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Entitled

Farmer Behavior and New Agricultural Technologies in the Rainfed Agriculture of Southern Niger: A Stochastic Programming Analysis

Complies with University regulations and meets the standards of the Graduate School for originality and quality

For the degree of Doctor of Philosophy

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Form No. 9
Revised 9-85

FARMER BEHAVIOR AND NEW AGRICULTURAL TECHNOLOGIES IN THE RAINFED AGRICULTURE OF SOUTHERN NIGER: A STOCHASTIC PROGRAMMING ANALYSIS

A Thesis

Submitted to the Faculty

of

Purdue University

by

Akinwumi Ayodeji Adesina

In Partial Fulfillment of

the Requirements for the Degree

of

Doctor of Philosophy

December 1988

This thesis is dedicated with much love to:

(1) My precious wife and son - Yemisi and Rotimi - for all their love, patience, understanding and sacrifice throughout my graduate program. We did it together: I love you!

(2) My precious parents - Mr. and Mrs. Roland F. Adesina, for dedicating their entire livelihood to ensure that I obtain an educational legacy. I salute your courageous dedication to your children. Thank you!

ACKNOWLEDGMENTS

Several notable individuals have contributed in no small way to my doctoral program at Purdue. I wish to express my appreciation to them all.

I thank my major professor, Dr. John H. Sanders, for inspiring me in research, for his careful guidance and unshaking steadfastness which made the completion of this thesis possible despite tremendous obstacles. When the shock of not being able to return for more field work came up, he continued to reassure me that it was not the end of life and that by dint of hard work I could surmount the obstacles. I remain always grateful to him for all his assistance. I am proud to have been his student.

The members of my committee (both past and present) contributed in no small way to carefully guiding my research. I thank Dr. Phillip Abbott for all his assistance since my first semester at Purdue. Dr. John D. Axtell and Dr. Deborah Brown have been very inspirational to me both in and out of classes. I appreciate all their kind support at various times in my research work. Their openness and friendliness remain always cherished. The willingness of Dr. Paul Preckel to serve on my examining committee despite the very short notice is very much appreciated. Dr. Tom Hertel has always been encouraging to me both in and out of classes. His advice at some critical periods of my research plans are appreciated. Dr. Jess Lowenberg-DeBoer offered useful comments on early versions of my research proposal and I thank him for his openness and suggestions. I also appreciate the unrelenting support that my Head of Department - Dr. Bill Dobson - and the former Assistant Head of Research - Dr. John M. Connor - gave me at various periods of my research. The kindness of Dr. Wilfred Candler (of the World Bank) in sending me copies of some of his work in this area of research are very much appreciated. Dr. Tim Baker was helpful in the modeling stage of this thesis. I also thank Dr. Robert Deuson for his assistances in getting useful data in the course of this current work.

I thank the Director General of INRAN - Dr. Idrissa Soummana, for his support which made my research trip to Niger in 1986 possible. I have also gained more understanding of Niger agriculture from interactions with several individuals. I thank Dr. John Clark, Dr. Reddy, Dr. Bationo, Mr. Issa Mammane, Mr. Maliki Khadi, Mr. Goube Goah and Mr. Ouattara, for sharing their wealth of understanding with me during my research trip. The assistance of the International Programs Office of Purdue University in arranging that trip is greatly acknowledged. My special thanks to Dr. Woods Thomas, Dr. Lowell Hardin and Katy Ibrahim for assistances rendered at various times in my research. I also thank INTSORMIL Program for financing my research and academic program through the INTSORMIL PRF-5 grant.

My work could not have been done without several friends who assisted me in various ways by sharing their love, time and prayers. I thank our dear and precious pastor and his wife, Dr. and Mrs. Delma Broersma, for being parents to us in this foreign land. The brethern of the Upper Room Fellowship have been a real family to us and we appreciate you all. Our precious and very dear friends -- Uzo, Sochi and Samuel Nzewi -- have been simply wonderful to us. We appreciate all the love they showered ceaselessly on us and for holding us up at those critical periods. We love you. The care and love of the Akinniyi's, Eneyo's, Tongo's, are very much appreciated. My dear classmates Monte Vandeveer and Barry Shapiro showed me much love for which I am thankful. Monte came in many times to pray and support me throughout my career here. Thanks and God bless you! Victor Oladokun - my very dear friend - supported me with prayers and calls even all the way from London! Thanks!

My brothers - Tunde, Kayode, and Leke - supported me in very many ways by their love, letters and prayers. I am very grateful. A big thank you to my sister, Yetunde, to Yinka and Bunmi Oloruntoba for all their love for us. My precious parents-in-law, Mr. and Mrs. B.S. Oloruntoba, have been a tremendous blessing to us, sacrificing of their time and resources at various times. Their visit to the U.S. was very encouraging to us more than words can express. We are very grateful. We love you!

I thank Patt Edwards for doing an excellent job with typing my thesis. She sacrificed much time and effort. I am grateful.

Above all, I give thanks unto the Lord and my Savior, Jesus Christ, for being my help, my strength, and shield. Blessed indeed are those who trust in the unfailing love of the Lord.

"It is of the Lord's mercies that I was not consumed,
because His compassion fails not.
They are new every morning: great is thy faithfulness.
The Lord is my portion, saith my soul; therefore will I
hope in Him.
The Lord is good unto them that wait for Him, to the
soul that seeketh Him."

[Lamentations 3: 22-24]

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ABSTRACT

Adesina, Akinwumi Ayodeji, Ph.D., December 1988. Farmer Behavior and New Agricultural Technologies in the Rainfed Agriculture of Southern Niger: A Stochastic Programming Analysis. Major Professor: John H. Sanders.

Agricultural production in Southern Niger is precarious and occurs in a fragile environment characterized by enormous rainfall variability, poor soil fertility, and large price and yield risks. Farmers have developed strategies of coping with the risks of crop production in this risky environment. Farmers make decisions sequentially throughout the season in order to adapt to stochastic events. An understanding of how farmer behavior affects choice of agricultural technologies is important for technology development programs.

The specific objectives of this study are to evaluate sequential decision making of smallholder farmers in southern Niger and to determine how this affects adoption of agricultural technologies. The study determined:

(a) the farm-level impacts of new agricultural technologies under five alternative rainfall scenarios. The technologies evaluated are early maturing cultivars, and improved cultivars at higher planting density and moderate levels of chemical fertilization;

(b) the returns to labor under alternative technologies and weather patterns;

(c) the impacts of a cereal price floor in good rainfall years when farmers have more cereal to sell.

A discrete stochastic programming model was used to incorporate risk and to capture farmers' sequential decisions. The empirical model was validated against observed farmer behavior.

The results showed that (a) farmers adopted early maturing cultivars in low rainfall years but used late season cultivars in higher rainfall years. By carrying a portfolio of cultivars, farmers were able to respond to ensuing stochastic weather patterns.

(b) Adoption of the technologies increased household nutritional positions, expected total farm incomes, and returns to labor. Total income estimates show that with adoption of agricultural technologies farmers can make between 42 and 57 percent higher than the rural wage rate. Moreover, in absolute terms, agricultural incomes are low even with agricultural technologies.

(c) The adoption of early maturing varieties reduced the variability of incomes received by farmers.

(d) A cereal price floor of 50 CFA/kg. has no effect on choice of agricultural technologies. Rather, it increases expected total returns to agriculture.

(e) The initial liquidity position of the farmer influences adoption of agricultural technologies.

CHAPTER I

INTRODUCTION

1.1. Overview

Understanding farmer behavior and how this affects farm-level decisions on the adoption of agricultural technologies is of paramount importance to the introduction of agricultural technologies to farmers in West Africa. There is a strong linkage between farmer goals, risk attitudes and the allocation of resources to alternative agricultural enterprises (Norman, et al., 1981). A principal obstacle to the successful introduction of agricultural technologies in the highly risky production agriculture of Sub-Saharan Africa is inadequate understanding of farmer behavior (Spencer, 1985).

One way to fill the gap between technology development and clientele adoption is to examine the factors which determine farmers' adoption of alternative cropping strategies. This understanding will allow researchers involved in production of new agricultural technologies to know the potential farm-level constraints and technology adjustments needed to ensure farm-level adoption.

While several studies have found African farmers are risk averse (Low, 1972; Niang, 1980; Narayana and Shah, 1984; Adesina, et al., 1988; Rodriguez and Anderson, 1988), empirical studies of how farmers express this underlying risk aversion in farm-level decision making is very limited. Balcet and Candler (1981) found that farmers in Northern

Nigeria respond to rainfall uncertainties in the rain-fed agricultural system by making farm-level decisions sequentially as a function of the evolving seasonal rainfall pattern. Farm plans are not made ex ante at the beginning of the growing season. Rather, farmers' choices of plant varieties, planting densities and fertilization practices are changed periodically during the crop season based upon expectations of rainfall patterns. The resulting mixed cropping pattern prevalent in the farming system is a result of such sequential adaptations of crop plans. Matlon (1980: p. 11) observed similar farm planning strategies among peasant farmers in Burkina Faso.

Other studies claim that decision adaptations to stochastic weather factors within the crop season is a common phenomena across Sahelian West Africa (see Norman, et al., 1981). For the Southern Maradi Region of Niger (our area of study) survey findings indicate a prevalence of this management decision practice (Swinton, et al., 1984; Unite Suivi d'Evaluation, 1986).

These adaptations (referred to in the agro-climatology literature as "weather responsive crop management tactics" or "response farming") are farm management practices that agro-climatologists argue require more analysis, especially with regard to adoption of new agricultural technologies (Sivakumar, 1988; Stewart, 1985). Earlier studies in Sahelian West Africa have not analyzed how this sequential decision-making practice affects the adoption of agricultural technologies (see Krause, et al., 1987; Adesina, et al., 1988; Roth, 1986; Jaeger, 1984; Niang, 1980; Richard, et al., 1976; Hopkins, 1975; Barnett, 1979; Borliaud, et al., 1977). The objective of this study is to evaluate how sequential decision making under conditions of uncertainty for small holder farmers in the Maradi region of Niger affects adoption of improved agricultural technologies.

1.2. Agricultural Technology and Farmer Adaptive Decisions

The observed farmer sequential decisions allows farmers to reduce risk and to increase income. This strategy is especially relevant in the introduction of improved cereal varieties to farmers. Rainfall in Maradi Region is marked by substantial variability (see Figure 1.1.).

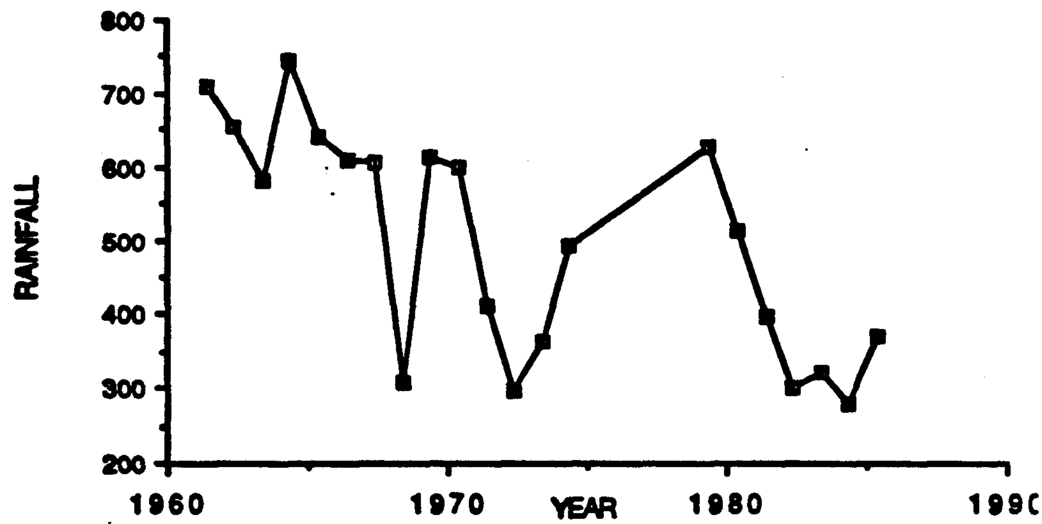

Figure 1.1. Annual Rainfall Trend in Maradi, Niger, 1961-1985.

Apart from this annual rainfall variability, there are also substantial variations in rainfall within the season. This seasonal variability is critical for crop production in this Sahelian area (Glantz, 1986). Rainfall exceeds the potential evapotranspiration in only two months of the year (July and August). Also due to the consistent declines in rainfall in August (the main rainfall period) over the years, the risks of late season drought have increased. Denett, *et al.* (1985) show that (in Niger as well as other locations in the Sahel) since 1968, rains in August have been at least 10 percent below the long-term average (see p. 357). The average growing season in Maradi lasts for only 85 days.

1.2.1. Implications of Rainfall Patterns for Cropping Decisions

Due to these climatic factors, the choice of appropriate varieties (i.e., late maturing or early maturing varieties of crops) to plant is crucial for ensuring survival of the household. Farmers are currently interested in short-season varieties due to the riskiness of crop production in low rainfall years. Farmers' traditional and photo-period sensitive varieties have long maturity dates relative to the length of the growing season in Maradi region. Typically, and depending on the variety, the maturity dates range from 110 days for millet, 129 days for sorghum, 124 days for cowpeas, and 111 days for peanuts (Unite Suivi d'Evaluation, 1986). These late maturing varieties have excellent yields potentials in good rainfall years with long growing seasons. However, these late maturing varieties often perform dismally in poor rainfall years with short growing seasons due to the late season moisture stress. These impacts are magnified for cowpeas which are traditionally planted 5-8 weeks after the millet and sorghum crops. In many years cowpeas fail and only cowpea hay is obtained (see on-farm trial results in Niger in Krause, et al., 1987; Ly, et al., 1986).

The sequential decision-making process can be regarded as a varietal portfolio decision (i.e., late maturing or early maturing varieties) to adjust to seasonal variation in rainfall in the replanting. Farmers can exploit the long growing season in good rainfall years with higher moisture levels by planting late maturing varieties. Also, they can make optimum use of the low rainfall in the dry years by planting early maturing varieties (see Andrews, 1987; Sivakumar, 1988; Matlon, 1987; ICRISAT, 1985 and 1986). Sometimes these cultivars may not be available during the crop season so the farmers will need to make a portfolio mix decision at the beginning of the season. Portfolio mix strategies have been documented in Burkina Faso (Matlon, 1980; Vierich and Stoop, 1987) where diffusion of early maturing millet and sorghum are occurring as a response to the rainfall uncertainties in the growing season. It is hypothesized in this study that farmers in the Maradi region of Niger will adopt combinations of early and late season varieties as an adaptive response to alternative rainfall trends within the season.

While varietal adoption can be important in increasing agricultural productivity in the southern Maradi region, its long run benefits may not be attained without complementary improvements in soil water management and soil nutrient supply. By definition of the area as a semi-arid zone (annual rainfall average is 540 mm) it is obvious that the principal constraint to agricultural productivity is water availability.

Soil fertility is, however, the next limiting factor in production. The predominantly sandy dune soils of the region are deficient in basic plant nutrients (especially nitrogen and phosphorous), have poor water retention capacity and low organic matter content. Improving soil fertility via moderate levels of chemical fertilization coupled with some water retention technique is therefore critical to increasing agricultural output (Andrews, 1986; Sanders, 1989; Matlon, 1987).

The importance of agronomic improvements is also evident if one considers the fact that less than 2 percent of total cultivated area of sorghum, millet and rice in the semi-arid region of West Africa is planted in new varieties from improved genetic material (Spencer, 1985). Therefore, improved varieties alone have not been very successful in solving low productivity problems of these agricultural systems. Field evidence in Burkina Faso (Roth, et al., 1985; Sanders, et al., 1987; Nagy, et al., 1988) show that significant yield improvements can be made from improved agronomy practices. Also, a technology consisting of combining improved varieties, higher planting densities and moderate levels of chemical fertilization has been shown in on-farm trials to be profitable in the traditional farming systems of the Maradi region of Niger (Krause, et al., 1987; Ly, et al., 1986). This technology can give high water use efficiency index (for similar technologies, see ICRISAT, 1985, 1986) and is therefore equivalent on the sandy dune soils to a water retention technique on soils with infiltration problems.

The impacts of these technologies (i.e., improved varieties and improved agronomy) will be analyzed in this study. Painter (1987) hypothesized that lack of profitable agricultural technologies has led to an unprofitable return to agricultural labor investments and that this may be one reason for continuing high out-migration from agriculture and the lack of investment in new agricultural technologies. The returns to labor may be so low even with new technologies that farmers prefer to either leave agriculture or to invest in other less risky and more remunerative activities. The impacts of these technologies on returns to labor will be investigated in some detail.

1.3. Objectives of Study

The objectives of this thesis are:

(1) to evaluate a behavioral model of small farmer decision-making;

(2) to evaluate the farm-level impacts of new agricultural technologies (under alternative weather patterns) on farm income, farm output, consumption levels and marketing patterns of small holder farmers in the Maradi region;

(3) to determine the returns to labor time actually worked by farmers under alternative weather patterns and technology choices. This is to determine if farmers are better off in agriculture than hiring out their labor in the rural labor market in low rainfall years as has been suggested in the literature; and

(4) to determine the impacts of an output price floor for millet and sorghum basic food crops on new technology introduction and farmer incomes.

1.4. Organization of the Thesis

The rest of this thesis is organized into five chapters. Chapter II discusses the socio-economic characteristics of farms in the region of study. The issues discussed include principal soil types, principal cropping systems, yields under current traditional technology, grain and livestock price movements in different rainfall years, and the role of livestock in consumption strategies. Characteristics of the representative farm used in the study are also discussed based on surveys of rural households in the study zone. Chapter III discusses the potential agricultural technologies to be considered in the empirical analysis. Chapter IV discusses the various methodological approaches for analyzing farm-level decisions under uncertainty and a justification for using discrete stochastic programming. The empirical model is also presented. Chapter V discusses the base model results, followed by a validation of the results. In Chapter VI results under alternative agricultural technologies are presented. Also, an investigation of the impacts of alternative price policies on new agricultural technology introduction is conducted. Chapter VII summarizes major results and makes suggestions for future studies.

CHAPTER II

AREA OF STUDY

In this chapter a discussion of the ecological and socio-economic characteristics of the farmers in the region of study is presented. The issues discussed include soil types and principal cropping systems on the various soil types, yields under traditional farmer practices, livestock holdings and the role of livestock in consumption strategies of rural households in low rainfall years. The study draws from extensive surveys of rural households in southern Niger.

The three major points in this chapter relevant for modeling in later chapters are: (1) the villages are marked by variability in soil types between villages and on the same farm. Farmers diversify cropping patterns to adapt to these variations in soil types. (2) Livestock sales play a major role in consumption strategies of farmers in low rainfall years. (3) Farmers in this region face large variability in yields and prices. This creates uncertainties in expected income and therefore makes the consideration of risk important in the modeling of farmer behavior.

2.1. Soil Types and Socio-Economic Characteristics in the Villages

The southern Maradi region is located in south central Niger and shares a common border with Nigeria. The village zone of this study is located in the Madarounfa arrondissement (French equivalent of a zone or district) (see Figure 2.1). In this arrondissement discussion will be based on three representative villages: Maiguero, Rigial Oubandawaki, and Kandamao. These three villages have distinct soil types which affect the cropping patterns and cultural farming practices in each village. Soils in Kandamao are heavy sandy-clay and the use of animal traction for cultivation is very common because of the difficulty of managing this soil. The villages of Rigial Oubandawaki and Maiguero, respectively, are made up of predominantly sandy soils. These sandy soils can be further divided into two types:

(1) sandy soils which have some silt content and are located in the valley areas. This soil type has a higher soil fertility than the predominantly sandy soils.

(2) aeolian sandy-dune soils formed from wind blown sands and having very low water retention capacity and organic matter content.

As a group, the sandy soils[1] are the most widely cultivated partly due to the ease of working these soils relative to the heavier sandy-clay soil type. In the study village of Maiguero, sandy soils predominate.

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1 This study will be investigating farm-level decisions in the village of Maiguero. Since the villages with sandy soils are the most common, the analysis for this village will be representative. The crops grown in the village generally include some area of sorghum, but the predominant crops are millet and cowpeas which tolerate the water stress and low soil fertility better than sorghum. Data availability is the principal reason for selecting this village site.

