# FARM RESOURCE ALLOCATION IN THE EXTREME NORTH OF CAMEROON

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# CHAPTER I

# INTRODUCTION

## Background

Cameroon is a central African country (Figure 1) which covers an area of 475,440 $km^2$ (183,398 sq. miles) and has an estimated population of 12,658,439 (Central Intelligence Agency, 1992). The extreme north of the country is a grassland area where farming and livestock constitute the major production activities. It has about 2,115,000 inhabitants of which 1,600,000 are farmers (BEDI, 1988). The climate is semi-arid with 500 to 900 mm annual rainfall and temperatures ranging from 24°C to 40°C. Farmers are smallholders with 2 to 4 hectares of land, and the main crops grown include cotton, onions, sorghum, millet, rice, peanut and cowpea. Sorghum and millet constitute the staple food in the region. Since 1965, the Agronomic Research Institute has focused activities on appropriate farming practices and high yielding varieties with relatively high maturity rate and tolerance to drought.

Within the Agronomic Research Institute, there is a farming system unit named the Testing and Liaison Unit (TLU). The unit serves as a link between on-station researchers and farmers as well as extension and development agencies. *Sodecoton* and

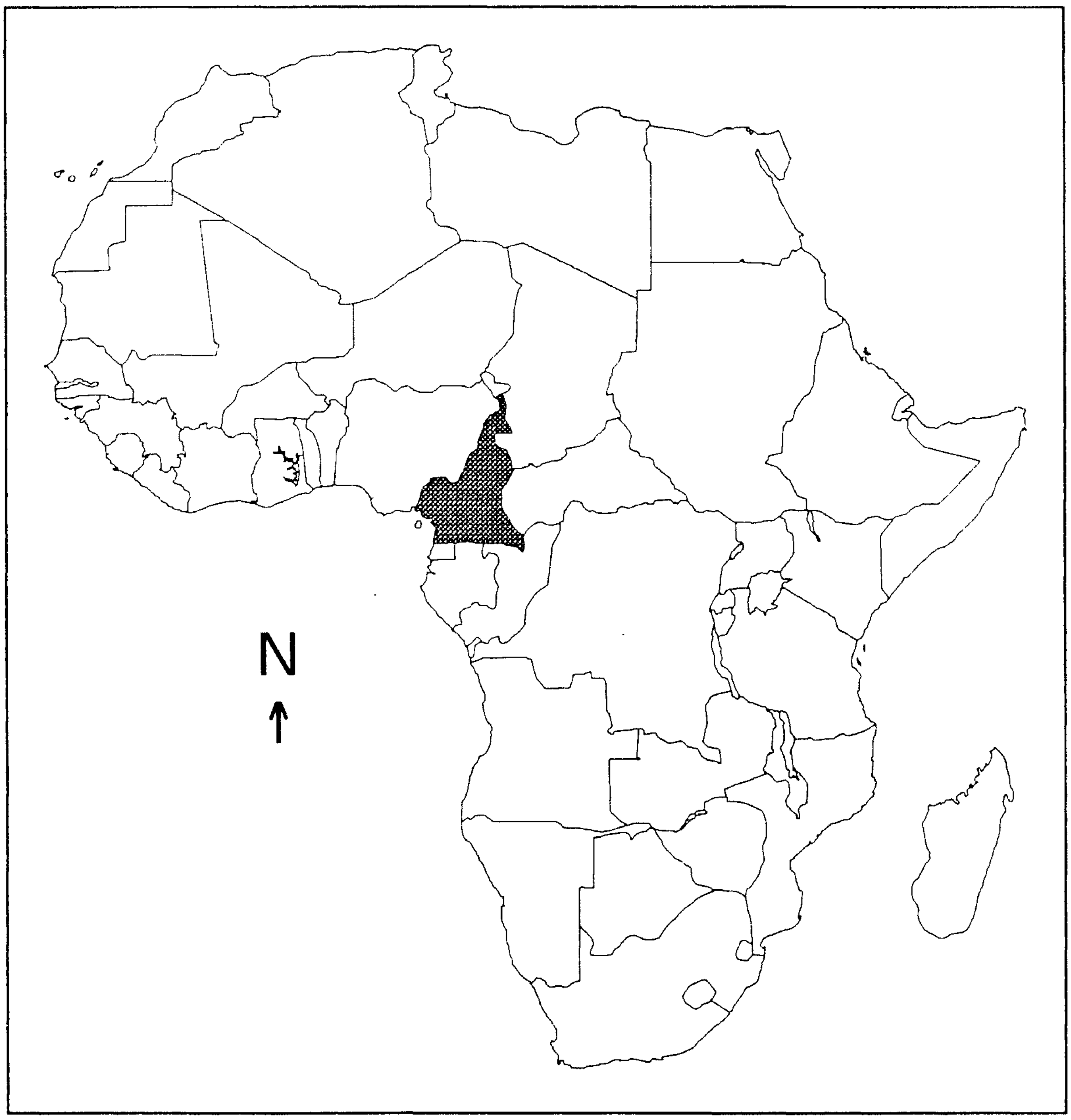


Figure 1. Location of Cameroon in Africa.

Source: Scholastic World Atlas, American Map Corporation, 1987.

*Semry*[1] are the two major development corporations in the study area with respective focus on cotton and rice productions. Extension activities have been conducted on a limited basis by these corporations and a few other organizations such as *Save the Children* and *Care International.* Since 1989, the National Extension Program has expanded its activities, and in the future, it will be responsible for all agricultural extension operations in the extreme north of Cameroon.

## Problem Statement

For the extreme north of Cameroon, there have been no studies on farm resource allocation. As a result, extension agents have found it very difficult to advise farmers regarding farm planning. The resource allocation issue became critical in 1989 when the Cameroon government announced an increase in fertilizer cost and a forthcoming decrease in cotton price. In mid 1989, the TLU research team designed a three-year study (1989-1991) to solve this lack of working documents on farm resource allocation. The study was conducted in four villages: Djoulgouf, Gatouguel, Djingliya and Zouaye.

## Objectives

The general objective of the study is to increase the efficiency of farm resource allocation in the study villages.

Specifically, the research will determine the optimal crop combinations that achieve a minimum target income and that satisfy production and consumption constraints

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[1] Sodecoton and Semry stand respectively for Cotton Development Corporation and Rice Improvement and Expansion Corporation.

prevailing in each of the four villages.

## Significance of the Study

The results of the present study will be useful from a practical standpoint. The study will generate farm economic data necessary for the extension program to advise farmers regarding crop combinations and the use and allocation of resources. Secondly, decision makers can use the results to design appropriate agricultural policies for the extreme north of Cameroon. Programs like fertilizer subsidy, loan for small machinery could be considered. Results of this study can guide the Cameroon government in setting cotton price for the region. Finally, the analytical model used in this study can be applied by other agricultural scientists working in subsaharan Africa.

# CHAPTER II

# REVIEW OF THE LITERATURE

## Optimization Models Used in Farm Planning

Several models are used in farm planning analysis. The following presentation emphasizes the characteristics of various models, their advantages and shortcomings.

### Linear Programming Model

Taha (1987) defined a linear programming (LP) model as a resource allocation model that seeks the best allocation of limited resources to a number of competing activities. In the model, an objective function is either maximized or minimized subject to a given set of resource constraints that the solution must satisfy. The objective function and the constraints must be linear. A complete list of the assumptions of the linear programming model is given in Appendix A.

A sensitivity analysis is usually conducted to evaluate the stability of the LP optimal solution to changes in activity return or cost ($c_j$), the resource constraint level ($b_i$), or the technical coefficient ($a_{ij}$). The sensitivity analysis can be performed as a range analysis or as parametric programming. LP models are relatively simple to build and many algorithms are available for their solution. However, they do not incorporate risk that is often attached to the $c_j$ and $b_i$ coefficients. The sensitivity analysis is designed to partially overcome this problem. In addition, the standard LP models do not incorporate the time factor which is addressed in multiperiod models.

## Multiobjective and Multiperiod Models

Multiobjective and multiperiod models are expansions of the standard LP model. In multiperiod models, the time period in which activities are performed are specified to keep track of resources used in each time period. One advantage of this model is that it can be set up such that net revenues generated in a given year can be used as a source of operating capital in the following year. As Bender, Kahan and Mylander (1992) pointed out, future costs and revenues are discounted so that the LP model solves for the maximum present value of income. These authors mentioned experience in building this type of model and the large amount of information required to set resources limits for future periods as problems related to the use of multiperiod models.

Multiobjective or goal programming departs from the idea that the farmer has one goal, which includes maximizing expected income and other subgoals such as consumption, leisure time, minimizing cost of hired labor, etc. Hazell and Norton (1986) suggested several ways to incorporate these goals in the LP model.

## Integer Programming

The LP model assumes that activity levels are infinitely divisible. This divisibility is not always the case and the round off which is sometimes made on optimal solutions can result in nonoptimal activity combinations. Examples of activities which cannot be performed in fractional units include buying a plow, buying a tractor or building a granary. An integer programming model can be mixed or pure depending on whether or not some or all the decision variables are integer values. One serious problem with integer programming is that of infeasibility especially when several variables must be integers.

Dynamic Programming

Dynamic programming is used to solve problems that involve decision making over time or deal with multistage processes. Examples include inventory and production planning. Computations are carried out in stages and recursively so that when each stage is optimized separately, the resulting decision is automatically feasible for the entire problem. States are defined and associated with each stage and they represent the link between succeeding stages. The major problem with dynamic programming as stated by Taha (1987) is that of dimensionality. Dimensionality occurs when several variables are used to define a state and as a result, data entry and computations are time consuming and require large computer memory.

Maximin and Minimax Criteria

Maximin and minimax criteria poorly incorporate risk in the selection of optimal farm plans. For the maximin criterion, the farmer is assumed to select the farm plan that has the maximum outcome under the worst state of nature. To formulate the corresponding math programming model, one needs to identify a finite number of states of nature and determine the activity gross margin for unfavorable time periods.

The minimax criterion assumes the selection of the farm plan that has the minimum value of the maximum regret. The maximum regret is defined as the difference between the maximum value of income (under perfect forecast) and the realized income. As Hazell and Norton mentioned, these two decision rules do not use information related to the probability of occurrence of each state of nature and also they do not take explicitly into account the covariance relations between activities gross margins.

Safety-First Model

A safety-first model assures that the farmer attains a minimum income necessary to meet his production costs and his family living cost each year. The problem with this model is the difficulty of translating it into a math programming model and its infeasibility for relatively large values of the minimum income.

Mean-Variance and MOTAD Models

Mean-variance and MOTAD models explicitly incorporate risk that can be associated with farm income. Under the mean-variance analysis, the farmer is assumed to select the farm plan with the lower variance of income, V(Y), given a level of mean income. The analyst develops a set of feasible farm plans that have minimum V(Y) for the associated expected incomes, E(Y). An EV frontier is traced out and the preference for a plan will depend on the utility function of the farmer. Deriving the EV frontier requires the minimization of the variance of income which in turn requires a quadratic programming algorithm. To overcome this difficulty, several models using the LP algorithm have been developed. These models include the mean-standard deviation (E,

$\sigma$) analysis, separable linear programming, MOTAD, and marginal risk constrained LP models. The MOTAD model is a Minimization of the Total Absolute Deviations of farm income from the mean. A mean-absolute deviation (EA) curve is derived as in the case of the EV analysis. If returns are normally distributed, the MOTAD results will tend to be similar to those of the mean-variance analysis.

In 1983, Tauer discussed some shortcomings of these two models (MOTAD and Mean-Variance). He pointed out that they do not necessarily generate solutions that meet the second degree stochastic dominance test. This failure of the test is particularly true for the Mean-Variance analysis when returns are not normally distributed unless the farmer has a quadratic utility function. In addition, Tauer noted that the sensitivity of the efficient frontier to minute changes in coefficient values is not considered.

## Stochastic and Chance-Constrained Programming

Stochastic and chance-constrained programming models recognize the fact that farmers can face shortages in resource supplies and as a result, the $a_{ij}$ and $b_i$ coefficients are not deterministic. The two models attempt to raise the probability of meeting the resource requirements to a desired level (90-95 percent). Hazell and Norton mentioned that if many chance-constraints are included in the model, its solution might pose serious statistical difficulties. Also, there is no guide as to what the farmer should do in the years during which resource requirements are not met. Finally, there are not many nonlinear algorithms to solve these models.

Target MOTAD Model

The target MOTAD model is used in the present study of farm resource allocation in northern Cameroon. The model was developed in 1983 by Tauer, and he claimed its superiority relative to Mean-Variance and MOTAD models. Tauer proved that results generated by the Target MOTAD are second degree stochastic dominant (SSD), whereas those from the two other models are not necessarily SSD.

With Target MOTAD, the expected farm income is maximized subject to the regular LP resource constraints and subject to meeting a given income target for each observed state of nature. Risk is measured as the expected sum of the negative deviations of the solution results from the target, and the risk parameter can be varied so that a risk-return frontier is obtained.

There are two main reasons that justify the selection of this model for the study. First, we are dealing with subsistence farmers and a model that considers a minimum level of income above consumption requirements seems very appropriate. Secondly, efficient farm plans derived from the model are also efficient by second degree stochastic dominance. As a result, there is no concern that a skewed distribution of returns might lead to different optimal results.

