PN-ABF-122
66152

THE IMPACT OF FARMING SYSTEMS RESEARCH ON AGRICULTURAL PRODUCTIVITY: THE CASE OF NORTH CAMEROON

by

D. S. Ngambeki, R. R. Deuson,
and J. Lowenberg-DeBoer *

90-1 January 1990

A paper presented at the Farming Systems Research/Extension Symposium, October 8-11, 1989, hosted by the University of Arkansas, in Fayetteville, Arkansas. This research is supported by the U.S. Agency for International Development, Science and Technology Bureau, Technology of Soil Moisture Management Project under USDA PASA No. BST-4021-P-AG-108D-00 and by the OAU/STRC/SAFGRAD/CAMEROON Farming Systems Research Program

* Visiting Professor and Assistant Professors at Purdue University, Department of Agricultural Economics, Krannert Building, W. Lafayette, Indiana 47905.

CONTENTS

ABSTRACT 1

ACKNOWLEDGEMENTS 2

1.0 Introduction 3

2.0 Description of the project area 4
2.1 Location and topology 4
2.2 Soil types and soil fertility 4
2.3 Climate 5
2.4 Vegetation 6
2.5 Rural economy 6

3.0 Traditional farming systems 7
3.1 Cropping systems 7
3.2 Livestock systems 8
3.3 Agroforestry systems 9

4.0 Traditional farm resources, income and constraints 10
4.1 Farm resources 10
4.1.1 Cultivable land 10
4.1.2 Farm labor and animal traction 10
4.2 Farm income 11
4.3 Major constraints 12

5.0 Materials and methods 13
5.1 The base model 13
5.1.1 Columns 14
5.1.2 Rows and RHS 15
5.2 The extension model 16
5.3 The SAFGRAD/FSR Project models 17
5.4 Data sources 19

6.0 Results 19
6.1 The Base-Project model 20
6.2 The extension-Project model 24

7.0 Conclusions 27

Table of Tables

Table 4.1 Labor and animal traction inputs (hrs ha^{-1}) for traditional crops in North Cameroon, panel survey (n=52), 1986-89 11

Table 4.2 Farm size (ha), net income per crop, and benefit-cost ratios for a cotton-based farming system in North Cameroon, 1986-89 11

Table 6.0 Sample size for technical coefficients by item and by year, North Cameroon, 1986-88 20

Table 6.1 The impact of the SAFGRAD/FSR technologies on gross margin and land allocation in the base model of a representative farm in North Cameroon, 1986-88 21

Table 6.2 SAFGRAD/FSR Technologies chosen by the base and extension models, respectively 23

Table 6.3 The impact of the SAFGRAD/FSR technologies on gross margin and land allocation in the extension model of a representative farm in North Cameroon, 1986-88 25

Table A-1 Crop activities and planting dates for the base model of a representative traditional farm in North Cameroon, 1986-88 29

Table A-2 Selling activities and minimum subsistence level per crop for a representative farm model of North Cameroon, 1986-88 30

Table A-3 Labor hiring activities: wage rate in U.S. dollars per day and per period for a representative farm of North Cameroon, 1986-88 31

Table A-4 Fixed resource supplies (RHS) of farmer and family labor, draught power, in hours per period, by farm operation, for the base model of a representative farm in North Cameroon, 1986-88 32

Table A-5 Crop yield coefficients per crop and variety for the base, extension, and project models, North Cameroon, 1986-88 33

Table A-6 Traditional, extension-recommended, and project-recommended cultural practices per crop, North Cameroon, 1986-88 34

Table of Figures

Fig. 1 Map of Cameroon showing administrative provinces 37

Fig. 2 Planting calendar per crop for the base-project model, North Cameroon, 1986-1988 38

Fig. 3 Planting calendar per crop for the extension-project model, North Cameroon, 1986-1988 39

Fig. 4 Schematic of the base and extension models 40

Fig. 5 The impact of the SAFGRAD/FSR technologies on land allocation in the base model of a representative farm in North Cameroon, 1986-1988 41

Fig. 6 The impact of the SAFGRAD/FSR technologies on land allocation in the extension model of a representative farm in North Cameroon, 1986-1988 42

Fig. 7 The impact of the SAFGRAD/FSR technologies on the amount of land fallowed (out of 16 ha available), by traditional farmers in North Cameroon, 1986-1988 43

ABSTRACT

In 1984, the Semi-Arid Food Grain and Development (SAFGRAD) Farming System Research Program was created to develop and disseminate new agricultural technologies among small farmers in the semi-arid zones of North Cameroon. The objectives of this paper are: (1) to show the impact of the SAFGRAD program on both traditional farmers and farmers who have already adopted extension recommendations in Northern Cameroon and, (2) to demonstrate how the technologies developed by the program can be integrated in a sustainable way into the existing farming systems.

To accomplish the above objectives, a linear programming model of a traditional representative farm in North Cameroon is constructed. The model distinguishes those farmers who have adopted agricultural practices previously recommended by the Extension Services from those purely traditional farmers who have not.

Results from linear programming models suggest the following conclusions. First, both the traditional farmer (represented in the base model) and the farmer that has already adopted the extension technologies (represented in the extension model) can increase their gross margin by over fifty percent by adopting the SAFGRAD/FSR technologies.

Second, the way in which resource allocation occurs when the Project technologies are integrated into the base model and the extension model suggest that indeed soil fertility and lack of short-cycle adaptable crop varieties are major production constraints in the research domains covered by the SAFGRAD/FSR Project.

Third, the introduction of a single technology may not have a significant impact on either the base-model farmer or the extension-model farmer. To benefit significantly from the SAFGRAD/FSR technologies, farmers need to adopt a combination of more than one technology. However, field observations made during the implementation of the Project indicate that farmers tend to adopt new technologies component by component rather than embracing a whole package. Model runs indicate that sequential adoption of SAFGRAD/FSR technologies is less beneficial than the adoption of a package, but that sequential adoption still offers appreciable yield and income increases over those derived from the traditional practices.

ACKNOWLEDGEMENTS

The authors wish to acknowledge Drs. L. Singh and V. M. Murinda, both agronomists, and Dr. W. Migongo-Bake, agro-forester, who participated in the implementation of the SAFGRAD/FSR/Cameroon Project for their contribution.

Special thanks are due to Ms. Ziyou Yu for her building the data base and providing the graphics. Mr. P. Jomini has graciously provided SAS consulting advice to the authors.

1.0 Introduction

In 1984, the Semi-Arid Food Grain and Development (SAFGRAD) Farming Systems Research Program was created in Cameroon (hereinafter referred to as SAFGRAD/FSR). Following the signing, in November 1985, of an agreement between the Government of Cameroon and the Scientific and Technical Research Commission of the Organization of African Unity (STRC/OAU), the International Fund for Agricultural Development (IFAD) supported SAFGRAD/FSR activities from February 1986 through April 1988.

The overall objectives of the SAFGRAD/FSR Program were: (1) to develop agricultural production technologies adapted to the conditions and the needs of small farmers in the semi-arid zones of Northern Cameroon, (2) to foster the transfer of agricultural technologies by carrying out agronomic and economic evaluation of the research results obtained on the research stations and by conducting on-farm trials in collaboration with farmers, and (3) to strengthen the National Farming Systems Program of Cameroon by working closely with the host institution, the Institut de Recherche Agronomique (IRA) and the Extension Service.

The objectives of this paper are: (1) to show the impact of the SAFGRAD program on both traditional farmers and farmers who have already adopted extension recommendations in Northern Cameroon and, (2) to demonstrate how the technologies developed by the program can be integrated in a sustainable way into the existing farming systems.

2.0 Description of the project area[1]

2.1 Location and topology

Cameroon is situated in Central Africa (latitude 2 to 13 degrees North and longitude 6 to 16 degrees East). It is bordered by the Gulf of Guinea in the South-West, by Equatorial Guinea, Gabon, and The Congo in the South, by Tchad in the East and by Nigeria in the West (Fig. 1.) The country spans 1,200 km from North to South and 800 km from East to West and covers 475,440 km^2 or 46.9 million ha. Cameroon is divided administratively in 10 provinces. The SAFGRAD/FSR Project's area covers the North Province and the Southern part of the Extreme North Province.

The elevation of the topography in Cameroon is between 600 m and 2000 m above sea level, with Mount Cameroon being the highest point (4090 m). The North Province lies in a large depression of the Benoue River Basin consisting of the Lower (less than 1000 m), Intermediate (1000-2000 m), and Upper (over 2000 m) Benoue Valleys.

2.2 Soil types and soil fertility

In the Lower Benoue Valley, the most extensive soil types are: the Tropaquents (wet soils found in depressions), Paleustalfs (dark grey clayey soils found in alluvial plains) and Paleustalfs (deep sandy soils found on uplands.) This zone has high potential for crops (especially irrigated) and high to very high potential for livestock.

In the Intermediate Benoue Valley, major soil types are: Tropaqualfs (gray clayey soils found on low lands), Ustropepts (gravelly soils found on hills), Ustrothents (steep and stony soils), and Chromusterts and Pellusterts (vertic and clayey soils.) This zone has medium potential for crops and medium to high potential for livestock.

---

1. Most of the following information is abstracted from: "Farming Systems Research Project. End-of-Project Consolidated 1986-1988 Activities Report of SAFGRAD/FSR/Cameroon." D. S. Ngambeki, V. M. Murinda, and W. Migongo-Bake. April 1989. Mimeograph (148 pp.)

In the Upper Benoue Valley, Plinthustalfs (very deep sandy soils) are found on uplands while Haplustalfs (deep ferruginous soils) and Tropaquepts (saturated soils) are found on foot slopes. This zone has high potential for crops and medium to high potential for livestock.

Most of the soils in the North Province are slightly acidic (pH: 6.2-6.5), low in organic matter and N, low in available P (5-15 ppm), and low in exchangable K (0.30 meg per 100 g ECC.)

2.3 Climate

Average annual air temperatures in the SAFGRAD/FSR Project area rise steadily from 26.5°C in January to 32.4°C in April and falls steadily again to 26°C in July, to remain almost constant until December. December, March and April have temperatures between 28°C and 45°C while November, December and January are cool months.

Northern Cameroon has a monomodal rainfall pattern. Rains start in April-May, peak in August, and end in October-November. Three agroclimatic zones, based on rainfall and vegetation, are covered by the SAFGRAD/FSR Project: (1) the Sahelian savanna zone (600-800 mm), (2) the Sudan savanna zone (800-1000 mm), and (3) the Northern Guinea savanna zone (above 1000 mm.) Rainfall characteristics in the Project's area are: (a) continuous decline of rainfall in 1986 and 1987, with a reversal in 1988, (b) tremendous irregularity in the rainfall pattern, (c) prolonged dry spells of 10 days or more during May, June and the first half of July, and (d) a decline of 10% in annual rainfall over the last twenty years.