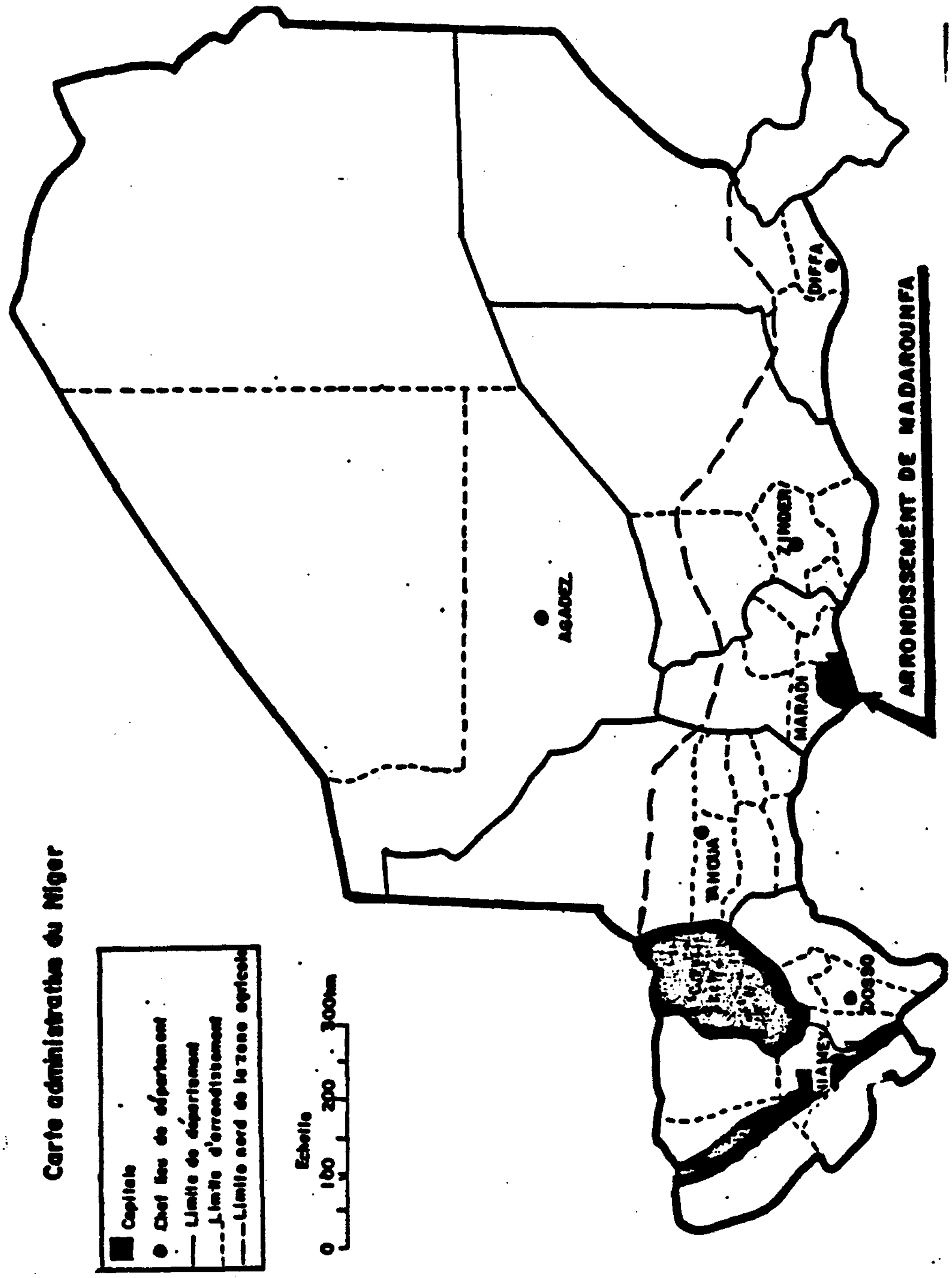

Figure 2.1. The Region of Study - Arrondissement de Madarounfa.

Table 2.1. Mean Values for Six Socio-Economic Indicators in Compact Soils and Sandy Soil Villages of Madarounfa, 1982.

Socio-Economic Characteristics	Units	Village Type Compact Soil	Sandy Soil	t-Value
Population Density	persons/ha.	3.8	3.5	0.44
Farm Size	ha.	3.0	2.0	1.78*
Age of Settlement	years	56	92	-1.10
Proportion of Hausas	%	63	98	-3.82**
Merchants	number	5	19	-1.33

*** Significant at 1%.

* Significant at 10%.

Source: Swinton and Ly (1984), p. 7.

A categorization of the socio-economic indicators in representative villages of Madarounfa is shown in Table 2.1. These values covered 33 villages composed of 7 villages with sandy-clay soils and 26 villages with sandy soils. The estimates show that villages with the heavier sandy-clay soils have larger farm sizes than villages with sandy soils. The mean farm size in the compact soil villages is 3.0 ha. compared to 2.0 ha. on the sandy soil villages. This may be due to the fact that villages with the heavier soils are more recent settlements than the sandy soil villages. Due to the difficulty of cultivating these heavier soils, farmers have traditionally left them for fallow and for growing pastures (Unite Suivi d'Evaluation, 1986). However, as the sandy soils villages became increasingly more populated, the resulting land scarcity resulted in movements into these heavier soils. Also villages with heavier soils use animal traction which further allows for cultivation of more land area.

The livestock holdings in each of the villages categorized by soil type is shown in Table 2.2. The compact soil villages have higher numbers of livestock compared to the sandy soil villages. While the mean number of sheep and goats in the villages with heavy soils is 11.4, the corresponding value for the sandy soil village is 5.9. Also the mean number of cattle in the villages with heavy soils is 4.3 compared to 1.1 in the villages with sandy soils.

Table 2.2. Mean Number of Animals in Compact and Sandy Soil Villages of Madarounfa, 1982.

	Village Type		
Type of Animal	Compact Soil	Sandy Soil	t-Value
Cattle	4.3	1.1	3.82**
Sheep and goats	11.4	5.9	4.64**

** Significant at the 1% probability level.

Source: Swinton and Ly (1984), p. 9.

The socio-economic characteristics on the two types of sandy soils present in the region of study (i.e., valley sandy silt and sandy dune soils) are shown in Table 2.3. The valley soils are more populated than the upland soils. The population density is 5.0 persons/ha. on the villages with sandy-silt soils of the valley compared to 3.2 persons/ha.

Table 2.3. Mean Values of Six Socio-Economic Characteristics in Sandy Soil Villages: Valley Villages and Upland Villages.

Characteristic	Unit	Valley Villages	Upland Villages	t-Values
Population Density	persons/ha.	5.0	3.2	3.76***
Farm Size	ha.	1.6	2.4	-2.63**
Age of Settlement	years	117	75	1.38
Merchants	number	32	10	2.13**

*** Significant at 1%.

** Significant at 5%.

Source: Swinton and Ly (1984).

for the upland sandy-dune soils. Due to this higher population density, the farm size on the valley villages are much smaller than the upland villages. Increasing population in the valley villages has been forcing farmers to bring more of the upland soils of low soil fertility into cultivation (Ferguson 1979; Sutter, 1979). Bringing this marginal land area into cultivation that is traditionally considered too risky for agriculture (and normally used by pastoralists for pastures) has often led to competition between pastoralists and farmers[2] (Curry, 1984:202; Gregoire and Raynaut, 1980:10,105 - cited in Painter, 1987). The result of this has been increasing soil degradation, soil fertility loss and low crop yields.

2 For a discussion of the breakdown of communal grazing rights in Burkina Faso, see Sanders, et al. (1987: p. 27).

2.2. Representative Farm's Socio-Economic Characteristics

Based upon these village survey estimates, the characteristics of the representative farm to be used in the development of the farm model are discussed below. Average household size of the representative farm used in this study consists of 3.0 members while the population actively involved in agriculture (i.e., *actifs*) is 2.4 (Swinton, 1985; Issa, *et al*., 1987). Labor for agricultural operations is supplied entirely by the household labor force with no labor hiring. The average farm size ranges from 2.0 to 4.0 hectares in the study zone. The representative farm has up to 3.5 hectares of land for cultivation. The land type is sandy soils on which millet and cowpeas are mostly cultivated.

The household has an initial stock of cash of 7000 CFA which can be used to buy seeds, fertilizer, and farm implements. Also, the household is endowed with six ruminants, consisting of three rams and three goats (based on Swinton and Ly, 1984, p. 9). Subsistence cereal requirements for the household consist of millet and sorghum. Per capita nutritional requirements are set at 266 kg./capital, an estimate comparable to 250 kg./capita recommended by the Government of Niger (Appendix Table A.1). These cereal requirements can be met by either domestic production or through grain purchases on the market (discussed in later sections).

2.3. Cropping Systems

The primary factors determining the crop patterns in the village of study are low and irregular rainfall and variations in soil fertility. The predominant crop is millet (*pennisetum typhoides*). This crop is well adapted to low soil fertility and low rainfall. The next most important cereal is sorghum (*sorghum bicolor*). This crop grows better under higher rainfall and better soil fertility conditions than millet can tolerate. Millet is therefore more common on the sandy soils which have lower water content and soil fertility. Sorghum is grown in scattered areas on the farm where heavier, clay soils exist, in water recession spots with silt accumulations, and under the legume trees. The leaf droppings from the trees lead to higher amounts of organic matter accumulation, which increases soil fertility and therefore allows for more sorghum cultivation. These two crops form the major subsistence crops and are eaten in various preparations. The major legumes in the cropping system are cowpeas (vigna unguiculata) and peanuts (arahides hypogea). Peanuts have higher soil fertility requirements than cowpeas. These crops are generally planted in association with millet and sorghum. The predominant types of intercrops are millet-cowpeas, millet-sorghum-cowpeas, millet-sorghum-peanuts, and sorghum-cowpeas-peanuts.

In a farming system characterized by low moisture availability and erratic weather patterns, the use of intercropping appears to be a diversification strategy for stabilizing income (Abalu, 1976) because of its ability to reduce the variance of output and/or net income (Lynam, et al., 1982, p. 253). Also, intercropping may allow for better use of resources through "interaction effects of more efficiently utilizing available light, water and nutrients or by insulation of multiple crops from the spread of crop specific pathogens or insects" (Lynam, et al., 1982, p. 254).

Survey estimates (Swinton and Ly, 1984) show that farmers match their cropping patterns to soil types, millet being more widely cultivated on the sandy soils while sorghum is more widely cultivated on the compact heavier soils and under legume trees. Similar separation of crops by soil types is found in other parts of the Sahel (Vierich and Stoop, 1987; Matlon, 1980). In the cereal-legume intercropping practiced in each soil type, cowpeas have now replaced peanuts as the principal cash crop. This shift away from peanuts is associated with the low rainfall patterns of recent years and the insect and disease problems in the late 1970's. Also, economic factors have not favored peanuts as cereal prices relative to peanuts have increased (Elliot Berg Associates, et al., 1983).

Although an important cropping practice in many years, intercropping use appears to be less in poor rainfall years. In the drought years, sole crops become more important (see Table 2.4). The occurrence of late rains forces farmers to plant and replant the principal cereal (millet) and further delay intercropping. In some years, farmers may not be able to plant additional crops (as desired) later in the season due to moisture stress. Village level evidence indicates this happened in the drought of 1984 and the low rainfall year of 1985. The frequency of millet sole crop increased from 17 percent in 1984 to 39 percent in 1985. Also, one notices a substantial decline in the area devoted to intercrop systems. The frequency of this intercrop declined from 74 percent in 1984 to 47 percent in 1985. Since 1984 was a disaster year, farmers apparently expected the poor rainfall to continue and therefore changed cropping patterns to include more sole crop millet. The performance of the model in capturing the system changes in low rainfall and drought years will be investigated in Chapters V and VI.

Table 2.4. Percentage Frequency of Cropping Systems Observed in Three Villages of Madarounfa in 1984 and 1985 Crop Seasons.

Crop Systems	Crop Season 1984	1985
Sole Crop		
Millet	16.5	39.0
Sorghum	5.8	4.9
Total	22.3	43.9
Crop Mixtures	73.6	46.9
Fallow Land	4.1	9.2

Source: Swinton (1987).

2.4. Crop Yields Under Current Farmer Practices

Crop yields under traditional technology are low due to very little use of modern inputs and the poor rainfall levels which often cause crop failure. An idea of yield distribution in three villages in our area of study can be obtained from Table 2.5.

These yield estimates show that:

(1) Crop yields are extremely low under traditional farmer technology with the drought year of 1984 and also low with the poor rainfall year of 1985. Therefore it is important to look at alternative technologies that farmers can adopt to increase crop yields.

(2) Due to both yearly and within-year variability in rainfall patterns, yields are also unstable. Farmers suffer crop failure in very low rainfall years due to drought. In years with higher rainfall, poor distribution of rains can also

Table 2.5. Mean Grain Yield (kg/ha.) from Different Crop Systems in Villages of Madarounfa in the Low Rainfall Years of 1984 and 1985.[1/]

Crop Systems	1984	1985
Millet		
Millet, Sole Crop	140	325
Millet-Sorghum	81	299
Millet-Cowpeas	146	385
Millet-Sorghum-Cowpeas	158	439
Total System	140	339
Sorghum		
Sorghum, Sole Crop	69	268
Millet-Sorghum	12	75
Millet-Sorghum-Cowpeas	10	42
Total System	14	78
Cowpeas[2/]		
Millet-Cowpeas	13	3
Millet-Sorghum-Cowpeas	17	1
Total System	16	2

Source: Swinton (1987).

1/ These estimates are averages for three village: Kandamao, Maiguero, and Rigial Oubandawaki.

2/ The lower yields in 1985 (a relatively higher rainfall year) compared to 1984 may be due to the fact that rains stopped abruptly in mid-September in 1985. Therefore, cowpeas, which are usually planted late, were drastically affected. This clearly shows that annual rainfall alone is not the critical factor affecting production but also the within-season rainfall distribution.

reduce crop yields substantially. Therefore it is important to not only consider yearly rainfall variability but also how rainfall patterns evolve within the season (Denett, Elston and Rogers, 1985, p. 359; Glantz, 1986; Kandel, 1984).

The long-term aggregate production patterns in Niger show that the principal strategy farmers are using to produce food crops is by extensification of land area (Figure 2.3). From 1960 to 1983 acreages cultivated show a strong upward trend. Millet acreage in Niger was expanded from 1.6 million hectares in 1960 to 3.1 million hectares in 1983. Sorghum cultivated area increased from 440 thousand hectares in 1960 to 1.1 million hectares in 1983. Cowpea cultivated area grew from 375 thousand hectares in 1960 to 1.5 million hectares in 1983. As cultivated area expanded, farmers reduced the practice of fallowing (Sutter, 1979; Ferguson, 1979) which traditionally has been used to restore soil fertility. Access to land of good quality[3] continues to decline (Painter, 1987, p. 6), leading to substantial downward spiral in yields[4] of the major cultivated crops (Figure 2.2). Also, yields are highly variable from year to year. To prevent this downward trend in yields, new agricultural technologies are needed. Technologies which are land intensive (as opposed to land extensive) and which address the soil fertility depletion problem are important to boost farm-level yields. Some technologies which have been developed and are currently being extended to farmers will be discussed in Chapter III and evaluated in Chapters V and VI.

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3 The depletion of vegetation cover on a continuous basis leads to exposure of the bare sandy soils to the very high temperatures and the action of wind and water erosion. These combined effects lead to soil degradation, loss of soil fertility and a decline in crop yields under traditional farmer practices.

4 It is important to note that these official aggregate yield estimates are often overstated by the government (Painter, 1987, p. 4; Norman, *et al.*, 1981). Actual yields on farmers' fields are substantially lower than reported in official statistics.

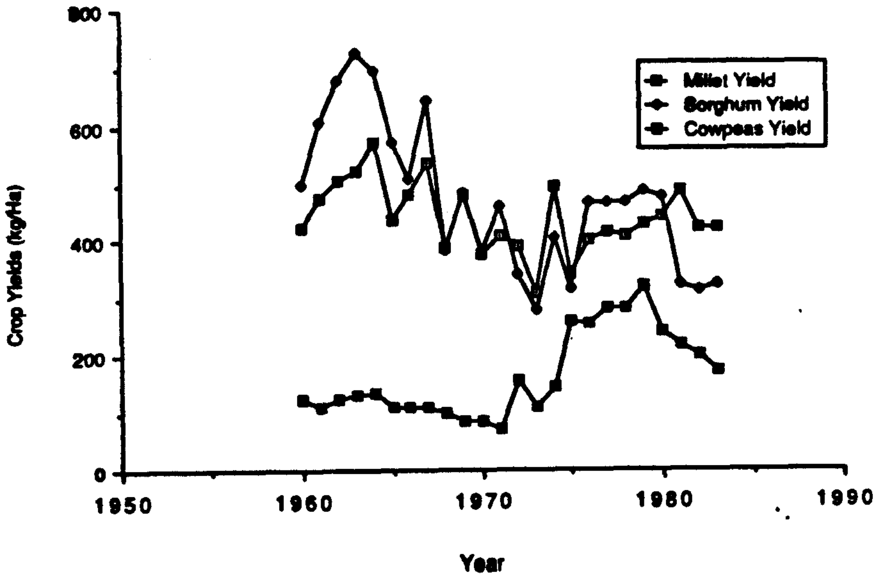

Figure 2.2. The Trends of Yields of Principal Crops in Niger from 1960 to 1983.

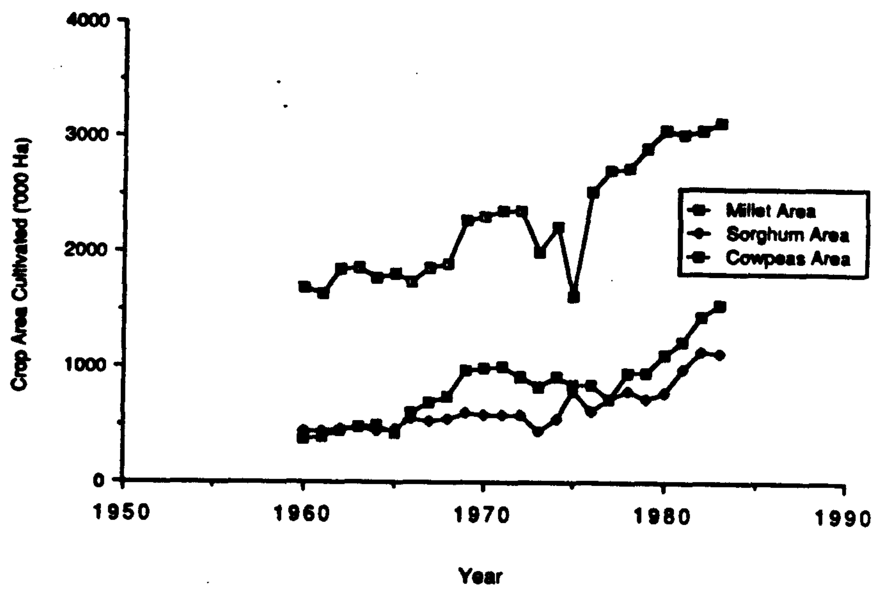

Figure 2.3. Cultivated Areas for Principal Crops in Niger from 1960 to 1983.

Farmers' strategies of coping with the high risks of crop production in this farming system is the subject of the next section.

2.5 Farmers' Risk Management Strategy in Low Rainfall Years

Meeting the nutritional needs of the household is the crucial responsibility faced by household heads. In good rainfall years when there are good cereal harvests this is generally not a serious problem. The problem arises in the low rainfall years when cereal harvests are poor or when crops fail. Unable to meet food requirements in such years, farmers are driven into the market to buy grains. Village level evidence of farmer purchases in 1984 to 1985 reinforce this point.

As was shown in the above section, farmers in our region of study suffered substantial losses of crops in the 1984 to 1985 period. In three representative villages of Madarounfa, farmers sold less than 4 percent of their output and had to buy substantial amounts of grains (see Swinton and Mammane, 1986). The principal problem farmers generally face is how to generate the cash for buying the needed grains (Painter, 1987:10). The main strategy farmers use is to sell off livestock in large numbers (Sutter, 1979:55; Swinton, 1988) and to use the resulting cash for buying grains. In all villages there was large sales of livestock (Table 2.6). Immediately following sales of livestock, most of the farmers bought grains (Table 2.7). The role of livestock in the full household adjustment patterns in low rainfall years is very important. These farmer adjustments have not been considered in previous studies (Roth, 1986; Jaeger, 1982; Krause, *et al.*, 1987). The observations in our village of study point out that it is important to study

Table 2.6. Farmer Adjustments of Livestock Inventories as an Adjustment to the Drought of 1984/85, Three Villages in Southern Niger.

Village Site	Animal Type								
	Cattle			Sheep			Goats		
	1984	1985	% Change 1984-85	1984	1985	% Change 1984-85	1984	1985	% Change 1984-85
Rigial Oubandawaki	48	37	-23	149	106	-29	249	143	-43
Maiguero	24	15	-38	42	31	-26	102	63	-38
Kandamao	58	37	-36	42	36	-14	60	113	88
All Villages	130	89	-31	233	173	-26	411	319	-22

Source: Swinton, S.M. and S. Mammane (1986). Les Exploitations Agricole dans Trois Villages de Madarounfa Face a La Sercheresse de 1984. Document No. 15F DECOR, Institut de Recherches Agronomiques du Niger.

Table 2.7. Percentages of Farmers in Three Villages of Madarounfa Who Bought Grains on the Market After Selling Livestock in the 1984/1985 Crop Season.

	Percentage Buying Grain After Selling:	
Village	Cattle	Sheep and/or Goats
Rigial Oubandawaki	53	58
Maiguero	NA 1/	66
Kandamao	82	54

1/ Not available.

Source: Swinton and Mammane (1986). Les Exploitation Agricoles Dans Trois Villages de Madarounfa Face a la Sercheresse de 1984. Document No. 15 Departement de Recherches en Economie Rural. Institute National de Recherches Agronomique du Niger.

farmer behavior not under one state of nature (usually a normal year)[5], but under alternative rainfall patterns.

2.6. Farmers and Substantial Price Uncertainties in Output Market

Since many farmers dispose of their livestock in poor rainfall years, large declines in livestock prices usually result. The prices of livestock in 1983-85 are shown in Table 2.8. It can be seen that livestock prices fell to their lowest levels in the 1984 drought year.

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5 Matlon (1984) observed that due to rainfall uncertainties in West Africa semi-arid tropics production, marketing and consumption patterns of farmers cannot be based on expectations of an average climatic situation.

Table 2.8. Average Livestock Prices (CFA) in Maradi Region from 1983-1986.

Animal Type	1983	1984	1985	1986
Goats	6950	4175	8721	8062
Sheep	21475	18800	25838	17438
Cow (Heifer)	56625	37000	46688	56625

Note: Prices are averages from September to December.

Source: Ministere de Resources Animales/Hydraulique, Direction des Etudes et Programmation. Data obtained through courtesy of ICRISAT Sahelian Centre, Niamey, Niger.

