Re-establishing *A. albida*
(Number and Percent of Responses)

Reason	No.	Per.
No seedlings/regeneration	45	62.5
Lack of technical skills	16	22.2
Takes too much time	3	4.2
Protection too difficult	7	9.7
Lack of land	2	2.8
Not a priority	1	1.4
Takes too long to grow	2	2.8
Absent too much	3	4.2
Cut by youth	7	9.7
Total responses	86	100.0
Source: Survey data.		

Informants were subsequently asked whether re-establishment of cad should be a priority for the GOS. The overwhelming majority of informants (99%) said yes. The lone dissenting informant felt that as the GOS has not been very successful in doing anything to alleviate the plight of the rural poor to date, he did not expect much from the

GOS in the way of help to re-establish cad. Instead, he felt that reestablishment of cad should be a priority of the people themselves.

In terms of actions desired by informants on behalf of the GOS, responses, summarized in Table 7.22 paralleled those for factors perceived as inhibiting re-establishment of cad; informants wanted the GOS to provide seedlings and technical training, actions which accounted for over 72% of total responses. Increased motivation/-awareness accounted for 7% of responses while providing direct payment for tree planting accounted for only 2% of responses.

Table 7.22

Actions Desired By Informants By GOS
For Re-establishment Of *A. albida*
(Number and Percent of Responses)

Action	No.	Per.
Provide seedlings	55	41.4
Provide technical training	41	30.8
Pay people to plant trees	3	2.3
Provide increased protection	18	13.5
Motivate people	9	6.8
Total responses	126	100.0
Source: Survey data		

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A number of informants (22) felt that in addition to the support described above, what was needed was increased protection of existing cad and other tree resources. However, how this increased level of protection should be provided was an issue of considerable discussion. Table 7.23 provides a summary of two possibilities identified by informants.

Table 7.23
Perceived Means of Protecting Existing
Tree Resources
(Number of Informants)

Means	Wolof	Serer
Local control of resources	9	1
Stronger DEF role	5	7
Source: Survey data.		

It is interesting to note that the majority of Wolof informants felt that given the authority, they could police and control their own tree resources better than the GOS. These informants suggested various mechanisms for doing this such as: (i) the creation of "comités de surveillance" (protection committees) above with power to sanction; (ii) delegating more authority to the CERs; and (iii) providing existing farmers organizations with increased authority to control their own resources.

In contrast, the majority of Serer informants expressed interest in seeing more of the "traditional" Eaux et Forêts work of policing and control. As one Serer farmer put it, "as the government is in major part responsible for deforestation by issuing charcoal permits, it should be the government that does something about it". Suggestions from this group of informants included: (i) increasing the number of DEF agents and giving them the means to do their jobs; (ii) creating a "cad project" for the NCPB; and (iii) creating a national service for reforestation and conservation of natural resources (i.e., "service national du reboisement et protection des

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arbres", service national de protection et surveillance, service national de reboisement et conservation des eaux et des sols"). Ironically, the four informants who suggested the creation of a national service had not seen a DEF agent for so long that they assumed that such a service no longer existed. These farmers were surprised to learn that in fact, such a service (the Direction de la Conservation des Sols et du Reboisement- DCSR, under the Ministry of Nature Protection) exists and receives external funding to the tune of approximately \$9,000,000 per year¹⁶⁶. Even more interesting is the fact that 13 of 18 informants desiring increased protection on behalf of the GOS were Serer.

While this ethnic difference with regard to the cad system will be discussed in Chapter 9, it is felt that one of the primary reasons for this difference in opinion is differences in "world view". In short, much of the browsing and branch lopping that takes place in Serer villages is done by village inhabitants with fairly large herds of animals. More often than not these individuals are related to other members of the village. As one Serer informant put it "we are ashamed (avoir honte) to tell a relation to stop grazing in our fields and cutting our cad trees....we prefer to have the DEF do this rather than have the authority ourselves". In contrast, the more aggressive Wolof farmers apparently feel little remorse in chasing their friends, neighbors and relatives out of their fields. As a case in point, all of the village protection committees identified in the study are located in Wolof villages.

Finally, several informants offered very innovative suggestions for enhancing the protection and conservation of tree resources. One

¹⁶⁶While the exact figure is not known, there are currently over 30 donor-financed forestry/natural resource projects located in the DSCR. Some of these projects are quite large (e.g, USAID 10 million dollar 5 year "Projet Reboisement du Sénégal", while others are quite small (NGO/PVO efforts). If one assumes an average yearly expenditure of \$300,000 per project, one arrives at a total external contribution of \$9,000,000.

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informant suggested that farmers who protect natural regeneration of cad trees on their fields could be exempt from all or part of the rural tax. Another suggested that peanut seed could be exchanged against increased cad regeneration/protection. A "cad" contest (with prizes of food or cash) between or within villages to see who could protect the most regeneration was the suggestion of another informant. Training one or two people in forestry techniques (propagation, nurseries, etc.) from a village to serve as local forestry resource people was another suggestion offered.

7.4 Theme 3: Perceptions concerning land tenure

The importance of land tenure in the promotion of agroforestry initiatives has been well documented¹⁶⁷. Where there is no security of tenure, agroforestry systems, either traditional or introduced, are bound to fail. The link between land tenure and state of the *A. albida* human ecological system must be examined in the light of the economic use of the land. As economic factors change, tenure patterns typically change with them (Bruce and Fortmann 1988). As an example, as fuelwood has become scarcer and thus more commercialized in Senegal, a hypothesis currently being formulated by some Senegalese and expatriate foresters, is that wealthy and/or better educated farmers are planting more trees (or protecting more natural regeneration including *A. albida*) than poorer farmers in order to position themselves for the day when tree establishment and tree tenure may be equated with land tenure. This is consistent with literature on the "tenure enhancing aspects of agroforestry" where a farmer may be able to use tree tenure as a means of securing land tenure (Millon 1955, Foster 1966, Bruce and Fortmann 1988).

¹⁶⁷Fortmann and Riddell (1985) provide a world-wide annotated bibliography on tree and tenure issues in agroforestry. Bruce and Fortmann (1988) provide a detailed analysis of some of the more important issues in land and tree tenure.

In the context of this study, land tenure is considered to be both an internal and an external variable in the *A. albida* system. Externally, the Law of National Domain (Law No. 64-46 of June 17, 1964) is the cornerstone of Senegalese land law. The fundamental feature of the law was that all land that had not been registered or was not registered in the delay granted by the law became part of the National Domain. It is estimated that between 98 and 99 percent of all Senegalese land was thus incorporated into the National Domain (Golan 1990).

The 1964 Law divides the National Domain into four categories: urban zones, classified zones, rural zones and pioneer zones. Urban zones consist of all land situated in communities and urban areas. Classified areas are forest areas and protected areas such as national parks. Rural zones consist of those lands which at the time of the Law were regularly exploited for agriculture, pasture or rural housing. All other land is designated pioneer zones. Rural zones are the administrative responsibility of the rural councils. These councils are composed of elected members chosen from the community.

The 1964 Law stipulates that anyone who personally cultivates land within a rural zone has use rights over the land, but that vacant or poorly used land can be redistributed as the rural council sees fit. Those who work their land by traditionally having done so, or through grant by the rural council, possess only use rights. Farmers with use rights cannot sell, rent or lend their land. All transactions must be conducted through the rural council; there is no legal land market. With the death of the original cultivator, heirs must obtain permission from the rural councils to continue working the land.

Internally, however, customary land tenure rights still prevail. Historically, land in the Peanut Basin was claimed by the first settlers by right of their having cleared it by fire. These men became known as the "masters of fire" or in Wolof, the "borom daye".

They usually claimed vast areas of land cleared by up to six days of burning. Being unable to cultivate all of their holdings themselves, these men accorded use rights or "rights of hatchet" to men who could cultivate the land. Once given use rights, the "master of the hatchet" or "borom n'gadio" had incontestable, irrevocable rights to that land as long as he paid yearly homage (either symbolic or an actual portion of harvest) to the master of fire. Rights of fire and hatchet were (and still are) passed from father to son. However, Golan (*op cit.*) reports that in most of what is considered to be the old Peanut Basin, the right of fire died out during the time of the French and only the right of hatchet remains. Whether considered as an internal or an external variable, however, security of land tenure does not appear to have a significant influence on the *A. albida* system. In a study of two villages in the NCPB, Golan (*op cit.*) concluded that security of tenure was not an issue in terms of farmer willingness to invest in improvements in the land. However, in terms of trees, the most common type of improvement, she did find farmers with less secure tenure situations have planted or maintained more trees than those farmers with more secure tenure. Her conclusion was that farmers with insecure tenure rights may want to more visibly "prove" their tenure through better stewardship of the land via tree planting.

Given Golan's research, land tenure as a factor in the *A. albida* system was intentionally not included as a major component of the socio-economic survey. However, the survey and group discussions did reveal a number of land conflicts resulting from the interaction between customary tenure and the Law of National Domain. Land disputes have occurred or are currently occurring in ten of the study

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The most common source of conflict appears to be over "unused" land. For the most part, this is land that has been left in fallow for some time due to the absence or death of the proprietor or occasionally, from lack of inputs. However, the owner (or his family) still claim rights to the land through the customary "right of hatchet". Additionally, the contested land is almost always located near the territorial limits of the village. Often a village will change its location and move closer to the contested area in order to more closely survey and protect their interests. This was the case of the villages of Darou Dieng and Thiabé Sanou.

Several examples will help to illustrate the types of conflict involved. Informants from Darou Dieng reported that they have been in conflict with three neighboring villages (Ndoucoumane, Fétodj and Nousladji) since of the death of the village founder in the early 1970's. These villages wanted to take land that had originally been cleared by Darou Dieng's founder, but was currently unexploited. All land in conflict was on the village "frontier". According to informants, before the law of National Domaine and under customary tenure, these fields--having been cleared by the village founder--belonged to the descendants of the founder under the "rights of hatchet". Following the law of National Domain, informants believed that "Darou Dieng" legally inherited these lands but stated that the neighboring villages did not respect this and hostilities resulted. The Sous Prefet from Ndindi was called in to settle the dispute. He ruled in favor in favor of the founder's descendants who were able to only

¹⁶⁸It is interesting to note that the majority of conflicts seemed to occur in the less populated north/north central portion of the study area rather than in the more densely populated southern portion. Moreover, seven of the ten villages reporting a conflict are Wolof villages, while two Serer villages (Loumbel Sayé and Tiabé Sano) reported conflicts with neighboring Wolof villages. In only one case was the conflict between two Serer villages.

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recently regain their land. The situation is similar in the village of Chérif Moulaye. According to one informant, following the death of the founder of the village, neighboring villages "tried to profit" from the death by annexing Cherif Moulaye "territorial" land. However, the land was later reclaimed by direct descendants of the founder through a ruling by the rural council.

The conflict problem in Loubel Sayé is somewhat different. During the drought of the early 70's, many farmers from Loubel Sayé left the village temporarily to try to earn a livelihood elsewhere. They abandoned their fields and those fields close to the "frontier" with the neighboring village of Ndioumane, began to be cropped by inhabitants of that village. However, after the drought, many people who left Loubel returned and wanted their fields back. Ndioumane would not cede the fields to their original owners and considerable conflict has resulted and the majority of cases are still before the rural council.

Only one conflict had trees as at least part of the problem. In 1978 on the death of the Firadossi village marabout, a group of Peul herders installed their herds and began pruning trees on land which had been originally cleared by the Firadossi marabout. When the marabout's disciples went to reclaim the land, the Peul refused to give it up and as one informant put it, "a range war began with one death on each side". The problem was brought before the Sous Prefet who ruled in favor of the marabout's disciples.

The above examples are only intended to illustrate that while the land tenure system in the NCPB is still grounded in customary practice for the majority of "exploited" land, the Law of National Domain is beginning to assert itself on "unused" land. Unfortunately, the impact of this conflict on the *A. albida* system and other tree planting/land stewardship activities is not known. None of the selected informants were directly involved in the conflicts described above and a biophysical inventory was not conducted on any of the

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contested fields. However, as a future study, it would be interesting to conduct such an inventory on these contested fields given Golan's assertion that farmers with less secure land tenure rights (i.e., those "occupying" unused fields) may actually have a higher tree density (either planted or naturally occurring) as a means of increasing visibility and eventual rights to the field.

7.4.1 Land tenure and unexploited land¹⁶⁹

One-half of the villages in the survey had some unexploited land available for development. It is estimated the total area of this land for the 18 villages to be about 700 ha with a maximum of 80 hectares for one village and a minimum of 1 ha for another village. The average size of unexploited land was about 20 ha. For the most part, these areas are primarily "khors" or "bas fonds" (clay depressions) and generally difficult to cultivate. In the past, these areas served as a pasture/range resource for a village's livestock and as a result, tree and soil resources are usually severely degraded. As livestock holdings have decreased for many farmers because of past droughts, vegetable gardening in the khors has become increasingly important where the water table is relatively close to the surface. Where the water table is deeper, some villages are now protecting these areas in order to enhance natural regeneration as discussed in Section 7.5 below.

Current uses of these areas are presented in Table 7.24. Clearly, traditional uses of these communal areas predominate. Animal grazing and firewood collection are about of equal importance followed by straw, fruit and service wood and medicinal plant collection. Improvement or development of these areas (i.e., vegetable gardens, woodlots and fruit tree plantings) appear to be fairly limited according to informants.

¹⁶⁹Unexploited land in the case of this study means land that has not been previously farmed/cropped. It should not be considered as fallow land or as "unused" land.

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Table 7.24

**Uses Of Unexploited Land
(Number and Percent of Responses)**

Use	No.	Per.
Reforestation	4	2.7
Firewood collection	31	20.5
Service wood collection	18	11.9
Fruit collection	23	15.2
Medicinal plant collection	9	6.0
Animal grazing	32	21.2
Fruit tree planting/gardens	4	2.7
Straw collection	26	17.2
Animal passage	4	2.7
Total responses	151	100.0
Source: Survey data.		

The importance of these areas in supplying the forest product needs of rural populations in the NCPB is also significant. Table 7.25 indicates that roughly one third of all straw/grasses, medicinal plants and service wood comes from these areas. In addition, they supply about 28% of household fuelwood supplies, 26% of indigenous fruit supplies and 18% of fodder supplies.

As would be expected for what are essentially common property areas, tree resources on unexploited areas also appear to be more severely stressed than on-farm tree resources. Informants were asked to indicate what they perceived the occurrence/frequency of distribution of the most important species according to use, where 0 = none, 1 = rare, 2 = some, and 3 = a lot. For each use category, perceived species occurrence is always higher on-farm than in the unexploited areas. Responses are also summarized in Table 7.26.

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Table 7.25

**All Species
Distribution and Occurrence**

Species	Fields		Unexploited		Fallow		Total farm	
	Per- cent	Occur- rence	Per- cent	Occur- rence	Per- cent	Occur- rence	Per- cent	Occur- rence
Grasses/straw	20.4	1.4	32.6	1.3	47.0	2.1	67.4	1.7
Firewood	33.6	1.7	28.0	1.3	38.6	1.8	72.2	1.7
Fruit	39.5	1.7	26.4	1.1	34.1	1.5	73.6	1.6
Medicinal plants	30.5	1.5	39.4	1.3	30.1	1.3	60.6	1.4
Forage/fodder	38.9	2.1	18.3	0.9	42.7	1.9	81.7	2.0
Service Wood	34.3	1.5	35.7	1.1	30.0	1.3	64.3	1.4
Source: Survey data.								

Table 7.26 suggests that women and children have major responsibility for the collection/harvesting of fuelwood and fruit accounting for 77.1% and 62.8% of responses respectively. The conversion of these areas into vegetable gardens may have an impact on women's ability to supply household fuelwood needs and place increased pressure on on-farm trees. Moreover, much of the indigenous fruit harvested from these areas is sold in the local markets and represents a significant source of income for many rural women. However, most of the profits from vegetable gardening go to the men of the household (Schoomacher 1991).

Table 7.26

**All Species
Collection and Harvesting Responsibilities
(Percent of responses)**

Species	Responsibility of			
	Men	Women	Children	Every- body
Grasses/Straw	64.7	1.5	5.7	28.1
Firewood	1.2	70.1	7.0	21.7
Fruit	4.8	35.6	27.2	32.5
Medicinal plants	63.4	9.3	0.0	24.5
Forage/fodder	70.7	5.9	4.2	19.2
Service Wood	76.1	6.0	0.0	17.9
Source: Survey data.				

As the above discussion suggests, common or unexploited areas around many villages represent important sources of tree and forest

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product supplies for many informants and their families. They also have considerable potential to provide increased forage, fuelwood and service wood supplies and relieve at least some of the pressure on on-farm trees through better and more rational management. A critical issue, however, is to what extent are these areas becoming "privatized", and what role, if any, does tree planting have on the privatization/land tenure process.

In order to explore this relationship, informants were first asked how these unexploited areas have changed in size over the past years. A total of sixteen (44.4%) informants felt that these areas have stayed more or less the same size while 15 informants (41.7%) thought that these areas had decreased in size. Those informants who felt that these areas had decreased in size unanimously believed that it was lack of agricultural land which had caused some farmers to begin to farm these areas in spite of the difficulties involved. Access to this land, according to informants, was gained through both customary/traditional procedures as well as by application of the law of national domain.

Four informants (11.1%) felt that the amount of unexploited land in and around their villages had actually increased in size due to the unavailability of agricultural inputs, primarily seed and fertilizer. The exodus of many farmers from rural areas was also cited by one informant as a factor. Apparently, the more difficult-to-farm areas in and around the khors are the first to be abandoned in difficult times.

Next, informants were asked if they believed that someone could gain rights to unexploited or communal land (domaine nationale) by planting trees on it. Only three informants indicated that they thought this might be possible but stated that no one in their village had actually done this nor had they heard of this happening in other villages.

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Finally, no evidence was found to suggest that any private tree planting was taking place on these areas through both field observations and in discussions with farmers. The only tree planting/natural resource activities taking place in these areas were communal in nature--either village woodlots/fruit tree plantations (in three villages) or natural forest management (two villages)¹⁷⁰.

While this limited evidence suggests that farmers in the NCPB are not using tree planting as a means of gaining tenure to the very limited amount of unexploited land currently available, group discussions with farmers suggest that as tree products become more valuable, this may become an issue in the future. As a case in point, several farmers mentioned vegetable gardening as a means of gaining long term rights to khor land.

As previously stated, in areas where the water table is relatively close to the surface, many farmers have established private vegetable gardens in NCPB bas fonds. While it is not known how these farmers actually gained rights to this land initially, group discussions with farmers suggested that these individuals: (i) had the capital necessary to begin vegetable gardening; and (ii) obtained the rights to the land through the CER under what appears to be the "autorisation d'occuper" method of increasing tenure security under the 1964 National Domain Law and the 1976 Law No. 76-66, "Portant Code du Domaine de l'Etat". Although the tenure system in the NCPB is still grounded in customary practice for the majority of exploited land, a break with tradition appears to be occurring in the case of unexploited land; as Hardy (1989) points out, in some areas the law of National Domain is beginning to assert itself.

¹⁷⁰This is not to say that as these woodlots and orchards mature and begin to yield benefits, common land may become privatized. This would be consistent with the Sahel's past experience in community woodlot management. As Bruce and Fortmann point out, large numbers of trees may be planted on communal land for both household or community subsistence use but once those trees take on a commercial value, private rights in that land tend to develop.

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Evidence from the study suggests that in the case of the unexploited khor lands, relatively wealthy farmers might be able to take advantage of the National Domain law to gain access to these areas and therefore bypass customary land allocation procedures. While this is only a hypothesis whose proof is well beyond the scope of this study, of primary concern is the fact that in certain areas of the NCPB, private vegetable gardens have decreased the amount of common khor land available to a village. As a result, farmer access to a wide variety of forest products may be decreasing. In particular, the conversion of these areas into vegetable gardens may have an impact on women's ability to supply household fuelwood needs and in turn, may place increased pressure on on-farm trees. Moreover, much of the indigenous fruit harvested from these areas is sold in the local markets and represents a significant source of income for many rural women. However, most of the profits from vegetable gardening go to the men of the household (Schoomacher 1991).

In conclusion, these areas have considerable potential to provide increased forage, fuelwood and service wood supplies and relieve at least some of the pressure on on-farm trees. The results of the survey suggest that this may be an area where additional research is needed on both the potential of the areas as well as on changes in tenure patterns.

7.5 Theme 4: Perceptions concerning village associations and groups

The importance of local organizations in community forestry and natural resource activities such as agroforestry has also been well documented¹⁷¹. Senegal has a number of these autonomous farmer organizations. The United Nations (1984) describes them as local clubs with good voluntary work modes at village-specific sites. Their goals are most often of direct benefit to the rural farmer through

¹⁷¹Blair and Olpadwala (1988) and Foley and Barnhard (1984) provide an excellent review of the importance of rural institutions and local organizations in social forestry projects.

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extension activities and resource dissemination. Membership is exclusively indigenous with limited outside intervention in the form of financial or logistical support. These groups emphasize traditional and informal organizational structures which allow participation of a wide variety of socially diverse people. Although these organizations appear voluntary, they most often appeal to farmers through the financial incentive of increased productivity. Local organizations also have a solid outreach potential to large numbers of otherwise inaccessible people.

The majority of informants (51 or 70.83%) felt that associations and farmers' groups had a more important role to play in natural resource management than they currently do. Asked what this role should be and how it might be strengthened, three major themes emerged. First, in terms of the most appropriate structure, the majority of informants (20) suggested that village level natural resource management and protection/surveillance committees need to be created. Or, in villages where farmers groups already exist for whatever purpose, these groups should be restructured to incorporate natural resource management concerns. One informant suggested that committees of existing groups which deal with natural resource issues need to be enlarged in order to permit broader participation of people with similar natural resource problems and concerns.

The second theme centered around the need for more local authority in controlling and protecting natural resources. Seven informants remarked that what was needed was for these committees to have more authority at the village level to control their own natural resources. Informants noted that given the lack of DEF agents (one per arondissement) and their relative immobility, DEF response to illicit cutting and pruning of trees is either not timely or non-existent. Visits by DEF agents to the villages surveyed are extremely rare (see Chapter 5) and farmers maintain that the only real control provided by the DEF is at the weekly markets which DEF agents attend to catch primarily those

selling firewood and charcoal without a permit¹⁷². Given this situation, some informants felt that they could do a better job themselves providing they had the authority to control tree poachers. More often than not, the only authority requested by these farmers is the right to exclude others from their fields, although some informants suggested that these committees should be able to conduct "proces verbaux" and issue fines.

The third major theme noted by eight informants was the need for the village committees to be given the financial and technical means necessary to do the job. One of the reasons why farmer organizations work so well in Senegal is that they focus on a particular economic activities such as animal fattening, vegetable gardening or seeds (see below) where benefits are received by members in a relatively short period of time, usually less than one year. However, benefits received from trees either directly through increased firewood, food or fodder supplies, or indirectly through soil conservation and/or amelioration require much longer periods and some form of financial support may be needed in the interim.

In terms of technical support, informants noted the need for "encadrement" for these committees in terms of organization, management and technical skills. Informants and other farmers remarked that all too often, villages have taken the initiative in forming agriculture or natural resource related village committees and associations but do not know where to turn to in terms of help in management, investment possibilities, financial assistance or providing better technical skills to its members¹⁷³.

¹⁷²It should be noted that two of the villages surveyed had a forest monitor. This is generally a farmer from a village who is hired by the DEF (most often remunerated by "vivres PAM") to keep an eye on illicit tree cutting and pruning in the village. The monitor has no authority to issue fines, etc. and can only report offenders to the DEF who then take action, if required.

¹⁷³As an example, in one village (Ndakh) we were proudly shown an women's association's postal savings account book. Members of the association had succeeded in raising over fcfa 900,000 (about \$6000)

In spite of informant and general farmer interest in the use of groups/associations for better natural resource management, only one formal, externally supported group identified in the survey had actually done any natural resource-related activities. The Groupement Fonds Européen de Développement de Ndimb Diol had established a windbreak around their vegetable garden. However, on a organizational level somewhat lower and more internal than the more formal types of groups discussed above, concerted action by farmers to protect and conserve their natural resources is very apparent in the NCPB. Moreover, the types of groups involved in natural resources lends some credence to Hannan and Freeman's argument (1982) that the development of social organizations is based more on competition and selection than adaption, as the major reason for farmer concerted action appears to be to enhance tree tenure.

7.5.1 Tree tenure and informant concerted action

Like land tenure, tree tenure can be both an external and an internal variable. Externally, forestry legislation in Senegal has, until recently, vested sweeping regulatory powers in the DEF to control use and management of virtually all forest resources, including the use and management of trees farmers plant or that are naturally regenerated on their own farms. The GOS has prevented individual ownership and management of trees by declaring them state property. Under Senegal's current forest code, all trees belong to the state and farmers must have permission from the local forestry agent to cut them. More often than not, this agent is perceived by farmers as more of a "policeman" than an extension agent. Many argue that

through fund-raising and marketing chickens and by monthly membership dues (50 fcfa per member per month). The group had wanted to invest this money in a vegetable gardening project. They were informed by the local water authority, however, that the water of the village tube well was too salty to permit vegetable growing. The group was now seeking another activity in which to invest their funds but had no idea as to what was possible and what the potential return on various activities might be. As we were the only quasi development-type people that had visited the village in two years, our opinions on what to do with the money were actively sought.

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this combination of factors discourages farmers from providing the care and protection *A. albida* trees need to survive and grow, while allowing nomadic pastoralists (and often friends, relatives and neighbors) to exploit the trees more or less at will as laws regarding harvest of trees are rarely enforced.

The legal instrument for forest protection and management is the "code forestier" or forest code¹⁷⁴. This code empowers the DEF to regulate farmer and community use and management of trees and forests on private farms, and in collective plantations and woodlots. The code requires private producers to obtain a permit from the local DEF agent before cutting most species of trees, whether for commercial or private use. Theoretically, the collection of dead wood, fruits and nuts is permitted without forest service approval although in practice, a permit is often required to harvest dead trees¹⁷⁵. The code also stipulates that cutting of all exotic species and all species planted by man must be approved by a DEF agent. Persons who fail to secure a permit are subject to fines and/or imprisonment.

Internally, however, tree tenure is quite different. First, DEF agents have wide discretionary powers in considering whether or not to grant permission to harvest trees. Second, and perhaps more importantly, there is usually only one DEF agent per arondissement and he is not likely to have any transportation to visit the more isolated villages to control "illicit" tree cutting or branch pruning. As discussed in Chapter 5, only three informants from two villages (located along a main road) reported that their villages had been visited by a DEF agent during 1989 for forest protection/control

¹⁷⁴The description of Senegal's current forestry code and proposed amendments draws primarily from Elbow and Lawry (1989).

¹⁷⁵Around one study village, there were quite a number of dead *cad* trees as a result of a drought/water table drop in 1986. Farmers reported that they had to obtain a permit from the local DEF agent (supposedly a difficult proposition) to harvest dead *cad* trees in their own fields. Informants suggested that one way to improve fuelwood supplies in the NCPB would be to allow the "free" harvest of dead trees.

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purposes. Rather than field visits, the more common practice is for DEF agents to attend the weekly markets and control and fine those selling wood and other forest products without a permit.

The net result is that from an internal perspective, the majority of farmers are free to do with their on-farm trees as they see fit. As an example, 29 informants (40%) reported pruning cad branches for forage without seeking authorization from the DEF. It is suspected that this number is actually higher than 40% as many informants were probably hesitant to inform "strangers" (i.e., the principal investigator and the enquêteurs) of what is essentially an illegal practice.

Given the lack of a DEF presence in the field, one might assume that there would be a tendency for farmers to "over-harvest" their on-field trees, including cad. However, just the opposite seems true. During the course of the study, one type of individual "protective" action and three types of "collective" action were identified which suggest that farmers are attempting to better manage their own tree resources (and environment) in the virtual absence of outside assistance.

7.5.1.1 Tree tenure and individual action

In terms of individual action, informants and other farmers from the study villages of Ndianga and Bakhdas have instituted the practice of marking their on-farm cad trees with pieces of bark or cloth as a sign of ownership. According to informants, the purpose is to discourage Peul herders from indiscriminately lopping branches from what are considered to be individually owned trees. The practice was apparently successful as informants reported that neighboring villages have started similar cad marking programs.

7.5.1.2 Tree tenure and collective action

Farmer collective action in the study area to protect the environment and tree resources appears to take three forms: (i) the formation of village "comités de surveillance"; (ii) the use of

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forest "monitors"; and (iii) concerted action for the protection of natural forests (natural forest management).

7.5.1.2.1 Comités de surveillance

"Comités de surveillance" (forest monitoring and protection committees) were found in six of the thirty-six villages in the survey including Ndianga, Ndoyoumbout, Chérif Moulaye, Bahkdas, Ndagane and Tiabé. While the structure and success of these committees differs somewhat from village to village, they are generally composed of a group of 10 to 20 (depending on the size of the village) chefs d'exploitation/carrés. Their objective in forming the group is to provide mutual surveillance of fields against illicit cutting of trees usually during the afternoon and early evening hours (between the hours of 2:00pm and 6:00pm). According to members of these groups, the reason for these particular hours is that this is the period when the majority of tree poaching takes place; at this time, farmers have returned from their fields for their noon meal and a siesta, and tree poachers take advantage of their absence. Thus, in order to control this phenomenon, farmers in these informal groups take turns patrolling each other's fields during peak afternoon poaching periods.

If poachers are apprehended by the farmers, they are given a verbal warning that the trees are private property and should not be cut. If a verbal warning is not sufficient to deter offenders, or in the case of repeat offenders, the DEF agent and/or other local authorities are informed and some form of official action is sought (usually a fine). Generally speaking, farmers give culprits one warning and if the offense is repeated then local authorities are summoned. This practice appears to work reasonably well in controlling much of the illicit cutting for firewood and charcoal, as well as for pruning for fodder in areas where animal populations are limited.

The system appears to be less effective in controlling Peul herders and in villages where one or two farmers have substantial

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livestock (cattle) holdings. Regarding this latter, members of the committees from Chérif Moulaye¹⁷⁶ and Ndoyombout reported that it was difficult to keep the wealthier members of the village (i.e., those with the most cattle) from pruning cad and other trees during poor rainfall/forage years. Similarly, members of the Bakhdas and Ndianga committees reported difficulty in controlling Peul herders who were currently camped on the outer limits of the village territory. As an innovative (and individual) solution to this problem, these committees went one step further than afternoon patrols and began tying pieces of old cloth or rope around their respective cad trees as a sign of ownership and interdiction to tree cutting/pruning.

One common theme among all the committees that was observed was their desire to have the authority for controlling their own natural resources (in particular, the right to exclude and the right to sanction) delegated to village level authorities. There was, however, no consensus on what particular local authority should have this power. Some farmers felt that the committees themselves should have the power to sanction while others believed that the village chief or the conseil agricole would be more suited to take such actions. These differences in opinion most probably stem from people's perception of these individuals, with trust and respect of village leaders playing a primary role in the type of local authority desired.

¹⁷⁶It is interesting to note that Chérif Moulaye's idea for a comité de surveillance came from a neighboring village (Ko). Farmers from Ko decided about two years ago to interdict all cutting of trees in the village territory. This action, according to farmers from Chérif, resulted in a significant difference in vegetative cover and natural regeneration between the two villages and Cherif decided to form its own committee. The eventual intent was to combine actions with farmers from Ko to protect even a wider area. However, success of the committee in Cherif has been somewhat limited for primarily two reasons. First, many farmers in Cherif cut trees (particularly nger) to sell for firewood in Tivaouane as a means of replacing income lost to reduced peanut production. Second, there are many farmers in Cherif with considerable numbers of animals and the committee has not been effective in controlling pruning of older trees and browsing of young ones.

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7.5.1.2.2 Forest monitors

The second type of concerted action undertaken by farmers in the NCPB is the use of forest monitors. Two study villages had this form of collective action, Kiel and Tiobé. Both of these villages have a "comité de surveillance pour la protection des arbres", but these committees function much differently than the ones discussed above. Given the environmental degradation around the two villages, the committees contacted their respective DEF agents who suggested that one member of the committee be chosen as a forest monitor (surveillant) for the village. This person's job would be to patrol the village territory and attempt to control illicit tree cutting. These monitors have the power to sanction offenders and if this power/authority is not respected, the DEF agent is called in as back-up. Monitors receive food aid (50 kg of millet per month) as recompense for lost farming income.

7.5.1.2.3 Natural Forest Management

The final type of concerted action on behalf of farmers to protect their environment involves collective action to protect natural forest areas within the territorial limits of a particular village. Three of the survey villages were undertaking this type of action; Palène, Keur Mbagne Diop and to a lesser extent, Ndoyombout.

The village of Palène has probably the best example of what can be done by farmers with no external input and using locally available resources. According to informants and other farmers from Palène, they were becoming increasingly concerned about their immediate environment. The number of trees were decreasing, soils were becoming poorer and poorer and crop yields were declining. Within the territorial limits of the village there was about 15 ha of severely degraded pasture land (khor) with remnants of the typical khor/clay vegetation type. During the drought of the 70's villagers reported that the majority of their livestock had perished and

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consequently, the area was only used for water collection and storage during the rainy season.

In 1984, recognizing the productive potential of the area (and the fact that the water table depth and soil type precluded any agricultural use at least for the immediate future), the village collectively decided to try and protect the area (*mise en défense*) from illicit tree cutting and overgrazing. The village organized a small group of farmers (12) to take turns patrolling the perimeter and interior of the area as a means of discouraging tree cutting and grazing. According to farmers, this worked well enough but they felt if they had more authority to manage the area, they could even be more successful.

To this end, they approached the local DEF agent in Bambey to inquire whether they could actually be given authority to manage the now burgeoning forest. The DEF agent and local administrative authorities agreed and in 1986 provided the village with a *note de service* authorizing the village to sanction any illicit cutting and grazing in the protected area.

The net result of this village's concerted action is that they now have 15 ha of savannah forest less than one kilometer from their homes. The area's ability to recover is incredible as anyone who has visited it will attest. There are a wide variety of species and the principal investigator estimates the mean annual biomass increment to exceed 7-8 m³ per hectare per year in some of the more fertile areas. Considering that village woodlots/block plantations usually only attain 2-3m³ per hectare per year in the Sahel (and are usually only single use), the potential for this area to provide a wide variety of forest products on a sustainable basis for the village is considerable¹⁷⁷. Currently, the only use of the forest permitted by

¹⁷⁷The contrast between natural forest management/*mise en défense* and village woodlots can be observed first hand in Palène. In the same year they began protecting the degraded pasture, the village also planted a small (one half ha) woodlot using primarily *Prosopis*

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the village is for cut and carry fodder¹⁷⁸ and the occasional harvesting of fruit (*Balanites aegyptiaca*) and medicinal species.

While this village's actions demonstrate what simple protection of an area can achieve, a major problem for Palène is management. The village has simply no idea on how to manage the area in order to obtain sustained benefits. Villagers were asked by the principal investigator if and when they would begin to harvest some of the species in the area. He was informed that the village fully intended to eventually use the area but did not know how to do this on a sustained basis. Essentially, they recognized the fact that they had a significant resource and did not want to risk wasting it without some technical expertise. The research team noted that many of the species in the area, particularly *Guiera senegalensis* and *Combretum* spp. could be thinned now in order to provide some immediate return on their investment while perhaps enhancing establishment of other, more economically valuable species.

Finally, it should be noted that Palène's forest has aroused the curiosity of at least two neighboring villages who have similar tracts of degraded khor pasture. The Palène village chief reports that farmers from these villages, noticing the rapid recovery of Palène's protected area, arranged to send delegations from their villages to Palène. The objective of these visits was to see the "forest" and discuss with the committee how such an action was undertaken. The chief reported that both of these villages have now undertaken a "mise en défense" on their own, although time did not permit the research team to independently confirm this.

juliflora. The difference between the woodlot and the natural forest is striking with the latter containing more than twice the biomass per unit area as the former. When farmers from the village were asked which type of forest they preferred (natural or artificial), they laughed and said "now that you have seen the difference, which one would you choose".

¹⁷⁸Sufficient to support the fattening of 15 head of sheep according to the village chief.

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The village of Keur Mbagne Diop¹⁷⁹ also has a "comité de surveillance et de la protection de la domaine nationale" whose goal is to protect a small parcel (about 30 ha) of forested savannah also located in a khor located about one kilometer from the village. Cutting of trees in this forest is not allowed by the committee but there is some fodder cut and carrying fodder taking place. As with the village of Palène, the major problem in Keur Mbagne Diop is technical; how to achieve sustained and rational use from the forest in the absence of technical expertise.

However, unlike Palène where all the village appeared to profit from the forest, some farmers in Keur Mbagne raised the issue of eventual distribution of benefits. Additionally, there is also some evidence that women have become at least temporarily disadvantaged by the mise en défense because a major source of fuelwood for the village has been eliminated.

The village of Ndoyombout also has, within its territorial limits, about 40-50 ha of degraded savannah forest (again a khor) and the village committee would like to take responsibility for improved management/development of the area. To this end, they consulted with the local DEF agent who suggested that the remnants of the forest be cleared and that it be progressively replaced with a village woodlot/block plantation. Clearing and planting began in 1988 and to date about 2 hectares of neem, eucalypt and *Casuarina spp.* have been planted. When the principal investigator suggested that it might be cheaper and more profitable to simply protect the area (mise en défense) as other villages have done, the committee agreed to discuss

¹⁷⁹In addition to undertaking actions to protect the forest, farmers from this village are the only ones in the study group who have actually planted cad trees in their fields by transplanting wildlings. Informants reported that due to the passage of animals there were many cad seedlings concentrated in only a small area and inhabitants of the village wanted to "spread" these around to their various fields.

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this option with DEF and expressed considerable interest in visiting Palène.

7.5.1.3 Current farmer actions vs. proposed modifications to the Forestry Code

The above types of action have one common theme; protection of existing resource via the right to exclude others. As discussed in Section 7.3 above, many informants and other farmers felt that what is needed in the NCPB was increased protection of existing tree resources rather than establishment of new ones. This perceived need and resulting informant actions need to be examined in light of proposed changes to Senegal's Forestry Code.

In the early 1980's, the DEF began to recognize that certain aspects of the current forest code, particularly the DEF's role in regulating the use and management of trees farmers plant on their farms, may be discouraging private investment in forestry. As a result, the GOS has been considering various drafts of a new Forest Code since 1984. The current draft code, still awaiting final action by the National Assembly, represents a significant departure from tree and tenure policies underpinning the current forest code. This draft code would, under specified conditions, grant to individuals and group rights to certain trees and forests currently monopolized by the State. Elbow and Lawry (1989:8-9) provide a review of some of the articles in the draft code. In terms of property and use rights of individuals:

Article 9 states that the forests or trees planted in the national domain as individual plantations, or trees and shrubs established as windbreaks or to protect the soil, are the private property of the person who established them...

Article 88 states that plantations of woody species established on the national domain, according to the rules of the disposition of this domain, are the property of he who established them. He disposes [of the plantation's products] as he likes, without any power, however, to degrade, physically or biologically, the resource base.

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In terms of property and use rights of groups:

Article 78 states that local collectives such as rural communities or all public collectives may possess artificial (planted) or natural forests

Article 81 states that local collectives have free and total use of the products of their forest domain. The revenues from the commercialization of the products of the community forest domain are entirely at the disposition of the community. However, communities are obligated to contribute to the Forest Fund at the rates established by the regulations.

Article 83 states that local collectives that possess forests have the ability to decide all activities of exploitation, enrichment, or regeneration of their forest resources.

In spite of these very positive revisions, as Elbow and Lawry (*op cit.*) point out, the draft code still requires owners of trees to secure the authorization of the DEF before harvesting and marketing trees. Article 53 states:

Owners wishing to debranch, cut down or exploit the trees of their property must inform the administration of the Forest Service which will deliver the authorization and eventually a service permit.

Elbow and Lawry (*op cit.*) argue that Article 53 compromises or nullifies gains made by farmers from other sections of the code. They also argue that while the majority of authorizations will be provided free of charge, the authorization process will introduce needless transaction costs to both farmers (in seeking out the authorization) and to the DEF in terms of staff time and costs in processing applications. While the purpose of this study is not to review or critique the draft forest code, nevertheless, some comments appear to be in order. First, in the context of current farmer actions to preserve and protect their environment, proposed modifications to the code tend to place more emphasis on the rights to the benefits of trees planted by an individual, rather than rights to exclude others from those benefits. However, collective actions currently undertaken by farmers in the NCPB suggest that the latter is perhaps more important.

Second, while the proposed code would recognize producer property rights to trees planted on farm, according to Elbow and Lawry (op. cit.), farmers would have no rights over the use of naturally propagated trees occurring on their farms. However, natural regeneration is perhaps one of the best as certainly cheapest means available to farmers to increase the number of on-farm trees. Moreover, and as pointed out in Chapter Three, the presence of these naturally occurring trees contributes significantly to soil stability and stable crop yields. Additionally, as the Biophysical Inventory indicates, there is a considerable amount of natural regeneration of valuable multi-purpose species, including *A. albida*, taking place. As has been shown above, and will be shown elsewhere in this study, farmers, through their management practices, determine whether or not naturally regenerated seedlings survive and mature. A forest code which does not (at least officially) confer the rights to naturally occurring trees on a farmer's own field seems rather pointless.

Finally, and perhaps most importantly, the points Lawry and Elbow make about Article 53 and the authorization process and the importance of tree tenure in general may be rather moot, at least for the NCPB. In short, if the DEF could not enforce the old forest code and farmers were left to their own devices in terms of natural resource management, how does the DEF intend to enforce a new code? In order for laws to be effective, they must be enforced. The study revealed that there was very little enforcement taking place among informants. As a result, it is expected that while the new forest code may have an impact at the community or group level, it is doubtful whether it will significantly encourage or discourage private tree planting at the individual or farm level. It is expected that farmers will continue to rely on their own actions and resources much as before.

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7.6 Conclusions and recommendations

Theme 1: Informant perceptions on the evolution of tree cover

In general, the survey found that the majority of informants have a fairly good understanding of the evolution of tree cover in the NCPB. While the majority of informants perceive tree cover for both *A. albida* and other species to be decreasing, many more informants believe *A. albida* tree cover to be increasing relative to other species. This perception is in fact supported by the results of the Biophysical Inventory which show relatively good stocking and regeneration rates for cad. For the majority of other species, however, tree cover indeed appears to be decreasing.

Farmer perceptions concerning other species also appear to be in line with the Biophysical Inventory. Of the 69 woody perennial species identified and counted, only *A. nilotica* v. *adansonii*, *A. raddiana*, *Balanites aegyptiaca*, *Bauhinia rufescens*, *Borassus aethiopum*, *Combretum glutinosum*, *Cordyla pinnata*, *Piliostigma reticulatum* and *Sisiphus mauritiana* appear to have relatively high stocking levels in all diameter classes as well as relatively high numbers of younger trees. Decreasing tree cover has left informants to be particularly concerned about current service wood and forage supplies. However, the majority of informants are nevertheless optimistic that supplies for these products will increase in the future.

Informants perceived drought, cutting for forage, cutting for service wood and poor field preparation techniques as the major reasons for the decline in cad and cover. According to informants and contrary to conventional wisdom, pruning cad for fuelwood has little impact on the system. This perception is corroborated by this study. For species other than cad, drought, cutting for firewood, cutting for forage and cutting for charcoal are perceived to be the major contributors to decline.

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An attempt to compare farmer perceptions with some empirical analyses suggest that rainfall has little impact on cad establishment but that water table depth is significantly related to both cad regeneration rate and cad density. While the analysis has several shortcomings¹⁸⁰, the relationship between drought, water table depth and cad density and regeneration has a number of implications for those concerned with reestablishment of the *A. albida* system in the NCPB.

In the more northern areas of the study area where relatively deep (60 to 70 meters), a lowering of the water table induced by drought indeed appears to be a prime culprit in cad's decline and will be a major obstacle to its re-establishment. In the more southern reaches of the *A. albida* zone where the water table is between 20 and 40 meters, a combination of drought and severe pruning for forage appear to be the primary culprits of cad's decline. This would suggest that in the southern regions of the NCPB, cad survival might be enhanced by proving farmers with alternative sources of forage.

Informants also perceived cutting cad for service wood as a major factor in cad's decline. The primary reason for doing this is that alternative sources of service wood (which are stronger and last longer than cad) have been nearly exhausted. However, informants tended to equate the quality of cad wood with the quality of neem service wood. As neem grows well in the NCPB, increasing supplies of this species might alleviate pressure on cad for service wood.

Informants who perceived an increase in cad tree cover attributed this to increased protection among farmers and to increased regeneration due to increased rainfall. While the latter perception

¹⁸⁰Not the least of which is the estimation of the age class and the relationship between the number of trees in that age class and rainfall for a particular year). Moreover, total rainfall, number of days of rainfall and in particular residual dry season soil moisture content obviously have an impact on younger tree growth rates and survival which the above analysis was unable to capture.