## Presentation of the Target MOTAD Model

A mathematical presentation of the Target MOTAD model is:

$$\text{Maximize} \quad E(Z) = \sum_{j=1}^{n} C_j X_j \tag{1}$$

subject to:

$$\sum_{j=1}^{n} A_{kj} X_j \leq B_k \tag{2}$$

$$T - \sum_{j=1}^{n} C_{rj} X_j - Y_r \leq 0 \tag{3}$$

$$\sum_{r=1}^{s} P_r Y_r = \lambda \tag{4}$$

$$X_j \geq 0 \tag{5}$$

$$Y_r \geq 0 \tag{6}$$

where: $E(Z)$ is the objective function, $C_j$ is the expected return from activity j, $X_j$ is the level of activity j, $A_{kj}$ is the technical requirement of activity j for resource constraint k, $B_k$ is the level of resource or constraint k, T is the target level of return, $C_{rj}$ is the return of activity j for state of nature or observation r, $Y_r$ is the deviation below T for state of nature or observation r, $P_r$ is the probability that state of nature or observation r will occur, $\lambda$ is the constant parameterized from M to 0, n is the number of constraints and resource equations, r is the number of states of nature or observations, s is the number of states of nature or observations, and M is a large number.

Equation (1) maximizes the expected returns of the solution set. Equation (2) fulfills the technical constraints. Equation (3) measures the revenue of a solution under state r and if that revenue is less than the target T, the difference is transferred to equation (4) via variable $Y_r$. Equation (4) sums the negative deviations after weighting them by their probability of occurrence $P_r$.

## Farm Planning Studies in Africa

In 1975, Wolgin studied the allocation of farm resources in Kenya, and he concluded that risk plays an important role in farmer decision making. He set up a model that maximized expected utility (as a function of income) subject to production constraints. One advantage of his model was the consideration of random disturbances that can affect prices and yields. In a study on farm resource allocation in Sudan, Mohamed (1984) set up a MOTAD model to derive an income-risk frontier. The interesting aspect of his study was the risk analysis he conducted to evaluate the sensitivity of optimal farm plans to changes in credit limitations, hired labor availability, irrigation water and product prices.

The issue of risk was also studied in northern Nigeria by Crawford and Milligan in 1982. They designed a simulation model for small farms to examine the income growth prospects under deterministic and stochastic conditions. The analysis of variance on the deterministic results indicated that the key determinants of financial performance are stochastic events, family size and resource endowment.

Still in Nigeria, Singh and Janakiram (1986) studied the interdependence between production and consumption decisions that characterize family plans. They maximized a utility function subject to three types of constraints: resources; minimum food production for consumption; and value of consumed goods be less than or equal to returns from crops and non-farm income. Their model performed fairly well since the optimal predicted values of crop production were very similar to observed values.

From a goal programming study conducted in Senegal, Barnett et al ( 1982 ) found the following goals to be of primary importance: minimum food production for consumption; maximization of returns and increase in leisure time; minimize expenditures on inputs and increase yields. The authors assigned weights to these goals following the Multiple Dimensional Scaling (MDS) procedure and they maximized the resulting objective function subject to resource constraints.

In a programming model for Egyptian agriculture, Sherbiny and Mokhlis (1974) estimated the magnitude of the possible gains arising from crop reallocation among 17 provinces. They set up an objective function to maximize the total net revenue of the agricultural sector subject to land area, cultivated crops and income constraints. The interesting features of the study were the inclusion of a minimum income constraint to be achieved and a constraint maintaining the existing crop system in each province. Their results indicated that a 22 percent increase in total net revenue could be achieved in the agricultural sector.

These past studies on resource allocation in Africa tend to emphasize the importance of minimum income and food security for subsistence farmers. These two aspects are incorporated in the present study. The target MOTAD model allows for a minimum target income to be achieved annually as well as the production of food for household consumption.

# CHAPTER III

# DESCRIPTION OF THE STUDY AREA AND RESEARCH DESIGN

## Sampling Procedure

The sampling area for the study is the mandate zone of the farming system unit based at Maroua research station (Figure 2). The TLU team applied a two-stage cluster sampling procedure to select the final sampling units. Villages represented the clusters, households and their cultivated plots were the secondary or final sampling units. First, a list frame comprising all villages in the study area was set up and four were randomly selected. In each of the four villages, a list of households was established from which 10 were randomly drawn.

## Description of the Study Area

The four randomly selected villages are: Djoulgouf, Djingliya, Gatouguel and Zouaye. These villages share some common features. They are in a semi-arid zone with high temperatures (25°C - 40°C) and low annual rainfall (600 - 900 mm). As apparent from Figure 3, the bulk of the rainfall is concentrated between July and September. The major cropping season is from May to November. Except for Gatouguel, access to the

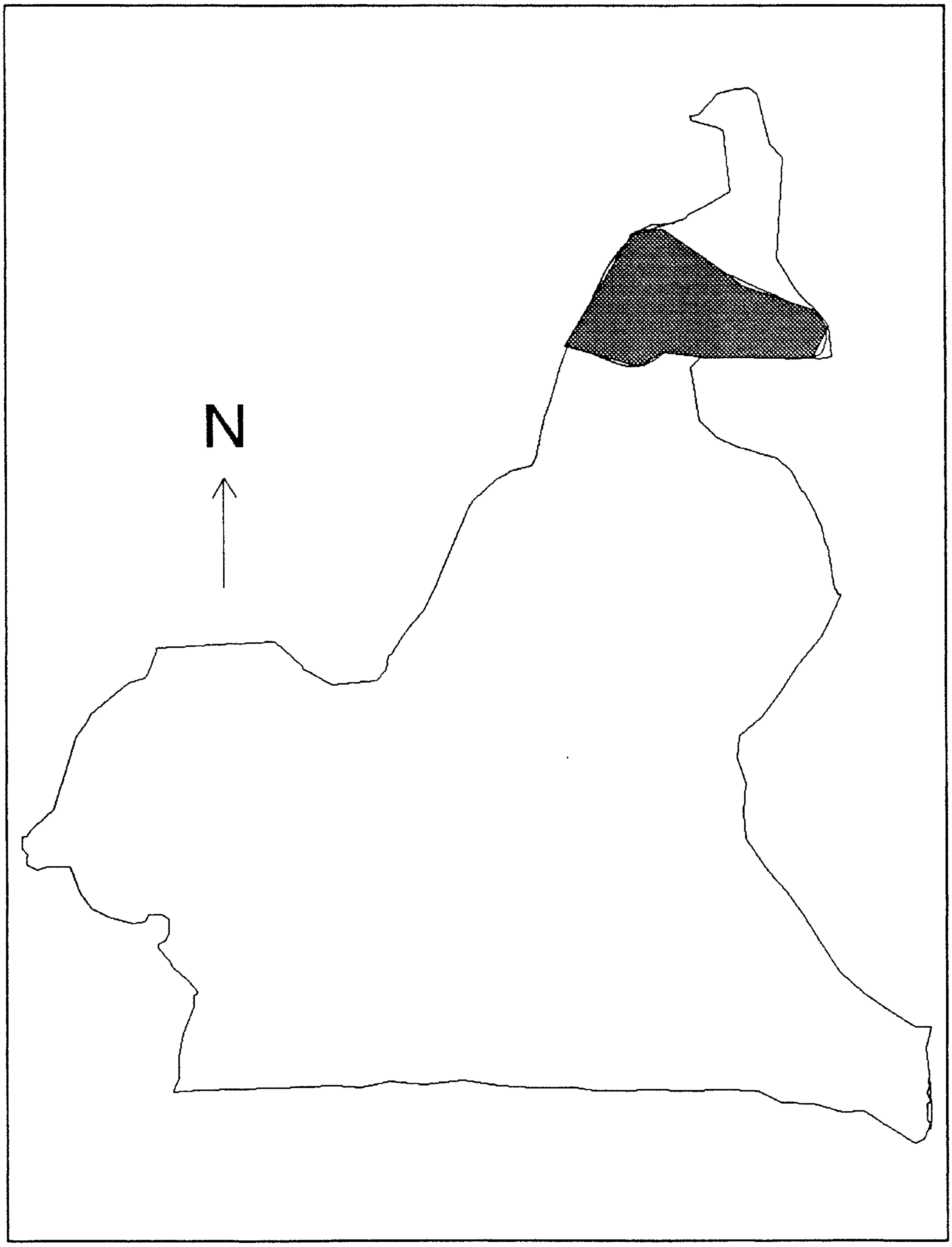


Figure 2. Mandate Area of the Farming Systems Unit in the Extreme North of Cameroon, Adapted from BEDI, 1988.

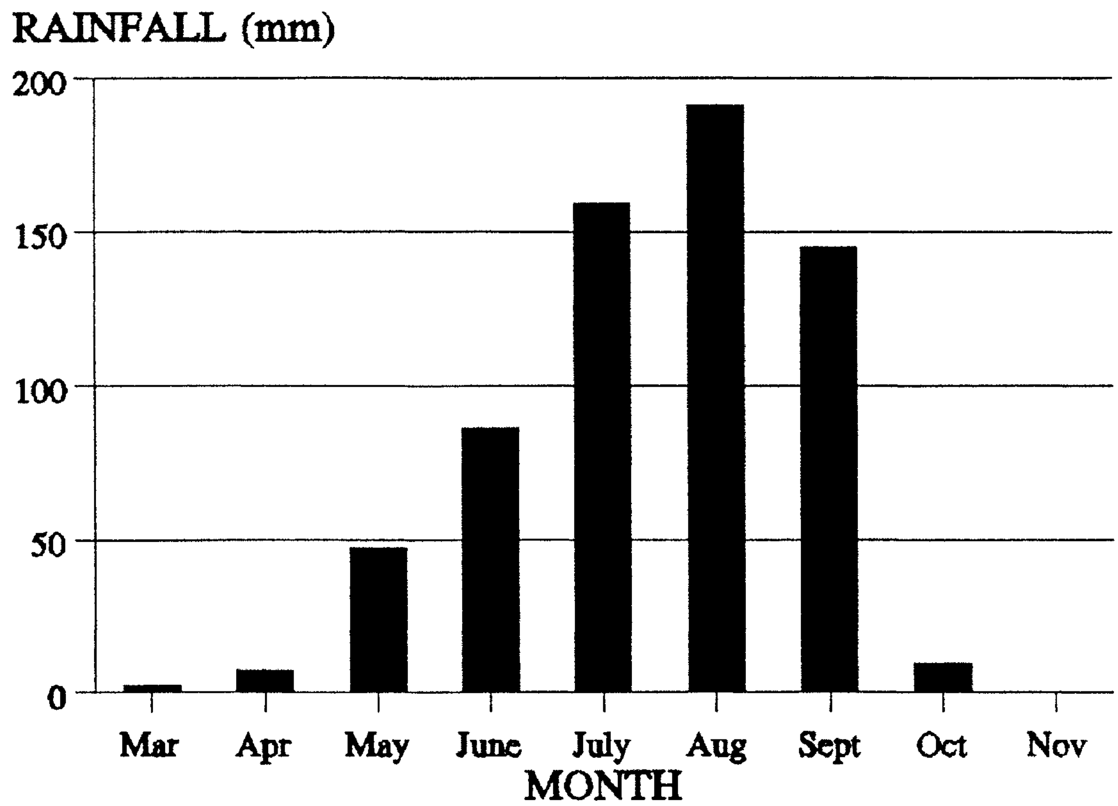


Figure 3. Average monthly rainfall for the study area, 1984-1988.

Source: DPA Extreme North of Cameroon, Annual Report 1989.

other three villages is very difficult during the rainy season because of poor road conditions. Sorghum is one of the major staple food consumed in the area. Cotton is widely grown and the related production and marketing activities are supervised by Sodecoton. Cotton/Sorghum rotation is promoted by the cotton corporation and is widely implemented by farmers. The company provides inputs (seeds, fertilizers and insecticide treatment) to cotton growers and deducts the corresponding cost at payment period. It also sells improved seeds and farm equipment (plows, trailers, etc) to farmers. Oxen plowing is practiced widely in the study area and it constitutes one of the few techniques used to increase labor productivity.

Besides farming, peasants are engaged in secondary activities such as retailing, raising small ruminants, production and sale of crafts and beverages. Selling and buying activities are conducted at the village market place on a weekly basis. Prices of all goods except cotton, are determined through demand and supply conditions. Cotton prices are fixed annually by the Cameroon government and farmers are paid by the cotton corporation. Although households live on a subsistence basis, they sell cotton and food surpluses to meet children's education, health care and other basic needs. Some farmers own cattle that are moved in a transhumance system by specialized herders. However, they do not like to disclose the number of animals in their herd or the related revenues. Their main reason for not disclosing the information is to avoid taxes which they claim are very high for cattle owners.

The working force in the households is usually three to six people. Most villages are governed by a chief commonly called *Lawan*. He is helped in his functions by the village subunits chief (*Djaourou*).

Djingliya

Djingliya is characterized by steep terraced hillsides, valleys and plains. Over the years, farmers have constructed terraces and the terraces are very appropriate for soil conservation. Farmland is very scarce because of the topography and also because of a relatively high population density (90-130 per sq. km).

