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DOCUMENTATION OF RESEARCH FOR FARMING SYSTEMS IN NORTHERN CAMEROON, 1986-1988

by

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A. Description of Study

1. Purpose

The creation in 1984 of SAFGRAD Farming System Programme (covering Burkina Faso, Benin and North Cameroon under the auspices of OAU/STRC/SAFGRAD, funded by IFAD) embodies the view that, while there is a lot of research information available both at International and National Agricultural Research Centres in Sub Saharan Africa, technologies may not be adopted by farmers because such technologies are not specific to farmer conditions in West African countries.

Following the signing of OAU/STRC agreement with Cameroon, November 1985, the IFAD supported SAFGRAD/FSR/Cameroon project was implemented from February 1986 through April 1989. The objectives of the SAFGRAD/FSR program here (1) to develop agricultural production technologies adapted to the conditions and the needs of small farmers in the semi-arid zones of Northern Cameroon (2) to foster the transfer of agricultural technologies by camping out agronomic and economic evaluation of the research results obtained on the research stations by conducting on-farm trials in collaboration with farmers, and (3) to strengthen the National Farming Systems Program of Cameroon by working closely with the host Institute of Agronomic Research (IRA) and the Extension Services.

The SAFGRAD/FSR Cameroon team, consisted of three scientists (an Agricultural Economist and Team Leader, Agronomist and Agroforestor) with their Cameroonian counterparts and 22 support staff. The FSR team collaborated with 10 scientists working on basic commodity research at various stations in the country. During the three year period 1986, 1987 and 1988, the FSR Team carried out a number of research activities including socioeconomic studies, on-farm agronomic trials, and agroforestry/livestock trials.

Data collected from the SAFGRAD/FSR Cameroon was brought to Purdue University in May 1989 for further analysis with the financial support of the U.S. Agency of Soil Moisture Management Project under USDA, PASA No. BST-4021-P-AG108D-00. The purpose of this documentation is to describe the data used for yield and risk analysis. Data included here are on-farm agronomic trials (consisting of evaluation of improved technologies of maize, cowpeas, white sorghum, groundnut, soil-water and soil-fertility management techniques) and socioeconomic studies. Data collection included: baseline surveys, farm labor surveys, farm resource surveys, animal traction surveys, and yield studies for traditional crops and new technologies. Table A.1 shows the data collected in the whole study and the number of farmers surveyed by year.

For research performed at Purdue, survey data was organized into the following data bases (to be described in Appendix A):