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may be faulty, the former perception is undoubtedly true and supports hypotheses presented in Chapter 4.

While increased fallow and parcase may have had an impact on cad regeneration in the past, currently this does not appear to be the case. There was no significant relationship between cad regeneration rates and fallow period or use of parcase. However, an important finding of this study is the highly significant relationship between manure use and cad regeneration rates. Informants who stall feed animals and subsequently spread the manure have significantly higher cad regeneration rates than informants who do not. The implications of this are that in areas of the NCPB with low cad populations (and presumably low pod production), regeneration might be enhanced by providing farmers with cad pods brought in from the outside. This topic should be the subject of additional research in terms of techniques and timing.

Theme 2: Informant perceptions on the role of *A. albida*

As with the evolution of tree cover, the majority of informants also appeared to have a good understanding of the role of cad in their environment. Also, the majority of informants desired additional cad trees on their land but specified that lack of seedlings or natural regeneration, inadequate technical skills and poor site conditions as factors hampering their ability to increase on-farm cad density.

In terms of tree management, of particular interest to those concerned with forestry/natural resources in the NCPB is the more or less equal distribution of responses in terms of better management of existing tree resources vs. planting of new tree resources. However, in practice, considerably more GOS and donor effort and resources are placed on the latter to the almost total neglect of the former.

Finally, results suggest that there may be an ethnic differences in perception with regard to protection of either planted or naturally regenerated trees. The majority of Wolof informants felt that given the authority, they could police and control their own tree resources

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better than the GOS. These informants suggested various mechanisms for doing this such as: (i) the creation of "comités de surveillance" as discussed above with power to sanction; (ii) delegating more authority to the CERs; and (iii) providing existing farmers organizations with increased authority to control their own resources.

In contrast, the majority of Serer informants expressed interest in seeing more of the "traditional" Eaux et Forêts work of policing and control. Suggestions from this group of informants included: (i) increasing the number of DEF agents and giving them the means to do their jobs; (ii) creating a "cad project" for the NCPB; and (iii) creating a national service for reforestation and conservation of natural resources (i.e., "service national du reboisement et protection des arbres", service national de protection et surveillance, service national de reboisement et conservation des eaux et des sols").

There are two implications of this difference in terms of policy or action programs. The first is that different approaches may be required for different ethnic groups. The second is that the traditional role of a forestry agent as a policeman rather than an extension agent in the NCPB may still be valid in some areas of the NCPB.

Theme 3: Perceptions concerning land tenure

Land tenure appear to have little impact on maintenance and/or expansion of the *A. albida* system. Previous research suggested that customary land tenure rights in the NCPB are such that security of land tenure was not an issue in terms of farmer willingness to invest in improved land stewardship practices such as tree planting and protection of natural regeneration. However, the study did reveal that conflict between the Law of National Domain and customary tenure is increasing, particularly in the case of fields that border on the territorial limits of a village and that have been left in fallow for some time. There is some evidence which suggests that those farmers

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invoking the Law of National Domain to gain control of contested fields may be planting trees or maintaining more natural regeneration on these fields in order to more visibly prove their tenure. However, the study was unable to confirm this hypothesis, hence this should be the subject of additional research.

Surprisingly, in an area as densely populated as the NCPB, one half of the villages in the survey had some unexploited land available for development. It is estimated the total area of this land for the 18 villages to be about 700 ha with a maximum of 80 hectares for one village and a minimum of 1 ha for another village. The average size of unexploited land was about 20 ha. For the most part, these areas are primarily "khors" or "bas fonds" (clay depressions) and generally difficult to work. In the past, these areas have served as a pasture/range resource for a village's livestock and as a result, tree and soil resources are usually severely degraded. Traditional uses of these communal areas predominate although vegetable gardening is becoming increasingly important in areas where the water table is nearer the surface. Additionally, these areas have considerable potential to provide increased forage, fuelwood and service wood supplies and relieve at least some of the pressure on on-farm trees.

No evidence was found to suggest that any private tree planting was taking place on these areas through both field observations and in discussions with farmers. The only tree planting/natural resource activities taking place in these areas were communal in nature. While evidence suggests that farmers in the NCPB are not using tree planting as a means of gaining tenure to the very limited amount of unexploited land currently available, group discussions with farmers indicate that as tree products become more valuable, this may become an issue in the future. As a case in point, several farmers mentioned vegetable gardening as a means of gaining long term rights to khor land via invoking the law of National Domain. However, privatization of these areas reduces village/household access to a wide variety of primary and

secondary forest products and increases pressure on on-farm trees. This should be the subject of additional research.

Among informant collective actions, improved management of khor areas (natural forest management) appears to be a prime target of opportunity for increased attention on behalf of the GOS, donors and NGOs alike. These areas have considerable potential to provide increased forage, fuelwood and service wood supplies and relieve at least some of the pressure on on-farm trees such as cad. They are also major sources of fruit/food and medicinal plants. They should be the subject of additional research both in terms of management techniques and in terms of the impact of privatization of these areas and loss of benefits.

Theme 4: Perceptions concerning village associations and groups

The main conclusion here is that with little if any external inputs farmers demonstrated that they can effectively organize themselves to protect and maintain their own environment and natural resources. The development of these social organizations appears to be based more on competition for resources and enhancing security of tree tenure than on adaptation to the environment. In the study area, farmer concerted action/social organization to protect the environment appears to take three forms: (i) the formation of village "comités de surveillance"; (ii) the use of forest "monitors"; and (iii) concerted action for the protection of natural forests (natural forest management). Each of these types of groups appears to have solid outreach potential and may be one of the better vehicles to use for expansion of the *A. albida* system.

The majority of informants felt that both formal and informal associations and farmers' groups had a more important role to play in natural resource management than they currently do. However, informants expressed a need for more local authority in controlling and protecting natural resources, and financial and technical means necessary to do the job.

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In terms of tree tenure, it was found that in spite of the GOS's current Forestry Code which states that all trees belong to the state and that authorization is required from the DEF to harvest them, the absence of DEF agents in the field permits the majority of informants to manage their on-farm tree resources as they see fit. However, rather than over-exploit these resources as might be expected, many informants are undertaking both individual and collective actions to better manage and protect their own tree resources with little, if any, external assistance or control. The common theme of all of these actions was found to be protection of the existing tree resources and natural regeneration via the right to exclude others.

While a new Forest Code is currently being proposed which will individuals and groups the rights to certain trees and forests currently monopolized by the State, the study suggests that any new code will not significantly encourage or discourage private tree planting at the farm level for three reasons: (i) it focuses on the right to benefits rather than the right to exclude others from benefits; (ii) it provides for farmers to gain the benefits of planted trees but retains control of naturally occurring trees for the State; and (iii) it will more than likely not be enforced due to cost and personnel restrictions.

Finally, there needs to be increased support to actions (both individual and collective) that farmers are currently undertaking to better protect and manage their own natural resources, rather than introducing new methods and technologies. This means an increased role for agriculture and forestry/natural resources training in order to better equip farmers with the skills necessary for improved natural resource management and decision making. Similarly, extension's role should be one of support rather than implementation of a preconceived notion of what needs to be done. It may also mean modifying system-

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specific and other natural resource policies such as the Forest Code to be more in line with and supportive of farmer current actions.

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CHAPTER 8

A. ALBIDA SYSTEM INTERACTIONS

"La vendrité, c'est du piment, si on te jette
à la face, tu te frottes les yeux¹⁸¹."

Wolof proverb (Cribier et al. 1986)

8.1 Introduction

The need to understand interactions between humans and their environment has become increasingly important over the past years as many of the world's traditional but resilient agricultural systems experience the effects of modernization. This need has been especially evident in Senegal's Peanut Basin where changes in population, technology, economics, politics and values have had significant consequences for the ways in which farmers and other inhabitants of the region use their resources and interact with each other and their natural environment. As the *A. albida* system makes up a large part of that environment, the impact of the above changes on the system has not been negligible.

This study yielded a number of biophysical and socio-economic variables whose interactions may combine to have an impact on not only the use of the system but on *A. albida* regeneration rates. A way of examining this data is to use exploratory factor analysis rather than trying to select the most appropriate variables. The purpose of factor analysis is to reduce a large set of variables linearly to obtain a smaller number of factors which can be used in place of the variables. The method of extraction used in this analysis is principal components which transforms the original variables into a set of composite variables (principal components) that are orthogonal to each other.

¹⁸¹Meaning literally that "truth is like hot pepper, when someone throws it in your face you rub your eyes".

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8.2 Methodology

Due to hardware limitations, a subset of 70 variables was extracted from the original data set. Variable subset selection was based on both the principal investigator's knowledge of the accuracy of these variables and the need to include a wide variety of both biophysical and socio-economic information. The variables selected, described in Appendix L, include those indicating tree cover/natural resources, farm production, on-farm use of organic matter/fertilizer, land quality, demographics, education, livestock, land allocation and agriculture and forestry training.

An R-mode principal components analysis was then conducted on these variables. Several different methods were used to choose the number of pertinent components to extract for rotation and further analysis. The first step in this process was to extract factors with an eigenvalue equal to or greater than one¹⁸² and conduct a "scree" test by plotting eigenvalues against the number of factors. This plot, presented in Figure 8.1, suggests two possible points of discontinuity; one after factor 5 and one after factor 15.

Based on the scree and the eigenvalue = 1 tests an initial 15 factors were selected for further analysis. The next step in the selection process was to reduce the number of factors one at a time and examine rotated loadings (VARIMAX option) for interpretation purposes. This procedure eliminated factors 11 through 15 as they were either uninterpretable or they only represented one or a combination of two related variables. A final total of 10 factors was therefore retained.

¹⁸²Specifying an eigenvalue of one or greater limits the extraction to components which represent at least one variable's worth of variance.

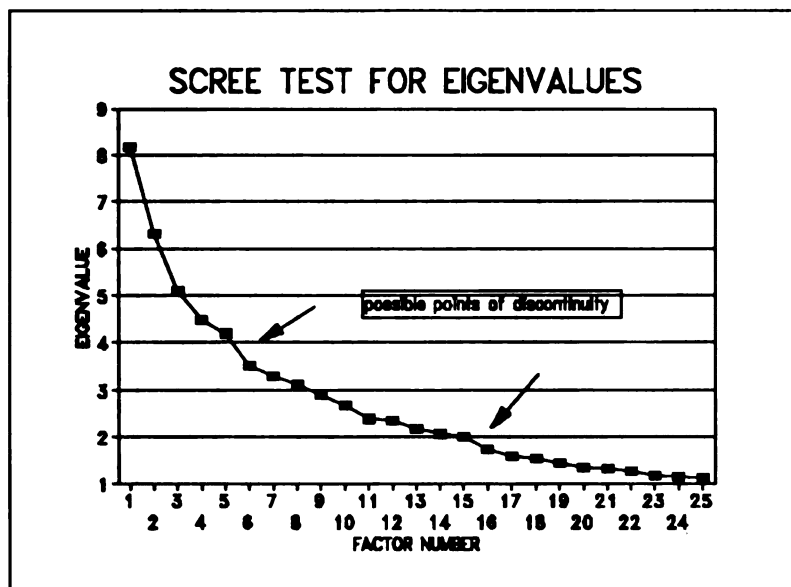


Figure 8.1
Scree Test for Eigenvalues

8.2.1 Communalities, percent common variance and percent total variance

Once the decision was made to extract 10 factors, another principal components analysis was conducted limiting the number of factors to 10 and using the VARIMAX rotation option. The rotated factor loadings matrix, communalities (h^2), percent total variance explained by the factors and the percent common variance explained are presented in Table 8.1.

Table 8.1

Varimax Rotated Loadings

Variable	Factor										h ²
	1	2	3	4	5	6	7	8	9	10	
HAADFAL	-0.809	-0.037	-0.204	-0.256	0.043	-0.009	-0.127	0.171	0.012	0.042	0.811
AREAC	-0.730	0.039	-0.194	-0.123	0.254	-0.059	-0.068	0.085	-0.245	-0.084	0.735
YSIFAL	0.722	-0.084	0.167	0.337	0.083	0.061	0.118	0.015	0.019	0.017	0.694
HAADMIL	0.709	0.106	-0.084	0.060	-0.007	-0.041	0.031	-0.100	0.178	-0.353	0.694
ETHNIC	0.670	0.076	-0.237	-0.199	0.051	-0.065	-0.244	-0.005	-0.046	-0.344	0.738
VILPOP	0.606	-0.183	0.012	0.070	-0.053	-0.309	-0.231	0.232	-0.160	-0.125	0.653
CARVIL	0.589	-0.074	0.017	0.049	-0.004	-0.246	-0.374	0.098	-0.091	-0.168	0.602
AVMILHA	0.561	0.174	0.065	0.225	0.085	-0.098	0.121	0.228	-0.107	-0.326	0.600
BIODIV	0.544	0.018	0.156	0.108	0.170	-0.147	-0.213	-0.004	0.477	0.045	0.658
TOTFAM	-0.113	0.756	-0.031	0.239	0.240	-0.248	-0.175	0.040	0.145	-0.006	0.814
SHPGOAT	0.025	0.715	0.119	-0.162	-0.150	0.103	0.202	0.151	-0.180	-0.123	0.697
TRACAN	-0.177	0.663	-0.064	-0.165	0.044	0.062	0.019	0.030	-0.124	-0.294	0.612
COWS	0.047	0.647	-0.004	-0.077	-0.159	0.053	0.078	0.123	-0.304	-0.242	0.628
YFEMALE	0.152	0.620	-0.005	0.162	0.132	-0.225	-0.118	0.049	0.006	-0.047	0.520
YMALE	-0.217	0.601	0.077	0.057	0.069	-0.345	-0.096	-0.028	0.195	0.107	0.601
DISROAD	0.185	0.594	-0.004	-0.059	-0.121	0.114	0.027	-0.017	-0.091	0.202	0.469
TOTADF	-0.110	0.541	-0.005	0.390	0.158	-0.227	-0.140	-0.137	0.097	0.008	0.581
AREAREC	0.211	0.516	-0.160	0.123	0.086	0.272	-0.042	-0.062	0.225	-0.055	0.492
TOTCAD	0.260	-0.135	0.714	-0.064	-0.142	-0.104	-0.092	0.048	-0.073	-0.160	0.673
TOTOTH	0.208	-0.069	0.708	-0.019	-0.040	-0.096	-0.086	0.049	0.017	-0.136	0.589
AVMOCHA	-0.042	0.023	0.680	-0.161	0.248	0.037	-0.203	0.076	0.241	0.259	0.726
HAADMOC	-0.021	0.018	0.655	-0.179	0.213	0.012	-0.246	0.029	0.260	0.265	0.706
AALB1140	-0.117	0.097	0.613	0.158	0.006	0.145	0.089	-0.062	0.005	0.075	0.462
AREALOAN	0.079	-0.106	0.533	-0.089	0.384	0.102	0.017	0.283	0.138	0.176	0.598
TOTHAY	0.134	0.053	-0.077	0.655	0.057	0.108	0.073	-0.040	-0.113	0.102	0.501
AVMANHA	0.081	0.012	0.057	0.589	-0.138	0.126	-0.101	0.157	0.000	-0.149	0.449
AALB4160	0.297	0.035	0.179	0.542	-0.268	0.111	0.272	-0.041	0.061	-0.193	0.616
DISSOD	-0.086	0.089	0.311	-0.524	0.083	0.050	-0.208	-0.147	0.012	0.154	0.485
GOODHA	0.051	0.060	-0.180	-0.060	0.699	0.276	0.005	-0.033	0.137	0.196	0.665
POORHA	0.120	0.008	0.027	0.330	-0.622	-0.213	-0.227	0.158	-0.107	-0.034	0.645
DISMAR	0.058	0.133	0.175	-0.022	0.582	0.044	-0.024	-0.072	0.005	0.073	0.404
PRUCAD	-0.237	-0.106	-0.191	0.129	-0.545	0.155	0.121	-0.102	0.298	0.141	0.575
TOTEXAG	0.107	-0.057	-0.050	0.139	0.076	0.686	-0.018	0.220	-0.018	0.065	0.567
PCTEXAG	0.134	-0.021	-0.042	0.171	0.120	0.670	0.023	0.184	0.129	0.007	0.564
FORCOEF	0.213	0.113	-0.216	0.078	0.156	-0.630	0.070	0.243	0.083	0.097	0.612
AGCOEF	0.282	0.140	-0.137	0.036	-0.098	-0.595	-0.021	0.248	0.118	0.106	0.569
CRNOTH	0.363	0.134	-0.239	0.201	0.134	-0.509	-0.084	0.013	0.160	0.101	0.568
AGE	-0.227	-0.006	0.018	0.061	0.117	-0.072	0.748	0.052	0.117	0.112	0.663
TIMEVIL	0.132	0.192	-0.225	0.123	0.002	-0.150	0.737	-0.211	-0.045	-0.035	0.734
YRSCHEF	-0.035	-0.090	-0.238	-0.028	0.147	-0.120	0.733	-0.001	-0.032	0.127	0.657

Table 8.1 continued

Varimax Rotated Loadings

Variable	Factor										h ²
	1	2	3	4	5	6	7	8	9	10	
AREASUP	0.213	0.088	0.084	0.166	-0.160	0.004	-0.057	0.830	-0.007	0.186	0.840
AREACE	0.112	0.050	-0.113	-0.270	0.235	0.086	0.013	-0.706	-0.146	0.030	0.684
HANOEX	0.011	0.097	-0.203	-0.237	0.070	0.026	-0.088	0.538	0.040	-0.196	0.449
HAAPPEA	0.327	0.030	-0.166	0.199	-0.112	0.031	-0.026	-0.192	-0.671	0.020	0.677
AVTOTPEA	-0.234	0.274	-0.160	0.112	0.409	-0.135	0.070	-0.137	-0.624	-0.146	0.788
HAPARAV	0.162	0.188	0.062	0.129	-0.087	0.191	0.139	0.046	0.154	-0.691	0.650
AVTOTCOW	-0.082	0.006	0.040	0.152	-0.038	0.046	0.190	-0.039	0.129	0.628	0.483
AVCOWHA	-0.014	0.010	0.133	0.379	0.106	0.153	0.071	-0.119	-0.038	0.600	0.576
HAAVCOW	-0.103	-0.032	0.126	-0.063	-0.030	-0.029	0.167	0.005	0.251	0.577	0.457
ANMONPAR	-0.017	0.068	0.090	0.354	-0.101	0.141	0.132	-0.104	0.264	-0.529	0.546
AREAOTH	-0.499	-0.211	0.032	0.132	-0.090	-0.132	0.071	-0.281	0.224	-0.337	0.585
PCTCAD	0.104	-0.110	0.094	0.058	0.135	-0.419	0.037	0.425	-0.027	-0.314	0.510
AVTOTMIL	0.215	0.436	-0.112	0.027	0.420	-0.111	-0.019	-0.064	-0.297	-0.274	0.606
EMRATE	0.120	-0.110	-0.164	0.261	-0.032	0.056	0.433	0.062	0.070	0.252	0.386
FAIRHA	-0.235	-0.099	0.236	-0.398	-0.097	-0.138	0.345	-0.220	-0.043	-0.249	0.539
HAKHOR	0.085	0.148	-0.102	-0.422	-0.103	0.235	0.044	0.267	0.158	-0.246	0.443
HAMANAV	0.239	-0.065	0.058	0.491	-0.210	0.143	0.099	0.221	-0.243	0.228	0.539
TOOLS	-0.489	0.408	0.050	0.276	0.101	-0.186	0.132	0.020	-0.288	-0.211	0.674
AACTIV	-0.122	0.011	-0.051	-0.049	-0.110	-0.003	0.313	0.020	-0.061	-0.199	0.174
NUNPAR	-0.280	0.001	-0.153	0.091	0.499	-0.190	-0.063	-0.068	-0.054	0.185	0.441
CONSMES	0.203	-0.129	0.131	-0.017	0.169	-0.368	0.148	0.330	-0.131	-0.183	0.421
WELL	-0.485	0.089	-0.189	-0.161	0.033	0.425	-0.034	-0.217	0.130	-0.175	0.583
PAROTH	0.015	-0.032	0.040	0.380	0.195	-0.015	-0.006	0.241	0.018	0.168	0.273
AVPEAHA	0.121	0.136	-0.169	0.412	0.304	-0.153	-0.016	0.012	-0.452	-0.140	0.571
TOTADM	-0.212	0.418	-0.027	0.111	0.346	0.115	0.112	0.233	0.006	-0.127	0.448
YARABIC	-0.142	0.366	0.277	-0.195	0.220	-0.084	-0.097	-0.188	-0.029	0.104	0.381
DSCERDEF	0.002	-0.049	0.126	-0.284	-0.076	0.036	-0.128	-0.385	0.364	0.101	0.413
AVDIS	-0.285	-0.219	0.137	0.015	-0.079	-0.218	-0.111	-0.207	-0.105	-0.101	0.278
ROTATHA	0.056	-0.035	-0.235	0.260	-0.349	0.175	-0.057	-0.031	-0.454	0.098	0.499
AARLOC	-0.228	-0.030	0.208	0.091	0.335	0.051	0.012	-0.090	0.038	-0.079	0.235
HAAVFER	-0.039	0.389	-0.097	-0.134	0.024	0.116	0.130	-0.015	-0.100	0.078	0.227
YFRENCH	0.286	-0.069	-0.017	0.018	0.262	-0.119	-0.328	-0.265	0.017	-0.065	0.353
REALSIL	-0.186	-0.045	-0.236	0.100	0.040	0.199	-0.024	0.339	0.246	-0.046	0.322
EXPCAR	0.271	-0.043	0.021	-0.210	-0.387	0.111	-0.064	-0.084	-0.112	0.044	0.308
CONFLICT	-0.446	0.163	0.108	-0.008	0.144	0.151	0.082	-0.101	0.212	-0.022	0.342
AFRENCH	0.345	0.041	-0.282	-0.032	0.393	-0.099	-0.010	0.037	0.004	-0.018	0.368
COMMUNAL	0.038	0.180	0.194	0.078	-0.043	0.181	0.384	0.363	-0.123	0.011	0.406
ASSOC	-0.188	0.093	0.161	-0.074	-0.057	0.064	0.021	0.020	-0.456	0.010	0.291
PRIVATE	0.278	-0.292	-0.138	0.201	0.357	-0.039	0.140	0.124	-0.123	-0.002	0.402
CADHA	-0.044	-0.001	0.428	0.083	-0.172	0.079	-0.030	-0.096	-0.019	0.001	0.238
EXTRATE	0.114	-0.118	-0.098	-0.157	0.002	-0.389	0.144	-0.059	0.041	0.001	0.238
PRUOTH	-0.244	0.075	-0.385	-0.022	-0.093	-0.051	-0.474	-0.021	0.240	0.001	0.508
% Tot. Var.	8.668	6.366	5.448	5.233	5.198	4.927	4.445	4.313	4.115	4.681	53.394
% Com. Var.	16.234	11.922	10.205	9.800	9.734	9.229	8.325	8.078	7.706	8.766	100.00

Source: Data from Biophysical and Socio-economic Surveys (see Appendix M).

A principal components analysis assumes that all of the variation within a specific population is accounted for in the variables used to describe that population. Therefore the communality of a variable where all 70 factors from the analysis are included would equal one. Interpretation of the h^2 is therefore limited to determining what fraction of this total variation is accounted for by the extracted components.

In terms of interpretation, the communalities of a principal components analysis can be considered to be a measure of the adequacy of the solution. This is roughly interpreted to mean that a variable is adequate when at least 40% of the variance (the communality) is explained by the extracted components (Yeates 1974). Using this approach, Table 8.1 suggests that all variables are adequate with the exception of EMRATE, AACTIV, PAROTH, YARABIC, DSCERDEF, ROTATHA, AARLOC, HAAVFER, YFRENCH, REALSIL, EXPCAR, CONFLICT, AFRENCH, COMMUNAL, ASSOC, PRIVATE, CADHA, and EXTRATE. These variables are not making major contributions to common factor space and are part of what Rummel (1970) refers to as "unique" factor space; they are not related to the other variables in the data set. As these variables did not load "high" on any factor (with the exception of ROTATHA on Factor 10 which can be explained) they will not be used for factor interpretation purposes¹⁸³.

Finally, the percent total variation can be used to evaluate the character of the extracted solution. Table 7.1 indicates that the 10 extracted components account for over 53% of the total variance in the data set. While this is not "fantastic" in terms of results, it is more than expected given the varied nature of the original data.

¹⁸³Ideally, these factors should be excluded from the analysis but Pigozzi (1989) argues that this would not make much difference in terms of interpretation and subsequent analyses.

8.3 Interpretation of components

For purposes of interpretation, rotated factor loadings were examined using a two stage primary and secondary approach. Primary factor loadings are considered to be any loading having an absolute value greater than or equal to 0.650 while secondary factor loadings are considered to be any loading which has a value between 0.450 and 0.650. Additionally, in interpreting component scores, it is necessary to view them not as individual values but as a continuum from lowest to highest reflecting a range which the composite variable attempts to measure,

8.3.1 Component 1: Population pressure (POPPRES)

The first component accounts for 8.7% of the total variance in the data set and is composed of the following variables and loadings:

PRIMARY		SECONDARY	
HAAVFAL	-0.809	VILPOP	0.606
AREAC	-0.730	CARVIL	0.589
YSIFAL	0.722	AVMILHA	0.561
ETHNIC	0.670	BIODIV	0.544
		AREAOTH	-0.499
		TOOLS	-0.489
		WELL	-0.485

This component clearly reflects population pressure in the North Central Peanut Basin. The high positive loadings for: the average number of years since fallow for all respondent fields (YSIFAL); whether the respondent is Wolof or Serer (ETHIC) with the Serer living in the more densely populated areas of the NCPB; combined with high negative loadings for the average percent of respondent's farm in fallow (HAAVFAL) and total farm area (AREAC), all suggest population pressure. The high positive secondary contributions of village population (VILPOP), carrés/village (CARVIL) also support this interpretation.

More difficult to explain is the high secondary loading of the biodiversity index (BIODIV). One might have expected to have a lower biodiversity index with increasing population pressure. However, this discrepancy is more than likely a reflection of rainfall and/or water

table depth (WELL); biodiversity increases as rainfall/water table depth decreases. In the same sense, population pressure would also be greater in areas where the water table is closer to the surface.

The high negative secondary loadings of the number of tools/household (TOOLS) and the percent of informant farm area allocated to the respondent by someone other than the chef de carré (AREAOTH) cannot be interpreted.

8.3.2 Component 2: Relative farm importance (FARMIMP)

The second component accounts for 6.4% of the total variance in the data set and is composed of the following variables and loadings:

PRIMARY		SECONDARY	
TOTFAM	0.756	COWS	0.647
SHPGOAT	0.715	YFEMALE	0.620
TRACAN	0.663	YMALE	0.601
		DISROAD	0.594
		TOTADF	0.541
		AREAREC	0.516

This component clearly reflects the relative importance of the respondent's farm operation. The high primary positive factor loadings of family size (TOTFAM), the number of sheep and goats (SHPGOAT), the number of traction animals (TRACAN), combined with the secondary positive factor loadings of number of cattle (COWS), household male and female youth (YFEMALE and YMALE), total adult household females (TOTADF) and the percent of farm area farmed on a temporary basin (AREAREC) all support this interpretation.

The high positive secondary loading of farm distance to the nearest paved road (DISROAD) is more difficult to interpret. However, it may suggest that farming operations are relatively more important as distance to the nearest paved road increases. This might be interpreted to mean that farmers living closer to a paved road are more apt to engage in off-farm activities and that farming operations become secondary activities.

8.3.3 Component 3: Land Availability (LANDAV)

The third component accounts for 5.5% of the total variance in the data set and is composed of the following variables and loadings:

PRIMARY		SECONDARY	
TOTCAD	0.714	AREALOAN	0.533
TOTOTH	0.708		
AVMOCHA	0.680		
HAAVMOC	0.655		

The high primary positive loadings of total number of *A. albida* trees per hectare per farm (TOTCAD) and total number of other species per hectare per farm (TOTOTH) suggest that this variable is related to farm tree density. The high positive secondary loading of percent of farm area loaned to other farmers (AREALOAN) suggests where tree density is high, informants tend to lend or rent more land to others.

However, this interpretation needs to be viewed in the context of the high positive loadings of average manioc yield per hectare per farm (AVMOCHA) and average percent of farm area in manioc (HAAVMOC). Based on principal investigator observations of farms in the NCPB where manioc is grown, there appears to be a tendency for manioc to be planted in areas where there are true "dior" soils (to facilitate extraction of the tuber) and where organic matter/fertility is generally enhanced by a relatively high density of trees/ha. This was certainly the case for informants and other farmers who grew manioc in the Tivaouane area. Additionally, discussions with informants suggest that those who grow manioc as a cash crop tend to reduce the area of their farm in peanuts. This may indicate that farmers who grow manioc have some excess farm area which could be loaned or rented to others.

Based on the above interpretation, this component is considered to be a reflection of land availability; where land availability is high, there would be a tendency to have a greater tree density per hectare as well as a greater tendency for farmers to loan or rent land.

8.3.4 Component 4: Organic matter (ORGMAT)

The fourth component accounts for 5.2% of the total variance in the data set and is composed of the following variables and loadings:

PRIMARY		SECONDARY	
TOTHAY	0.655	AVMANHA	0.589
		AALB4160	0.542
		DISSOD	-0.524
	HAMANAV		0.491

This component clearly reflects on-farm organic matter use and production. The high primary positive loading of average total peanut and cowpea hay produced per farm (TOTHAY) suggest that this hay is produced for relatively large numbers of animals. This is in turn reflected in the high positive secondary loadings of average manure use per hectare (AVMANHA) and the average percent of farm area on which manure is used.

The high positive secondary loading of the number of *A. albida* trees per hectare per farm over 41 cm in diameter (AALB4160) suggest that farmers who use manure also maintain a relatively high density of *A. albida* trees for fertility purposes.

The negative secondary loading of farm distance to the nearest SODEVA agent is more difficult to interpret. However, it may be that informants located at a greater distance from SODEVA agents (and more than likely have less contact with those agents) have a greater tendency to use traditional methods of maintaining soil fertility.

8.3.5 Component 5: Land quality (LANQUAL)

The fifth component also accounts for 5.2% of the total variance in the data set and is composed of the following variables and loadings:

PRIMARY		SECONDARY	
GOODHA	0.699	POORHA	-0.622
		DISMAR	0.582
		PRUCAD	-0.545
		NUMPAR	0.499

This component appears to reflect land quality. The high positive loading of the percentage of total farm land which informants

perceives to be fertile or "good" (GOOD), combined with the secondary loading of the percent of farm area perceived to be poor support this interpretation. Additionally, the secondary positive loading of number of fields per farm (NUMPAR) and secondary negative loading of *A. albida* pruning rate (PRUCAD), support this interpretation. For NUMPAR, it is assumed that the more fields an informant has, the more land he is able to leave in fallow in any given year. The high secondary loading for PRUCAD is also a reflection of land quality. As discussed in Chapter 7, many informants and other farmers reported that high cad pruning rates actually decrease soil fertility and resulting crop yields.

The secondary loading of distance from farm to the nearest weekly market is more difficult to interpret. However, it may be that farms closer to markets have been farmed for longer periods of time and are less fertile. The inverse relationship between PRUCAD and DISMAR tends to support this hypothesis: farms located at a greater distance from market centers tend to have less pressure on the cad trees and a resulting lower pruning rate.

8.3.6 Component 6: Farming interest (FARMINT)

The sixth component accounts for 4.9% of the total variance in the data set and is composed of the following variables and loadings:

PRIMARY		SECONDARY	
TOTEXAG	0.686	FORCOEF	-0.630
PCTEXAG	0.670	AGCOEF	-0.595
		CRNOTH	-0.509

This component clearly reflects informants' "interest" in farming as an occupation. The high secondary negative loadings of forestry-related formal training received (FORCOEF), formal agriculture-related training received (AGCOEF), combined with the high positive primary loadings of TOTEXAG (percent of adult family members undertaking some form of extra-agriculture activities) and PCTEXAG (percentage of farm income derived from extra-agriculture sources), support this contention. In short, the more an informant is involved

in extra-agriculture activities, the less the tendency is to participate in formal agriculture and training opportunities.

The high secondary loading of percent crown cover per hectare per farm of species other than cad (CRNOTH) lends credence to this interpretation. Informants who are more actively involved in off-farm activities would more than likely be less concerned with the presence of on-farm trees.

8.3.7 Component 7: Farming experience (FARMEX)

The seventh component accounts for 4.5% of the total variance in the data set and is composed of the following variables and loadings:

PRIMARY		SECONDARY	
AGE	0.748	PRUOTH	-0.474
TIMEVIL	0.737		
YRSCHEF	0.733		

This component clearly reflects informants' farming experience with the high primary factor loadings for informant age (AGE), time in village (TIMEVIL), and the number of years an informant has been a "chef d'exploitation". The relatively low secondary loading of on-farm pruning rate for species other than cad may also reflect farmer experience; informants with more experience tend to place a higher value on trees and conduct less pruning.

8.3.8 Component 8: Land allocation (LANDAL)

The eighth component accounts for 4.3% of the total variance in the data set and is composed of the following variables and loadings:

PRIMARY		SECONDARY	
AREASUP	0.830	HANOEX	0.538
AREACE	-0.706		

This variable reflects land allocation among informants. The high positive primary loading of AREASUP (the percent of total farm area received on becoming a "chef") contrasts with the high primary negative loading of AREACE - the percent of total farm area farmed before becoming chef. In short, the less area an informant had to farm before becoming a chef, the greater the tendency to receive an

additional land allocation on becoming a chef. This interpretation is supported by the high positive secondary loading of the estimate of the total land area in a village not used for agricultural purposes (HANOEX). HANOEX's contribution to this component suggests that in areas where there is more unexploited land, there is a greater tendency for the village chief to give supplemental land allocations.

8.3.9 Component 9: Cash crop farming (CASHCR)

The ninth component accounts for 4.7% of the total variance in the data set and is composed of the following variables and loadings:

PRIMARY		SECONDARY	
HAAVPEA	-0.671	AVTOTPEA	-0.624
		ASSOC	-0.456
		ROTATHA	-0.454
		AVPEAHA	-0.452
		BIODIV	0.477

This component clearly represents informants who are primarily engaged in peanut (or cash crop) production given the high primary negative loading of average percent of total farm area in peanuts (HAAVPEA), and the high secondary loading of average total peanut production (AVTOTPEA) and lower negative loading of average peanut yields per hectare (AVPEAHA). This interpretation is further supported by the secondary negative loadings of ROTATHA (the percent of total fields in which a peanut-millet rotation is practiced) and by ASSOC- a composite variable which indicates informant membership in associations, most of which are involved in peanut culture (e.g., the "sections villageoises").

More interesting to note is the secondary positive loading of BIODIV. This may suggest that peanut culture is contributing to a loss of biological diversity in the NCPB. As discussed elsewhere in this study, the close within and between-row spacing required by peanuts combined with the method of extraction used, is often blamed for the destruction of much natural regeneration of cad and other species.

It may also be that biodiversity is only reflecting rainfall, and indirectly land availability. The rainfall gradient within the study area decreases from southwest to northeast and biodiversity and land availability tend to follow this same pattern. As a result, as more land is available in the north (and less biodiversity), more total farm area could be devoted to peanut culture with little impact on biodiversity.

8.3.10 Component 10: Innovativeness (INNOVA)

The tenth and final component extracted also accounts for 4.7% of the total variance in the data set and is composed of the following variables and loadings:

PRIMARY		SECONDARY	
HAAVPAR	-0.691	AVTOTCOW	0.628
		AVCOWHA	0.600
		HAAVCOW	0.577
		ANMONPAR	-0.529

Of the total components extracted, this is perhaps the most difficult one to interpret. The high negative primary loading of the average percent of farm area subjected to parcase (HAAVPAR) combined with the secondary negative loading of ANMONPAR (the average number of animals months of parcase per hectare per farm), contrasts with the positive secondary loadings of what are essentially cowpea production variables: AVTOTCOW- average total cowpea production; AVCOWHA- average cowpea yields per hectare; and HAAVCOW- average percent of farm area in cowpeas. In short, there appears to be a relationship between cowpea production and the use of parcase; farmers who grow cowpeas tend to use less parcase.

One possible explanation for this relationship may be the following. Given that cowpeas are a relatively new crop in the NCPB, combined with the fact that parcase has decreased significantly in the NCPB in recent years due to a reduction in both the numbers of animals owned and in the passage of Peular herders, it may be that farmers who grow cowpeas might be younger, perhaps more innovative, and would more

than likely own fewer animals than the older (and more traditional) millet-peanut farmers. For purposes of this analysis, it is assumed that this is the case and the factor is interpreted to be a reflection of farmer innovativeness.

8.4 Mapping of factor scores

In order to assist with the interpretation of the components, factor scores were saved from the preceding analysis and used to compile a series of maps which show the spatial distribution of factor score values by location of informant. For mapping purposes, scores were grouped as a reflection of their "standardized" origin. However, given the dispersed nature of the data, this exercise was only useful in interpreting Component 1.

Figure 8.2 suggests that low factor scores (less than -1.000) for this component tend to be grouped in the northeast quadrant of the study area, which is in fact the driest, least populated area and has the least population pressure. In contrast, high factor scores (greater than 1.000) tend to be concentrated in the southwest quadrant of the study area which has the most rainfall and the highest population density. The map also suggests that population pressure decreases from southwest to northeast.

From this analysis, it is clear that Component 1 should include a rainfall variable. Unfortunately, given the limited number of meteorological stations in the NCPB, this was not possible.

8.5 Regression analysis

Factor scores from the 10 extracted components provide the basis for additional hypothesis testing and regression model development. A major advantage in using factor scores in regression is that providing the dependent variable is excluded from the principal components analysis, the orthogonality of the scores satisfies the requirements for truly "independent" variables.

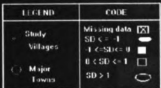


Figure 8.2

Mapping of Factor Scores for Component 1

Thus, the relationship between the 10 components extracted and the depended variables of CRNCAD (average percent *A. albida* crown cover per hectare per farm, *A. albida* regeneration rate (AALB1), and *A. albida* survival rates (AALB15- the average density per hectare of *A. albida* in the 1-5cm diameter class per farm), will be explored.

8.5.1 Population pressure

Conventional wisdom in Senegal suggests that population growth is perhaps the biggest factor in the decline of the *A. albida* system. Proponents of the population factor argue that the demographic pressure on the system has two facets; overcultivation and fuelwood harvesting. Overcultivation/agricultural expansion is thought to be the biggest non-climatic factor to loss of vegetation in the NCPB (Rodale 1989). Overcultivation is caused by two principal factors; (i) the increasing use of animal traction to cultivate larger surfaces at the expense of fallow or previously uncultivated areas (e.g., forests); and (ii) insufficient land in villages to permit fallowing, a consequence of both demographic pressure and the enlargement of the area cropped. Both factors may have a direct bearing on the *A. albida* system. Increased mechanization has been blamed for a reduction in on-field regeneration of *A. albida* and other indigenous species; farmers are reluctant (or do not take the time) to plow around seedlings. The reduction in both use and length of fallow may also be implicated in reduced natural regeneration of *A. albida* and other species.

Additionally, the primary energy source for the rural inhabitants of the NCPB is fuelwood¹⁸⁴. Freeman (1982) estimates that per capita consumption of fuelwood in the PB at 0.6 cubic meters per year. He also estimates that one- fourth of rural fuelwood supplies are coming from the remaining forests in the Sine Saloum while three-fourths are coming from other areas, mainly trees in the

¹⁸⁴The use of the term fuelwood here refers to both firewood and charcoal.

agricultural landscape such as *A. albida*, shrubs cleared from fields (*Gueira senegalensis* and *Combretum spp.*), and from non-woody sources such as crop residues (millet stalks) and manure.

If the population pressure continues as expected, the growing pressure on on-farm *A. albida* resources (particularly from urban markets) may raise their value to the point at which economic pressure to cut them may exceed their value as a continuing part of the agricultural system. While the population growth scenario is rather bleak in its implications for woody vegetation in the NCPB, there may be another possible scenario. Boserup (1965) argues that as population increases, there is an intensification of agriculture with increased labor investment in production and increased attention to soil fertility¹⁸⁵.

Based on the above discussion, the hypothesis is:

Hypothesis 8.1

$H_{(0)}$: There is no relationship between population pressure (POPPRES) and average cad crown cover per hectare per farm (CRNCAD).

$H_{(1)}$: CRNCAD is a negative function of POPPRES.

DEP VAR: CRNCAD N: 67 MULTIPLE R: .376 SQUARED MULTIPLE R: .142 ADJUSTED SQUARED MULTIPLE R: .128 STANDARD ERROR OF ESTIMATE: 1.870						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	2.266	0.229	0.000	.	9.917	0.000
POPPRES	0.754	0.230	0.376	1.000	3.275	0.002
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	37.503	1	37.503	10.723	0.002	
RESIDUAL	227.331	65	3.497			

¹⁸⁵Bartlett (1980) provides a concise review of the literature on this aspect which suggests a close relationship between population density, household access to land resources and the intensity of agricultural production. However, Boserup's (1965) sequential argument for agricultural development or adaptation, while perhaps valid for the historical development of traditional agroforestry systems, does not shed much light on why these traditional systems might be declining today.

The results of the regression suggest that while the predictive value of the model is low, the relationship is significant at the 99% confidence level (one-tailed). However, the directionality of the regression is not as predicted. The model suggests that CRNCAD is a positive function of population pressure which lends credence to Boserup's (op. cit.) argument that population pressure results in an intensification of agriculture with increased labor investment in production and increased attention to soil fertility.

8.5.2 Relative farm importance

Component 2 (FARMIMP) reflects the relative importance of informants' farming operations. It is expected that the more important farming operations (i.e., those with more cattle, tools, traction animals, etc.) would be more interested in conserving their population of cad trees. The hypothesis is:

Hypothesis 8.2

$H_{(0)}$: There is no relationship between relative farm importance (POPPRES) and average cad crown cover per hectare per farm (CRNCAD).

$H_{(1)}$: CRNCAD is a positive function of FARMIMP.

DEP VAR: CRNCAD N: 67 MULTIPLE R: .011 SQUARED MULTIPLE R: .000						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 2.018						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	2.280	0.247	0.000	.	9.244	0.000
FARMIMP	-0.021	0.248	-0.011	1.000	-0.085	0.932
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.029	1	0.029	0.007	0.932	
RESIDUAL	264.804	65	4.074			

The results of the regression suggest that there is no relationship between cad crown cover and relative farm importance and the null hypothesis must be accepted.

8.5.3 Land availability

Component 4 is a reflection of land availability among the villages in the study area. Land as a constraint to agriculture production appears to vary considerably from village to village. Thirty-eight informants (52.78%) indicated that the area they currently farmed was sufficient for their family needs. Moreover, insufficient land accounted for only 5.1% of combined production problems for the 1988 and 1989 cropping seasons.

When asked the degree of difficulty in obtaining additional land, twenty informants replied that it was very easy to easy, while 49 indicated that obtaining additional land was at least fairly difficult to very difficult. Three respondents did not answer. Table 8.2 summarizes responses to this question.

Table 8.2
Degree Of Difficulty In Obtaining
Additional Land
(Number and Percent of Responses)

Degree of difficulty	No.	Per.
Very easy	11	15.3
Easy	9	12.5
Fairly difficult	19	26.4
Very difficult	30	41.7
No response	3	4.2
Total	72	100.0
Source: Survey data.		

In this context, it is expected that in areas where land is more readily available for agriculture, *A. albida* percent crown cover would tend to be higher as a result of increased fallow (more regeneration) and reduced agriculture (less damage to seedlings/regeneration). The hypothesis is:

Hypothesis 8.3

$H_{(0)}$: There is no relationship between land availability (LANDAV) and average percent cad crown cover per hectare per farm (CRNCAD).

$H_{(1)}$: CRNCAD is a positive function of LANDAV.

DEP VAR: CRNCAD N: 67 MULTIPLE R: .189 SQUARED MULTIPLE R: .036
 ADJUSTED SQUARED MULTIPLE R: .021 STANDARD ERROR OF ESTIMATE: 1.982

VARIABLE	COEFFICIENT	STD ERROR	STD COEF TOLERANCE	T	P(2 TAIL)
CONSTANT	2.290	0.242	0.000	9.453	0.000
LANDAV	0.379	0.244	0.189	1.553	0.125

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	9.480	1	9.480	2.413	0.125
RESIDUAL	255.353	65	3.929		

The results of the regression suggest there may be a weak positive relationship between CRNCAD and LANDAV, significant only at the 90% confidence level (one-tailed). However, as a 95% confidence level is sought for hypothesis testing in this study, the null hypothesis must be accepted.