The prevailing farming system in Djingliya is a cropping system that involves a typical sorghum/millet rotation and various intercroppings like sorghum-peanut, millet-peanut and millet-cowpea. Cotton is grown exclusively in the plains. Secondary activities include stock cattle raising for sale or for the *Marai*[1] celebration. The village has about 250 families mainly from the *Mafa* tribe.

Djoulgouf

Djoulgouf is a small village of about 150 families from *Foulbe*, *Guiziga* and *Massa* tribes. They grow three major crops: rainy season sorghum, dry season sorghum (*mouskwari*) and cotton. The *mouskwari* crop has been described as a *second chance crop* in case the rainy season sorghum fails. The *Foulbe* tribe is predominant. Almost all the members are moslems, and they are strongly engaged in commercial activities.

[1] The Marai is a traditional feast for harvest held by the Mafa tribe once every 2-3 years. Nowadays, the celebration is not as strongly observed as in the past.

Zouaye

In Zouaye, the land is flat and as a result, fieldcrops are often damaged by flooding. The village is relatively big with 230 families and more than 300 hectares of cropland. Pure cropping is fairly common in Zouaye and the major crops are cotton, sorghum, millet, and voandzou. The *Toupouri* tribe is the largest tribe in the village and beverage production and sale constitutes their favorite secondary activity.

Gatouguel

In Gatouguel, the cropland area is estimated at 350 hectares and farmers grow mainly cotton, sorghum, peanut, corn and cowpea. There are three main ethnic groups in the village (*Fali*, *Guidar* and *Daba*), and the population is estimated at 250 households. The village is located along a highway and this facilitates the purchase of inputs and the sale of farm products.

Description of the Different Surveys Conducted

A total of three surveys were conducted. A survey of farming practices which consisted of collecting data on quantities of inputs used, farm operations and expenses, and quantities of goods produced for three years (1989-1991). The data were collected for the cultivated plots each year from land preparation to crop harvest. The second survey deals with households food consumption, income and expenditures. From May 1990 to April 1991, data were collected on types and quantities of food consumed, expenses on necessities (clothing, health care, etc.) and non-farm income. A three-year (1989-1991) price survey was also designed to gather prices on various farm inputs and equipment as well as farm product prices. The reporting units for the first two surveys were heads of households and their spouses.

Questionnaire Design and Data Collection

The research team conducted an exploratory survey in the study area in February-March 1989. During this survey, a draft of the questionnaire was made for each of the three studies. In April 1989, enumerators were recruited in each of the four selected villages. The enumerators were trained over a three-day training session during which the objectives of the studies and the questionnaires were fully explained. A pilot survey was conducted during the training session as a way to finalize the questionnaires.

Prior to the beginning of data collection in May 1989, the TLU team went to each village and explained to farmers the objectives of each of the three surveys. This introduction to the objectives appeared to be a very positive method of motivating farmers and encouraging them to participate in the studies. During the three-year period, the farmers showed a strong support for the studies. One explanation might be the fact that enumerators were village residents and they were selected from an initial list of candidates proposed by farmers.

The price survey was conducted at the village local market which is normally held once a week. The household consumption study also was conducted on a weekly basis and usually at the farmer's residence. Data on farm practices were collected almost every day and depended on the frequency of field operations during the cropping season. The TLU team planned a tour in each village two or three times a month to supervise the collection of data and to obtain farmers' opinions about the studies.

# CHAPTER IV

# DATA ANALYSIS

The surveys generated a large volume of data which had to be sorted, grouped, compared and analyzed. To determine the optimal crop combination in each village, which is the main objective of this study, the survey data were analyzed in several steps. These steps include an identification of major crop activities in each village, computation of some statistics (mean and standard deviation) on input use for each crop activity, determination of technical coefficients and constraints for the Target MOTAD model, construction and solution of the model, and sensitivity analysis of the model.

## Identification of Major Crop Activities

From the farming practices survey, a list of crops grown in each village is made. The crops can be cultivated in pure, association or rotation. For example, in Gatouguel, farmers grow sorghum in three different ways: as a pure crop and continuously on the same plot; in association with peanut which rotates with cotton; and as a pure crop and in rotation with cotton. These cropping methods automatically define three different crop activities. The definition of a crop activity considers the crop(s) grown and the cropping patterns (intercropping and rotation).

Two criteria are used to select the crop activities for the mathematical programming model. A crop activity is included in the model if it is performed by at least 50 percent of the sample or if, on the average, its cultivated area is at least 20 percent of the total cropland. In the short run, farmers' attitudes are not expected to change tremendously. Therefore, the inclusion of only major crop activities in the study is expected to generate an optimal crop combination that is likely to be adopted by the majority of the farmers. Table 1 provides for each crop activity identified, the percentage of crop area cultivated and the percentage of farmers who grow it. Based on the two criteria, the major crop activities for each of the four villages are chosen and they are summarized in Table 2.

Several statistics for input use for each major crop activity in each village were calculated. These statistics included percentages of farm operations performed by family and hired labor; land area rented; crop area seeded with purchased or treated seeds; crop area fertilized or treated. These percentages are important since they determine the level of input use and hired labor costs in each crop activity budget. Tables 3, 4, 5, and 6 provide an overview of the percentages for each crop activity in the four villages. The weighted average which appears in the tables is the sum over 3 or 4 years of percentage input use weighted by the annual crop area cultivated.

## Generation of Technical Coefficients for Crop Activities

A crop budget is a table showing the quantities and costs of operating and fixed inputs used per unit of land area of the activity, and the quantities and prices of output produced. A gross margin is the crop activity returns above operating costs. Several elements of the crop budgets are used as coefficients in the Target MOTAD model. For example, the amount of labor required by each crop per period of time generates the labor constraint equation in the model. The operating costs and output price for each crop activity are elements of the model's objective function. These two examples show the importance of generating accurate technical coefficients for each crop activity.

Since the different crops are competing for the same resources, their individual levels of input use are compared statistically. If the statistical test shows no difference for example among the means amount of labor required to clear the land for all the crops in a given village, then the operation clearing the land will have the same technical coefficient for all the crops compared. The test is conducted using the regression technique. Crop activities are dummy variables in the model. For each input use or farm operation, the mean value for a reference crop is compared to those of the remaining activities.

The Observed Significance Level (OSL) and t-statistic values are used to judge the equality or difference in means between the reference crop and each other crop activity in the model. In case of equality, the means are averaged, weighted using area cultivated, to determine a common mean for all the crops compared. If the first regression does not group all the crop means, then a second regression is run to classify the remaining crop means. The regression technique is chosen instead of an LSD or DUNCAN procedure to avoid possible statistical problems that unbalanced data can create.

To demonstrate this test procedure, the complete process for Zouaye village is presented. Four crop activities have been identified in Zouaye: three continuous pure croppings (Sorghum, Millet, Voandzou), and one rotation (Cotton-Sorghum). Sorghum production is taken as the reference crop. Any one of the four crops could have been

Table 1. List of Crop Activities for Surveyed Farms in the Study Villages, 1989-1991.

| Crop Activities | Annual Mean Hectarage | Percent of Total Hectarage | Percent Farmers Growing |
|---|---|---|---|
| **Djoulgouf** | | | |
| Cotton-Sorghum Rotation | 1.875 | 14.8 | 50 |
| Rainy Season Sorghum | 1.92 | 15.2 | 60 |
| Dry Season Sorghum | 8.125 | 64.1 | 90 |
| Cotton-Cotton-Sorghum-Sorghum Rotation | 0.5 | 3.9 | 20 |
| Cowpea-Sorghum Rotation | 0.25 | 2 | 20 |
| **Zouaye** | | | |
| Cotton-Sorghum Rotation | 3.88 | 28.9 | 50 |
| Sorghum Continuous Cropping | 3 | 22.4 | 50 |
| Millet Continuous Cropping | 3.42 | 25.5 | 50 |
| Voandzou Continuous Cropping | 1.5 | 11.2 | 50 |
| Peanut-Voandzou Rotation | 0.5 | 3.7 | 20 |
| Peanut-Cowpea Rotation | 0.62 | 4.6 | 20 |
| Corn Continuous Cropping | 0.5 | 3.7 | 20 |
| **Gatouguel** | | | |
| Cotton-Sorghum Rotation | 6.8 | 48.2 | 90 |
| Sorghum Continuous Cropping | 2.17 | 15.1 | 60 |
| Corn Continuous Cropping | 1.58 | 11.2 | 50 |
| Peanut-Sorghum in Rotation with Cotton | 2.06 | 14.6 | 50 |
| Cotton-Peanut Rotation | 0.25 | 1.8 | 10 |
| Cotton-Corn Rotation | 0.75 | 5.3 | 20 |
| Peanut-Cowpea in Rotation with Cotton | 0.5 | 3.5 | 10 |
| **Djingliya** | | | |
| Sorghum-Millet Rotation | 3.13 | 25.4 | 90 |
| Cotton-Sorghum-Millet Rotation | 2.49 | 20.2 | 60 |
| Millet-Cowpea in Rotation with Sorghum | 3.25 | 26.4 | 70 |
| Millet-Peanut in Rotation with Sorghum-Peanut | 2.44 | 19.9 | 60 |
| Millet-Peanut Rotation | 0.25 | 2 | 10 |
| Cotton-Sorghum Rotation | 0.5 | 4.1 | 20 |
| Cotton-Millet Rotation | 0.25 | 2 | 10 |

Table 2. List of Major Crop Activities for Surveyed Farms in the Study Villages, 1989-1991.

| Village | Major Crop Activities |
|---|---|
| Djoulgouf | Cotton-Sorghum Rotation |
| | Rainy Season Sorghum Continuous Cropping |
| | Dry Season Sorghum Continuous Cropping |
| Zouaye | Cotton-Sorghum Rotation |
| | Sorghum Continuous Cropping |
| | Millet Continuous Cropping |
| | Voandzou Continuous Cropping |
| Gatouguel | Cotton-Sorghum Rotation |
| | Sorghum Continuous Cropping |
| | Corn Continuous Cropping |
| | Association Peanut-Sorghum in Rotation with Cotton |
| Djingliya | Sorghum-Millet Rotation |
| | Cotton-Sorghum-Millet Rotation |
| | Association Millet-Cowpea in Rotation with Sorghum |
| | Association Sorghum-Peanut in Rotation with Millet-Peanut Association |

Table 3. Average Input Use for Surveyed Farms in the Djoulgouf Village, 1989-1991.

| | | Weighted Average Input Use Per Crop Activity (Percent) | | |
|---|---|---|---|---|
| Operation | Source | Sorghum | Mouskwari | Cotton-Sorghum Rotation |
| Land area rented | | 47.8 | 8.2 | 16.7 |
| | Family labor | 26.1 | 30.6 | 63.3 |
| Land area cleared | Hired labor | 0 | 69.4 | 10.0 |
| | Not cleared | 73.9 | 0 | 26.7 |
| | Family labor | 0 | ---- | 60.0 |
| Land area plowed | Hired labor | 13.1 | ---- | 16.7 |
| | Not plowed | 86.9 | ---- | 23.3 |
| | Family labor | 95.7 | 100 | 100 |
| | Hired labor | 4.3 | 0 | 0 |
| Land area seeded | With purchased seeds | 82.6 | 0 | 21.4 |
| | With treated seeds | 69.6 | ---- | 86.7 |
| Crop area transplanted | Family labor | ---- | 49 | ---- |
| | Hired labor | ---- | 51 | ---- |
| Crop area weeded | Family labor | 30.4 | 77.6 | 63.3 |
| | Hired labor | 69.6 | 22.4 | 36.7 |
| | Family labor | 4.3 | ---- | 100 |
| Crop area fertilized | Hired labor | 0 | ---- | 0 |
| | Not fertilized | 95.7 | ---- | 43.3 |
| Crop area (cotton) | Treated | ---- | ---- | 93.7 |
| | Not treated | ---- | ---- | 6.3 |
| Crop area harvested | Family labor | 69.6 | 78.6 | 60 |
| | Hired labor | 30.4 | 21.4 | 40 |

Table 4. Average Input Use for Surveyed Farms in the Zouaye Village, 1989-1991.

| | | Weighted Average Input Use Per Crop Activity (Percent) | | | |
|---|---|---|---|---|---|
| Operation | Source | Sorghum | Millet | Voandzou | Cotton-Sorghum Rotation |
| Land area rented | | 22.2 | 10.0 | 16.7 | 45.2 |
| | Family labor | 100 | 100 | 100 | 100 |
| Land area cleared | Hired labor | 0 | 0 | 0 | 0 |
| | Not cleared | 33.3 | 7.3 | 0 | 6.4 |
| | Family labor | 83.3 | 75.6 | 72.2 | 80.7 |
| Land area plowed | Hired labor | 16.7 | 24.4 | 27.8 | 19.3 |
| | Not plowed | 52.7 | 26.8 | 0 | 19.3 |
| | Family labor | 100 | 100 | 100 | 95.2 |
| Land area seeded | Hired labor | 0 | 0 | 0 | 4.8 |
| | With purchased seeds | 16.7 | 21.9 | 38.9 | 6.4 |
| | With treated seeds | 52.7 | 36.6 | 5.5 | 100 |
| | Family labor | 100 | 100 | 94.5 | 80.7 |
| Crop area weeded | Hired labor | 0 | 0 | 5.5 | 19.3 |
| | Family labor | 100 | ---- | ---- | 100 |
| Crop area fertilized | Hired labor | 0 | ---- | ---- | 0 |
| | Not fertilized | 94.5 | 100 | 100 | 50 |
| Crop area (cotton) | Treated | ---- | ---- | ---- | 100 |
| | Not treated | ---- | ---- | ---- | 0 |
| Crop area harvested | Family labor | 100 | 95.1 | 100 | 75.8 |
| | Hired labor | 0 | 4.9 | 0 | 24.2 |