Before June, evapotranspiration in the Project area exceeds precipitation, making available moisture the limiting factor. From the end of June to mid-September, precipitation exceeds evapotranspiration (no soil moisture stress.) Evapotranspiration increases after mid-September, during crop maturity. Beyond October, longer cycle crops experience soil moisture stress as evapotranspiration, again, exceeds precipitation.

2.4 Vegetation

The vegetation in the SAFGRAD/FSR Project's area ranges from wooded savanna in the South (800 mm) to open thornbush in the North (500-700 mm.)

Major tree species in the wooded savanna include Andasonia digitata, Butyrospermum parkii, Sclerocarya birrea, and Tamarindus indica. The trees are irregularly distributed with dense formations in the valleys. Major grass species are Hyperrhenia and Andropogon. Echinochloa and Cyperus species dominate on the bottom lands, which are often flooded.

In the Northern thornbush savanna, various Acacia species (e.g. albida, senegal), Andasonia digitata, Tamarindus indica, Balanites hegytiaca, and Pilistrigma reticulatum, are interspersed with grass and bush vegetation, such as: Penisetum and Setaria species and a common bush/tree, Ziziphus maurititania.

2.5 Rural economy

Cameroon is one of the few African countries which have experienced positive rates of economic growth in the 1980's (2.24% after inflation.) Per capita income averaged $800 per annum (1984-86.) Cameroon's population of 11 million (1986) grows at a rate of 2.4% per annum. Nearly half of the population is under 15 years of age. The Northern Provinces, where the SAFGRAD/FSR Project operates, are populated by 28% of the total population, with a low density of 17 persons per km^2. The economy of Cameroon is mainly based on agricultural productio, with coffee and cocoa contributing 85% (1985) and cotton alone contributing 8.4% of the foreign exchange earnings.

Only 6.3% of the 46.5 million ha in Cameroon are under cultivation. Livestock occupies 36.5% of the land, forests cover 42.1%, and 14.8% are under water. Important food crops are cereals (millet, sorghum, maize, and rice), starchy crops (plantain, cassava, yam, and cocoyam), palm oil, groundnuts, and fruits (banana and pineapple.) Northern Cameroon produces 60 to 80% of total cereal production. Northern Cameroon accounts also for 60% of the 4.3 million cattle and the 5.2 million sheep and goats in the country. The country, however, is not food self-sufficient (60-90% of demand.) Nearly all millet and sorghum is produced by small farmers, fifty percent of whom use traditional farming systems.

3.0 Traditional farming systems

A purely pastoral nomadic system employs 15% of the rural population in Northern Cameroon while 85% are involved in crop and livestock sedentary agriculture. Traditional cropping systems, livestock systems, and agroforestry systems are reviewed.

3.1 Cropping systems

The main traditional food crops are sorghum, millet, maize, and cowpea. Cotton is the dominant cash crop while groundnut is both a food and a cash crop. The most popular crops among traditional farmers are: red sorghum (grown by 85% of all farmers), cotton (78%), groundnut (73%), and maize (60%). Cotton is planted on the largest percentage of land (36%), followed by red sorghum (25%), groundnut (14%) and maize (13%).

The main crop associations on farmers fields in the North Province are: red sorghum-white sorghum (grown by 56% of the farmers), sorghum-cowpea (38%), groundnut-sorghum (25%), and groundnut-sorghum-maize (18%). The average farm size per family in the Project's area is 3.37 ha, but 70% of the farmers have farms of 0.25-2.00 ha. Farmers usually partition their farms in small plots (0.25 ha) and all crops (except cotton) are grown on less than one ha.

Crop rotations among farmers who grow cotton are usually: cotton/sorghum/sorghum, cotton/sorghum/cotton/maize (or groundnut), and cotton/maize (or groundnut.) Among farmers who do not grow cotton, the usual crop rotations are: sorghum/groundnut, maize/sorghum, maize/groundnut, and cowpea/maize.

The cropping calendar varies with the length of the agricultural season (4-6 months.) In the West Benoue region of the North Province, farmers tend to plant their principal crops (sorghum, groundnut, cotton and cowpea)in the last ten days of May. In North East Benoue, sorghum and groundnut are planted from May to mid-June, cotton at mid-June, and maize and cowpea in early June. However, to minimize the effect of intermittent rains, farmers stagger planting from late May to late July. In any case, sorghum is the first crop to be planted, followed by groundnut.

The most common land clearing method is slash and burn, especially for maize, cotton, and groundnut which are more susceptible to weed infestation. Light clearing is used for other crops.

Most farmers use an ox-plough to prepare the soil for the cultivation of maize, cotton, and groundnut (75%) but less so for sorghum, cowpea, and muskwari[2] (10-30%). Few use a hoe for soil preparation (1-6%). Only one percent of the farmers use a tractor.

From 58 to 71% of the farmers plant groundnut, maize and cotton in line while only 6-23% plant cowpea and sorghum in line.

Herbicides are not used at all on food crops, hence all weeding is done with a hoe or, as in North-East Benoue, with an oxen-drawn weeder (20% of farmers.) At the first weeding, more than half of the farmers make small mounds around the plant and make ridges 30 to 40 days after planting, to conserve moisture.

Farmers who grow cotton may obtain fertilizer on credit from a parastatal (SODECOTON) and repay at harvest. Two-thirds of them use fertilizer on cotton. Farmers also apply urea to maize (40% of them do) and to groundnut (10%). No mineral fertilizer is applied on traditional food crops and few farmers use organic fertilizers.

3.2 Livestock systems

Of total livestock in Cameroon, the North Province accounts for 15% of cattle, 10% of sheep, and 9% of goats. Most of the large ruminants are herded by the Fulbe nomads whereas the sedentary farmers keep a small number of cattle for animal traction, transport, milk, and emergency cash. Typically, the Fulbe herd one hundred cattle or more while the sedentary farmer owns 5-8 animals (e.g. a pair of oxen, some small ruminants and, in non-muslim communities, a couple of pigs.)

Major constraints in the sedentary livestock systems are: shortage of water, disease, and shortage of feed during the dry season. Due to a lack of feed during the dry season, some sedentary farmers pay a fee to the Fulbe to husband their oxen. The Fulbe move in their herds on farmers' fields to forage crop residues, adding manure to the soil in the process. Others keep them near the homestead where they graze them and supplement their diet with fodder from trees (e.g. *Khaya senegalis*, *Acacia albida*) and crop residues

2. Transplant sorghum (*Sorghum bicolor*, var. *Mouskouaris*, var. *Babouris*). It is a dry season sorghum which grows on residual moisture.

(e.g. groundnut and cowpea fodder, sorghum threshing.) Farmers who can afford it buy cottonseed cake from SODECOTON.

A more sustainable animal-crop integration could be achieved by integrating leguminous herbaceous and woody forages in the cropping system to provide fodder while crop residues are plowed in to increase organic matter content of the soil.

Most small farmers have a pair of oxen or access to one, hence animal traction is widely practiced. Ox-cart transport is also important. Animal traction ownership has increased among farmers growing cotton (a cash crop) and among those having access to SODECOTON and FONADER (a government agency) loans for the procurement of animal traction and peripheral farm implements. Animal traction is represented in the whole-farm model presented below.

3.3 Agroforestry systems

Most of the land opened for cultivation over the last 15 years has a moderate number of trees still standing in the fields. These trees are deliberately preserved by small farmers because of their economic value. For example, the nuts of *Butyrespernum parkii* are used to make local butter, the pods of *Tamarindus Indica* are used to make a beverage while its leaves are a source of fodder and its bark is used to make rope. About twenty major species of economic importance are found in the wetter parts (900 mm) of the North Province. Trees are also an effective mean of controlling soil erosion.

Several organizations such as: ONAREF, SODECOTON, CARE, and the North-East Benoue Project (NEB), have promoted tree planting by farmers. Small farmers tend to prefer planting small orchards (mostly mangoe and lime trees) near seasonal river beds (where the water table is never too low) to planting non-fruit trees. The most commonly planted non-fruit trees are: *Azadirachta indica*, *Cassia siemea*, and *Eucalyptus camaldulensis*.

Major constraints to tree planting are: (1) insufficient communications between farmers and seedling-supplying agencies, (2) insufficient water in the dry season, and (3) theft of fodder and fruit. Also, the growing importance of cotton fields, where trees can only be planted on the borders of large, consolidated blocks of plots, limit tree planting to non-cotton fields.

4.0 Traditional farm resources, income and constraints

Available land, labor and income are discussed with respect to the traditional farming systems described above. Major constraints to such systems are introduced.

4.1 Farm resources

4.1.1 Cultivable land

Although North Cameroon is sparsely populated (17 persons per km^2), cultivable land is scarce. For example, in the Benoue Division, farmers have access to 5.6 ha (average). However, 2.07 ha (37%) are sandy or crusted soils, highly eroded and with very low fertility levels. About 0.34 ha (6%) are ferruginous soils with medium to low fertility that can support sorghum and millet. Maize and cotton may be planted on 3.11 ha (55%) of black soils, with medium fertility. Vertisols, which are found at the bottom of valleys along river banks and are poorly drained in the rainy season, are usually planted to muskwari (0.08 ha or 1.5%). In addition to the appropriate soil fertility management techniques, farmers may elect to bring depleted fallow land into cultivation. They have access to about 10 ha of fallowed land.

In principle, land ownership is controlled by traditional rulers (the lamido, the religious and social leader represented by the village chief, the jahanuolo.) But in practice, farmers who cultivate the land effectively control it.

4.1.2 Farm labor and animal traction

The average farm family size in the North Province is 9-10 persons, half of whom are under the age of 16. Hence, 5.46 persons per family should be available for farming operations. However, the cost-route survey performed by SAFGRAD/FSR on seasonal labor flows indicates that an average of 2.75 persons are available to do farm work in each family. At least 85% of the farm labor is supplied by the family, the balance being hired. Animal traction is also used for ploughing, weeding, ridging and transport. The SAFGRAD/FSR Project monitored labor inputs and animal traction for farm operations for a panel of 52 farmers in 1986-89. Results are summarized in Table 4.1.

Table 4.1 Labor and animal traction inputs (hrs ha^{-1}) for traditional crops in North Cameroon, panel survey (n=52), 1986-89.

Input	Cotton	Maize	Groundnut	Sorghum	Cowpea
Labor:					
Family	461	275	371	218	204
Hired	77	22	36	38	23
Total	537	297	406	256	227
Animal traction:	43	19	18	11	14

4.2 Farm income

Farm income varies with the cropping system. For example, in a cotton-based farming system, the overall benefit-cost ratio (i.e. value of products at harvest divided by variable cost of production) is 1.45. However, this ratio differs with each crop, as shown in Table 4.2.

Table 4.2 Farm size (ha), net income per crop, and benefit-cost ratios for a cotton-based farming system in North Cameroon, 1986-89.