8.5.4 Organic matter

Component 4 is a reflection of informants' use of traditional methods of incorporating organic matter into the soil. It is expected that informants with a high use of organic matter would also have a tendency to have a greater percent cad crown cover on their farms. Additionally, as was discussed in Chapter 7, informants who stall feed cad pods to their animals and subsequently spread the manure on their fields tend to have higher cad regeneration rates which might also contribute to increased cad crown cover. The hypothesis is:

Hypothesis 8.4

$H_{(0)}$: There is no relationship between on farm organic matter use (ORGMAT) and average percent cad crown cover per hectare per farm (CRNCAD).

$H_{(1)}$: CRNCAD is a positive function of ORGMAT.

DEP VAR: CRNCAD N: 67 MULTIPLE R: .403 SQUARED MULTIPLE R: .162
 ADJUSTED SQUARED MULTIPLE R: .149 STANDARD ERROR OF ESTIMATE: 1.848

VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	2.273	0.226	0.000	.	10.072	0.000
ORGMAT	0.807	0.227	0.403	1.000	3.547	0.001

ANALYSIS OF VARIANCE

SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P
REGRESSION	42.944	1	42.944	12.580	0.001
RESIDUAL	221.890	65	3.414		

The results of the regression suggest that there is indeed a highly significant (99% one-tailed confidence level) between organic matter use and cad crown cover, but the predictive power of the model is weak. The null hypothesis is rejected.

8.5.5 Land Quality

Component 5 is an indication of perceptions of land quality among informants. Informants were asked to describe their fields. Responses are presented in Table 8.3 below. Almost one-half of the 305 fields surveyed (151 or 49.6%) surveyed were considered by informants to be "fair" or fairly fertile. Some fields were considered to be fairly good but were subjected to some wind erosion (35 or 11.5%) and water erosion (2 or 0.7%). The remaining fields were considered by respondents to be "poor"/infertile due to: wind erosion (64 or 20%), no fertilizer trees or fallow (26 or 8.5%), a combination of water and wind erosion (17 or 5.6%), water erosion only (4 or 1.3%), gravel on the surface (3 or 1%) and gravel combined with water erosion (3 or 1%). Wind erosion and "soil fertility" caused by lack of fertilizer, fallow or trees appear to be the main soil problems.

Table 8.3

**Respondent Perception Of Field Quality
(Number and Percent of Fields)**

Quality	No.	Percent
Fertile-fair	151	49.6
Poor-gravel	3	1.0
Poor-eroded-rain	4	1.3
Poor-eroded-wind	64	20.0
Fairly good-rain eros.	2	0.7
Fairly good-wind eros.	35	11.5
Poor-rain and wind eros.	17	5.6
Poor (no fert./trees/fallow)	26	8.5
Poor gravel-wind eros.	3	1.0
Total fields	305	100.0
Source: Survey data.		

Given informant perceptions, it is expected that there would be a positive relationship between cad crown cover and informant perceptions of field quality. The hypothesis is:

Hypothesis 8.5

$H_{(0)}$: There is no relationship between land quality (LANQUAL) and average percent cad crown cover per hectare per farm (CRNCAD).

$H_{(1)}$: CRNCAD is a positive function of LANQUAL.

DEP VAR: CRNCAD N: 67 MULTIPLE R: .166 SQUARED MULTIPLE R: .027						
ADJUSTED SQUARED MULTIPLE R: .013 STANDARD ERROR OF ESTIMATE: 1.991						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	2.273	0.243	0.000	.	9.344	0.000
LANQUAL	-0.332	0.245	-0.166	1.000	-1.355	0.180
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	7.276	1	7.276	1.836	0.180	
RESIDUAL	257.558	65	3.962			

The results of the regression suggest that there is a weak relationship between CRNCAD and LANQUAL, but the directionality of the relationship is not as predicted. However, as the relationship is only significant at the 90% confidence level (one-tailed), the null hypothesis must be accepted.

8.5.6 Interest in farming

Component 6 is a reflection of informant's interest in farming as primarily determined by participation in formal agriculture and forestry training opportunities and involvement in off-farm activities.

A total of 19 informants (24 household members) reported having had any formal agricultural training. The majority of informants (73.6%) acquired their agricultural skills through experience. Similarly, the majority of respondents reported acquiring their forestry skills through experience, but a total of 14 respondents (17 household members) reported having had some "formal" forestry training. In contrast, a total of 34 informants/households (52.8%) reported income from sources other than agriculture.

It is expected that farmers with a higher level of interest in their farms as represented by more participation in agriculture and forestry training opportunities and less off-farm income would tend to have a higher cad crown cover. The hypothesis is:

Hypothesis 8.6

$H_{(0)}$: There is no relationship between informant interest in farming (FARMINT) and average percent cad crown cover per hectare per farm (CRNCAD).

$H_{(1)}$: CRNCAD is a positive function of FARMINT.

DEP VAR: CRNCAD N: 67 MULTIPLE R: .096 SQUARED MULTIPLE R: .009						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 2.009						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	2.278	0.245	0.000	.	9.282	0.000
FARMINT	0.192	0.247	0.096	1.000	0.775	0.441
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	2.425	1	2.425	0.601	0.441	
RESIDUAL	262.409	65	4.037			

The results of the regression suggest that there is no relationship between informant interest in farming and percent cad

crown cover per hectare per farm. The null hypothesis must be accepted.

8.5.7 Farming experience

Component 7 reflects informants' farming experience as it is composed of variables indicating a farmer's age, the time spent in the village and the amount of time he/she has been a chef d'exploitation managing his/her own farm. It is expected that informants with more farming experience would have a tendency to take better care of their on-farm cad trees and as a result would have a higher percent of on-farm cad crown cover per hectare. The hypothesis is:

Hypothesis 8.7

$H_{(0)}$: There is no relationship between informant farming experience (FARMEX) and average percent cad crown cover per hectare per farm (CRNCAD).

$H_{(1)}$: CRNCAD is a positive function of FARMEX.

DEP VAR: CRNCAD N: 67 MULTIPLE R: .263 SQUARED MULTIPLE R: .069						
ADJUSTED SQUARED MULTIPLE R: .055 STANDARD ERROR OF ESTIMATE: 1.947						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	2.291	0.238	0.000	.	9.627	0.000
FARMEX	0.527	0.240	0.263	1.000	2.200	0.031
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	18.356	1	18.356	4.841	0.031	
RESIDUAL	246.478	65	3.792			

The results of the regression suggest that there is indeed a significant positive relationship (95% one-tailed probability) between average cad crown cover and informant farming experience. The null hypothesis is rejected

8.5.8 Land allocation

Component 8 reflects land allocation among informants based on the amount of unexploited land surrounding a village. The socio-economic survey indicates that the majority of informants' land (33.7%) was allocated by the chef de concession with informants receiving the major portion of their fields (57.5%) on becoming a chef

de concession. (56 or 77.78% of respondents were allocated additional land on becoming a "chef"). A small portion of land (3.5%) was allocated by someone else (usually an older relative) while only 0.9% of the area surveyed was actually cleared by a respondent. The results are summarized in Table 8.4.

Table 8.4
Land Allocation Decisions
(Hectares)

Decision	Max.	Min.	Avg.	Std.	Total	
					No.	Per.
Area allocated by chef	10	0	2.2	2.4	156.5	33.7
Area allocated by other	10	0	0.9	2.2	62.5	3.5
Area cleared by self	4	0	0.1	0.5	4.0	0.9
Supplemental area	15	0	3.8	3.6	266.7	57.5
Area received temporarily	3	0	0.2	0.6	13.6	2.9
Area loaned temporarily	10	0	0.7	1.6	48.8	10.5
Source: Survey data.						

There appears to be a considerable amount of land being borrowed or lent in the study area. Eleven informants (15.28%) indicated that in 1989, they received land on a temporary basis from people in the same village (6 or 54.55%) or from someone in a different village (5 or 45.45%). The total area received temporarily was about 14 ha or about 3% of the total area.

Twenty-five informants (34.72%) indicated that in 1989, they loaned area temporarily to others. Twenty-two or 88% loaned to people from the same village while 3 or 12% loaned to people from a different village. A total of about 50 ha were loaned in representing about 10.8% of the field area.

In terms of the relationship between land allocation and the amount of unexploited land in a village, one-half of the villages in the survey had some unexploited land available for development. The principal investigator estimates the total area of this land for the 18 villages to be about 700 ha with a maximum of 80 hectares for one village and a minimum of 1 ha for another village. The average size of unexploited land was about 20 ha. For the most part, these areas

are primarily "khors" or "bas fonds" (clay depressions) and generally difficult to work.

In the past, these areas have served as a pasture/range resource for a village's livestock and as a result, tree and soil resources are usually severely degraded. As livestock holdings have decreased for many farmers because of the drought, vegetable gardening in the khors has become increasingly important where the water table is relatively close to the surface. Where the water table is deeper, some villages are now protecting these areas in order to enhance natural regeneration as discussed above. These areas have considerable potential to provide increased forage, fuelwood and service wood supplies and relieve at least some of the pressure on on-farm trees.

Based on informant perceptions of land allocation and the amount of unexploited land available in a village, it might be expected that where LANDAL is high, there would be less pressure on the *A. albida* system. Alternatively, as cad does not tend to favor the majority of these areas due to their high clay content, LANDAL may have little if any impact on cad. The hypothesis is:

Hypothesis 8.8

$H_{(0)}$: Average percent cad crown cover per hectare per farm (CRNCAD) is a positive function of land allocation (LANDAL).

$H_{(1)}$: There is no relationship between CRNCAD and LANDAL.

DEP VAR: CRNCAD N: 67 MULTIPLE R: .118 SQUARED MULTIPLE R: .014						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 2.004						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	2.268	0.245	0.000	.	9.249	0.000
LANDAL	0.236	0.247	0.118	1.000	0.957	0.342
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	3.680	1	3.680	0.916	0.342	
RESIDUAL	261.154	65	4.018			

The results of the regression suggest that there is no relationship between land allocation and cad crown cover; the null hypothesis is rejected.

8.5.9 Cash crops

Component 9 reflects informants' tendency to cash crop (peanut) culture compared to millet or other crop culture. As discussed in Chapter 1, the introduction of peanut culture in the NCPB may have changed the traditionally adaptive social patterns of the farmers to what might be considered maladaptive patterns, particularly in the face of poor rainfall years and recurrent drought; in particular, a shift from ecologically sound practices such as the use of *A. albida*, to forms of modern industrial agriculture.

Informants themselves were concerned about peanut culture. One of the difficulties cited by farmers in terms of cultivation is that it is easier to cultivate around seedlings in millet fields where the spacing between millet plants is fairly large (1.0m to 1.2m) than in peanut fields where spacing between plants is much narrower (0.30m to 0.60m). The regeneration problem is exacerbated by the fact that the majority of the farmers follow crop rotations.

The plant spacing problem also has significant implications during crop harvest. While millet heads stalks are harvested by hand, peanuts are harvested using a horse or donkey drawn "lame souleveuse"¹⁸⁶ whose 0.30m to 0.40m blade leaves little between-row room for manoeuvring around seedlings.

Based on the above perceptions, the hypothesis is:

Hypothesis 8.9

$H_{(0)}$: There is no relationship between peanut culture (CASHCR) and average percent cad crown cover per hectare per farm (CRNCAD).

$H_{(1)}$: CRNCAD is a negative function of CASHCR.

¹⁸⁶Literally, "lifting blade".

DEP VAR: CRNCAD N: 67 MULTIPLE R: .009 SQUARED MULTIPLE R: .000						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 2.018						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	2.279	0.247	0.000	.	9.240	0.000
CASHCR	0.019	0.249	0.009	1.000	0.076	0.940
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.024	1	0.024	0.006	0.940	
RESIDUAL	264.810	65	4.074			

The results of the regression suggest that there is no relationship between cash crop/peanut-oriented informants and percent cad crown cover. The null hypothesis must be accepted.

8.5.10 Informant innovativeness

Component 10 reflects informants who may be more innovative than others and who might have a tendency to use more modern agricultural methods, thus perhaps neglecting traditional methods such as the use of *A. albida*. The hypothesis is:

Hypothesis 8.10

$H_{(0)}$: There is no relationship between informant innovativeness (INNOVA) and average percent cad crown cover per hectare per farm (CRNCAD).

$H_{(1)}$: CRNCAD is a negative function of INNOVA.

DEP VAR: CRNCAD N: 67 MULTIPLE R: .085 SQUARED MULTIPLE R: .007						
ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 2.011						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	2.281	0.246	0.000	.	9.284	0.000
INNOVA	-0.171	0.248	-0.085	1.000	-0.691	0.492
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	1.929	1	1.929	0.477	0.492	
RESIDUAL	262.905	65	4.045			

The results of the regression suggest that there is no relationship between informant innovativeness and cad crown cover and the null hypothesis must be accepted.

8.6 Model development

Using the extracted components, an attempt was made to develop a model for each of three independent variables: (i) CRNCAD- the average percent *A. albida* crown cover per hectare per farm; (ii) AALB1- the average *A. albida* regeneration rate per hectare per farm; and (iii) AALB15- the average number of *A. albida* seedlings per hectare per farm between 1cm and 5cm in diameter. While the first two independent variables are self-explanatory, AALB15 is in fact a reflection of regeneration/seedling survival and an indication of informant interest in protection and maintaining the *A. albida* system.

8.6.1 CRNCAD: Cad crown cover

With an alpha to enter and exit of 0.15, stepwise regression identified the components POPPRES, LANDAV, ORGMAT, LANQUAL and FARMEX as being the best approximation of the model. These components were used in a new model statement which yielded the following results:

DEP VAR: CRNCAD N: 67 MULTIPLE R: .662 SQUARED MULTIPLE R: .438						
ADJUSTED SQUARED MULTIPLE R: .392 STANDARD ERROR OF ESTIMATE: 1.562						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	2.274	0.191	0.000	.	11.900	0.000
POPPRES	0.758	0.192	0.378	1.000	3.940	0.000
LANDAV	0.379	0.192	0.189	1.000	1.972	0.053
ORGMAT	0.805	0.192	0.402	1.000	4.188	0.000
LANQUAL	-0.339	0.192	-0.169	1.000	-1.763	0.083
FARMEX	0.530	0.192	0.265	1.000	2.756	0.008
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	115.948	5	23.190	9.501	0.000	
RESIDUAL	148.886	61	2.441			

With an adjusted squared multiple R of only 0.392, the model's predictive power for crown cover is relatively weak. Undoubtedly

there are other factors which come into play which the study and principal components analysis were not able to capture. However, with the exception of LANDAV and LANQUAL, all of the components are highly significant with a confidence level of greater than 99% (one-tailed). The model itself is highly significant with a probability of 0.000.

The only apparent abnormality in the model is the sign of LANQUAL. Again, it was expected that CRNCAD would be a positive function of LANQUAL, but the model suggests otherwise. The principal investigator has no plausible explanation for this result.

8.6.2 AALB1: Cad regeneration

With an alpha to enter and exit of 0.15, stepwise regression identified the components LANDAV and ORGMAT as being the best approximation of AALB1. These components were used in a new model statement which yielded the following results:

DEP VAR: AALB1 N: 67 MULTIPLE R: .337 SQUARED MULTIPLE R: .113 ADJUSTED SQUARED MULTIPLE R: .086 STANDARD ERROR OF ESTIMATE: 0.734						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.780	0.090	0.000	.	8.699	0.000
LANDAV	0.189	0.090	0.247	1.000	2.097	0.040
ORGMAT	0.175	0.090	0.229	1.000	1.943	0.056
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	4.403	2	2.202	4.091	0.021	
RESIDUAL	34.446	64	0.538			

With an adjusted squared multiple R of only 0.086, the model's predictive power for cad regeneration is extremely weak. As in the case of CRNCAD, data collected and resulting principal component analyses are not a good reflection of cad regeneration rates. While the directionality of the variables is as predicted, they are only significant at the 95% confidence level (one-tailed). The model itself is only significant at the 95% confidence level.

8.6.3 AALB15: Cad survival

With an alpha to enter and exit of 0.15, stepwise regression identified the components POPPRES, FARMIMP, LANDAV, ORGMAT, FARMINT, and FARMEX as being the best approximation of AALB15. These components were used in a new model statement which yielded the following results:

DEP VAR: AALB15 N: 67 MULTIPLE R: .746 SQUARED MULTIPLE R: .557 ADJUSTED SQUARED MULTIPLE R: .513 STANDARD ERROR OF ESTIMATE: 7.817						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	7.605	0.956	0.000	.	7.956	0.000
POPPRES	2.563	0.962	0.229	1.000	2.663	0.010
FARMIMP	-1.709	0.963	-0.153	0.999	-1.776	0.081
LANDAV	7.046	0.963	0.629	1.000	7.319	0.000
ORGMAT	-2.164	0.962	-0.193	1.000	-2.249	0.028
FARMINT	-1.680	0.962	-0.150	1.000	-1.746	0.086
FARMEX	-1.757	0.963	-0.157	1.000	-1.825	0.073
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	4613.336	6	768.889	12.582	0.000	
RESIDUAL	3666.741	60	61.112			

With an adjusted squared multiple R of 0.513, this model has the highest predictive power among the three dependent variables modeled. LANDAV and POPPRES are highly significant (99% confidence level one-tailed), while the other variables in the model are all significant at the 95% one-tailed confidence level. Population pressure and land availability clearly have an positive impact on cad survival.

More difficult to explain are the negative coefficients for FARMIMP, ORGMAT, FARMINT and FARMEX. While bivariate relationships between these independent components and AALB15 were not tested, it was expected that the directionality of the relationships would all be positive. However, this is not the case.

This discrepancy is more than likely a function of time. AALB15 reflects cad seedlings that are roughly between 2-10 years of age, or regenerated during the period of heavy subsidies for agricultural inputs. As discussed in Chapter 4, when subsidies for fertilizer were

removed in 1984, farmers attitudes towards maintaining their cad populations changed for the positive. In short, the distribution of AALB15 among informant farms currently is more than likely a function of past practices with regard to the variables measured by the extracted components. For example, it is conceivable that no or little organic matter use in the past (the general practice when fertilizer was heavily subsidized) would have a negative impact on cad regeneration and subsequent seedling survival several years hence. Given the "snapshot" nature of the data, it was impossible to explore this hypothesis further.

8.7 Conclusions and recommendations

Several conclusions can be drawn from the preceding analyses. First, principal components analysis is a useful tool in analyzing the interactions between the *A. albida* social system and the *A. albida* ecosystem. A total of 10 components or factors were extracted from an original data set comprised of seventy variables. All ten components loaded with both biophysical and socio-economic variables and the interactions between the two could be interpreted. The fact that the extracted components accounted for only 53% of the total variance is more than likely a reflection of the principal investigators inability to collect the "right" data to describe a particular variables in some cases.

A main shortcoming found in the analyses is the failure to take into account the fact that the majority of the socio-economic variables and some biophysical variables (e.g., crop production) are based on farmers' perceptions or KASA during the course of the interviews (i.e., the present). However, the existence of certain biophysical variables, particularly trees, is more than likely based on farmers' perceptions, knowledge, attitudes, practices, etc. of several years before the study (i.e., the past). Neither the principal components analysis nor the principal investigator were able to

account for or measure these differences and resulting discrepancies in the cad seedling survival model. Researchers wishing to use this technique in the future would do well to take this anomaly into consideration and structure their interviews and surveys accordingly.

The second major conclusion drawn from the analyses is that contrary to popular belief, population pressure does not appear to be contributing to the decline of the *A. albida* system. On the contrary, the analyses tend to support Boserup's contention that as population increases, there is an intensification of agriculture with increased labor investment in production and increased attention to soil fertility. The relationship between the component population pressure and the independent variables of *A. albida* crown cover, *A. albida* regeneration rates and *A. albida* seedling survival was highly significant in all of the models developed.

Land availability and organic matter production and use by informants also appear to play a critical role in the maintenance of the *A. albida* system. Both components were significant in all three models. Land availability appears to influence the cad system as a result of existing cad and other species tree density; cad tree density appears to be higher in villages where agricultural land is generally more available. According to the models, this tends to result in a higher percentage of cad crown cover, increased regeneration rates and increased survival rates.

Finally, the analysis suggests that population pressure as measured by POPPRES, and land availability as measured by LANDAV do not appear to coincide. One might suspect that in areas where population pressure is high, land availability would be low. This does not appear to be the case. In fact, the two factors are orthogonal to each other which indicates that they are measuring different aspects of the data set and are not related. This suggests that land availability is not necessarily a function of population

pressure. This hypothesis should be further explored by additional research.

CHAPTER 9

THE A. ALBIDA SYSTEM AND ETHNIC CONSIDERATIONS

"Quand le Maure a des problèmes, il parle
Wolof¹⁸⁷."

Wolof proverb (Cribier et al. 1986)

9.1 Introduction

Production systems in the Peanut Basin have undergone radical changes with the implementation, two decades ago, of rural modernization. This modernization was achieved to a major extent by the introduction of peanuts as a cash crop and the resulting rapid monetarisation of the economy. This modernization process combined with a fairly homogenous biophysical environment has resulted in the development of fairly uniform cropping systems throughout the study area. Peanuts continue to provide the main cash crop while millet, sorghum, cowpeas (niébé) and cassava are the major food crops with cassava becoming an important secondary cash crop in the northern areas of the Peanut Basin (Rodale 1989).

The following is a brief description of a typical cropping system in the NCPB. Land surrounding a village is divided into individual plots on which crops may or may not be rotated depending on the distance from the field to the village. Fields near the households or compounds (toll keur) are usually not subject to rotation but are continuously planted with cereals, particularly millet. They are generally able to sustain production (and a certain degree of food security) under normal rainfall conditions as they receive the vast majority of organic matter (animal manure and household litter) produced by a compound. Outlying fields receive far

¹⁸⁷Prior to the troubles between Mauritania and Senegal, there were a considerable number of Maure traders in Senegal, even in remote areas. However, the Maures never integrated into Senegalese society and refused to speak Wolof or other local languages. This proverb means literally that when a Maure has problems, he can speak Wolof. In the context of the analyses presented in this Chapter, the proverb is taken to mean that people can adapt when they are forced to.

less household organic matter and traditionally, a millet-peanut rotation occasionally combined with cowpeas (intercropped or late overseeding with millet) is used along with *A. albida*, a 2-3 year grass fallow, the burning of crop residues and occasional parcase in order to maintain soil fertility. However, according to most GOS authorities, the use of *A. albida*, planned fallow and parcase have all declined in recent years¹⁸⁸. Additionally, the use of mineral fertilizer has essentially ceased in the study area since the inception of the New Agricultural Policy in 1984 which ended fertilizer subsidies and cheap credit for agriculture inputs (Kelly 1988).

9.2 Differences between Wolof and Serer production systems

In spite of the NCPB's relatively homogenous biophysical environment and cropping systems, it varies considerably in terms of demographic pressure and ethnic composition. As a result, farming or production systems (as opposed to cropping systems) in the Peanut Basin are generally differentiated by the region's two major ethnic groups; the Wolof, with their relatively lower population concentration and more extensive production system, and the Serer, with their higher population concentration and more intensive production system.

In order to understand the differences between these systems some historical perspective is needed. As Stomal-Weigel (1988) observes, throughout their history, the Wolof have been perceived as a society which is politically very structured with a very evident

¹⁸⁸ While the apparent decline in the use of traditional methods to maintain soil fertility, particularly *A. albida*, has been discussed in greater detail in previous chapters, the primary reasons cited for the decline in the use of planned fallow are: (i) the increasing use of animal traction to cultivate larger surfaces at the expense of fallow; and (ii) insufficient land in villages to permit fallowing, a consequence of both demographic pressure and the enlargement of the area cropped (Rodale 1989). The use of parcase is thought to have decreased as a result of the reduction in animal populations following the 1970's drought.

social hierarchy but lacking any sort of agricultural traditions. As Pelissier (1966) writes of the Wolof,

"Organisation politique et hiérarchisation sociale sont restées étrangères pour ne pas dire hostiles au développement d'institutions agraires dont on ne trouve aucune trace ni même aucune amorce en pays wolof (p.110)."

The Serer, on the other hand, have been perceived throughout their history as a fundamentally egalitarian society with strong agricultural traditions. Stomal-Weigel (1988) writes that the Serer:

"apparaissent comme une société véritablement paysanne aux techniques agricoles très perfectionnées dont l'originalité du système de production traditionnel s'exprimait par la place dominante du mil ainsi que par l'intégration de l'élevage à l'agriculture (p.21-22)."

The *A. albida* tree, as Swift (1977) observed, was also an integral part of the Serer production system, with Serer farmers "carefully" selecting *A. albida* and other trees for retention in fields in order to provide organic matter to the soil and thus increases the yield and protein composition of millet. In fact, Felker (1978), citing Pelissier¹⁸⁹ (1967), reports that in Serer (Senegal) language, "yaram-sas" - to raise an *A. albida*, is used in the same general context as "yaram o ndiay" which means to raise a child.

Differences between Wolof and Serer production systems became even more pronounced with the spread of Islam¹⁹⁰ among the Wolof combined with the introduction of peanuts as a cash crop. The Wolof,

¹⁸⁹Pelissier (1967) provides, perhaps, the most in-depth information of the cultural aspects of the *A. albida* system in Serer agriculture in Senegal.

¹⁹⁰There are three main Islamic brotherhoods in Senegal: the Khadria located in the Moyenne Casamance and composed primarily of the Mandingo ethnic group; the Tidjanés with their center in Tivouane and composed of mainly Toucouleur, but with also about one-half of the Wolof population; and the Mourides with their center in Touba-Mbacké and with a practically all Wolof ethnic composition (Jeune Afrique 1983). In terms of agriculture and peanut production in the Peanut Basin, the Mourides exert a much greater influence than the Tidjanés. Of the 120 large-scale landholdings in the Peanut Basin, over 100 belong to the Mouride marabouts (Colvin 1983).

looking for new sources of political power following the disappearance of the centralized monarchies converted "en masse" to Islam while the Serer attempted to preserve their egalitarian society (Gastellu 1981). Taking advantage of the new market economy, Mouride "taalibés" (disciples), incited by their "marabout" (quranic teacher/religious leader) quickly expanded peanut production¹⁹¹ by putting more land into peanut cultivation and by clearing new lands usually at the expense of maintaining soil fertility. Peanuts progressively replaced food crops (millet and sorghum) as the dominant factor in Wolof production systems (Stomal-Weigel 1988).

The Serer, by maintaining their egalitarian economy, were able to insert peanuts in their traditional production systems without disrupting their social organization or the ecological benefits derived from their traditional system. Priority was always accorded to food production (millet) and soil productivity was maintained by integrating peanuts into the traditional millet-fallow/manure rotation (Gastellu 1981). The net result was that by the early 1960's, the intensive Serer system was capable of maintaining a significantly higher population density than the more extensive Wolof production system.

In 1965, the GOS began its "Programme Agricole" (Agricultural Program) period. The main objective of the Programme Agricole was to increase peanut production and yields by introducing new techniques (improved seed, line seeding, animal traction and mineral fertilizer) and providing cheap credit in order to facilitate farmer adoption of these new techniques. During the 20 year period of the Programme Agricole, differences between Wolof and Serer production systems became less pronounced. In a study comparing the evolution of

¹⁹¹Some estimates place Mouride (disciples and marabouts) peanut production as high as 75% of total production in 1957-58. More recently, the large-scale Mouride landholdings account for only 5-6% of production but the marabouts influence in agriculture in the Peanut Basin remains strong (Colvin 1983).

production systems in a Serer and Wolof village, Stomal Weigel (1988) found that the Programme Agricole caused profound changes in both systems which resulted in reduced yields, reduced crop diversity, increased mechanization and a continuous cropping system (reduced fallow) brought about by increased mechanization.

Stomal-Weigel (op cit.) goes on to say that the effects of the GOS's agriculture modernization program were more pronounced in the Wolof village than in the Serer village. Inhabitants of the Serer village were more concerned with maintaining soil fertility and increasing manual labor productivity which caused them to retain certain elements of their traditional system. In particular, while there was considerable substitution of chemical fertilizer for manure in both systems, Serer farmers continued to maintain *A. albida* trees while the majority of *A. albida* trees on the Wolof farms were dead¹⁹². Additionally, in the Serer village, increased mechanization had not compromised certain cultural techniques (manual weeding of emerging millet) as it had done in the Wolof village.

With support from the World Bank, the GOS began its agricultural sector reform (structural adjustment) program in 1980. This reform culminated in the development of Senegal's Nouvelle Politique Agricole in 1984 and state disengagement from the agricultural sector began. An emphasis was placed on privatization and subsidies on agricultural inputs (particularly fertilizer) were reduced and eventually eliminated in 1988. Price and marketing controls on cereal grains (except rice) were also eliminated. As was indicated in Chapter 4, this structural adjustment program appears to have had a profound effect on use of the *A. albida* system by NCPB farmers.

In the above context, cultural differences between Wolof and Serer farmers may still be an important factor in the use of the *A. albida* system in the NCPB. In fact, when the principal investigator

¹⁹²The cause of death was not specified.

was preparing the research proposal, several Senegalese colleagues believed that the only factor which had an impact on the system was ethnic differences. They argued that Serer farmers would surpass Wolof farmers on every aspect of the *A. albida* system from crown cover to tree density and regeneration rates. However, during the course of the initial village visits and subsequent socio-economic survey and biophysical inventory, differences between Wolof and Serer farmers in terms of *A. albida* were not very apparent. In fact, the principal investigator's working hypothesis on ethnic differences with regard to the cad system became simply that there were not any differences. The specific hypothesis to be tested therefore is:

Hypothesis 9.1

H(0): Serer farmers have significantly higher numbers of *A. albida* trees (and percent crown cover and regeneration rates) than Wolof farmers.

H(1): There are no significant differences between Wolof and Serer farmers in terms of numbers of *A. albida* trees (and percent crown cover and regeneration rates).

9.3 Methodology

The study yielded a number of biophysical and socio-economic variables which might reflect ethnic differences with regard to both use of the *A. albida* system and other related factors. These variables were sorted by ethnic group (39 of the respondents were Wolof while 33 were Serer) and organized according natural resource related variables and other variables. A description of variables used in the analysis is presented in Appendix N. Tukey's HSD test was then used (which accounts for unequal n's) to test the above hypothesis.

9.4 Results

9.4.1 Natural resource-related variables

The results of the analysis suggest that there are only two natural resource-related variables for which there are significant differences between Wolof and Serer informants; CRNOTH and CONSMES. CRNOTH is the average percent crown cover per hectare per farm of

species other than *A. albida*. CONSMES is the percent of total farm area where the informant farmer has undertaken soil conservation measures (windbreaks, live fences and other tree planting) other than protecting *A. albida*. For both variables, the mean for Serer informants was significantly greater than the mean for Wolof informants as indicated in Table 9.1 below. The higher percent of crown cover for Serer informants may be a reflection of CONSMES, or alternatively, due to higher rainfall in the southern parts of the study area, where the majority of Serer informants are found. There was no significant difference between Wolof and Serer farmers for any of the variables describing *A. albida*. The complete results of the analysis are presented in Appendix O.

Table 9.1
Differences by Ethnic Group--
Natural Resource Variables

VARIABLE	MEAN		OVERALL MEAN	CHI-SQ.	PROB. 2-TAIL	T-TEST	PROB. 2-TAIL
	WOLOF	SERER					
CRNOFH	0.875	1.639	1.255	41.412	0.000	2.368	0.021**
CONSMES	6.677	14.468	10.248	5.061	0.024	1.725	0.089*
* significant at the 95% confidence level (chi-square)							
** significant at the 99% confidence level (chi-square)							
Source: Data from Appendix O.							

9.4.2 Other variables

While the primary purpose of this analysis was to examine differences between Wolof and Serer informants in terms of natural resources, particularly the use of *A. albida*, other variables were also examined. For the most part, this analysis supports general perceptions about Wolof and Serer farmers. As Table 8.2 indicates, Wolof informants had significantly larger farm sizes (AREAC), a greater percentage of land in fallow (HAAVFAL), grew more cowpeas (HAAVCOW, AVCOWHA, AVTOTCOW), and grew more manioc (AVMOCHA, HAAVMOC) than their Serer counterparts. Wolof informants also had a significantly higher emmigration rate (EMRATE), a higher adult literacy rate in Arabic and Wolof (AARLOC), and had a significantly

higher percent of total farm area which was allocated by someone other than the chef de carré (AREAOH).

Serer informants on the other hand, had significantly higher millet yields (AVMILHA) and greater total millet production (AVTOTMIL) without having a significantly higher percent of farm area in millet production. Serer informants also had a higher adult French literacy rate than their Wolof counterparts (AFRENCH), and tended to farm a greater percent of their total farm area on a temporary (i.e., loaned) basis (AREAREC). Additionally, Serer informant villages had significantly higher village populations.

Finally, the analysis tends to support Stomal-Weigel's (1988) assertion that differences between Wolof and Serer production systems are becoming less pronounced as a result of Senegal's Programme Agricole. In particular, there are no significant differences in variables related to peanut production (HAVPEA, AVPEAHA, AVTOTPEA), manure use (HAMANAV, AVMANHA) and animals (COWS, SHPGOAT, TRACAN).

The complete results of the analysis are presented in Appendix O.

Table 9.2
Differences by Ethnic Group--
Other Variables

VARIABLE	MEAN		OVERALL MEAN	CHI-SQ.	PROB. 2-TAIL	T-TEST	PROB. 2-TAIL
	WOLOF	SERER					
AREAC	7.665	5.008	6.447	13.114	0.000	2.641	0.010**
HAAPAL	21.454	8.022	15.297	17.071	0.000	3.602	0.001**
HAAPCOW	3.590	0.717	2.273	44.815	0.000	2.843	0.006**
HAAPMOC	1.591	0.000	--	--	--	--	**
AVMILHA	314.608	492.104	395.960	4.794	0.029	3.744	0.000**
AVMOCHA	15.667	0.000	--	--	--	--	**
AVCOWHA	45.367	13.998	30.985	15.314	0.000	2.611	0.011**
YSINFAL	14.340	20.641	17.228	3.890	0.049	2.741	0.008**
AVTOTMIL	713.831	1088.761	885.674	3.337	0.068	3.089	0.003**
AVTOTCOW	38.987	6.919	24.289	52.869	0.000	2.950	0.004**
HAKHOR	1.998	8.074	4.783	35.319	0.000	2.074	0.042**
VILPOP	326.054	597.515	454.029	11.258	0.001	3.435	0.001**
AFRENCH	1.923	6.574	4.055	5.444	0.020	2.079	0.041**
AARLOC	15.776	8.398	12.395	2.768	0.096	1.938	0.057*
EMIRATE	8.952	3.333	6.377	7.799	0.005	2.164	0.034**
AREAOH	16.919	1.047	9.890	82.239	0.000	2.824	0.006**
AREAREC	1.187	4.690	2.815	32.476	0.000	1.853	0.068*

* significant at the 95% confidence level (chi-square)

** significant at the 99% confidence level (chi-square)

Source: Data from Appendix O.

9.5 Conclusions

The results of the analysis suggest that at least among 72 randomly selected informants, there are no significant differences between Wolof and Serer informants in terms of use of the *A. albida* system. The general conclusion which might be drawn from this analysis is that Senegal's Programme Agricole period has indeed reduced differences between Wolof and Serer production systems. While differences might have been apparent two decades ago, it now appears that Wolof informants are becoming more interested in soil fertility. In the face of removal of fertilizer subsidies, Wolof farmers appear to be emulating their Serer counterparts by protecting and maintaining more *A. albida* trees on their farms and by using more manure.

CHAPTER 10

CONCLUSIONS AND RECOMMENDATIONS

"Our ability to maintain sustainable agriculture will be dependent largely on our successfully manipulating the interactions of biotic and abiotic factors that operate within ecosystems to produce system nutrient accumulation and persistence.... our understanding of these interactions is dependent on our ability to produce a consistent concept of ecosystem behavior into which specific knowledge is placed."

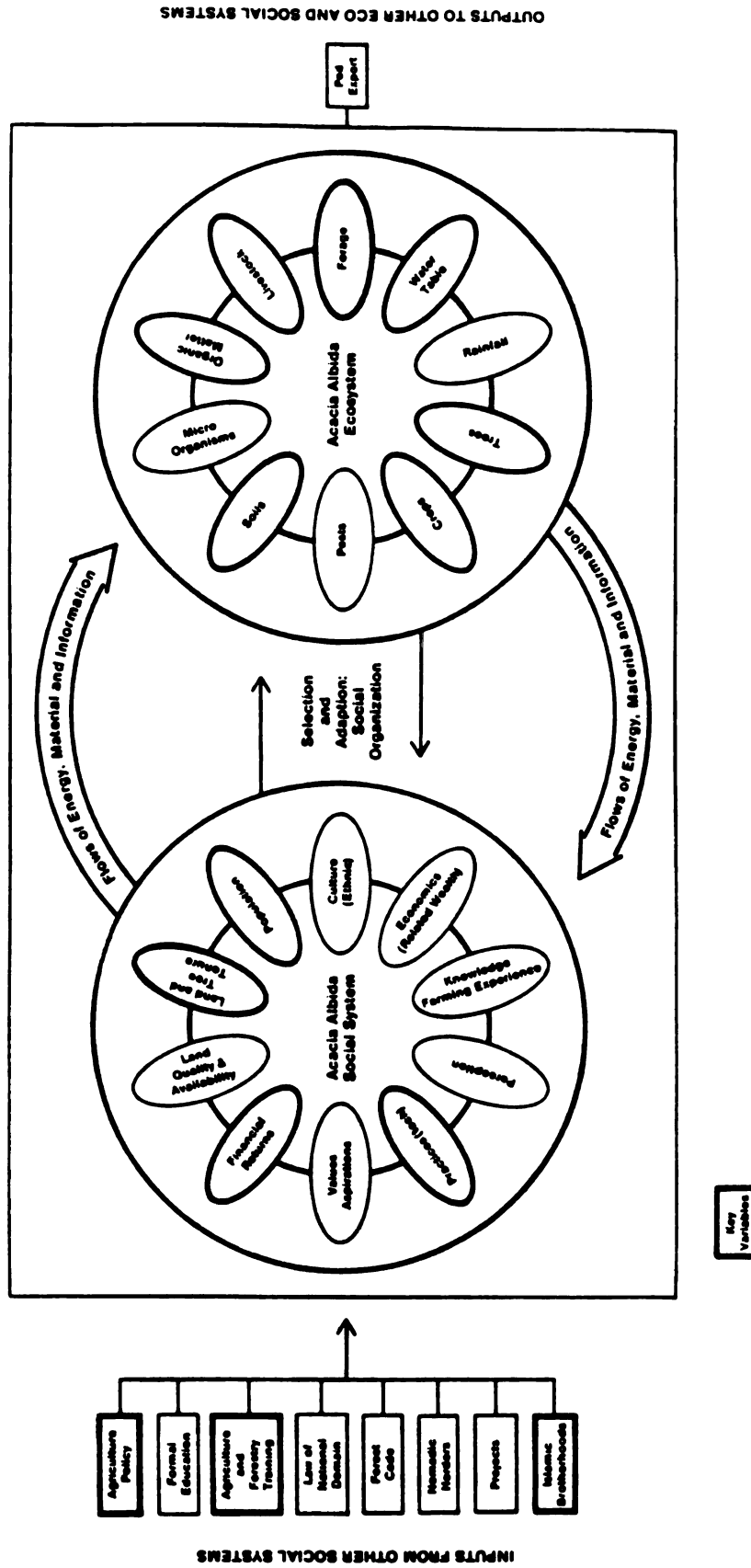
Robert Woodmansee (1984)

10.1 Introduction

One of the immediate applications of this research is to contribute to the knowledge of Senegalese and expatriate professionals, experts, planners, extension agents, and development practitioners about the extent, sophistication, and value of *A. albida* system. In this context, a human ecological systems approach was used to facilitate conceptualization of how *A. albida* human and ecosystem interactions are related, and how efforts (individual or collective) might contribute to a greater understanding and increased use of the system in the NCPB. Perhaps more importantly, this approach identifies points of decision or "levers" which those concerned with sustainable agriculture and natural resource development and management in Senegal may need to manipulate (or leave alone) in order to ensure sustainable production of agriculture and forest products.

10.2 Overall conclusions and recommendations

Drawing on the analyses, conclusions and recommendations presented in previous chapters, critical points of decision or levers for improved management of the *A. albida* system are depicted in Figure 10.1 - a revised *A. albida* human ecological system. Based on these points of decision, the following general recommendations are offered with regard to the *A. albida* system in particular and improved natural resource management in general in the NCPB.



First, the economic incentives facing the NCPB's rural populations are major determinants of how natural resources are managed. Maintenance and wider use of the *A. albida* system and improved natural resource management may depend more on general agricultural and economic policies than on policies and projects which focus on the system itself. In short, farmers appear to respond more to a program approach than to the traditional project approach supported by the GOS and many donors.

Second, with little if any external inputs farmers demonstrated that they can effectively organize themselves to protect and maintain their own environment and natural resources. The development of these social organizations appears to be based more on competition for resources and enhancing security of tree tenure than on adaptation to the environment. In the study area, farmer concerted action/social organization to protect the environment appears to take three forms: (i) the formation of village "comités de surveillance"; (ii) the use of forest "monitors"; and (iii) concerted action for the protection of natural forests (natural forest management). Each of these types of groups appears to have solid outreach potential and may be one of the better vehicles to use for expansion of the *A. albida* system.

Third, support (extension, training, projects) to NCPB farmers for *A. albida* and other natural resource efforts is virtually non-existent or is based on pre-conceived ideas of what farmers problems and needs are. There needs to be increased support to actions (both individual and collective) that farmers are currently undertaking to better protect and manage their own natural resources, rather than introducing new methods and technologies. This means an increased role for agriculture and forestry/natural resources training in order to better equip farmers with the skills necessary for improved natural resource management and decision making. Similarly, extension's role should be one of support rather than implementation of a preconceived notion of what needs to be done. It may also mean modifying system-

specific and other natural resource policies such as the Forest Code to be more in line with and supportive of farmer current actions.

Fourth, among informant collective actions, improved management of khor areas (natural forest management) appears to be a prime target of opportunity for increased attention on behalf of the GOS, donors and NGOs alike. These areas have considerable potential to provide increased forage, fuelwood and service wood supplies and relieve at least some of the pressure on on-farm trees such as cad. They are also major sources of fruit/food and medicinal plants. They should be the subject of additional research both in terms of management techniques and in terms of the impact of privatization of these areas and loss of benefits.

Fifth, sustainable agriculture in the NCPB requires soil maintenance to continue the productive capacity of the land indefinitely. In turn, soil maintenance, particularly for dior soils, requires organic matter input, establishing production demands consistent with the soil and water resources available and managing the land accordingly. It will also require a mental shift among many GOS personnel from production/commodity-based research and development programs to programs which focus on conserving and enhancing the natural resource base and its contribution to soil maintenance. While soil maintenance does not exclude inorganic soil amendments or production increases resulting from varietal research, it does require a better balance between commodities programs and natural resource-based agricultural research.

To maximize the sustainable production potential of most NCPB farming systems, the productive capacity of the soil must be restored. This requires a two step approach. First, the existing resource must be stabilized; that is, the soil and water must be retained within the farming systems through erosion control and water conservation. As the preceding analysis suggests, some farmers in the NCPB appear to be doing just this through the use of indigenous on-farm trees and

shrubs which maintain levels of organic matter sufficient for low but stable crop yields in average rainfall years.

The second step - applicable to the majority of NCPB farmers - is to rebuild and enhance the soil to its maximum productive capacity. In turn, this will promote soil and water conservation. With the exception of traditional techniques such as *A. albida*, manure and parcase, other techniques for rebuilding the soil such as composting, green manure crops and improved agronomic practices are not well known in Senegal, or if known, have not been adopted. While some of these newer techniques require little cash expenditure, many will require a significant investment of labor. This means that the benefits of a particular soil building technology need to exceed costs. In turn, this requires more stringent research designs where benefits can actually be demonstrated/proven rather than assumed. Moreover, costs and benefits of these "new" technologies need to be compared with the traditional technologies; new is not always better.

Once this is achieved, a third stage would be to establish land use and land management practices and production expectations that can be sustained while maintaining the restored resource. It is at this stage that the use of inorganic fertilizer and improved varieties can begin to make significant increases in crop yields. As with many countries in sub-Saharan Africa, Senegal has, in the past, tended to focus on the third stage (commodities and fertilizer) to the neglect of the first two stages. This focus needs to change.

Finally, and perhaps most importantly, in addition to trying to increase per hectare yield of basic food and cash crops, those concerned with rural development and policy formulation in Senegal must also devote increased attention to building on peasant subsistence farming systems in order to increase farmer resilience against soil degradation and in poor rainfall years. As Todaro (1977) writes, "the main motivating force in a peasant's life may be the maximization not of income, but of survival." Thus, risk-avoiding

peasants such as those in the NCPB are likely to prefer a technology of food production which combines a low mean per hectare yield with a low variance (fewer fluctuations about the mean) to alternative technologies which may promise a higher mean yield but also present the risk of greater variance. If properly conceived and implemented, the re-introduction of *A. albida* via natural regeneration may be one of the most historically tried and accessible technologies available today to aid in creating this resilience.