Unlike livestock, grain prices were extremely high in low rainfall years but collapsed in good rainfall years. The post-harvest grain market price structure (1983-1987) in the area of study is shown in Table 2.9. Millet prices rose from 89 CFA/kg. in 1983 to 160 CFA/kg. in 1984. Sorghum prices rose from 79 CFA/kg. in 1983 to 144 CFA/kg. in 1984. Cowpeas prices also increased from 200 CFA/kg. in 1983 to 234 CFA/kg. in 1984. With the occurrence of good rains in 1986, grain prices declined substantially. Millet prices declined from 160 CFA/kg. in 1984 to 35 CFA/kg. in 1986, a drop of 357 percent! Sorghum prices declined from 144 CFA/kg. in 1984 to 35 CFA kg. in 1986, a drop of 311 percent! Cowpeas prices declined from 234 CFA/kg. in 1984 to 132 CFA/kg. in 1986, a drop of 77 percent. Prices had not yet recovered their 1983 levels.

Table 2.9. Average Post-Harvest Grain Prices (CFA/kg.) in Maradi Region, 1983-1987.

Year	Crop				
	Cowpeas	Millet	Sorghum	Maize	Rice
1983	200	89	79	93	221
1984	234	160	144	138	218
1985**	129	59	67	73	198
1986*	132	35	35	74	225
1987***	133	50	50	NA	NA

* This was the price in nearby Zinder market and is used here as a proxy.
** Maradi price averages from September-December 1985.
*** Maradi price averages from August 1987-January 1988.
NA not available.

Source: Prices are unpublished data obtained from the University of Michigan Project (ASDG Project) in Niger.

Although the government sets minimum cereal price floors at 70 CFA/kg., the pricing policy is not effective in good rainfall years. The official marketing agencies for millet and sorghum (OPVN) and cowpeas (SONARA) are unable to hold prices up due to their poor financial positions, and lack of sufficient warehouses and transportation facilities (see Elliot Berg Associates, et al., 1983). The uncertainties in prices and income due to these wide swings in produce prices may present problems to adoption of agricultural technologies requiring purchase of cash inputs. Also considering such uncertainties is important in modeling farmer responses (Adesina and Brorsen, 1987). In the empirical model we will also consider these price variabilities and the impacts of alternative price policies in good rainfall years.

2.7. Conclusions

This chapter reviewed the socio-economic and ecological factors affecting farm production in the area of study. Four points are important to draw from this analysis, especially as it relates to new technology choices and modeling of farm-level decisions:

(1) The villages are marked by variability in soil types between villages and on the same farm. Farmers diversify cropping patterns to adapt to these variations in soil types. The village of study (Maiguero) is representative of farms in this region both in cropping patterns and soil type.

(2) Livestock sales play a major role in consumption strategies of farmers in low rainfall years.

(3) Farmers in this region face large variability in yields and prices of marketed output. This creates uncertainties in expected income and therefore makes the consideration of risk important in the modeling of farmer behavior. Farmers also have adaptive responses to the stochastic nature of their environment and these responses need to be included in the modeling.

(4) Land extensification is the primary strategy used by farmers to produce the major food crops. This extensive agricultural practice has led to soil fertility deterioration, wind and water erosion and soil degradation. Yields under traditional technology are low and are on a persistent downward trend as fallowing practices are reduced in order to expand cultivated area. Agricultural technologies are needed to prevent the yield declines. Especially important are yield increasing

technologies (i.e., land intensive technologies) which will boost farm-level production. Measures are needed to address the soil fertility depletion on farmers' fields. Yield increasing technologies which have been developed in Niger will be discussed in the next chapter and analyzed in Chapters V and VI.

CHAPTER III

AGRICULTURAL TECHNOLOGIES

In this chapter the discussion of the technologies evaluated with the empirical model is presented. These technologies include (a) early maturing varieties of millet and cowpeas developed at research stations and currently being recommended for farmers. These varieties are the CIVT millet variety and TN 5-78 cowpea variety. Both options of cultivating these varieties as sole crops or as intercrops will be evaluated. (b) An improved agronomy technical package (tested in three years of on-farm trials by INRAN) consists of early maturing varieties of millet and cowpeas, planted at high planting densities and with chemical fertilizer (50 kg./ha. urea and 50 kg./ha. of simple superphosphate). These technologies will be compared with traditional farming practices. The approach taken in this thesis is to evaluate performance of these technologies for various weather scenarios. Research stations need this sort of information to evaluate the potential of these new agricultural technologies.

3.1. Improved Millet and Cowpea Varieties

Due to the fact that millet and cowpeas are the most important intercrops in southern Niger, the principal thrust of agronomic research at the national agricultural research center (INRAN) has been directed to these crops[1] (see INRAN, 1984; Reddy and Gonda, 1984; Ly, et al., 1985). Principal developments of experiment station[2] breeding programs have been improved millet and cowpea varieties. Notable among these are CIVT-millet, P3 Kolo-millet, and 3/4 HK-millet, TN-5-78-cowpeas, and TN-27-80-cowpeas. These varieties have been tested in experiment station and on-farm trials and are currently being recommended to farmers (see Reddy, 1988, for agronomic recommendations for millet and cowpea cropping systems in different rainfall zones of Niger). In southern Maradi, the varieties mostly recommended are CIVT-millet and TN-5-78-cowpeas in sole crops or as intercrops.

These early maturing varieties can play a critical role in allowing farmers flexibility in cropping decisions. The local varieties planted by farmers have late maturity dates and yield poorly in low rainfall years with short growing seasons. Cowpeas are the most affected in such low rainfall years because they are planted (late) after the millet crop has been established. While this farmer practice allows for optimum use of available soil moisture in good rainfall years, it leads to poor yields and often crop failure for cowpeas in low rainfall years. Unite Suivi d'Evaluation (1986: p. 22) suggests that farmers should adopt these early maturing varieties since the utilization of late maturing varieties when the rains stop abruptly in mid-September often results in crop failure. While the early maturing cultivars have these advantages

1. For detailed discussion of various technologies which INRAN has examined, see Reddy (1988).

2. The ICRISAT West African program has also developed various millet and cowpea cultivars. The three major cowpea cultivars are: IT 83S-844 (an extra-early variety), IT 82D-716 (an early erect variety) and TVX 3236 (an early semi-erect variety).

in low rainfall years, it is important to also note that they have other disadvantages. Early flowering millet varieties are more susceptible to head worm (Rhaguva albipunctella) attack, grain mold (Andrews, 1987, p. 17), and insect pests such as the scarabid beetle (Rhinyptia Infuscata) (see ICRISAT West African Programs, 1987, p. 5). Also, these varieties do not yield as well as long-season cultivars in good rainfall years. Farmers's use of long-season cultivars generally allows them to effectively use water, nutrients as well as capitalize on advantages of intercropping (Andrews and Kassam, 1976 - cited in Andrews, 1986, p. 5).

This study will evaluate the potential adoption patterns and farm-level impacts of these improved varieties with and without chemical fertilization. Farmers' adoption of alternative varietal choices under different weather patterns will be investigated. The results obtained in three years (1985-1987) from the performance of these improved varieties on farmers' fields in Maiguero Village are presented in Table 3.1. These results are presented for three alternative cropping systems without application of chemical fertilizer. These cropping systems are:

(a) Cropping System 1 (traditional farmer practice) - Cultivation of local varieties of millet and cowpeas under farmers' traditional planting densities;

(b) Cropping System 2 - cultivation of improved varieties of millet (CIVT) and cowpeas (TN-5-78) planted at farmers' traditional planting densities; and

(c) Cropping System 3 - cultivation of improved varieties of millet (CIVT) and cowpeas (TN-5-78) planted at higher densities than farmer practice.

Table 3.1. Yields of Millet and Cowpeas under Three Alternative Cropping Systems: Results from Trials in Farmers' Fields from 1985 to 1987 Crop Seasons, Maiguero Village.

	Crop Yield (kg./ha.)		
	Millet	Cowpea Grain	Cowpea Hay
Cropping System 1[1/]			
1985	284	0	778
1986	279	67	n.a.
1987	154	4	94
Cropping System 2[2/]			
1985	358	0	787
1986	310	84	n.a.
1987	180	12	48
Cropping System 3[3/]			
1985	309	0	1069
1986	238	150	n.a.
1987	146	40	83

1/ Cropping system 1: Traditional farmer practice - local varieties of millet and cowpeas planted at traditional planting densities.

2/ Cropping system 2: Improved varieties of millet (CIVT) and cowpeas (TN-5-78) planted at farmers' traditional planting densities.

3/ Cropping system 3: Improved varieties of millet (CIVT) and cowpeas (TN-5-78) planted at higher plant densities recommended by experiment station.

Source: (a) 1985 and 1986 data were taken from Krause, *et al.*, (1987), "Labor Management Effects on the Relative Profitability of Alternative Millet-Cowpeas Intercrop Systems in Niger," Paper presented at Farming Systems Symposium, Arkansas, USA.
(b) 1987 data obtained from INRAN/DECOR data set (Courtesy of M. Krause).

Three points are important to note from these results:

(1) Yields are generally low regardless of choice of technologies. Across the three cropping systems, the maximum millet yield obtained was 358 kg./ha. The maximum cowpea grain yield was 150 kg./ha.

(2) By shifting from traditional technology to cropping system 2 (i.e., changing to improved varieties) the farmer gained a yield increase of 26 percent in 1985, 11 percent in 1986 and 17 percent in 1987. However, these increases are variable and are not substantial (averaging 18 percent over the three years of trials).

(3) In 1986 (a very good year) the millet yield from the traditional technology was comparable to cropping system 2, and substantially better than cropping system 3. Therefore, local varieties show excellent potentials in the good rainfall year.

(4) Relative to traditional farmer practice, the two alternative cropping systems gave higher cowpea grain yields in the 1986 and 1987 seasons when cowpea grains were harvested.

(5) The variability in the yield of cowpea is higher than that of millet.

(6) Cropping system 3 gave lower millet yields in two of the three years than the other two alternative systems. Since millet is the most important crop, it is evident that this technology does not meet the profitability criteria.[3]

3. This cropping option will therefore not be considered in the modeling. It is, however, important to consider cropping system 1 since it is the current farmer practice. The poor performance of the cropping system with higher planting densities (i.e., cropping system 3) is due to the fact that increasing densities (in absence of fertilization) mines the available nutrients in the soil and also creates increased competition for water resources.

In the empirical modeling, the traditional technology and the improved varieties will be evaluated to determine the farm-level impacts of each alternative on consumption, grain marketing and cash income of farmers.

3.2. Sole Cropping and Intercropping of Millet and Cowpea Systems

The possibility of planting millet and cowpea sole crops is another option open to farmers. In low rainfall years, experiment stations are recommending that farmers should plant sole crops of cowpeas. Reddy (1988, p. 10) recommends that when the rainy season length is 60 days or less[4], farmers should "cultivate short season [early maturing] cowpeas in sole crops, or in association with millet" (p. 10). Especially when rains do not arrive until mid-July (i.e., in marginal zones), planting early maturing varieties of cowpeas in sole stands is recommended (Reddy, 1988, p. 13). The potential for sole cropping has also been demonstrated in trials at the ICRISAT Sahelian Center (see Table 3.2). Results from ICRISAT trials show that:

(1) If millet and cowpeas are planted together simultaneously, it leads to a fall in the yield of millet and an increase in the yield of cowpeas. Early planting of the cowpea in the intercrop allows the cowpea crop to escape mid or late season drought but also leads to competition (for nutrients and water) with the millet early in the season.

4. Normal rainy season length is 85 days in Maradi.

Table 3.2. Grain Yields (kg./ha.) of Millet and Cowpeas from Three Alternative Sowing Dates of Three Cultivars of Cowpeas, ICRISAT Sahelian Centre, Niger.

	Cowpeas Cultivars							
	IT 83 S-844[a]		IT 82 D-716[b]		TVX 3236[c]		Local Sadore[d]	
	Cowpeas	Millet	Cowpeas	Millet	Cowpeas	Millet	Cowpeas	Millet
Date of Planting Millet and Cowpeas								
Simultaneously	234	1070	377	1060	484	1040	0.0	342
Cowpeas Planted 6 Days after Millet	104	1320	197	1230	240	1310	0.0	631
Cowpeas Planted 25 Days after Millet	0.0	1220	72	1510	80	1120	0.0	1310
Sole Cowpeas	376	0.0	603	0.0	932	0.0	0.0	0.0
Sole Millet	0.0	1380	0.0	1380	0.0	1380	0.0	0.0

a/ An extra early erect variety.
b/ An early erect variety.
c/ An early semi-erect variety.
d/ A local spreading variety.

Source: ICRISAT Sahelian Center Annual Report (1985), p. 63.

(2) Progressively delaying the time when the cowpeas are intercropped into the millet (a practice similar to farmers' sequential cropping decision-making) allows for better millet yields. In fact, the longer into the season the farmer delays interplanting the cowpea into the millet plot the higher is the yield of millet. However, this leads to substantial declines in cowpea yield.

(3) Sole crops of millet and cowpeas had higher yields than intercropped millet and cowpeas.

In the empirical modeling, the options of planting sole cropped cowpeas in the cropping system (using either local or early maturing varieties) will be evaluated. For example, in low rainfall years, farmers may still be able to delay cowpea planting until the second stage in the season (i.e., July-August) without sacrificing much on cowpea yields, if early maturing varieties are planted in sole crops.

3.3. Improved Agronomy Technical Package

As an attempt to resolve the low soil fertility problem on farmers' fields, the National Agricultural Research Centre of Niger began a series of on-farm trials in 1985 to evaluate the on-farm performance of an improved agronomy technical package. The package consists of the use of improved (early maturing varieties) of millet and cowpeas, increasing planting densities above traditional farmer densities and combining these with the application of chemical fertilizer. This technology was tested in three different agro-ecological zones of Niger[5] from 1985 to

5. Testing was carried out in Libore, Kouka (in the Niamey zone), and Kandamao, Rigial Oubandawaki and Maiquero (in southern Maradi zone).

1987. The results obtained on farmers' plots are given in Table 3.3. These particular values are for the village of study, Maiguero. The results show that:

(1) In every year, the improved agronomy package yielded much more millet than current traditional practices. The impact was more pronounced in the excellent rainfall year of 1986 when yields of millet obtained were 627 kg./ha. for the improved agronomy technical package compared to 279 kg./ha. for traditional farmer practices.

Table 3.3. On-Farm Trials Yields (kg./ha.) Obtained in the Village of Maiguero under Improved Agronomy Technical Package and Traditional Technology during 1985-1987 Crop Seasons.

	Crops		
	Millet	Cowpea Hay	Cowpea Grain
1985			
Traditional	284	278	0
Recommended	590	1387	N.A.
1986			
Traditional	279	N.A.	67
Recommended	627	N.A.	245
1987			
Traditional	154	94	4
Recommended	323	80	31

* Traditional technology represents current farmer practices and consists of the use of late maturing varieties and traditional planting densities. The recommended practice consists of the use of early maturing varieties planted at higher planting densities than traditional farmer practice, and with application of chemical fertilizer (i.e., 50 kg./ha. of urea and 50 kg. of simple super-phosphate/ha.).

Sources: Ly, *et al*., 1985; Krause, *et al*., 1987; and Departement de Recherches en Economie Rural, Institute National de la Recherche Agronomique du Niger.

(2) The yield of cowpea grain was also much higher for the improved agronomy package relative to current farmer practices.

(3) Although cowpea crop failure was experienced in 1987 (as well as in 1985), the cowpea grain yields from the improved agronomy package was 87 percent higher than output from using traditional practices.

(4) The yield of cowpeas is more variable than that for millet. Millet, as mentioned earlier, has a higher drought tolerance.

The farm-level impacts of these technologies will be investigated in this study under different weather scenarios. Combining the on-farm trial results with the extensive cropping systems yield estimates for 1984 and 1985 in Swinton (1987), and survey data on crop system yields in Unite Suivi d'Evaluation (1986, p. 39), the yield distributions for alternative crop systems are derived[6] and shown in Tables 3.4 through 3.6.

6. For details, see Appendix C.

Table 3.4. Cropping Systems Yields at Five Levels of Output Corresponding to Possible Weather States.

Cropping Systems	Millet Yield Levels				
	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Improved millet (CIVT) sole crop	381	381	250	175	104
Local millet cultivar sole crop	396	360	236	152	91
Local millet/local sorghum	304	280	209	88	73
Local millet/local sorghum/cowpea(TN-5-78)	249	226	155	120	78
Local millet/local sorghum/local cowpeas	276	251	134	87	72
Improved millet (CIVT)/Cowpea (TN-5-78) Planted at farmers' density	221	201	233	125	107
Local millet/local cowpeas	286	260	165	100	82
Improved millet (CIVT)/cowpeas (TN-5-78) Higher planting density + 50 kg./ha. of urea and 50 kg./ha. simple super-phosphate	627	627	590	323	96

Table 3.5. Cropping Systems Yields at Five Levels of Output Corresponding to Possible Weather States.

Cropping Systems	Sorghum Yields				
	Very Good	Good	Normal	Poor	Very Poor
Local millet/local sorghum	305	218	109	65	12
Local millet/local sorghum/cowpeas (TN-5-78)	207	148	74	45	30
Local millet/local sorghum/local cowpeas	151	108	54	33	10

Table 3.6. Cropping Systems Yields at Five Levels of Output Corresponding to Possible Weather States.

Cropping Systems	Yield Levels (cowpeas)				
	Very Good*	Good	Normal	Poor	Very Poor
Local millet/local sorghum/cowpea (TN-5-78)	100	67	108	90	25
Local millet/local sorghum/local cowpea	210	134	50	42	8
Local millet/improved cowpeas (TN-5-78)	67	67	8	26	13
Improved millet (CIVT)/improved cowpeas (TN-5-78)	84	84	12	38	19
Local millet/local cowpeas	134	134	4	13	7
Improved cowpeas (TN-5-78) sole crop	140	140	120	100	30
Local cowpeas sole crop	160	160	80	60	20

* In some cases where yield estimates are not available for the very good state of nature, it is assumed that similar yields as in the good state of nature serve as a minimum yield level.

CHAPTER IV

METHODOLOGY AND EMPIRICAL MODEL

In this chapter a discrete stochastic program (DSP) is developed to analyze farmer decision-making. It is then compared with farmers' decision-making in the region. A discussion of the generalized form of the DSP model concludes the chapter.

4.2. Observed Farmer Decision-Making and Implication for Choice of Methodology

Farm management decision making in rainfed agriculture is characterized by uncertainties. Decisions have to be made at a time when the outcome of such decisions are not known with certainty. Between the time span when decisions are made and when their outcomes become known, exogenously determined random events outside the control of the farmer interact to alter the expected outcomes of initial decisions. Such uncertainties may relate to rainfall, temperature, diseases and pests, prices, resource availabilities, yields and the economic policy environment (Dillon, 1986; Rae, 1971a, 1971b). However, farmers make decisions every day through multiple stages in order to adjust planning decisions in response to these stochastic factors.

In southern Maradi the intercropping practice of farmers clearly reflects the ability of farmers to selectively alter cropping patterns within the season. Such adaptive crop choices have been referred to as "a risk reduction strategy" (Balcet and Candler, 1981). A diagrammatic representation of how farmers in southern Maradi make cropping decisions is presented in Figure 4.1. The planning horizon of farmers is divided into three stages: Stage 1 (May-June), Stage 2 (July-September) and Stage 3 (October-March). At the start of the season in Stage 1, farmers wait for the arrival of rains before planting activities begin. Rains in this stage can arrive early ("early rains") or late ("late rains") relative to the mean date of onset of rain in the area. If rains start early, farmers can generally except a long growing season, while late rains generally lead to a short growing season. In the Maradi region, if rains start 20 days earlier than the average onset, farmers have a 95 percent chance of a growing season above 75 days.[1] However, if rains start late (suppose 20 days late), farmers only have a 17 percent chance of a normal growing season length (see Sivakumar, 1988, p. 301). Clearly then, the onset of rains has significant implications for farmers' crop management tactics. In the model formulation, farmers decide in Stage 1 (see Figure 4.1): (a) whether to use short-season or long-season varieties of millet and sorghum. This decision is very important for the success of the farm plan. Sivakumar (1988) indicated that "delayed rains signal the need for early action since traditional and improved cultivars of median season length are likely to have poor yields" (p. 304); or (b) whether to plant millet and sorghum in sole stands or to intercrop them.