Crop	Plot size (ha)	Yield (t/ha)	Net income (FCFA)	B/C ratio
White sorghum	0.22	1.60	27,782	4.70
Muskwari	0.07	1.66	7,814	3.25
Red sorghum	0.86	1.25	30,830	2.34
Maize	0.46	1.70	28,616	1.94
Groundnut	0.49	1.01	13,196	1.36
Cotton	1.25	1.20	18,202	1.10
Cowpea	0.02	0.60	101	1.05
All crops	3.37	----	126,541	1.45

[1] One U.S. dollar equals 300 FCFA.

4.3 Major constraints

The major production constraints identified in the SAFGRAD/FSR Project area are:

Declining soil fertility
Moisture stress
Lack of short-cycle crop varieties
Labor shortage
Forage shortage

High population pressure on cultivable land, deforestation, continuous cropping with slash-and-burn land clearing practices, and soil erosion have contributed to declining levels of soil fertility. The upper Benoue valley and the Extreme North Province are especially affected.

Erratic low rainfall combined with high temperature at the beginning of the planting season induce moisture stress. Predominantly sandy soils with poor water retention capacity, or low infiltration rate and compaction due to crusting in the prolonged dry season do not permit adequate soil preparation and planting in May or June.

Long-cycle local varieties of sorghum, millet, maize, cowpea and groundnut are no longer adapted to the growing season which has grown shorter in the drought years of the 1980's.

Farmers in Northern Cameroon experience severe labor bottlenecks at critical periods (planting and weeding.)

With 60% of the country's livestock, North Cameroon farmers experience severe shortages of animal feed in the dry season.

In addition to these production constraints, farmers in the Project zone face wide fluctuations in product prices. They harvest their crop in October or November and most of them sell 20 to 100% of their products immediately after harvest, when food crop prices are at their lowest point. They do so to meet pressing need for cash. Moreover, storage facilities that reduce storage losses are sorely needed.

The constraints identified above, as well as the characteristics of the traditional farming systems, will be incorporated in the linear programming model described below.

5.0 Materials and methods

The SAFGRAD/FSR Project attempted to relax all of the major production constraints identified above. In the following model, three of the five major constraints are addressed: (1) declining soil fertility, (2) lack of short-cycle crop varieties, and (3) labor shortage at planting and weeding times.

First, a linear programming model of a traditional representative farm is constructed. Its objective is to depict mathematically the traditional farming systems, as they are described in Section 3.0 above, prior to the introduction of new technologies. We called this model **the base model**. Second, existing extension technologies are added to the base model to study the impact on farm income and resource use of extension programs prior the SAFGRAD/FSR Project. We called this model **the extension model**. Third, the technologies developed by the Project are added sequentially to both the base model and the extension model to study the impact of these technologies on both groups of farmers (the traditional ones and those who have adopted extension recommandations.) We called these models: **the base-Project model** and **the extension-Project model**. These models, and the data to support them, are discussed in turn.

5.1 The base model

In the base model, the problem is to find a traditional farm plan, defined by a set of activity levels X_j, $j = 1$ to n, which has the largest possible gross margin Z (equation 5.1), without violating any of the fixed resource constraints (equation 5.2), nor involving any negative activity levels (equation 5.3):

$$\max Z = \sum_{j=1}^{n} c_j X_j \qquad (5.1)$$

subject to:

$$\sum_{j=1}^{n} \mathbf{A}\, X_j \leq b_i, \text{ all } i = 1 \text{ to } m \text{ and } j = 1 \text{ to } n \qquad (5.2)$$

$$X_j \geq 0, \text{ all } j = 1 \text{ to } n \qquad (5.3)$$

$$bi \geq 0, \text{ all } i = 1 \text{ to } m$$

where:

X_j is a n-element column vector (j = 1 to n) of farm activities;
c_j is a n-element column vector of expected returns (in U.S. $ per ha);
A is a matrix of i resources (i = 1 to m) required to produce j activities (j = 1 to n);
b_i is a m-element column vector of resources available.

Several conventions are adopted here. Equation (5.1) is called the objective function. In this model, the objective function is total gross margin (i.e. yield times price at harvest minus total variable costs.) The constraints are called rows and the activities are called columns. The fixed resource supplies (b_i) are called right-hand side (RHS).

5.1.1 Columns

The traditional farming systems activities included in the base model may be grouped into three categories: (1) production activities, (2) selling activities, and (3) labor hiring.

Production activities are based on land clearing, soil preparation, planting, weeding, ridging, harvesting and transporting traditional varieties, cultivated either as sole crops or intercropped, at different time periods, depending upon the onset of the rains. In modeling seasonality, one to six planting dates per crop or crop associations have added to the number of columns. The major characteristic of the traditional production activities is intercropping. One fallowed land activity is also included in the base model to take into account the regeneration of soil-fertility. Crop activities and planting dates are described in detail in the appendix (Table A-1.)

Selling activities for seven crops are added to the model. Only grain selling is considered at this point. Selling prices of these crops at harvest and minimum subsistence levels required by the representative farm family in each crop are reported in Table A-2.

Labor hiring cover 14 periods, from January 1 (harvest of cotton) through December 31 (harvest of muskwari.) The prevailing wage rate in each period is reported in Table A-3.

5.1.2 Rows and RHS

Constraints to traditional farming systems modeled here include: land, family labor for planting and weeding, draught power, and crop production.

Land falls into five categories, according to its fertility level: F1-class land is made of black soils (3.11 ha for maize and cotton cultivation), F2-class land consists of ferruginous soils with medium to low fertility (1.46 ha for sorghum and groundnut), F3-class land encompasses all sandy soils with low fertility levels (0.9 ha for late season groundnut), vertisols (0.75 ha for muskwari) make up F4-class land and fallowed land (F5-class) are soils of depleted fertility levels (10 ha). The latter, however, could be regenerated by soil fertility management techniques. In practice, farmers cultivate an average of 6.22 ha and leave an average of 10 ha under fallow. Hence, in this representative farm, 6.22 ha are available for cultivation and 10 ha are fallowed. However, these proportions are not fixed. With the introduction of soil fertility management technology, the model allows land to be taken out of fallow and put under cultivation. The available land in each class represents the right-hand side of the constraints.

The model distinguishes between farmer's labor and the labor of the rest of the family. This is because the owner-operator provides skilled labor and management which other members of the family may not have. Fixed resource supplies (RHS) for farmer and family labor, as well as draught power (a pair of oxen) are reported in Table A-4.

Crop production constraints are row vectors of yield coefficients. Yield coefficients for the base model are displayed in table A-5. Traditional cultural practices are reported by crop in Table A-6.

A minimum food requirement constraint is included in the model in order to ensure food security for the farm family. In the case of uncertainty due to bad weather, poor soils, and plant diseases, this minimum food requirement must be met in a similar manner as the application of a safety-first criterion. Moreover, a minimum food requirement reduces the value of the gross margin of the farm. Subsistence levels[3] for each crop are in Table A-2.

To summarize, the base model is characterized by intercropping. The traditional farmer cultivates an average of 6.22 ha in seven crops, either as sole crops or in association. He attempts to remedy the poor soil fertility constraint by deep ploughing. He lacks adapted (short-cycle) crop varieties and relies entirely on traditional, long-cycle varieties susceptible to drought conditions.

5.2 The extension model

Prior to the SAFGRAD/FSR Project, the Extension Service in North Cameroon had issued a number of recommendations designed to address the soil fertility constraint by recommending the use of N, P and K fertilizers. Lack of short-cycle varieties was compensated by the introduction of maize variety TZPB, groundnut variety 28-206, cotton variety Bulk 96-97, cowpea variety TVx3236, and white sorghum varieties S43 or S35. Specific recommendations as to land preparation, seeding rate, plant density, thinning, chemical treatments and fertilizer application were also issued (these are summarized in Table A-6.)

Thus, the base model is altered to represent the extension-recommended package of technologies (varieties, fertilizer, and cultural practices.) The reasons for building this model are to: (a) determine the impact of the extension recommendations on the traditional farming systems and, (b) determine the impact of the SAFGRAD/FSR Project technologies on those farmers who had already adopted the extension recommendations. The significance of this exercise lies with the very mandate of the SAFGRAD/FSR Project which called for the development of improved technologies **in close collaboration with the Extension Service.**

3. Subsistence levels were derived from: Agricultural Development Indicators", Winrock International. 1987. Morrilton. Arkansas.

5.3 The SAFGRAD/FSR Project models

Two such models have been created. The base-Project model predicts the impact of the technologies recommended by SAFGRAD/FSR Project on the traditional farmers whereas the extension-Project model predicts the impact o the SAFGRAD/FSR technologies on farmers who have already adopted extension recommendations. This second model is particularly relevant since it is likely that the SAFGRS/FSR technologies will be transferred by the Extension Service first to their client farmers who have already f.'lowed recommendations made previous to the SAFGRAD/FSR ones.

As discussed earlier, the SAFGRAD/FSR Project technologies attempt to relax soil fertility, variety, and labor constraints among both types of farmers (traditional and "extension".) Technologies to be included in the Project models were selected on the basis of the results of on-farm trials conducted in North Cameroon from 1986 through 1988. Technologies characterized by significantly higher yields (determined by ANOVA) than either the traditional or the extension technologies and with marginal rates of return (MRR) greater than unity were chosen to be included in the models.

The application of 5 metric tons of animal manure and 25 kg of N per ha is recommended by the project to increase soil fertility. This recommendation is born from the results of three years of researcher-managed trials conducted in 1986-88. This combination of animal manure and low level of N fertilizer increased yield of sorghum (S34) from 1719 kg ha^{-1} (control) to 3594 kg ha^{-1}, or 209%. Likewise, this recommendation increased maize (CMS8501) yield by 2015 kg ha^{-1} (2 times.) There were no significant interactions between treatments and sites or seasons. The marginal rate of return on farmer-managed trials in 1988 was 7.77 or 777%. This means that for every dollar invested in this soil fertility technology, the farmer recuperated his one-dollar investment and earned an additional $ 6.77 (the marginal rate of return is defined as the marginal net benefit divided by the marginal cost.) Because of its agronomic and economic performance in on-farm trials, this technology was included in both Project models.

The SAFGRAD/FSR Project introduced short-cycle varieties of maize (CMS8501), sorghum (CS61 AND CS95), cowpea (VYA), and groundnut (K1-441-77.) In 1986 and 1988, years of relative abundant rainfall, no significant differences could be found between CMS8501 and long-cycle varieties. But in 1987, a drought year, CMS8501 out yielded TZPB-K81 (an extension-recommended

long-cycle variety) by 28% and Mexican 17E (a local long-cycle variety) by 26%. ANOVA indicated no significant location x variety interaction. Depending upon location and year, this variety had a MRR ranging from 1.01 (in West Benoue, 1988) to 1.78 (in North-East Benoue, 1987.) CMS8501 was recommended for seed multiplication and subsequent extension in 1988 and is included in the project models.