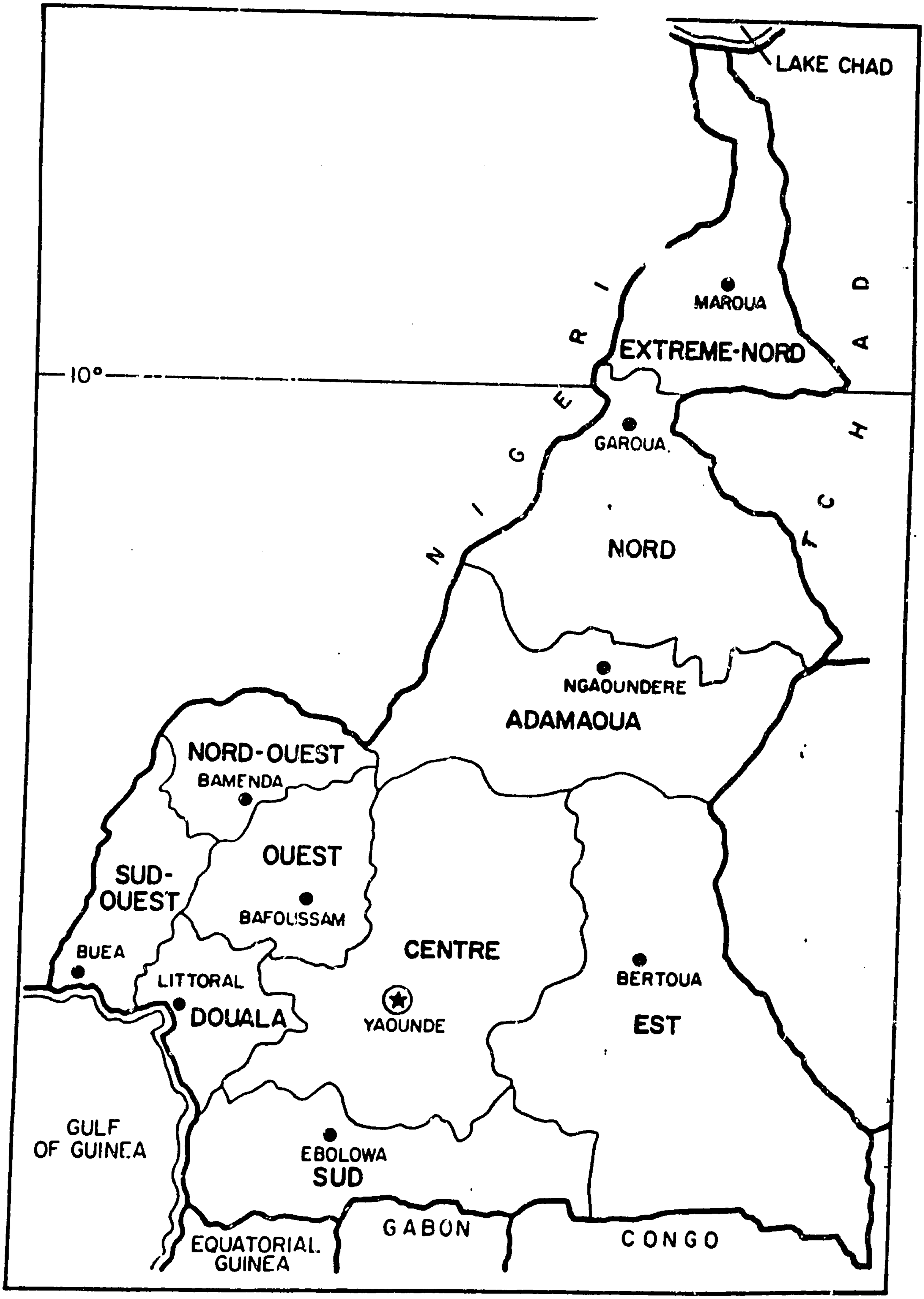
FARMW - Traditional crop yields

SAFTEC - Crop yields of improved technologies

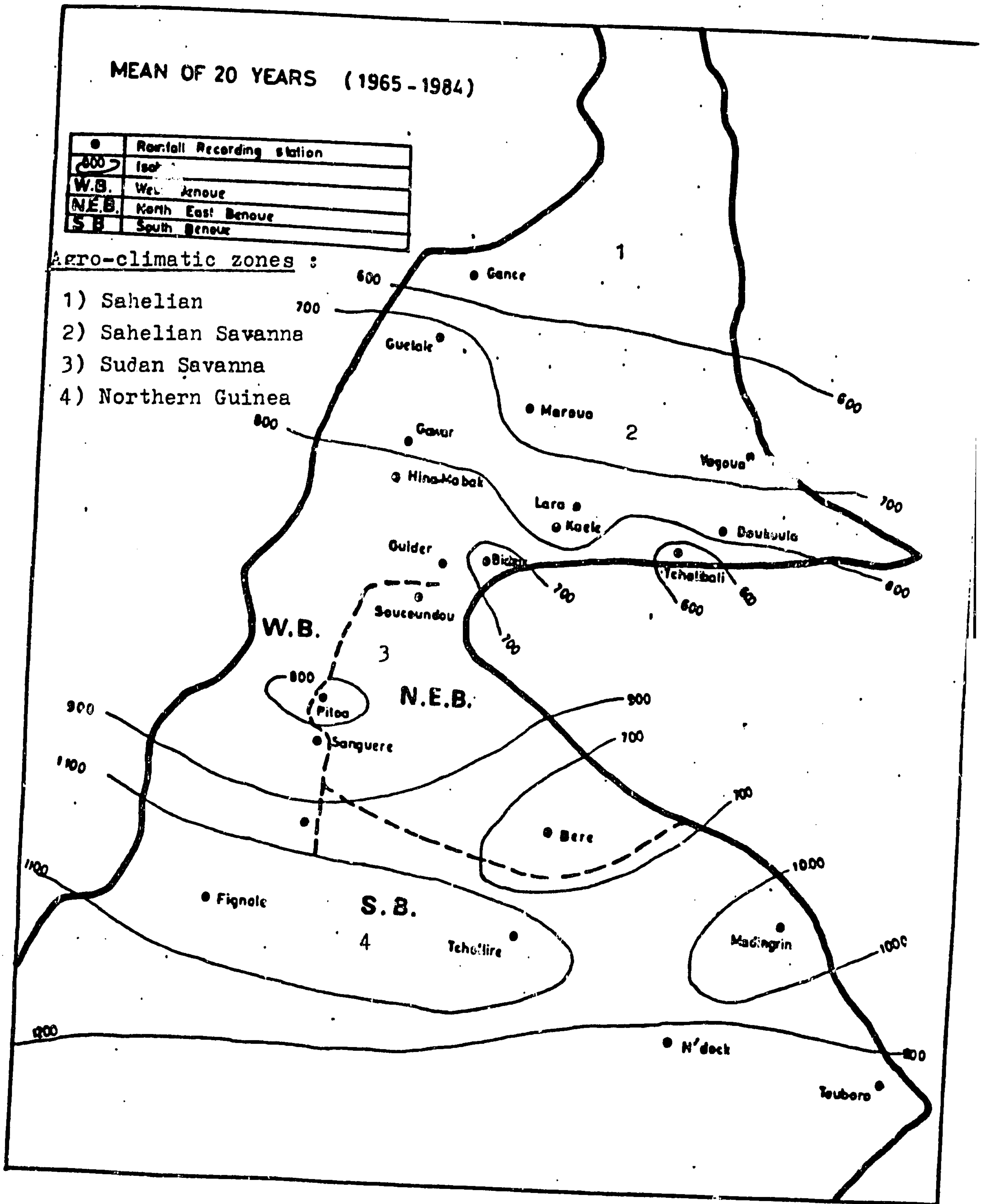
FARM17 - Farm labor.