1 The average length of the growing season in Maradi is 85 days.

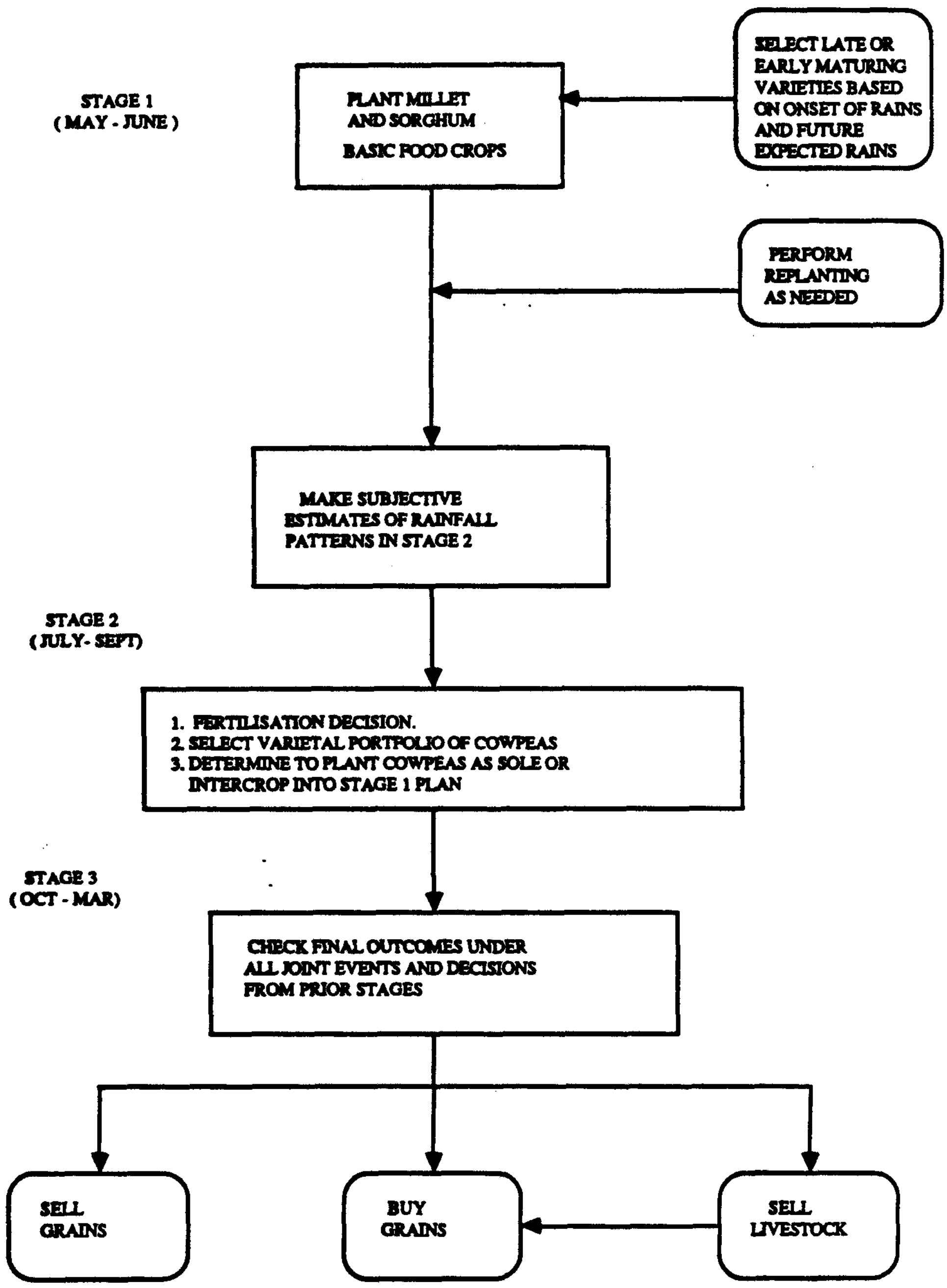

Figure 4.1. A Schematic Diagram of Decisions on a Typical Farm in Southern Maradi, Niger.

Between Stage 1 and the start of Stage 2, the farmer would have been able to observe the outcomes of rainfall events since he made the initial cereal planting decisions. Based on the cereal stand establishment and his expectations of future rainfall patterns, farmers then make the following Stage 2 decisions:

a. Whether to continue with the cereal plan selected in Stage 1, without the addition of cowpeas in Stage 2. The decision whether to plant sole crops of cowpeas is also taken.

b. Whether to interplant the cereal plots carried in from Stage 1 with an additional crop of cowpeas in Stage 2.

c. If the decision is taken to plant the additional crop of cowpeas, which varieties (i.e., short season or long season) should be selected. For example, when rains start late in Stage 1, the resulting short growing season does not allow for the late maturing cowpeas variety to complete the crop cycle. Therefore, the choice of cowpea variety to cultivate is very important.

d. Farmers also decide if they wish to apply chemical fertilizer or not. This decision is generally taken in this stage because rainfall reaches its peak in this stage (in August) and hence the risk of inadequate precipitation is lowest. Application of Urea fertilizer in the absence of an assured water supply can lead to yield loss and this delayed fertilization practice of farmers is a risk adaptation strategy (Unite Suivi d'Evaluation, 1986).

At the beginning of Stage 3, farmers will already know the outcomes of all the crop management decisions taken in the year. Risk management decisions are taken in this stage to respond to the resulting crop output in view of the family's consumption and cash objectives. The choices taken in this stage are:

(a) sell grains;

(b) sell livestock to generate cash for buying grains to supplement any household grain deficits; and

(c) buy grains.

Details of the observed adjustments by farmers in the region were already described in Chapter II.

Farmers in the study zone take decisions in a multi-stage framework which is a strategy that allows them to maintain a flexible production plan that is changeable as the season progresses. Hence, focusing on a one year farm level model (which captures these farm plan decisions) is appropriate. In the next section, the currently available models for analyzing farmer decision-making are reviewed.

4.2. Choice of Methodology Based on Observed Farmer Behavior in Southern Maradi

The choice of methodology in empirical research is influenced by several factors amongst which are (a) relevance to the problem, (b) ease of use, and (c) data availability. The most commonly used methodology in studying farm-level behavior of farmers is linear programming models

(Low, 1974; Heyer, 1972; Roth, 1986; Adesina; 1985).[2] These models allow researchers to model the whole farm, including farm resources (such as labor, land of different quality, capital) and the interactions of the crop and livestock systems.

To incorporate farm-level risks and the response of farmers, various modifications of LP have been used. These include "safety-first" models (McInerney, 1967; Boussard and Petit, 1967; Low (1974) on Ghana, and Heyer (1972) on Kenya), "MOTAD" (Mean Absolute Deviation) (Hazell, 1971; for empirical applications in Africa, see Adesina, et al., 1988; Jaeger, 1984; Rodriquez and Anderson, 1988; Niang, 1980) and "Target MOTAD" (Tauer, 1983; Watts, et al., 1984), and quadratic programming Markowitz, 1959; Rae, 1970). While these models handle risk in one way or another, they all have limitations:

(1) Only the objective function coefficients are stochastic in these models. However, it has been shown earlier that farmers in South Maradi face uncertainties in not only prices and yields, but in within-season rainfall distribution which in turn affects resource availabilities and resource use intensities. Farmers' labor use varies with the rainfall patterns. Obviously, then, the input-output coefficients influencing farm-level decisions and adoption of agricultural technology are stochastic. The above models do not allow for stochastic resource constraints.

(2) None of the models allows the decision maker to:

3. Farm partial-budgeting is the starting point for doing LP analysis. Budgeted costs and returns then feed into LP models as coefficients. The limitations of partial budgeting in farm-level work as well as advantages of whole-farm modeling are well known (see Ghodake and Hardaker, 1981).

(a) update information on random events affecting his decisions;

(b) take decisions in sequential multiple stages, wherein decisions taken at current time, t, are dependent on decisions taken in prior periods, t-1, t-2, ..., etc., as well as on the outcomes of states of nature influencing these prior decisions;

(c) adaptively change crop plans and other decisions as more information is available on the outcomes of random events in each stage of the decision process.

Due to the multi-stage decision making of farmers in Maradi and their response to outcomes under alternative weather patterns, the above-mentioned approaches cannot adequately characterize farmer decision-making. An alternative methodology is to use the RINOCO (Risky Input-Output Coefficients) approach developed by Wicks and Guise (1978). However, this approach, while allowing for stochastic input-output coefficients does not allow for multi-stage sequential decision-making.

A methodology which overcomes most of the limitations of the earlier approaches is discrete sequential stochastic programming (DSP) (Cocks, 1968; Rae, 1971a, 1971b).

4.3. Discrete Stochastic Programming (DSP)

DSP is a method of solving sequential decision problems with uncertainty. It can provide solutions to programming problems where the functional, input-output coefficients and/or resource supplies can be represented by discrete probability distributions (Cocks, 1968). To use this approach in empirical problem solving, a series of steps must be followed, such as: specification of all possible actions open to the farmer, random events influencing decisions, probabilities of these random events occurring in each stage of decision making, an objective function to be optimized by the decision maker, and an appropriate information structure linking decisions in each stage of the planning horizon.

Due to the need to specify resource supplies and input-output coefficients for each state of nature within each stage of the decision planning horizon, the matrix size for solving a realistic DSP problem is larger than its linear programming counterpart. Therefore, DSP can easily run into the "curse of dimensionality" problem, although this matrix size can be reduced to a manageable proportion by (a) appropriate selection of only relevant stages/states of nature and by (b) checking each row of the sub-matrices to test for dominance. This may be needed because the size of the matrix increases very quickly the more detailed the characterization of stages and possible stages of nature.

The first step in specification of a DSP model is the development of a probability model. This step consists of the following subdivisions (Rae, 1971b):

- Isolation of decision dates and division of the planning horizon into distinct stages where decisions can be made.
- Construction of possible stochastic events in each stage.
- Specification of subjective probabilities for the occurrence of the stochastic events in each stage.
- Specification of the information structure assumed for the decision maker (i.e., whether he has (1) perfect information on

outcomes of past and present decisions, (2) incomplete knowledge of the past, or (3) complete knowledge of the outcome of past decisions but only probabilistic knowledge on the outcomes of future stages.

Following development of the probability model, activities and input-output coefficients (which are functions of the states of nature) must be specified for each state of nature. Lastly, the utility function of the decision maker must be specified.

A representation of the probability model of a hypothetical decision tree within the DSP framework is shown in Figure 4.2. The information structure assumed in this model is that of perfect knowledge of the past, i.e., at the time decisions are made in the beginning of stage t, the outcomes of decisions in previous t-1 stages are known but the farmer only has probabilistic knowledge on the outcomes of future stages, although such knowledge is conditional on previously accumulated knowledge in prior stages.

The notation used in the hypothetical model is as follows:

X_{pt} - vector of activity levels initiated at the beginning of stage t, given the occurrence of random event p in previous stage;

E_{spt} - random event "s" in stage t, following the occurrence of "p" event in the previous stage. These values are the random states of nature influencing decisions in each stage;

Y_{ij} - final outcomes of expected pay-offs of decisions taken when event i is followed by event j;

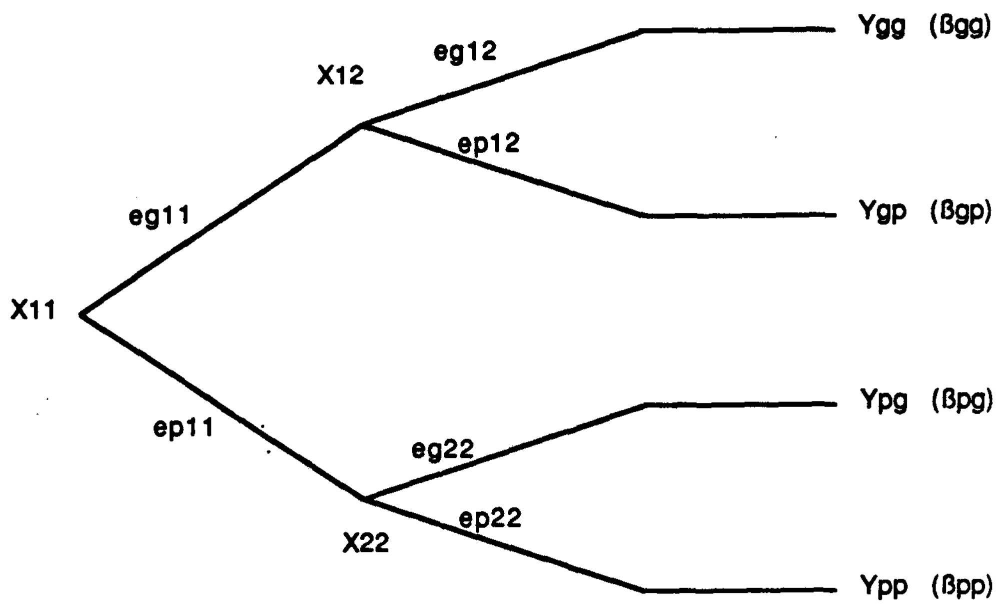

Figure 4.2. A Hypothetical Discrete Stochastic Programming Model.

β_{ij} = joint probability of the occurrence of events i and j. Note that these probabilities must sum to unity over all states of nature.

The decision vector X_{11} is initiated at the beginning of Stage 1. At the beginning of Stage 2, the farmer would have known the outcomes of the random events which occurred in Stage 1. He can therefore use this information to decide on optimal decisions for Stage 2 (i.e, can respond to these outcomes by changing farm plans as needed). If event e_{g11} occurs in Stage 1, the optimal strategy is to initiate decision vector X_{12}. But if event e_{p11} occurs, the optimal sequential strategy for Stage 2 is X_{22}. Therefore, the information structure allows decisions made at the beginning of any stage to depend only on previous decisions (in earlier stages), the realized values of random variables and the expected probabilities of random events in future time periods.

This ability of the DSP model to allow for multi-stage decision-making is its strong advantage over the afore-mentioned approaches of modeling farm-level decisions of farmers. However, despite its advantages over the other approaches, empirical applications using DSP are very few and have been mainly in developed agriculture (Apland, 1979, on crop residue supply in the United States; Tice, 1979, on nitrogen fertilization in Indiana, USA; Rae, 1971b, on vegetable production, New Zealand; Tice and Clouser, 1982, on fertilization in Indiana, USA; Brown and Drynan, 1986, on plant location in Australia). The only empirical application of this methodology in peasant or traditional agriculture (Balcet and Candler, 1981) was in northern Nigeria.

Since it has been shown that farmers in southern Maradi follow a sequential multi-stage decision-making process which allows them to adaptively change crop plans (to reduce production and income risks and increase income) the methodology chosen should allow for this behavior. Since DSP allows the decision maker to adaptively redefine/alter crop decisions in a sequential manner, its use is appropriate for analyzing decision making of the farmers in southern Maradi. The strength of DSP in this study is that it makes it possible to (1) characterize the decision stages by dividing the planning period into a number of stages, (2) specify the random events or "states of nature" within each stage, (3) incorporate the probabilities that each "state of nature" will occur[3], (4) specify activities and farm constraints specific for each state of nature within each stage of the decision planning horizon, (5) link activities and farm resources between all states/stages of the planning horizon, and (6) collect all final outcomes from all possible joint events of states of nature and their associated risks into the objective function.

4.4. Division of Decision Stages and States of Nature Correspondence

The decision stages and the decision alternatives taken by farmers in the empirical model are as shown in Figure 4.1. The stochastic events in the decision stages where cropping decisions are made (i.e.,

3. The ideal thing to do is to obtain farmers' subjective probabilities. However, researchers use their own "expert" probabilities which then makes the model a long-run normative decision-making model rather than a short-run diffusion model (see Rae, 1971a, b; Balcet and Candler, 1981).

Stage 1 and Stage 2) are categorized as follows: In Stage 1 the start of rains (and consequently the start of the season) can be early or late.[4] When rain starts early, two alternative patterns are possible[5] -- "good" or "weak" rains.[6] In Stage 2, rainfall events are also classified as "good" or "weak". Hence, the five combinations of the joint states of nature in Stage 1 and Stage 2 are described as follows:

a. Very Good Year - "good" rain in Stage 1 followed by "good" rain in Stage 2;

b. Good Year - "weak" rain in Stage 1 followed by "good" rain in Stage 2;

c. Normal Year - "good" rain in Stage 1 followed by "weak" rain in Stage 2;

d. Poor Year - "weak" rain in Stage 1 followed by "weak" rain in Stage 2.

e. Very Poor Year - "late" rain in Sage 1 followed by "weak" rain in Stage 2.

The probability associated with these states of nature are 0.34 for the Very Good Year, 0.24 for the Good Year, 0.23 for the Normal Year, 0.16 for the Poor Year, and 0.03 for the disaster (Very Poor) year. The

4. See Sivakumar (1988) for a detailed discussion of the agro-climatological description of rainfall and start/end of season in Niger.

5. These alternative patterns are based on similar categorization of rainfall in Maradi Region by Koechlin (1980).

6. Following Balcet and Candler (1981) and Rae (1971b), respectively, no strict meterological description is attached to these events. Farmers generally know what they mean by good or weak rains. These events as used here are arbitrary classifications.

very poor year is typical of the severe drought year of 1984 when farmers experienced widespread crop failure. Based on long-run historical patterns, the chance of this state of nature occurring is very low, hence, the probability associated with it in the model. This model is more realistic as opposed to naive models which may put a higher weight on this most recent drought experience.[7] The model used here therefore is a long-run normative decision-making model as are those of Rae (1971a, 1971b) and Balcet and Candler (1981).

4.5. Empirical Model

The empirical model constructed for the Maiguero village of southern Maradi is presented in this section. The model consists of 150 constraints and 200 decision variables. The basic version of the model is presented below in matrix notation. The empirical model is specified as:

(1) $\text{Max } E(\Pi) = \beta_{gg}\Pi_{gg} + \beta_{gw}\Pi_{gw} + \beta_{ww}\Pi_{ww} + \beta_{wg}\Pi_{wg} + \beta_{1w}\Pi_{1w}$

S.T.

(2) $A_{g1}X_{g1} <= B_{g1}$

(3) $A_{w1}X_{w1} <= B_{w1}$

(4) $A_{11}X_{11} <= B_{11}$

(5) $A_{gg2}X_{gg2} <= B_{gg2}$

(6) $A_{wg2}X_{wg2} <= B_{wg2}$

(7) $A_{gw2}X_{gw2} <= B_{gw2}$

---

7. See Appendix Table C.11 for the derivation of the probabilities associated with the different states of nature.

(8) $$A_{ww2}X_{ww2} <= B_{ww2}$$

(9) $$A_{1w2}X_{1w2} <= B_{1w2}$$

(10) $$-TX_{g1} + TX_{gg2} <= 0$$

(11) $$-TX_{g1} + TX_{gw2} <= 0$$

(12) $$-TX_{w1} + TX_{wg2} <= 0$$

(13) $$-TX_{w1} + TX_{ww2} <= 0$$

(14) $$-TX_{11} + TX_{1w2} <= 0$$

(15) $$-C_{g1}X_{g1} - C_{gg2}X_{gg2} + \Pi_{gg} = 0$$

(16) $$-C_{w1}X_{w1} - C_{wg2}X_{wg2} + \Pi_{wg} = 0$$

(17) $$-C_{g1}X_{g1} - C_{gw2}X_{gw2} + \Pi_{gw} = 0$$

(18) $$-C_{w1}X_{w1} - C_{ww2}X_{ww2} + \Pi_{ww} = 0$$

(19) $$-C_{11}X_{11} - C_{1w2}X_{1w2} + \Pi_{1w} = 0$$

(20) $$\Pi_{gg}, \Pi_{gw}, \Pi_{wg}, \Pi_{ww}, \Pi_{1w}, X_{gg2}, X_{gw2}, X_{wg2}, X_{ww2}, X_{1w2} >= 0$$

Notation

A_{g1}, A_{w1}, A_{11} = (nxn) matrix of stochastic resource requirements under "good", "weak" and "late" rainfall states in Stage 1;

B_{g1}, B_{w1}, B_{11} = (nx1) vector of Stage 1 resource supplies for "good", "weak" and "late" rainfall states in Stage 1;

A_{gg2}, A_{wg2} = (nxn) matrix of resource requirements in Stage 2 for the Very Good and Good states of nature stochastic events, respectively;

A_{gw2}, A_{ww2} = (nxn) matrix of resource requirements in Stage 2 for the normal and poor states of nature stochastic events, respectively;

A_{1w2} = (nxn) matrix of resource requirements in Stage 2 for the very poor state of nature stochastic events;

B_{lw2} = (nxl) vector of Stage 2 resource supplies for the very poor state of nature;

B_{wg2}, B_{ww2} = (nxl) vector of resource supplies for the good and poor states of nature, respectively;

B_{gg2}, B_{wg2} = (nxl) vector of resource supplies for the very good and good states of nature, respectively;

Π_{ij} = profits from farm plans selected when state of nature i and j occur in stages 1 and 2, respectively. For example, Π_{gg} is profits in the very good year.

C_{gl}, C_{wl}, C_{ll} = (lxn) vector of net margins (i.e., payoffs-costs) for crop activities initiated in Stage 1 (under "good", "weak", and "late" rainfall states, respectively) and continued through Stage 2 without any addition of new crop plans;

C_{gg2}, C_{wg2}, C_{gw2}, C_{ww2}, C_{lw2} = (lxn) vectors of net margins (i.e., payoffs-costs) for crop activities selected under "good", "weak", and "late" rainfall in Stage 1 and are continued into Stage 2 (with additions of cowpeas crop plans in Stage 2). These are categorized by their respective states of nature, i.e., very good, good, normal, poor and very poor, respectively;

β_{ij} = probabilities associated with the five states of nature. Note that $\Sigma\Sigma\beta_{ij}$=1;

X_{ij2}= (nxl) vector of cropping activities in Stage 2, under joint states of nature i and j, respectively/

T = a matrix for preserving proper sequencing of activities and resource transfers.

X_{g1}, X_{w1}, X_{11} - (nxl) vector of millet and sorghum initial cropping activities initiated in Stage 1, but are transferred into Stage 2 where additional crop plans of cowpeas can be added.

Equation (1) is the objective function and represents a weighted sum of the pay-offs from all joint events of states of nature (the weights being the associated probabilities of the respective joint events)

Equations (2)-(4) represent input-output coefficients and resource supplies corresponding to activities performed in Stage 1 under "good", "weak" and "late" rains, respectively. Hence, at the start of the season, rainfall can either be early or late. If early rainfall state occurs, it can either be "weak" or "good" rains. The input-output coefficients and labor supplies are disaggregated for each of these specific states of nature. Activities specified include planting of millet and sorghum (sole crop or as intercrops). Replanting activities are allowed under each rainfall state. Also similar disaggregation is performed for acreage supplies. Allowances are provided for the transfer of fallow and cereal cropped land from Stage 1 into Stage 2. (See Tables 4.1 and 4.2 for a picture of a simplified tableau.)