Table 5. Average Input Use for Surveyed Farms in the Gatouguel Village, 1989-1991.

| | | Weighted Average Input Use Per Crop Activity (Percent) | | | |
|---|---|---|---|---|---|
| Operation | Source | Sorghum | Corn | Peanut-Sorghum-Cotton Rotation | Cotton-Sorghum Rotation |
| Land area rented | | 57.7 | 42.1 | 25 | 5.4 |
| Land area cleared | Family labor | 100 | 100 | 100 | 94.6 |
| | Hired labor | 0 | 0 | 0 | 5.4 |
| | Not cleared | 0 | 0 | 0 | 0 |
| Land area plowed | Family labor | 100 | 100 | 95.7 | 100 |
| | Hired labor | 0 | 0 | 4.3 | 0 |
| | Not plowed | 76.9 | 5.3 | 30.3 | 44.5 |
| Land area seeded | Family labor | 96.2 | 79 | 97 | 87.3 |
| | Hired labor | 3.8 | 21 | 3 | 12.7 |
| | With purchased seeds | 65.4 | 0 | 35.7 | 23.6 |
| | With treated seeds | 69.3 | 73.7 | 21.4 | 81.8 |
| Crop area weeded | Family labor | 65.4 | 89.5 | 84.9 | 93.6 |
| | Hired labor | 34.6 | 10.5 | 15.1 | 16.4 |
| Crop area fertilized | Family labor | 100 | 100 | 100 | 100 |
| | Hired labor | 0 | 0 | 0 | 0 |
| | Not fertilized | 42.3 | 0 | 50 | 46.4 |
| Crop area (cotton) | Treated | ---- | ---- | 100 | 100 |
| | Not treated | ---- | ---- | 0 | 0 |
| Crop area (harvested) | Family labor | 92.3 | 94.7 | 90.9 | 90 |
| | Hired labor | 7.7 | 5.3 | 9.1 | 10 |

Table 6. Average Input Use for Surveyed Farms in the Djingliya Village, 1989-1991.

| | | Weighted Average Input Use Per Crop Activity (percent) | | | |
|---|---|---|---|---|---|
| Operation | Source | Sorghum/Millet | Millet-Cowpea/ Sorghum | Millet-Peanut/ Sorghum-Peanut | Cotton/Sorghum Millet |
| Land area rented | | 88 | 53.8 | 82.1 | 100 |
| | Family labor | 100 | 100 | 100 | 100 |
| Land area cleared | Hired labor | 0 | 0 | 0 | 0 |
| | Not cleared | 4 | 0 | 5.1 | 0 |
| | Family labor | 45 | 100 | 100 | 90 |
| Land area plowed | Hired labor | 55 | 0 | 0 | 10 |
| | Not plowed | 60 | 82.7 | 56.4 | 13.3 |
| | Family labor | 98 | 100 | 100 | 80 |
| | Hired labor | 2 | 0 | 0 | 20 |
| Land area seeded | With purchased seeds | 4 | 0 | 2.6 | 5 |
| | With treated seeds | 90 | 100 | 97.4 | 80 |
| Crop area weeded | Family labor | 90 | 100 | 84.6 | 76.7 |
| | Hired labor | 10 | 0 | 15.4 | 23.3 |
| | Family labor | 100 | ---- | 100 | 100 |
| Crop area fertilized | Hired labor | 0 | ---- | 0 | 0 |
| | Not fertilized | 96 | 100 | 87.2 | 63.3 |
| Crop area (cotton) | Treated | ---- | ---- | ---- | 100 |
| | Not treated | ---- | ---- | ---- | 0 |
| Crop area harvested | Family labor | 100 | 100 | 100 | 100 |
| | | 0 | 0 | 0 | 0 |

considered. Sorghum is selected because it is the major staple crop in the region. A series of regression equations is defined and the dependent variables are the mean time (in hours) necessary to clear, seed, plow, weed and harvest one hectare of sorghum.

<u>Clearing Land</u>

To test whether there was a difference in the time it took to clear land across the activities, the following equation is defined:

$$\text{Clear SO}_j = \beta_0 + \beta_1 MI_j + \beta_2 VO_j + \beta_3 CCSR_j + \beta_4 SCSR_j + e_j \qquad (1)$$

where Clear SO is the time necessary to clear one hectare of sorghum land; MI, VO, CCSR and SCSR are dummy variables for millet, voandzou, cotton crop in cotton-sorghum rotation activity, and sorghum crop in cotton-sorghum rotation; and j is the observation. The test was $H_0$: $\beta_i = 0$ versus $H_1$: $\beta_i \neq 0$ for i = 1, 2, 3, and 4. The following result is obtained:

$$\text{Clear SO} = 63.57 + \underset{\substack{(5.27)\\\{0.31\}}}{5.37}\,MI + \underset{\substack{(5.15)\\\{0.12\}}}{8.16}\,VO + \underset{\substack{(5.35)\\\{0.34\}}}{5.09}\,CCSR + \underset{\substack{(5.43)\\\{0.62\}}}{2.73}\,SCSR,\quad n = 58$$

Values in parentheses are standard errors of the parameter estimates and in brackets are the observed significant level of the parameter estimates. Using a 5 percent significance level ($\alpha$), one concludes that there is no significant difference between the mean time of clearing the land for sorghum and clearing the land for each of the other crop activities. No significant difference being the case, a weighted average is calculated to obtain a common clearing time for the four crops. The weight is the crop area cultivated relative to the total acreage. Therefore, we calculate time to clear land as:

$$\text{Clear} = (63.57*9 + 66.30*7.75 + 68.66*7.75 + 68.94*10.25 + 71.73*4.5) / 39.25$$

$= 67.45$ hours

It takes 67.45 hours to clear the land for each hectare of the four crops in Zouaye.

Plowing Land

To test whether there was a difference in the time it took to plow land with oxen across the activities, the following equation is defined:

$$PlowldSO_j = \beta_0 + \beta_1 MI_j + \beta_2 VO_j + \beta_3 CCSR_j + \beta_4 SCSR_j + e_j \qquad (2)$$

where PlowldSO is the time necessary to plow one hectare of Sorghum land by oxen and MI, VO, CCSR and SCSR are dummy variables as defined for equation one. The following result is obtained:

$$\underset{}{PlowldSO} = 26.4 + \underset{\substack{(2.69)\\ \{0.53\}}}{1.71\,MI} + \underset{\substack{(2.63)\\ \{0.85\}}}{0.51\,VO} + \underset{\substack{(2.60)\\ \{0.25\}}}{3.07\,CCSR} + \underset{\substack{(2.85)\\ \{0.21\}}}{3.62\,SCSR}, \quad n=41$$

At $\alpha = 5$ percent, there is no significant difference between the mean time of plowing with oxen the sorghum land and that of each of the remaining crops. A weighted average is computed as earlier to get a common plowing time.

$$Plow = (26.40*1.75 + 30.02*5.75 + 29.47*5.75 + 28.11*6.25 + 26.91*3.5) / 23$$

$$= 28.61 \text{ hours.}$$

The 28.61 hours is a pooled plowing time for the four crops. This result applies only to the fraction of the land plowed with oxen. For some of the crops, an additional hoe plowing is done over a fraction of the hectare. A similar regression was run for hoe plowing time and the results indicated no significant differences in means. The corresponding weighted average is calculated:

$$Hoeplow = (60.67*2.5 + 58.0*1.25 + 68.0*1.0 + 64.0*2.5) / 7.25 = 62.37 \text{ hours}$$

The plowing time per crop is computed using the oxen and hand hoeing percentages for each crop and the results are presented in Table 7.

Table 7. Plowing Time Results for each Crop in Zouaye for Surveyed Farms, 1989-1991.

| Crop | Percent Oxen | Percent Hoe | Plowing Time (Hrs/Ha) |
|---|---|---|---|
| Sorghum | 41.2 | 58.8 | 48.5 |
| Millet | 83.3 | 16.7 | 34.2 |
| Voandzou | 77.8 | 22.2 | 36.1 |
| Cotton-Sorghum | 93.7 | 6.3 | 30.7 |

Seeding time

The estimated equation for seeding time per hectare is:

$$\begin{array}{llllll} SeedSO = 59.79 - & 17.35\ MI + & 1.27\ VO - & 1.68\ CCSR - & 1.13\ SCSR, & n = 67 \quad (3) \\ & (2.3) & (2.3) & (2.4) & (2.4) & \\ & \{0.0001\} & \{0.58\} & \{0.49\} & \{0.65\} & \end{array}$$

It appears that the seeding time for sorghum is not statistically different from that of all the other crops except millet. The pooled seeding time is calculated as follows:

(59.79*9 + 61.06*4.5 + 58.11*7.75 + 58.66*7.75) / 29 = 59.24 hours.

The millet crop requires 42.44 hours (59.79 - 17.35) per hectare for seeding.

Weeding time

The estimated equation for weeding time per hectare is:

$$\underset{}{WeedSO} = 296.61 - \underset{\substack{(15.5)\\ \{0.0001\}}}{146.30\ MI} - \underset{\substack{(15.5)\\ \{0.03\}}}{34.75\ VO} + \underset{\substack{(16.4)\\ \{0.4\}}}{14.16\ CCSR} - \underset{\substack{(16.4)\\ \{0.4\}}}{13.73\ SCSR},\ n=67 \quad (4)$$

These results show an equality of means between Sorghum and Cotton-Sorghum. The pooled mean is calculated for the two crop activities.

Weeding = (296.61*9 + 310.77*7.75 + 282.88*7.75) / 24.5 = 296.75 hours.

Millet and Voandzou weeding times are significantly lower and therefore, a separate regression is calculated to compare their means.

$$WeedMI = 150.31 + \underset{\substack{(14.8)\\ \{0.0001\}}}{111.56\ VO},\ n = 30$$

The second regression shows a significant difference between the mean weeding time for millet and that of Voandzou. The weeding time is set to 150.31 hours for millet and 261.87 hours for Voandzou per hectare.

Harvesting time

The harvesting equation considers only Millet, Sorghum in continuous cropping and Sorghum in rotation. Cotton and Voandzou are excluded because their harvesting method is different. The separation is made to ensure that comparison is done for crops with similar harvesting patterns and this appears necessary to keep the analysis relevant.

$$HarvesSO = 325.74 - \underset{\substack{(14.9)\\ \{0.002\}}}{50.49\ MI} + \underset{\substack{(15.8)\\ \{0.139\}}}{23.88\ SCSR},\ n = 40$$

Harvesting times for continuous Sorghum and Sorghum in rotation (with Cotton) are statistically equal. The weighted average gives a common mean of 336.79 hours per hectare. Millet harvesting time is 275.25 hours per hectare.

Harvesting = (325.74*9 + 349.62*7.75) / 16.75 = 336.79 hours.

Because of different harvesting patterns, harvesting times for Cotton and Voandzou cannot be compared. They are set equal to their individual mean harvesting times which are 336.89 and 401.2 hours.

To get the harvesting time of Cotton-Sorghum rotation activity, a simple average of the individual values is considered.

Cotton-Sorghum: (336.79 + 336.89) / 2 = 336.84 hours.

Seeds used and Sorghum produced

A t test is conducted to compare the mean quantities of seeds used for continuous Sorghum and Sorghum in rotation. The data used are summarized in Table 8.

Table 8. Sorghum Seeding and Yield Data for Continuous and Rotation Sorghum.

| Sorghum | Number | Quantities of seeds | | Sorghum produced | |
|---|---|---|---|---|---|
| Activity | Obs. | Mean (kg) | Std Dev. | Mean (kg) | Std Dev. |
| Continuous Crop | 13 | 28.08 | 5.07 | 1103.85 | 12.0 |
| In Rotation | 12 | 28.55 | 4.94 | 1310.00 | 11.3 |

The t-test for mean quantities of seeds used per hectare was calculated as:

$$t_{calc} = (28.55 - 28.08) / [ ((12*5.07^2 + 11*4.94^2) / 23) (1/13 + 1/12)]^{1/2}$$

$$= 0.23, \ \ OSL = 0.80$$

For the mean quantities of sorghum produced per hectare, a regression is run to compare continuous sorghum and rotation sorghum. The regression result is given as follows:

$$SO = 1103.8 + 206.2CS, \ n = 25, \ OSL = 0.043$$

At a 5 percent significance level ($\alpha$ = 5 percent), the mean quantity of seeds necessary for one hectare of Sorghum (continuous cropping) is not statistically different from that of the Sorghum crop in rotation. A weighted average is calculated using the two means and the acreage during the three-year period.

$$(28.08*9 + 28.55*7.75) / 16.75 = 28.30 \text{ kgs.}$$

Continuous Sorghum requires 28.3 kgs of seeds per hectare and Cotton-Sorghum activity 14.2 kgs. The latter represents 50 percent of the total quantity since the two-year rotation is reduced to one year to allow valid comparisons. The regression test indicates that sorghum yield from Cotton-Sorghum rotation is statistically higher than that of continuous Sorghum cropping. Table 9 provides a summary of all the tests results for crop activities in Zouaye.