Short-cycle sorghum varieties CS61 and CS95 were tested for the first time in on-farm trials in 1988 and yielded 1579 kg ha^{-1} and 1463 kg ha^{-1}, respectively. They out yielded significantly the local variety (790 kg ha^{-1}) but were more susceptible to midges (Contarinia sorghicola.) When compared with local varieties, CS61 and CS95 had MRRs of 3.8 and 3.5, respectively, in 1987. Both varieties are included in both Project models.

Traditional cowpea varieties rarely exceed 250 kg ha^{-1} in North Cameroon. The SAFGRAD/FSR Project introduces the variety VYA (improved local variety) which yielded 3 to 4.5 times more than the local variety in 1987 and 1988, respectively, in on-farm trials. In addition to its good yield, VYA is preferred by farmers for its larger and white seeds, because its pods do not shatter in drying, and because it produces more forage. VYA had MRRs of 2.25 in 1987 and 4.13 in 1988. VYA is included in both Project models.

Groundnut (Arachis hypogea) ranks third after sorghum and maize as a food crop and second after cotton as a cash crop in the North Province of Cameroon. The variety K1-441-77 is included in both Project models although its yield was not significantly different from that of the extension-recommended variety (28-206) in 1986 (a wet year.) However, because of its short cycle, it is not adversely affected by drought. In 1986, its MRR varied from 12 (West Benoue to 15 (South-East Benoue.)

In the Project models, technologies are added sequentially (i.e. activities, or columns, representing them are inserted) either into the base model (base-Project model) or into the extension model (extension-Project model.) Input-output coefficients (yields, labor requirements) are changed accordingly in the matrix. Thus the base-Project model has now the option of choosing among traditional and Project technologies whereas the extension-Project model may choose extension and/or Project technologies.

5.4 Data sources

In this analysis, farmers were divided into two groups: those using traditional farming systems practices (base model) and those who have adopted extension recommendations (extension model). The data to characterize these two groups were drawn from a baseline survey of 220 farmers conducted in March-June 1986, at the onset of the SAFGRAD/FSR Project. This was done on two sites in South-East Benoue and three sites in each West and North-East Benoue. Research domains[4] were then defined by stratifying the SAFGRAD/FSR Project study area agro-ecological zones (sahelian savanna, sudan savanna, and guinea savanna.) Latter, criteria such as: cropping patterns, soil types, and farmers' socio-economic setting, were applied to define recommendation domains. A list of village in each research domain was compiled and two to three primary villages were drawn at random. An additional two to three secondary villages were then selected in the periphery of the primary villages. Exhaustive lists of farm families were then established in each village (1800 in West Benoue and 2558 in North-East Benoue.) Through a multi-stage random sampling procedure, sub-samples of farm families were then drawn to select farm for conducting on-farm trials. Sample size for the derivation of technical coefficients are shown, by item in Table 5.4.

All data were stored in both ASCII and SAS format . SAS sub-routines were used to calculate descriptive statistics used in constructing the technical coefficients.

6.0 Results

The results[5] are discussed in terms of the base-Project model and the extension-Project model, respectively.

4. As defined by Peter Hildebrand (personal communication, June 1989), a research domain may represent the preliminary stage prior defining recommendation domains.
5. The models were solved using LINDO. See: "User's Manual for Linear, Integer and quadratic Programming with LINDO" Linus Schrage. Third Edition. 1987. The Scientific Press.

Table 6.0 Sample size for technical coefficients by item and by year, North Cameroon, 1986-88.

Item	1986	1987	1988	Total
Seasonal farm labor	----	112	52	164
Fixed farm resources				119
Animal traction				42
Farm prices				124
On-farm variety trials[1]:				
Maize	24	30	20	74
Sorghum	6	12	12	30
Cowpea	1	8	12	21
Groundnut	22	----	----	22
On-farm soil management trials:				
Researcher-managed	2	4	2	8
Farmer-managed	----	----	12	12

[1] Managed jointly by researchers, extension agents and farmers.

6.1 The Base-Project model

As indicated in section 5.1, TB represents the status of production techniques in the traditional farming systems in the target area. Various levels of SAFGRAD/FSR Project technologies T_1, T_2 and T_3 (see Table 6.2, columns 1 and 2) are then introduced to the base model TB in order to address three of the identified major production constraints. T_1 is the soil fertility management technique consisting of 5t ha^{-1} of animal manure or crop residues, in combination with 25 kg N ha^{-1}. T_2 is the introduction of an improved maize variety CMS8501 and T_3 is the introduction of a set of four technologies (soil fertility management, improved maize variety CMS8501, improved cowpea variety VYA and improved groundnut variety K1-144-77 along with their components, as in Table 6.2.)

Table 6.1 and Fig 5 show the impact of the SAFGRAD/FSR technologies on gross margin and land allocation in the base model of the representative farm in North Cameroon in 1986-1988.

Table 6.1 The impact of the SAFGRAD/FSR technologies on gross margin and land allocation in the base model of a representative farm in North Cameroon, 1986-88.

Item	Unit		SAFGRAD/FSR technology		
		TB	T1	T2	T3
Farm size	ha	6.22	7.29	4.70	8.43
Fallow	ha	9.78	8.72	11.31	7.57
Gross margin:					
Total	U.S.$	1479	1509	1617	2339
Per ha	U.S.$	238	207	344	277
Crops grown:					
Maize	ha	2.50	2.71	2.50	7.30
% of total	%	40	37	53	87
Groundnut	ha	0.27	0.27	0.27	0.16
% of total	%	4	4	6	2
Cowpea	ha	0.90	1.96	0.24	0.22
% of total	%	14	27	5	3
Cotton	ha	0.61	0.40	0.61	0.00
% of total	%	10	5	13	0
Muskwari	ha	0.75	0.75	0.75	0.75
% of total	%	12	10	16	9
Red/white sorghum	ha	1.08	0.77	0.33	0.33
% of total	%	17	11	7	4
Red sorghum/maize	ha	0.11	0.42	0.00	0.00
% of total	%	2	6	0	0

Although T_1 increased the gross margin by only 2% it makes substantial changes in the allocation of land to various crops. Introducing soil fertility management technology to TB, increases the farm size from 6.22 ha to 7.29 ha (17%) and reduces fallow land from 9.78 ha to 8.72 ha. Land allocated to cowpea is more than doubled from 0.9 ha to 1.96 ha (118%). T_1 also increased the land allocated to maize as a sole crop by 8% and to red sorghum/maize intercrop by 282%. But, T_1 considerably reduced the land allocated to red/white sorghum intercrop, from 1.08 ha to 0.77 ha

(-29%) and that of cotton from 0.61 ha to 0.4 ha. Thus the introduction of T_1 reduces the farmer's dependence on cotton as a cash crop, and on red and white sorghum both as cash and subsistence crops. The solution forced by T_1 also suggests that the adoption of a soil fertility management technology may induce the base-model farmer to regenerate some of his depleted land and put it back into crop production.

The introduction of T_2 to the base model TB, made a different kind of impact. T_2 increased the gross margin from 1479 dollars to 1617 dollars (9%), but it reduced the farm size from 6.22 ha to 4.7 ha (-25%) thus increasing the fallow land from 9.78 ha to 11.31 ha (see Fig. 7). As for the allocation of land to various crops, T_2 partitioned the maize crop activity between the traditional and improved varieties. Thus, 0.76 ha of land was allocated to the improved maize variety CMS8501 and it allocated 1.15 ha of land to the traditional maize variety Mexican 17E. Red sorghum/maize intercrop was completely dropped. The land allocated to cowpea sole crop and to red/white sorghum intercrop was considerably reduced. The solution forced by T_2 suggests that the adoption of an improved maize variety alone can increase production slightly in the base model, but since an improved maize variety is by nature a high-fertility demanding crop, the farmer may have to leave most of his low fertility or depleted soils to fallow.

The introduction of four technologies with their respective components (T_3) to the base model TB, showed a very dramatic impact on both the gross margin, the farm size and the allocation of land to various crops. T_3 increased the gross margin from 1479 dollars to 2339 dollars (58%). It also increased the farm size from 6.22 ha to 8.43 ha (35%). Land allocated to maize was increased from 2.50 ha to 7.3 ha making it almost three times the land allocated to maize by the traditional farmer. The main features of the solution forced by T_3 are that: (a) as land allocated to maize increases, cotton sole crop and red sorghum/maize intercrop hectarage drops to zero, (b) land under groundnut and cowpea crops as well as that under red/white sorghum intercrops decreases while land allocated to muskwari is unchanged, (c) all the land under maize (7.3 ha) is planted to the improved variety CMS8501 while all the land under groundnut (0.16 ha) is planted to the improved variety

K1-441-77. Thus the solution forced by T_3, in which more land is allocated to maize, suggests that the introduction of SAFGRAD/FSR technologies induces the traditional farmer to consider maize as both a food crop and a alternative cash crop to cotton and groundnut. This is pictured in figure 5.

Table 6.2 column 3, shows that when technologies T_1, T_2 and T_3 are introduced in the base model, 1.06 ha of land types F_2 or F_5 are planted using the soil fertility management technology under T_1; 0.76 ha of land is planted to maize variety CMS8501 under T_2; and under T_3, both soil fertility management technologies and land maize variety CMS8501 and groundnut variety K1-441-77 are chosen. This is suggesting that soil fertility is indeed the principal constraint in the traditional farming systems (base model).

Table 6.2 SAFGRAD/FSR Technologies chosen by the base and extension models, respectively.

Technology	Description	SAFGRAD/FSR technologies chosen by	
		Base model	Extension model
		---------- ha	----------
T1	LDM2[a] by land type:		
	F1/F5 (moderate fertility)	0	3.55
	F2/F5 (low fertility)	1.06	5.71
	F3/F5 (poor fertility)	0	0
T2	Maize variety CMS8501	0.76	0.47
T3	LDM2 by land type:		
	F1/F5	4.19	4.19
	F2/F5	6.55	6.55
	F3/F5	6.56	1.42
	MZ2: CMS8501	7.30	2.16
	GT2: Groundnut K1-441-77	0.15	0.16
	SG2: Sorghum CS61 or CS95	0	0
	CP2: Cowpea VYA	0	0

[a] 5 t ha^{-1} of organic manure and 25 kg N ha^{-1}

Referring back to fig. 2, one can observe that the planting activities under technologies T_B, T_1 and T_2 are particularly crowded from April 25 through June 20. But the planting activities under T_3 are spread throughout the planting period. This is suggesting that the introduction of the four SAFGRAD/FSR technologies to the base model not only relaxes the constraints of declining soil fertility and lack of adaptable crop varieties, but also alleviates the shortage of labor at planting and weeding times.