Equations (5)-(9) represent constraints for crop activities, input-output coefficients and resource supplies corresponding to the five possible states of nature in Stage 2 of the season. For example, Equation (5) represents those for the activities performed when "good" rains in Stage 2 follow the occurrence of "good" rains in Stage 1 (i.e. very good year). These activities include weeding (both first and second weedings) and thinning of cereal plots carried over from Stage 1, planting (and weeding) of alternative cowpea varieties, fertilization

Table 4.1. A Simplified Picture Matrix of Cropping Options in Stage 1.

		Timely Planting** (Good and Weak Rains)					Late Planting					
		Millet		Millet/Sorghum			Millet		Sorghum	Millet/Sorghum		
	RHS	Impv. Millet	Local Millet	Impv. Millet/ Local Sorghum	Local Millet/ Local Sorghum	Fallow	Impv. Millet	Local Millet	Local Sorghum	Impv. Millet/ Local Sorghum	Local Millet/ Local Sorghum	Fallow
Land Constraint (ha.)												
Timely Rains	3.5	1	1	1	1	1	-	-	-	-	-	
Late Rains	3.5	-	-	-	-	-	1	1	1	1	1	1
Labor Constraint (hrs.)												
Timely Rain (good) planting	B_G	+	+	+a/	+	-	-	-	-	-	-	-
Timely Rain (weak) planting)	B_W	+*	+*	+ *	+*		-	-	-	-	-	-
Late Rains Planting	B_L	-	-	+ *	+*	-	+*	+*		+*	+*	
Transfer of Land into Stage 2												
Timely Rain (good)												
Impv. Millet	0	-1	-	-	-	-	-	-	-	-	-	-
Local Millet	0	-	-1	-	-	-	-	-	-	-	-	-
Impv. Millet/ Local Sorghum	0	-	-	-1	-	-	-	-	-	-	-	-
Local Millet/ Local Sorghum	0	-	-	-	-1	-	-	-	-	-	-	-
Fallow	0	-	-	-	-	-1	-	-	-	-	-	-
Timely Rain (weak)												
Impv. Millet	0	-1	-	-	-	-	-	-	-	-	-	-
Local Millet	0	-	-1	-	-	-	-	-	-	-	-	-
Impv. Millet/ Local Sorghum	0	-	-	-1	-	-	-	-	-	-	-	-
Local Millet/ Local Sorghum	0	-	-	-	-1	-	-	-	-	-	-	-
Fallow	0	-	-	-	-	-1	-	-	-	-	-	-
Late Rains												
Impv. Millet	0	-1	-	-	-	-	-	-	-	-	-	-
Local Millet	0	-	-1	-	-	-	-	-	-	-	-	-
Impv. Millet/ Local Sorghum	0	-	-	-1	-	-	-	-	-	-	-	-
Local Millet/ Local Sorghum	0	-	-	-	-1	-	-	-	-	-	-	-
Fallow	0	-	-	-	-	-1	-	-	-	-	-	-

* Activity coefficients include additional labor for replanting activities.
** Planting activities should be differentiated by good and weak rains. This is not done here to allow tableau simplification.
a/ Represents the drawing on of labor supply for corresponding activities. These coefficients are disaggregated by state of nature.

Table 4.2. A Simplified Picture Representation of Farming Options in Stage 2 when Good Weather in Stage 2 Followed the Occurrence of Good Weather in Stage 1 (i.e., Very Good Year).

		FINAL CROPPING ACTIVITIES										
		(1) Impv. Millet/ Impv. Cowpeas at High Plant Density Plus Fert.	(2) Impv. Millet	(3) Local Millet	(4) Impv. Millet/ Impv. Cowpeas (Farmers' Density)	(5) Local Millet/ Local Cowpeas (Farmers' Density)	(6) Local Millet/ Impv. Cowpeas (Farmers' Density)	(7) Local Millet/ Local Sorghum	(8) Local Millet/ Local Sorghum/ Local Cowpeas	(9) Local Millet/ Local Sorghum/ Impr. Cowpeas	(10) Local Cowpeas	(11) Improved Cowpeas
	HRS											
TRANSFER OF LAND FROM STAGE 1												
Impv. Millet	0	+1	+1	-	+1	-	-	-	-	-	-	-
Local Millet	0	-	-	+1	-	+1	+1	-	-	-	-	-
Local Millet/ Local Sorghum	0	-	-	-	-	-	-	+1	+1	+1	-	-
Fallow	0	-	-	-	-	-	-	-	-	-	+1	+1
LABOR USE (HRS.) (July-Sept.)												
1st Weeding		+	+	+a/	+	+	+	+	+	+	+	+
2nd Weeding		+	+	+	+	+	+	+	+	+	+	+
CROP YIELDS (KG.)												
Millet	0	-627	-381	-396	-221	-286	-	-304	-276	-249	-	-
Sorghum	0	-	-	-	-	-	-	-305	-151	-207	-	-
Cowpeas	0	-245	-	-	-84	-134	-67	-	-210	-100	-160	-140

a/ + - represents the drawing on of labor supply for corresponding activities. Activities include thinning, weeding, planting of cowpeas where appropriate, and fertilization where appropriate. These were not disaggregated to facilitate easy representation in tableau.

activities, buying and consumption of grains in the dry periods preceding harvesting ("soudure"). Other activities include cash supplies for buying seeds and fertilizer. Subsistence constraints for millet and sorghum are also specified for each state of nature. Based on minimum nutritional and energy requirements per household member,[8] the total cereal needs is estimated to be 800 kg. per household. This cereal need can be met from millet or sorghum production or through grain purchases on the market. Activities for selling livestock, selling and buying grains to adjust to the eventual output outcomes of decisions taken in Stages 1 and 2 are also specified. The household is endowed with 3 rams and 3 goats as initial livestock inventory.[9] Since the model is an annual model, livestock breeding is not included. The household can sell livestock to generate cash requirements for buying supplementary grains.

Equations (10)-(14) are transfer rows which transfer crop activities and resources from Stage 1 to Stage 2 under corresponding states of nature. The transfer matrices (i.e., T) are not identity matrices but have non-zero off diagonal elements as activities and resources from a specific state of nature in Stage 1 can be transferred into more than one set of cropping activities in Stage 2. For example, land transferred from "good" state of nature in Stage 1 is available to activities performed under "good" and "weak" states of nature in Stage 2

8. The average household size is 3.0 while the active members of the household engaged in agriculture (i.e., _actifs_) is 2.4 (Swinton, 1985; Issa, _et al_., 1987). The minimum grain requirement per capita is 266 kg. which is comparable to 250 kg./capita recommended by the Niger Government (Table A.1).

9. Based on Swinton and Ly (1984, p. 9) which showed that mean number of sheep and goats in sandy soil villages is 6.0 (see Chapter II).

(i.e., activities done when "good/good" (very good year) and "good/weak" (normal year) joint events sequences occur in Stage 1 and Stage 2). Also, millet and sorghum planted in Stage 1 can be transferred into Stage 2 where cowpeas can be interplanted or the grains can be left without adding cowpeas. These constraints therefore preserve the proper sequencing of activities and resource transfers.

Equations (15)-(19) define the expected profits from crop plans selected under the joint events. The net margins are computed by subtracting from gross returns the variable costs of production associated with each activity.

Equation (20) is non-negativity constraint on the decision variables in the model.

It is clear from the model specification that the farmer is allowed to make alternative decisions depending on the occurrences of alternative states of nature.

4.6. Data

The labor data used in the empirical model represents hours worked per cropping option and were developed using data from rural household surveys in Maradi region of southern Niger in Swinton (1987), Unite Suive d'Evaluation (1986), Legal (1985), and Roesch (1982). These data covered cropping patterns, cultural practices and labor use of millet, sorghum and cowpeas sole crops and intercrops under traditional farmer practices.

Information on labor use and yields for improved agricultural technology (i.e., early maturing varieties + higher planting density + fertilization) are actual data obtained in three years of on-farm trials in the village of study. These data were obtained from published reports of the economics section of Niger's national agricultural research institute (Ly, _et al_., 1985; Krause, _et al_., 1987). Additional yield data were obtained from experiment station field trials in the area of study (INRAN, 1986). Livestock monthly prices were obtained from the International Livestock Center for Africa in Niamey. Monthly grain prices for Maradi region were obtained from field data collected by the University of Michigan Agricultural Sector Project in Niger. Data on livestock holdings and sale patterns in dry rainfall years were taken from Swinton and Ly (1984, p. 9), Swinton (1988, p. 32) and Swinton and Mammane (1984), respectively.

CHAPTER V

BASE MODEL RESULTS AND VALIDATION

The results for the empirical model evaluated with traditional technologies are presented in this chapter. The base model results include: selected cropping systems, expected farm production under each state of nature,[1] post-harvest risk management decisions and income characteristics of the entire farm plan selected by the farmer. A validation of the results against observed farmer behavior and with other studies is emphasized in this chapter.

5.1. Cropping Systems under Traditional Technology

The model results for cropping systems under traditional technology for each state of nature are shown in Table 5.1.

The principal points from these results are:

(1) Farmers planted intercrops of local varieties of millet, sorghum, and cowpeas in most states of nature (four out of five). Sorghum

1. The states of nature are as discussed in Chapter IV. State 1 is equivalent to a very good year (i.e., good rains in Stage 1, followed by good rain in Stage 2); State 2 is equivalent to a good year (i.e., weak rains in Stage 1, followed by good rain in Stage 2); State 3 is equivalent to a normal year (i.e., good rains in Stage 1 followed by weak rain in Stage 2); State 4 is equivalent to a poor year (i.e., weak rain in Stage 1, followed by weak rain in Stage 2); State 5 is equivalent to a very poor year (i.e., rain started late in Stage 1, and was followed by weak rain in Stage 2). Throughout the rest of the discussion these states of nature will be categorized as above.

Table 5.1. Farm Plan under Traditional Technology (Hectares Harvested).

Cropping System	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Local millet sole crop	-	-	-	0.88	1.53
Local millet/local cowpeas	-	-	-	0.88	-
Local millet/local sorghum/ local cowpeas	0.92	0.93	0.47	-	-
Local cowpeas sole crop	0.8	0.8	0.8	0.8	0.8
Local millet/local sorghum	0.92	0.93	1.23	-	-

Source: Model results.

drops out of the rotation in the low rainfall years.

(2) In most states of nature, farmers started cropping decisions in stage 1 with planting of the millet and sorghum crop mixture. Sorghum was never planted as a sole crop in stage 1. In stage 2, farmers divided the crop plan from stage 1 into millet and sorghum intercrop, and the rest into millet and sorghum interplanted with cowpeas. The results are reflective of observed farmer production patterns in the village. Farmers do not plant sole crops of sorghum. As indicated in Chapter II, intercropping is the basis of the farming systems with the most common intercrops being: millet interplanted with cowpeas, millet and sorghum interplanted with cowpeas, and millet interplanted with sorghum (see Swinton, *et al*., 1984; Swinton, 1987).

(3) In the state of nature characterized by very poor rainfall, the model predicts that farmers do not plant sorghum in the crop mix.

Millet was the only cereal planted and this was as a sole crop. This is consistent with observed farmer production adjustments in drought years. As pointed out in Chapter II, farm-level evidence shows a shift into a higher proportion of sole cropping of millet in drought years. Since rains start late in drought years, farmers continue to re-plant the principal cereal crop (millet) until it is well established. This replanting operation often pre-empts the addition of other crops into the millet plots. Sorghum is less drought tolerant than millet hence it is a more risky crop, and sorghum crop failure can be experienced in poor rainfall years. This shift to sole cropped millet is an adaptive response to poor rainfall. Similar adaptations of crop selection to rainfall have been found among peasant farmers in other parts of Sahelian West Africa (Vierich and Stoop, 1987; Matlon, 1980).

5.2. Expected Production Patterns under Traditional Technology

The crop production by state of nature are shown in Table 5.2. The production pattern shows that farm output varies substantially with the different states of nature. In each state of nature the predominant output was millet output. In the very good and good states of nature, millet production was 531 kg. and 496 kg., respectively. This output declined to 386 kg. in the normal year, 222 kg. in the poor year and 139 kg. in the very poor year. In the better rainfall states when sorghum was produced, a similar declining pattern of output with decreased rainfall is observed. Drastic declines in cowpea output occur in the normal, poor and very poor rainfall states. In terms of expected total output (all crops), the estimates show farmers expect to produce 890 kg. over all states of nature.

Table 5.2. Crop Output (kg.) by State of Nature and Expected Output under Traditional Technology.

	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Crop Output by State of Nature					
Millet	531	496	386	222	139
Sorghum	418	304	186	0	0
Cowpeas	320	253	112	59	16
Total	1269	1053	684	281	155
Expected Output Over All States of Nature					
Millet			427		
Sorghum			258		
Cowpeas			205		
Total			890		

Source: Model results.

The substantial reduction in both cereal and cowpea output in these low rainfall years is linked to the poor performance of the local maturing cultivars planted by farmers under traditional technology. Because of the shortness of the growing season in these poor rainfall scenarios, these varieties are not able to complete their cycle before the late season dry spell sets in. In the good rainfall years, however, these cultivars gave higher outputs since the longer growing season allows them to make optimum use of the soil moisture for grain filling.

5.3. Post-Harvest Risk Management Strategies under Traditional Technology

In response to the final outcome of crop output resulting from the cropping decisions taken earlier in the season, farmers take three decisions. These decisions are grain sales, grain purchases on the market and the sale of livestock (see Chapter II for detailed discussion). The model results for the post-harvest decisions under traditional technology are presented in Table 5.3. The major points from the results are:

(1) The model predicts that farmers sold cereals only in the very good year. The amount of cereal sale was 149 kg. Cowpeas, the major cash crop, was sold in every state of nature to generate cash income. The total expected volume of grain sales over all the states of nature is 256 kg.

Table 5.3. Cereal Sales and Purchases and Livestock Sales with Traditional Technologies.

	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Crop Sales (kg.)					
Millet	-	-	-	-	-
Sorghum	149	-	-	-	-
Cowpeas	320	253	112	59	16
Total	469	253	112	59	16
Sale of Livestock					
Sheep	-	-	1	2	3
Goats	-	-	-	-	2
Grain Bought on the Market (kg.)					
Millet	-	-	228	579	661
Sorghum	-	-	-	-	-

Source: Model results.

The estimates of marketing of grains obtained in this study are consistent with those cited in other studies of Niger. Various studies claim the amount of millet and sorghum farmers sell is very small, ranging from 0 to 4 percent of cereal production in very poor years (Swinton and Mammane, 1984) to approximately 15 percent in better rainfall years (see University of Michigan, 1977; Club du Sahel, 1979; Government of Niger, 1978; Elliot Berg Associates, et al., 1983). Raynaut (1973) found an estimate of 17 percent. The amount of cereals sold in the very good year (i.e., State 1) in the model represents 16 percent of the total amount of millet and sorghum produced. This is consistent with the above studies. For the low rainfall states of nature, the model estimates in this study show that no millet or sorghum was sold by the farmer. This estimate falls within the 0 to 4 percent range cited by Swinton and Mammane (1984) for the poor rainfall years of 1984 and 1985 in the study zone. To generate cash, however, farmers sold cowpeas.

(2) No grains were bought by the farmer in the states of nature with better rainfall (i.e., very good and good rainfall states).

(3) Farmers bought grains in the post-harvest period in the states of nature with lower rainfall (i.e., normal, poor and very poor states of nature). The amount of millet bought was 228 kg. in the normal rainfall year, 579 kg. in the poor rainfall year, and 661 kg. in the very poor rainfall year. Village level evidence confirms these results. Swinton and Mammane (1984) found that farmers bought substantial amounts of grains in low rainfall years. Other studies of Niger (Painter, 1987; Sutter, 1979) similarly found that pervasive grain buying occurred in low rainfall years.

(4) Due to the production deficits in the low rainfall states of nature, the model predicts that farmers will sell livestock in order to generate cash for buying grains. The amount of livestock sold consisted of one ram in the normal rainfall year, two rams in the poor rainfall year, and three rams and two goats in the very poor rainfall year, respectively. This is a reduction of the livestock inventory[2] by 16 percent in State 3, 33 percent in State 4 and 83 percent in State 5. Therefore, increasing numbers of animals are sold with progression into the drought year.

These model results are consistent with village-level evidence provided in Chapter II, showing that substantial numbers of livestock are sold by farmers to generate cash for grain purchase (see Swinton and Mammane, 1986; Swinton, 1988). Livestock plays a very important role in allowing farmers in this village to adapt to outcomes under different rainfall situations.

5.4. Expected Cash Income, Cash Income under Alternative States of Nature

The income characteristics of all the farm decisions taken under traditional technology are presented in Table 5.4. The estimates show that cash income declines with the change in rainfall patterns from high to low rainfall states of nature. These income changes are directly linked to the declining volume of grain farmers sold with transition into the low rainfall states. The cash income in the very good year is 463 percent higher than cash income in the poor rainfall year. The

2. The initial livestock inventory consists of three rams and three goats.

Table 5.4. Cash Income, Expected Cash Income and Other Risk Characteristics of Farm Plan: Traditional Technology.

	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Cash Income (CFA)	45261 (142)[1/]	31635 (99)	13749 (43)	8027 (25)	2064 (6)
Total Income (CFA)[2/]	73226 (230)	59600 (187)	42735 (134)	24677 (77)	13104 (41)
Expected Cash Income (CFA)			27410 (86)		
Coefficient of Variation of Cash Income (All States)			0.72		
Coefficient of Variation of Total Income (All States)			0.52		

[1/]Values in parentheses are dollar equivalents. Exchange rate: 318 CFA = 1 U.S. dollar (West Africa, October 10, 1988).

[2/]With the imputed value of cereals consumed by the household.

expected cash income over all states of nature is 27410 CFA ($86).

The estimates of farmer cash incomes under traditional technology show that in absolute values, farmers' incomes are very low. These farmers have few resources and are often forced to further deplete these resources (especially livestock) in order to generate cash to meet consumption expenditures of grain purchases. With the consideration of the value of cereals consumed at home, incomes of farmers are substantially higher than revealed by these cash incomes. Absolute total income ranges from 73226 CFA ($230) in the very good year to 24677 CFA ($77) in the poor year. Consequently, subsistence consumption of cereals is an important part of household income.

5.5. Conclusions

The major issues shown by the results of the empirical model presented in this chapter are:

(1) Validation of the model results showed that the empirical model describes the production patterns in the village zone of the study well. Based on cropping and marketing patterns, it was observed that estimates in this study agree with those cited by other studies and with observed farmer behavior.

(2) The model predicts that farmers will buy large amounts of grains in post-harvest periods of low rainfall years. They will also sell livestock to generate cash supplies to buy grains. These livestock sale and grain sale and re-purchase patterns observed in the empirical model results are consistent with what farmers are observed to do in the study zone.

(3) In absolute dollar terms, returns to agriculture under traditional technology are low. Incomes received also decline substantially with lower rainfall. New agricultural technologies and complementary cereal pricing policies may be needed to achieve higher productivity and higher total incomes for farmers in this risky agricultural environment. Especially important is the ability of these technologies to increase domestic cereal consumption in the various states of nature. This is one of the focuses of the next chapter.

CHAPTER VI

FARM LEVEL IMPACTS OF NEW AGRICULTURAL TECHNOLOGIES AND COMPLEMENTARY POLICIES[1]

A major conclusion from the last chapter was that agricultural output and incomes are low absolutely and fluctuate substantially with traditional technologies. Two principal instruments to improve agricultural output and farmer income are (1) new agricultural technologies which can increase crop yields, and (2) pricing policy instruments which can put a floor on the cereal price decline in good rainfall years. In this chapter farm level impacts of alternative agricultural technologies with and without price policy are evaluated.

The set of technologies evaluated consist of (a) early maturing varieties of millet and cowpeas, both in sole crop systems and intercrop systems; and (b) an improved agronomy technology package consisting of early maturing varieties of millet and cowpeas, planted at higher plant densities than traditional farmers' practices, and with application of chemical fertilizer (i.e., 50 kg./ha. of simple super-phosphate and 50 kg./ha. of Urea). The returns to labor will be computed for each technology and comparison made with the rural wage rate or opportunity cost of labor.

1. The interested reader may turn to section 6.9 for a summary of the principal results from the analysis in this chapter.

6.1. Crop Systems Cultivated with Introduction of Early Maturing Varieties of Millet and Cowpeas

The cropping systems selected by the farmer with the introduction of early maturing varieties are shown in Table 6.1 for five states of nature. The farm plan from the model predicts that:

(a) More diversified crop patterns are adopted in the very good year due to the excellent rainfall existing to support such production patterns.

(b) Early maturing varieties of millet planted in sole crop were adopted in the poor and very poor rainfall states.

(c) The intercropped combination of early maturing millet and early maturing cowpeas were adopted in the poor rainfall years. With transition into the poor rainfall year, farmers shifted into sole cropping of the early maturing millet variety. These patterns of

Table 6.1. Farm Plan when Improved Varieties of Millet and Cowpeas are Introduced (Hectares Harvested).