For the three other villages, the definition of equations and the testing procedures are identical to those applied for Zouaye village. Only the results obtained for the tests conducted are presented.

Table 9. Results of Crop Comparisons Tests in Zouaye for Surveyed Farms, 1989-1991.

| Item | Unit | Sorghum | Millet | Voandzou | Cotton/Sorghum |
|---|---|---|---|---|---|
| land clearing | hours | 67.4 | 67.4 | 67.4 | 67.4 |
| land plowing | hours | 48.5 | 34.2 | 36.1 | 30.7 |
| seeding | hours | 59.2 | 42.4 | 59.2 | 59.2 |
| weeding | hours | 296.7 | 150.3 | 261.9 | 296.7 |
| harvesting | hours | 336.8 | 275.2 | 401.2 | 336.8 |
| sorghum seeds | kgs | 28.3 | ---- | ---- | 14.2 |
| sorghum yield | kgs | 1103.8 | ---- | ---- | 655.0 |
| millet seed | kgs | ---- | 16 | ---- | ---- |
| millet yield | kgs | ---- | 986.7 | ---- | ---- |
| Voandzou seeds | kgs | ---- | ---- | 42.3 | ---- |
| Voandzou yield | kgs | ---- | ---- | 1134.7 | ---- |
| cotton seeds | kgs | ---- | ---- | ---- | 14.2 |
| cotton yield | kgs | ---- | ---- | ---- | 521.1 |

## Statistical Tests for Data in Djoulgouf

Three crop activities were identified in the village of Djoulgouf: rainy season Sorghum, dry season sorghum (Mouskwari) and Cotton-Sorghum rotation. Mouskwari is grown during the dry season and it requires nursery and transplanting operations. The plant uses residual moisture from the soil to grow and this is why it grows better on heavy clay soils which are commonly called vertisols. Because of this specific feature, the mouskwari crop is excluded from comparison with the two other crops (which are cultivated during the "normal" cropping season). Table 10 provides the activity coefficients that were used as a result of the test.

## Statistical Tests for Data in Gatouguel

There are four crop activities in Gatouguel: continuous Corn, continuous Sorghum and two rotations: Cotton with Sorghum and Cotton with intercrop of Peanut and Sorghum. Table 11 presents the activity coefficients used as a result of the tests.

## Statistical Tests for Data in Djingliya

Djingliya has four crop activities which are all rotations: sorghum with millet, sorghum with intercrop of millet and cowpea, cotton with sorghum with millet, and intercrop of sorghum and peanut with intercrop of millet and peanut. The reference crop is millet which is a subcrop within the sorghum/millet rotation. Comparisons involve subcrops instead of crops because of differences in cropping patterns that exist among the four crop activities. For example, cotton/sorghum/millet is a three-year rotation involving three pure subcrops and sorghum/millet-cowpea is a two-year rotation involving

Table 10. Results of Crop Activities Comparisons in Djoulgouf for Surveyed Farms, 1989-1991.

| Items Tested | Unit | Sorghum | Cotton/Sorghum | Mouskwari |
|---|---|---|---|---|
| Sorghum seeds | kgs | 17.6 | 8.8 | 2 |
| Land clearing | hrs | 66.3 | 66.3 | 90.7 |
| Land plowing | hrs | 30.3 | 57.3 | ---- |
| Seeding | hrs | 54.8 | 58.2 | ---- |
| Weeding | hrs | 239.0 | 296.4 | 58.1 |
| Harvesting | hrs | 336.6 | 328.9 | 233.7 |
| Sorghum yield | kgs | 751.2 | 532.5 | 973.4 |
| cotton seeds | kgs | ---- | 18.5 | ---- |
| nursery work | hrs | ---- | ---- | 46.4 |
| transplanting | hrs | ---- | ---- | 132.5 |
| cotton yield | kgs | ---- | 366.3 | ---- |

Table 11. Results of Crop Comparisons in Gatouguel for Surveyed Farms, 1989-1991.

| Item tested | Unit | Sorghum | Cotton/Sorghum | Corn | Cotton/Sorghum -Peanut |
|---|---|---|---|---|---|
| sorghum seeds | kgs | 22.5 | 11.3 | ---- | 4.4 |
| cotton seeds | kgs | ---- | 15.6 | ---- | 15.6 |
| land clearing | hours | 67.8 | 67.8 | 67.8 | 67.8 |
| land plowing | hours | 30.4 | 30.4 | 30.4 | 40.6 |
| seeding | hours | 60.2 | 60.2 | 66.8 | 63.5 |
| weeding | hours | 305.1 | 305.1 | 305.1 | 305.1 |
| harvesting | hours | 367.3 | 363.9 | 363 | 392.9 |
| sorghum yield | kgs | 1100.0 | 714.0 | ---- | 103 |
| cotton yield | kgs | ---- | 573.4 | ---- | 573.4 |
| corn seeds | kgs | ---- | ---- | 28.5 | ---- |
| peanut seeds | kgs | ---- | ---- | ---- | 15.9 |
| peanut yield | kgs | ---- | ---- | ---- | 449.9 |
| corn yield | kgs | ---- | ---- | 3645.4 | ---- |

one pure subcrop (sorghum) and one intercropping (millet-cowpea). Comparing these two rotations directly might lead to confusing conclusions. Taking this example, the approach here is to compare sorghum or subcrops in both rotations and compute the final input requirements of the two crop rotations from the intermediate test results. The results are summarized in Table 12.

## Fertilization and Insecticide Treatment

In the four villages, fertilization[1] is mainly performed by household labor and insecticide treatment is done on cotton by trained agents usually from the cotton corporation. Mean labor time for the activities are compared across villages and within each village for the different crops. Results show that labor time required by each of the two activities is not statistically different from one village to another. Fertilizing requires 14.8 hours per hectare for each crop activity and insecticide treatment[2] on cotton takes 12.2 hours per hectare.

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[1] In the study, only mineral fertilizers are considered. It was not possible to collect labor time for kitchen waste and manure fertilization.

[2] Insecticide treatment on cotton is repeated 4 to 7 times during the cropping season. The 12.2 hours of labor is the total time for all the replications. Other crops like cowpea are also treated but this was not apparent in the survey.

Table 12. Results of Crop Comparisons in Djingliya for Surveyed Farms, 1989-1991.

| Item tested | Unit | Sorghum/ Millet | Sorghum/ Millet-Cowpea | Cotton/ Sorghum/ Millet | Sorghum-Peanut /Millet-Peanut |
|---|---|---|---|---|---|
| Sorghum seeds | kgs | 5.7 | 10.6 | 5.4 | 5.9 |
| Millet seeds | kgs | 6.0 | 6.0 | 4.0 | 6.0 |
| Land clearing | hours | 75.6 | 75.6 | 75.6 | 75.6 |
| Land plowing | hours | 31.4 | 31.4 | 31.4 | 31.4 |
| Seeding | hours | 53.3 | 57.7 | 54.8 | 59.2 |
| Weeding | hours | 236.6 | 236.6 | 252.8 | 236.6 |
| Harvesting | hours | 234.8 | 316.3 | 334.3 | 333.5 |
| Millet yield | kgs | 224.5 | 164.3 | 149.6 | 297.7 |
| Sorghum yield | kgs | 320.9 | 320.9 | 213.9 | 295.8 |
| peanut seeds | kgs | ---- | ---- | ---- | 13.4 |
| cotton seeds | kgs | ---- | ---- | 9.3 | ---- |
| cowpea seeds | kgs | ---- | 4.9 | ---- | ---- |
| peanut yield | kgs | ---- | ---- | ---- | 531.7 |
| cotton yield | kgs | ---- | ---- | 329.7 | ---- |
| cowpea yield | kgs | ---- | 215.2 | ---- | ---- |

## Other Elements of the Crop Budgets

### Input and Output Prices

Prices of inputs and outputs are taken from the results of the three-year price survey (1989-1991) and they are the averages of the prices collected. In the analysis, goods are supposed to be sold after harvest which occurs in September-November for most foodcrops in the four villages. Except for cotton, prices of all other products are determined by demand and supply conditions at the village local market. Cotton prices are set annually by the government and figures presented here are averages of grade 1 and grade 2 prices. The mouskwari crop is harvested in January and as a result, January and February prices have been averaged. Farmers purchase inputs such as sorghum, millet, peanut seeds or farm tools (hoe, sickle, cutlass), at the village market. Prices are for May-July period which is the seeding time for most foodcrops in the region. Fertilizers, pesticides, plows and other assets can be purchased at the cotton corporation (SODECOTON). In addition, SODECOTON provides as a package to farmers, cotton seeds, fertilizers and insecticide treatment for cotton farming. During 1989-91, the cost of the package has varied between 29,448 frs cfa and 35,973 frs cfa per hectare. Table 13 presents average prices of inputs used and output produced in the four villages. Price differences across villages are explained by the poor road conditions existing in the extreme north of Cameroon.

### Farm Tools Repair

The annual tool repair cost for the sample is allocated to crop activities based on

Table 13. Average Prices of Inputs and Outputs in the Study Villages, 1989-1991.

| Item | Units | Djingliya | Gatouguel | Zouaye | Djoulgouf |
|---|---|---|---|---|---|
| Sorghum seed | frs cfa / kg | 112 | 42 | 100 | 75 |
| Sorghum | frs cfa / kg | 62 | 38 | 50 | 45 |
| Millet seed | frs cfa / kg | 112 | --- | 125 | --- |
| Millet | frs cfa / kg | 62 | --- | 50 | --- |
| Peanut seed | frs cfa / kg | 300 | 175 | --- | --- |
| Peanut | frs cfa / kg | 125 | 100 | --- | --- |
| Cowpea seed | frs cfa / kg | 220 | --- | --- | --- |
| Cowpea | frs cfa / kg | 60 | --- | --- | --- |
| Voandzou seed | frs cfa / kg | ---- | ---- | 100 | --- |
| Voandzou | frs cfa / kg | --- | --- | 75 | --- |
| Mouskwari seed | frs cfa / kg | --- | --- | --- | 100 |
| Mouskwari | frs cfa / kg | --- | --- | --- | 70 |
| Corn seed | frs cfa / kg | ---- | 50 | --- | --- |
| Fresh corn | frs cfa / kg | --- | 25 | --- | --- |
| Cotton | frs cfa / kg | 91.5 | 91.5 | 91.5 | 91.5 |
| Urea | frs cfa / 50 kg | 5,700 | 5,700 | 5,700 | 5,700 |
| NPK | frs cfa / 50 kg | 6,700 | 6,700 | 6,700 | 6,700 |

Table 14. Farm Tools Used in the Four Villages, 1989-1991.

| Tool | Unit cost (frs cfa) | Economic Life | Average Number of tools per household | | | |
|---|---|---|---|---|---|---|
| | | (years) | Djoulgouf | Djingliya | Gatouguel | Zouaye |
| Sickle | 300 | 3 | 1.0 | 3.7 | 2.6 | 1.3 |
| Hoe | 400 | 3 | 3.3 | 3.8 | 3.1 | 4.5 |
| Cutlass | 1000 | 5 | 1.0 | 1.2 | 1.0 | 3.7 |
| Seeder | 100 | 2 | 0.0 | 3.5 | 0.0 | 1.3 |
| Transplanter | 500 | 5 | 1.0 | 0.0 | 0.0 | 0.0 |
| Ax | 1000 | 10 | 1.7 | 2.7 | 2.0 | 1.2 |
| Mattock | 2000 | 10 | 0.0 | 0.4 | 0.0 | 1.1 |
| Plow | 34000 | 20 | 0.2 | 0.6 | 1.4 | 0.5 |

## Opportunity Cost of Family Labor

The cost of family labor has been computed as a weighted average wage per hour that the farmer could earn from casual farming operations and non farm activities. Farm operations for which labor is hired mainly include land clearing, plowing and weeding. Non-farm activities generating revenues are cutting and selling firewood, collecting and selling fruits, brewing and selling local beverages. The opportunity cost of family labor frs CFA per hour is 37.4 in Djoulgouf, 42.7 in Djingliya, 51.3 in Gatouguel and 48.5 in Zouaye.

## Crop Activity Budgets

From the analysis of the operations for each crop activity, 15 crop activity budgets are generated and in Table 15, the crop activities are ranked based on their gross margin per hectare.

## Construction of the Target MOTAD Model

### Objective Function

The objective function maximizes expected income generated by the crop activities. For the case of Zouaye village, the objective function has four production activities (Sorghum, Voandzou, Millet and Cotton-Sorghum), four purchasing activities (hiring labor, renting land, buying urea and cotton charge), four selling activities for the goods produced, one capital transfer activity, three activities that transfer sorghum, millet and voandzou from production to consumption, and three deviation variables for the short fall below target income in years 1989, 1990 and 1991. A target MOTAD tableau for Zouaye Village is given in Figure 4.

## Production Constraints

The production constraints are divided into land, family labor, and operating capital constraints.