6.2 The extension-Project model

In the extension model, TE represents the level of technology of traditional farmers who have adopted technologies recommended by extension. These were improved maize, cowpea, groundnut, sorghum and cotton varieties, along with some specific agronomic recommendations. See section 5.2 above and Table A-6. As in the base model, the SAFGRAD/FSR technologies T_1, T_2 and T_3 were introduced in the extension model.

Table 6.3 and Fig. 6 show the impact of the SAFGRAD/FSR technologies on gross margin and land allocation. The introduction of the soil fertility management technology T_1 to the extension model increases the gross margin from 1577 dollars to 2196 dollars (39%). Farm size increases from 5.09 ha to 8.64 ha (70%) while fallow is reduced from 10.92 to 7.36 ha (see Fig. 8). As for the allocation of land to various crops, the introduction of T_1 increases the land under maize from 3.04 ha to 6.66 ha (119%) and drops the cotton crop activity. The land planted to all the other crops remains as in the extension model TE.

Table 6.2, above, shows that the introduction of soil fertility management techniques to the extension model TE, may induce the farmer to apply the technique to 9.26 ha of land types F1/F5 and F2/F5 so as to make the fertility levels suitable for maize crop production.

The introduction of T_2 to the extension model, increases the gross margin from 1577 dollars to 1630 dollars (3.4%). Like in the base model, the introduction of T_2 to the extension model reduces the farm size from 5.09 ha to 4.61 ha (-9.4%) and increases the land under fallow from 10.92 ha to 11.39

Table 6.3 The impact of the SAFGRAD/FSR technologies on gross margin and land allocation in the extension model of a representative farm in North Cameroon, 1986-88.

Item	Unit		SAFGRAD/FSR technology		
		TE	T1	T2	T3
Farm size	ha	5.09	8.64	4.61	8.76
Fallow	ha	10.92	7.36	11.39	7.24
Gross margin:					
Total	U.S.$	1577	2196	1630	2425
Per ha	U.S.$	310	254	354	277
Crops grown:					
Maize	ha	3.04	6.66	2.68	7.30
% of total	%	60	77	58	83
Groundnut	ha	0.18	0.18	0.18	0.16
% of total	%	3	2	4	2
Cowpea	ha	0.72	0.72	0.25	0.22
% of total	%	14	8	5	3
Cotton	ha	0.07	0.00	0.43	0.00
% of total	%	1	0	9	0
Muskwari	ha	0.75	0.75	0.75	0.75
% of total	%	15	9	16	9
Red/white sorghum	ha	0.33	0.33	0.33	0.33
% of total	%	6	4	7	4

ha (see Fig 8.) As for land allocation, T_2 allocates 2.68 ha or 58% of the farm size to maize and increases the allocation of land to cotton from 0.07 ha to 0.43. Under T_2, the land allocated to groundnut, red/white sorghum intercrop and muskwari remains constant but that allocated to cowpea is reduced by 65%. As Table 6.2 shows, the solution forced by the introduction of T_2 allocates 0.47 ha to SAFGRAD/FSR improved maize variety CMS8501. However, T_2 also forces the allocation of 0.48 ha to the maize variety TZPB recommended by extension and 1.726 ha to the traditional maize variety Mexican

17E to total 2.68 ha planted to all three varieties of maize[6]. The solution forced by T_2 suggests that when the maize technology alone is introduced in the extension model, the farmer may reduce his farm size because most of his land is not fertile enough for maize crop. Furthermore, the farmer may not replace all his maize varieties by a new one partly because the fertility level of some of his land is not suitable for the new variety and partly because he needs to ensure that he can always meet his minimum subsistence level.

The introduction of T_3 in the extension model has a dramatic impact on the extension-model farmer. T_3 increases the gross margin from 1577 dollars to 2425 dollars (58%) and farm size from 5.09 ha to 8.76 ha (72%). Like T_2 and T_1, T_3 also increases the allocation of land to maize, in this case from 3.04 ha to 7.30 ha, thus allocating 83% of the farm size to maize. T_3 also drops the cotton crop activity, maintains red/white sorghum, muskwari and groundnut at about the same level as in TE but reduces by 69% the land under cowpea. Figure 6 shows the impact of the SAFGRAD/FSR technologies on land allocation in the extension model.

Table 6.2 column 4, shows that when the SAFGRAD/FSR technologies are introduced as a package (T_3) in the extension model, the soil fertility management technology was chosen for all the four types of land F1, F2, F3 and F5 to make them suitable for maize crop production. The solution forced by T_3 indicates that the extension-model farmer adopts the SAFGRAD/FSR soil fertility management technique on 12.16 ha or 75% of his total land. Column 4 of Table 6.2 also shows that 2.16 ha are allocated to SAFGRAD/FSR maize variety CMS8501 and 0.16 ha to SAFGRAD/FSR groundnut variety K1-441-77.

Fig. 3 shows that the planting activities of TE are crowded during the period April 25 to June 10. But the planting activities in T_3 and T_4 are well spread through the planting period April 25 to July 31, thus relaxing the labor constraint during this period of planting and weeding.

6. This is not shown in either Table 6.2 or Table 6.3. These numbers are derived from the solution output.

7.0 Conclusions

The main objectives of this paper are: (1) to show the future impact of the SAFGRAD/FSR program on both traditional farmers and farmers who have already adopted extension recommendations, and (2) to demonstrate how the technologies developed and tested by the SAFGRAD/FSR Project (soil fertility management and crop varieties), and now being transferred to farmers by the Extension Service, can be integrated in a sustainable way into the existing production systems and raise their productivity and profitability.

This paper has addressed three of the major production constraints identified in the Project zone in North Cameroon, namely: declining soil fertility, lack of adaptable crop varieties and shortage of labor at planting and weeding times. Results from linear programming models suggest the following conclusions. First, both the traditional farmer (represented in the base model) and the farmer that has already adopted the extension technologies (represented in the extension model) can increase their gross margin by over fifty percent by adopting the SAFGRAD/FSR technologies.

Second, the way in which resource allocation occurs when the Project technologies (T_1, T_2 and T_3) are integrated into the base model and the extension model suggest that indeed soil fertility and lack of short-cycle adaptable crop varieties are major production constraints in the research domains covered by the SAFGRAD/FSR Project.

Third, the introduction of a single technology, like an improved maize variety or a soil fertility management technique, may not have a significant impact on either the base-model farmer or the extension-model farmer. To benefit significantly from the SAFGRAD/FSR technologies, farmers need to adopt a combination of more than one technology. However, field observations made during the implementation of the Project indicate that farmers tend to adopt new technologies component by component rather than embracing a whole package. These observations also suggest that it is not necessary to lump together new technologies into inseparable packages for farmers to benefit from separate technologies. Model runs indicate that sequential adoption of SAFGRAD/FSR technologies is less beneficial than the adoption of a package, but that sequential adoption still offers appreciable yield and income increases over those derived from the traditional practices.

Finally, the results in this paper have shown that farmers in North Cameroon, whether traditional ones or those who have already participated in extension programs, can adopt the SAFGRAD/FSR soil fertility management technique in combination with some of the crop technologies like maize or groundnut and raise both the productivity and profitability of their farm in a sustainable manner.

Table A-1 Crop activities and planting dates for the base model of a representative traditional farm in North Cameroon, 1986-88.

Crop activity	Planting date
Red sorghum - white sorghum	April 25 - May 10
	May 11 - 20
Red sorghum - groundnut	April 25 - May 20
Red sorghum - maize	June 1 - 10
	June 11 - 20
Red sorghum - cowpea	June 21 - 30
Red sorghum	May 11 - 20
	May 21 - 31
	June 1 - 10
	June 11 - 20
	June 21 - 30
Groundnut	April 25 - May 20
	May 11 - 20
	May 21 - 31
	June 1 - 10
	June 11 - 20
	June 21 - 30
Groundnut - maize	June 1 - 10
Cotton	May 21 - 31
	June 1 - 10
	June 11 - 20
	June 21 - 30
	July 1 - 10
Maize	May 11 - 20
	May 21 - 31
	June 1 - 10
	June 11 - 20
	June 21 - 30
	July 1 - 10
Maize - cowpea	June 21 - 30
Cowpea	June 21 - 30
	July 1 - 10
	July 11 - 20
	July 21 - 31
	August 1 - 20
Muskwari	September 20 - 30
	October 1 - 30
	November 1 - 20

Table A-2. Selling activities and minimum subsistence level per crop for a representative farm model of North Cameroon, 1986-88.

Crop	Price ($/ton)	Minimum level of subsistence (ton/year)
Red sorghum	250	0.26
White sorghum	266	0.26
Groundnut	333	0.3
Cotton	467	-
Maize	300	0.26
Cowpea	366	0.2
Muskwari	316	0.25

Table A-3. Labor hiring activities: wage rate in U.S. dollars per day and per period for a representative farm of North Cameroon, 1986-88.

Hiring Period	Wage Rate ($/day)
April 1 - 20	3.40
April 20 - May 20	4.20
May 21 - June 10	7.10
June 11 - June 30	12.00
July 1 - July 20	12.00
July 21 - August 10	12.00
August 11 - August 31	7.10
Sept. 1 - 30	7.10
Oct. 1 - 30	10.00
Nov. 1 - 30	10.00
Dec. 1 - 31	8.00

Table A-4. Fixed resource supplies (RHS) of farmer and family labor, draught power, in hours per period, by farm operation, for the base model of a representative farm in North Cameroon, 1986-88.

Period	Dates by Farm Operation	Labor: Farmer	Labor: Family	Draught power
		Total hours		
	Harvesting cotton:			
1	January 1-31	100	88	-
2	February 1-28	72	36	-
3	March 1-31	52	25	-
4	April 1-20	48	68	-
	Early planting:			
5	April 21 - May 20	156	273	86
6	May 21 - June 10	108	189	90
7	June 11 - June 30	102	179	85
	Late planting:			
8	July 1 - July 20	102	179	85
	Normal weeding:			
9	July 21 - August 10	102	179	85
10	August 11 - August 31	114	200	76
11	September 1-30	156	273	104
	Harvesting:			
12	October 1-31	162	284	108
13	November 1-30	150	263	100
14	December 1-31	150	263	100

5t ha^{-1} organic measure and 25kg N ha^{-1}

Table A-5. Crop yield coefficients per crop and variety for the base, extension, and project models, North Cameroon, 1986-88.

	Base model		Extension model		Project model	
Crop	Variety	Yield ($t\ ha^{-1}$)	Variety	Yield ($t\ ha^{-1}$)	Variety	Yield ($t\ ha^{-1}$)
Maize	Mexican 17E	1.4	TZPB	3.0	CMS8501	3.8
Groundnut	Local	1.1	28-206	1.7	K1-441-77	1.9
Cowpea	Local	0.8	TVx3236	0.9	VYA	1.0
Red sorghum	Local	1.2	-	-	-	-
White sorghum	Local	0.9	S34 or S35	1.6	CS61 or CS95	1.8
Muskwari	Local	1.1	-	-	-	-
Cotton	Local	0.6-1.2	Bulk 96-97	0.9-1.2	-	-

Table A-6. Traditional, extension-recommended, and project-recommended cultural practices per crop, North Cameroon, 1986-88.