	State of Nature				
Cropping System	Very Good	Good	Normal	Poor	Very Poor
Early millet sole crop	-	-	-	0.88	1.53
Local millet sole crop	-	-	-	-	-
Early millet/early cowpea	-	-	-	0.90	-
Local millet/local cowpea	-	-	-	-	-
Local millet/local sorghum	1.05	0.93	1.09	-	-
Local millet/local sorghum/ local cowpeas	0.7	0.93	-	-	-
Local millet/local sorghum/ early cowpeas	0.36	-	1.09	-	-
Early cowpeas sole crop	-	-	0.8	0.8	0.8
Local cowpeas sole crop	0.8	0.8	-	-	-
Local millet/early cowpeas	-	-	-	-	-
Early millet/local cowpeas	-	-	-	-	-

Source: Model results.

adoption in the poor and very poor rainfall years are supported by current agronomic recommendations from experiment stations. Reddy (1988) recommends that in low rainfall years (and especially when rainfall starts late) farmers may be better off planting early maturing varieties of cowpeas and millet either in sole crop or as intercrops.

(d) In each state of nature, farmers devoted 0.8 ha. to cultivation of cowpeas in sole crop. However, while local maturing varieties were used in the very good and good rainfall years, respectively, the farmer changed into use of the early maturing cowpea variety in the normal, poor and very poor rainfall years.

The implications of these results is that farmers can change their choices of crop varieties by selecting appropriate cultivars to fit the variability in the weather pattern. Such flexible crop management tactics will allow farmers to adapt to the riskiness of crop production in the stressful Sahelian environment. Andrews (1987) indicated that if farmers follow such varietal mixtures they can protect themselves against the risk of low or short rainfall periods by planting early maturing cultivars and making optimum use of available soil moisture in good rainfall years by planting late maturing cultivars.

The results of farmer adoption patterns also has implications for technology development programs at the National Agricultural Research Centre and at ICRISAT Sahelian Centre. The orientation of future breeding programs depends on what one expects of the future Sahelian weather pattern. Some researchers claim that rainfall in the Sahel will continue to be low and, that the persistent droughts may signal a permanent change in the weather pattern (see Gregory, 1982; Nicholson, 1983; Lamb, 1982; Lamb, 1983). Apart from this, annual rainfall declines, Dennett, *et al*., 1985, show that rainfall in August (the main rainfall peak period) has continued on a persistent downward trend over the last 16 years. If one subscribes to the position of a permanent weather change, then breeding efforts need to be oriented towards early maturing varieties. However, if these rainfall trends are nothing more than a cyclical weather pattern indistinguishable from a random series (Bunting, *et al*., 1976; Landsberg, 1975), then breeding programs may want to diversify and also produce improved intermediate period and longer period cultivars. Since farmers' varietal portfolio mixes continue to involve selective utilization of both local and early varieties, it would seem that such diversification is justified. Plant breeders need to also improve upon longer season local cultivars since the model predicts that the early cultivars are not always selected in good rainfall years. The model shows that by carrying a portfolio mix of both cultivars, farmers will be able to adapt plantings to the ensuing rainfall patterns in the season.

6.2. Expected Farm Production with Adoption of Early Maturing Varieties

The expected farm output and production by state of nature are shown in Table 6.2. The estimates show that with the introduction of early maturing varieties, farmers achieve higher production levels than with traditional technology. The expected millet output is 460 kg., expected sorghum output is 258 kg., and expected cowpea output is 234 kg. Total expected output for all crops is 890 kg. The total expected output with introduction of early maturing varieties is 18 percent

Table 6.2. Crop Output (kg.) by State of Nature and Expected Output with Introduction of Early Maturing Varieties.

	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Crop Output by State of Nature					
Millet	600	496	397	264	159
Sorghum	500	304	200	0	0
Cowpeas	310	253	214	113	24
Total	1410	1053	811	377	183
Expected Output Over All States of Nature					
Millet			460		
Sorghum			289		
Cowpeas			234		
Total			983		

Source: Model results.

higher than the corresponding estimate under traditional technology. These estimates of expected farm-level productivity increases from adopting improved cultivars alone in the absence of improved agronomy characteristics[2] is corroborated by Matlon's (1987) observation that "yield advantage of most improved cultivars rarely exceeds 15 percent under farmers' low-input management" (p. 31). The results also indicate that it is probably necessary to concentrate on improving the agronomic environment (through water and soil management practices) before the in-

1. Improved agronomy is defined here as practices to reduce stress, such as improved plant nutrient supply, soil fertility and water management, respectively.

troduction of these new varieties.[3]

6.3. Post-Harvest Decisions with the Introduction of Early Maturing Varieties

The predicted pattern of the post-harvest decisions taken by the farmer with the introduction of improved varieties is shown in Table 6.3. The estimates show that farmers sold more grains than under traditional technology. Cereals were sold only in the very good years. This amount of cereals sold (300 kg.) is double the cereal sales with traditional technologies (149 kg.). With the new cultivars, farmers now sell millet instead of sorghum in the best rainfall years. In all the other

Table 6.3. Cereal Sales and Purchases and Livestock Sales with Introduction of Improved Varieties.

	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Crop Sales (kg.)					
Millet	300	-	-	-	-
Sorghum	-	-	-	-	-
Cowpeas	310	253	214	150	24
Total	610	253	214	150	24
Sale of Livestock					
Sheep	-	-	1	2	3
Goats	-	-	-	-	2
Grains Bought on the Market (kg.)					
Millet	-	-	203	536	641
Sorghum	-	-	-	-	-

Source: Model results.

3. Also see Sanders (1988) and Andrews (1987) for a similar argument for a technology development strategy in the Sahel.

rainfall states except the best one, the increased millet production was not sold but kept in the household to supplement the deficit subsistence grain requirement. However, to generate cash, farmers sold cowpeas in each state of nature. Due to the adoption of the early maturing cowpea variety, farmers were able to sell more cowpeas than they were with the traditional technology. For example, cowpea sales in the normal year increased from 112 kg. to 214 kg. with adoption of early maturing cowpeas. In the poor year, the farmer still increased cowpea sales from 59 kg. to 150 kg. with the adoption of an early maturing cowpea cultivar. In the very poor year, there is crop failure even with the availability of new cultivars.

In the post-harvest period there is no difference (compared to traditional technology) in the number of livestock sold by farmers with the introduction of early maturing varieties. Livestock were sold in all of the states of nature in which rainfall was not above normal. Farmers bought grains after selling livestock. However, slightly lower amounts of grain millet were bought with the introduction of early maturing varieties. In the normal year (i.e., State 3), 203 kg. of millet was bought in the post-harvest period period compared to 228 kg. under traditional technology. This represents a minimal decrease in purchase requirements of only 12 percent.

Therefore, in terms of millet bought in the post-harvest period, only very marginal improvements are achieved with the introduction of early maturing millet varieties. Farmers still face large cereal deficits in low rainfall years despite adoption of early maturing millet varieties.

6.4. Expected Income and Cash Incomes by State of Nature with Introduction of Early Maturing Varieties

The expected cash income and cash incomes by state of nature are shown in Table 6.4. Expected cash income with adoption of early maturing varieties is 32743 CFA ($103) compared to 27410 CFA ($86) obtained with traditional technology. When the value of home consumption is taken into account, the expected total income with introduction of early maturing varieties is 59328 CFA ($186) compared to 53204 CFA ($167) with traditional technology. This represents an increase of 11 percent. In absolute terms these incomes are still low even with adoption of early maturing varieties.

Table 6.4. Cash Incomes, Expected Cash Income and Other Farm Plan Characteristics: New Variety Introduction.

	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Cash Income (CFA)[1]	49222 (155)[2]	31635 (99)	25658 (81)	15322 (48)	3096 (10)
Total Income[3]	77187 (243)	59600 (187)	55855 (175)	35122 (110)	15736 (50)
Expected Cash Income (CFA) (All States)			32743 (102)		
Coefficient of Variation of Cash Income (All States)			0.59		
Coefficient of Variation of Total Income (All States)			0.44		

1/ Exchange rate: 318 CFA = $1 (West Africa, October 10, 1988).

2/ Values in parentheses are dollar equivalents of the estimates.

Source: Model results.

Moreover, the coefficient of variation and the standard deviation of expected income show that the adoption of early maturing varieties lowers the riskiness of farmers' income. Compared to the traditional technology, the coefficient of variation of expected total income was decreased by 18 percent. The introduction of early maturing varieties reduces the risk of crop failure in the low rainfall years and thereby lowers income variability.

6.5. Introduction of Improved Agronomy Package

The farm plan with the introduction of the improved agronomy package (i.e., improved varieties + higher planting densities + chemical fertilization) is shown in Table 6.5 for the five states of nature. The results show that farmers continued to devote most of their farm plan to non-fertilized cropping systems. The improved agronomy package was adopted in four out of the five states of nature. The patterns of the technology show farmers adopted 0.4 ha. of the new technology package in the very good year, 0.7 ha. with the good, normal and poor states of nature, respectively. The technology was not adopted in the very poor state of nature. This farmer decision to not adopt the technology in this state of nature is a direct response to the very low rainfall in the state of nature. This is consistent with observed farmer behavior in 1984.

6.5.1. Expected Production with Introduction of Improved Agronomy Package

Expected total output with the adoption of the improved agronomy package (1133 kg.) is 27 percent higher than the estimate with

Table 6.5. Farm Plan with Introduction of Improved Agronomy Packages (Hectares Harvested).

Cropping System	State of Nature: Very Good	Good	Normal	Poor	Very Poor
Early millet sole crop	0.37	0.72	0.72	1.12	1.53
Local millet sole crop	-	-	-	-	-
Early millet/early cowpeas	-	-	-	-	-
Local millet/local cowpeas	-	-	-	-	-
Local millet/local sorghum	0.89	0.1	0.36	-	-
Local millet/local sorghum/ local cowpeas	-	0.1	-	-	-
Local millet/local sorghum/ early cowpeas	0.89	-	0.36	-	-
Early cowpeas sole crop	-	-	0.8	0.8	0.8
Local cowpeas sole crop	0.8	0.8	-	-	-
Local millet/early cowpeas	-	-	-	-	-
Early millet/local cowpeas	-	-	-	-	-
Early millet/early cowpeas Higher planting density and 50 kg./ha. SSP and 50 kg./ha. urea	0.37	0.72	0.72	0.72	-

Source: Model results.

traditional technology varieties and 10 percent higher than the estimate with the introduction of early maturing varieties (Table 6.6). The variations in output by state of nature is also enormous. Total crop output in the very good year is approximately three times the output in the poor year (Table 6.7).

6.5.2. Post-Harvest Decisions with Introduction of the Improved Agronomy Package

The post-harvest decisions of farmers with the introduction of the improved agronomy package are shown in Table 6.8. These estimates show

Table 6.6. Expected Farm Output (kg.) (Over All States of Nature) for Alternative Technologies and Percentage Increments by Level of Technology.

	Expected Output (kg.)
Choice of Technology	
Traditional (1)	890
Improved Varieties (2)	983
Introduction of Improved Agronomy (3)	1133
Percentage Increases by Technology	
(2) as % of (1)	10%
(3) as % of (1)	27%
(3) as % of (2)	15%

Source: Model results.

Table 6.7. Crop Output (kg.) by State of Nature and Expected Output with Introduction of Improved Agronomy Technical Package.

	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Crop Output by State of Nature					
Millet	868	771	733	477	159
Sorghum	456	29	65	0	0
Cowpeas	308	316	135	95	24
Total	1632	1116	933	572	183
Expected Output Over All States of Nature					
Millet			728		
Sorghum			177		
Cowpeas			228		
Total			1133		

Source: Model results.

Table 6.8. Grain Sales and Purchases and Livestock Sales with the Introduction of Improved Agronomy Package.

	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Crop Sales (kg.)					
Millet	524	-	-	-	-
Sorghum	-	-	-	-	-
Cowpeas	308	316	135	95	24
Total	832	316	135	95	24
Sale of Livestock					
Sheep	-	-	-	1	3
Goats	-	-	-	-	2
Grains Bought on the Market (kg.)					
Millet	-	-	-	323	641
Sorghum	-	-	-	-	-

Source: Model results.

that farmers were able to sell 524 kg. of millet in the very good year compared with 300 kg. with the introduction of improved varieties and 149 kg. with traditional technology. The amount of millet bought in the normal and poor states of nature also declined substantially with the adoption of the improved agronomy package. In the normal year, no millet was bought by the farmer, a major drop from the 203 kg. bought with the adoption of early maturing varieties and 228 kg. bought with traditional technology. Essentially, in the normal state of nature the farmer became self-sufficient in grain production with the adoption of the improved agronomy package. In the poor state of nature the farmer bought 323 kg. of millet, a substantial decline from 579 kg. bought with traditional technology and 536 kg. bought with the adoption of early maturing varieties.

The extent to which the farmer moves closer to domestic self-sufficiency in grains under each technology is summarized in Table 6.9. In the very good and good states of nature, farmers are self-sufficient in cereal production. Deficits occur in the normal, poor and very poor states of nature, respectively. Adoption of early maturing varieties makes farmers 75 percent self-sufficient in the normal year, 33 percent self-sufficient in the poor year, and 20 percent self-sufficient in the very poor year. With adoption of the improved agronomy package, farmers became fully self-sufficient in the normal year and attained 60 percent cereal sufficiency in the poor year. Neither of the new technologies have an effect on home consumption objectives in the disaster (very poor) years, but the probabilities are very low for these types of years and food aid is generally made available to farmers.

Table 6.9. Cereal Self-Sufficiency Index* under Alternative Technologies.

	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Traditional	1.0	1.0	0.72	0.28	0.17
Improved Varieties	1.0	1.0	0.75	0.33	0.20
Improved Agronomy	1.0	1.0	0.99	0.60	0.20

* These values represent the amount of cereals (millet and sorghum) produced as a proportion of subsistence requirements. These values range between 0 and 1. The closer they are to 1 the better is the ability of the farmer to feed his household.

Source: Computed from model results.

The increased millet production with the adoption of the improved agronomy package also has a major impact on reducing the need for the farmer to sell livestock inventories in order to generate cash for buying millet. For example, livestock sales declined by 50 percent in the normal and poor rainfall years when farmers adopted the improved agronomy package. Therefore, depletion of farmers' capital assets is reduced, a very important effect not directly measured by income changes.

6.5.3. Expected Cash Income and Expected Total Income with Introduction of Improved Agronomy Technical Package

The cash income and other income characteristics with the introduction of the improved agronomy package are shown in Table 6.10. The cash income per state of nature range from 56372 CFA ($179) under the very good state of nature to 39470 CFA ($124) under the good year, 16150 CFA ($51) under the normal year, 12849 CFA ($40) under the poor year and 3096 CFA ($10) under the very poor year. The expected cash income over all states of nature is 34642 CFA ($109). This expected cash income is 6 percent higher than with adoption of early maturing varieties and 26 percent higher than expected cash income with the traditional technology. Comparing the cash incomes in the normal and poor rainfall years with those under adoption of early maturing varieties one notices that the values are lower for the adoption of the improved agronomy package. This is explained by observing that (1) substantial increases in millet production arising from adoption of the improved agronomy package are retained for home consumption in order to move the household toward

Table 6.10. Cash Income, Expected Cash Income and Other Farm Plan Characteristics: Introduction of Improved Agronomy Package.

	State of Nature				
	Very Good	Good	Normal	Poor	Very Poor
Cash Income (CFA)[1]	56872 (179)[2]	39470 (124)	16150 (51)	12849 (40)	3096 (10)
Total Income (CFA)[3]	84837 (267)	67435 (212)	56732 (178)	48624 (153)	15736 (50)
Expected Cash Income (CFA) (All States of Nature)		34642 (109)			
Coefficient of Variation of Cash Income (All States of Nature)		0.69			
Coefficient of Variation of Total Income (All States)		0.42			

1/ Exchange rate: 318 CFA = $1 (West Africa, October 10, 1988).

2/ The values in parentheses are dollar equivalents of the estimates.

3/ With the imputed value of cereals consumed in the household.

Source: Model results.

cereal self-sufficiency, and (2) the production of the main cash crop cowpeas was reduced in favor of more cultivation of the subsistence millet crop. If allowance is made for the imputed value of cereal consumption in the estimated total income increase, the impact of the improved agronomy package is more pronounced. The estimates of the expected total income (i.e., with the imputed value of home consumption) are shown in Table 6.11. The expected total income with the introduction of an improved agronomy package is 24 percent higher than with are shown in Table 6.11. The expected total income with the introduction of an improved agronomy package is 24 percent higher than with traditional technology and 11 percent higher than with the use of improved varieties alone. In absolute terms expected total income with introduction of the improved agronomy package is 66197 CFA or $208.

Table 6.11. Comparison of Expected Cash Income (CFA) and Expected Total Income* (CFA) under Three Alternative Technologies.

Technology	Expected Cash Income	Expected Total Income
Traditional	27410 (86)**	53204 (167)
Introduction of Early Maturing Varieties	32743 (103)	59328 (186)
Introduction of Improved Agronomy Technical Package	34642 (109)	66172 (208)

* This is with the imputed value of home consumption of cereals. Cereals consumed at home are valued at the market rate. These prices for millet are: 35 CFA/kg. in the good years, 51 CFA/kg. in the normal year, 75 CFA/kg. in the poor year and 80 CFA/kg. in the very poor year.

** Values in parentheses are absolute $U.S. values of the income estimates. Exchange rate: 318 CFA = $1. (West Africa, October 10, 1988).

Source: Computed from model results.

6.6. Returns to Labor under the Three Alternative Technologies

If only cash returns (excluding the value of home consumption) are considered, then the returns to labor[4] with these technologies are very low. Farmers would then be better off looking for alternative employment since the opportunity cost of agricultural labor is estimated to be 100 CFA/hour. However, including the value of home consumption raises the total income returns to labor for all the new technologies above the opportunity cost of labor except in the disaster year (Table 6.12). When expected total income returns over all states of nature are considered, improved varieties have an expected labor return value 42 percent higher than the opportunity cost of labor and 5 percent higher than traditional technologies. The improved agronomy technical package has an expected labor return value 52 percent higher than the opportunity cost of labor and 16 percent higher than traditional technology (Table 6.13).

The major conclusions from these estimated returns to labor are:

(1) In low rainfall states of nature, the model predicts that farmers' cash returns to labor will be substantially lower than the rural wage rate. However, total income hourly returns are only below average opportunity costs in the disaster (very poor) state. Village level studies show that some villages are deserted in drought years as farmers temporarily migrate out of agriculture in search of off-farm employment opportunities (see Caldwell, 1975, p. 13-15; Painter, 1987). Also in these years, large numbers of poor household heads turn to

4. Returns to man-equivalent hours worked in the crop year.

Table 6.12. Cash and Total Returns to Labor under Alternative Technologies for Five Weather Patterns.

State of Nature	Technology[1/]	Cash Income/ Hours Worked (CFA/hr.)	Total Income/ Hours Worked (CFA/hr.)
Very Good			
	(1)	101	163
	(2)	104	163
	(3)	114	171
Good			
	(1)	76	143
	(2)	76	143
	(3)	108	185
Normal			
	(1)	31	97
	(2)	58	127
	(3)	38	133
Poor			
	(1)	36	110
	(2)	48	111
	(3)	32	123
Very Poor			
	(1)	10	61
	(2)	15	77
	(3)	15	74

1/ (1) - traditional technology; (2) - introduction of improved early maturing varieties; and (3) - introduction of improved agronomy technical package. Rural wage rate - 100 CFA/hr. (Issa, *et al*., p. 14).

Source: Model results.

Table 6.13. Expected Cash and Total Income Returns (Over All States of Nature) to Labor (CFA/Hour) Categorized by Level of Technology.

	Technology		
	Traditional	Improved Varieties	Improved Agronomy Technical Package
Expected Cash Income/Hour of Expected Labor Time Worked (All States of Nature) (CFA/hour)1/	70	79	82
Expected Total Income/Mean Labor Time Worked (All States of Nature)	135	142	157
Rural Wage Rate2/ (CFA/hour)	100	100	100

1/ Exchange rate: 318 CFA = $1 (West Africa, October 10, 1988).

2/ Taken from Issa, et al., 1987, p. 14.

Source: Model results.

hiring out their labor on fields of richer farmers (Sutter, 1979, p. 72) in order to generate more cash.

(2) When the imputed value of cereal consumed by the farm household is taken into consideration in calculating the returns to labor, farmers make more than the rural wage rate. Therefore, basing evaluation solely on cash returns underestimates returns to labor.

(3) Total returns to labor increase with transition from traditional technology to introduction of early maturing varieties and also

improved agronomy packages. However, in absolute terms the total returns to labor are very low regardless of technology choice.

6.7. Price Policy Impacts With and Without New Agricultural Technology

As raised earlier in Chapter II, the current price floors set by the OPVN for millet and sorghum have been ineffective in preventing price collapse in good rainfall years. The government of Niger has been unable financially or administratively to effectively support cereal prices in these good rainfall years. The impact of price policy with and without the adoption of new agricultural technology is the subject of this section.

The estimated impacts of the alternative price scenarios[5] (for millet and sorghum) in the good rainfall years with the three technologies are shown in Table 6.14. Two points are important: (1) the expected total income gains from the new price policy and (2) the income loss to farmers from the price collapse that occurred in the very good rainfall year when the official price was non-operational.

With the use of traditional technology, total income in the very good year[6] increased by 19 percent when the 50 CFA/kg. suggested alternative price is set for cereals. By using improved varieties, and the improved agronomy technical package, total income increases of 28 and 43

5. The current OPVN price floor is 70 CFA/kg. The alternative price considered is 50 CFA/kg. The OPVN is the official marketing agency in charge of cereals.

6. Recall that millet or sorghum were sold only in this state of nature.

Table 6.14. Total Cash Income Effects with Alternative Price Level for Cereals in Good Rainfall Years: Comparison of Three Levels of Technology.