2. Description of project area

<u>Location and topology</u>. Cameroon is situated in Central Africa (latitude 2 to 13 degrees North and longitude 6 to 16 degrees East). It is bordered by the Gulf of Guinea in the South-West, by Equatorial Guinea, Gabon, and The Congo in the South, by Tchad in the East and by Nigeria in the West (Fig. 1.) The country spans 1,200 km from North to South and 800 km from East to West and covers 475,440 km^2 or 46.9 million ha. Cameroon is divided administratively in 10 provinces (see maps).

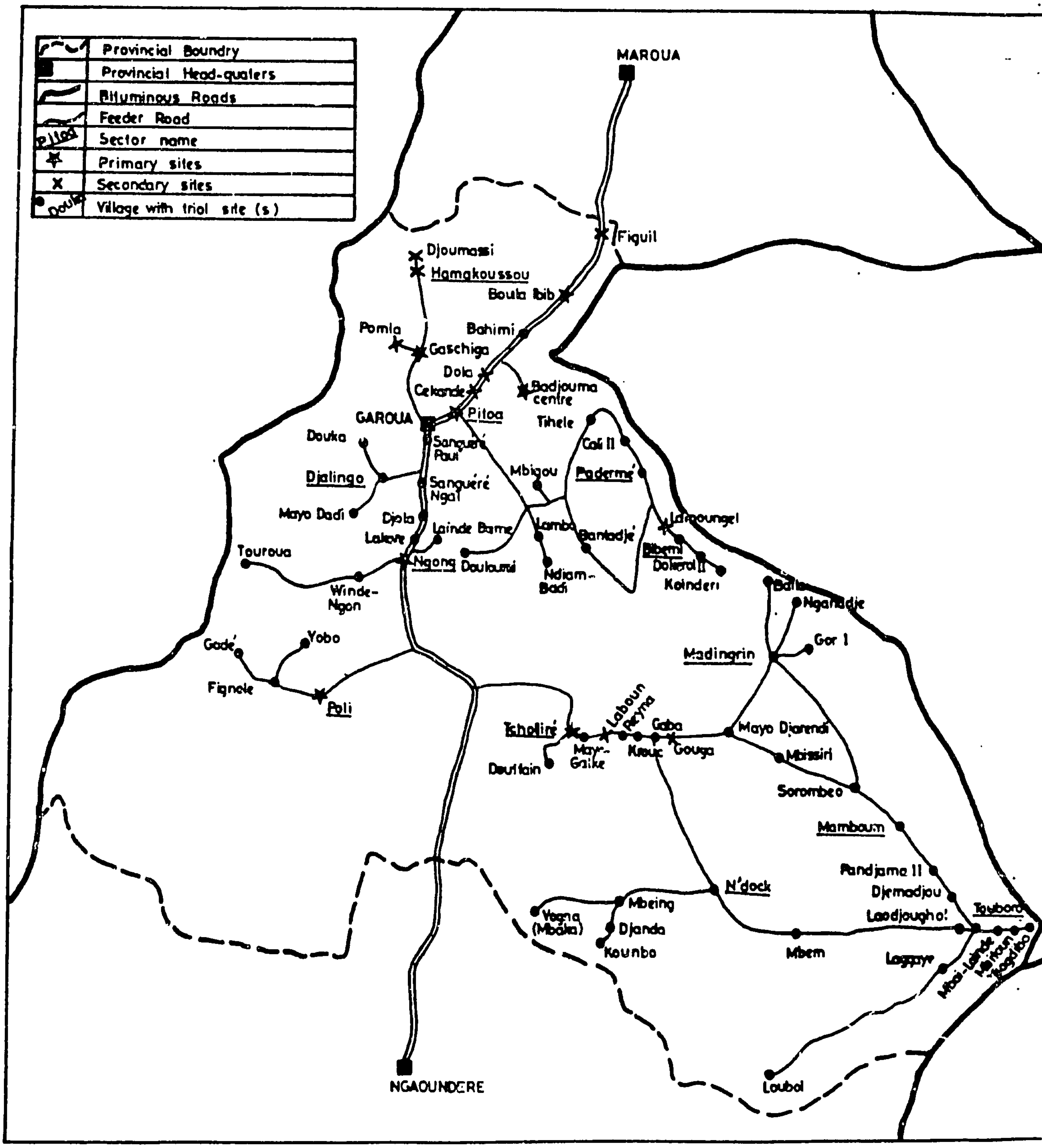


: Map of Cameroon showing administrative provinces



Rainfall of North and Extreme North Provinces

MAP OF NORTH PROVINCE SHOWING SAFGRAD SOCIO-ECONOMIC SURVEYS AND AGRONOMIC TRIAL SITES



The SAFGRAD/FSR project area covers North Province and Southern part of Extreme North Province. The North Province lies in a large depression on the river Banne basin with an altitude of 1000 m to 2000 m above sea level. The area extends into the mandara highlands on the North-western side and Diamore plains in the North plus Danay on the Eastern side. Then it is boardered by Admaoua highlands on the Southern side.

Soil types and soil fertility. In the Lower Benoue Valley, the most extensive soil types are: the Tropaquents (wet soils found in depressions), Paleustalfs (dark grey clayey soils found in alluvial plains) and Paleustalfs

Table 1 below summarizes the data collection for these data boxes.

(deep sandy soils found on uplands.) This zone has high potential for crops (especially irrigated) and high to very high potential for livestock.

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

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

Most of the soils in the North Province are slightly acidic (pH: 6.2-6.5), low in organic matter and N, low in available P (5-15 ppm), and low in exchangable K (0.30 meg per 100 g ECC.) Note that for practical purposes, in this study the soils in project area are divided in three major categories: sandy soils, the clayey soils, and wet soils.

Table 1. Sample of selected farmers in North Cameroon 1986 through 1988.

Item	1986	1987	1988	Total
Baseline Survey	220	-	-	220
Seasonal Farm Labor (FARM17)		78	52	130
Fixed farm resources (FTOOLS)		119	101	220
Animal traction (FTPOWER)	6	42	27	75
Farm sizes and crop yields, traditional methods (FARMW)	90	78	52	220
Farm prices (FTRAD)		124	78	205
Yields for improved technologies (SAFTEC)				
maize	24	30	20	74
white sorghum	6	12	12	30
cowpeas	1	8	12	21
groundnuts	22	-	-	22
soil-fertility management	2	4	14	20

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

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