### Land and Family Labor Constraints

In the four villages, there are crops that can be grown only on certain types of soils. For example, the mouskwari sorghum in Djoulgouf is cultivated exclusively on

| | SIGN | RHS | SORG PROD | MILL PROD | VOAN PROD | CTSO PROD | HIRE LBMJ | HIRE LBJA | HIRE LBSN | RENT LAND | CTON CHGE | BUY UREA | SELL SORG | SELL MIL | SELL VOAN | SELL COT | SORG TR | MIL TR | VOAN TR | K TR | SF 89 | SF 90 | SF 91 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cj VALUE | | | -6700.2 | -6907.6 | -10921 | -6676 | -95.1 | -95.1 | -37.1 | -10000 | -15849 | -113.3 | 50 | 50 | 75 | 101.7 | | | | | | | |
| LAND | L | 2.125 | 1 | 1 | 1 | 1 | | | | -1 | | | | | | | | | | | | | |
| MJLYLB | L | 1224.2 | 128 | 129.8 | 163.7 | 148.4 | -1 | | | | | | | | | | | | | | | | |
| JLYAGLB | L | 979.4 | 297.6 | 150.3 | 261.9 | 304.3 | | -1 | | | | | | | | | | | | | | | |
| SNLB | L | 1224.2 | 337.4 | 275.2 | 401.2 | 337.4 | | | -1 | | | | | | | | | | | | | | |
| MAXK1 | E | 26310 | 4342.9 | 5345.6 | 8336.8 | 5356.2 | 95.1 | 95.1 | | 10000 | | 113.3 | | | | | | | | 1 | | | |
| MAXK2 | L | 3045 | | | | | | | 37.1 | | | | | | | | | | | -1 | | | |
| MAXLDRT | L | 1 | | | | | | | | 1 | | | | | | | | | | | | | |
| SORGBL | L | 0 | -1103.8 | | | -655 | | | | | | | 1 | | | | 1 | | | | | | |
| MILBL | L | 0 | | -986.7 | | | | | | | | | | 1 | | | | 1 | | | | | |
| VOANBL | L | 0 | | | -1134.7 | | | | | | | | | | 1 | | | | 1 | | | | |
| COTONBL | L | 0 | | | | -521.1 | | | | | | | | | | 1 | | | | | | | |
| SORGCONS | G | 1129 | | | | | | | | | | | | | | | -1 | | | | | | |
| MILCONS | G | 752 | | | | | | | | | | | | | | | | -1 | | | | | |
| VOANCONS | G | 37 | | | | | | | | | | | | | | | | | -1 | | | | |
| SODCOTBL | L | 0 | | | | 1 | | | | | -1 | | | | | | | | | | | | |
| UREABL | L | 0 | 5.5 | | | 3.2 | | | | | | -1 | | | | | | | | | | | |
| 89COTBL | L | 0 | | | | -511.2 | | | | | | | | | | 1 | | | | | | | |
| 89SORGBL | L | 0 | -775 | | | -643.5 | | | | | | | 1 | | | | 1 | | | | | | |
| 89MILBL | L | 0 | | -860 | | | | | | | | | | 1 | | | | 1 | | | | | |
| 89VOANBL | L | 0 | | | -1008 | | | | | | | | | | 1 | | | | 1 | | | | |
| 89INCOME | G | 30000 | -6700.2 | -6907.6 | -10921 | -6676 | -95.1 | -95.1 | -37.1 | -10000 | -17986 | -110 | 58 | 60 | 78 | 130 | | | | | 1 | | |
| 90SORGBL | L | 0 | -1272.5 | | | -662.5 | | | | | | | 1 | | | | 1 | | | | | | |
| 90MILBL | L | 0 | | -1054 | | | | | | | | | | 1 | | | | 1 | | | | | |
| 90VOANBL | L | 0 | | | -1220 | | | | | | | | | | 1 | | | | 1 | | | | |
| 90COTBL | L | 0 | | | | -450 | | | | | | | | | | 1 | | | | | | | |
| 90INCOME | G | 30000 | -6700.2 | -6907.6 | -10921 | -6676 | -95.1 | -95.1 | -37.1 | -10000 | -14724 | -110 | 42 | 40 | 72 | 87.5 | | | | | | 1 | |
| 91SORGBL | L | 0 | -1232 | | | -680 | | | | | | | 1 | | | | 1 | | | | | | |
| 91MILBL | L | 0 | | -1046 | | | | | | | | | | 1 | | | | 1 | | | | | |
| 91VOANBL | L | 0 | | | -1180 | | | | | | | | | | 1 | | | | 1 | | | | |
| 91COTBL | L | 0 | | | | -544.4 | | | | | | | | | | 1 | | | | | | | |
| 91INCOME | G | 30000 | -6700.2 | -6907.6 | -10921 | -6676 | -95.1 | -95.1 | -37.1 | -10000 | -14836 | -120 | 50 | 50 | 75 | 87.5 | | | | | | | 1 |
| AVNEGDE | E | λ | | | | | | | | | | | | | | | | | | | 0.33 | 0.33 | 0.33 |

Figure 4. Target Motad Tableau for Zouaye Village

Table 16. Cropland Available Per Household in the Four Villages.

| Village | acreage (ha) | Cropland type/ Crop use | Maximum acreage that can be rented (ha) |
|---|---|---|---|
| Djoulgouf | 0.525 | sorghum | 0.25 |
| | 1.575 | mouskwari | 0.25 |
| | 0.4 | cotton/sorghum | 0.25 |
| Zouaye | 2.125 | millet, sorghum voandzou cotton/sorghum | 1 |
| Gatouguel | 0.85 | cotton/peanut-sorghum | |
| | 1.925 | sorghum, corn and cotton/sorghum | 0.5 |
| Djingliya | 0.75 | lowland (cotton/sorghum/millet) | 0.25 |
| | 1.5 | highland (sorghum/millet, sorghum/millet-cowpea, sorghum-peanut/millet-peanut) | |

operating capital available. The land on which minor crops are grown is not considered in the total acreages. The family labor available each period has been estimated from a household study conducted in 1989. On the average, farmers work seven hours per day and 20 days per month. The number of farm working people in the household is multiplied by 140 to get the total working hours available per month. It is assumed that farmers will spend 80 percent of the total time on the major crop activities which are considered in the present study. The remaining time is reserved for minor crops. Table 17 provides for the four villages, the family labor available per period for the major crop activities.

Operating Capital Constraints

There are two major periods during which labor is hired, May-August and September-November. The wage rate per period is determined as a weighted average of paid farm operations for which casual labor is needed. During the period May-August, the family operating capital can be used to rent land, rent oxen, hire labor, repair tools and buy seeds, insecticide or fertilizer. An operating capital constraint is defined so as to incorporate all these competing activities. As an example, the May-August operating capital constraint for Zouaye village has a capital transfer activity (KTR) which allows any unused capital in period one to be transferred to period two (Figure 4).

During the period September-November, the operating capital is used mainly to hire labor in all the four villages except in Djoulgouf where hiring labor competes with renting land for the mouskwari crop. A corresponding operating capital constraint

Table 17. Family Labor Available Per Period in Each Village (hrs).

| | May-June | July-August | Sept-Nov | Jan-Feb |
|---|---|---|---|---|
| Djoulgouf | 507.2 | 390.2 | 702.3 | 351.1 |
| Djingliya | 788.5 | 788.5 | 1249.6 | ---- |
| Gatouguel | 1124.2 | 1124.2 | 405.2 | ---- |
| Zouaye | 1224.2 | 979.4 | 1224.2 | ---- |

Table 18. Estimated Operating Capital and Wage Rate for Hired Labor.

| | Estimated wage rate (frs cfa/hr) | | | Operating capital available (frs cfa) | |
|---|---|---|---|---|---|
| Village | May-August | Sept-Nov | Jan-Feb | May-August | Sept-Nov |
| Djoulgouf | 63.6 | 41.9 | 41.9 | 23,847.5 | 20,245 |
| Djingliya | 88.9 | 88.9 | ---- | 16,696.9 | 2,250 |
| Gatouguel | 101.9 | 32.8 | ---- | 26,050 | 2,787 |
| Zouaye | 95.1 | 37.1 | ---- | 26,310 | 3,045 |

involving these two activities is set up for the Djoulgouf village. Estimates of wage rate and operating capital per period are presented in Table 18. The capital market is poorly developed in the extreme north of Cameroon and as a result, the farm operating capital comes from household savings or relatives' donations.

## Consumption Constraints

Consumption constraints were determined from the result of the household consumption survey conducted in 1990-1991. It is assumed that the household size and nutrition habits will not change in the short run. Therefore, the annual food quantities resulting from the 1990-1991 survey are expected to satisfy the households consumption needs in the coming years. The constraints assure that the optimal plan yields the minimum food needed per year for each observed state of nature (1989, 1990, 1991). Consumption needs for households in Zouaye are 1,129 kgs of sorghum, 752 kgs of millet and 37 kgs of voandzou.

## Minimum Income Constraint

The minimum income constraint is defined as the Target constraint. In the study, the risk parameter $\lambda$, (expected deviation from the target income) is allowed to vary from zero to 20,000. The minimum income per village has been determined from the household consumption and expenditures survey. It is equal to 20,000 frs cfa for Djoulgouf village and 30,000 frs cfa for each of the other three villages. The minimum income covers additional foods (rice, tea, meat and fish) and primary health care expenses.

## Target MOTAD Results and Comparative Analysis

The output of the model indicates that cotton, peanut, voandzou and mouskwari are the most important cash earning crops for the households. Secondly, the optimal solutions show the prevalence of crop rotations compared to continuous pure croppings. In Zouaye and Gatouguel for example, crop rotations represent 59 and 95 percent of the total cropping area. Except for Djoulgouf farmers, the optimal solutions do not include any labor hiring activities. Table 19 summarizes the results of the model for the four villages. There are two factors that limit production at optimum: operating capital is the major scarce resource in Zouaye and Gatouguel; land constitutes the most limiting resource for farmers in Djoulgouf and Djingliya. Table 20 presents shadow prices of resources for the four villages.

### Comparison of Target MOTAD Results and Farmers' Practices

For each of the four villages, the optimal crop combination indicates higher acreages compared to farmers' practices (Table 21). On the average, the current household acreage is about 60 to 70 percent of the optimal acreage.

The farmer is supposed to hire additional land or use more of the cropland available. Except for Djingliya, the ranking of crop activities by acreage obtained from the model is fairly similar to the farmer practice. The model crop combination differs from the current practice in that it recommends more crop activities that provide food and revenues (cotton/sorghum, sorghum-peanut/millet-peanut) at the expense of activities that are mainly food producing (sorghum, sorghum/millet,. . .).

Table 19. Results of the Target MOTAD Model for each Village.

| Activity | Unit | Quantity | Used for |
|---|---|---|---|
| **Djoulgouf** E(Z) = 23,560.4 frs cfa | | | |
| Sorghum | ha | 0.775 | |
| Mouskwari | ha | 1.825 | |
| Cotton/Sorghum | ha | 0.65 | |
| Rent Land | ha | 0.25 | Sorghum |
| Rent Land | ha | 0.25 | Mouskwari |
| Rent Land | ha | 0.25 | Cotton/Sorghum |
| Hire Labor Sept-Nov | hrs | 366 | Mouskwari |
| Hire Labor Jan-Feb | hrs | 75.4 | Mouskwari |
| Sell Mouskwari | kgs | 818.8 | |
| Sell Cotton | kgs | 134.2 | |
| Buy Urea | kgs | 178.7 | |
| **Gatouguel** E(Z) = 127,310 frs cfa | | | |
| Corn | ha | 0.149 | |
| Cotton/Sorghum | ha | 1.776 | |
| Cotton/Peanut-Sorghum | ha | 1.232 | |
| Sorghum | ha | 0.0 | |
| Rent Land | ha | 0.38 | Cotton/Peanut-Sorghum |
| Sell Sorghum | kgs | 11.75 | |
| Sell Peanut | kgs | 413.1 | |
| Sell Cotton | kgs | 1,601.6 | |
| **Zouaye** E(Z) = 45,884.72 frs cfa | | | |
| Sorghum | ha | 0.0 | |
| Millet | ha | 0.874 | |
| Voandzou | ha | 0.359 | |
| Cotton/Sorghum | ha | 1.754 | |
| Rent Land | ha | 0.86 | Cotton/Sorghum |
| Sell Voandzou | kgs | 324.8 | |
| Sell Cotton | kgs | 789.5 | |
| **Djingliya** E(Z) = 91,957.4 frs cfa | | | |
| Sorghum/Millet | ha | 0.0 | |
| Sorghum/Millet-Cowpea | ha | 0.129 | |
| Sorghum-Peanut/Millet-Peanut | ha | 1.621 | |
| Cotton/Sorghum/Millet | ha | 0.75 | |
| Rent Land | ha | 0.25 | Sorghum-Peanut/Millet-Peanut |
| Sell Peanut | kgs | 647.4 | |
| Sell Millet | kgs | 377.9 | |
| Sell Cotton | kgs | 185.0 | |
| Buy Urea | kgs | 10.4 | |

Table 20. Shadow Prices for Resources in the Four Villages.

| Village / Resource | Shadow Price (frs CFA) |
|---|---|
| **Djoulgouf** | |
| Sorghum land (ha) | 24,663.2 |
| Mouskwari land (ha) | 33,187.7 |
| Cotton/Sorghum land (ha) | 15,263.5 |
| Sept-Nov family labor (hr) | 41.9 |
| Jan-Feb family labor (hr) | 41.9 |
| **Djingliya** | |
| Sorghum-peanut/millet-peanut land (ha) | 68,255.7 |
| Cotton/sorghum/millet land (ha) | 18,458.0 |
| **Gatouguel** | |
| June-August operating capital (frs CFA) | 2.5 |
| Cotton/peanut-sorghum land (ha) | 56,004.2 |
| Cotton/sorghum land (ha) | 40,153.0 |
| **Zouaye** | |
| June-August operating capital (frs CFA) | 2.98 |
| Land (ha) | 39,819.1 |

## Household Financial Analysis

This section presents what the household balance sheet would be at the beginning and at the end of the cropping season. The analysis considers that the farmer is growing the crop combination generated by the model. The results presented in Table 22 show a significant increase in household equity in the four villages. The increase ranges from 40,000 frs to 160,000 frs. Also, the current assets of the farmer at the end of the cropping season are significantly larger compared to the initial value.