	Cereal Prices (CFA/kg.)								
	35 (Base Price)			50 (Alternative Price)			Current Government Price (70 CFA/kg.)		
	Traditional	Improved Variety	Improved Agronomy	Traditional	Improved Variety	Improved Agronomy	Traditional	Improved Variety	Improved Agronomy
Total Income (Very Good Year)	73226 (230)1/	77187 (242)	84837 (266)	87446 (274)	93724 (294)	104678 (392)	106406 (334)	115657 (363)	131133 (412)
Expected Total Income (All States of Nature)	53204 (167)	59328 (187)	66172 (208)	60892 (191)	67827 (213)	75794 (238)	71173 (223)	79120 (249)	88624 (278)

1/ The values in parentheses are dollar equivalents of the estimates. Exchange Rate: 318 CFA = $1 (West Africa Magazine, October 10-18, 1988).

Source: Model results.

percent, respectively, are achieved with the use of the new price policy. Therefore, adoption of agricultural technologies will allow farmers the ability to respond to and capture higher benefits from the use of agricultural price policy instruments. One can conclude from these results that technology development programs may have to be given prior attention before price policy can have a meaningful impact at the farm level.

In terms of the adoption patterns, the model predicts that the setting of the 50 CFA/kg. price floor has no effect on the technology choice and production patterns selected under the base price scenario. Borsdorf (1979, pp. 33-34) claims that "...the effect of [Nigerien] government policy on cereal production is essentially nil."[7] Maina (1982) also found that millet and sorghum production are not responsive to official market prices since they are generally subsistence crops. The desire to first produce for subsistence appears to be the motive behind production patterns. The results of this section agree with these observations. At these low cereal prices, millet and sorghum will continue to be low valued crops and produced for subsistence in most years. The main impact of the price floor at 50 CFA/kg. is in terms of total income of farmers via the value of increased home consumption made possible by adoption of agricultural technologies. Farmers desire to meet consumption requirements of these basic cereals drives them to adopt the higher yielding agricultural technologies. Price alone has no impact on these adoption patterns over this price range. The argument then is for

7. Borsdorf's (1979) observation was not based on any quantitative farm-level analysis.

a need to have more viable agricultural technologies which can assist farmers in moving closer to self-sufficiency in cereal production in most years. Given the high risks of rainfall variability, production, storage and exchange of cereals is so precarious that the desire to satisfy subsistence requirements will continue to be an insurance strategy for the household. Estimates of marketed surplus are so low that it is unlikely that a price floor for these subsistence crops can have much impact. While the government may want to set such a 50 CFA/kg. price floor[8] for millet and sorghum, its anticipated impacts will be on increasing farmer income. Also, such an impact will be minimal in the absence of agricultural technologies at the farm level.

The importance of a price policy is supported by the substantial income losses that farmers experience in these good rainfall years. The model predicts that the government's inability to maintain a 70 CFA/kg.[9] cereal price floors leads to an estimated total income loss of 45 percent with traditional technology, 50 percent loss with adoption of improved varieties, and 55 percent loss with the use of the improved agronomy technical package. Therefore, if the policy was effective, farmers, by adopting the agricultural technologies, would have obtained substantial increases in income.

8. Even the operationalization of a price floor policy needs to be based on the demand elasticity for these cereals and the ability of the marketing agencies to effectively buy all cereals available for sale.
9. As compared with the 35 CFA/kg. market price (see Table 2.9) that occurred with the price collapse of 1986.

6.8. Sensitivity Analysis of Impacts of Initial Cash Position of the Farmers on Technology Adoption

The starting cash position of farmers influences the adoption of agricultural technologies requiring utilization of large amounts of non-farm inputs. A sensitivity analysis of the farm-level response of the changes in the initial cash balance of the farmer show that more of the improved agronomy technical package is adopted with increases in initial cash levels. Increasing the starting cash position from 7000 CFA to 9000 CFA leads to an 11 percent increase in the use of this technology in the good rainfall year and 30 percent increases in the normal and poor rainfall years. When the initial cash position is 11,000 CFA, the farmer increased the use of the technical package by 40 percent and 55 percent in the normal and poor rainfall years, respectively. Increasing adoption of these technologies further moved the household towards domestic grain self-sufficiency.

These impacts of the sensitivity analysis indicate that one of the critical problems farmers face which mitigates against increased adoption of agricultural technologies is poor financial resources. There is currently no government policy to help relax these financial constraints. Based on these results, policy makers who wish to encourage adoption of the technology package should consider the provision of inputs to farmers in the form of production credit. Regardless of the profitability of agricultural technologies, the perennial problems of liquidity, if not resolved, will continue to discourage adoption of technologies requiring substantial cash outlays. The issue of liquidity as it affects technology use is a controversial point in the literature. Painter (1987) argues that there exists remittances from relatives who have migrated into neighboring countries and that these remittances rather than being used in agriculture are used to diversify the household away from agriculture. However, it is this author's view that provision of inputs in-kind to farmers will accelerate technology adoption. Official credit lending has been tried in the past in Niger and was unsuccessful. Accessibility and availability of inputs on time appears to have a more important role to play in the technology adoption process.

6.9. Summary of Principal Results

The principal model predictions from the analysis in this chapter are summarized below:

(1) Farmers adopt early maturing varieties in low rainfall years but late season varieties dominate in the higher rainfall years. Therefore, by carrying a portfolio mix of cultivars of varying maturity dates, farmers can adjust production patterns to the ensuing rainfall.

(2) With adoption of early maturing varieties, expected farm output over all states of nature was increased by 18 percent compared to traditional farmer practices.

(3) Regardless of the adoption of early maturing varieties, farmers could not avoid crop failure in disaster years such as 1984.

(4) Despite the adoption of early maturing varieties, farmers still face large cereal deficits in low rainfall years, although the absolute amounts of the deficits were lower than those experienced under traditional technology.

(5) In terms of expected total income (including the imputed value of home consumption), adoption of early maturing varieties led to an 11

percent increase in returns to the household. Moreover, adoption of these cultivars reduces the variability of incomes by lowering the risks of crop losses in low rainfall years. The coefficient of variation of the expected total income declined from 52 percent to 44 percent with adoption of early maturing varieties. With the adoption of the improved varieties combined with improved agronomy practices, the coefficient of variation of total income declined to 42 percent.

(6) With the adoption of the improved agronomy technical package, expected total output at the farm level increased by 27 percent compared to traditional technology and 15 percent compared to adoption of early maturing varieties alone.

(7) Adoption of the improved agronomy technical package leads to the highest gains in expected output thereby moving farmers closer to domestic cereal grain self-sufficiency in most years (except the disaster year). Improved nutrition and consumption are important to these small farmers.

(8) Adoption of the improved agronomy technical package also substantially reduces the need for the rural households to deplete their livestock resources in order to generate cash for cereal purchases in low rainfall years. For example, livestock sales declined by 50 percent in normal and poor rainfall years with the adoption of the improved agronomy technical package. This represents additional indirect income effects not captured by total income.

(9) With the adoption of the improved agronomy technical package, expected total income of the farmer increased by 24 percent compared to traditional technology and by 11 percent compared to adoption of early maturing varieties.

(10) Utilization of cash returns to agriculture underestimate agricultural profitability and returns to labor under the alternative technologies. Using expected cash incomes, farmers earn less than the rural wage rate under all the three alternative technologies. However, when the imputed value of subsistence cereal consumption are taken into account, farmers' expected total returns to labor are higher than the opportunity cost of labor. With use of traditional technology, expected returns to labor is 35 percent higher than the rural wage rate. With improved varieties and the improved agronomy technical package, the expected total returns are 42 and 57 percent, respectively, higher than the rural wage rate.

(11) In the disaster year, farmers receive substantially less than the opportunity cost of labor. In such years, food aid and migration out of agriculture may be necessary to ensure the survival of farmers.

(12) The use of an alternative cereal price floor of 50 CFA/kg. in good rainfall years has the effect of increasing expected farmer income. However, at this very low cereal price, there was no effect of this price floor of 50 CFA/kg. on the technology adoption pattern at the farm level.

(13) The initial cash position of the farmer influences the adoption of agricultural technologies requiring non-farm inputs, e.g., the model predicts that increasing farmers' initial cash position from 7000 CFA to 11000 CFA will increase adoption of the technical package by 40 percent in the normal rainfall years.

CHAPTER VII

CONCLUSIONS

Agricultural production in southern Niger is critical to the overall agricultural productivity of Niger because the region is located in one of the higher rainfall zones of Niger (rainfall averages 500-600 mm/year). Increases in farm-level productivity in this region as well as nationally have come predominantly from extensification of the cultivated land area. Yields of major crops -- millet, sorghum and cowpeas -- have continued on a downward trend[1] due to increasing soil degradation resulting from continuous cultivation, soil fertility loss and erosion. Worsening the scenario is the low and highly irregular rainfall patterns and the poor water retention capability of most of the soils.

The sustainability of the farming systems depends upon the development of yield-increasing technologies. Technology development programs have concentrated efforts on the sandy soils of this region on which millet and cowpeas are predominantly cultivated. There currently exists technical recommendations to farmers based on on-farm trials' verification of these packages (Reddy, 1988; Issa, et al., 1987; Krause, et al.,

1. For millet and sorghum, aggregate yields have been decreasing throughout the 1970s and 1980s. For cowpeas, yields have always been very low (less than 150 kg./ha.) throughout the 1960-1971 period. Yields have also been declining.

1987). Among the principal technologies available are new early maturing cultivars, and early maturing cultivars planted at higher densities with application of moderate levels of chemical fertilization. This study evaluated the farm-level impacts of these technologies and potential adoption patterns given farmers' methods of making sequential decisions as a response to the stochastic events within the crop season.

The modeling results indicated that farmers by (a) carrying a portfolio mix of cultivars of varying maturities and (b) making decisions sequentially in the season, can adapt to the ensuing rainfall patterns. According to the model results, early maturing cultivars would be adopted in low rainfall years with shorter growing season length. The ability of the early season cultivars to avoid crop failure in these low rainfall years was a distinct advantage. The late maturing cultivars were adopted in the higher rainfall years with longer growing season lengths. This portfolio strategy allows farmers flexibility in crop decisions. The late season cultivars exploit the available soil moisture and nutrients in the good rainfall years, while the early season cultivars allow farmers to optimize the scarce water resources in the low rainfall years. Also, the adoption of early season cultivars reduced the coefficient of variation of total incomes from 52 percent under traditional technology to 44 percent. Early season cultivars therefore can be a component of farmers' risk reduction strategies.

These results have implications for plant breeding programs in Niger, especially in INRAN, the ICRISAT Sahelian Centre and in the INTSORMIL collaborative research programs. The future direction of breeding programs will depend upon the expectations of the Sahelian rainfall pattern. If the recent low rainfall patterns (and intermittent droughts of 1968-1984) are a signal of a permanent change in the Sahelian weather patterns (Gregory, 1982; Nicholson, 1983; Lamb, 1982; Lamb, 1983), breeding programs need to be oriented towards early maturing cultivars. An opposing view is that the recent 16 years of dry weather (1968-1984) only represents another long-run cycle dry period as seen before in historical records (Bunting, et al., 1976; Landsberg, 1975). In this case, breeders would want to also diversify into improved intermediate and late season cultivars. Such a diversification may be justified any way since the early cultivars were not adopted in all weather scenarios simulated.

The different portfolio strategies recommended from the model results will require an efficient seed market in Niger. Accessibility to improved seeds will be critical for the successful implementation of such an adaptive cropping strategy in the face of stochastic factors. It is suggested that a seed bank be established at the departmental level to facilitate the production and diffusion of improved cultivars to farmers at the beginning of the crop season. Model results indicate that farmers will adopt these early season cultivars if available.

For these small-holder farmers of southern Niger, meeting household consumption requirements is a precarious problem given the rainfall uncertainties and yield/price risks in the agricultural system. Improving the consumption and nutritional status of agricultural households is an important objective of most Nigerien agricultural development programs. Moreover, according to the model results and empirical observations, farmers in this region are not able to satisfy domestic cereal needs in normal, poor and very poor rainfall years. With traditional technologies, farmers attained 72 percent cereal self-sufficiency in the normal rainfall years, 28 percent cereal self-sufficiency in the poor rainfall years, and 17 percent cereal self-sufficiency in disaster years such as 1984. With adoption of improved agricultural technologies, household nutritional status was enhanced. With adoption of the early season cultivars plus improved agronomy packages, farmers attained self-sufficiency in the normal rainfall year and 60 percent self-sufficiency in the poor year. In disaster years such as 1984, no major impact (i.e., only a 3 percent increase in self-sufficiency status) was obtained, even with adoption of early season cultivars. However, based on historical rainfall patterns, the evaluation of the probability of this type of year was extremely low at only 3 percent. The role of emergency food aid and migration across the frontiers into neighboring countries such as Ivory Coast and Nigeria is expected to continue to play a major role in disaster years such as 1984.

Farmers in this region have traditionally sold livestock (especially small ruminants) to buy grains on the market as an insurance strategy against crop failure or not being able to meet domestic cereal requirements. These emergency livestock sales deplete household capital assets. With the adoption of the early cultivars with improved agronomy, emergency livestock sales declined substantially, i.e., by 50 percent in normal and poor rainfall years. This is an additional income effect from adoption of the combined agricultural technology not captured by the total income estimates. This reduction in forced livestock sales can play a major role in stabilizing agricultural households' asset positions and lead to higher farmer wealth.

Agricultural incomes in the southern region of Niger (Maradi) are very low compared to other higher rainfall and heavier clay soil regions of neighboring countries in Mali and Burkina Faso. Unfortunately, Niger itself has very little of these higher rainfall, better soils regions. Expected total income estimates with traditional technology (in southern Maradi) is $167/year. This translates into an adult per capita income of $56. This estimate compares favorably with the per capita household income estimate of $65 obtained by Cuevas (1986) in a survey of 896 agricultural households in Niger.[2] Moreover, agricultural incomes show substantial variability from one year to the next based on the rainfall patterns. Total income estimates from the model results range from $230 in the excellent rainfall year to $77 in the poor rainfall year. With the adoption of early season cultivars alone, expected total farm income increased to $184. With adoption of early season cultivars and improved agronomy practices, expected total farm income increased to $208, a respectable 25 percent increase over traditional farmer practices. Agricultural technology adoption also reduces the variability of total farm income. The coefficient of variation of total income declined from 52 percent with traditional technology to 42 percent with the adoption of early cultivars and improved agronomy practices.

Income remittances from migrants are becoming important for these smallholder farmer incomes (Painter, 1987). Incentives to work outside of the agricultural sector will increase with economic growth. The expected total returns to agricultural labor according to model results range from 42¢ per hour (135 CFA) with traditional technology to 45¢ per hour (142 CFA) with the adoption of early season cultivars alone, and

2. The rural survey covered five departments of Niger, namely: Niamey, Dosso, Tahoua, Maradi and Zinder. The survey was done in July-August 1985.

49¢ per hour (157 CFA/hour) with the adoption of early cultivars and improved agronomy practices. The adoption of improved cultivars plus improved agronomy practices represents a 57 percent increase above the average rural wage rate in the Maradi region. This average rural wage rate of 31¢ per hour (100 CFA/hour) is considered to be the opportunity cost for this labor. While in absolute terms, these returns to new technologies are still low, nonetheless, farmers made substantial increases in returns to labor over the opportunity costs by adopting agricultural technologies.

An important area where urgent government action is needed is in the area of cereal price floors. In 1986, the second year of moderately good rainfall in the Sahel, millet and sorghum prices dropped to 35 CFA/kg. compared to 160 CFA/kg. and 144 CFA/kg., respectively, in 1984. The lack of sufficient budgetary allocations to the official marketing agencies was one of the major problems for the non-operationalization of the official price floor of 70 CFA/kg. Based on model results, the failure to sustain this price floor in the excellent rainfall year had substantial income impacts at the farm level. If the farmer used improved technologies (at this price floor), total farm income would have increased by 50 to 55 percent over incomes with traditional technologies.

Some minimal government policies are required to complement adoption of agricultural technologies and consolidate incomes gained from the adoption. It is suggested that the government consider setting a lower but effective price floor for cereals in good rainfall years, i.e., 50 CFA/kg. With this price floor, total farm income with traditional technology will increase from $230 to $274 and with the improved agronomy technical package, total farm income will increase from $266 to $392. The combined effect of the 50 CFA/kg. price floor with the improved agronomy technical package increases expected total income (over all states of nature) from $167/year to $238 year, a substantial increase of 43 percent. Such a price floor policy will only require budgetary commitments in good rainfall years to prevent a complete price collapse. Some governmental support such as this will help sustain interest in dryland cereal production and in the adoption of agricultural technologies.

The current lack of a production credit scheme in Niger will continue to limit the capacity of farmers with poor capital resources to be interested in high yielding technologies which require substantial cash outlays. Based on the modeling results, the initial cash position of the farmer positively influences the adoption of agricultural technologies. While agricultural technologies may be profitable at the farm level, these technologies often necessitate additional cash expenditures which many farmers may not be able to afford in most years. The government could consider a production credit scheme where farmers can receive inputs in kind to facilitate technology use.

The challenges for future agricultural research programs is how to further increase productivity on the predominantly sandy soils of this region. This is not an easy task given the highly fragile ecological environment. The poor soil fertility and low water retention of these soils will necessitate that research efforts be directed towards millet and cowpeas which do better under these conditions than sorghum. Cowpeas may have a major role to play in transforming the agricultural system and farmer incomes. First, in most years cowpeas prices are two to three times those of millet and sorghum. Second, the proximity of southern Maradi to the large urban demand centers of northern Nigeria can serve as an impetus to increased cowpea cultivation (Elliot Berg Associates, et al., 1983, p. 61). Cowpeas are a major staple food in Nigeria. However, a technology program which seeks to appropriate the potential of cowpeas will need to address the serious problems of insects, pests and diseases which drastically reduces cowpea yields under farmers' conditions and in storage. It also appears from model results that sole cropping of early cowpeas (after millet and sorghum establishment) in low rainfall years offers a good potential for farmers to operate a successful sequential cropping strategy.

Given the poor ecological environment of these farming systems, plant breeders cannot be expected to produce varieties that are high yielding, resistant to biotic and abiotic stresses and which perform well under the varied agro-ecological conditions. It appears that too much is being expected from agricultural research programs, often too soon. The process of technology development and diffusion takes time. Commitment on the part of USAID and various governmental agencies to long-time investments in research and institutional building will be crucial for the overall agricultural development of Niger. While the available technologies evaluated in this study have important (although small) impacts on farmer incomes, more research efforts are needed to substantially boost agricultural production. Measures are clearly needed to improve the agronomic environment of these sandy soils. Also, the potentials for small scale irrigation schemes which can help stabilize the agronomic environment may be needed. Without investments in improving the water retention and low soil fertility of these sandy soils, it is not likely that major yield increases can be obtained.

Given the level of poverty in this agricultural system, it is doubtful if farmers will have enough capital resources to sustain technology adoption in the absence of governmental assistance. With the increasing external debt position of Niger, the government has pursued a policy of price-realignment (under pressures from the World Bank) which involves drastic reductions in subsidies on agricultural inputs (Appendix Tables B.4 and B.5). Also, subventions to the agricultural agency in charge of input supply to farmers (Central d'Approvisionnement) have been drastically reduced in the past few years (Appendix Table B.6). Farmers cannot be expected to bear all the heavy financial burdens of investments in agricultural technologies requiring substantial cash inputs. The peasant farmers have poor resources, and commitment on the part of the government to continue subsidization of agricultural inputs will be important to long-term sustainability of the technology adoption process in Niger.

Also, given the high risks to agricultural investments, farmers cannot be expected to bear all the risks. In developed economies, there are measures that prevent price collapses. The government of Niger will need to address the issue of the precipitous fall in cereal prices in good rainfall years and put in place an effective cereal price floor.

Since in low rainfall years farmers cannot meet cereal subsistence requirements, more governmental support will be needed in food assistance programs. This will require the operation of an effective buffer stock policy and emergency food delivery schemes to assist farmers.

Moreover, the long-term solution to these cereal deficits lies in the development of appropriate high yielding technologies.

7.1. Suggestions for Future Research

The present study has shown that in absolute terms, agricultural incomes are low in this region even with adoption of currently available agricultural technologies. An issue not considered, however, is the role of remittances from family members, who have migrated, on the farm household decision-making process. Evidence in the literature suggests that the remittances are spent mainly on buying cereals to satisfy consumption requirements (Painter, 1987). Very little is invested in agricultural production. This lack of investment in agriculture is hypothesized to be due to the lack of profitable and low-risk technologies for adoption. With the existence of current profitable and less risky technologies, it could well be that this view may change. It is therefore suggested that a future study be conducted to develop a two sector model to link agricultural households to the external economies in migrants' destination. Such a model can then look at impacts of migrants' incomes remittances to the remaining farmers on the technology adoption process.

Also important is a study into the comparative analysis of production patterns and farmer risk attitudes in rainfed versus irrigated farming systems of Niger. This present study looked at the rainfed agricultural sector. With the second phase of Purdue University's Niger Project in operation now, such a study should be facilitated. An in-depth field survey will be needed in this regard.

Finally, the role of sorghum in the farming system needs to be investigated. There are currently no on-farm farmer-managed trials on the performance of sorghum varieties developed in Niger. While there exists a limited number of potential sorghum lines (e.g., the pre- and post-flowering drought resistant varieties such as P-898012 and P-954035 developed at Purdue University), the actual farm-level performance of these varieties under farmer management needs to be evaluated. As a component of farmers' crop mix, any gains in sorghum output will also contribute further to farmers' consumption objectives.

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APPENDICES

Appendix A

Table A.1. Estimated Cereal Consumption in Niger by Various Studies and the Government of Niger Estimates (Kilogram per Capita per Year).