APPENDICES

APPENDIX A
SOCIO-ECONOMIC SURVEY QUESTIONNAIRE

**INSTITUT SENEGALAIS DE
RECHERCHES AGRICOLES**

ISRA/DRPF - DAKAR

FICHE ENQUETE SUR LE CADD
"ETUDE SOCIO-ECONOMIQUE"

James R. Seyler

Novembre 1989

ENQUETES--CADD

Code:.....

Date:.....

Enquêteur.....

1. RENSEIGNEMENTS GENERAUX

- 1.1 Nom chef d'exploitation /...../
- 1.2 Village /...../
- 1.3 Communauté Rurale /...../
- 1.4 Arrondissement /...../
- 1.5 Département /...../
- 1.6 Région /...../
- 1.7 Nom de la personne enquêté /...../
- 1.8 Groupe ethnique /...../
- 1.9 Age /...../
- 1.10 Statut /...../
- 1.11 Combien d'exploitation dans le carré? /...../
- 1.12 Combien de carrés dans le village? /...../
- 1.13 Distance au plus proche marché hebdomadaire. /...../
- 1.14 Distance à la plus proche route goudronnée. /...../
- 1.15 Distance au plus proche agent SODEVA. /...../
- 1.16 Distance au plus proche agent des Eaux et Forêts. /...../
- 1.17 Distance au plus proche CER. /...../
- 1.18 Profondeur du puit du village /...../

2.0 HISTORIQUE DU VILLAGE

- 2.1 Depuis combien de temps avez-vous habité le village? /...../
- 2.2 Pouvez-vous nous dire la date de création de votre village ou nous indiquer un événement historique de référence survenu au même moment?
- Date: /...../ Evenement: /...../

2.3 Pourquoi ce village porte-il ce nom?.....

2.4 Le village, a-t-il toujours été appelé ainsi?

Oui /...../ Non /...../

2.4.1 Si non, pourquoi a-t-on changé le nom du village?.....

.....

2.5 Qui a créé ce village? /...../

2.5.1 D'où venait-t-il? /...../

2.5.2 Etait-il seul? Oui /...../ Non /...../

2.5.3 Si non, combien de personnes l'ont accompagné? /...../

2.6 Y'avait-il déjà des villages installés dans la zone?

Oui /...../ Non /...../

2.6.1 Si oui, combien?

Peu /...../ Quelques uns /...../ Beaucoup /...../

2.6.2 Si oui, avez-vous une idée des limites du terroir de votre village avec ces villages?

Oui /...../ Non /...../

2.7 L'emplacement du village, a-t-il déjà changé?

Oui /.../ Non /.../

2.7.1 Si oui, pourquoi?.....

.....

2.8 Depuis que vous êtes au village, avez-vous constaté que le nombre arbres a:

Augmenté /...../ Resté a peu pres le même /...../ Diminué /...../

2.8.1 Si le nombre d'arbres a augmenté, à quoi attribuez-vous cette augmentation:

1. un projet de reboisement. /...../

(spécifiez le projet:.....)

2. les gens du village s'occupent à planter les arbres eux-mêmes. /..../
3. les gens du village s'occupent à protéger les arbres poussant naturellement aux champs. /..../
4. d'autres raisons (Spécifiez:).....

2.8.2 Si le nombre d'arbres a diminué ces dernières années, à quoi contribuez-vous cette diminution?

- | | | | |
|----------------------------------|--------|--|--------|
| 1. feux de brousse | /..../ | 6. coupe bois de service | /..../ |
| 2. sécheresse | /..../ | 7. coupe charbonniers | /..../ |
| 3. coupe bois de feu | /..../ | 8. sarclage aux champs | /..../ |
| 4. trop d'émondage | /..../ | 9. régénération brouté par le bétail | /..../ |
| 5. défrichement pour agriculture | /..../ | 10. quelq'un vous a dis de les enlevés | /..../ |
| 11. d'autres raisons | /..../ | | |
| Spécifiez..... | | Spécifiez qui:..... | |
| | | Et quand?..... | |

2.9 Depuis que vous êtes au village, avez vous constaté un changement dans la qualité de l'environnement autour du village?

Oui /...../ Non /...../ Ne sais pas /...../

2.9.1 Si oui, qu'est-ce qu'y a changé?

- | | | | |
|---------------------------------|---------|---------------------------|---------|
| 1. fertilité réduite aux champs | /...../ | 4. plus d'érosion | /...../ |
| 2. moins de forage | /...../ | 5. moins de pluies | /...../ |
| 3. moins de plantes médicinales | /...../ | 6. autres, spécifiez..... | |

.....

2.10 Pour le cadd en particulier, depuis que vous êtes au village, avez-vous constaté que le nombre de cadds a:

Augmenté /.../ Resté à peu près le même /.../ Diminué /.../

Si augmenter, passer à la question 2.10.1.
Si diminuer, passer à la question 2.10.2.
Si reste le même, passer à la question 3.

2.10.1 Si le nombre de cadds a augmenté ces dernières années, à quoi contribuez-vous cette augmentation:

1. un projet de reboisement. /...../

(specifiez le projet et la date de commencement.....

.....

2. les gens du village s'occupent à planter /...../
les cadds eux-mêmes.

3. les gens du village s'occupent à protéger /...../
les petits cadds poussant naturellement aux champs.

4. d'autres raisons (Spécifiez:).....

2.10.2 Si le nombre de cadds a diminué ces dernières
années, à quoi contribuez-vous cette diminution?

1. feux de brousse /.../ 6. coupe bois de service /.../

2. sécheresse /.../ 7. coupe charbonniers /.../

3. coupe bois de feu /.../ 8. sarclage aux champs /.../

4. trop d'émondage /.../ 9. régénération brouté /.../
par le bétail

5. défrichement pour /.../
l'agriculture 10. quelq'un vous a /.../
dis de les enlevés

Spécifiez qui:.....

Et quand?.....

11. d'autres raisons (Spécifiez):.....

2.11 A votre avis, y-a-t-il suffisamment de bois autour du village pour
satisfaire les besoins actuels en bois de feu pour le village?

Oui /...../ Non /...../ Ne sais pas /...../

2.12 A votre avis, y-a-t-il suffisamment de bois autour du village
pour satisfaire les besoins en bois de feu pour les generations
à venir?

Oui /...../ Non /...../ Ne sais pas /...../

2.13 A votre avis, y-a-t-il suffisamment de bois autour du village
pour satisfaire les besoins actuels en bois de service pour le
village?

Oui /...../ Non /...../ Ne sais pas /...../

2.14 A votre avis, y-a-t-il suffisamment de bois autour du village
pour satisfaire les besoins en bois de service pour les
generations à venir?

Oui /...../ Non /...../ Ne sais pas /...../

2.15 A votre avis, y-a-t-il suffisamment de forage autour du village
pour en satisfaire les besoins actuels du betail?

Oui /...../ Non /...../ Ne sais pas /...../

2.16 A votre avis, y-a-t-il suffisamment de forage autour du village pour en satisfaire les besoins futurs du bétail?

Oui /...../ Non /...../ Ne sais pas /...../

3.0 CARACTERISTIQUES DE L'EXPLOITATION

3.1 Information concernant les membres adultes de l'exploitation (âgés de plus de 16 ans).

Nb.	Nom et Prénom	Age	Sexe	Statut ¹ CC, CE... ...	Education (années ou niveau)	Situation de Présence	Français				Arab			
							lire		écrire		lire		écrire	
							O	N	O	N	O	N	O	N
1														
2														
3														
4														
5														
6														
7														
8														
9														
10														
11														
12														
13														
14														
15														
16														
17														

¹ CC- Chef de Concession (carré); CE- Chef exploitation;
 CD- Chef de ménage dépendant; SF- Sourga familiale;
 NO- Norane; NA- Navetane

3.2 Information concernant les jeunes de l'exploitation (âgés entre 6 et 15 ans)

No.	Nom et Prénom	Age	Sexe	Education (années ou niveau)	Situation de Présence	Va à l'école?		Observations
1						Oui	Non	
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								

3.3 Combien d'enfants y-a-t-il dans l'exploitation qui ont moins de six ans d'âge?

Garçons...../

Filles...../

3.4 Quelqu'un de l'exploitation a-t-il émigré ces deux dernières années?

Oui /..../ Non /..../

3.4.1 Si oui:

Année	Statut	Période SS/SH	Durée	Destina- tion	Activité exercée	Revenu

Oui /.../ Non /.../

[illegible]

Oui /.../ Non /.../

[illegible]

3.7 Cheptel de rente de l'exploitation:

[illegible]

3.8 Animaux de trait utilisés dans l'exploitation:

[illegible]

3.9 Equipement agricole disponible dans l'exploitation:

[illegible]

3.9.1 En cas de non disponibilité ou d'insuffisance de matériel agricole dans l'exploitation, avec quoi travaillez-vous?

- | | | | |
|------------------------|--------|---------------------------|--------|
| 1. emprunt | /..../ | 4. cultive manuellement | /..../ |
| 2. location | /..../ | 5. contre de travail | /..../ |
| 3. échange de matériel | /..../ | 6. autre (spécifiez)..... | |
| | | | |

4.0 PARTICIPATION A DES ASSOCIATIONS

4.1 Etes-vous membre d'une association ou groupement?

Oui /...../ Non /...../

Si oui, passer à l'ANNEX, "PARTICIPATION A DES ASSOCIATIONS"

Si non, passer à la question 4.2.

4.2 Si non, pourquoi:

- | | |
|--|---------|
| 1. Ca ne m'intéresse pas | /...../ |
| 2. Il n'y en a pas au village | /...../ |
| 3. Ca demand trop de temps | /...../ |
| 4. Je ne m'entends pas avec les dirigeants | /...../ |
| 5. Autres raisons (Spécifiez):..... | |
| | |

4.3 A votre avis, les associations des agriculteurs, ont-elles un plus grand rôle à jouer dans la conservation des ressources naturelles (reboisement, défense et restauration des sols, etc.)?

Oui /...../ Non /...../

4.3.1 Si oui, que doit-on faire pour améliorer ce rôle?....

.....

4.3.2 Si non, pourquoi et quelle autre forme d'organisation

proposeriez-vous?.....

.....

.....

4.4 Sommaire du nombre de personnes dans l'exploitation inscrites à diverses associations:

Type	Personnes de plus de 25 ans		Personnes de 15 à 25 ans	
	Hommes	Femmes	Hommes	Femmes
	Effectif=	Eff.=	Eff.=	Eff.=
Sections villageoises				
G.P. statut officiel				
G.P. statut non-officiel				
Tontines				
Dahiras				
Maisons familiales				
Mbotayas				
GIE ²				

5.0 FONCIER ET SEGMENTATION

5.1 Quel age aviez-vous au moment où vous étiez devenu CE? /...../

5.2 Mode d'émancipation:

1. Demandé à être CE /...../
2. Devenu CE sur proposition du CC /...../
3. " " après décès du CC /...../
4. " " relève du CC trop agé /...../
5. " " par suite d'un conflit avec le CC /...../
6. " " par suite d'un conflit avec
quelqu'un d'autre dans la concession /...../
7. " " par suite d'un conflit entre membres
d'exploitations différentes /...../
8. Autres, spécifiez.....

5.3 Superficie disponible avant de devenir CE.

1. allouée par le CE /...../
2. allouée par quelqu'un d'autre /...../
3. défrichée par moi-même /...../
- TOTAL /...../

²Groupement d'Interêt Economique

5.4 Avez-vous bénéficié d'une allocation supplémentaire de terre après être devenu CE?

Oui /...../ Non /...../

5.4.1 Si oui, de qui (lien de parenté)?.....

Superficie reçue.....

5.5 Y-a-t-il un membre de l'exploitation qui reçoit des terres de façon temporaire d'une autre exploitation?

Oui /...../ Non /...../

5.5.1 Si oui, de qui (lien de parenté)?.....

5.5.2 Du même village? Oui /...../ Non /...../

5.5.3 Quelle superficie?.....

5.6 Avez-vous (ou un membre de votre exploitation) prêté des terres de façon temporaire à une autre exploitation?

Oui /...../ Non /...../

5.6.1 Si oui, à qui (lien de parenté)?.....

5.6.2 Du même village? Oui /...../ Non /...../

5.6.3 Quelle superficie?.....

5.6.4 Précisez la raison pour laquelle vous avez prêté des terres.

.....

5.7 La superficie totale disponible à l'exploitation, est-elle suffisante pour les besoins de l'exploitation?

Oui /...../ Non /...../

5.8 Indiquez le degré de difficulté pour obtenir des terres supplémentaires.

1. Très facile /...../

2. Assez Facile /...../

3. Assez difficile /...../

4. Très difficile /...../

6.0 PERFORMANCE DE L'EXPLOITATION

6.1 Quelles ont été les productions de votre exploitation ces deux dernières campagnes?

Culture	1988/89			1989/90		
	vari- été	date de semis	produ- ction	vari- été	date de semis	produ- ction ³
Mil						
..... Niébé						
..... Arachide						
..... Fanes d'arachide						
..... Fanes de niébé						
..... Autre.....						

6.2 Ces productions, ont-elles couvertes les besoins de nourriture et autres dépenses de l'exploitation?

Production	1988				1989			
	Mil	Niébé	Arachide	Autre	Mil	Niébé	Arachide	Autre
Suffisante								
..... Insuffisante								

6.3 Ces productions, ont-elles couvertes les besoins de nourriture du bétail?

Production	1988		1989	
	Fanes Arach.	Fanes Niébé	Fanes Arach.	Fanes Niébé
Suffisante				
..... Insuffisante				

³en kg ou diokhs

6.4 Au cas où vous n'avez pas produit assez, à quoi attribuez-vous cette déficience?

CULTURE	Manque de semences	Mauvaises pluies	Manque de terres	Manque de main-d'œuvre	Mauvaises pauvres terres	Manque d'engrais	Manque animaux trait	Mauvaise variété	Retard de sem	Autre (préc.)
1 Mil										
1 Niébé										
9 Arach.										
8 Fan.Ar										
8 Fan.Ni										
Autre										
1 Mil										
1 Niébé										
9 Arach.										
8 Fan.Ar										
9 Fan.Ni										
Autre										

6.5 Au cas où vous n'avez pas produit assez pour couvrir les besoins de nourriture familiale et d'autres dépenses de l'exploitation, quelles solutions avez-vous trouvées à ce problème?

1. demande d'aide alimentaire /...../
2. demande d'aide financière /...../
3. emprunt d'argent ou de nourriture /...../
4. exercice d'activités extra-agricole /...../
5. gage d'un matériel /...../
6. vente d'un animal /...../
7. autres, précisez:.....

6.6 Au cas où vous n'avez pas produit assez de nourriture pour le bétail, quelles solutions avez-vous trouvées à ce problème?

Précisez.....

.....

.....

6.7 Au cas où votre production vivrière est supérieure aux besoins, qu'avez-vous fait du surplus?

1. stockage à domicile /...../
2. vente /...../
3. prêt /...../
4. aide à des parents /...../
5. autres, précisez:.....

6.8 En cas de vente, quelle utilisation avez vous fait du revenu?

- | | | | |
|-------------------------|--------|---------------------------|--------|
| 1. achat semences | /..../ | 6. location terre | /..../ |
| 2. achat engrais | /..../ | 7. mariage | /..../ |
| 3. achat mat. agricole | /..../ | 8. achat animaux rente | /..../ |
| 4. réparation matériel | /..../ | 9. aide à des parents | /..../ |
| 5. achat animaux traits | /..../ | 10. autres, précisez..... | |

6.9 Depuis que vous êtes cultivateur, avez-vous constaté en générale que les rendements des cultures à l'hectare ont augmenté, diminué ou resté à peu près le même?

Culture	augmenté	diminué	pas changé
Mil			
.....			
Arachide			
.....			
Niébé			
.....			
.....			

6.10 S'il y a eu diminution des rendements pour certaines cultures ces dernières années, à quoi l'attribuez-vous?

CULTURE	R A I S O N						
	mauvaises pluies	sol érodé par le vent	sol érodé par la pluie	baisses de fertilité	manque de matériel agricole ⁴ (spécifiez)	ne sais pas	autres (spécifiez)
Mil							
Arachide							
Niébé							

6.11 Avez-vous jamais fait le parcase sur un de vos champs?

Oui /...../ Non /...../

Si oui, passer à la question 6.12.

Si non, passer à la question 6.17.

⁴manque de semences, main d'oeuvre, engrais, outils, terres, credit, etc.

6.12 Si oui, y-a-t-il une culture particulière qui en profitent après?

Oui /...../ Non /...../

6.12.1 Si oui, laquelle?

6.13 Quelle est la fréquence de parage que vous faites actuellement?

1. tous les ans /...../

2. tous les 2 ans /...../

3. tous les 3 ans /...../

4. tous les 4 ans /...../

5. autre, précisez.....

.....

6.14 Cette fréquence, est-elle suffisante pour maintenir la fertilité du sol?

Oui /...../ Non /...../

6.14.1 Si non, quelle fréquence préféreriez-vous et pourquoi?

.....
.....

6.15 Y-a-t-il des facteurs qui vous empêchent de faire le parage suivant ce rythme?

Oui /...../ Non /...../

6.15.1 Si oui, lesquelles?.....

.....
.....

6.16 Selon votre expérience, y-a-t-il plus, moins ou à peu près la même quantité de semis d'arbres (broussaille) après le parage.

Plus /...../ Moins /...../ A peu près le même /...../

6.16.1 Si plus, constatez-vous s'il y a des espèces d'arbres qui sont plus favorisées par le parage que d'autres?

Oui /...../ Non /...../ Pas d'opinion /...../

6.16.2 Si oui, quelles espèces?

/...../

/...../

/...../

6.17 S'il vous arrive de gagner 1,000,000 fcfa, qu'en feriez-vous?

.....

6.18 Si vous pouviez devenir President de la Republique Sénégalaise pour un jour, que feriez-vous pour que les cultivateurs du bassin arachidier puissent:

1. avoir suffisamment de bois de feu.....

.....

2. maintenir la fertilité des sols.....

.....

3. augmenter les rendements des cultures.....

.....

7.0 NIVEAU DE CONNAISSANCES TECHNIQUES AGRICOLES

7.1 Comment avez-vous acquis les techniques agricoles?

1. experience familiale /...../

2. à travers les sessions de formation /...../

3. à la fois experience personnelle et formation /...../

4. autres, spécifiez.....

.....

Si (1) ou (4) passer a la question 7.2.

Si (2) ou (3) passer a l'ANNEX B, "FORMATION AGRICOLE"

7.2 Au cas où vous n'avez jamais participé a une session de formation, avez-vous reçu des conseils de quelqu'un qui y a participé?

Oui /...../

Non /...../

7.2.1 Si non, pensez-vous que cela aurait apporté des améliorations dans vos connaissances techniques?

Oui /...../

Non /...../

7.2.2 Justifiez votre réponse.....

.....

.....

8.0 NIVEAU DE CONNAISSANCES TECHNIQUES FORESTIERES

8.1 Vos parents, ont-ils planté les arbres quand vous étiez jeune?

Oui /...../ Non /...../

8.1.2 Si oui, où?

1. autour de la maison /.../ 4. dans un projet /.../
Spécifiez.....

2. autour des champs /..../ 5. aux terres communales /..../

3. dans les champs /..../ 6. autres, précisez.....

8.2 Comment avez-vous acquis les techniques forestières?

1. Je n'en connais pas /...../

2. experience familiare /...../

3. à travers les sessions de formations /...../

4. à la fois expérience personnelle et formation /...../

5. autres, spécifiez.....

.....

Si (1) passer à la question 8.3.

Si (2) ou (5) passer à la question 8.4.

Si (2) ou (3) passer à l'ANNEX B, "FORMATION FORESTIERE"

8.3 Si vous n'en connaissez pas, pouvez-vous indiquer pourquoi?

1. C'est trop difficile /...../

2. Les arbres prennent trop de temps pour grandir /...../

3. Je ne vois pas d'utilité /...../

4. Autres, spécifiez.....

.....

8.4 Au cas où vous n'avez jamais participé a une session de formation, avez-vous reçu des conseils de quelqu'un qui y a participé?

Oui /...../ Non /...../

8.4.1 Si non, pensez-vous que cela aurait apporté des améliorations dans vos connaissances techniques?

Oui /...../

Non /...../

8.4.2 Justifiez votre réponse.....

.....
.....

Passer à la question 8.6.

8.5 Parmi les techniques forestières suivantes, lesquelles pouvez-vous faire vous-même sans assistance technique?

1. Etablir une pépinière /...../

2. Planter les arbres (préparation du site et trouaison) /...../

3. Faire l'entretien des arbres (arrosage, enlever les mauvaises herbes) /...../

4. Autres techniques, spécifiez.....

.....

8.6 Ces deux dernières années, avez-vous ou un membre de votre exploitation planté ou assisté à planter des arbres forestiers ou fruitiers sur votre propre terrain?

Oui /...../

Non /...../

Si oui, passer à l'ANNEX C, "PLANTATIONS PRIVÉES"

Si non, passer à la question 8.6.

8.7 Pouvez-vous citer tous les bienfaits du cadd que vous connaissez?

1. bois de feu /..../ 6. lutte contre l'érosion /..../ éolienne

2. fourrage (feuilles) /..../

7. ombrage pour le bétail /..../ en saison sèche

3. fourrage (gousses) /..../

4. rendements des cultures /..../

8. fixe les sols /..../

5. commercialisation des gousses /..../

9. autres, précisez.....

8.8 Parmi ces bienfaits, pouvez-vous mettre par ordre d'importance les trois qui sont les plus importantes vis à vis votre exploitation?

1.....

2.....

3.....

8.9 Comment avez-vous appris que le cadd est benefique?

- 1. experience /...../
- 2. formation /...../
- 3. à la fois experience et formation /...../
- 4. radio /...../
- 5. un projet /...../
- 6. un agent de sensibilisation /...../

spécifiez.....

- 7. autre, spécifiez.....
-

8.10 Pour ce qui est de l'agriculture, à quoi attribuez-vous l'effet bénéfique du cadd?

- 1. à cause des animaux qui restent en dessous pendant la saison seche /...../
- 2. à cause des feuilles qui tombent et enrichissent le sol /...../
- 3. à cause des arbres qui protègent le sol contre l'érosion /...../
- 4. autres, spécifiez.....
-

8.11 Prenez-vous des actions spéciales pour protéger les jeunes cadds dans vos champs?

Oui /...../ Non /...../

8.11.1 Si oui, lesquelles:

- 1. labour autour des jeunes plants de cadd /...../
- 2. sélection de meilleurs plants pour leur maintien dans les champs /...../
- 3. tuteurage des jeunes plants de cadd /...../
- 4. l'élagueage pour éduquer les jeunes planst /...../
- 5. protection des jeunes plantes contre les animaux /...../
- 6. autres, spécifiez.....
-

8.11.2 Si non, pourquoi:

1. Ca prend trop de temps /...../
2. Je ne vois pas d'avantage /...../
3. C'est trop difficile /...../
4. Autres, spécifiez.....
-
-

8.12 Avez-vous constaté que les effets benefiques du cadd sur les rendements varient avec la culture ?

Oui /...../

Non /...../

8.12.1 Si oui, pouvez-vous indiquer comment varient ces effets?

Culture	augment beaucoup	augment un peu	pas d'effet	diminue	sans opinion
Mil					
.....					
Arachide					
.....					
Niébé					
.....					
.....					

8.13 Si vous pouviez associer le cadd avec une seule culture, laquelle choisiriez-vous?

/...../

8.13.1 Pourquoi?.....

.....

8.14 Pratiquez-vous l'émondage du cadd pour alimenter le bétail?

Oui /...../

Non /...../

Si non, passer à la question 8.15.

Si oui, passer à la question 8.16

8.15 Si non, pourquoi?

1. suffisamment de fourrage /...../
2. interdiction par les Eaux et Forêts /...../

3. je ne coupe pas le cadd /...../

4. autres, précisez.....

.....

8.16 Si oui, quels animaux en bénéficient?

/...../

/...../

8.17 Si oui, à quel époque pratiquez-vous la coupe?

Mois /...../

8.18 Si oui, constatez-vous une diminution des rendements de cultures quand vous coupez beaucoup de branches?

Oui /...../ Non /...../

8.18.1 Si oui, pourquoi coupez-vous alors beaucoup de

branches?.....

.....

8.19 Pratiquez-vous la cuillette des gousses de cadd pour alimenter le bétail?

Oui /...../ Non /...../

8.19.1 Si oui, quels animaux en profitent?

/...../

/...../

8.20 Y-a-t-il quelqu'un de l'exploitation qui fait la commercialisation des gousses de cadd?

Oui /...../ Non /...../

8.20.1 Si oui, qui?.....

8.20.2 Si oui, quel est le prix de vente, unité de vente et combien est-ce que cette activité apporte à la maison par an?

.....

8.21 Êtes-vous satisfait avec le nombre de cadd que vous avez actuellement aux champs?

Oui /...../ Non /...../

8.21.1 Si non, voulez-vous augmenter ou diminuer la quantité?

Augmenter /...../ Diminuer /...../

8.21.2 Justifiez votre réponse.....

.....

8.21.2 Si vous voulez augmenter la quantité, selon vous, quelle distance entre les arbres pourrait satisfaire vos besoins?

/...../

8.22 Y-a-t-il des facteurs qui vous empêchent de planter ou conserver plus de caddes?

Oui /...../ Non /...../

8.22.1 Si oui, lesquels?

1. manque de plants /...../

2. manque de connaissances techniques /...../

3. ça prend trop de temps pour le faire /...../

4. c'est trop difficile pour les protéger contre les bêtes /...../

5. manque de terrain /...../

6. ce n'est pas une priorité /...../

8. ça prend trop de temps pour les arbres à pousser /...../

7. autres, précisez.....

.....

8.23 Comme vous savez, le gouvernement sénégalais s'inquiète de la sévérité de la dégradation environnementale au bassin arachidier. Une des actions que le gouvernement pense pour renverser la situation est d'aider les cultivateurs du bassin arachidier à rétablir le cadd aux champs. Pensez-vous que ceci doit être une action prioritaire?

Oui /...../ Non /...../

8.23.1 Si oui, quelles actions pourrait-il (le gouvernement) entreprendre pour rendre plus facile cette tâche?

1. donner des semis /...../

2. donner les cours de formation technique /...../

3. assurer que la personne qui plante un /...../

arbre a le droit de le couper

4. payer les gens a planter les arbres /...../

5. autres, specifiez.....

.....

8.23.2 Si non, pourquoi et quelles autres actions préféreriez-vous que le gouvernement entreprenne?.....

.....

.....

8.24 Dans vos champs, y-a-t-il des espèces que vous préservez outrele cadd?

Oui /...../

Non /...../

8.24.1 Si oui, lesquelles, pour quelles raisons, et y-a-t-il des actions spécifiques que vous entreprenez pour les conserver?

Espèces	Raison	Actions Spécifique
.....		
.....		
.....		

8.25 Parmi ces arbres, la quantité, est-elle suffisante pour satisfaire les besoins de la famille, ou préféreriez-vous en avoir encore plus?

quantité suffisante /...../

en veux plus /...../

8.25.1 Si vous en voulez encore, quelles espèces préféreriez-vous en particulier, combien, et où envisageriez--vous de les planter?

Espèces	Nb	Endroit ⁵
.....		
.....		
.....		

8.25.2 Y-a-t-il d'autres espèces forestières ou fruitières que vous aimeriez avoir?

Oui /...../

Non /...../

8.25.3 Si oui, quelles espèces, combien, où les planteriez-vous et pour quelle utilisation?

Espèces	Nb	Endroit ⁶	Utilisation
.....			
.....			
.....			

8.25.4 Y-a-t-il des facteurs qui vous empêche de planter ces arbres?

Oui /...../

Non /...../

8.25.4.1 Si oui, lesquelles?

1. manque de plants /...../

2. manque de connaissances techniques /...../

⁵ 1. près de la maison; 2. en bordure des champs; 3. éparpillé aux champs; 4. en lignes de grands écartments aux champs; 5. terre communale; 6. en petit peuplement; 7. autres endroits, à spécifier.

⁶ 1. près de la maison; 2. en bordure des champs; 3. éparpillé aux champs; 4. en lignes de grands écartments aux champs; 5. terre communale; 6. autres endroits, à spécifier.

3. ça prends trop de temps /...../
4. c'est trop difficile pour les protéger contre les bêtes /...../
5. manque de terrain /...../
6. ce n'est pas une priorité /...../
7. Il ya a trop de risques /...../
8. autres, précisez.....

8.26 D'après votre expérience, y-a-t-il des arbres qui gênent la culture?

Oui /...../ Non /...../

8.26.1 Si oui, lesquelles et pour quelles raisons?

Espèces	Raisons
.....	
.....	
.....	

8.27 On voit souvent des "restes" de haie vive d'Euphorbia dans le coin. En avez-vous autour de vos champs?

Oui /...../ Non /...../

8.27.1 Si oui, constatez-vous une difference de rendement entre les cultures entourés de haies et les autres?

Oui /...../ Non /...../

8.27.2 Si oui, le rendement, est-il plus ou moins aux champs protégé de haies?

Plus /...../ Moins /...../

8.27.2.1 Si le rendement est plus, à quoi attribuez-vous cet effet?

1. les feuilles qui tombent et enrichissent le sol /...../

2. protection des cultures contre le vent /..../
 3. ne sais pas /..../
 4. autres, spécifiez.....

8.27.3 Aimeriez-vous rétablir ces haies?

Oui /...../ Non /...../

8.27.3.1 Si oui, y-a-t-il des facteurs qui vous empêchent de le faire?

Spécifiez.....

8.27.3.2 Si non, pourquoi?.....

.....

8.28 Pouvez-vous indiquer si vous êtes très d'accord, un peu d'accord, pas d'accord, pas du tout d'accord ou sans opinion sur les phrases suivantes?

PHRASE	Tres d'accord	Un peu d'accord	Pas d'accord	Pas du tout d'accord	Sans opinion
les arbres attirent les oiseaux					
la personne qui plante un arbre devrait avoir le droit de le couper					
planter les arbres, c'est trop dur, c'est le travail des jeunes					
planter les arbres, c'est le travail des femmes					
planter les arbres, c'est le travail des hommes					
planter les arbres, c'est le travail du gouvernement					
planter les arbres, c'est le travail de tout le monde					
les riches du village sont plus intéressés à planter les arbres que les pauvres					

8.29 Parmi la liste suivante des rôles et usages de l'arbre, pouvez-vous citer par ordre d'importance, les trois que vous jugez les plus essentiels?

Pharmacopé	1.....
Bois de service	2.....
Bois de feu	3.....
Conservation des sols	
Alimentation humaine	
Alimentation animale	

8.30 Selon vos choix, pouvez-vous donner des renseignements concernant les espèces d'arbres préférés pour chaque catégorie?

8.30.1 Alimentation animale

QUESTION	ESPECES D'ALIMENTATION ANIMALE					
	Nom.....		Nom.....		Nom.....	
1. Pourquoi ces espèces sont-elles appréciées?						
2. Leur disponibilité ⁷ :						
.....						
aux champs?						
.....						
aux terres communales?						
.....						
autres lieux?						
.....						
3. Tendance a la disponibilité ⁸ :						
.....						
aux champs?						
.....						
aux terres communales?						
.....						
autres lieux?						
.....						
4. Personne responsable						
5. Méthode d'utilisation						
.....						
coupe branches						
.....						
cuillette des fruits/gousses						
.....						
autres.....						
6. Saison pratiquée						
7. Pratique de la vente?	Oui	Non	Oui	Non	Oui	Non
8. Si oui, prix de vente et l'unité?						
9. Pratique de l'achat?	Oui	Non	Oui	Non	Oui	Non
10. Si oui, prix d'achat et l'unité?						

⁷ 0 = nulle; 1 = faible; 2 = moyenne 3 = forte

⁸ - = en diminution; = = constante; + = en croissance

8.30.2 Alimentation humaine

QUESTION	ESPECES D'ALIMENTATION HUMAINE					
	Non.....		Non.....		Non.....	
1. Pourquoi ces espèces sont-elles appréciées						
2. Leur disponibilité ³ :						
.....						
aux champs?						
.....						
aux terres communales?						
.....						
autres lieux?						
.....						
3. Tendance à la disponibilité ⁴ :						
.....						
aux champs?						
.....						
aux terres communales?						
.....						
autres lieux?						
.....						
4 Personne responsable						
5. Méthode d'utilisation						
.....						
feuilles						
.....						
fruits/gousses						
.....						
écorces						
.....						
autres.....						
6. Saison pratiquée						
7. Pratique de la vente?	Oui	Non	Oui	Non	Oui	No
8. Si oui, prix de vente et l'unité?						
9. Pratique de l'achat?	Oui	Non	Oui	Non	Oui	No
10. Si oui, prix d'achat et l'unité?						

³ 0 = nulle; 1 = faible; 2 = moyenne 3 = forte

⁴ - = en diminution; = = constante; + = en croissance

8.30.3 Bois de feu

QUESTION	ESPECES BOIS DE FEU					
	Nom.....		Nom.....		Nom.....	
1. Pourquoi ces espèces sont-elles appréciées?						
2. Leur disponibilité ⁵ :						
.....						
aux champs?						
.....						
aux terres communales?						
.....						
autres lieux?						
.....						
3. Tendance a la disponibilité ⁶ ?						
.....						
aux champs?						
.....						
aux terres communales?						
.....						
autres lieux?						
.....						
4 Personne responsable						
5. Méthode d'utilisation						
.....						
coupe branches						
.....						
cuillette de bois mort						
.....						
coupe arbre						
6. Saison pratiquée						
7. Pratique de la vente?	Oui	Non	Oui	Non	Oui	Non
8. Si oui, prix de vente et l'unité?						
9. Pratique de l'achat?	Oui	Non	Oui	Non	Oui	Non
10. Si oui, prix d'achat et l'unité?						

⁵ 0 = nulle; 1 = faible; 2 = moyenne 3 = forte

⁶ - = en diminution; = = constante; + = en croissance

8.30.4 Bois de service

QUESTION	ESPECES BOIS DE SERVICE		
	Nom.....	Nom.....	Nom.....
1. Pourquoi ces espèces sont-elles appréciées?			
2. Leur disponibilité ⁷ :			
.....			
aux champs?			
.....			
aux terres communales?			
.....			
autres lieux?			
.....			
3. Tendance a la disponibilité ⁸ :			
.....			
aux champs?			
.....			
aux terres communales?			
.....			
autres lieux?			
.....			
4 Personne responsable			
5. Méthode d'utilisation			
.....			
coupe branches			
.....			
coupe arbre			
.....			
autres,			
.....			
6. Saison pratiquée			
7. Pratique de la vente?	Oui Non	Oui Non	Oui Non
8. Si oui, prix de vente et l'unité?			
9. Pratique de l'achat?	Oui Non	Oui Non	Oui Non
10. Si oui, prix d'achat et l'unité?			

⁷ 0 = nulle; 1 = faible; 2 = moyenne 3 = forte

⁸ - = en diminution; = = constante; + = en croissance

8.30.5 Pharmacopé

QUESTION	ESPECES DE PHARMACOPE					
	Nom.....		Nom.....		Nom.....	
1. Pourquoi ces espèces sont-elles appréciées?						
2. Leur disponibilité ⁹ :						
aux champs?						
aux terres communales?						
autres lieux?						
3. Tendance à la disponibilité ¹⁰ :						
aux champs?						
aux terres communales?						
autres lieux?						
4. Personne responsable						
5. Partie utilisée						
feuilles						
fleurs						
écorce						
autres.....						
6. Saison pratiquée						
7. Pratique de la vente?	Oui	Non	Oui	Non	Oui	Non
8. Si oui, prix de vente et l'unité?						
9. Pratique de l'achat?	Oui	Non	Oui	Non	Oui	Non
10. Si oui, prix d'achat et l'unité?						

⁹ 0 = nulle; 1 = faible; 2 = moyenne 3 = forte

¹⁰ - = en diminution; = = constante; + = en croissance

8.30.6 Conservation des sols

QUESTION	ESPECES DE CONSERVATION DES SOLS		
	Nom.....	Nom.....	Nom.....
1. Pourquoi ces espèces sont-elles appréciées?			
2. Leur disponibilité ¹¹ ;			
.....			
aux champs?			
.....			
aux terres communales?			
.....			
autres lieux?			
.....			
3. Tendance à la disponibilité ¹² ;			
.....			
aux champs?			
.....			
aux terres communales?			
.....			
autres lieux?			
.....			
4 Personne responsable			
5. Méthode d'utilisation			
.....			
haies vives			
.....			
brise vent			
.....			
autres			
.....			

¹¹ 0 = nulle; 1 = faible; 2 = moyenne 3 = forte

¹² - = en diminution; = = constante; + = en croissance

9.0 CONTACT AVEC LES AGENTS DE SENSIBILISATION

9.1 Pouvez-vous indiquer: (i) les agents de sensibilisation qui ont rendu visite cette dernière campagne; (ii) le mois de leur visite; (iii) avec qui ils ont parlé; (iv) le sujet traité; et (v) son utilité.

Agent de (Institution)	Nb. de visites	Mois	Parlé avec qui (Statut)	Sujet traité	Utilité			
					tres utile	utile	peu utile	rien apporté de nouveau
	1.							
	2.							
	3.							
	4.							
	5.							
	1.							
	2.							
	3.							
	4.							
	5.							
	1.							
	2.							
	3.							
	4.							
	5.							
	1.							
	2.							
	3.							
	4.							
	5.							

10.0 TERRES COMMUNALES

10.1 Existent-elles des terres communales au village?

Oui /...../

Non /...../

Si oui, passer à la question 9.2.

Si non, passer à la question 11.0.

10.2 Si oui, y-a-t-il à peu pres combien d'hectares? /...../

10.3 A quoi servent-elles ces terres?

- | | |
|--------------------------------------|---------|
| 1. cultures maraichères | /...../ |
| 2. reboisement | /...../ |
| 3. ramassage bois de feu | /...../ |
| 4. ramassage bois de service | /...../ |
| 5. ramassage fruits sauvages | /...../ |
| 6. collection de plantes médicinales | /...../ |
| 7. pâturage | /...../ |
| 8. plantation d'arbres fruitiers | /...../ |
| 9. ramassage de paille | /...../ |
| 10. autres, précisez..... | |
| | |

Si (3), (4), (5), (6), (7) ou (9), passer a la question 10.4.
Si (1), (2), ou (6) passer a la question 10.5.

10.4 Pour les tâches suivantes, pouvez vous indiquer: (i) les espèces recherchées; (ii) statut/sexes de la personne responsable; (iii) le(s) mois que le travail se fait; (iv) la quantité qui vient de champs ou des terres communales; (v) le temps requis; et (vi) leur disponibilité?

Tâche	Espèces Principales	Respons- abilité de: Statut/Sexes	Mois	È venant de vos champs	È venant de terre communale	temps requis/ semaine	Dispon- bilité ¹³
Ramassage de paille	1.						
	2.						
	3.						
Ramassage bois de feu	1.						
	2.						
	3.						
Ramassage fruits sauvages	1.						
	2.						
	3.						
Ramassage plantes medic- inales	1.						
	2.						
	3.						
Ramassage espèces four- ragères	1.						
	2.						
	3.						
Ramassage bois de service	1.						
	2.						
	3.						
Autre	1.						
	2.						
	3.						

10.5 Ces deux dernières années, avez-vous ou un membre de votre exploitation planté ou assisté à planter des arbres forestiers ou fruitiers aux terres communales du village?

Oui /...../

Non /...../

Si oui, passer à l'ANNEX E, "PLANTATIONS COMMUNALES"

Si non, passer à la question 10.6.

¹³ 0 = nulle; 1 = faible; 2 = moyenne; 3 = forte.

10.6 Depuis que vous êtes au village, avez-vous constaté que la superficie de terre communale appartenant au village a:

diminué /..../ resté à peu près le même /..../ augmenté /..../

10.6.1 Au cas où la superficie a diminué, à quoi attribuez-vous ce phénomène?

1. manque de terres /...../
2. les riches du village en profitent /...../
3. les personnes qui y ont plantés les arbres en profitent /...../
4. autres, précisez.....
-

11.0 AUTRE

11.1 Y-a-t-il d'autres commentaires ou suggestions sur le cadd ou autres choses que vous voulez qu'on mette dans le rapport?

.....

.....

.....

.....

.....

.....

.....

.....

12.0 IMPRESSION DE L'ENQUETEUR

.....

.....

.....

.....

.....

.....

ANNEX A

PARTICIPATION A DES ASSOCIATIONS

A.0 PARTICIPATION A DES ASSOCIATIONS

- A.1 Si oui, pouvez-vous indiquer lesquelles, leur activité dominante, l'année que vous êtes devenu membre et votre fréquence de participation aux réunions?

Association	Activité dominante	Membre depuis quand?	Participation			
			Jam-ais	Rare-ment	Assez-souv.	Tou-jours
.....						
.....						
.....						

- A.2 Exercez-vous des responsabilités dans cette (ces) association(s)?

Oui /...../ Non /...../

A.2.1 Si oui, lesquelles?.....

.....

- A.3 Prenez-vous la parole au cours des rencontres?

Association	Prendre parole			
	Jam-ais	Rare-ment	Assez-souv.	Tou-jours
.....				
.....				
.....				

- A.4** Quelles sont les activités agricoles ou forestières menées par ces associations ces deux dernières années? Par qui ont-elles été choisies, les membres en assemblée, les dirigeants, ou l'équipe d'encadrement?

Association	ACTIVITES							
	Cette année	Choisi par			l'Année dernière	Choisi par		
		Mem.	Dir.	Enc.		Mem.	Dir.	Enc.
	1.				1.			
	2.				2.			
	3.				3.			
	1.				1.			
	2.				2.			
	3.				3.			
	1.				1.			
	2.				2.			
	3.				3.			

- A.5** Parmi les activités citées ci-dessus, lesquelles ont satisfait le plus vos besoins?

1..... 2..... 3.....

A.5.1 Justifiez vos choix.....

.....

- A.6** Lesquelles ont satisfait le moins vos besoins?

1..... 2..... 3.....

A.6.1 Justifiez vos choix.....

.....

.....

- A.7** En tant qu'adhérent au groupement ou association, participez-vous aux travaux de groupes (dits "travaux communaux")?

1. Rarement /...../

2. De temps en temps /...../

3. Toujours /...../

4. Ca dépend du travail /...../

A.7.1 Si ça dépend du travail, quel travail préférez-vous faire en groupe?.....

A.8 De façon générale, jugez-vous le travail communal:

- 1. Décevant /...../
- 2. Mediocre /...../
- 3. Satisfaisant /...../
- 4. Tres satisfaisant /...../

A.8.1 Justifiez votre réponse.....

A.9 De façon générale, quelles critiques formulez-vous sur:

A.9.1 les associations d'agriculteurs.....

A.9.2 les groupements villageois.....

A.10 Quelles améliorations souhaiteriez-vous pour:

A.10.1 les associations.....

A.10.2 les groupements.....

RETOURNER A LA QUESTION 4.3

ANNEX B

FORMATION AGRICOLE

B.0 FORMATION AGRICOLE

B.1 Pouvez-vous expliquer la nature de la formation, l'Institution formatrice, la période et le statut de la personne dans l'exploitation qui en a bénéficié?

Nom et prenom	Statut	Nature de la Formation	Institut	Année
.....				
.....				
.....				
.....				
.....				

B.2 Cette formation, a-t-elle jamais traité le sujet du rôle des arbres en agriculture (agroforesterie, reboisement)?

Oui /...../ Non /...../

B.2.1 Si oui, quelle formation et de quoi a-t-on discuté?.....

B.3 Cette formation, a-t-elle jamais traité le sujet de la conservation des sols (DRS)?

Oui /...../ Non /...../

B.3.1 Si oui, quelle formation et de quoi a-t-on discuté?.....

B.4 Quelle était la méthode utilisée dans cette formation:

1. discussions au niveau d'exploitation /...../
2. demonstrations dans les champs /...../
3. à la fois (1) et (2) /...../

4. autres, spécifiez.....

B.5 A quel niveau d'organisation?

1. individuel-homme /...../
 2. individuel-femme /...../
 3. toute exploitation (hommes et femmes) /...../
 4. du groupement de producteurs /...../
 5. ouvert à tous les villageois /...../
 6. autres, spécifiez.....

**B.6 Quelle importance accordez-vous à la formation dont vous ou
 quelqu'un de l'exploitation a bénéficié?**

1. pas de tout importante /...../
 2. un peu importante /...../
 3. importante /...../
 4. très importante /...../

RETOURNER A LA QUESTION 8.1

ANNEX C**FORMATION FORESTIERE****C.0 FORMATION FORESTIERE**

C.1 Pouvez-vous expliquer la nature de la formation, l'Institution formatrice, la période et le statut de la personne dans l'exploitation qui en a bénéficié?