Northern Cameroon has a monomodal rainfall pattern. Rains start in April-May, peak in August, and end in October-November. Before June, evapotranspiration in the Project area exceeds precipitation, making available moisture the limiting factor. From the end of June to mid-September, precipitation exceeds evapotranspiration (no soil moisture stress.) Evapotranspiration increases after mid-September, during crop maturity. Beyond October, longer cycle crops experience soil moisture stress as evapotranspiration, again, exceeds precipitation.

Farmers first crop of red sorghum and groundnut is at the onset of rains in early May, then continue with the planting of other crops in May and June. Harvesting is carried out in November/December and even January in case of cotton. On the average, April 21 to May 30 is the period for early planting, May 31 to June 20 is the normal planting period and June 21 to July 10 the late planting period.

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

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

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

Production of Food Crops. The important food crops in Cameroon, are cereals millets/sorghum, maize and rice and starch food crops plantain, cassava, yam, cocoyams, palm oil and bananas. The cash crop include cotton, cocoa, coffee, oil seed crops, rubber, bananas and pineapples. Whereas groundnut serves a dual purpose of food and cash crop. Considering the land mass of Cameroon being about 46.5 million hectares only 6.3% is under agricultural production whereas 36.5% is under livestock, 42.1% under forest and about 14.8% is under water.

By 1980s, food crop production in Cameroon was in thousand tons, 407 millet and sorghum, 416 maize, 69 rice, 80 groundnuts, 5 sesame, 618 cassava, 415 yams, 66.9 sweet potatoes, 808 cocoyams and 24 irish potatoes. But these production levels satisfy only 60 to 90% of the domestic demand. (Office of Statistics, Yaounde, 1981-1986 five year Development Plan).

In Northern Cameroon, where the SAFGRAD/FSR is based the most important food crops are millet, sorghum, maize and cowpeas. Whereas cotton is a very important cash crop and groundnut serves a dual purpose of both cash and food crops.

Northern Cameroon produces 60% to 80% of the cereal production in the country. That is 60% maize, 80% of sorghum and millets and about 70% of the groundnuts. Yet the farm yields of these crops are still very low ranging between 0.3 to 1.2t/ha.

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

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

In Northern Cameroon, the average farm size in the extreme North Province and in West Benoue is 9 to 10 persons. But in the larger part of the project area, the average size is 5 persons per farm family, consisting of the male farmer as the head of the household, his three children, two of whom are of working age, 10-18 years. Using the coefficients of 1 for a man, 0.75 for a woman and 0.5 for children, each farm family has about 2.75 man-units of labor. The availability of family labor in hours per period is obtained by allowing a six day working week, times a six hour working day times 2.75 man-units.