Table 21. Farmers' Practices Versus Target MOTAD Results.

| Crop Activities | Farmers' Practice | Model Results (ha) |
| --- | --- | --- |
| **Djoulgouf** | | |
| Cotton/sorghum | 0.375 | 0.650 |
| Sorghum | 0.32 | 0.775 |
| Mouskwari sorghum | 0.903 | 1.825 |
| Total acreage | 1.598 | 3.25 |
| **Zouaye** | | |
| Cotton/sorghum | 0.776 | 1.750 |
| Sorghum | 0.60 | 0.0 |
| Millet | 0.684 | 0.874 |
| Voandzou | 0.30 | 0.359 |
| Total acreage | 2.36 | 2.98 |
| **Gatouguel** | | |
| Cotton/sorghum | 0.755 | 1.776 |
| Sorghum | 0.362 | 0.0 |
| Corn | 0.316 | 0.149 |
| Cotton/peanut-sorghum | 0.412 | 1.232 |
| Total acreage | 1.845 | 3.157 |
| **Djingliya** | | |
| Sorghum/millet | 0.348 | 0.0 |
| Cotton/sorghum/millet | 0.415 | 0.750 |
| Sorghum-peanut/millet-peanut | 0.464 | 0.1290 |
| Sorghum/millet-cowpea | 0.407 | 1.621 |
| Total acreage | 1.634 | 2.5 |

Table 22. Balance Sheets of Households in the Four Villages.

| Village: Djoulgouf | | Date: June 30 | |
|---|---|---|---|
| Assets | | Liabilities | |
| Current Assets: | | Current Liabilities: | |
| Operating capital | 44,092.5 | Land & oxen rent payable | 9,820.3 |
| Household seeds | 690.0 | Casual labor payable | 16,244.6 |
| | | Sodecoton debt | 6,605.8 |
| Fixed Assets: | | | |
| Farm tools | 11,620 | Total Liabilities | 34,657.7 |
| | | Household Equity | 21,744.8 |
| Total Assets: | 56,402.5 | | |

| Village: Djoulgouf | | Date: January 30 | |
|---|---|---|---|
| Assets | | Liabilities | |
| Current Assets: | | Current Liabilities: | |
| Production | 108,797 | Sodecoton debt | 6,605.8 |
| | | Product for consumption | 42,714 |
| Fixed Assets: | | | |
| Farm tools | 8,925.4 | Total Liabilities | 49,319.8 |
| | | Household Equity | 68,402.6 |
| Total Assets: | 117,722.4 | | |

| Village: Djingliya | | Date: June 30 | |
|---|---|---|---|
| Assets | | Liabilities | |
| Current Assets: | | Current Liabilities: | |
| Operating capital | 18,946.9 | Land & oxen rent payable | 11,270.7 |
| Household seeds | 9,358.8 | Casual labor payable | — |
| | | Sodecoton debt | 7,372.5 |
| Fixed Assets: | | | |
| Farm tools | 28,080 | Total Liabilities | 25,309.5 |
| | | Household Equity | 31,076.2 |
| Total Assets | 56,385.7 | | |

| Village: Djingliya | | Date: December 30 | |
|---|---|---|---|
| Assets | | Liabilities | |
| Current Assets: | | Current Liabilities: | |
| Production | 144,486.5 | Sodecoton debt | 7,372.5 |
| | | Product for consumption | 23,482.5 |
| Fixed Assets: | | | |
| Farm tools | 21,876.8 | | |
| | | Total Liabilities | 30,855 |
| Total Assets | 166,363.3 | Household Equity | 135,508.3 |

Table 22. (continued)

| **Village: Gatouguel** | | **Date: June 30** | |
|---|---|---|---|
| Assets | | Liabilities | |
| Current Assets: | | Current Liabilities: | |
| Operating capital | 28,837 | Land & oxen rent payable | 17,974 |
| Household seeds | 3,361 | Casual labor payable | — |
| | | Inputs payable | 9,651.2 |
| Fixed Assets: | | Sodecoton debt | 44,353 |
| Farm tools | 52,620 | | |
| | | Total Liabilities | 71,978.2 |
| Total Assets | 84,818 | Household Equity | 12,839.8 |

| **Village: Gatouguel** | | **Date: December 30** | |
|---|---|---|---|
| Assets | | Liabilities | |
| Current Assets: | | Current Liabilities: | |
| Production | 221,898.9 | Sodecoton debt | 44,353 |
| | | Product for consumption | 35,998.4 |
| Fixed Assets: | | | |
| Farm tools | 43,994.8 | Total Liabilities | 80,351.4 |
| Total Assets | 265,893.7 | Household Equity | 185,542.3 |

| **Village: Zouaye** | | **Date: June 30** | |
|---|---|---|---|
| Assets | | Liabilities | |
| Current Assets: | | Current Liabilities: | |
| Operating capital | 29,355 | Land & oxen rent payable | 22,401.4 |
| Household seeds | 5,179.4 | Casual labor payable | — |
| | | Inputs payable | 8,789.8 |
| Fixed Assets: | | Sodecoton debt | 25,862.7 |
| Farm tools | 26,420 | | |
| | | Total Liabilities | 57,053.9 |
| Total Assets | 60,954.4 | Household Equity | 3,900.5 |

| **Village: Zouaye** | | **Date: December 30** | |
|---|---|---|---|
| Assets | | Liabilities | |
| Current Assets: | | Current Liabilities: | |
| Production | 159,465 | Sodecoton debt | 25,862.7 |
| | | Product for consumption | 64,050 |
| Fixed Assets: | | | |
| Farm tools | 19,581.8 | | |
| | | Total L0iabilities | 89,912.7 |
| Total Assets | 179,046.8 | Household Equity | 89,134.1 |

## Risk and Sensitivity Analysis

The risk analysis shows how an increase in the expected deviation from the target income ($\lambda$) would affect the optimal results. The model was run for three values of $\lambda$: 0,10,000 and 20,000. It appears that the change in $\lambda$ does not affect the optimal crop combination and expected income in the four villages. This is explained by the fact that the income generated at each state of nature is greater than the target. In addition, annual consumption constraints are the most binding ones towards achieving higher expected incomes. On Table 23, optimal crop combinations generated by target MOTAD are very similar to those of the standard LP model. The major difference is the relative higher expected income obtained from the LP model. This is not surprising because the LP model would satisfy the consumption constraints on an average basis while the target MOTAD would satisfy the same constraints at each state of nature. This limits the expected income that can be achieved under the target MOTAD model.

Sensitivity analysis is performed to evaluate the stability of the optimal solutions to changes in sensitive parameters. In this study, a crop activity parameter is considered to be sensitive if its coefficient of variation (CV) is greater than or equal to 15 percent. The choice of 15 percent is arbitrary but we expect it to be close to the minimum value that can impact the optimal solutions significantly. Tables 24 and 25 present the CV values of the crop activity parameters calculated from the three-year data. Input and output prices appear to be fairly stable except for cotton prices that show up to 24 percent variation. Crop yields are more volatile in Djoulgouf compared to the other three villages. Sorghum, millet and peanut yields show relatively higher variability.

Table 23. Target MOTAD and LP Results.

| Village/Income/Crop Activity | LP Results | Target MOTAD Results |
|---|---|---|
| **Djoulgouf** | | |
| Expected income (frs CFA) | 61,896.3 | 23,560.4 |
| Mouskwari sorghum (ha) | 1.825 | 1.825 |
| Sorghum (ha) | 0.775 | 0.775 |
| Cotton/sorghum (ha) | 0.650 | 0.650 |
| **Djingliya** | | |
| Expected income (frs CFA) | 149,014.7 | 91,957.4 |
| Sorghum-peanut/millet-peanut (ha) | 1.625 | 1.621 |
| Sorghum/millet-cowpea (ha) | 0.125 | 0.129 |
| Cotton/sorghum/millet (ha) | 0.75 | 0.75 |
| **Gatouguel** | | |
| Expected income (frs (CFA) | 159,913.3 | 127,310 |
| Cotton/sorghum (ha) | 1.817 | 1.776 |
| Cotton/peanut-sorghum (ha) | 1.267 | 1.232 |
| Corn (ha) | 0.108 | 0.149 |
| **Zouaye** | | |
| Expected income (frs CFA) | 70,981.8 | 45,884.7 |
| Cotton/sorghum (ha) | 1.724 | 1.754 |
| Millet (ha) | 0.762 | 0.874 |
| Voandzou (ha) | 0.479 | 0.359 |

Table 24. Coefficient of Variation for Crop Yields for Surveyed Farms, 1989-1991 (Percent).

| Crop | Djoulgouf | Djingliya | Gatouguel | Zouaye |
|---|---|---|---|---|
| Sorghum continuous | 20.8 | ---- | 21.2 | 25.0 |
| Sorghum rotation | 33.9 | 35.2 | 19.6 | 12.8 |
| Cotton | 19.1 | 14.0 | 10.6 | 9.1 |
| Millet | ---- | 32.1 | ---- | 11.1 |
| Corn | ---- | ---- | 24.4 | ---- |
| Peanut | ---- | 25.9 | 14.6 | ---- |
| Voandzou | ---- | ---- | ---- | 9.9 |

Table 25. Coefficient of Variation for Input Prices and Output Prices for Surveyed Farms, 1989-1991 (Percent).

| Price | Djoulgouf | Djingliya | Gatouguel | Zouaye |
|---|---|---|---|---|
| Urea | 5.1 | 5.1 | 5.1 | 5.1 |
| NPK | 7.7 | 7.7 | 7.7 | 7.7 |
| Cotton Charges | 11.7 | 11.7 | 11.7 | 11.7 |
| Cotton | 23.4 | 23.4 | 23.4 | 23.4 |
| Sorghum | 6.7 | 10.5 | 10.5 | 8.0 |
| Millet | --- | 10.5 | --- | 10.0 |
| Peanut | --- | 3.3 | 6.0 | --- |
| Cowpea | --- | 6.8 | --- | --- |
| Corn | --- | --- | 12.0 | --- |

Given the CV values of the variables, the effects of the following change assumptions are analyzed in the four villages: 10 and 20 percent decrease in sorghum and cotton yields; 10 and 15 percent decrease in cotton prices; and a 10 to 20 percent increase in cotton charges, urea and NPK costs. These changes are very likely to occur in the near future, given the gradual reduction in inputs subsidy decided by the cotton company and the Cameroon government declaration of falling prices for cotton and other major agricultural export products.

For individual villages, the sensitivity analysis will analyze the effects of a 10 to 20 percent reduction in peanut yields in Gatouguel and Djingliya, and the effect of decreasing millet yield by 10-20 percent in Djingliya. All these changes are made *ceteris paribus*, that is, holding all other variables in the model constant. This procedure is to prevent confusion and complexity that may arise from interpreting results of simultaneous changes in several variables.

Effect of a 10-20 Percent Decrease in Sorghum Yields

A reduction of up to 20 percent in sorghum yield does not affect the optimal crop combination and the expected income in Djoulgouf, Djingliya and Gatouguel. However, if the mouskwari sorghum yield falls by more than 10 percent, the target income constraint in Djoulgouf cannot be met. This result can be presumed since mouskwari production represents 60 percent of the total crop area and most of its production is sold. In Zouaye, the reduction in sorghum yield would introduce continuous sorghum in the optimal solution and would increase the cotton/sorghum acreage at the expense of voandzou production. These adjustments in acreages constitute a compensation necessary to produce more sorghum to meet the consumption constraint. In addition, the expected income would fall by 12.6 percent for a 10 percent reduction in sorghum yield, and if the decrease goes beyond 10 percent the model becomes infeasible.

Effect of a 10-20 Percent Reduction in Cotton Yield

In Djoulgouf and Djingliya, the reduction in cotton yield by 10-20 percent does not impact the optimal crop mix and the expected income. For the other two villages, the optimal crop combination is unaffected but the expected income is reduced. In Zouaye, the reduction in income is 13 percent while in Gatouguel it approaches 20 percent.

Effect of a 10-15 Percent Reduction in Cotton Prices

A 15 percent price reduction in cotton prices (that is from 90 frs to 76.5 frs per kg) does not affect the optimal crop combinations in Djingliya and Gatouguel. However, the reducing effect on expected income is highly significant. In Gatouguel, household income falls from 127,310 frs cfa to 87,000 frs cfa (about 32 percent reduction). This result is not surprising since Gatouguel farmers get their revenues mainly from peanut and cotton sales. The income loss in Djingliya is about seven percent. In Djoulgouf and Zouaye, a cotton price reduction beyond five percent (below 85.5 frs cfa per kg) would render the model infeasible because the target income constraints are not satisfied.