Nom et prenom	Statut	Nature de la Formation	Institut	Année
.....				
.....				
.....				
.....				
.....				

C.2 Cette formation, a-t-elle jamais traité le sujet du rôle des arbres en agriculture (agroforesterie)?

Oui /...../ Non /...../

C.2.1 Si oui, quelle formation et de quoi a-t-on

discuté?.....

.....

.....

C.3 Cette formation, a-t-elle jamais traité le sujet de la conservation des sols (defense et restauration des sols)?

Oui /...../ Non /...../

C.3.1 Si oui, quelle formation et de quoi a-t-on

discuté?.....

.....

.....

C.4 Quelle était la méthode utilisée dans cette formation:

1. discussions au niveau d'exploitation /...../

2. demonstrations dans les champs /...../

3. a la fois (1) et (2) /...../
4. autres, specifiez.....
-

C.5 A quel niveau d'organisation?

1. individuel-homme /...../
2. individuel-femme /...../
3. toute exploitation (hommes et femmes) /...../
4. du groupement de producteurs /...../
5. ouvert à tous les villageois /...../
6. autres, spécifiez.....
-

C.6 Quelle importance accordez-vous a la formation dont vous ou quelqu'un de l'exploitation a bénéficié?

1. pas de tout importante /...../
2. un peu importante /...../
3. importante /...../
4. très importante /...../

RETOURNER A LA QUESTION 8.6

ANNEX D

PLANTATIONS PRIVEES

D.0 PLANTATIONS PRIVEES

D.1 Si oui: (i) quelles espèces; (ii) combien de plants ont été plantés; (iii) qui les a plantés; (iv) où ont-ils été plantés; et (v) quelle a été l'utilisation prévue?

Especès	Nb	Statut	Lieu	Utilisation Prévue
.....				
.....				
.....				
.....				
.....				
.....				

D.2 Qui a choisi ces especès?

1. vous même /...../
2. agent Eaux et Forêts /...../
3. agent d'un projet /...../
- Spécifiez lequel.....
4. autre, spécifiez.....

D.3 D'où venait les plants?

1. pépinière villageoise /...../
2. votre propre pépinière /...../
2. autre pépinière /...../
- Où..... Quelle distance.....

D.4 Etes-vous content avec le choix des especès?

Oui /...../ Non /...../

D.4.1 Si oui, pourquoi?.....
.....

- D.4.2 Si non, pourquoi?.....

 D.4.3 Auriez-vous préféré d'autres? Oui /...../ Non /...../
 Si oui, lesquelles?.....
- D.5 Au cas où vous n'avez pas élevé les plants vous même, a-t-on
 donné les plants gratuitement ou fallait-il payer?
 gratuit /...../ payé /...../
 D.5.1 Si payé, combien?...../
- D.6 Selon vous, qui bénéficiera de ces arbres lors qu'ils atteignent
 l'âge d'exploitation?
 1. tous le village /...../
 2. la personne qui les a plantés /...../
 3. Service des Eaux et Forêts /...../
 4. le projet /...../
 Spécifiez lequel.....
 5. le chef du village /...../
 6. ne sais pas /...../
 7. autres, précisez.....

- D.7 A votre avis, ces plantations privées, ont-elles échouées ou
 réussies?
 Echoué /...../ Reussi /...../ Pas d'opinion /...../
- D.7.1 Si vous pensez que ces plantations ont echouées, à quoi
 attribuez-vous l'échec?
 1. ne sais pas /...../ 4. mal organisé /...../
 2. séchèresse /...../ 5. planté a la /...../
 mauvaise epoque
 3. gens trop paresseux /...../ 6. mauvaises espèces /...../
 7. autres, précisez.....

RETOURNER A LA QUESTION 8.6

ANNEX E**PLANTATIONS COMMUNALES****E.0 PLANTATIONS COMMUNALES**

E.1 Si oui: (i) quelles espèces; (ii) combien de plants ont été planté; (iii) qui les a planté; et (iv) quelle a été l'utilisation prévue?

Espèces	Nb	Statut	Utilisation Prévue
.....			
.....			
.....			
.....			
.....			
.....			

E.2 Qui a choisi ces espèces?

1. le village en assemblée /...../
2. agent des Eaux et Forêts /...../
3. agent d'un projet /...../
4. autre, spécifiez.....

E.3 D'où venait les plants?

1. pépinière villageoise /...../
 2. autre pépinière /...../
- Où..... Quelle distance.....

E.4 Etes-vous content avec le choix des espèces?

Oui /...../ Non /...../

E.4.1 Si oui, pourquoi?.....
.....

E.4.2 Si non, pourquoi?.....
.....

E.4.3 Auriez-vous préféré d'autres? Oui /..../ Non /..../

Si oui, lesquelles?.....

.....

E.5 A votre avis, ces plantations communales, ont-elles échouées ou réussies?

Echoué /...../ Réussi /...../ Pas d'opinion /...../

E.5.1 Si vous pensez que ces plantations ont échouées, à quoi attribuez-vous l'échec?

1. ne sais pas /...../ 4. mal organisé /...../

2. séchèresse /...../ 5. planté a la /...../
mauvaise époque

3. gens trop paresseux /...../ 6. mauvaises espèces /...../

7. autres, précisez.....

.....

E.6 Les plants, étaient-ils donnés au village gratuitement ou fallait-il payer?

gratuit /...../ payé /...../

E.6.1 Si payé, combien?...../

E.7 Selon vous, qui bénéficiera de ces arbres lors qu'ils atteignent l'âge d'exploitation?

1. tous le village /...../

2. le proprietaire du champ /...../

3. les personnes qui les ont plantées /...../

4. le Dept. des Eaux et Forêts /...../

5. le projet /...../

6. le chef du village /...../

7. ne sais pas /...../

8. autres, précisez.....

.....

RETOURNER A LA QUESTION 9.6

APPENDIX B

BIOPHYSICAL INVENTORY QUESTIONNAIRE

**INSTITUTE SENEGALAIS DE
RECHERCHES AGICOLE**

ISRA/DRPF - DAKAR

FICHE ENQUETE SUR LE CADD

"INVENTAIRE BIOPHYSIQUE"

James R. Seyler

November 1989

INVENTAIRE BIOPHYSIQUE

(A remplir pour chaque champ ou parcelle appartenant
ou louer par chaque famille enquêtée, y compris
les parcelles en jachère)

Date d'Inventaire:.....
Nom de l'enquêteur:.....
Région:.....Département:.....
Village:.....Groupe Ethnique:.....
Nom personne enquêtée.....
Code:.....Parcelle Nu:.....

1.0 Quelle est la superficie de la parcelle? /......./

2.0 Quelle est la distance de la parcelle du village? /...../

3.0 Quelle est la mode d'acquisition de la parcelle?

1. alloué par le chef d'exploitation /...../

2. alloué par quelqu'un d'autre /...../

Specifiez qui.....

3. défriché par vous même /...../

4. loué /...../

Spécifiez qui et la mode de paiement

.....

5. héritage /...../

6. autre, spécifiez.....

.....

4.0 Quelles cultures y ont été plantées ces cinq dernières années et
quel a été le rendement?

Année	Culture	Rendement (en diokhs ou kg)
Cette année (1989)		
l'Année dern.(1988)		
1987 ???		
1986 ???		
1985 ???		

5.0 Quelle était la dernière année que cette parcelle a été laissée en jachère? /...../

5.1 Pour combien de temps avez-vous laissé cette parcelle en jachère /...../

5.2 Pourquoi l'avez-vous laissé en jachère?

1. Pour donner un repos à la parcelle /...../
2. Manque de semences /...../
3. Manque de main d'oeuvre /...../
4. Manque d'animaux de trait /...../
5. Manque d'engrais /...../
6. Autres, spécifiez.....

5.3 Selon vous, la fréquence actuelle que vous laissez cette parcelle en jachère, est-elle suffisante pour maintenir la fertilité des sols?

Oui /...../

Non /...../

5.3.1 Si non, quel rythme préféreriez-vous? Tous lesannées.

5.3.2 Y-a-t-il des facteurs qui vous empêchent à faire la jachère suivant ce rythme?

Oui /...../

Non /...../

5.3.3 Si oui, lesquels?.....
.....
.....

6.0 Avez-vous jamais utilisé engrais chimique sur cette parcelle?

Oui /...../

Non /...../

6.1 Si oui:

Année	Oui	No	Si oui, Combien?(sacs) Quel type?	
Cette année (1989)				
l'Année dern.(1988)				
1987 ???				
1986 ???				
1985 ???				

7.0 Avez-vous jamais utilisé la fumure sur cette parcelle?

7.1 Si oui:

Année	Oui	No	Si oui, Combien (char.)	Methode
Cette année (1989)				
l'Année dern.(1988)				
1987 ???				
1986 ???				
1985 ???				

8.0 Avez-vous jamais utilise la composte sur cette parcelle?

8.1 Si oui:

Année	Oui	Non	Si oui, Combien?(char.)	Méthode
Cette année (1989)				
l'Année dern.(1988)				
1987 ???				
1986 ???				
1985 ???				

9.0 Avez-vous jamais fait le parcage sur cette parcelle?

Oui /...../

Non /...../

9.1 Si oui, quand?.....

9.2 Quelle culture en profite après? /...../

9.3 Qui était le propriétaire du troupeau?.....

9.4 D'où venait-il?.....

9.5 Comment avez-vous arrangé avec le propriétaire pour faire le parcage.....

.....

9.6 A peu pres combien d'animaux y-avait-il au troupeau? /..../

9.7 Mois pratiqué.....

9.8 Durée.....

10.0 Y-a-t-il de l'évidence que l'interlocuteur a entrepris des mesures de conservation des sols dans cette parcelle?

10.1 Si oui:

Type	Oui	Non	Dispositif	Espèces
Brise vents				
Haies vives				
Terraces				
Plant. arbres				
Protection cad				
Autre				

11.0 Quel est le type du sol de cette parcelle?

Dior /...../ Deck-dior /...../ Deck /...../ Khour /...../

12.0 Quelle est l'impression de l'interlocuteur de la qualité de cette parcelle?

1. Bon/fertile /...../
2. Erodé par le vent /...../
3. Gravillons en surfaces /...../
4. Erodé par la pluie /...../
5. Autre (spécifiez).....

13.0 Régénération du cadd (plants moins d'un cm diamètre): (trois échantillons de 10m de coté choisis au hazard dan la parcelle)

Plot	Nombre
1	
2	
3	
Moy./parcelle	
Moy./ha	

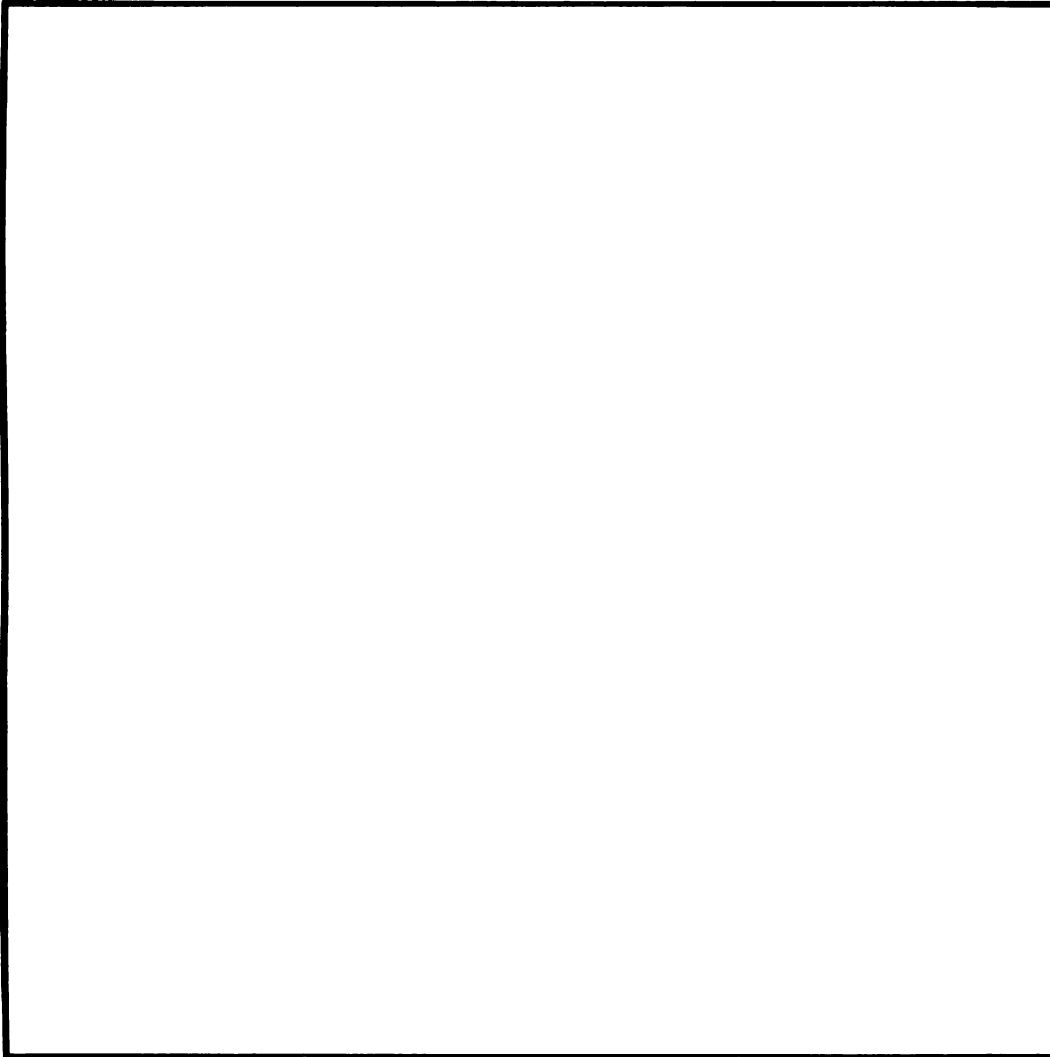
14.0 Echantillon de sol prise? Oui /...../ No /...../

Numéro du code.....

15.0 Impression de l'enquêteur sur la parcelle,

.....
.....
.....
.....
.....
.....
.....

CARTE DE LA PARCELLE
(pour déterminer la superficie)



INVENTAIRE-CADD

Nb.	Cadd	Circon. cm	Diam. cm	Cime1 m	Cime2 m	MoyCime m	SupCime m ²	Dégré d'émon- tage (N,L,M,S) ¹
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

TOTAL

% superficie cime/parcelle _____ (cadd)

% superficie cime/hectare _____ (cadd)

¹N=Nulle; L=Légère (5-20%); M=Modéré (20-40%); S=Sévère (>40%)

INVENTAIRE-CADD

Nb.	Cadd	Circon. cm	Diam. cm	Cime1 m	Cime2 m	MoyCime m	SupCime m ²	Degré d'émon- tage (N, L, M, S) ²
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								
41								
42								
43								
44								
45								
46								
47								
48								
49								
50								
TOTAL								

% superficie cime/parcelle _____ (cadd)
 % superficie cime/hectare _____ (cadd)

²N=Null; L=Légère (5-20%); M=Modéré (20-40%); S=Sévère (>40%)

INVENTAIRE-CADD

Nb.	Cadd	Circon. cm	Diam. cm	Cime1 m	Cime2 m	MoyCime m	SupCime m ²	Dégré d'émon- tage(N,L,M,S) ³
51								
52								
53								
54								
55								
56								
57								
58								
59								
60								
61								
62								
63								
64								
65								
66								
67								
68								
69								
70								
71								
72								
73								
74								
75								
TOTAL								

% superficie cime/parcelle _____ (cadd)

% superficie cime/hectare _____ (cadd)

³N=Nulle; L=Légère (5-20%); M=Modéré (20-40%); S=Sévère (>40%)

INVENTAIRE- AUTRES ESPECES

Nb	Espèces	Circon. cm	Diam. cm	Cime1 m	Cime2 m	MoyCime m	SupCime m ²	Dég.Em ⁴ N,L,M,S
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								
21								
22								
23								
24								
25								

TOTAL

* superficie cime/parcelle _____ (autre)

* superficie cime/hectare _____ (autre)

⁴N=Null; L=Légère (5-20%); M=Modéré (20-40%); S=Sévère (>40%)

INVENTAIRE- AUTRES ESPÈCES

Nb	Espèces	Circon. cm	Diam. cm	Cime1 m	Cime2 m	MoyCime m	SupCime m ²	Dég. Km ⁵ N, L, M, S
26								
27								
28								
29								
30								
31								
32								
33								
34								
35								
36								
37								
38								
39								
40								
41								
42								
43								
44								
45								
46								
47								
48								
49								
50								
TOTAL								

% superficie cime/parcelle _____ (autre)

% superficie cime/hectare _____ (autre)

⁵N=Nulle; L=Légère (5-20%); M=Modéré (20-40%); S=Sévère (>40%)

APPENDIX C

A COMPARISON OF DIOR SOIL ANALYSES FROM 1954 TO 1989

Table 1

Soil Analyses 1954-1959

Authority	Boujer	Bonfile	Bonfile	Malguy	Buseon	Average 1954-1959					
Date	1954	1956	1956	1957-58	1958-59						
Site	Mbayack	Diavao	Dangalma	Bambey	Lambaye			MEAN	MAX	MIN	STD
GRANULOMETRY											
	Organic matter (%)	0.30	0.25	0.40	0.28	0.30		0.31	0.40	0.25	0.05
	Clay (%)	1.60	1.80	2.40	4.00	na		2.45	4.00	1.60	0.94
	Fine silt (%)	0.30	0.30	1.20	0.80	na		0.65	1.20	0.30	0.38
	Coarse silt (%)	na	na	na	2.70	na		2.70	2.70	2.70	0.00
	Fine sand (%)	61.20	53.20	61.40	72.50	na		62.06	72.50	53.20	6.87
Coarse sand (%)	36.60	44.40	34.60	27.80	na		35.85	44.40	27.80	5.92	
CHEMICAL											
	pH	6.70	6.00	6.80	6.00	5.10		6.12	6.80	5.10	0.61
	Ca (me/100g)	1.20	0.78	2.01	1.00	1.16		1.23	2.01	0.78	0.42
	Mg (me/100g)	0.50	0.23	0.39	0.15	1.16		0.57	1.16	0.23	0.35
	K (me/100g)	0.05	0.05	0.08	na	0.43		0.15	0.43	0.05	0.14
	P2O5 ppm	na	na	na	0.01	na		0.07	0.12	0.01	0.04
	P (%)	0.09	0.06	0.12	0.020	0.05		0.018	0.020	0.012	0.003
	N (%)	1.90	0.012	0.019	2.00	0.020		2.16	3.18	1.11	0.70
	CEC	na	1.11	2.60	na	3.18		na	na	na	na

Table 2
Soil Analyses 1973-1977

Authority	Pieri	Nicou	Nicou	Pieri	Average 1973-1977			
					1973	1974	1975	1977
Date	1973	1974	1975	1977				
Site	Bambey	Bambey	Bambey	Bambey				
Granulometry								
Organic matter (%)	0.40	3.40	0.40	0.36	0.39	0.40	0.36	0.01
Clay	1.80	1.60	3.30	2.20	2.68	3.40	1.80	0.69
Fine silt	1.00	4.10	1.50	1.10	1.30	1.60	1.00	0.25
Coarse silt	4.10	70.20	4.10	5.00	4.33	5.00	4.10	0.39
Fine sand	66.00	20.30	70.80	69.10	69.03	70.80	66.00	1.85
Coarse sand	26.70		19.80	22.50	22.33	26.70	19.80	2.72
Chemical								
pH	5.50	na	5.40	5.80	5.57	5.80	5.40	0.17
Ca (me/100g)	0.44	na	0.70	0.95	0.80	0.70	0.44	0.11
Mg (me/100g)	0.12	na	0.20	0.25	0.19	0.25	0.12	0.05
K (me/100g)	0.06	na	0.06	0.07	0.07	0.06	0.06	0.01
P2O5 ppm	na	na	na	na	0.15	0.26	0.02	0.10
P (%)	0.26	na	0.18	0.02	0.019	0.023	0.016	0.003
N (%)	0.016	0.023	0.019	1.40	1.33	1.75	0.95	0.29
CEC	1.20	0.95	1.75	na	na	na	na	na

Table 4
A Comparison of Dior Soil Analyses from 1954 to 1989

Characteristic	Mean			Maximum			Minimum			Standard Deviation		
	1954-59	1973-77	1987-89	1954-59	1973-77	1987-89	1954-59	1973-77	1987-89	1954-59	1973-77	1987-89
Granulometry												
Number of samples	4	4	5	4	4	5	4	4	5	4	4	5
Organic matter (%)	0.31	0.39	0.85	0.40	0.40	0.72	0.25	0.36	0.30	0.05	0.01	0.15
Clay	2.45	2.68	3.32	3.40	3.40	4.90	1.80	1.80	1.70	0.94	0.69	1.08
Fine silt	0.65	1.30	0.64	1.20	1.80	1.00	0.30	1.00	0.40	0.38	0.25	0.22
Coarse silt	2.70	4.33	5.34	2.70	5.00	10.30	2.70	4.10	3.00	0.00	0.39	2.69
Fine sand	62.08	69.03	61.38	72.50	70.80	69.20	53.20	65.00	55.40	6.87	1.85	4.33
Coarse sand	35.85	22.33	28.68	44.40	28.70	35.10	27.80	19.80	23.00	5.92	2.72	4.88
Chemical												
Number of samples	5	3	13	5	3	13	5	3	13	5	3	13
pH	6.12	5.57	6.47	6.80	5.80	7.51	5.10	5.40	5.30	0.61	0.17	0.54
Ca (me/100g)	1.23	0.60	1.08	2.01	0.70	2.29	0.78	0.44	0.57	0.42	0.11	0.42
Mg (me/100g)	0.57	0.19	0.26	1.16	0.25	0.64	0.23	0.12	0.10	0.35	0.05	0.16
K (me/100g)	0.15	0.07	0.07	0.43	0.08	0.15	0.05	0.08	0.02	0.14	0.01	0.04
P ₂ O ₅ ppm	na	na	11.88	na	na	24.00	na	na	4.50	na	na	6.40
P (%)	0.07	0.15	na	0.12	0.28	na	0.01	0.02	na	0.04	0.10	na
N (%)	0.016	0.019	0.021	0.020	0.023	0.044	0.012	0.016	0.009	0.003	0.003	0.010
CEC	2.16	1.33	1.590	3.16	1.75	2.19	1.11	0.95	1.08	0.70	0.29	0.45

APPENDIX D
RESULTS OF SOIL ANALYSES

Table 1
Dior Soils Analyses

CODE	pH	N (%)	P	K	Ca	Mg	O.M. (%)
			(pounds/acre)				
E61A2	6.4	0.037	15	124	762	133	0.91
G12A3	6.8	0.018	17	62	381	56	0.72
D41A3	6.6	0.019	16	80	914	200	0.72
G71B2	5.5	0.011	13	44	305	56	0.52
D12D1	6.8	0.020	23	44	686	104	0.72
D51A1	6.3	0.019	16	44	686	113	0.72
F62B2	6.5	0.015	11	89	610	89	0.81
E22D2	6.2	0.015	36	62	381	113	0.72
F22E2	6.4	0.026	31	62	381	80	0.72
E32C3	6.4	0.013	48	27	381	53	0.41
G22B1	6.1	0.015	17	62	305	62	0.72
F21E3	7.0	0.014	28	36	457	94	0.52
F41B1	5.8	0.022	80	168	457	75	0.91
C41B1	6.0	0.027	22	80	381	80	0.72
C3A2D2	6.6	0.021	17	44	686	151	0.72
D61C1	5.3	0.009	15	62	229	47	0.72
D22D1	6.2	0.025	82	142	457	104	1.22
C11D3	6.8	0.022	18	44	381	89	0.52
F71C3	6.5	0.017	18	27	381	80	0.62
C62B2	5.8	0.017	20	27	305	62	0.72
C22C2	5.4	0.023	78	116	762	98	0.52
B41A3	6.4	0.015	29	27	305	71	0.52
B22B1	5.3	0.023	16	151	533	176	0.72
C31B1	6.1	0.010	49	53	305	66	0.52
F5A2D1	5.7	0.032	93	98	610	160	0.91
G42A3	5.7	0.018	9	18	457	75	0.72
A31D2	6.5	0.042	24	116	305	160	1.12
Source: Survey data.							

Table 2
Dior Soils
Summary Analyses (n=27)

	pH	N (%)	P	K	Ca	Mg	O.M. (%)
			(pounds/acre)				
Maximum	7.0	0.042	93	168	914	200	1.22
Minimum	5.3	0.009	9	18	229	47	0.41
Mean	6.2	0.020	31	71	474	98	0.72
Std. Dev.	0.5	0.008	24	41	175	40	0.18
Source: Survey data.							

CODE	pH	N (%)	P	K	Ca	Mg	O.M. (%)
			(pounds/acre)				
F31A1	5.8	0.023	43	44	533	132	0.81
E41A2	6.6	0.047	23	124	990	248	1.22
H22E3	7.8	0.034	123	133	152	232	1.31
G62A3	6.8	0.050	56	185	1143	168	1.62

Source: Survey data.

	pH	N (%)	P	K	Ca	Mg	O.M. (%)
			(pounds/acre)				
Maximum	7.8	0.050	123	185	1143	248	1.62
Minimum	5.8	0.023	23	44	152	132	0.81
Mean	6.8	0.039	61	122	705	195	1.24
Std. Dev.	0.7	0.011	38	50	390	47	0.29

Source: Survey data.

CODE	pH	N (%)	P	K	Ca	Mg	O.M. (%)
			(pounds/acre)				
H41A1	6.4	0.021	11	53	457	104	0.72
C52A2		0.036	16	89	990	168	0.91
F52C3	6.6	0.019	17	89	610	224	0.81
	5.2						
Source: Survey data.							

	pH	N (%)	P	K	Ca	Mg	O.M. (%)
			(pounds/acre)				
Maximum	6.6	0.036	17	89	990	224	0.91
Minimum	5.2	0.019	11	53	457	104	0.72
Mean	6.1	0.025	15	77	686	165	0.81
Std. Dev.	0.6	0.008	31	72	244	119	0.08

Source: Survey data.

APPENDIX E

DATA AND SUMMARY STATISTICS FOR SECTION 3.5.2 ANALYSES

DATA

CODE\$	FARMO\$	FIELDNO\$	TYPE	ORG	DISVIL	ROTAT
F7	1	3	0	0.62	0.20	1
G4	2	1	0	0.72	0.40	0
D6	1	3	0	0.72	0.05	0
D4	1	1	0	0.72	0.80	1
E3	2	3	0	0.41	3.50	1
G1	2	1	0	0.72	4.00	1
B4	1	1	0	0.52	0.20	1
F2	1	5	0	0.52	0.15	0
A2	1	3	1	0.81	0.15	0
H1	2	2	1	0.72	0.70	1
G6	2	1	2	1.62	0.01	0
H2	2	5	2	1.31	0.01	0
F5	2	3	3	0.81	0.30	1

TOTFAL CRNOTE	MAN8889 GUER	PAR8889	TOTCONS	CRNCAD	
0	0.00	0	0	0.08	1
3	0.00	0	1	0.14	0
0	8.01	0	1	0.00	1
0	0.00	0	0	1.94	0
0	0.00	0	0	2.70	1
2	0.00	0	0	0.04	0
1	3.23	0	0	6.28	0
1	0.00	0	0	2.50	0
0	2.63	1	2	1.03	0
1	0.00	0	0	0.00	0
0	3.16	0	1	6.77	0
0	0.00	0	0	0.59	0
0	0.00	1	0	2.05	1

TOTCRN
0.86
0.18
6.88
2.29
2.97
0.09
6.67
2.50
1.21
0.06
11.62
1.59
2.53

SUMMARY STATISTICS

	TYPE	ORG	DISVIL	ROTAT	TOTPAL
N OF CASES	13	13	13	13	13
MINIMUM	0.000	0.410	0.010	0.000	0.000
MAXIMUM	1.000	1.620	4.000	1.000	3.000
RANGE	1.000	1.210	3.990	1.000	3.000
MEAN	0.385	0.786	0.805	0.538	0.615
VARIANCE	1.064	0.109	1.777	0.269	0.923
STANDARD DEV	1.032	0.330	1.333	0.519	0.961
STD. ERROR	0.487	0.091	0.370	0.144	0.266
SKEWNESS(G1)	1.119	1.518	1.813	-0.154	1.420
KURTOSIS(G2)	-0.125	1.511	1.537	-1.976	0.944
SUM	4.000	10.220	10.470	7.000	8.000
C.V.	1.490	0.419	1.655	0.964	1.561

	MAN8889	PAR8889	TOTCONS	CRWCAD	CRNOTE
N OF CASES	13	13	13	13	13
MINIMUM	0.000	0.000	0.000	0.000	0.000
MAXIMUM	8.011	1.000	2.000	6.774	6.884
RANGE	8.011	1.000	2.000	6.774	6.884
MEAN	1.310	0.154	0.385	1.856	1.178
VARIANCE	5.765	0.141	0.423	5.287	4.584
STANDARD DEV	2.401	0.376	0.650	2.299	2.141
STD. ERROR	0.666	0.104	0.180	0.638	0.594
SKEWNESS(G1)	1.857	1.919	1.388	1.243	1.995
KURTOSIS(G2)	2.627	1.682	0.751	0.305	2.368
SUM	17.026	2.000	5.000	24.132	15.318
C.V.	1.833	2.441	1.691	1.239	1.817

	GUER	TOTCRN
N OF CASES	13	13
MINIMUM	0.000	0.063
MAXIMUM	1.000	11.616
RANGE	1.000	11.553
MEAN	0.308	3.035
VARIANCE	0.231	11.547
STANDARD DEV	0.480	3.398
STD. ERROR	0.133	0.942
SKEWNESS(G1)	0.833	1.419
KURTOSIS(G2)	-1.306	1.113
SUM	4.000	39.450
C.V.	1.561	1.120

APPENDIX F

ADDITIONAL HYPOTHESES TESTED FOR SECTION 3.5.2

Hypothesis 1

- $H_{(0)}$: There is no relationship between soil organic matter content of samples taken from outside the influence of *A. albida* (ORG) and distance from the field where the sample was taken to the village (DISVIL)
- $H_{(1)}$: Soil organic matter is in part a negative function of the distance from the field to the village.

DEP VAR: ORG N: 13 MULTIPLE R: .344 SQUARED MULTIPLE R: .118 ADJUSTED SQUARED MULTIPLE R: .038 STANDARD ERROR OF ESTIMATE: 0.323						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.855	0.106	0.000	.	8.069	0.000
DISVIL	-0.085	0.070	-0.344	1.000	-1.214	0.250
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.154	1	0.154	1.474	0.250	
RESIDUAL	1.150	11	0.105			

Hypothesis 2

- $H_{(0)}$: There is no relationship between soil organic matter content of samples taken from outside the influence of *A. albida* (ORG) and the number of years a particular field has been in fallow from 1985-1989 (TOTFAL).
- $H_{(1)}$: Soil organic matter is in part a positive function of the number of years a field has been in fallow.

DEP VAR: ORG N: 13 MULTIPLE R: .245 SQUARED MULTIPLE R: .060 ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 0.334						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.838	0.111	0.000	.	7.530	0.000
TOTFAL	-0.084	0.100	-0.245	1.000	-0.836	0.421
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.078	1	0.078	0.700	0.421	
RESIDUAL	1.226	11	0.111			

Hypothesis 3

$H_{(0)}$: There is no relationship between soil organic matter content of samples taken from outside the influence of *A. albida* (ORG) and average manure per hectare (in charettes) used in 1988 and 1989 (MAN8889) on the field where the sample was taken.

$H_{(1)}$: Soil organic matter is in part a positive function of quantity of manure used on the field.

DEP VAR: ORG N: 13 MULTIPLE R: .138 SQUARED MULTIPLE R: .019 ADJUSTED SQUARED MULTIPLE R: .000 STANDARD ERROR OF ESTIMATE: 0.341						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.761	0.109	0.000	.	7.002	0.000
MAN8889	0.019	0.041	0.138	1.000	0.461	0.654
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.025	1	0.025	0.213	0.654	
RESIDUAL	1.279	11	0.116			

Hypothesis 4

H_0 : There is no relationship between crown cover per hectare of species other than *A. albida* (CRNOTH), whether the field was subject to parcage in 1988 or 1989 (PAR8889), and soil organic matter content (ORG) of soil samples taken from outside the influence of the tree canopy.

H_1 : Soil organic matter content from outside the tree canopy, is in part, a positive function of the percent total other species crown cover per hectare and whether the field was subjected to parcage.

DEP VAR: ORG N: 13 MULTIPLE R: .457 SQUARED MULTIPLE R: .209 ADJUSTED SQUARED MULTIPLE R: .051 STANDARD ERROR OF ESTIMATE: 0.321						
VARIABLE	COEFFICIENT	STD ERROR	STD COEF	TOLERANCE	T	P(2 TAIL)
CONSTANT	0.687	0.113	0.000	.	6.068	0.000
CRNOTH	0.071	0.044	0.463	0.969	1.621	0.136
PAR8889	0.100	0.251	0.114	0.969	0.398	0.699
ANALYSIS OF VARIANCE						
SOURCE	SUM-OF-SQUARES	DF	MEAN-SQUARE	F-RATIO	P	
REGRESSION	0.272	2	0.136	1.321	0.310	
RESIDUAL	1.031	10	0.103			

APPENDIX C
VARIABLES, DATA AND SUMMARY STATISTICS FOR
SECTION 4.2 ANALYSES

VARIABLES USED

TOTAL12	Total number of <i>A. albida</i> trees by age class at a diameter growth rate of 1.2cm per year.
PERPEA	The percent of total arable area in peanuts for the Departments of Thiès and Diourbel.
SUBPC	The percent of fertilizer subsidy.
LOGTOT	The natural log value of TOTAL12.
LOGSUB	The natural log value of SUBPC
LOGPEA	The natural log value of PERPEA.

DATA

YEAR	TOTAL12	PERPEA	SUBPC	LOGTOT	LOGSUB	LOGPEA
1965	24	46.83	46	3.18	3.83	3.85
1966	22	46.26	44	3.09	3.78	3.83
1967	12	47.39	40	2.48	3.69	3.86
1968	13	50.79	45	2.56	3.81	3.93
1969	6	47.71	32	1.79	3.47	3.87
1970	6	50.60	34	1.79	3.53	3.92
1971	12	50.45	45	2.48	3.81	3.92
1972	3	51.83	62	1.10	4.13	3.95
1973	13	44.87	55	2.56	4.01	3.80
1974	9	48.93	44	2.20	3.78	3.89
1975	4	54.33	70	1.39	4.25	3.99
1976	16	52.26	57	2.77	4.04	3.96
1977	12	53.59	53	2.48	3.97	3.98
1978	23	49.32	50	3.14	3.91	3.90
1979	6	48.81	54	1.79	3.99	3.89
1980	18	47.49	61	2.89	4.11	3.86
1981	23	40.23	70	3.14	4.25	3.69
1982	23	50.32	77	3.14	4.34	3.92
1983	14	52.63	50	2.64	3.91	3.96
1984	40	35.41	0	3.69		3.57
1985	66	20.14	16	4.19	2.77	3.00
1986	365	34.92	27	5.90	3.30	3.55
1987	857	38.58	20	6.75	3.00	3.65
1988	1381	29.82	9	7.23	2.20	3.40

SUMMARY STATISTICS

	TOTAL12	PERPEA	SUBPC	LOGTOT
N OF CASES	24	24	24	24
MINIMUM	3.000	20.141	0.000	1.099
MAXIMUM	1381.000	54.325	77.000	7.231
RANGE	1378.000	34.184	77.000	6.132
MEAN	123.667	45.563	44.208	3.099
VARIANCE	105137.188	70.097	377.042	2.381
STANDARD DEV	324.249	8.372	19.418	1.543
STD. ERROR	66.187	1.709	3.964	0.315
SKEWNESS(G1)	3.087	-1.539	-0.542	1.465
KURTOSIS(G2)	8.470	1.846	-0.213	1.542
SUM	2968.000	1093.512	1061.000	74.382
C.V.	2.622	0.184	0.439	0.498

	LOGSUB	LOGPEA
N OF CASES	23	24
MINIMUM	2.197	3.003
MAXIMUM	4.344	3.995
RANGE	2.147	0.992
MEAN	3.733	3.798
VARIANCE	0.260	0.052
STANDARD DEV	0.510	0.228
STD. ERROR	0.106	0.046
SKEWNESS(G1)	-1.514	-2.115
KURTOSIS(G2)	2.001	4.409
SUM	85.865	91.146
C.V.	0.137	0.060

APPENDIX H
ESTIMATION OF SOIL AND RAINFALL FACTORS

Procedure used to estimate rainfall factor:

1. Rain day data for the Departments of Thiès and Diourbel from 1965 to 1989 were averaged and the maximum and minimum number of rain days for the period were determined.
2. Twenty random numbers (the period of analysis) were then generated based on the limits of the maximum and minimum rain days.
3. Poor, average and good rainfall years were determined by calculating standard deviation for the random rain day numbers. The standard deviation for this series of numbers was 10 with a mean of 40. Thus, a year with only 29 rain days would be considered poor while a year with 51 rain days would be considered good. This information was used to adjust prices and harvest labor costs.
4. Estimation of the actual rainfall factor draws on the regression analyses provided in Chapter 6, section 6.2. For millet, the regression provided the following equation:

$$\text{Millet yield} = 11.3 * \text{No. rain days} + 54.6$$

This model was then used to generate millet yields based on the randomly generated rain days over the period of analysis. The mean yield for the series was calculated and the rain factor was determined by comparing differences between the mean yield and yield predicted by the model. For example, in year one:

$$\begin{aligned} y &= 11.3 * 41 + 54.6 = 517 \\ 517 - 513 &= 4 \\ 4/513 &= 0.01 = \text{the rain factor for year one} \end{aligned}$$

5. As the predictive power of the above regression model was weak, this rain factor was then used to modify the average yield for each of the models provided by Martin.
6. The entire procedure was repeated to estimate a rain factor for peanuts based on the regression provided in Chapter 6, section 6.2.