Livestock. Livestock production is an important component of the land use system in Northern Cameroon. The region carries over 60 per cent of the 4.361 million cattle, 2.358 million sheep and 2.917 million goats in the country. These are two livestock systems in the Northern Cameroon, one sedentary small farmers who own your animals, consisting of a pair of oxen for draught power, a cow plus one to two small ruminants as a form of savings for emergency cash. Second, there are the nomadic pastoralists who keep large herds (50-100 animals) of cattle. The nomadic herdsmen graze their animals on natural range lands during the rainy season.

During the dry season, the months of January through April/May are hot and dry and all the vegetation in the Sahelian and Sudan savanna zones gets desiccated and often destroyed by bush burning. Both the sedentary livestock farmer and the nomadic pastoralist suffer from the shortage of feed and water. The nomadic hardomen transhumance from the dry zones, southwards in search of grazing grounds and water. While the sedentary livestock farmers tend to entrust their few cows to the nomadic herdsmen and pay a fee of about $3.30

dollars per cow per month. But this arrangement is not favorable for draught anaimals which would not be available to do the early pough in May when the ıains come.

3. Methodology of data collection

The SAFGRAD Farming Systems Research Program used an approach of integrating four aspects of the whole farm covering crops, tree-shrubs, livestock and off-farm subsystems. The FSR team conducted (1986-1988) research activities on cropping, soils, tree-crop-combinations, tree-crop-livestock interactions, farm resources and the economics of new technological interventions into the existing farming systems in Northern Cameroon.

In order to develop appropriate technologies for adoption by farmers, the FSR research procedures were standardized into four points for all the FSR team and its collaborators. The adopted four points for all the FSR team and its collaborators. The adopted FSR standard procedures were:

1. Diagnostic or current systems done by FSR team, farmers and extension agents
2. Design of technological intervention to address identified constraints by FRS team, station researchers and extension agents
3. Testing and evaluation of technological interventions at farm level by FSR team, farmers and extension agents.
4. Transfer of technolgies to farmers by farmers and extension agents.

<u>Selection of Sites and Participating Farmers</u>. Since a well structured agricultural statistical data was nonexistent, in order to obtain representative sites and farmes in each recommendation domain, a multi-stage random sampling procedure was used.

Thus the area of study was classified into agroecological zones, Sahelian savanna zone less than 600 mm of rainfall, Sudan savanna zone 600-800 mm of rainfall and N. Guinea savanna zone 800-1000 mm of rainfall and S. Guinea savanna zone over 1000 mm of rainfall. The same area was again stratified into geogrphical regions of West Benne, North East Benue and South East Benue according to major soil types and cropping patterns. Each geographical region, was in turn subdivided into production unit areas or sectors according to certain criteria regarding cropping systems, soil characteristics, farm settlements and farmers socioeconomic setting so as to define recommendation domains.

Then for each recommendation domain, one to two primary sites were selected randomly. Then an additional two to three secondary sites (villages) were also selected in the periphery of the primary sites again using random numbers. In all there were three primary sites in West Benue, 3 in North East Benue and 3 in South East Benue (see Fig. 2). It should be noted that at the initial stage, before sampling, the FSR accompanied by extension agents, made a rapid exploratory survey round the entire area of study, in order to collect the information that is used for the selection of sites.

As for selection of farmers, an exhaustive list of farm families in the primary and secondary sites were compiled by Research Assistants under supervision. For instance, 1800 farm families were listed in selected sites of West Benue, 2558 in North East Benue and 2200 in South East. Again using random numbers 5 to 10 farmers were sampled depending on the size of villages at the selected sites. Then farmers were sampled for each of the respective research activities.

<u>Conducting on-farm trials</u>. SAFGRAD/FSR conducted on-farm trials in the studied are to test and evaluate new technologies which had been developed by researchers both at national and international levels. The farmers in the region fall into two major categories, SODECOTON and traditional farmers.

Basically, there are three types of on-farm trials. Namely:

i) research - managed and researcher - implemented;

ii) researcher - managed and farmer - implemented and

iii) farmer - managed and farmer - implemented. But in this documentation they are all combined without distinction.

All the SAFGRAD/CAMEROON/FSR trials were conducted on-farmer's fields and non at the research station. This was intended to bring the test of technologies under the farmer's environment and solicit farmer's participation even at the technology developing stage.

The extension farmers consist of 39% of SODECOTON and 9% by Ministry of Agriculture. That is over 50% of the farmers are producing under traditional methods. Because of the different methods of production practiced by the major target groups of farmers, different on-farm trials were designed for each of the groups. That is the extension target group of farmers and traditional target group of farmers. SODECOTON is a cotton corporation responsible for promotion of cotton plus advising farmers who are under its close supervision on food crops.