Effect of a 10-20 Percent Increase in Cotton Charges

If the cotton charges increase from 29,349 frs to 35,218.8 frs per hectare, the optimal crop combinations remained unchanged for Zouaye, Gatouguel and Djingliya. Reductions in expected income range from one to seven percent in these three villages. In Djoulgouf, there would be a reduction in cotton/sorghum acreage and if the cotton charges rise beyond $32,283.9 frs (more than 10 percent), the income and sorghum consumption constraints are not satisfied.

Effect of a 10-20 Percent Increase in Urea Cost

Increases in urea cost do not affect the optimal crop combination in the four villages and the reductions in expected income are very small (less than two percent). This result can be anticipated since urea is used in very small quantities on foodcrops in the four villages.

Effect of a 10-20 Percent Decrease in Peanut and Millet Yields

In Djingliya and Gatouguel, the reduction in peanut and millet yields do not impact the optimal crop combinations while a 20 percent reduction in peanut yield would cause a slight decrease (three percent) in expected income.

# CHAPTER V

# FINDINGS

Optimal results generated by the target MOTAD model are fairly stable to increases in urea cost and cotton charges, and to reductions in cotton, peanut and millet yields. Reductions in sorghum yields and cotton prices would impact primarily farmers in Djoulgouf and Zouaye, and the study shows that expected revenues are relatively smaller in these two villages. Current farmers' acreages are about 60 to 70 percent of the optimal crop acreages generated by the model. Financial analysis of the model results indicates an increase of up to 160,000 frs in households equity. Operating capital and cropland are the major limiting factors of production in the study villages.

## Optimal Farm Plan in each Village

### Zouaye

To maximize the expected income given the production and consumption constraints, the household should grow 0.874 ha of millet, 0.359 ha of voandzou and 1.754 ha of cotton/sorghum. Cultivation of continuous sorghum is not in the optimal solution and the 1,129 kgs of sorghum needed to satisfy the consumption constraint should come from the cotton/sorghum activity. The household should sell 324.8 kgs of voandzou and 789.5 kgs of cotton to get an expected income of 45,884.7 frs. The household should rent 0.86 hectare of land for the cotton/sorghum activity and no hired labor is necessary.

Djoulgouf

The expected income is 23,560.4 frs and the household should grow 0.775 ha of sorghum, 1.825 ha of mouskwari sorghum and 0.650 ha of cotton/sorghum. A total of 0.75 ha of land should be rented and allocated as follows: 0.75 ha for cotton/sorghum, 0.25 ha for sorghum and 0.25 ha for the mouskwari crop. To meet the sorghum consumption constraint, 647.9 kgs should be transferred from sorghum and 776.1 kgs from mouskwari activities. The farmer should hire 366 of labor in October and 75.4 hours in January for the mouskwari crop operations.

Gatouguel

The optimal solution suggests that farmers should grow 0.149 ha of corn, 1.776 ha of cotton/sorghum and 1.232 ha of cotton/peanut-sorghum. This crop combination yields an expected income of 127,310 frs which is obtained from the sale of 1601.6 kgs of cotton, 413.11 kgs of peanut and 11.75 kgs of sorghum. The farmer should purchase 38.7 kgs of urea and 7.4 kgs of NPK for the corn and sorghum productions. Corn production is directed entirely to home consumption.

Djingliya

Households should grow 0.129 ha of sorghum/millet-cowpea, 1.621 ha of sorghum-peanut/millet-peanut and 0.75 ha of cotton/sorghum/millet. They should sell 647.4 kgs of peanut, 377.9 kg of millet and 185 kgs of cotton to generate 91,957.4 frs cfa. The farmer should rent 0.25 ha of land for the sorghum-peanut/millet-peanut activity, and sorghum and millet crops will need 10.4 kgs of urea.

CHAPTER VI

# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

## Summary

The objective of this study was to determine the optimal crop combination given the production and consumption constraints prevailing in each of the four study villages which are Djoulgouf, Djingliya, Gatouguel and Zouaye. The sensitivity analysis of the target MOTAD results show that they are fairly stable to increases (up to 20 percent) in urea costs and cotton charges, and reductions (up to 20 percent) in cotton, peanut and millet yields. Results of the study indicate that operating capital constitutes the limiting resource in Gatouguel and Zouaye while cropland is the major scarce factor in Djoulgouf and Djingliya. Optimal crop combinations generated by the target MOTAD model are very similar to the LP results. The main difference between the two model outputs is the relative higher income generated by the LP. Farmers can get LP incomes during years when consumption constraints are not binding. The target MOTAD crop combination shows an improvement in the financial situation of the farmers. Increases in households equity range from 40,000 frs to 160,000 frs for the four villages. The current farmers acreages are similar to those obtained from the target MOTAD; the model acreages are relatively higher and they are allocated mostly to crop activities that provide food and revenues (cotton/sorghum, sorghum-peanut/millet-peanut) at the expense of activities that are mainly food producing (sorghum, sorghum/millet). In Gatouguel, households should grow 0.149 ha of corn, 1.776 ha of cotton/sorghum and 1.232 ha of cotton/peanut-sorghum. This combination gives an expected income of 127,310 frs cfa which is four times greater than the 30,000 frs target. Cotton price reduction is the unique change that drives down the expected income significantly. For example, a 15 percent reduction would cause household income to fall by 30 percent. Corn and peanut consumption constraints are satisfied by growing 0.149 ha of corn and at least 0.15 ha of cotton/peanut-sorghum. The annual sorghum requirement, 985.2 kgs consumption becomes binding quickly as prices of inputs vary. As long as the cotton/sorghum acreage does not fall below 1.5 ha, the sorghum consumption constraint can still be met.

In Djoulgouf, the farmer should grow 0.775 ha of sorghum, 1.825 ha of mouskwari sorghum and 0.65 ha of cotton/sorghum. This optimal combination is more sensitive to price variations, especially a reduction in cotton prices. If cotton price falls below 85 frs per kg, the model becomes infeasible. One reason is the fact that the expected income 23,560.4 frs cfa is not significantly higher than the 20,000 frs target and as a result, the target income constraint becomes quickly binding to variations in the crop activity parameters. The second reason is that the sorghum consumption constraint becomes also binding as changes in parameters cause the sorghum or mouskwari acreage to be reduced.

In Djingliya, households should get their income from the sale of cotton, peanut and millet. To maximize income, the farmer should grow 0.75 ha of cotton/sorghum/millet, 1.621 ha of sorghum-peanut/millet-peanut and 0.129 ha of sorghum/millet-cowpea. Each of these three crop activities contributes to the sorghum and millet consumption constraints and as a result, variations affecting acreage or prices have less impact on the capability of the optimal crop combination to satisfy the food constraint. The expected income 91,957.43 frs cfa is three times higher than the 30,000 frs target and it is fairly stable to price variations. For example, a 15 percent price reduction in cotton price (from 90 frs to 76.5 frs per kg) would cause the expected income to fall by only 7 percent.

In Zouaye, the household should sell 324.8 kgs of voandzou and 789.5 kgs of cotton to generate an expected income of 45,884.7 frs cfa. The optimal crop combination suggests 0.874 ha of millet, 0.359 ha of voandzou and 1.754 ha of cotton/sorghum. Considering input and output prices variations, cotton price reduction is the one that affects the expected income significantly. If cotton price falls from 90 frs cfa to 85.5 frs cfa (5 percent reduction), the expected income would decrease from 45,884.7 frs to 33,120.9 frs (about 28 percent reduction). Among the food consumption constraints, sorghum appears to be the most critical. If sorghum yields fall by more than 10 percent, the cotton/sorghum activity will not provide enough sorghum to meet the household needs and as a result the model becomes infeasible.

## Discussions of the Research Findings

The optimal acreages generated by the model appear in decimal terms and they indicate that the farmer can buy small increments of fertilizers or that he can rent or cultivate infinite portions of land. In practice, this is difficult to achieve because most farmers in the extreme north of Cameroon rent land in 0.125 ha and 0.25 ha increments.

In addition, urea and NPK fertilizers are sold exclusively in 50 kgs bags. These practices being the case, it is necessary to check if a round off of acreages will satisfy the consumption and target income constraints. For the four villages, the round off gives a lower expected income but all the constraints are satisfied. In Gatouguel, the farmer should grow 0.25 ha of corn, 1.75 ha of cotton/sorghum, 1.375 ha of cotton/sorghum-peanut and the expected household income is 119,930.4 frs cfa. For Djingliya, the income is 91,863.6 frs and it is obtained from growing 0.125 ha of sorghum/millet-cowpea, 1.625 ha of sorghum-peanut/millet-peanut and 0.75 ha of cotton/sorghum/millet. In Zouaye, the expected income falls from 45,884.7 frs to 42,757.2 frs and the household should cultivate 0.875 ha of millet, 0.5 ha of voandzou and 1.75 ha of cotton/sorghum. The round off for Djoulgouf gives 0.75 ha of sorghum, 1.875 ha of mouskwari sorghum, 0.5 ha of cotton/sorghum and an expected income of 22,905.7 frs.

## Recommendations to the Cotton Corporation

An increase of up to 10 percent in cotton charges per hectare, (that is from 29,369 frs to 32,283.9 frs) would reduce households' income by almost 10 percent in the study villages. If the charges were to rise above 32,283.9 frs per hectare, some farmers would reduce their cotton acreages significantly. Results of the study indicate that such a situation is likely in Djoulgouf village where cotton farming would be reduced by at least 20 percent. Unless the benefits from increasing cotton charges outweigh the loss due to reduction in cotton farming, the cotton corporation (SODECOTON) is advised not to increase the charges above 32,283.9 frs per hectare.

## Recommendations to the Government

Cotton price constitutes a key variable in farm planning decisions in the extreme north of Cameroon. Cotton farming is optimal in each of the study villages and cotton is one of the main sources of income for households. From the results of the study, if cotton price falls below 76.5 frs per kg, household income will be reduced by 20 to 40 percent in the surveyed villages, and cotton farming would be significantly reduced. Unless some compensation measures are taken, reductions in cotton prices below 85.5 frs per kg are not recommended. At this unit price for cotton, the study shows that farmers would still grow the optimal crop combination in each of the four villages.

## Limitations of the Study

The present study on farm resource allocation generated optimal crop combination for four individual villages in the extreme north of Cameroon. If resources are available, it would be beneficial to design a complete optimization study so as to generate conclusions for the entire extreme north of Cameroon. The three-year data series that was used, appeared to be very short to conduct a more advanced risk analysis that would incorporate probabilities of obtaining observed yield levels for the different crops identified.

Finally, Cameroon and other members of the CFA zone have agreed in February 1994, to devaluate their currency relative to the french franc. This decision might have brought changes in nominal prices of the inputs and output considered in this study. Detailed information about the devaluation are not known and therefore, it appears difficult to make the appropriate adjustments regarding the results of the present study.

However, it is recommended that any future adjustment of the results to inflation generated by the devaluation be done on the basis of real prices for inputs and output.

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APPENDIXES

# APPENDIX A

# ASSUMPTIONS OF THE LINEAR PROGRAMMING MODEL (HAZELL AND NORTON, 1986)

1. Optimization. The objective function is either maximized or minimized.

2. Fixedness. At least one constraint has a non zero right hand side coefficient.

3. Finiteness. There are a finite number of activities and constraints to be considered so that a solution may be sought.

4. Determinism. All $c_j$, $a_{ij}$ and $b_i$ coefficients in the model are assumed to be known constants.

5. Continuity. It is assumed that resources can be used and activities produced in quantities that are fractional units.

6. Homogeneity. It is assumed that all units of the same resource or activity are identical.

7. Additivity. The activities are assumed to be additive in the sense that when two or more are used, their total product is the sum of their individual products. That is no interaction effects between activities are permitted.

8. Proportionality. The gross margin and resource requirements per unit of activity are assumed to be constant regardless of the level of the activity used. A constant gross margin per unit of activity assumes a perfectly elastic demand curve for the product and perfectly elastic supplies of any variable inputs that may be used. Constant resource requirements per unit of activity are equivalent to a Leontief production function.

# APPENDIX B

# SCIENTIFIC NAMES OF CROPS GROWN

# IN THE STUDY VILLAGES

| Common crop name | Scientific name | Family |
|---|---|---|
| Cotton | Gossypium spp | Malvaceae |
| Sorghum | Sorghum vulgare | Gramineae |
| Peanut | Arachis hypogaea | Leguminosae |
| Corn | Zea mays | Gramineae |
| Cowpea | Vigna unguiculata | Leguminosae |
| Millet | Pennisetum glaucum | Gramineae |
| Voandzou | Voandzeia subterranea | Leguminosae |

# APPENDIX C

# ANNUAL ACREAGES AND PRODUCTIONS FOR THE DIFFERENT CROPS CULTIVATED IN THE EXTREME NORTH OF CAMEROON

Total number of farm households: 274,400

| Crop | Annual acreage (hectare) | Production (thousand kgs) |
|---|---|---|
| Sorghum and Millet | 373,494 | 290,838 |
| Cotton | 45,821 | 40,312 |
| Cowpea | 26,506 | 15,286 |
| Peanut | 18,166 | 9,082 |
| Corn | 9,303 | 6,301 |
| Voandzou | 4,893 | 2,519 |
| Rice | 465 | 1,307 |

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