APPENDIX H ESTIMATION OF SOIL AND RAINFALL FACTORS

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Days rainfall	41	45	38	39	55	42	27	26	56	53	45	31	27	30	42	31	54	48	50	25
Mean=40																				
S.D.= 10																				
Rain year	A	A	A	A	A	G	A	P	G	G	A	P	P	P	A	P	G	G	G	P
MILLET YIELDS																				
Base (Y=11.3*BS-54.6)	517	562	483	495	675	529	450	348	686	653	562	404	359	393	529	404	664	596	619	337
Mean	517	513	513	513	513	513	513	513	513	513	513	513	513	513	513	513	513	513	513	513
Rain factor	0.81	0.10	-0.06	-0.04	0.32	0.03	-0.12	-0.32	0.34	0.27	0.10	-0.21	-0.30	-0.23	0.03	-0.21	0.29	0.16	0.21	-0.34
MODULE 3 (400)																				
Soil loss (0.5%/year)	403	436	372	378	516	399	335	253	515	486	413	288	250	274	377	278	478	423	438	216
Soil loss	376	374	372	370	369	367	365	363	361	359	358	356	354	352	351	349	347	345	344	342
Adjusted yield	0	2	4	6	7	9	11	13	15	17	18	20	22	24	25	27	29	31	32	34
Adjusted yield	403	434	368	372	509	390	324	241	500	469	395	267	228	250	352	251	449	392	405	182
MODULE 2 (550)																				
Soil loss (0.5%/year)	554	600	513	522	713	554	466	355	715	677	577	406	355	389	532	396	672	597	619	314
Soil loss	526	523	521	518	516	513	510	508	505	503	500	498	495	493	490	488	485	483	481	478
Adjusted yield	0	3	5	8	10	13	16	18	21	23	26	28	31	33	36	38	41	43	45	48
Adjusted yield	554	597	508	515	703	541	324	241	695	653	552	267	228	250	496	251	631	554	573	182
MODULE 1 (700)																				
Soil loss (0.5%/year)	705	764	654	667	911	708	598	457	916	867	742	524	460	504	606	514	866	771	800	413
Soil loss	676	673	669	666	663	659	656	653	649	646	643	640	637	633	630	627	624	621	618	615
Adjusted yield	0	3	7	10	13	17	20	23	27	30	33	36	39	43	46	49	52	55	58	61
Adjusted yield	705	761	647	657	897	691	324	241	889	838	709	267	228	250	640	251	814	716	741	182
PEANUT YIELDS																				
Base (Y=14.6*BS-54.6)	757	816	713	728	962	772	552	538	977	933	816	611	552	596	772	611	947	860	889	523
Mean	752	752	752	752	752	752	752	752	752	752	752	752	752	752	752	752	752	752	752	752
Rain factor	0.81	0.08	-0.05	-0.03	0.28	0.03	-0.27	-0.29	0.30	0.24	0.08	-0.19	-0.27	-0.21	0.03	-0.19	0.26	0.14	0.18	-0.30
MODULE 3 (800)																				
Soil loss (0.5%/year)	805	864	751	763	1008	802	565	546	1009	959	831	609	544	587	770	595	950	853	881	488
Soil loss	759	755	751	748	744	740	737	733	729	726	722	718	715	711	708	704	701	697	694	690
Adjusted yield	0	4	8	11	15	19	22	26	30	33	37	41	44	48	51	55	58	62	65	69
Adjusted yield	805	860	744	752	993	784	543	520	900	826	794	569	499	539	719	540	891	791	815	419
MODULE 2 (850)																				
Soil loss (0.5%/year)	856	918	799	811	1072	854	602	582	1074	1021	885	650	588	626	821	636	1013	910	940	523
Soil loss	809	805	801	797	793	789	785	781	777	773	769	765	762	758	754	750	746	743	739	735
Adjusted yield	0	4	8	12	16	20	24	28	32	36	40	44	47	51	55	59	63	66	70	74
Adjusted yield	856	914	790	799	1056	833	543	520	1042	985	845	569	499	539	766	540	950	844	870	419
MODULE 1 (950)																				
Soil loss (0.5%/year)	956	1027	894	908	1200	956	675	653	1204	1145	994	731	654	706	924	717	1139	1024	1058	592
Soil loss	908	903	899	894	890	886	881	877	872	868	864	859	855	851	846	842	838	834	830	826
Adjusted yield	0	5	9	14	18	22	27	31	36	40	44	49	53	57	62	66	70	74	78	82
Adjusted yield	956	1022	884	895	1182	934	543	520	1169	1105	949	569	499	539	862	540	1069	950	980	419

APPENDIX I **DETAILED BUDGETS FOR ALL MODELS**

MODEL 1: HIGH INTENSIFICATION

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rain year	A	A	A	A	G	A	P	P	G	G	A	P	P	P	A	P	G	G	G	P
REVENUE																				
Millets																				
Price/kg	71	71	71	71	60	71	90	90	60	60	71	90	90	90	71	90	60	60	60	90
Modulo 1 (700)	705	761	647	657	897	691	324	241	889	838	709	267	228	250	640	251	814	716	741	182
Millets revenue	50082	54030	45962	46637	53831	49085	29160	21690	53346	50254	50324	24030	20520	22500	45452	22590	48825	42857	44475	16300
Peasants																				
Pods																				
Price/kg	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Modulo 1 (950)	956	1022	884	895	1182	934	543	520	1169	1105	949	569	499	539	862	540	1069	950	900	419
Pod revenue	75561	80747	69872	70683	93404	73776	42897	41080	92313	87502	74992	44951	39421	42581	68135	42660	84440	75073	77591	33101
Hay																				
Price/kg	30	30	30	30	25	30	35	35	25	25	30	35	35	35	30	35	25	25	25	35
Modulo 1 yield	1500	1493	1487	1480	1893	1467	650	644	1867	1861	1434	618	612	605	1409	593	1816	1810	1804	548
Hay revenue	45000	44799	44598	44399	47334	44003	22757	22529	46680	46519	43030	21628	21406	21185	42270	20745	45412	45257	45103	19080
TOTAL REVENUE	170643	179576	160432	161719	194569	166863	94814	85299	192340	184075	168346	90609	81347	80346	155856	85995	178678	163287	166970	69561
COSTS																				
Millets																				
Variable Costs																				
Seed (kg.)	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Price	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
Total seed	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960
NPK (14-7-7)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Price	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Total NPK	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200
Urea	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Price	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
Total Urea	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600	4600
Labor																				
Price	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Quantity	46	46	46	46	52	46	35	35	52	52	46	35	35	35	46	35	52	52	52	35
Total Labor	23000	23000	23000	23000	26000	23000	17500	17500	26000	26000	23000	17500	17500	17500	23000	17500	26000	26000	26000	17500
Millets variable costs	36760	36760	36760	36760	39760	36760	31260	31260	39760	39760	36760	31260	31260	31260	36760	31260	39760	39760	39760	31260

Model 1 continued

[illegible]

Parents

[illegible]

Fixed costs

[illegible]

MODEL L4: HIGH INTENSIFICATION WITH 99% FERTILIZER SUBSIDY

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rain year	A	A	A	A	G	A	P	P	G	G	A	P	P	P	A	P	G	G	G	P
REVENUE																				
Millet	71	71	71	71	60	71	90	90	60	60	71	90	90	90	71	90	60	60	60	90
Price/kg	705	761	647	657	897	691	324	241	889	838	709	267	228	250	640	251	814	716	741	182
Module 1 (700)	50082	54030	45962	44637	53831	49085	29160	21690	53366	50254	50324	24030	20520	22500	45452	22590	48825	42957	44475	16380
Millet revenue																				
Peasants																				
Pods	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Price/kg	956	1022	884	895	1182	934	543	520	1169	1105	949	569	499	539	862	540	1069	950	960	419
Module 1 (950)	75561	80747	69872	70683	93404	73776	42897	41080	92313	87502	74992	44951	39421	42581	68135	42660	84440	75073	77591	33101
Pod revenue																				
Hay	30	30	30	30	25	30	35	35	25	25	30	35	35	35	30	35	25	25	25	35
Price/kg	1500	1493	1487	1480	1893	1467	650	644	1867	1861	1434	618	612	605	1409	593	1816	1810	1804	568
Module 1 yield	45000	44799	44598	44599	47234	44003	17745	17570	46680	46319	43030	16835	16625	16450	42270	16100	45412	45257	45103	15365
Hay revenue																				
TOTAL REVENUE	170643	179576	160432	161719	194569	166863	89802	80340	192360	184075	168346	85816	76566	81531	155856	81350	178678	163287	166970	64846
COSTS																				
Millet	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Variable Costs																				
Seed (kg.)	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
Price	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960
Total seed	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
NPK (14-7-7)	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
Price	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100
Total NPK	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Urea	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
Price	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300	2300
Total Urea																				
Labor	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Price	46	46	46	46	52	46	35	35	52	52	46	35	35	35	46	35	52	52	52	35
Quantity	23000	23000	23000	23000	26000	23000	17500	17500	26000	26000	23000	17500	17500	17500	23000	17500	26000	26000	26000	17500
Total Labor																				
Millet variable costs	30360	30360	30360	30360	33360	30360	24860	24860	33360	33360	30360	24860	24860	24860	30360	24860	33360	33360	33360	24860

MODEL 1.9: HIGH INTENSIFICATION WITH 90% FERTILIZER SUBSIDY

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rain year	A	A	A	A	G	A	P	P	G	G	A	P	P	P	A	P	G	G	G	P
REVENUE																				
Millet	71	71	71	71	60	71	90	90	60	60	71	90	90	90	71	90	60	60	60	90
Price/kg	705	761	647	657	897	691	324	241	889	838	709	267	228	250	640	251	814	716	741	182
Module 1 (700)	50082	54030	45962	46637	53831	49085	29160	21690	53366	50254	50324	24030	20520	22500	45452	22590	48825	42957	44475	16380
Peasane																				
Pods	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Price/kg	956	1022	884	895	1182	934	543	520	1169	1105	949	569	499	539	862	540	1069	950	900	419
Module 1 (950)	75561	80747	69872	70683	93404	73776	42897	41080	92313	87302	74992	44951	39421	42581	68135	42660	84440	75073	77591	33101
Hay																				
Pods	30	30	30	30	25	30	35	35	25	25	30	35	35	35	30	35	25	25	25	35
Price/kg	1500	1493	1487	1480	1893	1467	650	644	1867	1861	1434	618	612	605	1409	593	1816	1810	1804	568
Module 1 yield	45000	44799	44598	44399	47334	44003	17745	17570	46680	46519	43030	16835	16625	16450	42270	16100	45412	45257	45103	15365
Hay revenue	170643	179576	160432	161719	194569	166863	89802	80340	192360	184075	168346	85816	76566	81531	155856	81350	178678	163287	166970	64046
TOTAL REVENUE																				
COSTS																				
Millet																				
Variable Costs																				
Seed (kg.)	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Price	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
Total seed	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960
NPK (14-7-7)																				
Price	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Total NPK	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800	800
Urea																				
Price	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Total Urea	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
Labor																				
Price	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400	400
Quantity	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Total Labor	46	46	46	46	52	46	35	35	52	52	46	35	35	35	46	35	52	52	52	35
Millet variable costs	25160	25160	25160	25160	28160	25160	19600	19600	28160	28160	25160	19600	19600	19600	25160	19600	28160	28160	28160	19600

MODEL 2: MODERATE INTENSIFICATION

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rain year	A	A	A	A	G	A	P	P	G	G	A	P	P	P	A	P	G	G	G	P
REVENUE																				
Millet	71	71	71	71	60	71	90	90	60	60	71	90	90	90	71	90	60	60	60	90
Price/fg	554	597	508	515	703	541	324	241	695	653	552	267	228	250	496	251	631	554	573	182
Module 2 (\$50)	39350	42415	36039	34632	42171	38382	29160	21690	41683	39208	39176	24030	20520	22500	35208	22590	37878	33238	34402	16380
Peanut																				
Pods	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Price/fg	856	914	790	799	1066	833	543	520	1042	985	845	569	499	539	766	540	950	844	870	419
Module 2 (\$50)	67585	72196	62435	63132	83432	65940	42897	41080	82340	77827	66784	44951	39421	42581	60536	42660	75070	66661	68708	33101
Hay																				
Price/fg	30	30	30	30	25	30	35	35	25	25	30	35	35	35	30	35	25	25	25	35
Module 2 yield	1340	1334	1328	1322	1726	1310	584	578	1702	1697	1281	555	549	544	1258	532	1457	1451	1646	510
Hay revenue	40200	40018	39838	39658	43149	39301	20440	20230	42560	42415	38424	19426	19226	19026	37738	18630	41417	41277	41138	17850
TOTAL REVENUE	147135	154629	138312	139322	168752	143523	92497	83000	166583	159449	144384	88407	79167	84107	133482	83880	154365	141176	144249	67331
COSTS																				
Millet	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Variable Costs	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
Seed (kg)	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960
Total seed	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
NPK (14-7-7)	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Price	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200	8200
Total NPK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urea	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
Price	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Urea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Labor	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Price	42	42	42	42	48	42	32	32	48	48	42	32	32	32	42	32	48	48	48	32
Quantity	21000	21000	21000	21000	24000	21000	16000	16000	24000	24000	21000	16000	16000	16000	21000	16000	24000	24000	24000	16000
Total Labor	30160	30160	30160	30160	33160	30160	25160	25160	33160	33160	30160	25160	25160	25160	30160	25160	33160	33160	33160	25160
Millet variable costs	30160	30160	30160	30160	33160	30160	25160	25160	33160	33160	30160	25160	25160	25160	30160	25160	33160	33160	33160	25160

MODEL 2.5: MODERATE INTENSIFICATION WITH 50% FERTILIZER SUBSIDY

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rain year	A	A	A	A	G	A	P	P	G	G	A	P	P	P	A	P	G	G	G	P
REVENUE																				
Millets																				
Price/kg	71	71	71	71	60	71	90	90	60	60	71	90	90	90	71	90	60	60	60	90
Modèle 2 (350)	554	597	508	515	703	541	324	241	695	653	552	267	228	250	496	251	631	554	573	182
Modèle 2 (550)	39350	42415	34039	34532	42171	38382	29160	21690	41683	39208	39176	24030	20520	22500	35208	22590	37878	33238	34402	16380
Peanuts																				
Pods																				
Price/kg	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Modèle 2 (850)	856	914	790	799	1056	833	543	528	1842	985	845	569	499	539	766	540	958	844	878	419
Pod revenue	67585	72196	62435	63132	83432	65840	42897	41080	82340	77827	66784	44951	39421	42581	60536	42860	75070	66661	68708	33101
Hay																				
Price/kg	30	30	30	30	25	30	35	35	25	25	30	35	35	35	30	35	25	25	25	35
Modèle 2 yield	1340	1334	1328	1322	1726	1310	584	578	1702	1697	1281	555	549	544	1258	532	1657	1651	1646	510
Hay revenue	40200	40018	39838	39658	43149	39301	20440	20230	42560	42415	38424	19426	19226	19826	37738	18630	41417	41277	41138	17850
TOTAL REVENUE	147135	154629	138312	139322	168752	143523	92497	83000	166583	159449	144384	88407	79167	84107	133482	83880	154365	141176	144249	67331
COSTS																				
Millets																				
Variable Costs																				
Seed (kg.)	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Price	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
Total seed	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960
NPK (14-7-7)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Price	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41	41
Total NPK	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100	4100
Urea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Price	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46	46
Total Urea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Labor																				
Price	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Quantity	42	42	42	42	48	42	32	32	48	48	42	32	32	32	42	32	48	48	48	32
Total Labor	21000	21000	21000	21000	24000	21000	16000	16000	24000	24000	21000	16000	16000	16000	21000	16000	24000	24000	24000	16000
Millets variable costs	26060	26060	26060	26060	29060	26060	21060	21060	29060	29060	26060	21060	21060	21060	26060	21060	29060	29060	29060	21060

MODEL 3: BASE CASE

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rate year	A	A	A	A	G	A	P	P	G	G	A	P	P	P	A	P	G	G	G	P
REVENUE																				
Millet																				
Pricing	71	71	71	71	60	71	90	90	60	60	71	90	90	90	71	90	60	60	60	90
Module 3 (400)	403	434	368	372	509	390	324	241	500	469	395	267	228	250	352	251	449	392	405	182
Millet revenue	28618	30800	26116	26427	34051	27680	29157	21647	34000	28161	28028	24070	20526	22523	24964	22546	26930	23519	24329	16345
Peanut																				
Pods																				
Pricing	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Module 3 (800)	805	860	744	752	993	784	543	520	980	926	794	569	499	539	719	540	891	791	815	419
Pod revenue	63631	67953	58750	59389	78479	61906	42876	41067	77306	73123	62714	44929	39445	42572	56771	42686	70419	62489	64481	33109
Hay																				
Pricing	30	30	30	30	25	30	35	35	25	25	30	35	35	35	30	35	25	25	25	35
Mod 3 yield	1260	1254	1249	1243	1568	1233	507	502	1546	1541	1206	481	475	470	1185	460	1505	1500	1494	439
Hay revenue	37800	37834	37469	37304	39201	36978	17752	17564	38662	38529	36176	16822	16638	16456	35549	16094	37617	37489	37582	13300
TOTAL REVENUE	130049	136367	122335	123121	148191	126564	89786	80279	146049	139814	126919	85820	76609	81551	117284	81346	134967	123498	126092	64834
COSTS																				
Millet																				
Variable Costs																				
Seed (kg.)	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Price	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
Total seed	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960	960
NPK (14-7-7)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Price	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82	82
Total NPK	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Urea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Price	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92	92
Total Urea	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Labor																				
Price	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Quantity	32	32	32	32	37	32	25	25	37	37	32	25	25	25	32	25	37	37	37	25
Total Labor	16000	16000	16000	16000	18500	16000	12500	12500	18500	18500	16000	12500	12500	12500	16000	12500	18500	18500	18500	12500
Millet variable costs	16960	16960	16960	16960	19460	16960	13460	13460	19460	19460	16960	13460	13460	13460	16960	13460	19460	19460	19460	13460

MODEL 4: INTRODUCTION OF A. ALBIDA- ALL BENEFITS

YEAR		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rain year		A	A	A	A	G	A	P	P	G	G	A	P	P	P	A	P	G	G	G	P
REVENUE																					
Millet																					
Price/kg	71	71	71	71	71	60	71	90	90	60	60	71	90	90	90	71	90	60	60	60	90
Module 3 (400)	403	436	372	378	516	399	335	253	515	486	486	413	288	250	274	377	278	478	423	438	216
Millet revenue	28618	30933	26382	26826	30959	28341	30160	22814	30887	29157	29334	25885	22501	24658	26773	25017	28669	25362	26275	19419	
Peas																					
Pods																					
Price/kg	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Module 3 (800)	805	864	751	763	1008	802	690	546	1009	959	959	831	609	544	587	770	595	950	853	881	488
Pod revenue	63631	68253	59349	60284	79669	63390	54492	43135	79743	75768	65646	48145	42945	46355	60835	47029	75040	67387	69574	38537	
Hay																					
Price/kg	30	30	30	30	25	30	35	35	25	25	25	30	35	35	35	30	35	25	25	25	35
Mod 3 yield	1260	1254	1249	1243	1568	1233	507	502	1546	1541	1541	1206	481	475	478	1185	460	1505	1500	1494	439
Hay revenue	37800	37634	37469	37504	39201	36978	17752	17564	38662	38529	36176	16822	16638	16456	33549	16094	37617	37409	37362	15380	
Cud																					
Soil conservation																					
Millet (kg saved)	0	0	0	0	0	0	3	4	5	5	6	13	14	15	16	18	37	40	42	44	47
Price	71	71	71	71	60	71	90	90	60	60	60	71	90	90	90	71	90	60	60	60	90
Total	0	0	0	0	0	231	338	405	303	345	345	888	1260	1350	1440	1243	3346	2374	2516	2657	4197
Peas (kg saved)	0	0	0	0	0	0	5	6	7	8	8	19	20	22	24	26	54	58	61	65	68
Price	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Total	0	0	0	0	0	0	375	435	514	593	652	1462	1580	1738	1857	2015	4303	4578	4852	5125	5397

Cad Streetwood

TOTAL REVENUE	130049	137000	123559	124954	150434	130417	104793	86313	151673	157270	150013	114152	142344	149130	180335	171950	249718	239929	244200	224250
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Miller

[illegible]

MODEL 5: INTRODUCTION OF A. ALBIDA- SOIL CONSERVATION AND YIELD BENEFITS ONLY

YEAR	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Rain year	A	A	A	A	G	A	P	P	G	G	A	P	P	P	A	P	G	G	G	P
REVENUE																				
Milliet	71	71	71	71	60	71	90	90	60	60	71	90	90	90	71	90	60	60	60	90
Price/kg	403	436	372	378	516	399	335	253	515	486	413	288	250	274	377	278	478	423	438	216
Module 3 (400)	28618	30933	26382	26826	30959	28341	30160	22814	30887	29157	29334	25885	22501	24658	26773	25017	28649	25362	26275	19419
Milliet revenue																				
Peasants																				
Pods																				
Price/kg	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Module 3 (800)	865	864	751	763	1008	802	690	546	1009	959	831	609	544	587	770	595	950	853	881	488
Pod revenue	63431	68253	59349	60284	79669	63390	54492	43135	79743	75768	65646	48145	42845	46355	68835	47029	75040	67387	69574	38537
Hay																				
Price/kg	30	30	30	30	25	30	35	35	25	25	30	35	35	35	30	35	25	25	25	35
Mod 3 yield	1260	1254	1249	1243	1568	1233	507	502	1546	1541	1206	481	475	470	1185	460	1505	1500	1494	439
Hay revenue	37800	37634	37469	37504	39201	36978	17752	17564	38662	38529	36176	16822	16638	16456	35549	16094	37617	37489	37562	15380
Cad																				
Soil conservation																				
Milliet (kg saved)	0	0	0	0	0	3	4	5	5	6	13	14	15	16	18	37	40	42	44	47
Price	71	71	71	71	60	71	90	90	60	60	71	90	90	90	71	90	60	60	60	90
Total	0	0	0	0	0	231	338	405	303	345	888	1260	1350	1440	1243	3346	2374	2516	2657	4197
Peasants (kg saved)	0	0	0	0	0	5	6	7	8	8	19	20	22	24	26	54	58	61	65	68
Price	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79	79
Total	0	0	0	0	0	375	435	514	593	652	1462	1590	1736	1857	2015	4303	4578	4852	5125	5397
Peasant Hay (kg saved)	0	0	0	0	0	7	8	10	11	12	27	30	33	35	35	80	85	90	96	101
Price	30	30	30	30	25	30	35	35	25	25	30	35	35	35	30	35	25	25	25	35
Total	0	0	0	0	0	203	289	333	275	306	810	1033	1136	1225	1125	2806	2133	2261	2388	3520
Total conservation	0	0	0	0	0	809	1061	1251	1170	1303	3159	3873	4226	4572	4382	10455	9085	9629	10170	13113
Cad & crop yields																				
% cad cover	0	0.01	0.02	0.03	0.04	0.85	0.86	0.87	0.88	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55	0.6
Increases (40%)	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
Price	0	2	3	5	6	8	10	11	13	16	24	32	40	48	56	64	72	80	88	96
Total	71	71	71	71	60	71	90	90	60	60	71	90	90	90	71	90	60	60	60	90
Peasant hay	0	114	227	341	384	568	864	1008	768	960	1704	2880	3600	4320	3976	5760	4320	4800	5280	8640
Increases (20%)	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221	221
Hay	0	2	4	7	9	11	13	15	18	22	33	44	55	66	77	88	99	111	122	133
Price	30	30	30	30	25	30	35	35	25	25	30	35	35	35	30	35	25	25	25	35
Total	0	66	133	199	221	332	464	541	442	553	995	1547	1934	2321	2321	3094	2486	2763	3039	4641
Total yield benefits	0	180	360	540	605	900	1328	1549	1210	1513	2699	4427	5534	6641	6297	8854	6806	7563	8319	13281
Total cad benefits	0	180	360	540	605	1786	2389	2880	2380	2816	5858	8300	9759	11162	10679	19309	15991	17191	18489	26394
TOTAL REVENUE	130049	137000	123559	124954	150434	130417	104793	86313	151673	146270	137013	99152	91844	90638	133035	107450	157218	147429	151700	99750

APPENDIX J

SPECIES OCCURENCE

Table 1

Species Distribution per 100 Hectares
by Diameter Class

SPECIES	DIAMETER CLASS							
	1-5cm	6-10cm	11-20cm	21-30cm	31-40cm	41-50cm	51-60cm	>60cm
<i>Acacia albidia</i>	580.4	21.1	22.6	23.5	43.9	58.8	51.9	110.7
<i>Acacia ataxacantha</i>	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
<i>Acacia macrostachya</i>	0.6	0.0	0.9	0.2	0.0	0.0	0.0	0.0
<i>Acacia nilotica</i>	6.5	1.3	1.5	1.7	1.1	1.3	0.4	0.9
<i>Acacia raddiana</i>	37.1	3.0	1.9	1.9	1.3	1.1	0.4	1.3
<i>Acacia senegal</i>	4.5	0.6	0.0	0.0	0.0	0.0	0.0	0.0
<i>Acacia seyal</i>	18.1	0.6	0.6	0.9	0.0	0.0	0.0	0.0
<i>Acacia sieberiana</i>	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4
<i>Adansonia digitata</i>	0.2	1.5	0.6	6.2	6.0	7.5	5.4	31.0
<i>Adenium obesum</i>	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
<i>Afzalia africana</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
<i>Alphania senegalensis</i>	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
<i>Anacardium occidentale</i>	0.0	0.0	0.0	0.2	0.4	0.4	0.2	0.2
<i>Annona senegalensis</i>	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Anogeissus leiocarpus</i>	0.0	0.2	0.2	0.0	0.2	0.4	1.3	4.1
<i>Antiaris africana</i>	0.0	0.0	0.2	0.2	0.6	0.9	1.5	3.0
<i>Azadirachta indica</i>	0.9	1.5	2.2	3.2	1.7	0.6	0.2	0.0
<i>Balanites aegyptiaca</i>	110.7	23.7	18.1	13.8	12.3	14.2	7.3	6.2
<i>Bauhinia rufescens</i>	6.5	0.0	1.9	2.4	1.5	0.4	0.0	0.0
<i>Bombax costatum</i>	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.2
<i>Borassus aethiopum</i>	0.6	0.2	0.4	3.2	4.1	3.4	3.7	1.3
<i>Calotropis procera</i>	0.4	0.0	0.6	0.2	0.0	0.0	0.0	0.0
<i>Cassia italica</i>	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Cassia sieberiana</i>	0.0	0.2	0.4	0.0	0.2	0.0	0.0	0.2
<i>Celiba pentandra</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6
<i>Celtis integrifolia</i>	0.0	0.0	0.2	0.4	0.2	0.0	0.0	0.9
<i>Cola cordifolia</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
<i>Combretum acaule</i>	1.7	0.0	0.2	0.0	0.0	0.0	0.0	0.2
<i>Combretum glutinosum</i>	3.2	0.4	2.2	4.5	2.8	3.4	3.0	1.3
<i>Combretum micranthum</i>	1.5	0.0	0.4	0.0	0.2	0.2	0.0	0.0
<i>Combretum nigricans</i>	0.2	0.0	0.0	0.0	0.0	0.2	0.0	0.0
<i>Commiphora africana</i>	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
<i>Cordia pinnata</i>	4.7	0.0	0.6	0.0	0.9	0.6	2.2	3.2
<i>Crataeva religiosa</i>	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
<i>Dalbergia melanoxylon</i>	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Detarium microcarpum</i>	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.4
<i>Dichrostachys glomerata</i>	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Diospyros mespiliformis</i>	0.0	0.0	0.0	0.6	0.9	1.5	0.6	3.9
<i>Entada africana</i>	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
<i>Eucalyptus spp.</i>	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
<i>Ficus glumosa</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
<i>Ficus gnaphalocarpa</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
<i>Ficus iteophylla</i>	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.6
<i>Ficus polita</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
<i>Ficus thonningii</i>	0.0	0.0	0.0	0.2	0.0	0.0	0.2	0.0
<i>Gardenia spp.</i>	0.6	0.2	0.2	0.4	0.2	0.2	0.0	0.0
<i>Grewia bicolor</i>	0.0	0.0	0.2	1.1	0.2	0.2	0.0	0.2
<i>Hammaria undulata</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4
<i>Heeria insignis</i>	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
<i>Hymenocardia acida</i>	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0

Table 1 continued

<i>Lannea acida</i>	0.0	0.0	0.2	0.2	0.2	0.0	0.0	0.0
<i>Mangifera indica</i>	0.0	0.0	0.0	0.6	1.3	1.5	0.6	0.9
<i>Mitragyna inermis</i>	0.0	0.0	0.2	0.2	0.0	0.0	0.0	0.0
<i>Morus mesozygia</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
<i>Nauclea latifolia</i>	0.0	0.0	0.0	0.4	0.2	0.2	0.0	0.0
<i>Parinari macrophylla</i>	0.0	0.0	0.2	0.9	2.6	1.5	0.9	1.9
<i>Parkia biglobosa</i>	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
<i>Piliostigma reticulatum</i>	6.5	0.2	1.9	1.9	2.4	2.2	1.3	0.4
<i>Prosopis africana</i>	0.2	0.0	0.0	0.0	0.0	0.0	1.1	1.3
<i>Pterocarpus erinaceus</i>	0.0	0.0	0.0	0.4	1.5	0.4	1.1	2.4
<i>Sclerocarya birrea</i>	0.0	0.2	0.0	0.6	0.4	0.2	0.4	0.0
<i>Securinega virosa</i>	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
<i>Sesamum alatum</i>	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0
<i>Strychnos spinosa</i>	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
<i>Tamarindus indica</i>	0.0	0.0	0.2	0.4	0.9	1.7	0.0	8.0
<i>Terminalia avicennoides</i>	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0
<i>Terminalia macroptera</i>	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0
<i>Uvaria chamae</i>	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0
<i>Veronia colorata</i>	0.0	0.2	0.0	0.0	0.0	0.2	0.0	0.0
<i>Zizyphus mauritiana</i>	19.6	1.5	4.3	5.4	2.4	1.7	0.9	0.9

SOURCE: Biophysical Inventory

Table 2

**Study Area Species Distribution
Total by Diameter Class**

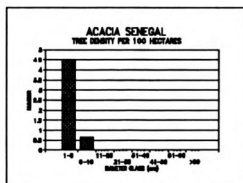
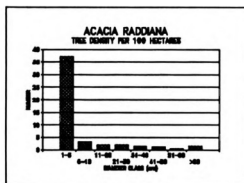
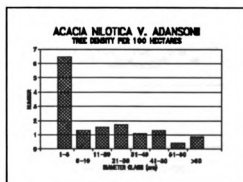
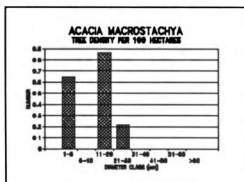
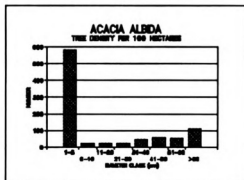
SPECIES	DIAMETER CLASS							
	1-5cm	6-10cm	11-20cm	21-30cm	31-40cm	41-50cm	51-60cm	>60cm
<i>Acacia albida</i>	2694	98	105	109	204	273	241	4118
<i>Acacia ataxacantha</i>	0	0	0	0	1	0	0	0
<i>Acacia macrostachya</i>	3	0	4	1	0	0	0	0
<i>Acacia nilotica</i>	30	6	7	8	5	6	2	68
<i>Acacia raddiana</i>	172	14	9	9	6	5	2	228
<i>Acacia senegal</i>	21	3	0	0	0	0	0	20
<i>Acacia seyal</i>	84	3	3	4	0	0	0	90
<i>Acacia sieberiana</i>	5	0	0	0	0	0	0	2
<i>Adansonia digitata</i>	1	7	3	29	28	35	25	272
<i>Adenium obesum</i>	0	0	0	1	0	0	0	0
<i>Afzalia africana</i>	0	0	0	0	0	0	0	3
<i>Alphania senegalensis</i>	0	0	0	0	1	0	0	0
<i>Ascardium occidentale</i>	0	0	0	1	2	2	1	7
<i>Annona senegalensis</i>	2	0	0	0	0	0	0	0
<i>Anogeissus leiocarpus</i>	0	1	1	0	1	2	6	30
<i>Antiaris africana</i>	0	0	1	1	3	4	7	30
<i>Azadirachta indica</i>	4	7	10	15	8	3	1	40
<i>Balanites aegyptiaca</i>	514	110	84	64	57	66	34	920
<i>Bauhinia rufescens</i>	30	0	9	11	7	2	0	50
<i>Bombax costatum</i>	0	0	0	0	1	0	0	2
<i>Borassus aethiopum</i>	3	1	2	15	19	16	17	70
<i>Calotropis procera</i>	2	0	3	1	0	0	0	0
<i>Cassia italica</i>	1	0	0	0	0	0	0	0
<i>Cassia sieberiana</i>	0	1	2	0	1	0	0	3
<i>Ceiba pentandra</i>	0	0	0	0	0	0	1	3
<i>Celtis integrifolia</i>	0	0	1	2	1	0	0	8
<i>Cola cordifolia</i>	0	0	0	0	0	0	0	1
<i>Combretum aculeatum</i>	8	0	1	0	0	0	0	10
<i>Combretum glutinosum</i>	15	2	10	21	13	16	14	90
<i>Combretum micranthum</i>	7	0	2	0	1	1	0	10
<i>Combretum nigricans</i>	1	0	0	0	0	1	0	0
<i>Commiphora africana</i>	0	0	0	1	0	0	0	0
<i>Cordyla pinnata</i>	22	0	3	0	4	3	10	53
<i>Crataeva religiosa</i>	1	1	0	0	0	0	0	0
<i>Dalbergia melanoxylon</i>	1	0	0	0	0	0	0	0
<i>Detarium microcarpum</i>	0	0	0	0	0	1	1	3
<i>Dichrostachys glomerata</i>	19	0	0	0	0	0	0	19
<i>Diospyros mespiliformis</i>	0	0	0	3	4	7	3	30
<i>Eucalyptus spp.</i>	0	0	0	1	0	0	0	0
<i>Ficus glumosa</i>	0	0	0	0	0	0	0	2
<i>Ficus gnapalocarpa</i>	0	0	0	0	0	0	0	2
<i>Ficus iteophylla</i>	0	0	0	0	0	1	0	3
<i>Ficus polita</i>	0	0	0	0	0	0	0	1
<i>Ficus thonningii</i>	0	0	0	1	0	0	1	0
<i>Gardenia spp.</i>	3	1	1	2	1	1	0	0
<i>Grewia bicolor</i>	0	0	1	5	1	1	0	9
<i>Hannoa undulata</i>	0	0	0	0	0	0	0	2
<i>Heeria insignis</i>	0	0	0	0	1	0	0	0
<i>Hymenocardia acida</i>	0	0	0	0	1	0	0	0
<i>Lannea acida</i>	0	0	1	1	1	0	0	0
<i>Mangifera indica</i>	0	0	0	3	6	7	3	20
<i>Mitragyna inermis</i>	0	0	1	1	0	0	0	0
<i>Morus mesozygia</i>	0	0	0	0	0	0	0	1

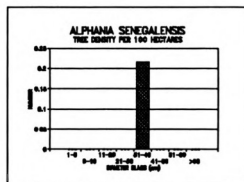
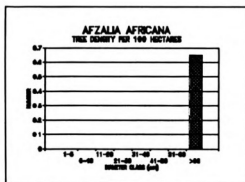
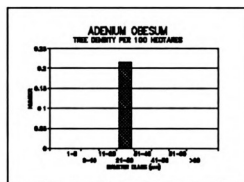
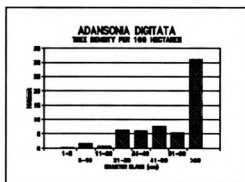
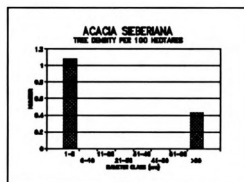
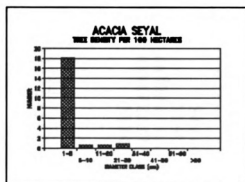
Table 2 continued

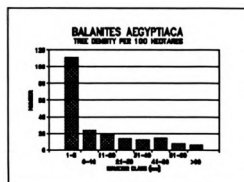
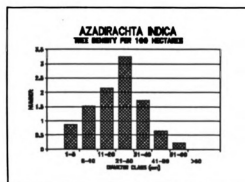
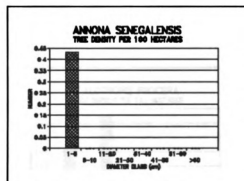
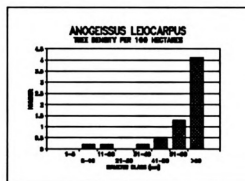
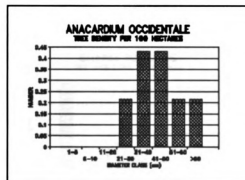
<i>Nauclea latifolia</i>	0	0	0	2	1	1	0	0
<i>Parinari macrophylla</i>	0	0	1	4	12	7	4	39
<i>Parkia biglobosa</i>	0	0	0	0	0	0	0	9
<i>Piliostigma reticulatum</i>	30	1	9	9	11	10	6	78
<i>Prosopis africana</i>	1	0	0	0	0	0	5	18
<i>Pterocarpus erinaceus</i>	0	0	0	2	7	2	5	27
<i>Sclerocarya birrea</i>	0	1	0	3	2	1	2	9
<i>Securinega virosa</i>	2	0	0	0	0	0	0	8
<i>Sesamum alatum</i>	1	0	1	0	0	0	0	8
<i>Strychnos spinosa</i>	0	0	0	1	0	0	0	8
<i>Tamarindus indica</i>	0	0	1	2	4	8	0	52
<i>Terminalia aviceanoides</i>	0	0	1	0	0	0	0	8
<i>Terminalia macroptera</i>	0	0	0	0	0	1	0	8
<i>Uvaria chamae</i>	0	0	0	1	0	0	0	8
<i>Veronia colorata</i>	0	1	0	0	0	1	0	8
<i>Zizyphus mauritiana</i>	91	7	20	25	11	8	4	178

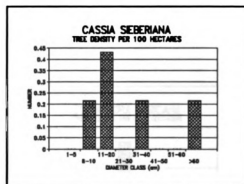
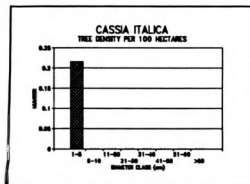
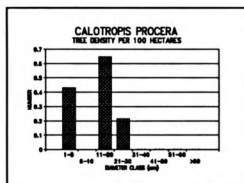
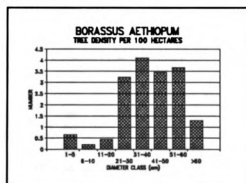
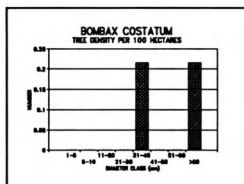
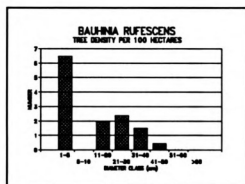
Source: Biophysical Inventory.

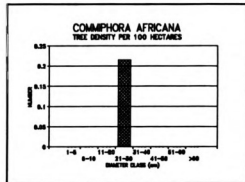
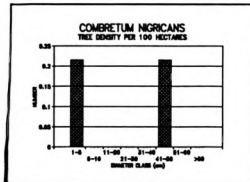
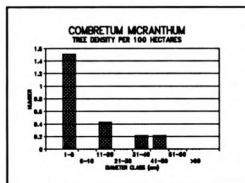
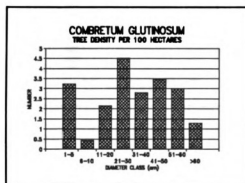
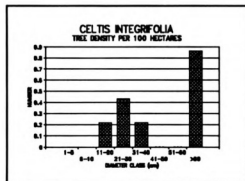
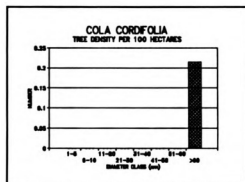
APPENDIX K
SPECIES DISTRIBUTION

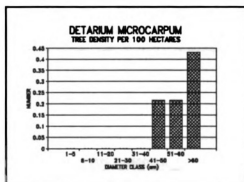
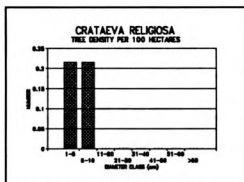
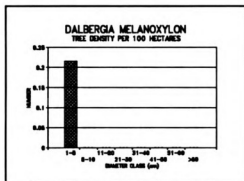
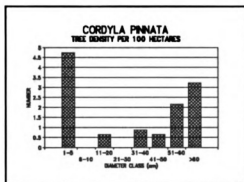


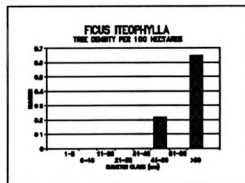
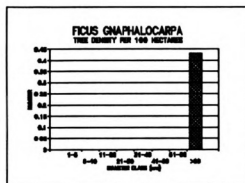
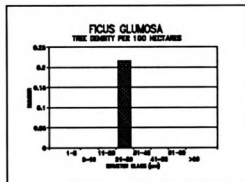
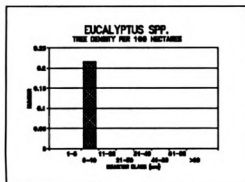
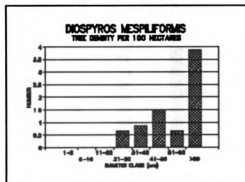
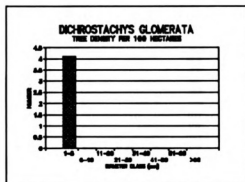


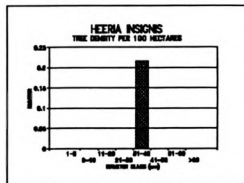
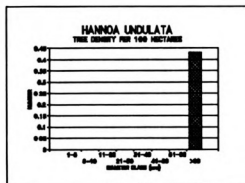
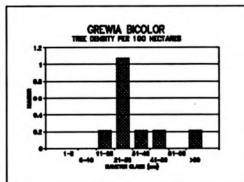
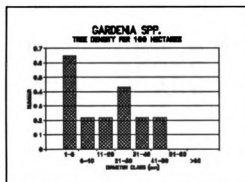
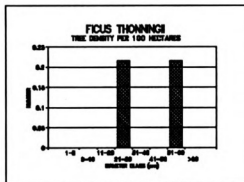
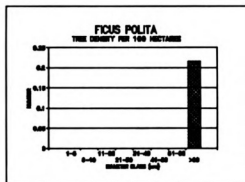


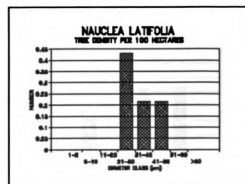
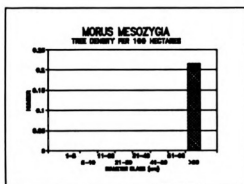
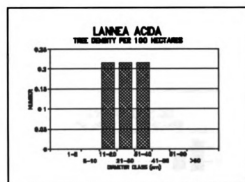
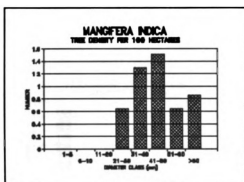
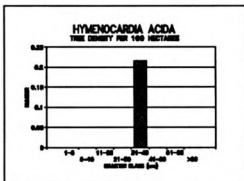


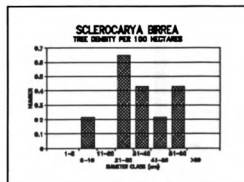
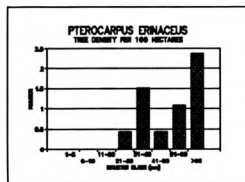
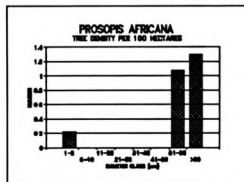
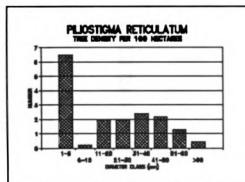
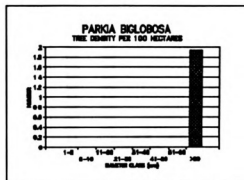
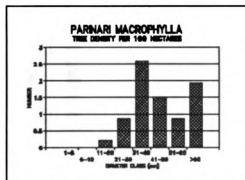


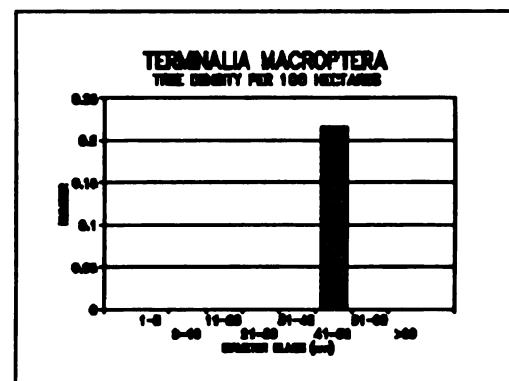
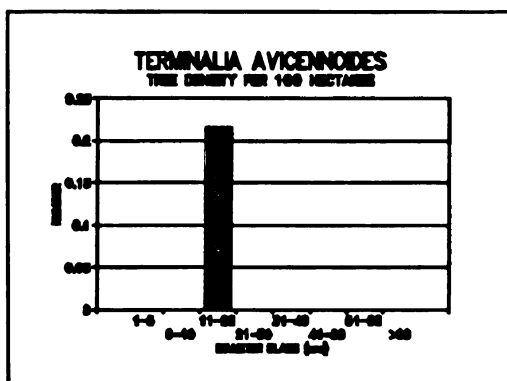
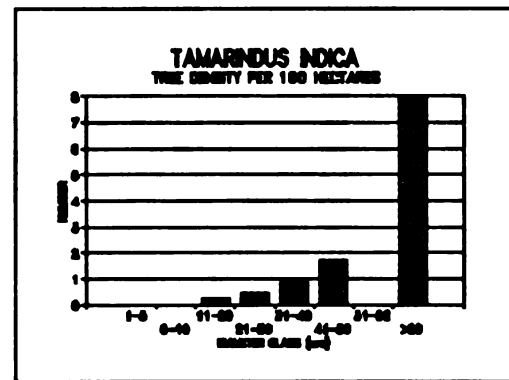
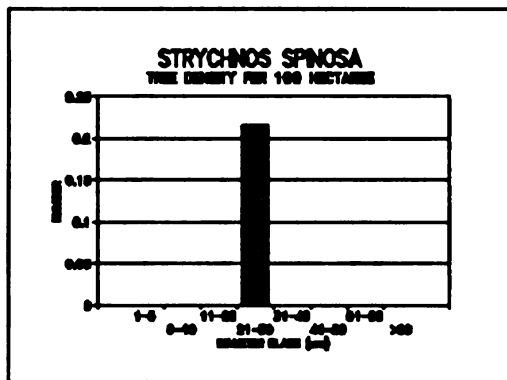
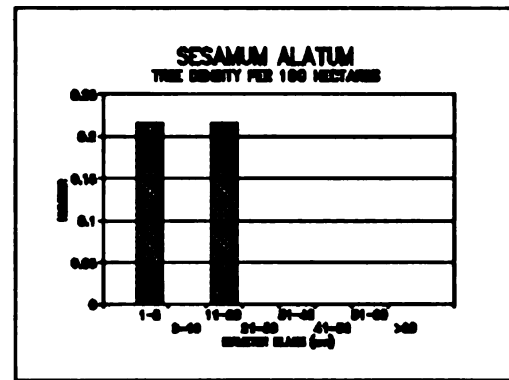
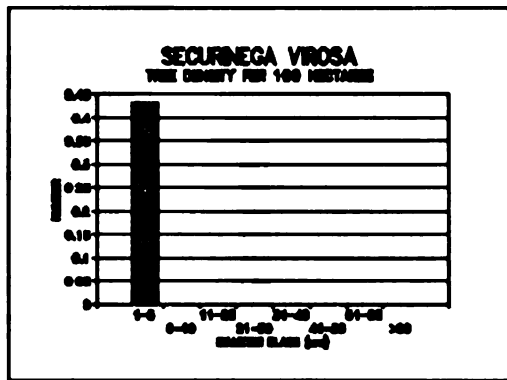


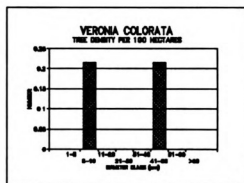
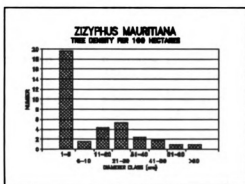
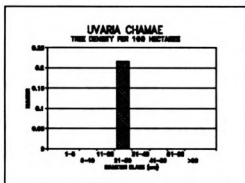












APPENDIX L

DESCRIPTION OF VARIABLES USED IN PRINCIPAL COMPONENTS ANALYSIS

DEPENDENT VARIABLES

CRMCAD	Average percent <i>A. albida</i> crown cover per hectare per farm
AALB1	Average <i>A. albida</i> regeneration rate per hectare per farm (average number of seedlings of less than 1 cm in diameter from all field sample plots -300 m ² per field sample plot)
AALB15	Average number of <i>A. albida</i> seedlings per hectare per farm between 1 and 5 cm in diameter

INDEPENDENT VARIABLES

VARIABLES DESCRIBING TREE COVER/NATURAL RESOURCES

TOTCAD	Average number of <i>A. albida</i> trees greater than 1 cm in diameter per hectare and per farm
AALB1140	Average number of <i>A. albida</i> trees per hectare per farm between 11 and 40 cm in diameter
AALB6160	Average number of <i>A. albida</i> trees per hectare greater than 41 cm in diameter
PRUCAD	<i>A. albida</i> pruning rate- an estimate of the average percent of <i>A. albida</i> crown cover removed per hectare and per farm by pruning
CRNOTH	Average percent other species crown cover per hectare per farm
PRUOTH	Other species pruning rate- an estimate of the average percent of other species crown cover removed by pruning per hectare and per farm
TOTOTH	Average number of other species per hectare per farm greater than 1 cm in diameter
BIODIV	Average number of different species per hectare per farm
HANOEX	Estimate of total area of land not used for agricultural purposes in the village in hectares (terres non-exploitées)
CADHA	Percent of total farm area where farmer makes an effort to actively manage <i>A. albida</i> (staking, pruning, protection, etc.)
CONSMES	Percent of total farm area where farmer has taken other soil conservation measures (windbreaks, live fences and other tree planting)
PCTCAD	Percent of actions undertaken by respondent to enhance <i>A.</i> <i>albida</i> out of a total of five possible actions

REALSIL	percent of "realistic" species desired by farmers divided by the total number of species desired (realistic plus unrealistic)
PRIVATE	"private tree planting"- a dummy variable, 0 for no private tree planting by the respondent and 1 if the respondent has planted trees on his/her own land
COMMUNAL	"communal tree planting"- a dummy variable, 0 if respondent has not participated in communal tree plantings activities and 1 if her or she has

FARM PRODUCTION VARIABLES

NUMPAR	Total number of fields per farmer
AREAC	Total farm area in hectares
AVDIS	Average distance between farmer's fields and the village (km)
HAAVFAL	Average percent of farm in fallow 1985-1989
HAAVMIL	Average percent of farm in millet/sorghum 1985-1989
AVMILHA	Average millet yields per hectare 1985-1989 (kg)
HAAVPEA	Average percent of farm in peanuts 1985-1989
AVPEAHA	Average peanut yields per ha 1985-1989 (kg)
HAAVCOW	Average percent of farm in cowpeas 1985-1989
AVCOWHA	Average cowpea yields per hectare 1985-1989 (kg)
HAAVMOC	Average percent of total farm area in manioc 1985-1989
AVMOCHA	Average manioc yields per hectare per farm 1985-1989 (kg)
YSINFAL	Average number of years since fallow for all fields
AVTOTMIL	Average total millet production 1985-1989 (kg)
AVTOTPEA	Average total peanut production 1985-1989 (kg)
AVTOTCOW	Average total cowpea production 1985-1989 (kg)
TOTHAH	Average total peanut and cowpea hay produced per farm in 1988 and 1989
TOOLS	Total number of animal traction-type implements
ROTATHA	Percent of total farm area where rotations are followed
TOTEXAG	Percent of adult family members undertaking some form of extra-agriculture activity in 1989
PCTEXAG	Percent of farm income derived from extra-ag sources in 1989 (estimated by taking total extra-ag income and dividing by value of total ag production (millet, cowpeas, peanuts and manioc))

VARIABLES DESCRIBING ON-FARM USE OF ORGANIC MATTER/FERTILIZER

HAMANAV	Average percent of farm area on which manure was used 1985-1989
AVMANHA	Average manure used per hectare per farm 1985-1989 (charettes)
HAPARAV	Average percent of farm area which had parcage 1985-1989
ANMONPAR	Average animal-months parcage per hectare 1985-1989 (number of animals times the number of months)
PAROTH	Percent of total farm area which had parcage prior to 1985
HAAVFER	Average percent of total farm area on which fertilizer was used 1985-1989

VARIABLES DESCRIBING QUALITY OF LAND

HAKHOR	Percent of total farm area with khor soil type
GOODHA	Percent of total farm area which farmer perceives to be fertile/good
FAIRHA	Percent of total farm area which farmer perceives to be of fair quality
POORHA	Percent of total farm area which farmer perceives to be of poor quality/infertile

DEMOGRAPHIC VARIABLES

ETHNIC	A dummy variable which indicates the ethnic group to which the farmer belongs, 0 if Wolof, 1 if Serer
AGE	Age of farmer/respondent
VILPOP	Village population
EXPCAR	Number of exploitations within a carré
CARVIL	Number of carrés in the village
DISMAR	Distance to the nearest weekly market (km)
DISROAD	Distance to the nearest paved road (km)
DISSOD	Distance to the nearest SODEVA agent (km)
DISCERDEF	Distance to the nearest forestry agent/CER (in the case of this study, DEF agents were always located in CER offices)
WELL	Depth of village well/water table (m)
TIMEVIL	Length of time farmer/respondent has lived in village (years)
VILCRE	Age of village (years)
TOTADM	Total adult males in the household (>15 years)
TOTADF	Total adult females in the household (>15 years)

YMALE	Total male youths in household (6-15 years)
YFEMALE	Total female youths in household (6-15 years)
TOTFAM	Total number of individuals in household including children under 6 years
AACTIV	Percentage of active adults in household
YRSCHIEF	Number of years respondent has been "chef exploitation" or "chef ménage dépendent"
EMRATE	Percent of adult family members who have emigrated in the past two years and have been gone longer than one year
CONFLICT	a dummy variable which indicates whether the village/farmer has had a conflict over land with another village/farmer, 0 if no, 1 if yes

VARIABLES DESCRIBING EDUCATION LEVEL

AFRENCH	Percent of adult family members with some knowledge of french (speak, read and/or write)
AARLOC	Percent of adult family members with some knowledge of arabic (speak, read and/or write) or some formal knowledge of Wolof or Serer (read and/or write)
YFRENCH	Percent of youth in household with some knowledge of french (speak, read and/or write)
YARABIC	Percent of youth in household with some knowledge of arabic (speak, read and/or write)

ANIMAL-RELATED VARIABLES

COWS	Total number of cows (large ruminants) owned or held by household, includes cows held for fattening purposes
SHPGOAT	Total number of sheep and goats owned or held by household, includes sheep held for fattening purposes
TRACAN	Total number of traction animals (oxen, horses and donkeys)

LAND ALLOCATION-RELATED VARIABLES

AREACE	Percent of total farm area farmed before becoming chef/area allocated by chef de carré
AREAOth	Percent of total farm area which was allocated by someone other than the chef de carré
AREASUP	Percent of total farm area received on becoming chef
AREAREC	Percent of total farm area farmed on a temporary basis in 1989
AREALOAN	Percent of total farm area loaned to others in 1989

AGRICULTURE AND FORESTRY EXTENSION AND TRAINING VARIABLES

AGCOEF	"agriculture training coefficient"- this is a composite variable which represents the number of agriculture training sessions in which a farmer participated plus the number of
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those sessions which discussed trees in agriculture and/or soil conservation and weighted by a factor of two

- FORCOEF** "forestry training coefficient"- this is a composite variable which represents the number of forestry-related training sessions in which a farmer participates plus the number of those sessions which discussed trees in agriculture and/or soil conservation
- EXTRATE** "extension rate"- a composite variable which represents the total number of visits made by extension agencies during the last campaign times the total number of different agencies
- ASSOC** "association participation rate"- a composite variable which represents the average years membership per organization, plus the participation level (weighted), plus the speaking level (weighted), plus any offices held, plus how activities are chosen, plus the number of organizations to which a farmer belongs.