<u>On-Farm Trials for Traditional Farmers</u>. Before the cropping season, the FSR team visited each primary site and met with traditional farmers for the preparation of on-farm trials in their villages.

At a meeting, presided over by the Chief of the village, the FSR team explained to the farmers through interpreter, the objectives of the FSR program and the need for farmers to actively participate in the on-farm trials.

The FSR team together with the farmers reviewed in previous year's results, and the major production constraints prevailing in each sector and the themes being proposed by the FSR team for the on-farm trials. The treatments included in the trials were based on the available promising technologies. The farmers indicating their interest. For instance, in 1987, farmers in Gaschiga, Hama-kousson sectors, opted for:

i) soil water conservation techniques;

ii) the use of animal traction for various farm operations like ploughing, weeding and transportation.

Whereas farmers in Pitoa sector opted for testing of cowpea varieties in both cases, the farmers decisions were within the priorities of the FSR team. Each farmer was responsible for the supply of labor for all the farm activities from ploughing to harvesting and the researchers were to supply seeds, fertilizers and insecticides in case of cowpea trails along with protocols out-lining the procedures that should be followed. In case of the use of animal traction each participating farmer had to have a pair of oxen, an ox-plough and ox-cart.

<u>On-Farm Trials for Extension Farmers</u>. In order to decide what technologies should be tested with the extension farmers, in each February, meetings were made between FSR team, station researchers and extension agents. After reviewing the results of station and on-farm trial results, the meeting proposed trials to be conducted by the FSR team with farmers. Then subsequent meetings were made between FSR team farmers and extension agents.

From 1986 through 1988, trials were conducted on the basis of recommendation domains. That is spread out to cover agroecological zones, soil types, cropping patterns and climatic conditions in the region. The extension staff participated in farmer selections, field selection, lying up of the treatments and supervision of the trials. SAFGRAD team made regular tours of the trial sites during the season. The whole FSR team visited at the beginning of the season, to distribute planting materials: seeds and chemicals and to verify on the choice of land: the mid-vegetative growth phase of the crops, the main purpose of which was to record observations. Third important visit was in mid-September to record observations and distribute harvesting materials and instructions for harvesting. The last important visit was at the very end of the season to weigh and take harvest samples.

Method of Data Collection. In order to maintain the quality of research data being collected and to facilitate the day to day execution of the research activities, SAFGRAD/FSR Cameroon had nine research assistants. Six of the research assistants were posted to reside and work at the primary sites. Then three of the research assistants performed various tasks in the field or at the office.

The field assistants at primary sites were equipped with the necessary materials such as questionnaire forms, spring balance, rain gauge, and a record book. the field research assistants were also given new motor bikes (or 100 cc.) to enable them to make quick rounds to villages where they were assigned a number of agronomic trials and to follow up at least 20 farmers each to note observations, make interviews with farmers and collect data at regular intervals.

The frequency of visits to farmers depends on each specific detailed study. For instance for farm labor, the field staff has to visit each farmer every two days and spend a working day with the farmer at his farm one every week. Data on utilization of animal traction in relation to data on animal feed, is collected every two days. Price data are collected weekly while storage data are collected at three repeated visits namely at harvest, three months after harvest and six months after harvest. Then other important agronomic observations are made at land preparations, planting, weeding, during vegetative growth and at harvesting.

Farm Labor. Seasonal flow of farm labor (1987 and 1988) consists of hours of family and hired labor per farm family for all farm operations for each crop. Farm operations for each crop may include all or some of the following: bush clearing, soil preparation, first planting, second planting, first weeding, second weeding, ridging, fertilization (once and/or twice), spraying, harvesting, and transporation.

During the cost-route surveys, farm labor was recorded by source, that is family or hired, number of male, female and children who worked for each day as well as the number of hours worked per day. The data file contains labor in hours by its source (male, female or children, and hired).

Appendix A. Description of Data Bases

Data Base FARMW

Variable Name	Units	Description
Year	86, 87, or 88	Year of data collection.
Sect	1 to 6	Sectors location:
		1- Pitoa sector
		2- Bibemi sector
		3- Boula-Ibib sector
		4- Hamakousson sector
		5- Djalingo sector
		6- Ngong sector
Farm	number	farmer code within sector
AGEF	"	age of farmer
NMEN	"	number of men in a farm family
NFEM	"	number of women in a farm family
NCHD	"	number of children in a farm family
AREA1	ha	area planted to red sorghum
AREA2	ha	area planted to cotton
AREA3	ha	area planted to traditional maize
AREA4	ha	area planted to traditional groundnut
AREA5	ha	area planted to muskwari
AREA6	"	area planted to cowpeas
AREA8	"	area planted to traditional white sorghum
QTIT1	kg	quantity red sorghum harvested
QTIT2	"	" cotton
QTIT3	"	" traditional maize

FARMW cont.