Crop	Traditional Practices	Extension-recommended practices	SAFRAD/FSR Project-recommended practices
Red sorghum	-local varieties -intercrop red and white sorghum -plant early at the onset of rains April 25/May 10 -50 kg/ha of seed, 5 grains/hill -thin to 2/3 plants -no fertilizers	No recommendation	No recommendation
White sorghum	Same as in red sorghum	-short cycle varieties S34/S35 -plant June 15 to July 10 -50 kg/ha seed -thin to 2 plants/hill -plant in lines 80 x 40 cm -(problem of mould and birds damage) -apply urea	-short-cycle varieites CS61/CS95 -plant June 30 to July 20 -20 kg seed/ha; 3 seeds/hill -thin to one plant/hill -apply urea 20 kg N/ha -space 80 x 20 cm
Maize	-maize variety: mexican 17E -deep plough -apply little or no fertilizer -plant 32 kg/ha seed and thin to 2 or 3 plants/hill; wide spacing or 80 x 40 cms -stagger planting	-maize varieties: mexican 17E and T2PB -plant 1-30 June -spacing 80 x 25 cm -32 kg/ha seed, plant 3 grains -thin 2 plants/hill -apply 35, 20, 15 kg/ha of NPK	-maize varieties CMS8501 and CMS8503 (streak virus tolerant) -plant June 1 to July 10 -30 kg/ha seed, plant 2 grains and thin to 1 plant/hill -spacing 80x20 cm or a density of 62,000 plants/ha -apply 60, 30, 30 kg/ha of NPK fertilizers (in 2 doses) -use thioral or Marshal seed treatment at 100g/10 kg seed -deep plough -do 1 1/2 weedings + ridging

Table A-6 continued

Crop	Traditional Practices	Extension-recommended practices	SAFRAD/FSR Project-recommended practices
Groundnut	-local varieties -stagger planting from onset of rains April/May to June 30 -one weeding, no fertilizer -plant 80,000 plants/ha	-local improved variety 28-206 -plant May/June -spacing 40 x 25 cm, plant 2 grains and thin to 1 plant/hill or 100,000 plants/ha	-improved varieties K1-441-77 and IB66 -plant 40x20 cm, plant 2 grains, thin to 1 plant/hill or 125,000 plants/ha -apply 100 kg/ha single super-phosphate (18 kg P_2O_5/ha)
Cotton	-various varieties -thin to 2 plants/hill -apply 30, 10, 15 NPK -apply 1 1/2 weedings -apply 3 to 5 sprays of insecticides -stagger planting June to July 10	-cotton variety Bulk 96-97 -plant May to June 30 -plant 5 grains per hill -thin to 1 plant/hill -spacing 80 x 50 cm. -apply 66, 20, 30 kg/ha of NPK fertilizers -apply 5 to 8 sprays of insecticide -deep plough -two weedings and ridge 40 days after planting	No recommendation
Cowpeas	-local varieties (spreading type) of large white seeds -stagger planting June to August 10 -intercrop cowpea with sorghum, maize or cotton -no fertilizer -little or no insecticide -one weeding	-variety TVX 3236 -20 kg seed/ha -plant July 5-15 -3 sprays of insecticide	-improved local variety VYA with with large white seeds -spreading type -plant 20 kg seed/ha; 2 seeds/hill -thin to 1 plant/hill -spacing 80 x 20 cm. -1 1/2 weedings -2 sprays of insecticide -50 kg/ha of single super-phosphate (or 9 kg P_2O_5/ha)

Table A-6 continued and concluded

Crop	Traditional Practices	Extension-recommended practices	SAFRAD/FSR Project-recommended practices
Muskwari	-local varieties -make seedling nurseries in September -select vertisols that are flooded during the season -clear the land with cutlass early October -transplant seedlings from nurseries to the field at end of rains in October while soils still wet -make deep holes with a huge sharp stick -add a cup of water then place the seedling and cover the hole by hand -spacing 80 x 100 cm -may or may not plough before planting -weed with a hoe 4 weeks after transplanting -no fertilizers -crop grows on residual moisture in the dry season and without irrigation	No recommendation	No recommendation

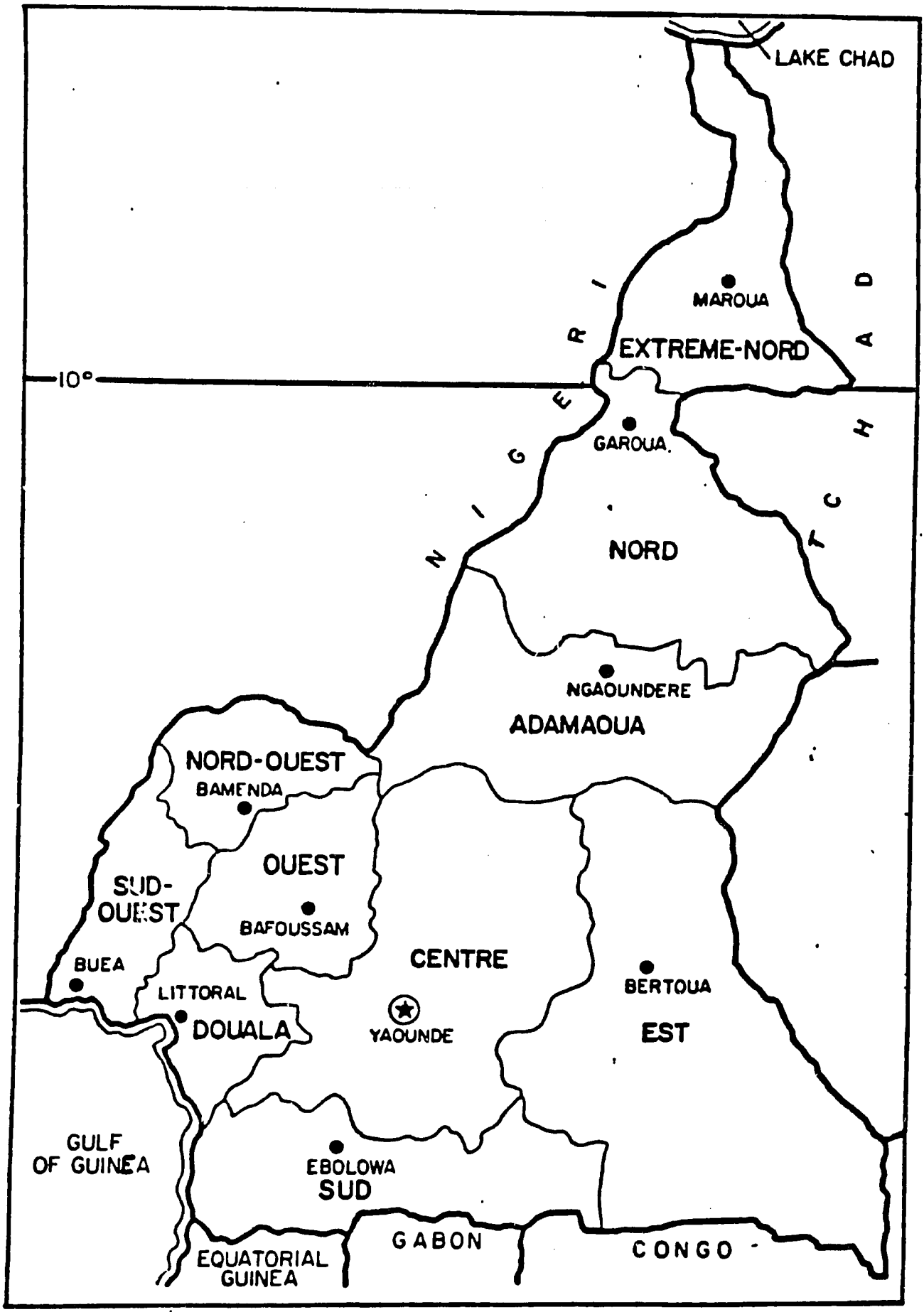
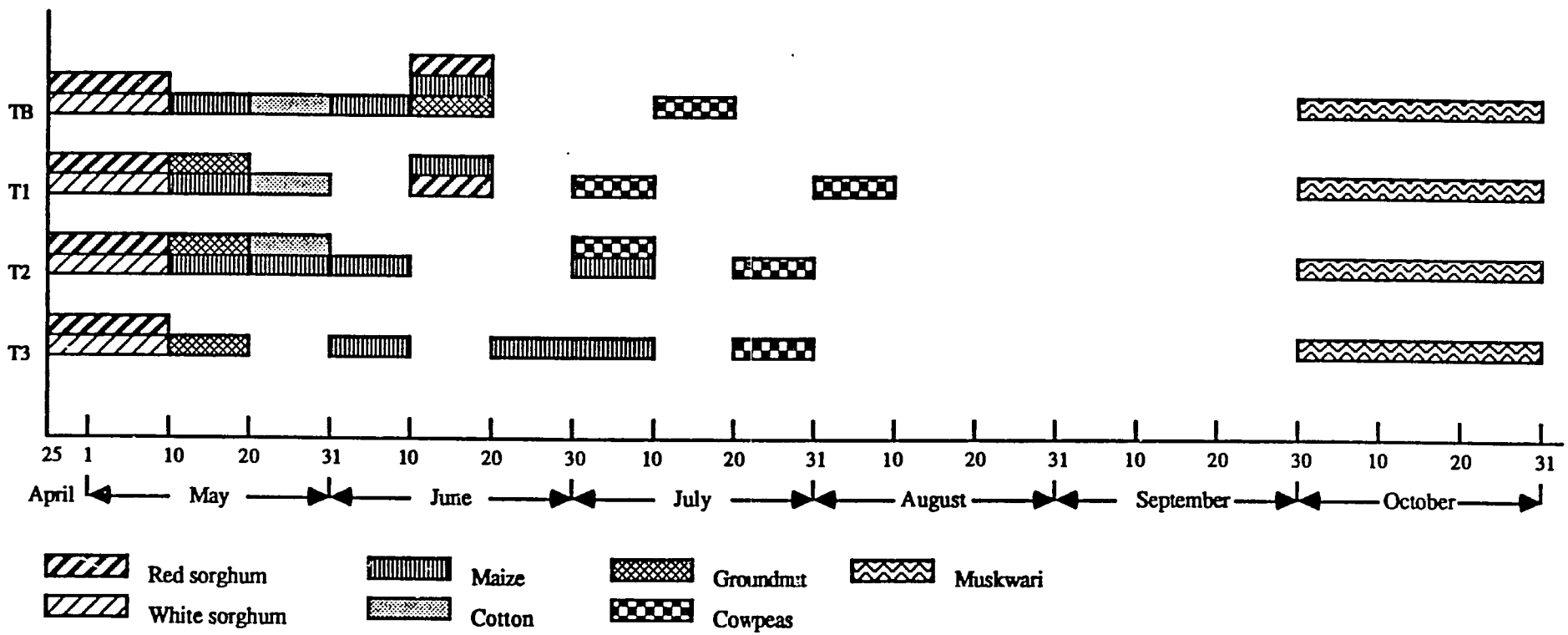