APPENDIX M

DATA AND SUMMARY STATISTICS FOR CHAPTER 8 ANALYSES

CODES	NUMPAR	AREAC	AVDIS	PRUCAD	CRNOTH	PAROTH
Mbay1	5	9.86	1.24	20.80	1.64	0.00
Mbay2	5	13.27	0.56	15.60	1.04	50.64
Mbed1	4	5.20	0.98	13.25	3.76	44.04
Mbed2	5	3.36	1.21	5.80	2.86	0.00
Ndian1	4	3.82	0.38	23.50	0.53	0.00
Ndian2	3	3.99	0.11	27.00	1.90	0.00
Ndioul	6	5.80	0.51	0.67	3.21	0.00
Ndiou2	4	4.26	0.50	3.25	3.28	0.00
Kmbag1	6	5.74	0.47	1.17	1.68	0.00
Kmbag2	5	7.45	0.12	4.60	1.53	0.00
Ndiar1	3	9.08	0.85	14.67	0.55	0.00
Ndiar2	4	4.29	0.48	11.50	0.52	0.00
Kiel1	5	4.58	0.81	17.00	0.83	43.45
Kiel2	4	3.76	1.10	0.25	0.45	0.00
Fas1	4	4.20	1.14	12.75	1.07	0.00
Fas2	4	6.24	1.43	9.25	1.04	0.00
Ndoy1	3	3.27	0.77	18.33	1.24	0.00
Ndoy2	2	0.79	0.60	7.50	0.00	0.00
Boul1	4	3.40	0.39	27.75	0.63	0.00
Boul2	4	3.24	0.40	20.25	0.50	0.00
Cher1	4	4.68	0.98	21.00	0.34	0.00
Cher2	2	11.28	0.80	11.50	1.05	0.00
Loum1	5	9.85	0.33	2.00	1.25	16.04
Loum2	5	10.85	0.35	1.00	1.47	0.00
Ndim1	4	5.06	0.40	25.25	1.86	0.00
Ndim2	4	2.62	0.29	20.75	2.10	0.00
Lagn1	5	9.07	1.61	21.20	0.13	0.00
Lagn2	4	5.89	0.46	21.75	0.50	0.00
Bakh1	5	9.99	0.11	6.80	1.77	58.66
Bakh2	4	6.32	0.19	13.75	0.90	60.28
Fird1	3	8.16	1.00	32.67	0.37	0.00
Fird2	4	17.56	0.50	16.50	0.35	0.00
Ngom1	4	24.81	0.47	9.25	0.37	30.03
Ngom2	6	8.23	0.11	8.17	1.02	34.26
Bari1	2	1.16	0.18	15.00	0.17	0.00
Bari2	4	2.63	1.28	6.00	0.49	39.16
Ndag1	4	3.88	0.28	8.25	2.57	0.00
Ndag2	5	4.95	0.09	4.00	3.00	0.00
Tiab1	3	4.79	0.73	1.33	0.63	0.00
Tiab2	6	6.99	0.46	0.00	1.25	0.00
Tial1	3	4.60	0.45	18.67	0.95	34.78
Tial2	8	7.13	0.43	26.38	1.61	0.00
Tofal	5	5.54	0.20	32.40	1.80	0.00
Tofa2	4	5.51	0.01	13.75	10.10	78.58
Pale1	4	2.46	0.11	15.75	0.33	88.21
Pale2	4	3.39	0.30	18.75	0.32	0.00
Ndam1	6	19.80	0.43	26.50	0.64	0.00
Ndam2	5	18.94	2.90	16.00	0.32	0.00
Ndng1	3	2.12	0.37	5.33	4.14	0.00
Ndng2	3	3.40	1.17	6.67	0.00	0.00
Darol	4	8.35	1.18	20.00	0.63	0.00
Daro2	5	5.87	1.46	6.20	1.71	0.00
Ndof1	3	2.27	1.00	15.00	0.21	0.00
Ndof2	3	2.96	1.50	16.33	2.46	0.00
Babal	5	2.60	0.84	33.80	1.64	0.00
Baba2	5	2.15	0.92	16.20	1.17	48.37
Toug1	3	2.92	1.70	9.00	0.97	0.00
Toug2	5	3.69	0.26	17.60	0.50	43.90
Kman1	5	4.49	0.24	6.40	0.35	0.00
Kman2	5	11.10	2.50	4.00	0.32	0.00
Tiob1	3	5.80	0.43	24.33	0.47	0.00
Tiob2	4	6.60	0.33	14.50	0.19	0.00
Ndak1	4	4.16	0.40	14.50	2.12	0.00
Ndak2	3	2.94	1.72	23.67	0.25	0.00
Lamal	6	9.37	0.43	7.17	0.56	0.00
Lama2	3	4.79	0.17	16.00	1.06	0.00
Losal	4	4.52	0.34	0.00	0.82	0.00
Losa2	5	11.04	0.24	0.00	0.43	0.00
Pall	5	9.80	0.51	13.00	1.13	0.00
Pal2	6	4.23	1.65	24.50	0.11	0.00
Gued1	4	11.25	0.23	0.00	0.39	0.00
Gued2	3	6.04	0.23	12.67	0.63	0.00

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PRUOTH	TOTOTH	BIODIV	HAAVFAL	HAAVMIL	AVMILHA	HAKHOR
21.20	27.48	1.22	17.97	38.42	462.20	0.00
32.20	14.62	1.06	56.10	19.32	130.60	0.00
10.75	9.62	2.88	5.92	58.69	652.60	0.00
21.80	11.61	2.98	0.00	57.74	511.20	0.00
3.75	16.49	2.09	4.82	60.31	724.80	0.00
12.00	15.29	1.75	0.00	35.59	177.80	0.00
15.33	11.21	3.45	2.03	64.07	245.60	15.86
10.75	11.03	2.82	0.00	54.18	260.60	0.00
10.67	14.11	1.39	17.56	47.53	385.00	0.00
13.60	11.54	1.88	4.62	56.16	395.60	0.00
11.00	6.72	0.66	24.71	40.84	401.20	0.00
11.50	8.86	0.93	30.77	30.30	121.60	0.00
28.20	27.95	2.62	24.89	39.43	241.40	10.92
0.00	50.00	4.26	0.00	35.43	162.40	0.00
11.50	22.86	3.33	0.00	48.14	539.80	0.00
13.25	28.21	1.76	25.26	20.51	136.60	0.00
16.67	20.18	0.92	7.89	48.38	661.40	39.45
0.00	35.44	1.27	0.00	56.71	997.60	27.85
1.75	10.00	1.76	2.94	49.71	217.60	0.00
12.00	5.56	0.62	15.12	38.43	106.25	24.07
11.25	32.26	1.92	0.00	52.26	451.20	0.00
9.50	24.73	1.24	49.18	20.00	117.20	0.00
18.40	7.31	1.02	25.16	40.57	644.80	0.00
9.60	7.83	1.57	36.98	30.03	392.60	0.00
27.75	11.66	2.37	15.26	43.83	305.20	0.00
13.50	8.40	2.29	3.36	45.42	339.00	0.00
0.00	9.37	0.77	21.39	37.75	289.60	0.00
26.25	15.11	1.02	0.00	52.36	209.87	0.00
2.80	26.83	0.80	0.00	51.61	234.00	0.00
7.00	40.66	1.42	0.00	25.28	283.00	0.00
27.33	9.68	1.10	43.33	46.27	59.20	0.00
23.25	16.06	0.57	79.13	10.89	165.80	26.77
21.75	3.87	0.60	28.21	37.79	166.60	0.00
4.67	11.79	1.46	18.18	35.24	225.00	5.71
25.00	16.38	3.45	0.00	50.69	401.00	0.00
13.25	17.87	2.28	0.00	44.71	992.80	0.00
12.00	19.33	2.84	0.00	51.08	511.40	0.00
14.00	12.93	2.22	8.12	57.33	755.40	0.00
10.00	6.68	1.46	35.82	50.86	318.00	0.00
2.50	9.30	1.00	28.24	45.64	521.00	0.00
6.00	16.52	1.52	0.00	52.17	517.80	0.00
12.13	10.52	0.98	35.34	32.37	353.40	0.00
17.40	10.65	1.81	1.77	74.98	295.80	13.72
21.50	13.43	1.63	0.00	59.42	608.40	0.00
5.75	4.88	3.25	4.72	51.30	666.60	0.00
0.00	5.60	2.36	6.49	50.56	476.80	0.00
11.50	11.52	0.76	57.76	15.07	94.00	0.00
28.00	5.39	0.53	38.72	22.01	129.40	0.00
17.67	46.23	2.83	0.00	86.98	823.00	0.00
0.00	56.18	0.29	8.53	44.41	576.80	0.00
1.75	4.43	1.08	26.20	26.37	266.20	0.00
3.00	31.69	2.04	26.06	39.18	427.80	18.23
0.00	27.75	2.20	5.73	47.22	719.40	0.00
0.00	15.88	2.03	0.00	60.68	840.50	0.00
27.40	13.08	2.31	4.00	69.15	459.00	0.00
20.40	13.02	4.19	3.53	67.72	470.60	0.00
7.67	9.93	1.03	0.00	36.99	305.40	0.00
1.00	8.67	0.81	0.00	39.46	400.00	0.00
10.00	26.73	1.11	35.59	24.32	568.00	0.00
15.80	18.38	1.26	28.61	41.15	152.30	0.00
16.00	7.07	1.03	36.90	30.34	218.00	0.00
9.50	6.82	0.91	36.36	23.94	318.40	0.00
7.50	63.22	1.68	0.00	40.00	393.20	0.00
1.67	19.73	2.38	14.97	45.03	322.00	0.00
8.33	6.72	1.07	17.93	35.82	552.00	0.00
15.67	12.11	1.67	6.18	61.92	261.20	79.75
6.25	17.70	2.43	10.97	60.00	698.60	38.72
12.20	3.08	0.82	6.47	46.58	446.40	11.96
7.60	8.27	0.71	13.08	39.16	424.40	0.00
0.00	11.58	1.89	17.73	40.00	398.80	16.31
11.00	28.44	0.80	12.73	64.53	299.60	0.00
34.33	11.75	1.32	12.05	45.23	110.80	15.07

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HAAVPEA	AVPEAHA	HAAVCOW	AVCOWHA	YSIFAL	AVTOTMIL	VILPOP
34.83	966.60	0.91	133.40	24.00	1534	136
1.91	374.60	0.77	39.20	3.40	124	136
29.54	378.60	0.00	0.00	23.00	1247	1305
42.26	1219.20	0.00	0.00	30.00	927	1305
21.47	544.20	0.00	0.00	23.00	1310	231
33.23	421.60	0.00	0.00	30.00	294	231
27.79	540.20	0.00	0.00	25.30	844	587
41.60	303.60	2.35	30.00	30.00	832	587
34.91	1029.20	0.00	0.00	20.50	1000	426
39.22	509.80	0.00	0.00	24.20	1642	426
51.10	536.60	0.00	0.00	6.70	1630	186
34.36	71.67	0.00	0.00	2.50	256	186
17.42	185.20	6.33	14.40	9.40	476	404
8.67	3.00	11.44	121.00	30.00	466	404
34.90	880.20	1.67	114.20	30.00	712	646
22.34	275.20	1.51	85.20	23.00	336	646
43.73	755.80	0.00	0.00	20.30	594	451
0.00	0.00	0.00	0.00	30.00	373	451
44.35	216.60	3.00	11.80	22.75	360	320
36.88	73.25	2.84	4.40	9.25	120	320
45.30	1015.60	2.44	105.20	11.00	1236	
30.82	334.80	0.00	0.00	3.50	680	
32.65	844.00	1.62	12.60	13.40	1715	866
31.32	592.20	0.00	0.00	8.20	1352	866
26.68	250.80	9.45	70.00	0.75	581	378
11.20	0.00	6.72	25.00	15.25	1000	378
40.00	498.80	0.86	20.60	14.40	1348	610
45.30	390.40	2.34	69.60	30.00	746	610
46.71	791.20	1.68	14.20	30.00	375	166
13.23	555.40	1.33	14.20	30.00	656	166
10.39	79.60	0.00	0.00	1.00	204	48
3.33	146.80	0.00	0.00	1.50	353	48
33.99	569.60	0.00	0.00	9.25	1430	94
40.34	173.67	0.83	35.20	25.00	1275	94
49.31	760.60	0.00	0.00	30.00	234	1412
55.29	1163.20	0.00	0.00	30.00	967	1412
48.92	477.20	0.00	0.00	23.25	1004	540
34.55	773.40	0.00	0.00	24.20	2170	540
13.70	224.00	0.00	0.00	3.30	770	119
25.12	1055.40	1.00	114.20	3.20	1682	119
46.96	510.80	0.87	200.00	30.00	1080	168
25.39	622.20	2.75	69.20	16.00	468	168
23.25	535.40	0.00	0.00	24.60	1049	378
40.22	747.20	0.36	120.00	24.50	1721	378
43.98	722.00	9.35	0.00	17.75	829	808
40.35	380.80	2.60	113.60	22.75	750	808
23.09	388.20	1.84	11.00	3.50	650	36
37.99	275.40	0.00	0.00	3.00	330	34
13.02	174.00	0.00	0.00	30.00	1233	1272
47.06	428.60	0.00	0.00	11.30	764	1272
23.28	620.50	24.14	8.00	2.50	295	560
34.75	1000.40	0.00	0.00	7.20	1002	560
47.05	828.60	0.00	0.00	20.30	782	1007
39.32	142.40	0.00	0.00	30.00	1199	1007
24.92	404.20	1.92	48.00	20.40	765	280
28.74	594.80	7.35	30.40	19.20	650	280
46.58	556.80	3.01	227.40	30.00	468	305
44.34	743.20	7.15	136.50	30.00	745	305
23.07	594.80	17.02	166.60	12.80	432	258
29.55	378.60	4.11	24.60	3.20	247	258
12.76	72.60	17.59	13.00	2.70	340	419
35.15	574.40	4.55	28.20	8.75	480	419
40.00	304.80	0.00	0.00	30.00	648	547
40.00	430.33	0.00	0.00	5.67	540	547
46.25	826.40	0.00	0.00	12.30	1950	396
31.90	331.80	0.00	0.00	21.30	680	396
29.03	761.33	0.00	0.00	16.75	1880	148
46.96	378.75	0.00	0.00	14.20	2230	148
43.76	618.40	0.00	0.00	12.80	1694	210
42.32	715.40	0.00	0.00	3.20	562	210
22.74	300.20	0.00	0.00	9.25	2172	175
42.72	284.40	0.00	0.00	20.00	280	175

AVTOTPEA	AVTOTCOW	ROTATHA	HAMANAV	AVMANHA	HAPARAV	CARVIL
2788	60	100.00	0.00	0.00	0.00	18
270	20	5.73	9.46	7.99	0.00	18
810	0	20.00	0.00	0.00	7.19	97
1420	0	72.62	0.00	0.00	9.17	97
520	0	70.42	38.06	11.96	37.28	26
620	0	100.00	15.59	0.93	4.41	26
860	0	42.76	28.14	6.19	4.21	54
700	15	29.11	0.00	0.00	0.00	54
2050	0	70.56	7.46	1.72	4.88	55
1120	0	76.91	51.11	3.27	9.26	55
2400	0	100.00	31.10	2.53	7.64	17
107	0	100.00	14.13	4.28	0.00	17
380	10	19.65	8.30	1.47	0.00	50
5	52	0.00	19.63	1.20	0.00	50
560	0	100.00	0.00	0.00	0.00	43
620	40	92.47	5.35	0.80	0.00	43
563	0	100.00	11.62	3.24	11.62	50
0	0	0.00	28.86	1.40	20.00	50
356	6	85.00	19.41	0.24	0.00	39
108	53	100.00	7.90	0.63	7.90	39
1814	60	100.00	19.96	2.67	0.00	
2020	0	100.00	40.00	1.04	0.00	
1850	10	85.58	34.46	5.25	16.08	100
1820	0	47.47	17.12	2.95	0.00	100
520	84	100.00	19.13	3.29	0.00	38
0	300	20.61	43.82	2.11	0.00	38
1120	8	100.00	3.31	0.27	0.00	51
988	48	68.76	52.29	3.08	0.00	51
1307	30	91.59	44.90	3.94	3.96	13
670	60	6.01	25.32	4.73	5.41	13
124	0	10.29	8.33	0.12	0.00	4
133	0	73.23	5.54	1.36	0.00	5
3190	0	77.71	54.62	1.05	2.83	12
0	60	79.71	3.72	2.50	9.09	12
430	0	100.00	20.00	5.17	9.31	126
1380	0	100.00	37.49	11.47	0.00	126
890	0	100.00	0.00	0.00	0.00	73
1110	0	49.49	31.68	5.42	0.00	73
450	0	0.00	0.00	0.00	6.30	17
1680	40	43.06	5.64	0.81	0.00	17
1300	67	100.00	27.83	1.07	0.00	26
610	200	82.19	48.75	1.96	0.00	26
630	0	51.26	22.24	4.28	6.32	41
1500	12	80.40	55.93	1.93	0.00	41
730	0	88.21	48.46	2.69	0.00	50
520	50	87.02	46.49	3.95	0.00	50
1800	20	67.88	17.39	3.31	0.00	5
1340	0	76.45	8.16	0.00	0.00	4
100	0	32.55	0.00	0.00	0.00	75
600	0	77.94	50.00	2.56	0.00	75
765	40	39.64	13.80	1.83	0.00	34
1433	0	91.99	4.80	1.06	0.00	34
980	0	100.00	35.42	15.00	12.95	95
160	0	80.07	76.76	3.28	0.00	50
293	12	30.38	36.38	7.84	10.54	60
416	24	24.65	19.35	4.49	4.19	60
578	63	92.47	87.40	5.40	0.00	20
1075	100	84.01	81.90	10.42	0.00	20
720	138	79.73	15.63	2.90	0.00	60
1033	13	89.73	4.11	1.40	0.00	60
81	30	87.93	0.00	0.00	0.00	54
1377	24	6.06	4.85	3.75	0.00	53
583	0	100.00	53.75	3.92	0.00	85
490	0	100.00	0.00	0.00	0.00	85
3300	0	93.70	5.10	4.50	0.00	45
660	0	79.75	22.38	3.09	13.82	45
840	0	61.28	5.40	0.33	20.00	28
1526	0	0.00	0.00	0.00	0.00	28
2700	0	56.12	0.00	0.00	5.92	43
1240	0	62.65	24.59	6.52	0.00	43
1400	0	20.89	0.00	0.00	18.56	38
734	0	100.00	34.17	2.00	5.73	38

DISROAD	DISSOD	DSCERDEF	WELL	TIMEVIL	TOTADM	TOTADF
0.3	16.0	16.0	71	54	4	3
0.5	3.0	20.0	71	41	4	3
6.0	6.0	6.0	7	60	4	4
3.5	3.5	3.5	7	40	1	3
2.0	1.5	15.0	64	60	2	4
1.2	1.5	18.0	64	64	2	2
0.1	7.0	20.0	10	52	2	3
0.1	7.0	20.0	10	52	1	2
7.0	7.0	7.0	35	59	2	2
7.0	7.0	7.0	35	45	3	4
18.0	7.0	7.0	72	64	5	4
17.0	7.0	7.0	72	40	3	2
7.0	25.0	11.0	22	30	2	2
8.0	25.0	25.0	22	5	2	2
0.0	8.0	30.0	57	55	1	2
0.0	9.0	30.0	57	36	2	4
6.0	6.0	6.0	8	60	2	1
8.0	5.0	5.0	8	58	3	2
4.0	9.0	23.0	50	71	1	1
4.0	9.0	23.0	50	35	1	1
10.0	10.0	17.0	17	61	4	2
9.0	10.0	17.0	17	57	4	6
0.0	6.0	6.0	90	32	3	4
0.3	5.0	5.0	43	35	3	2
11.0	11.0	13.0	15	30	2	9
10.0	11.0	20.0	15	50	2	2
3.5	16.0	16.0	26	47	2	3
3.5	16.0	16.0	26	36	2	3
4.0	6.0	12.0	14	48	1	3
6.5	6.5	12.0	33	45	7	4
0.8	7.0	15.0	90	30	1	1
0.5	7.0	14.0	90	3	1	1
3.0	3.0	3.5	9	45	4	3
2.0	16.0	2.0	9	35	1	1
12.0	5.0	5.0	16	30	1	1
12.0	12.0	12.0	16	30	4	2
21.0	1.0	16.0	25	53	3	4
21.0	1.0	16.0	25	56	3	6
6.0	8.0	8.0	40	48	2	1
6.0	8.0	8.0	40	35	2	3
16.0	7.0	7.0	45	55	1	3
16.0	7.0	7.0	44	47	1	1
15.0	6.0	6.0	19	34	4	1
16.0	6.0	6.0	16	46	1	3
7.0	7.0	17.0	51	62	1	2
7.0	7.0	14.0	45	44	4	1
6.0	7.0	7.0	48	56	3	2
7.0	7.0	7.0	48	34	2	1
7.0	4.0	4.0	12	60	1	1
7.0	7.0	7.0	12	30	1	1
7.0	12.0	22.0	33	64	1	2
7.0	12.0	22.0	33	60	3	2
3.0	6.0	6.0	24	50	1	3
3.0	6.0	6.0	24	50	1	1
3.5	9.0	11.0	70	34	2	2
7.0	9.0	12.0	70	47	2	2
9.0	3.0	3.0	25	56	1	2
7.0	2.0	2.0	25	60	3	1
8.0	8.0	8.0	50	62	2	4
8.0	8.0	8.0	48	62	5	5
10.0	16.0	10.0	60	60	2	2
10.0	16.0	10.0	60	60	3	2
7.0	14.0	26.0	35	35	1	1
7.0	14.0	26.0	35	35	2	2
3.0	13.0	25.0	63	70	1	3
3.0	18.0	25.0	63	60	5	2
15.0	29.0	12.0	70	45	2	2
15.0	29.0	12.0	70	31	2	1
8.0	14.0	8.0	50	73	2	4
8.0	14.0	8.0	50	57	2	1
12.0	16.0	16.0	70	45	1	2
10.0	15.0	20.0	70	30	1	1

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AARLOC	AACTIV	YMALE	YFEMALE	YFRENCH	YARABIC	EMRATE
50.0	100.0	2	2	0.0	0.0	22.2
42.9	100.0	6	1	0.0	0.0	0.0
0.0	100.0	2	3	0.0	0.0	11.1
0.0	75.0	1	2	0.0	0.0	0.0
16.7	100.0	1	1	0.0	0.0	14.3
0.0	100.0	1	0	0.0	0.0	42.9
0.0	100.0	3	2	60.0	0.0	16.7
16.7	66.7	0	1	100.0	0.0	0.0
25.0	100.0	1	0	100.0	0.0	0.0
14.3	100.0	0	2	50.0	0.0	22.2
0.0	88.9	4	2	0.0	8.3	0.0
20.0	100.0	1	0	0.0	0.0	16.7
0.0	75.0	3	1	25.0	37.5	0.0
25.0	75.0	2	1	33.3	33.3	0.0
0.0	100.0	1	0	0.0	100.0	25.0
16.7	83.3	3	1	25.0	0.0	0.0
0.0	100.0	2	1	33.3	0.0	0.0
0.0	100.0	1	0	0.0	0.0	16.7
0.0	100.0	0	0	0.0	0.0	0.0
0.0	100.0	0	0	0.0	0.0	0.0
50.0	100.0	0	1	0.0	0.0	14.3
30.0	100.0	4	4	0.0	6.3	0.0
0.0	71.4	1	2	100.0	0.0	0.0
30.0	60.0	1	0	0.0	0.0	0.0
9.1	81.8	3	2	0.0	40.0	0.0
25.0	75.0	2	0	0.0	0.0	20.0
0.0	60.0	0	0	0.0	0.0	0.0
0.0	100.0	2	0	0.0	0.0	0.0
0.0	100.0	1	0	0.0	0.0	0.0
50.0	100.0	2	3	0.0	20.0	0.0
25.0	100.0	0	0	0.0	0.0	0.0
0.0	100.0	0	1	0.0	0.0	0.0
0.0	100.0	0	1	0.0	0.0	0.0
0.0	100.0	1	1	0.0	0.0	0.0
0.0	100.0	1	1	0.0	0.0	33.3
0.0	83.3	0	1	0.0	0.0	0.0
28.6	85.7	3	3	33.3	16.7	0.0
0.0	88.9	4	4	50.0	25.0	10.0
0.0	66.7	2	1	0.0	33.3	0.0
20.0	80.0	2	0	0.0	50.0	0.0
25.0	75.0	2	0	0.0	10.0	20.0
0.0	100.0	2	1	0.0	16.7	33.3
0.0	100.0	0	2	0.0	0.0	0.0
0.0	100.0	3	1	50.0	0.0	0.0
0.0	66.7	0	1	0.0	0.0	0.0
20.0	100.0	0	1	0.0	0.0	28.6
0.0	100.0	3	2	0.0	0.0	0.0
0.0	100.0	2	0	0.0	0.0	0.0
0.0	100.0	2	1	0.0	0.0	0.0
50.0	100.0	0	1	0.0	0.0	0.0
0.0	100.0	2	1	0.0	0.0	25.0
40.0	100.0	2	0	0.0	0.0	28.6
0.0	75.0	3	2	0.0	0.0	0.0
33.3	100.0	1	1	0.0	0.0	0.0
16.7	66.7	1	1	50.0	0.0	0.0
0.0	100.0	0	0	0.0	0.0	0.0
0.0	100.0	1	2	0.0	0.0	25.0
25.0	100.0	0	0	0.0	0.0	33.3
0.0	100.0	1	2	0.0	0.0	0.0
50.0	100.0	1	0	0.0	0.0	0.0
0.0	50.0	1	1	0.0	0.0	0.0
40.0	100.0	2	1	33.3	33.3	0.0
0.0	100.0	1	0	100.0	0.0	0.0
25.0	100.0	0	1	100.0	0.0	0.0
0.0	100.0	0	0	0.0	0.0	0.0
14.3	100.0	2	0	0.0	0.0	0.0
25.0	100.0	3	2	0.0	0.0	0.0
33.3	100.0	3	1	0.0	50.0	0.0
0.0	100.0	1	0	0.0	50.0	0.0
0.0	100.0	2	2	0.0	50.0	0.0
0.0	100.0	0	3	0.0	0.0	0.0
0.0	100.0	0	0	0.0	0.0	0.0

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PCTEXAG	COWS	SHPGOAT	TOOLS	YRSCHEP	AREAO TH	AREAREC
0.0	0	2	9	39	0.0	0.0
0.0	0	0	7	12	28.0	0.0
0.0	10	6	2	30	0.0	0.0
0.0	10	0	5	23	0.0	0.0
48.4	2	4	5	14	60.0	0.0
27.5	0	4	3	45	0.0	0.0
0.0	0	4	4	16	0.0	0.0
0.0	0	2	0	35	0.0	0.0
52.5	1	3	3	34	0.0	0.0
0.0	3	9	2	20	0.0	0.0
4.5	4	3	9	26	0.0	18.1
42.5	0	0	4	1	0.0	0.0
0.0	0	4	4	10	0.0	0.0
26.4	0	4	2	1	0.0	0.0
0.0	0	0	2	10	0.0	0.0
10.3	0	4	2	9	0.0	0.0
0.0	1	3	3	12	0.0	0.0
66.6	3	1	2	30	0.0	0.0
0.0	3	3	2	50	0.0	0.0
0.0	5	4	2	5	0.0	0.0
31.1	0	6	6	22	0.0	0.0
22.5	0	8	8	23	0.0	0.0
43.3	6	1	5	0	0.0	0.0
20.5	0	10	5	30	0.0	0.0
0.0	0	8	5	8	27.3	0.0
0.0	0	6	2	30	0.0	0.0
0.0	0	4	3	20	0.0	0.0
47.5	0	1	2	6	0.0	0.0
0.0	0	4	8	24	22.2	0.0
11.6	1	12	4	17	14.9	7.3
0.0	1	0	8	30	100.0	0.0
69.0	0	5	1	3	0.0	0.0
26.4	1	4	8	31	0.0	5.7
0.0	0	2	3	23	0.0	0.0
0.0	1	2	6	7	0.0	0.0
19.8	3	0	4	9	0.0	0.0
51.2	5	8	3	30	0.0	43.6
25.6	5	1	7	20	0.0	28.8
0.0	0	5	1	25	0.0	0.0
0.0	0	6	3	10	0.0	0.0
52.5	0	4	4	14	0.0	14.0
0.0	0	8	3	47	0.0	0.0
56.7	0	1	2	17	0.0	15.3
0.0	0	3	5	15	0.0	0.0
53.5	0	5	2	34	0.0	0.0
22.5	0	10	3	43	0.0	0.0
0.0	0	14	7	11	0.0	0.0
0.0	0	0	7	55	10	0.0
0.0	4	2	0	25	0.0	0.0
22.6	4	10	4	10	0.0	0.0
0.0	0	4	2	29	23.5	0.0
0.0	0	10	4	38	53.8	0.0
0.0	1	8	4	25	0.0	0.0
0.0	2	3	3	32	0.0	0.0
31.5	0	2	1	15	15.8	16.1
30.7	0	0	2	2	16.7	27.1
40.2	0	4	4	4	0.0	0.0
52.5	0	2	3	60	0.0	0.0
63.4	0	6	4	40	0.0	0.0
0.0	0	0	7	10	68.2	0.0
30.7	0	0	4	46	0.0	0.0
0.0	0	4	7	40	0.0	0.0
0.0	0	0	4	3	0.0	0.0
54.9	0	18	2	6	10	0.0
0.0	0	8	7	40	0.0	0.0
31.7	5	8	6	30	0.0	23.8
0.0	1	2	6	23	0.0	0.0
35.8	0	0	3	5	0.0	0.0
8.7	0	7	7	40	61.9	0.0
0.0	4	10	2	10	0.0	0.0
0.0	4	14	6	20	0.0	0.0
0.0	0	8	0	4	0.0	0.0

HANOEX	REALSIL	EXTRATE	ASSOC	AGCOEF	FORCOEF	AALB1140
0.0	3.2	0	16	0	0	0.71
7.0	37.5	2	0	0	0	0.30
28.0	14.3	0	0	6	4	0.00
30.0	0.0	0	0	5	3	0.00
0.0	77.8	0	6	0	0	1.57
0.0	40.7	0	0	0	0	0.25
7.0	25.9	25	0	5	4	0.00
8.0	21.6	0	0	0	0	0.23
20.0	15.4	0	0	0	0	0.00
20.0	21.9	0	0	3	2	0.54
0.0	23.1	0	10	0	0	3.08
0.0	45.9	0	9	0	0	2.33
0.0	44.4	0	8.7	0	0	0.00
0.0	0.0	0	0	0	0	5.85
0.0	0.0	0	10	0	0	0.00
0.0	58.8	0	23	0	0	0.80
30.0	0.0	1	30	0	0	0.00
30.0	58.3	1	0	1	0	0.00
0.0	0.0	5	0	0	0	0.29
0.0	32.0	5	0	0	0	0.31
0.0	67.9	0	9	0	0	1.28
0.0	0.0	0	12	0	0	2.22
3.0	43.8	0	20	0	0	0.30
15.0	44.4	0	11	1	1	0.55
0.0	38.1	0	22.3	0	0	0.00
0.0	0.0	0	8	0	0	0.00
0.0	0.0	0	0	0	0	1.87
10.0	0.0	1	17	3	0	3.23
0.0	0.0	0	12	0	0	6.21
0.0	70.4	1	18	0	0	3.64
0.0	22.7	0	0	0	0	0.74
80.0	86.1	0	18	0	0	0.68
0.0	59.0	0	21	0	0	0.20
0.0	99.1	0	9	0	0	1.09
30.0	87.5	1	0	0	0	0.00
25.0	46.4	4	11	0	1	0.00
15.0	0.0	0	0	0	0	0.00
15.0	83.3	0	0	5	2	0.00
15.0	0.0	0	0	0	0	0.63
15.0	82.6	0	0	0	0	0.57
0.0	97.1	0	0	0	0	0.43
0.0	13.3	0	0	0	0	0.42
10.0	0.0	0	0	0	0	0.00
9.0	50.0	0	0	5	4	0.00
15.0	59.3	0	9	0	0	0.00
15.0	68.2	0	24.5	0	0	0.00
50.0	52.0	0	0	0	0	0.25
0.0	90.3	0	0	0	0	0.00
0.0	50.0	0	0	0	0	1.89
0.0	18.2	4	21	0	1	0.00
0.0	77.1	6	31.5	4	3	0.00
60.0	27.1	6	21	0	3	2.04
4.0	0.0	1	19	1	0	0.88
4.0	40.0	9	0	3	0	0.68
0.0	81.7	0	0	0	0	2.31
1.3	15.3	0	0	0	0	1.40
0.0	0.0	0	8	0	0	1.37
0.0	36.8	0	15.5	0	0	0.54
10.0	50.0	0	0	4	3	3.12
0.0	50.0	0	0	0	0	0.54
15.0	75.6	4	0	4	0	0.17
0.0	0.0	12	28	0	0	0.15
14.0	20.0	0	10	7	0	0.24
0.0	0.0	0	0	0	0	1.02
30.0	33.3	0	0	0	0	1.60
30.0	98.8	1	0	1	0	0.21
50.0	33.3	0	21	1	0	0.44
0.0	34.5	1	17	0	0	0.00
0.0	6.3	1	12	0	0	1.53
6.0	0.0	5	10	1	0	0.95
0.0	0.0	0	16	0	0	1.07
1.0	62.5	0	15	0	0	1.32

ANMONPAR	CONSMES	TRACAN	PRIVATE	COMMUNAL	PCTCAD	TOTHAY
0.00	0.00	2	0	0	60	3.42
0.00	3.84	2	0	0	40	0.00
4.49	20.00	3	0	0	80	2.88
32.59	30.36	2	1	0	100	11.88
265.04	0.00	2	0	0	40	10.43
11.36	0.00	2	1	0	0	4.19
2.46	31.21	1	1	0	40	4.46
0.00	0.00	1	1	0	20	1.35
0.71	0.00	2	1	0	40	2.93
2.27	47.79	3	1	1	60	3.96
13.19	0.00	9	0	1	0	3.59
0.00	0.00	3	0	1	60	0.82
0.00	31.66	3	0	0	0	0.00
0.00	0.00	1	0	0	40	0.00
0.00	0.00	1	1	0	20	2.49
0.00	0.00	1	0	0	20	4.77
11.59	0.00	1	0	1	60	0.97
25.20	72.15	1	0	1	60	0.00
0.00	0.00	1	0	0	0	0.87
2.81	0.00	1	0	0	0	0.35
0.00	0.00	4	0	0	60	3.69
0.00	0.00	3	0	0	60	1.23
13.83	0.00	3	1	0	40	9.67
0.00	52.53	2	0	0	100	1.75
0.00	0.00	2	0	0	0	0.29
0.00	0.00	1	0	0	40	0.00
0.00	0.00	1	0	0	40	1.16
0.00	0.00	1	0	0	0	1.88
2.83	38.84	2	0	1	80	1.88
2.81	0.00	2	1	1	40	14.31
0.00	0.00	1	0	0	40	2.38
0.00	0.00	2	0	0	20	3.13
1.30	14.15	1	1	0	40	2.25
2.41	8.02	1	1	0	80	8.82
2.22	0.00	1	0	0	40	6.24
0.00	11.03	2	0	0	40	4.72
0.00	0.00	2	0	0	40	5.17
0.00	0.00	4	0	0	60	6.37
3.97	0.00	1	0	0	60	0.00
0.00	60.37	1	0	0	20	6.65
0.00	0.00	1	0	0	40	6.96
0.00	0.00	2	1	0	40	2.30
9.95	0.00	5	0	0	20	1.23
0.00	57.89	1	0	0	40	12.77
0.00	0.00	0	0	1	40	3.65
0.00	26.84	1	1	1	20	7.65
0.00	3.74	4	0	0	40	2.68
0.00	0.00	3	0	0	40	1.85
0.00	48.58	1	1	0	60	0.72
0.00	57.35	2	1	0	60	1.20
0.00	0.00	1	0	0	60	4.54
0.00	0.00	1	0	0	40	5.08
13.24	0.00	1	0	0	60	7.44
0.00	19.93	2	1	0	80	1.24
3.45	20.77	2	0	0	40	9.56
1.96	0.00	1	1	0	40	7.55
0.00	0.00	1	0	0	0	28.91
0.00	0.00	1	1	0	0	13.73
0.00	15.37	1	0	1	20	7.64
0.00	0.00	3	0	0	20	1.74
0.00	0.00	2	0	0	60	1.43
0.00	0.00	3	0	0	40	2.16
0.00	0.00	1	0	0	40	1.28
0.00	0.00	1	0	0	40	2.05
0.00	0.00	2	0	0	40	2.29
3.65	0.00	3	0	0	40	1.57
41.98	0.00	5	0	0	60	4.33
0.00	0.00	2	0	0	40	1.29
1.24	65.41	2	0	0	20	3.17
0.00	0.00	1	0	0	40	1.49
20.68	0.00	7	0	0	20	3.90
0.19	0.00	0	0	0	20	1.31