Variable Name	Units	Description
QTIT4	"	" traditional groundnut
QTIT5	"	" muskwari
QTIT6	"	" traditional cowpeas
QTIT8	"	" traditional white sorghum harvested
SD	1 or 0	a dummy for type of soil 0- clayey 1- sandy
WP	11, 13, 23	indicator for weather pattern 11 - dry, 13 - intermediate, 23 - wet weather (see Appendix C)
PL1B1	4 to 7	month of planting red sorghum
PL1A1	1 to 30	day of month of planting red sorghum
PL1B2	4 to 7	month of planting cotton
P11A2	1 to 30	day of the month of planting cotton
P11B3	4 to 7	month of planting traditional maize
P11A3	1 to 30	day of the month of planting groundnut
P11B4	4 to 7	month of planting traditional groundnut
P11A4	1 to 30	day of the month of planting groundnut
P11B5	8 to 12	month of planting muskwari
P11B6	6 to 9	month of planting cowpeas
P11A6	1 to 30	day of the month of planting cowpeas
P11B8	4 to 8	month of planting traditional white sorghum
P11A8	1 to 30	day of the month for planting traditional white sorghum

SAFTEC

Variable	Units	Description
Year	86,87,or 88	Year of on-farm trial.
Sector	1 to 8	Sector location of trial
Farm	num	Farmer code within sector
WP	11, 13, 23	indicator for weather pattern 11 - dry, 13 - medium, 23 - wet weather
SD	1 or 0	dummy for soil type
MAXE17	kg/ha	maize variety Mex. 17 yield
TZPB	"	maize variety TZPB yield
MSA2B	"	maize variety SAFITA 2B yield
CMS501	"	maize variety CMS8501 yield
CMS503	"	maize variety CMS8503 yield
CMS611	"	maize variety CMS8611 yield
SFER	"	fertilizer levels of N 60kg/ha, 75 kg/ha, 90 kg/ha or 105 kg/ha for maize varieties Mex .17, TZPB, CMS8501, CMS8503, CMS611
M100	kg/ha.	maize yield with fertilizer of 100 kg/N/ha, Mex .17
M25	"	maize yield with fertilizer/manure of 25
kg/N/ha		
	"	plus 5t/ha of animal manure, Mex .17
MR25	"	maize yield with treatment of 25kg/N/ha plus 5t/ha crop residues, Mex .17

SAFTEC cont.

Variable	Units	Description
M5T	"	maize (Mex .17) yield with treatment 5t/ha of animal manure
MFPR	"	maize (Mex .17) yield for farmer's practices with without fertilizers
MRID	"	maize (Mex. 17) yield for simple ridges, 30 days after planting
M2RN	"	Mex. 17 yield for tied ridges at 2m., 30 days after planting
M3RN	"	maize (Mex. 17) yield for ridges tied at 3m. interval
MFLOT	"	yield (Mex. 17) for improved practices without ridges
MSEED	1 or 2	maize seed treatment; 1- thioral; 2- marshall;
SCS61	kg	white sorghum variety CS61 yield
SCS95	kg	white sorghum variety CS95 yield
SCS63	kg	white sorghum variety CS63 yield
S34	kg	white sorghum varieties S34/S35 yield
SR5	kg	red sorghum local varieties yield
CTVX3	kg	cowpeas improved variety TVX3236
CVYA	kg	cowpeas improved variety vya yield
GM513	kg	groundnut variety M513 yield
G28	kg	groundnut variety 28-206 yield
GM513	kg	groundnut variety M513 yield
GK1	kg	groundnut variety K1-441-77 yield

Variables	Units	Description
MPDAY	date	day of the month of planting maize, experiments (Mex. 17) through CMS.
MPMOT	1 to 12	month of planting maize, experiments (Mex. 17) through CMS.
SPDAY	date	day of the month of planting sorghum (red and white)
SPMOT	1 to 12	month of planting sorghum (red and white)
MRDAY	date	day of planting maize, experiments M100 through MFLOT
MRMOT	1 to 12	month of planting maize, experiments M100 through MFLOT
GPDAY	date	day of planting improved groundnut
GPMOT	1 to 12	month of planting groundnut
CPDAY	date	day of planting improved varieties of cowpeas
CPMOT	1 to 12	month of planting improved varieties of cowpeas

FARM17 Data Base

Variables	Units	Description
Sect	1-6	sectors or locations of selected sites
		1- Pitoa; 2- Bibemi; 3- Boula-Ibib;
		4- Hamakousson; 5- Djalingo; 6- Ngong
Farm	number	farmer codes within sector
Area	number	area planted by crop
Crop	1 to 8	crop identifier
		1 - red sorghum, 2 - cotton, 3 - maize,
		4 - groundnut, 5 - muskwari, 6 - cowpeas,
		8 - white sorghum
AGET	number	age of the farmer
TSIE	number	family size
QTIT	kg	quantity harvested
year	86, 87, 88	year of data collection
DEFLM	hrs	family labor, male, for land clearing per crop
DEFLF	hrs	" ,female, " " " "
DEFLC	hrs	" ,children " " " "
DEFLT	hrs	total family labor, " " " "
PRELM	hrs	male/farmer's labor for soil preparation per crop
PRELF	hrs	female " " " "
PRELC	hrs	children " " " "
PRELT	hrs	total " " " "
PL1LM	hrs	male/farmer's labor for first planting
PL1LF	hrs	female " " " "
PL1LC	hrs	children " " " "

FARM17 cont.