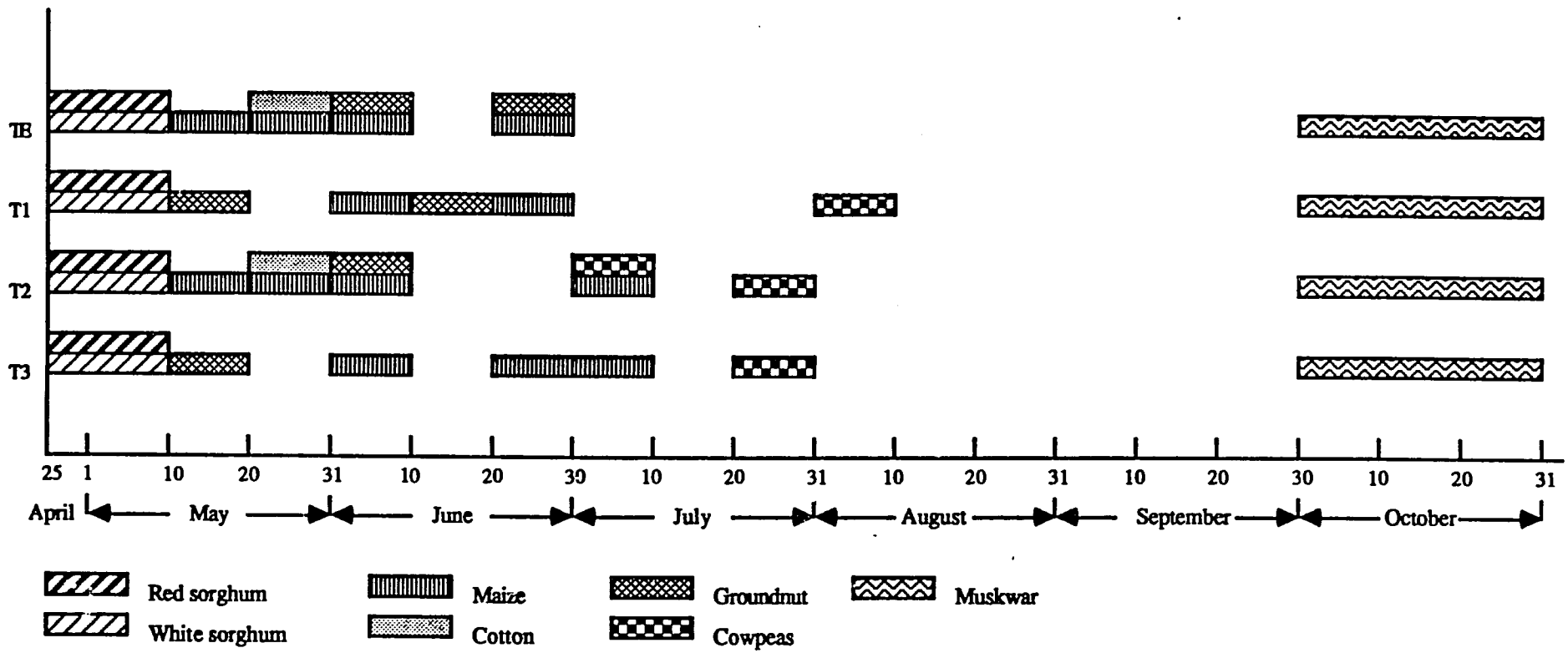
Fig. 1 : Map of Cameroon showing administrative provinces

Figure 2. Planting calendar per crop for the base-project model, North Cameroon, 1986-1988.



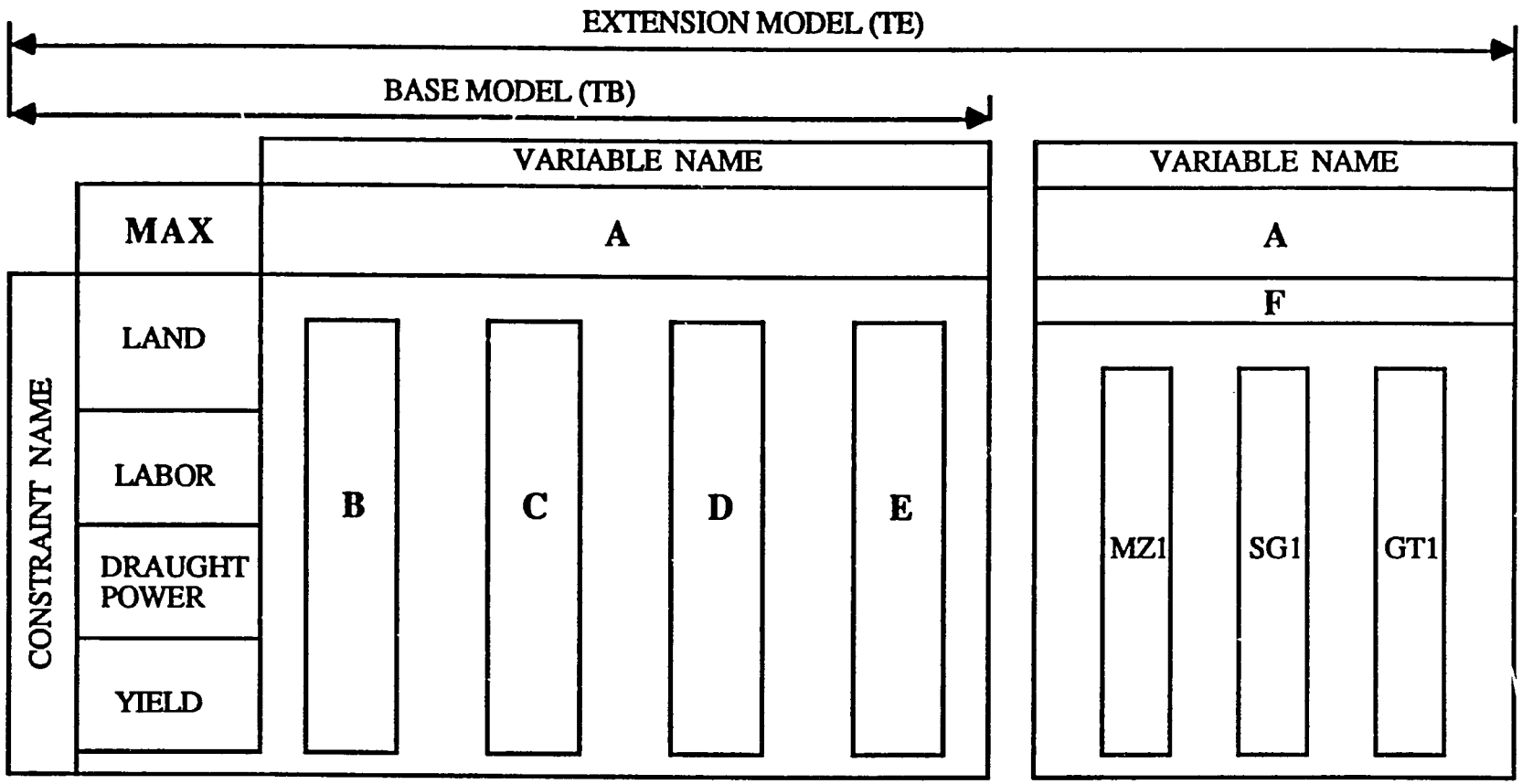
TB: Planting activities in the traditional farming system (base model).
T1: Planting activities in the base-project model with introduction of a soil management technignes.
T2: Planting activities in the base-project model with introduction of an improved maize variety.
T3: Planting activities in the base-project model with introduction of a package of 4 technologies.

Figure 3. Planting calendar per crop for the extension-project model, North Cameroon, 1986-1988.



TE: Planting activities in the extension farming system (extension-model).
T1: Planting activities in the extension-project model with introduction of a soil management technignes.
T2: Planting activities in the extension-project model with introduction of an improved maize variety.
T3: Planting activities in the extension-project model with introduction of a package of 4 technologies.

Figure 4. Schematic of the base and extension models



A = Objective function.
B = Crop production activities.
C = Labor hiring activities.
D = Minimum grain for subsistence.
E = Resource endowment.
F = Existing extension technologies: MZ1 =Maize; SG1 = Sorghum; GT1 = Groundnut.

Figure 5. The impact of the SAFGRAD/FSR technologies on land allocation in the base model of a representative farm in North Cameroon, 1986-1988