HAAVFER	ETHNIC	HAAVMOC	AVMOCHA	TOTCAD	GOODHA	FAIRHA
0.00	0	0.0	0.0	10.65	81.95	18.05
0.00	0	0.0	0.0	6.78	56.52	0.00
0.00	1	0.0	0.0	3.46	100.00	0.00
0.00	1	0.0	0.0	5.06	0.00	0.00
0.00	0	0.0	0.0	9.42	0.00	0.00
0.00	0	0.0	0.0	9.02	77.94	0.00
0.00	1	0.0	0.0	4.66	31.21	0.00
0.00	1	0.0	0.0	3.52	100.00	0.00
0.00	1	0.0	0.0	9.41	100.00	0.00
0.00	1	0.0	0.0	6.58	100.00	0.00
7.64	0	0.0	0.0	5.40	27.75	0.00
0.00	0	0.0	0.0	3.50	48.48	0.00
0.00	0	24.6	98.6	22.49	54.37	0.00
0.00	0	33.9	404.2	41.49	73.67	26.33
0.00	0	0.0	0.0	11.90	0.00	74.52
0.00	0	0.0	0.0	18.75	92.47	7.53
0.00	1	0.0	0.0	19.57	0.00	0.00
0.00	1	0.0	0.0	35.44	0.00	100.00
0.00	1	0.0	0.0	7.06	70.29	29.71
0.00	1	0.0	0.0	4.32	0.00	0.00
0.00	0	0.0	0.0	26.92	47.22	26.50
0.00	0	0.0	0.0	17.02	100.00	0.00
0.00	1	0.0	0.0	4.06	100.00	0.00
0.00	0	0.0	0.0	3.59	0.00	0.00
0.00	0	0.0	0.0	8.50	9.88	0.00
0.00	0	0.0	0.0	3.44	79.39	0.00
0.00	1	0.0	0.0	6.95	16.54	12.46
0.00	1	0.0	0.0	12.39	0.00	0.00
0.00	0	0.0	0.0	18.02	19.82	0.00
0.00	0	0.0	0.0	22.63	66.93	6.01
0.00	0	0.0	0.0	5.51	0.00	58.33
0.00	0	0.0	0.0	2.73	56.61	0.00
18.02	0	0.0	0.0	1.81	36.44	0.00
0.00	0	0.0	0.0	5.47	65.74	0.00
0.00	1	0.0	0.0	12.93	0.00	0.00
0.00	1	0.0	0.0	15.21	100.00	0.00
14.85	1	0.0	0.0	11.34	100.00	0.00
0.00	1	0.0	0.0	4.65	18.18	0.00
0.00	1	0.0	0.0	4.59	100.00	0.00
0.00	1	0.0	0.0	8.15	82.55	0.00
0.00	0	0.0	0.0	6.74	39.13	0.00
4.15	0	0.0	0.0	3.93	40.39	0.00
0.00	1	0.0	0.0	4.15	100.00	0.00
0.00	1	0.0	0.0	7.80	0.00	0.00
0.00	0	0.0	0.0	1.22	41.46	0.00
0.00	0	0.0	0.0	0.88	40.71	0.00
0.00	0	2.2	108.2	3.74	67.68	32.32
0.00	0	1.3	0.0	0.79	35.64	64.36
0.00	1	0.0	0.0	36.32	51.42	0.00
0.00	1	0.0	0.0	56.18	0.00	20.59
6.37	0	0.0	0.0	2.16	7.78	68.98
6.81	0	0.0	0.0	21.98	100.00	0.00
0.00	1	0.0	0.0	25.99	0.00	0.00
0.00	1	0.0	0.0	13.18	0.00	0.00
9.62	1	0.0	0.0	9.23	20.00	0.00
0.00	1	0.0	0.0	6.05	86.98	0.00
0.00	0	0.0	0.0	6.85	7.53	0.00
0.00	0	0.0	0.0	5.69	100.00	0.00
18.75	0	0.0	0.0	15.37	100.00	0.00
0.00	0	0.0	0.0	13.33	100.00	0.00
0.00	0	0.0	0.0	4.66	0.00	0.00
4.85	0	0.0	0.0	5.15	46.97	53.03
0.00	0	0.0	0.0	56.49	0.00	12.02
0.00	0	0.0	0.0	15.65	0.00	25.17
0.00	1	0.0	0.0	5.12	64.78	0.00
0.00	1	0.0	0.0	7.72	100.00	0.00
19.12	1	0.0	0.0	1.77	38.72	0.00
0.00	1	0.0	0.0	0.00	100.00	0.00
0.00	0	0.0	0.0	5.82	0.00	100.00
0.00	0	0.0	0.0	8.04	0.00	53.43
0.00	1	0.0	0.0	25.07	0.00	100.00
11.26	1	0.0	0.0	7.12	0.00	56.29

TOTFAM	AREACE	AREASUP	CADHA	AGE	EXPCAR	DISMAR
15	83.33		0.00	67	1	16.0
16	12.00	60.00	0.00	58	1	3.0
18	0.00	100.00	0.00	60	3	6.0
9	0.00	100.00	38.39	40	1	3.5
10	40.00	0.00	75.92	60	1	1.5
7	28.57	71.43	0.00	70	1	1.2
11	75.00	25.00	0.00	52	1	7.0
7	100.00	0.00	0.00	52	1	7.0
6	100.00	0.00	0.00	59	1	7.0
14	0.00	100.00	24.70	45	1	7.0
17	55.56	44.44	0.00	64	2	1.2
8	0.00	100.00	0.00	40	3	1.2
10	66.67	33.33	74.02	45	1	4.5
9	0.00	100.00	73.67	56	1	20.0
5	100.00	0.00	74.52	55	1	8.0
12	100.00	0.00	73.24	36	4	9.0
7	0.00	100.00	100.00	60	2	9.0
7	0.00	100.00	0.00	58	2	9.0
2	100.00	0.00	21.76	71	1	6.0
2	33.33	66.67	0.00	35	5	6.0
7	50.00	50.00	100.00	61	2	14.0
23	16.67	83.33	100.00	57	3	14.0
12	100.00	0.00	0.00	32	1	25.0
10	0.00	100.00	0.00	55	1	0.3
22	0.00	72.73	0.00	30	1	4.0
7	33.33	66.67	0.00	50	1	3.0
5	100.00	0.00	0.00	47	2	3.5
13	12.50	87.50	0.00	36	1	3.5
5	33.33	44.44	80.18	70	1	6.0
18	8.51	76.60	93.35	62	1	6.5
4	0.00	0.00	0.00	65	1	2.0
6	23.53	76.47	26.77	47	1	3.0
8	23.81	76.19	0.00	61	1	12.0
4	0.00	100.00	100.00	68	1	12.0
4	0.00	100.00	0.00	30	2	0.0
7	0.00	100.00	0.00	30	2	0.0
20	75.00	25.00	74.23	53	1	14.0
21	29.94	70.06	0.00	56	1	14.0
8			41.96	48	1	7.0
9	46.32	53.68	0.00	35	1	7.0
7	50.00	50.00	95.65	74	1	7.0
7	0.00	100.00	86.82	47	1	7.0
7	0.00	100.00	0.00	34	2	6.0
14	0.00	100.00	0.00	46	1	6.0
5	36.36	63.64	19.92	62	1	9.0
6	0.00	100.00	72.27	73	1	9.0
13	20.00	80.00	88.69	56	1	7.0
7	0.00	0.00	0.00	77	1	7.0
7	100.00	0.00	0.00	60	5	7.0
4	0.00	100.00	0.00	30	2	7.0
6	52.94	23.53	0.00	64	1	7.0
9	23.08	23.08	0.00	68	1	7.0
9	0.00	100.00	100.00	50	1	0.5
6	0.00	100.00	0.00	50	1	0.5
7	31.58	52.63	0.00	34	1	5.0
4	16.67	66.67	42.33	47	1	7.0
8	71.43	28.57	0.00	56	4	3.0
6	16.67	83.33	0.00	60	2	2.0
9	30.77	69.23	0.00	70	2	8.0
14	31.82	0.00	0.00	35	1	8.0
6	46.15	53.85	48.28	86	2	0.0
9	100.00	0.00	69.70	61	1	0.0
5	25.00	75.00	100.00	35	2	0.0
7	0.00	0.00	74.83	33	2	0.0
6			30.52	70	1	7.0
11	0.00	100.00	0.00	60	1	7.0
15	40.00	60.00	0.00	45	2	3.0
8	100.00	0.00	0.00	31	1	3.0
7	33.33	4.76	0.00	73	1	8.0
8	30.77	69.23	41.84	57	1	8.0
7	100.00	0.00	100.00	45	2	7.0
4	100.00	0.00	100.00	30	3	5.0

TOTEXAG	AREALOAN	AALB4160	CONFLICT	POORHA	AFRENCH
0.0	0.0	1.12	1	0.00	0.0
0.0	0.0	0.60	1	43.48	0.0
0.0	19.2	0.77	0	0.00	12.5
0.0	0.0	3.87	0	100.00	0.0
33.3	0.0	7.07	1	100.00	0.0
25.0	0.0	7.52	0	22.06	25.0
0.0	34.5	1.03	0	68.79	40.0
0.0	0.0	0.70	0	0.00	33.3
50.0	17.4	3.48	0	0.00	0.0
0.0	13.4	2.01	0	0.00	14.3
22.2	0.0	2.31	1	72.25	0.0
40.0	7.0	1.17	1	0.00	0.0
0.0	0.0	0.87	0	45.63	0.0
25.0	186.2	0.80	1	0.00	0.0
0.0	0.0	3.57	0	25.48	0.0
16.7	16.0	0.80	0	0.00	0.0
0.0	0.0	3.67	0	100.00	0.0
20.0	63.3	7.59	0	0.00	0.0
0.0	0.0	2.65	0	0.00	0.0
0.0	0.0	4.01	0	100.00	0.0
16.7	0.0	9.19	1	26.28	0.0
20.0	0.0	4.17	1	0.00	0.0
14.3	10.2	1.02	0	0.00	21.4
20.0	92.2	1.47	0	100.00	10.0
0.0	0.0	5.14	0	90.12	0.0
0.0	0.0	1.15	0	20.61	0.0
0.0	0.0	3.42	0	71.00	0.0
40.0	0.0	1.53	0	100.00	0.0
0.0	10.0	8.91	0	80.18	0.0
9.1	31.6	7.59	0	27.06	0.0
0.0	0.0	0.00	1	41.67	0.0
50.0	0.0	0.23	1	43.39	0.0
28.6	0.0	1.25	0	63.56	0.0
0.0	36.5	1.46	0	34.26	0.0
0.0	0.0	5.17	0	100.00	0.0
33.3	0.0	3.04	0	0.00	25.0
28.6	0.0	7.47	0	0.00	14.3
11.1	0.0	2.83	0	81.82	11.1
0.0	20.9	2.51	1	0.00	0.0
0.0	42.9	1.00	1	17.45	20.0
50.0	0.0	4.78	1	60.87	0.0
0.0	0.0	2.81	1	64.52	0.0
40.0	0.0	3.43	0	0.00	0.0
0.0	0.0	1.63	0	100.00	0.0
66.7	122.0	1.22	0	58.54	0.0
20.0	0.0	0.88	0	59.29	40.0
0.0	0.0	0.51	0	0.00	0.0
0.0	0.0	0.11	0	0.00	0.0
0.0	0.0	2.83	0	48.58	0.0
50.0	11.8	1.47	0	79.41	0.0
0.0	0.0	0.96	1	23.23	0.0
0.0	0.0	4.94	1	0.00	0.0
0.0	0.0	7.49	0	100.00	0.0
0.0	0.0	6.42	0	100.00	0.0
33.3	0.0	6.92	1	80.00	0.0
25.0	27.9	3.72	1	13.02	0.0
33.3	0.0	5.48	0	92.47	0.0
50.0	54.2	3.52	0	0.00	0.0
16.7	0.0	3.12	1	0.00	0.0
0.0	18.0	0.09	1	0.00	0.0
50.0	25.9	1.38	0	100.00	0.0
0.0	45.5	1.21	0	0.00	0.0
0.0	0.0	1.68	0	87.98	0.0
25.0	0.0	3.06	0	74.83	0.0
0.0	0.0	1.81	0	35.22	0.0
42.9	0.0	1.67	0	0.00	0.0
0.0	33.2	0.00	1	61.28	25.0
33.3	0.0	0.00	1	0.00	0.0
16.7	0.0	3.67	1	0.00	0.0
0.0	0.0	2.84	1	46.57	0.0
0.0	0.0	0.36	0	0.00	0.0
0.0	0.0	0.33	0	43.71	0.0

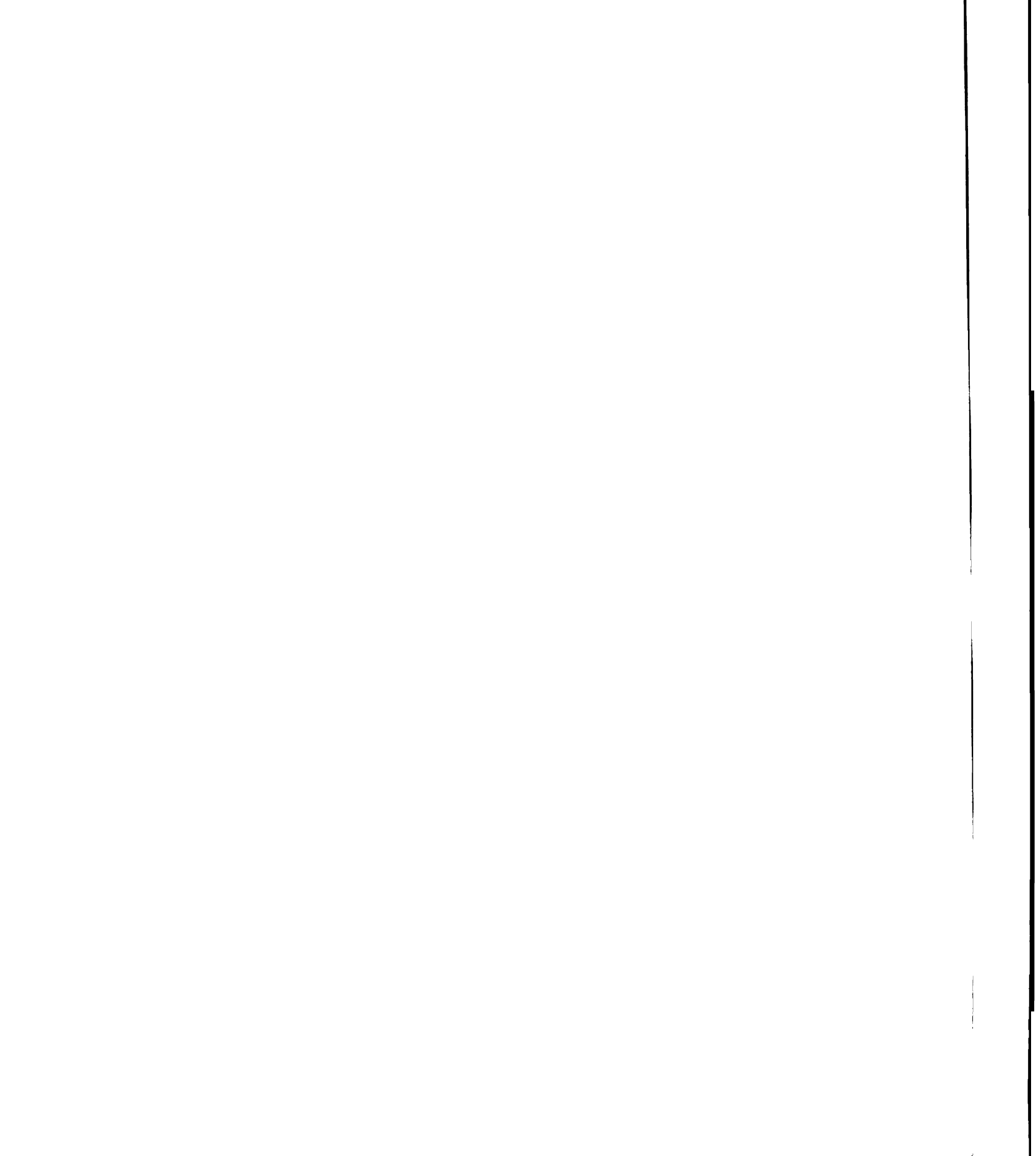
SUMMARY STATISTICS

	NUMPAR	AREAC	AVDIS	PRUCAD	CRWOTH
N OF CASES	72	72	72	72	72
MINIMUM	2.000	0.790	0.013	0.000	0.000
MAXIMUM	8.000	24.810	2.900	33.800	10.097
RANGE	6.000	24.020	2.887	33.800	10.097
MEAN	4.236	6.447	0.684	13.557	1.225
VARIANCE	1.225	19.605	0.322	78.490	1.983
STANDARD DEV	1.107	4.428	0.567	8.859	1.408
STD. ERROR	0.130	0.522	0.067	1.044	0.166
SKEWNESS(G1)	0.402	1.905	1.565	0.242	3.810
KURTOSIS(G2)	0.667	4.266	2.791	-0.706	20.209
SUM	305.000	464.200	49.229	976.108	88.205
C.V.	0.261	0.687	0.830	0.653	1.149

	PRUOTH	TOTOTH	BIODIV	HAAVFAL	HAAVMIL
N OF CASES	72	72	72	72	72
MINIMUM	0.000	3.080	0.294	0.000	10.888
MAXIMUM	34.333	63.221	4.255	79.134	86.981
RANGE	34.333	60.141	3.961	79.134	76.093
MEAN	12.149	16.858	1.692	15.297	44.494
VARIANCE	77.144	150.866	0.809	290.450	207.221
STANDARD DEV	8.783	12.283	0.899	17.043	14.395
STD. ERROR	1.035	1.448	0.106	2.008	1.696
SKEWNESS(G1)	0.525	1.778	0.846	1.313	0.089
KURTOSIS(G2)	-0.394	3.200	0.172	1.663	0.240
SUM	874.725	1213.788	121.806	1101.405	3203.590
C.V.	0.723	0.729	0.532	1.114	0.324

	AVMILHA	HAAVPEA	AVPEAHA	HAAVCOW	AVCOWHA
N OF CASES	72	72	72	72	72
MINIMUM	59.200	0.000	0.000	0.000	0.000
MAXIMUM	997.600	55.285	1219.200	24.144	227.400
RANGE	938.400	55.285	1219.200	24.144	227.400
MEAN	395.960	32.710	503.187	2.273	30.985
VARIANCE	47539.961	165.613	86274.649	20.091	2792.874
STANDARD DEV	218.037	12.869	293.725	4.482	52.848
STD. ERROR	25.696	1.517	34.616	0.528	6.228
SKEWNESS(G1)	0.719	-0.683	0.337	2.945	1.904
KURTOSIS(G2)	0.067	-0.244	-0.473	9.249	2.916
SUM	28509.117	2355.137	36229.497	163.680	2230.900
C.V.	0.551	0.393	0.584	1.972	1.706

	YSIFAL	AVTOTMIL	AVTOTPEA	AVTOTCOW	ROTATEA
N OF CASES	72	72	72	72	72
MINIMUM	0.750	120.000	0.000	0.000	0.000
MAXIMUM	30.000	2230.000	3300.000	300.000	100.000
RANGE	29.250	2110.000	3300.000	300.000	100.000
MEAN	17.228	885.674	962.022	24.289	67.552
VARIANCE	103.125	295037.842	569714.136	2341.801	1100.291
STANDARD DEV	10.155	543.174	754.794	48.392	33.171
STD. ERROR	1.197	64.014	88.953	5.703	3.909
SKEWNESS(G1)	-0.165	0.751	1.129	3.543	-0.798
KURTOSIS(G2)	-1.391	-0.296	1.086	15.160	-0.733
SUM	1240.417	63768.500	69265.600	1748.833	4863.714
C.V.	0.589	0.613	0.785	1.992	0.491



	HAMANAV	AVMANHA	HAPARAV	PAROTH	CADHA
N OF CASES	72	72	72	72	72
MINIMUM	0.000	0.000	0.000	0.000	0.000
MAXIMUM	87.397	15.000	37.277	88.211	100.000
RANGE	87.397	15.000	37.277	88.211	100.000
MEAN	22.423	2.841	3.813	9.311	31.160
VARIANCE	454.357	9.416	44.241	429.929	1560.543
STANDARD DEV	21.316	3.068	6.651	20.735	39.504
STD. ERROR	2.512	0.362	0.784	2.444	4.656
SKEWNESS(G1)	1.010	1.768	2.502	2.149	0.710
KURTOSIS(G2)	0.529	3.557	7.929	3.659	-1.208
SUM	1614.472	204.557	274.570	670.422	2243.550
C.V.	0.951	1.080	1.744	2.227	1.268

	HAKHOR	AGE	VILPOP	EXPCAR	CARVIL
N OF CASES	72	72	70	72	70
MINIMUM	0.000	30.000	34.000	1.000	4.000
MAXIMUM	79.749	86.000	1412.000	5.000	126.000
RANGE	79.749	56.000	1378.000	4.000	122.000
MEAN	4.783	52.708	454.029	1.528	46.257
VARIANCE	160.556	191.956	126001.854	0.872	788.455
STANDARD DEV	12.671	13.855	354.967	0.934	28.079
STD. ERROR	1.493	1.633	42.427	0.110	3.356
SKEWNESS(G1)	3.719	-0.061	1.255	2.112	0.817
KURTOSIS(G2)	16.463	-0.829	0.881	4.294	0.477
SUM	344.375	3795.000	31782.000	110.000	3238.000
C.V.	2.649	0.263	0.782	0.611	0.607

	DISMAR	DISROAD	DISSOD	DSCERDEF	WELL
N OF CASES	72	72	72	72	72
MINIMUM	0.000	0.000	1.000	2.000	7.000
MAXIMUM	25.000	21.000	29.000	30.000	90.000
RANGE	25.000	21.000	28.000	28.000	83.000
MEAN	6.276	7.171	9.347	12.681	40.083
VARIANCE	22.171	26.700	35.497	52.523	545.261
STANDARD DEV	4.709	5.167	5.958	7.247	23.351
STD. ERROR	0.555	0.609	0.702	0.854	2.752
SKEWNESS(G1)	1.275	0.727	1.442	0.590	0.311
KURTOSIS(G2)	2.838	0.129	2.314	-0.628	-0.981
SUM	451.900	516.300	673.000	913.000	2886.000
C.V.	0.750	0.721	0.637	0.572	0.583

	TIMEVIL	TOTADM	TOTADP	AFRENCH	AARLOC
N OF CASES	72	72	72	72	72
MINIMUM	3.000	1.000	1.000	0.000	0.000
MAXIMUM	73.000	7.000	9.000	40.000	50.000
RANGE	70.000	6.000	8.000	40.000	50.000
MEAN	47.236	2.264	2.431	4.055	12.395
VARIANCE	197.422	1.662	2.108	93.653	269.237
STANDARD DEV	14.051	1.289	1.452	9.677	16.408
STD. ERROR	1.656	0.152	0.171	1.141	1.934
SKEWNESS(G1)	-0.673	1.127	1.724	2.413	0.993
KURTOSIS(G2)	0.584	1.229	4.643	4.904	-0.271
SUM	3401.000	163.000	175.000	291.944	892.424
C.V.	0.297	0.569	0.597	2.387	1.324

	AACTIV	YMALE	YFEMALE	YFRENCH	YARABIC
N OF CASES	72	72	72	72	72
MINIMUM	50.000	0.000	0.000	0.000	0.000
MAXIMUM	100.000	6.000	4.000	100.000	100.000
RANGE	50.000	6.000	4.000	100.000	100.000
MEAN	92.362	1.431	1.042	13.102	8.339
VARIANCE	172.502	1.657	1.026	801.902	336.925
STANDARD DEV	13.134	1.287	1.013	28.318	18.356
STD. ERROR	1.548	0.152	0.119	3.337	2.163
SKEWNESS(G1)	-1.468	0.833	0.899	2.183	2.634
KURTOSIS(G2)	0.897	0.734	0.434	3.657	7.837
SUM	6650.072	103.000	75.000	943.333	600.417
C.V.	0.142	0.900	0.973	2.161	2.201

	EMRATE	TOTEXAG	PCTEXAG	COWS	SEPGOAT
N OF CASES	72	72	72	72	72
MINIMUM	0.000	0.000	0.000	0.000	0.000
MAXIMUM	42.857	66.667	69.018	40.000	39.000
RANGE	42.857	66.667	69.018	40.000	39.000
MEAN	6.377	14.677	17.155	2.111	6.139
VARIANCE	126.797	336.277	472.015	29.678	39.811
STANDARD DEV	11.260	18.338	21.726	5.448	6.310
STD. ERROR	1.327	2.161	2.560	0.642	0.744
SKEWNESS(G1)	1.515	0.918	0.869	5.051	2.406
KURTOSIS(G2)	1.019	-0.347	-0.650	30.962	8.837
SUM	459.127	1056.710	1235.130	152.000	442.000
C.V.	1.766	1.249	1.266	2.580	1.028

	TOOLS	YRSCHEP	AREAOZH	AREAREC	AREALOAN
N OF CASES	72	72	70	71	72
MINIMUM	0.000	0.000	0.000	0.000	0.000
MAXIMUM	9.000	60.000	100.000	43.605	186.170
RANGE	9.000	60.000	100.000	43.605	186.170
MEAN	4.028	21.986	9.890	2.815	13.050
VARIANCE	5.041	211.451	600.834	65.336	914.723
STANDARD DEV	2.245	14.541	24.512	8.083	30.244
STD. ERROR	0.265	1.714	2.930	0.959	3.564
SKEWNESS(G1)	0.424	0.466	2.683	3.188	3.674
KURTOSIS(G2)	-0.629	-0.557	6.265	10.227	15.632
SUM	290.000	1583.000	692.307	199.869	939.603
C.V.	0.557	0.661	2.478	2.871	2.318

	HANOEX	REALSIL	EXTRATE	ASSOC	AGCOEF
N OF CASES	72	72	72	72	72
MINIMUM	0.000	0.000	0.000	0.000	0.000
MAXIMUM	80.000	99.057	25.000	31.500	7.000
RANGE	80.000	99.057	25.000	31.500	7.000
MEAN	10.101	36.015	1.333	8.049	0.833
VARIANCE	251.844	968.392	13.099	84.571	3.042
STANDARD DEV	15.870	31.119	3.619	9.196	1.744
STD. ERROR	1.870	3.667	0.427	1.084	0.206
SKEWNESS(G1)	2.174	0.393	4.550	0.748	2.022
KURTOSIS(G2)	5.253	-1.018	24.632	-0.606	2.800
SUM	727.300	2593.089	96.000	579.500	60.000
C.V.	1.571	0.864	2.714	1.143	2.093

	FORCOEF	AALB1140	AALB4160	ANNOMPAR	CONSMES
N OF CASES	72	72	72	72	72
MINIMUM	0.000	0.000	0.000	0.000	0.000
MAXIMUM	4.000	6.206	9.188	265.037	72.152
RANGE	4.000	6.206	9.188	265.037	72.152
MEAN	0.431	0.890	2.840	6.909	10.248
VARIANCE	1.150	1.564	5.758	1010.037	374.918
STANDARD DEV	1.072	1.250	2.400	31.781	19.363
STD. ERROR	0.126	0.147	0.283	3.745	2.282
SKEWNESS(G1)	2.390	2.330	0.974	7.623	1.822
KURTOSIS(G2)	4.299	6.183	0.027	59.187	2.037
SUM	31.000	64.062	204.507	497.430	737.834
C.V.	2.491	1.405	0.845	4.600	1.889

	TRACAM	PRIVATE	COMMUNAL	PCTCAD	TOTHAY
N OF CASES	72	72	72	72	72
MINIMUM	0.000	0.000	0.000	0.000	0.000
MAXIMUM	9.000	1.000	1.000	100.000	28.913
RANGE	9.000	1.000	1.000	100.000	28.913
MEAN	1.972	0.250	0.139	39.722	4.106
VARIANCE	2.168	0.190	0.121	546.401	20.703
STANDARD DEV	1.472	0.436	0.348	23.375	4.550
STD. ERROR	0.174	0.051	0.041	2.755	0.536
SKEWNESS(G1)	2.314	1.155	2.088	0.187	2.744
KURTOSIS(G2)	7.230	-0.667	2.361	0.047	10.851
SUM	142.000	18.000	10.000	2860.000	295.637
C.V.	0.747	1.744	2.507	0.588	1.108

	CONFLICT	HAAVFER	ETHNIC	HAAVMOC	AVMOCHA
N OF CASES	72	72	72	72	72
MINIMUM	0.000	0.000	0.000	0.000	0.000
MAXIMUM	1.000	19.115	1.000	33.936	404.200
RANGE	1.000	19.115	1.000	33.936	404.200
MEAN	0.333	1.687	0.458	0.862	8.486
VARIANCE	0.225	20.601	0.252	24.075	2529.885
STANDARD DEV	0.475	4.539	0.502	4.907	50.298
STD. ERROR	0.056	0.535	0.059	0.578	5.928
SKEWNESS(G1)	0.707	2.803	0.167	5.943	7.094
KURTOSIS(G2)	-1.500	6.882	-1.972	34.296	52.088
SUM	24.000	121.432	33.000	62.041	611.000
C.V.	1.424	2.691	1.095	5.694	5.927

	TOTCAD	GOODHA	FAIRHA	POORHA	TOTFAM
N OF CASES	72	72	72	72	72
MINIMUM	0.000	0.000	0.000	0.000	2.000
MAXIMUM	56.490	100.000	100.000	100.000	23.000
RANGE	56.490	100.000	100.000	100.000	21.000
MEAN	11.369	45.877	13.134	40.342	9.069
VARIANCE	133.849	1566.313	695.372	1502.886	22.291
STANDARD DEV	11.569	39.577	26.370	38.767	4.721
STD. ERROR	1.363	4.664	3.108	4.569	0.556
SKEWNESS(G1)	2.174	0.153	2.097	0.320	1.197
KURTOSIS(G2)	5.016	-1.523	3.388	-1.442	0.891
SUM	818.573	3303.131	945.638	2904.625	653.000
C.V.	1.018	0.863	2.008	0.961	0.521

	AREACE	AREASUP
N OF CASES	70	70
MINIMUM	0.000	0.000
MAXIMUM	100.000	100.000
RANGE	100.000	100.000
MEAN	35.771	54.339
VARIANCE	1330.478	1535.272
STANDARD DEV	36.476	39.183
STD. ERROR	4.360	4.683
SKEWNESS(G1)	0.713	-0.258
KURTOSIS(G2)	-0.871	-1.458
SUM	2503.966	3803.728
C.V.	1.020	0.721

APPENDIX N
DESCRIPTION OF VARIABLES USED IN
WOLOF VS. SERER ANALYSIS

NATURAL RESOURCE-RELATED VARIABLES

CRNCAD	Average percent <i>A. albida</i> crown cover per hectare per farm
AALB1	Average <i>A. albida</i> regeneration rate per hectare per farm (average number of seedlings of less than 1 cm in diameter from all field sample plots -300 m ² per field sample plot)
AALB15	Average number of <i>A. albida</i> seedlings per hectare per farm between 1 and 5 cm in diameter
AALB610	The average number of <i>A. albida</i> trees per hectare per farm between 6 and 10 cm in diameter
AALB1120	The average number of <i>A. albida</i> trees per hectare per farm between 11 and 20 cm in diameter
AALB2130	The average number of <i>A. albida</i> trees per hectare per farm between 21 and 30 cm in diameter
AALB3140	The average number of <i>A. albida</i> trees per hectare per farm between 31 and 40 cm in diameter
AALB4150	The average number of <i>A. albida</i> trees per hectare per farm between 41 and 50 cm in diameter
AALB5160	The average number of <i>A. albida</i> trees per hectare per farm between 51 and 60 cm in diameter
AALB60	The average number of <i>A. albida</i> trees per hectare per farm greater than 60 cm in diameter
TOTCAD	Average number of <i>A. albida</i> trees greater than 1 cm in diameter per hectare and per farm
PRUCAD	<i>A. albida</i> pruning rate- an estimate of the average percent of <i>A. albida</i> crown cover removed per hectare and per farm by pruning
CRNOTE	Average percent other species crown cover per hectare per farm
PRUOTE	Other species pruning rate- an estimate of the average percent of other species crown cover removed by pruning per hectare and per farm
TOTOTE	Average number of other species per hectare per farm greater than 1 cm in diameter
BIODIV	Average number of different species per hectare per farm
HANOEX	Estimate of total area of land not used for agricultural purposes in the village in hectares (terres non-exploitées)

CADHA	Percent of total farm area where farmer makes an effort to actively manage <i>A. albida</i> (staking, pruning, protection, etc.)
CONSMES	Percent of total farm area where farmer has taken other soil conservation measures (windbreaks, live fences and other tree planting)
PCTCAD	Percent of actions undertaken by respondent to enhance <i>A. albida</i> out of a total of five possible actions
REALSIL	percent of "realistic" species desired by farmers divided by the total number of species desired (realistic plus unrealistic)
PRIVATE	"private tree planting"- a dummy variable, 0 for no private tree planting by the respondent and 1 if the respondent has planted trees on his/her own land
COMMUNAL	"communal tree planting"- a dummy variable, 0 if respondent has not participated in communal tree plantings activities and 1 if her or she has

OTHER VARIABLES

FARM PRODUCTION VARIABLES

NUMPAR	Total number of fields per farmer
AREAC	Total farm area in hectares
AVDIS	Average distance between farmer's fields and the village (km)
HAAVFAL	Average percent of farm in fallow 1985-1989
HAAVMIL	Average percent of farm in millet/sorghum 1985-1989
AVMILEA	Average millet yields per hectare 1985-1989 (kg)
HAAVPEA	Average percent of farm in peanuts 1985-1989
AVPEAHA	Average peanut yields per ha 1985-1989 (kg)
HAAVCOW	Average percent of farm in cowpeas 1985-1989
AVCOWEA	Average cowpea yields per hectare 1985-1989 (kg)
HAAVMOC	Average percent of total farm area in manioc 1985-1989
AVMOCHA	Average manioc yields per hectare per farm 1985-1989 (kg)
YSINFAL	Average number of years since fallow for all fields
AVTOTMIL	Average total millet production 1985-1989 (kg)
AVTOTPEA	Average total peanut production 1985-1989 (kg)
AVTOTCOW	Average total cowpea production 1985-1989 (kg)
TOTHAY	Average total peanut and cowpea hay produced per farm in 1988 and 1989
TOOLS	Total number of animal traction-type implements

ROTATHA	Percent of total farm area where rotations are followed
TOTEXAG	Percent of adult family members undertaking some form of extra-agriculture activity in 1989
PCTEXAG	Percent of farm income derived from extra-ag sources in 1989 (estimated by taking total extra-ag income and dividing by value of total ag production (millet, cowpeas, peanuts and manioc)

VARIABLES DESCRIBING ON-FARM USE OF ORGANIC MATTER/FERTILIZER

HAMANAV	Average percent of farm area on which manure was used 1985-1989
AVMANHA	Average manure used per hectare per farm 1985-1989 (charattes)
HAPARAV	Average percent of farm area which had parcase 1985-1989
ANMONPAR	Average animal-months parcase per hectare 1985-1989 (number of animals times the number of months)
PAROTH	Percent of total farm area which had parcase prior to 1985
HAAVFER	Average percent of total farm area on which fertilizer was used 1985-1989

VARIABLES DESCRIBING QUALITY OF LAND

HAKHOR	Percent of total farm area with khor soil type
GOODHA	Percent of total farm area which farmer perceives to be fertile/good
FAIRHA	Percent of total farm area which farmer perceives to be of fair quality
POORHA	Percent of total farm area which farmer perceives to be of poor quality/infertile

DEMOGRAPHIC VARIABLES

ETHNIC	A dummy variable which indicates the ethnic group to which the farmer belongs, 0 if Wolof, 1 if Serer
AGE	Age of farmer/respondent
VILPOP	Village population
EXPCAR	Number of exploitations within a carré
CARVIL	Number of carrés in the village
DISMAR	Distance to the nearest weekly market (km)
DISROAD	Distance to the nearest paved road (km)
DISSOD	Distance to the nearest SODEVA agent (km)
DISCERDEF	Distance to the nearest forestry agent/CER (in the case of this study, DEF agents were always located in CER offices)
WELL	Depth of village well/water table (m)

TIMEVIL	Length of time farmer/respondent has lived in village (years)
VILCRE	Age of village (years)
TOTADM	Total adult males in the household (>15 years)
TOTADF	Total adult females in the household (>15 years)
YMALE	Total male youths in household (6-15 years)
YFEMALE	Total female youths in household (6-15 years)
TOTFAM	Total number of individuals in household including children under 6 years
AACTIV	Percentage of active adults in household
YRSCHEF	Number of years respondent has been "chef exploitation" or "chef ménage dépendent"
EMRATE	Percent of adult family members who have emigrated in the past two years and have been gone longer than one year
CONFLICT	a dummy variable which indicates whether the village/farmer has had a conflict over land with another village/farmer, 0 if no, 1 if yes

VARIABLES DESCRIBING EDUCATION LEVEL

AFRENCH	Percent of adult family members with some knowledge of french (speak, read and/or write)
AARLOC	Percent of adult family members with some knowledge of arabic (speak, read and/or write) or some formal knowledge of Wolof or Serer (read and/or write)
YFRENCH	Percent of youth in household with some knowledge of french (speak, read and/or write)
YARABIC	Percent of youth in household with some knowledge of arabic (speak, read and/or write)

ANIMAL-RELATED VARIABLES

COWS	Total number of cows (large ruminants) owned or held by household, includes cows held for fattening purposes
SHPGOAT	Total number of sheep and goats owned or held by household, includes sheep held for fattening purposes
TRACAN	Total number of traction animals (oxen, horses and donkeys)

LAND ALLOCATION-RELATED VARIABLES

AREACE	Percent of total farm area farmed before becoming chef/area allocated by chef de carré
AREAOth	Percent of total farm area which was allocated by someone other than the chef de carré
AREASUP	Percent of total farm area received on becoming chef

AREAREC Percent of total farm area farmed on a temporary basis in 1989

AREALOAN Percent of total farm area loaned to others in 1989

AGRICULTURE AND FORESTRY EXTENSION AND TRAINING VARIABLES

AGCOEF "agriculture training coefficient"- this is a composite variable which represents the number of agriculture training sessions in which a farmer participated plus the number of those sessions which discussed trees in agriculture and/or soil conservation and weighted by a factor of two

FORCOEF "forestry training coefficient"- this is a composite variable which represents the number of forestry-related training sessions in which a farmer participates plus the number of those sessions which discussed trees in agriculture and/or soil conservation

EXTRATE "extension rate"- a composite variable which represents the total number of visits made by extension agencies during the last campaign times the total number of different agencies

ASSOC "association participation rate"- a composite variable which represents the average years membership per organization, plus the participation level (weighted), plus the speaking level (weighted), plus any offices held, plus how activities are chosen, plus the number of organizations to which a farmer belongs

APPENDIX O

RESULTS OF TUKEY'S HSD TEST

NATURAL RESOURCE-RELATED VARIABLES

VARIABLE	MEAN		OVERALL		PROB.		PROB.	
	WOLOF	SERER	MEAN	CHI-SQ.	2-TAIL	T-TEST	2-TAIL	
CRNCAD	2.118	2.701	2.386	0.002	0.965	1.243	0.218	
CRNOTH	0.875	1.639	1.255	41.412	0.000	2.368	0.021	**
PRUCAD	15.864	10.831	13.557	1.620	0.203	2.488	0.015	
PRUOTH	11.484	12.935	12.149	0.002	0.962	0.696	0.489	
TOTOTH	17.518	16.079	16.858	0.743	0.389	0.493	0.624	
BIODIV	1.548	1.861	1.692	0.477	0.490	1.482	0.143	
TOTCAD	11.116	11.668	11.369	0.076	0.782	0.200	0.842	
AALB1	0.942	0.696	0.829	6.052	0.014	1.235	0.221	
AALB15	6.957	8.062	7.464	0.296	0.587	0.426	0.671	
AALB610	0.237	0.102	0.175	7.825	0.005	1.663	0.101	
AALB1120	0.299	0.101	0.208	50.077	0.000	1.347	0.182	
AALB2130	0.285	0.147	0.222	6.044	0.014	1.623	0.109	
AALB3140	0.552	0.351	0.460	1.492	0.222	1.035	0.304	
AALB4150	0.774	0.562	0.677	0.430	0.512	1.035	0.304	
AALB5160	0.701	0.538	0.626	0.010	0.920	0.900	0.371	
AALB60	1.310	1.806	1.537	0.370	0.543	1.391	0.169	
AGCOEF	0.538	1.182	0.833	2.090	0.148	1.576	0.120	
FORCOEF	0.256	0.636	0.431	7.154	0.007	1.511	0.135	
PRIVATE	0.205	0.303	0.250	0.598	0.440	0.949	0.346	
COMMUNAL	0.179	0.091	0.139	2.729	0.099	1.077	0.285	
PCTCAD	36.923	43.030	39.722	0.027	0.869	1.106	0.272	
CADHA	40.248	20.421	31.160	0.999	0.318	2.177	0.033	
REALSIL	39.548	31.840	36.015	0.069	0.793	1.048	0.298	
CONSMES	6.677	14.468	10.248	5.061	0.024	1.725	0.089	*

OTHER VARIABLES

VARIABLE	MEAN		OVERALL		PROB.		PROB.	
	WOLOF	SERER	MEAN	CHI-SQ.	2-TAIL	T-TEST	2-TAIL	
NUMPAR	4.308	4.152	4.236	0.008	0.927	0.594	0.555	
AREAC	7.665	5.008	6.447	13.114	0.000	2.641	0.010	**
AVDIS	0.776	0.575	0.684	6.285	0.012	1.507	0.136	
HAAVFAL	21.454	8.022	15.297	17.071	0.000	3.602	0.001	**
HAAVMIL	36.317	54.158	44.494	0.048	0.826	6.644	0.000	
HAAVPEA	30.432	35.403	32.710	0.242	0.623	1.653	0.103	
HAAVCOW	3.590	0.717	2.273	44.815	0.000	2.843	0.006	**
HAAVMOC	1.591	0.000						**
HAMANAV	23.384	21.288	22.423	0.242	0.623	0.413	0.681	
HAPARAV	1.963	6.001	3.813	0.059	0.807	2.676	0.009	
HAAVFER	1.708	1.662	1.687	0.132	0.716	0.043	0.966	
PAROTH	11.390	6.855	9.311	1.530	0.216	0.924	0.359	
AVMILHA	314.608	492.104	395.960	4.794	0.029	3.744	0.000	**
AVPEAHA	468.671	543.980	503.187	0.746	0.388	1.085	0.281	
AVCOWHA	45.367	13.988	30.985	15.314	0.000	2.611	0.011	**
AVMOCHA	15.667	0.000						**
AVMANHA	2.746	2.954	2.841	1.861	0.173	0.285	0.777	
ANMONPAR	7.697	5.977	6.909	50.420	0.000	0.227	0.821	
YSINFAL	14.340	20.641	17.228	3.890	0.049	2.741	0.008	**
AVTOTMIL	713.831	1088.761	885.674	3.337	0.068	3.089	0.003	**
AVTOTPEA	980.568	940.104	962.002	1.362	0.243	0.225	0.823	
AVTOTCOW	38.987	6.919	24.289	52.869	0.000	2.950	0.004	**
TOTHAY	4.301	3.876	4.106	5.821	0.016	0.393	0.696	
ROTATHA	71.461	62.931	67.552	0.006	0.937	1.089	0.280	
HAKHOR	1.998	8.074	4.783	35.319	0.000	2.074	0.042	**
AGE	58.051	46.394	52.708	0.231	0.630	3.896	0.000	
TIMEVIL	47.949	46.394	47.236	2.246	0.134	0.465	0.643	
YRSCHF	24.051	19.545	21.986	3.063	0.080	1.317	0.192	
VILPOP	326.054	597.515	454.029	11.258	0.001	3.435	0.001	**
EXPCAR	1.436	1.636	1.528	2.175	0.140	0.906	0.368	
CARVIL	35.000	58.879	46.257	0.811	0.368	3.900	0.000	
DISMAR	6.138	6.439	6.276	0.069	0.793	0.268	0.789	
DISROAD	6.823	7.582	7.171	0.948	0.330	0.618	0.539	
DISSOD	9.500	9.167	9.347	0.847	0.357	0.235	0.815	
DSCERDEF	13.372	11.864	12.681	0.606	0.436	0.878	0.383	
WELL	43.821	35.667	40.083	0.638	0.424	1.489	0.141	
TOTADM	2.462	2.030	2.264	2.024	0.155	1.425	0.159	
TOTADF	2.564	2.273	2.431	2.490	0.115	0.847	0.400	
YMALE	1.564	1.273	1.431	0.067	0.796	0.956	0.342	
YFEMALE	0.949	1.152	1.042	0.736	0.391	0.845	0.401	
TOTFAM	9.282	8.818	9.069	0.016	0.898	0.413	0.681	
AACTIV	93.095	91.496	92.362	0.002	0.969	0.512	0.610	
COWS	1.462	2.879	2.111	10.556	0.001	1.102	0.274	
SHIPGOAT	5.692	6.667	6.139	0.271	0.603	0.650	0.518	
TOOLS	4.641	3.303	4.028	0.916	0.339	2.622	0.011	
TRACAN	1.949	2.000	1.972	0.001	0.978	0.146	0.884	
AFRENCH	1.923	6.574	4.055	5.444	0.020	2.079	0.041	**
AARLOC	15.776	8.398	12.395	2.768	0.096	1.938	0.057	*
YFRENCH	8.120	18.990	13.102	3.689	0.055	1.642	0.105	
YARABIC	10.139	6.212	8.339	4.835	0.028	0.903	0.369	
EMRATE	8.952	3.333	6.377	7.799	0.005	2.164	0.034	**
TOTEXAG	16.279	12.783	14.677	0.112	0.738	0.804	0.424	
PCTEXAG	18.453	15.620	17.155	0.017	0.896	0.548	0.586	
EXTRATE	0.949	1.788	1.333	13.600	0.000	0.980	0.330	
ASSOC	10.064	5.667	8.049	0.025	0.874	2.068	0.042	
AREACE	31.888	40.656	35.771	5.024	0.025	0.999	0.321	

AREASUP	51.193	43.436	54.339	1.278	0.258	0.751	0.455	
AREAOTH	16.919	1.047	9.890	82.239	0.000	2.824	0.006	**
AREAREC	1.187	4.690	2.815	32.476	0.000	1.853	0.068	*
AREALOAN	13.765	8.929	11.548	10.734	0.001	0.882	0.381	
HANOEX	7.359	13.342	10.101	2.677	0.102	1.612	0.111	
GOODHA	44.166	47.899	45.877	1.970	0.160	0.396	0.693	
FAIRHA	16.067	9.668	13.134	0.028	0.867	1.026	0.308	
POORHA	38.572	42.433	40.342	1.438	0.230	0.419	0.677	
CONFLICT	0.462	0.182	0.333	2.159	0.142	2.589	0.012	

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