Population Group	Consumption Estimates 1	2	3	4	5	6	7	8
Rural Sedentary	212.8	250.0	-	-	-	480.11	339.5	-
Nomad	120.0	-	-	-	200.0	290.3	-	-
Urban	140.0	-	-	-	-	364.3	-	-
Total	190.5	-	220.0	250.0	-	-	-	186.0

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2. Becker, John, An Analysis and Forecast of Cereals Availability in the Sahelian Entente States of West Africa. USAID, January 1974.
3. University of Michigan, Marketing, Price Policy, and Storage of Food Grains, Volumes I and II, CRED, CILSS, Club du Sahel, August 1977.
4. Current Estimate, Ministry of Rural Development, GON.
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6. Eddy, E., Labor and Land Use on Mixed Farms in the Pastoral Zone of Niger, CRED, University of Michigan, July 1979.
7. Daves, T. and J. Elterich, Several Aspects of Marketing and On-Farm Storage of Cereals in Niger, Survey Results, and Recommendations, Conseil d l'Entente, April 1978.
8. CILSS Report on Niger, unauthored, undated.

Source: Roe Borsdorf, 1979. Marketing Profile: Cereal and Cash Crops, Niger Agricultural Sector Assessment, Vol. II, Part F, USAID, Niamey, Niger, p. 5.

Appendix B

General Macro-Economic Background on Niger and the Agricultural Sector

Niger, with a population of 6.6 million, has been experiencing an annual population growth rate of 3.0 percent. Average life expectancy (as typical of the Sahelian countries) is low, at 44 years. Fifty-five percent of the population constitute the active labor force (15-54 years). Moreover, the agricultural sector is the primary employer of labor, accounting for 91 percent of the labor force in 1980 (Table B.1).

While agricultural production is important to the overall economic growth of Niger, its percentage contribution to the gross domestic product (GDP) has declined in the last 20 years. The agricultural sector's contribution to the GDP declined from 68 percent in 1965 to 46 percent in 1986 (Appendix Table B.2). As Niger vigorously pursued the mining and exportation of uranium, mining and other natural resources exploration have increased their relative contribution to the GDP compared to agriculture. The share of fuels, minerals and metals (mainly uranium) in merchandise exports grew from 0 percent in 1965 to 81 percent in 1986 (Table B.3.). The price of uranium grew phenomenally in 1974-1979, leading to expansion of export earnings from $55 million in 1975 to $477 million in 1980. Presently, the economy of Niger is undergoing an economic crisis with the fall in uranium world prices in 1981. Compounded with the depreciation of the CFA in the early 1980's, the big drop in uranium prices led to a precipitous decline in export earnings from $477 million in 1980 to $278 million in 1982 (Toh, 1987). The structural adjustment program initiatives following the increasing external debt crisis of Niger[1] has resulted in the streamlining of prices and substantial reductions in government subsidies on many agricultural inputs[2] (Tables B.4 and B.5).

1. For a detailed discussion of Niger's external debt situation, see Toh (1987).

2. The Government of Niger's agency in charge of agricultural input deliveries is Centrale d'Approvisionnement (CA). The trend of financial allocations to this agency is shown in Table B.6.

Table B.1. Population Characteristics and Sectoral Distribution of the Labor Force in Niger.

Population (Millions) Mid-1986	Life Expectancy 1986	Population Growth/Projections Average Annual Growth Rate of Population (%)			Labor Force					
					% of Population of Working Age (15-64 years)		% of Labor Force in:			
							Agriculture		Industry & Services	
		1965-80	1980-86	1986-2000	1965	1985	1965	1980	1965	1980
6.6	44	2.7	3.0	3.2	51	51	95	91	5	9

Source: Compiled and adapted from World Development Report, 1988, published for the World Bank by Oxford University Press.

Table B.2. Structure of Production and Percentage Sectoral Contribution, Niger.

Gross Domestic Product (GDP) (million $)		Distribution of GDP (%)							
		Agriculture		Industry		Manufacturing		Services, etc.	
1965	1986	1965	1986	1965	1986	1965	1986	1965	1986
670	2080	68	46	3	16	2	4	29	39

Source: Compiled and adapted from World Development Report, 1988, published for the World Bank by Oxford University Press.

Table B.3. Structure of Merchandise Exports, Niger.

Percentage Share of Merchandise Exports									
Fuels, Minerals and Metals		Other Primary Commodities		Machinery & Other Transport Equip.		Other Manufactures		Textile & Clothing	
1965	1986	1965	1986	1965	1986	1965	1986	1965	1986
0	81	95	16	1	1	4	2	1	-

Source: Compiled and adapted from World Development Report, 1988, published for the World Bank by Oxford University Press.

Table B.4. Evolution of Government Subsidies on Agricultural Inputs Distributed by Centrale d'Approvisionnement from 1979 to 1984, Niger.

Agricultural Inputs	Range[a/] of Subsidies by Year (%)					
	1979	1980	1981	1982	1983	1984
Transportation Materials[b/]	59-54	51-62	24-37	21	14-15	0.6-1.5
Fertillizer[d/]	32-53	23-50	22-61	21-59	22-60	12-60
Fungicides	67	52	53	16	15	5
Cultivation Equipment[c/]	59-82	60-82	57-80	44-79	43-69	34-50

a/ Depending on type of equipment or input.
b/ Animal carts (e.g., charette bovine, charette asine).
c/ Ploughs (e.g., equipement charrue 10", equipement cultivateur 5 dents et 3 dents, equipement buttoir, houe asine, semoir).
d/ Includes simple superphosphate, triple superphosphate, NPK 15-15-15, NPK SB 14-23-12(6-2), Ureau, Phosphate of Tahoua, Ammonium Sulphate, Calcium Nitrate, 26-12-0, and 20-20-0.

Source: Adapted by author from records of Union Nigerienne de Credit et de Cooperation (UNCC).

Table B.5. Percentage Subsidies on Agricultural Inputs in Niger, 1985-1988.

	Period			
	June 1985	June 1986	June 1987	June 1988
Agricultural implements	50	33	20	15
Fertilizer	30	33	20	20

Source: Adapted from records of Union Nigerienne de Credit et de Cooperation (UNCC).

Table B.6. Evolution of Government of Niger's Financial Allocations for Agricultural Inputs Delivery by Central d'Approvisionnement.

Year	Amount Agency Requested	Amount Given	Percentage Covered
1973/74	50,000,000	35,000,000	70
1974/75	97,500,000	40,319,000	41
1975/76	121,185,060	80,865,000	66
1976/77	367,257,000	338,000,000	92
1977/78	655,000,000	370,000,000	56
1978/79	1,345,000,000	480,000,000	35
1979/80	1,551,110,000	450,000,000	29
1980/81	1,582,290,000	600,000,000	38
1981/82	1,584,000,000	600,000,000	37
1982/83	1,134,000,000	300,000,000	26
1983/84	1,100,000,000	550,000,000	50
1984/85	1,100,000,000	300,000,000	27

Source: <u>Central d'Approvisionnement</u>, Ministere du Developpement Rural, Republique du Niger.

Appendix C

Table C.1. Millet Yields Estimates ("Very Good" State of Nature).

	Yield Estimates (kg./ha.)	
	(1)[a/]	(2)[b/]
Improved millet sole crop	561	381
Local millet sole crop	660	396
Local millet/local sorghum	468	304
Local millet/local sorghum/local cowpeas	425	276
Local millet/local sorghum/improved cowpeas	383	249
Improved millet/improved cowpeas	341	221
Local millet/local cowpeas	440	286
Improved millet/improved cowpeas at higher planting densities plus 50 kg./ha. of urea and 50 kg./ha. simple super phosphate	627[c/]	627[c/]

a/ With the exception of the last cropping system, all initial yield estimates were computed from yields for the "good" state of nature by assuming incremental effect of 10 percent.

b/ Initial yield estimates discounted with the exception of last cropping system.

c/ Actual yields obtained in on-farm trials by the National Agricultural Research Center of Niger (INRAN) in the village of Maiquero in 1986, an excellent rainfall year. (Source: Krause, *et al*., 1987).

Table C.2. Millet Yield Estimates ("Good" State of Nature).

	Yield Estimates (kg./ha.)	
	(1)[i/]	(2)[g/]
Improved millet sole crop	510[f/]	381
Local millet sole crop	600[e/]	360
Local millet/local sorghum	430	280
Local millet/local sorghum/local cowpeas	387[d/]	251
Local millet/local sorghum/improved cowpeas	348	226
Improved millet/improved cowpeas	310[a/]	201
Local millet/improved cowpeas	279[b/]	181
Local millet/local cowpeas	400[c/]	260
Improved millet/improved cowpeas at high planting densities plus 50 kg./ha. of urea and 50 kg./ha. of simple super-phosphate	627[h/]	627[h/]

a/ Yield obtained in on-farm trials by INRAN (Maiquero village) in 1986, for treatment #2, i.e., improved millet + improved cowpeas + higher plant density (source: Krause, et al., 1987).

b/ On-farm trial result for treatment #1 (Maiquero village) in 1986, in trials conducted by INRAN (source: Krause, et al., 1987).

c/ Based on the well documented better performance of local long-season varieties in good rainfall years (see Andrews, 1987; Andrews and Kassam, 1976). The yield for this cropping system in Swinton (1987) data set was 445 kg./ha. This is considered to be the lower bound estimate for yield in this state of nature.

d/ Survey estimate by Swinton (1987) for this activity in 1985. This is used here as a lower bound initial estimate for the "good" state of nature.

e/ Swinton (1987) estimate for sole crop millet was 647 kg./ha. However, this survey had very high coefficient of variation and these were often estimates on one or two fields. Therefore, yields in general are much lower than reported in that survey. Using the yield difference between sole crop millet and millet/cowpeas (i.e., 202 kg./ha.) in that survey, the initial yield of sole crop millet was estimated by adding the difference to the base yield of millet/cowpea system.

f/ Based on the better performance of local varieties in good rainfall years (Matlon, 1987; Andrews, 1987), yields of improved varieties were increased by 15 percent, an estimated yield impact supported by Matlon (1987).

g/ Discounting initial yield estimates.

h/ Actual on-farm trial data (source: Krause, et al., 1987) in village of Maiquero in 1986.

i/ Initial yield estimates.

Table C.3. Millet Yield Estimates ("Normal" State of Nature).

	Yield Estimates (kg./ha.)	
	(1)[h/]	(2)[f/]
Improved millet sole crop	384[c/]	250
Local millet sole crop	364[b/]	236
Local millet/local sorghum	322[d/]	209
Local millet/local sorghum/local cowpeas	206[e/]	134
Local millet/local sorghum/improved cowpeas	238[e/]	155
Improved millet/improved cowpeas	358[a/]	233
Local millet/local cowpeas	284[a/]	165
Improved millet/improved cowpeas at higher planting densities plus 50 kg/ha. of urea and 50 kg./ha. of simple super-phosphate	590[g/]	590[g/]

a/ From on-farm trials conducted in the village of Maiquero by INRAN during the 1985 crop season. Note that in this year improved cowpeas (TN-88-63) were not available and so the researchers used local varieties as a proxy in treatment #2 (source: Ly, et al., 1986, p. 5, p. 16).
b/ In trials conducted at Tarna Station (Rapport de l'Agronomie General Campagne 1984, Section de l'Agronomie General, Maradi, INRAN) using millet-cowpea systems, the difference between sole and intercrop yield was 80 kg./ha. Same yield differential is used here to derive the yield estimate.
c/ Varietal effect of 20 kg./ha. in this rainfall scenario.
d/ Swinton (1987) survey estimates in Maiquero village show that difference between millet sole crop and that of millet/sorghum intercrop was 42 kg./ha. Based on this, the initial yield estimate for local millet/local sorghum intercrop were estimated from the sole crop yield.
e/ Based on observed yield differences in survey of Maiquero cropping systems reported by Swinton (1987). Differences of 116 kg./ha. was observed between millet/sorghum and millet/sorghum/cowpeas in 1985 survey. Estimates here preserve that trend.
f/ Initial yields discounted.
g/ On-farm trial yield for improved agronomy technology in Maiquero village (source: Ly, et al., 1985).
h/ Initial yield estimates.

Table C.4. Millet Yield Estimates ("Poor" State of Nature).

	Yield Estimates (kg./ha.)	
	(1)[g/]	(2)[h/]
Improved millet	254[b/]	175
Local millet	234[a/]	152
Local millet/local sorghum	136[e/]	88
Local millet/local sorghum/local cowpeas	134[e/]	87
Local millet/local sorghum/improved cowpeas	154[f/]	120
Improved millet/improved cowpeas	180[c/]	125
Local millet/improved cowpeas	168[d/]	109
Local millet/local cowpeas	154[c/]	100

a/ Calculated from on-farm trial 1987 result for Maiquero village. Intercropped millet-cowpeas yield in the trial was 154 kg./ha. Moreover, Rapport de l'Agronomie Generale Campagne 1984, Maradi, Niger found that difference between sole cropped millet and intercropped millet with no fertilizer is 80 kg./ha. Therefore, 80 kg./ha. was added to the reported yields in the on-farm trial treatment #1 for Maiquero in 1987.
b/ Varietal yield effect of 9 percent over local variety.
c/ Yields for improved millet/improved cowpeas are for treatment #2 in 1987 Maiquero on-farm trials. Yields for local millet/local cowpeas are yields for treatment #1 in 1987 on-farm trials.
d/ Local millet/improved cowpea yield based on varietal impact of 9 percent from utilization of improved cowpeas. This rate was adopted from Rapport Provisoire de la Campagne (1985) de la Section Agronomie Generale, INRAN, 1985, p. 14.
e/ Adapted from Unite Suivi de'Evaluation (1986, p. 14).
f/ Based upon a yield increase of 20 kg/ha. over local millet/local sorghum/local cowpeas.
g/ Initial yield estimates.
h/ Initial yield estimates discounted.
i/ Intial yield estimates.

Table C.5. Millet Yield Estimates ("Very Poor" State of Nature).

	Yield Estimates (kg./ha.)	
	(1)[e/]	(2)[d/]
Improved millet sole crop	160[a/]	104
Local millet sole crop	140[a/]	91
Local millet/local sorghum	113[a/]	73
Local millet/local sorghum/local cowpeas	111	72
Local millet/local sorghum/improved cowpeas	121[c/]	78
Improved millet/improved cowpeas	166[b/]	107
Local millet/local sorghum	126[b/]	82

a/ Yields in trials at Magaria in 1984. Rainfall was 217 mm in this area. (Source: Rapport de l'Agronomie Generale Campagne, 1984, Section d'Agronomie Generale, Maradi, Niger.

b/ Synthesized from: Unite Suivi d'Evaluation (1986), Les Systems de Culture au Sud du Departement de Maradi: Analyse des Pratiques Culturales et de Leur Influence Sur les Rendements. Projet de Developpement Rural de Maradi. The survey estimates were discounted by half. This is based on the observation that millet yields reported for similar areas in Rapport de l'Agronomie Generale (1984), INRAN/Maradi, was half those reported in this survey. Hence to streamline the baseline yield values, such adjustment was necessary.

c/ Based on better performance of improved varieties in low rainfall years. This expected yield performance is 13 percent, an estimate close to those in literature on millet in West Africa (Matlon, 1987; Andrews, 1987).

d/ Initial yield estimates discounted to farm level.

e/ Initial yield estimates.

Table C.6. Yields of Alternative Cropping Systems (Cowpeas) ("Good" State of Nature).

Cropping System	Yields (kg./ha.)
Local millet/local sorghum/local cowpeas	134
Local millet/local sorghum/improved cowpeas	67
Improved millet/improved cowpeas	84[a/]
Local millet/improved cowpeas	67[b/]
Local millet/local cowpeas	134[c/]

a/ Actual yields (in treatment #2) from on-farm trials in the village of Maiquero in 1986. The trials were conducted by the Economics Division of INRAN (DECOR). (Source: Krause, et al., 1987).

b/ Actual yield from on-farm trials in the village of Maiquero. This value is for treatment #1 in that trial, i.e., local varieties of millet and cowpeas planted at farmers' traditional densities. However, in this year improved cowpeas (TN-5-78) were used in this treatment. (see: Krause, et al., 1987, p. 23).

c/ Local varieties do better in good rainfall years compared to early maturing varieties.

Table C.7. Yields of Alternative Cropping Systems (Cowpeas) ("Normal" State of Nature).

Cropping System	Yields (kg./ha.)
Local millet/local sorghum/local cowpeas	50[c/]
Local millet/local sorghum/improved cowpeas	108[c/]
Improved millet/improved cowpeas	12[a/]
Local millet/local cowpeas	4[b/]
Local millet/improved cowpeas	8

a/ Actual yield from on-farm trial in 1987 at the village of Maiquero. This is the yield for treatment #2, i.e., improved millet + improved cowpeas planted at farmers' traditional plant densities. (Source: Departement de Recherches en Economie Rurale. Institut National de Recherches Agronomiques du Niger. Data obtained from M. Krause.)

b/ Actual yields from on-farm trials in 1987 at the village of Maiquero. This value is for treatment #1, i.e., these local varieties planted at farmers' traditional plant densities. (Source: Same as a/ above.)

c/ Based on 20 percent yield increase over the "poor" yield.

Table C.8. Yield Estimates of Alternative Cropping Systems (Cowpeas) ("Very Poor" State of Nature).[d]

Cropping System	Yields (kg./ha.)
Local millet/local sorghum/local cowpeas	17[e]
Local millet/local sorghum/improved cowpeas	50
Improved millet/improved cowpeas	38[b]
Local millet/improved cowpeas	26[c]
Local millet/local cowpeas	13[a]

a/ Actual recorded yield for this cropping system in Swinton (1987) survey of farms in region of study.

b/,c/ Synthesized from a/ based on the fact that improved early maturing varieties yield better in low rainfall years.

d/ These values were adapted downwards by factor of 2 to generate distribution of yields in this disaster year when farmers suffered substantial crop failure. Yields for the "poor" states of nature were adapted from these estimates.

e/(Actual average yield for this cropping system in three villages of Arrondissement de Madarounfa (i.e., Maiquero, Rigial Oubandawaki and Kandamao) reported in Swinton (1987).

Table C.9. Sorghum Yields Estimates ("Very Poor" State of Nature).[a]

Cropping System	Yields (kg./ha.)
Local millet/local sorghum	12[b]
Local millet/local sorghum/local cowpeas	10[b]
Local millet/local sorghum/improved cowpeas	30[c]

a/ A disaster year of widespread crop failure.

b/ Average yield in three villages (Kandamao, Maiquero, and Rigial Oubandawaki) in region of study. (Source: Computed from Swinton, 1987).

c/ Assuming varietal impact of early cowpeas increases yields.

Table C.10. Sorghum Yield Estimates ("Normal" State of Nature).

Cropping System	Yields (kg./ha.)
Local millet/local sorghum	109[a/]
Local millet/local sorghum/local cowpeas	54[a/]
Local millet/local sorghum/improved cowpeas	74[a/]

a/ Actual yields obtained by manual traction households in the village of Maiquero in 1985 crop season. (Source: Swinton, 1987).

Additional Notes on Sorghum Yield Estimates

Yields for the corresponding cropping systems under the "very good", "good" and "poor" states of nature were synthesized from the baseline values of the "normal" and "very poor" states of nature, respectively. Yields in the "very good" state of nature are assumed 40 percent higher than those in the "good" state of nature; yields in the "good" state of nature are assumed doubled over that in the "normal" state of nature, and finally, yields in the "poor" state are assumed lower than yields in the "normal" state by 40 percent.

Table C.11. Probabilities of States of Nature.[a/]

	State of Nature				
	Very Good	Good	Normal[b/]	Poor	Very Poor
Rainfall (mm/year)	> 594	484-594	350-483	267-349	< 267
Initial Probabilities[a/]	0.30	0.24	0.23	0.19[c/]	0.04[c/]
Probabilities Estimates Used[c/]	0.34	0.24	0.23	0.16	0.03

a/ Based on annual rainfall in Maradi Region of Niger from 1961 to 1985.

b/ The average annual rainfall in this period was 483 mm/year.

c/ Several authors have argued that the recent low rainfall patterns (characterized by "poor" and "very poor" states of nature, respectively) are a temporary cyclical phenomena (see: Bunting, *et al*., 1976; Landsberg, 1975). Therefore, the probabilities of these states of nature were adjsuted downwards and the estimate for the "very good" state of nature adjusted upward.

VITA

VITA

Akin Adesina was born on the 6th of February, 1960 to Roland and Eunice Adesina. He attended Ejigbo Baptist High School from 1970 to 1974 where he passed the West African Ordinary Level Examinations in Grade 1 division. He later attended the Ibadan Polytechnic where he passed the Cambridge University of London's Advanced Level Examinations. Admitted to the University of Ife, Nigeria in 1977, he studied for a Bachelor's Degree in Agriculture with specialization in Agricultural Economics. He completed the degree in 1981 in the First-Class Honors Division and was the first candidate to qualify for this degree with such distinction.

He worked briefly as a Graduate Assistant in Agricultural Economics at the University of Ife, Nigeria before commencing his graduate study program at Purdue University in 1983. He completed both the M.S. and Ph.D. degrees in Agricultural Economics at Purdue University. He completed the graduate program with a grade point average of 5.84 out of 6.0. He worked as a Graduate Instructor in Research under the INTSORMIL PRF-5 project.

A Federal Government of Nigeria Scholar, he was also inducted into two international honors societies at Purdue University in recognition of high scholarship and contribution to agriculture. He was awarded the Rockefeller Foundation Social Science Post-Doctoral Research Fellowship in 1988. He will be working as the Assistant Principal Economist for the International Crop Research Institute for the Semi-Arid Tropics (ICRISAT) on the West African Regional Sorghum Program.

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