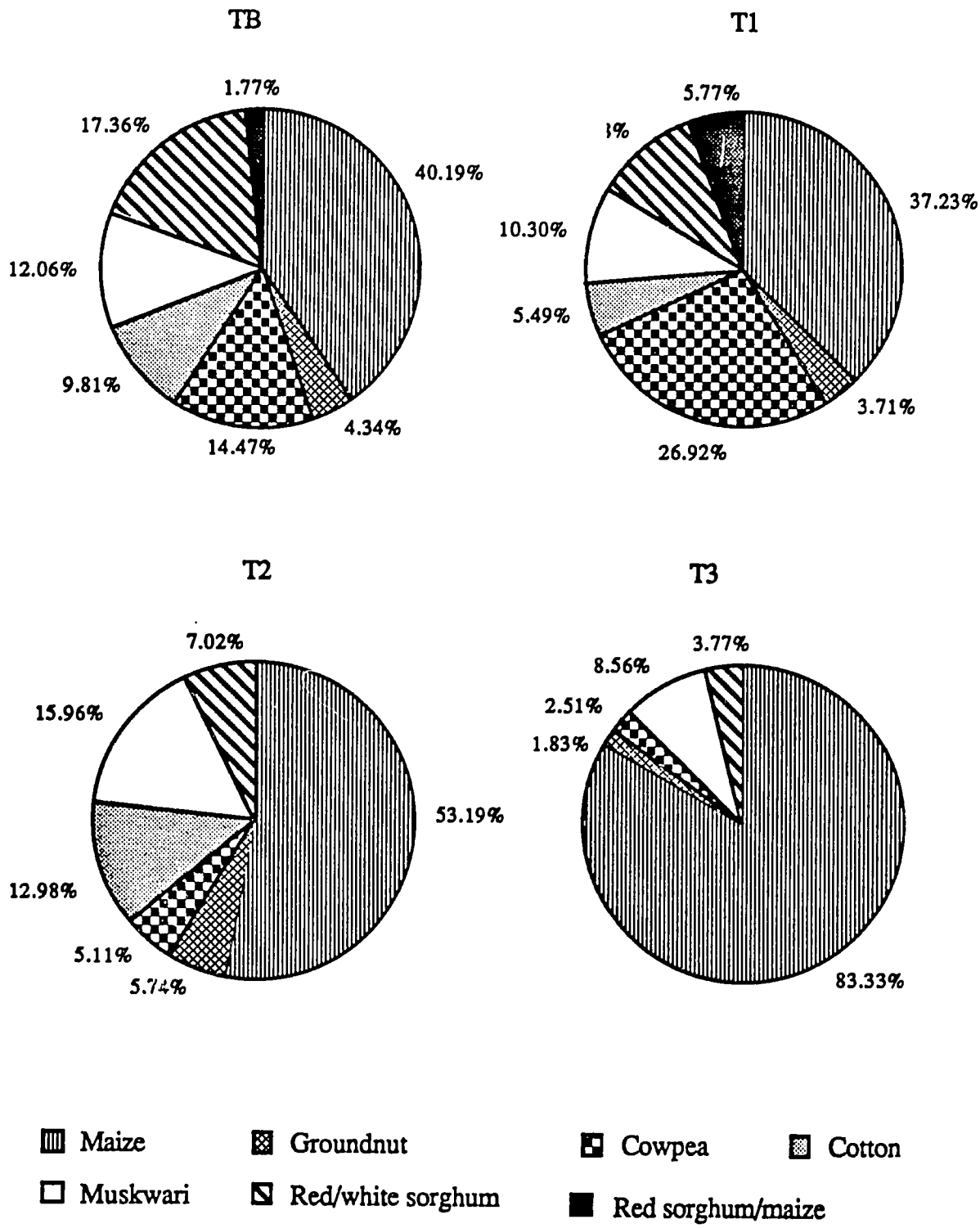


Figure 6. The impact of the SAFGRAD/FSR technologies on land allocation in the extension model of a representative farm in North Cameroon, 1986-1988

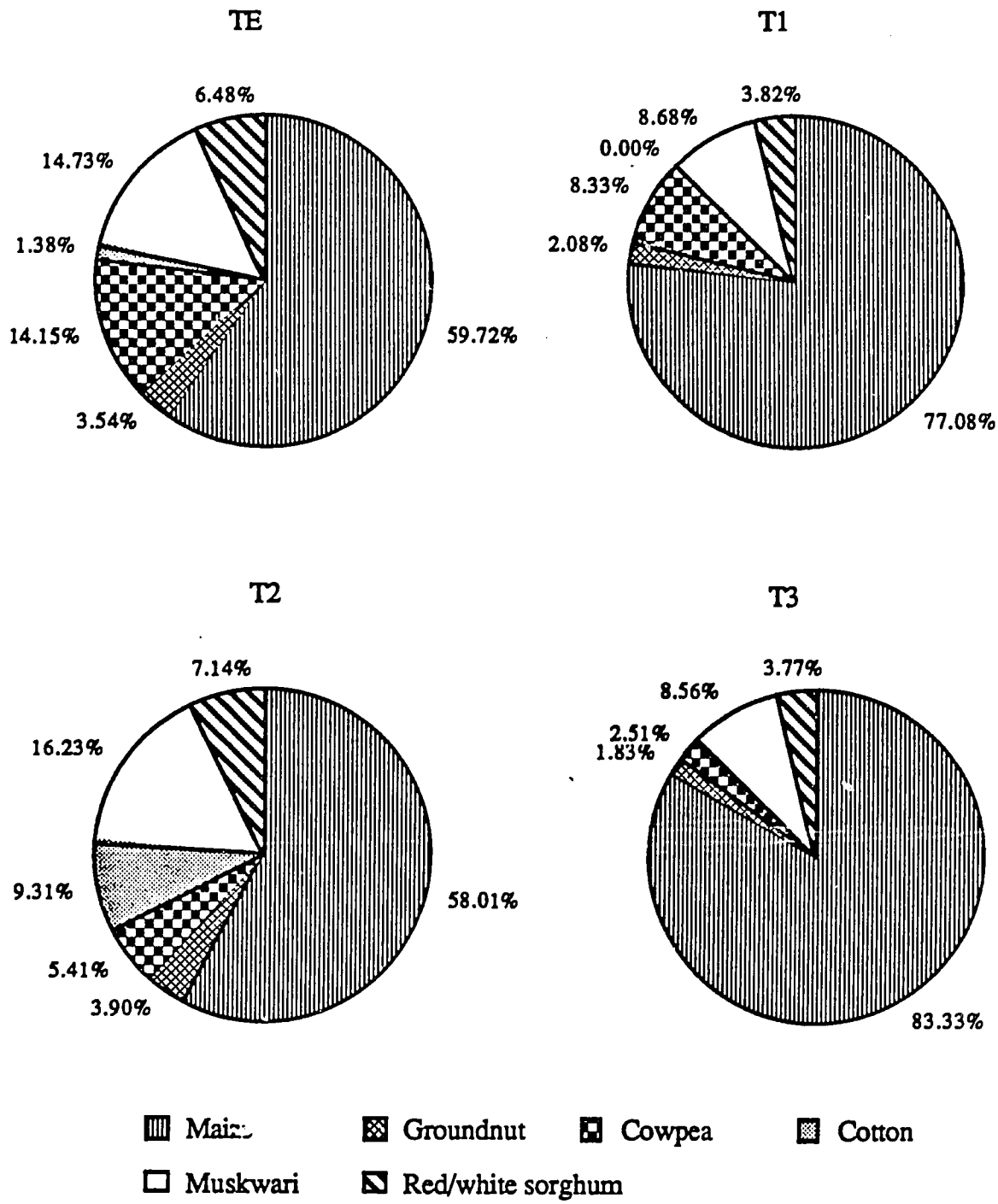


Figure 7. The impact of the SAFGARD/FSR technologies on the amount of land fallowed (out of 16 ha available), by traditional farmers in North Cameroon, 1986-1988

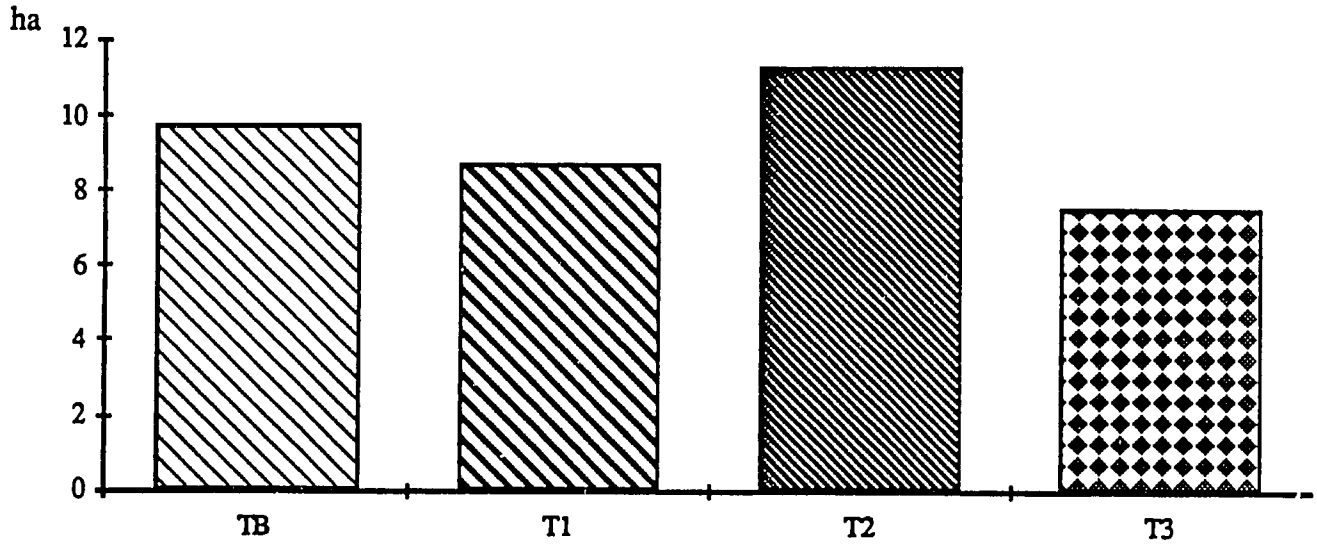
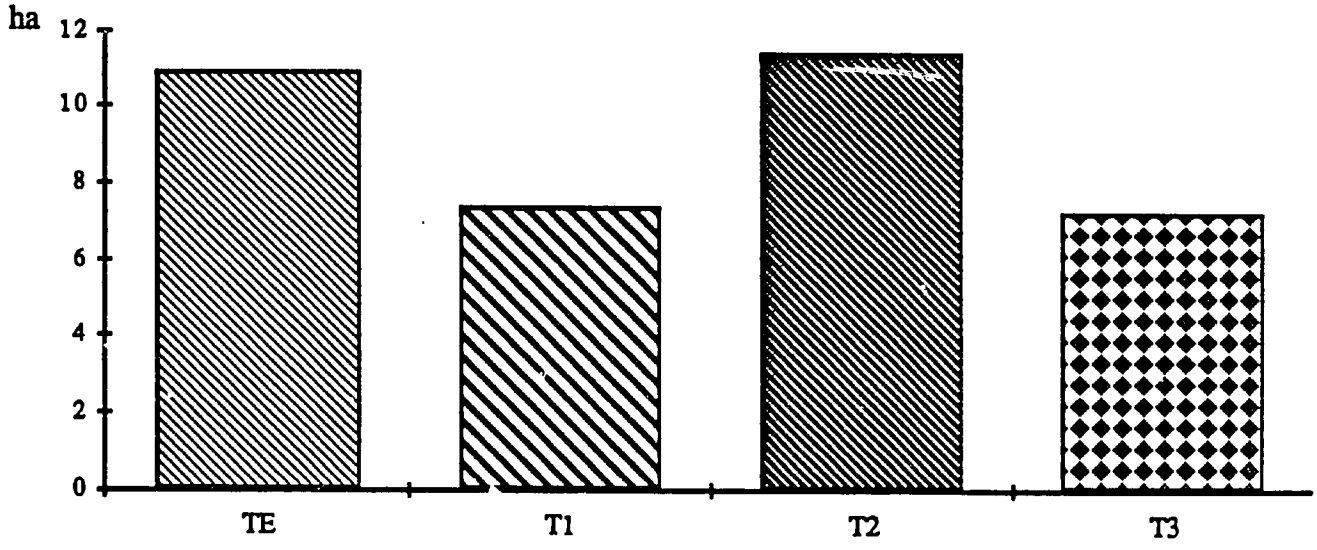



Figure 8. The impact of the SAFGARD/FSR technologies on the amount of land fallowed (out of 16 ha available), by farmers who have adopted extension recommendations in North Cameroon, 1986-1988