Variables	Units	Description
PL1LT	hrs	total " " " "
PL2LM	hrs	male/farmer's labor for second planting
PL2LF	hrs	female " " " "
PL2LC	hrs	children " " " "
PL2LT	hrs	total " " " "
WD1LM	hrs	male/farmer's labor for first weeding
WD1LF	hrs	female " " " "
WD1LC	hrs	children " " " "
WD1LT	hrs	total " " " "
RIDLM	hrs	male/farmer's labor for ridging
RIDLF	hrs	female " " " "
RIDLC	hrs	children " " " "
RIDLT	hrs	total " " " "
FERLM	hrs	male/farmer's labor for fertilization
FERLF	hrs	female " " " "
FERLC	hrs	children " " " "
FERLT	hrs	total " " " "
SPRLM	hrs	male/farmer's labor for spraying
SPRLF	hrs	female " " " "
SPRLC	hrs	children " " " "
SPRLT	hrs	total " " " "
HARLM	hrs	male/farmer's labor for harvesting
HARLF	hrs	female " " " "
HARLC	hrs	children " " " "
HARLT	hrs	total " " " "
TRNLM	hrs	male/farmer's labor for transport
TRNLF	hrs	female " " " "

FARM17 cont.

Variables	Units	Description
TRNLC	hrs	children " " " "
TRNLT	hrs	total " " " "
DEF1M	hrs	hired labor, male, for land clearing
DEF2F	hrs	" , female " " "
DEF3C	hrs	" ,children " " "
DEFSL	hrs	total hired labor, " " "
PRE1M	hrs	male hired labor for soil preparation
PRE2F	hrs	female " " " "
PRE3C	hrs	children " " " "
PRESL	hrs	total " " " "
PL11M	hrs	male hired labor for first planting
PL12F	hrs	female " " " "
PL1SL	hrs	total " " " "
PL21M	hrs	male hired labor for second planting
PL22F	hrs	female " " " "
PL23C	hrs	children " " " "
PL2SL	hrs	total " " " "
WD11M	hrs	male hired labor for first weeding
WD12F	hrs	female " " " "
WD13C	hrs	children " " " "
WD1SL	hrs	hired " " " "
WD21M	hrs	male hired labor for second weeding
WD22F	hrs	female " " " "
WD23C	hrs	children " " " "
WD2SL	hrs	total " " " "
RID1M	hrs	male hired labor for ridging per crop
RID2F	hrs	female " " " "

FARM17 cont.

Variables	Units	Description
RID3C	hrs	children " " " "
RIDSL	hrs	total " " " "
FER11M	hrs	male hired labor for fertilization
FER12F	hrs	female " " " "
FER13C	hrs	children " " " "
FER1SL	hrs	total " " " "
HAR1M	hrs	male hired labor for harvesting
HAR2F	hrs	female " " " "
HAR3C	hrs	children " " " "
HARSL	hrs	total " " " "
TRN1M	hrs	male hired labor for transport
TRN2F	hrs	female " " " "
TRN3C	hrs	children " " " "
TRNSL	hrs	total " " " "
JD1	number	days after January first, Julian date for land clearing
JD2	number	Julian date for soil preparation
JD3	number	Julian date for first planting
JD4	number	Julian date for second planting
JD5	number	Julian date for first weeding
JD6	number	Julian date for harvesting
JD7	number	Julian date for ridging
JD8	number	Julian date for fertilization
JD9	number	Julian date for second weeding
JD10	number	Julian date for transport
JD11	number	Julian date for spraying

B. Regression Analysis of Yields

1. Purpose and Description of Methods

Farm observations in this study included those using traditional technologies, those using the extension techniques and varieties, and those using SAFGRAD techniques and varieties. Crops studied included maize, cotton, groundnut, red sorghum, white sorghum, transplant sorghum (muskwari), and cowpea. (Maize experiments for SAFTEC for 1986 were not used in the regression analysis because first year results for new technologies were less successful.)

The purpose of regression analysis is to measure the separate the effects of technology, planting date, and soil on yields. For example, below we discuss maize to demonstrate the methodology.

New varieties for maize include Mexican 17E (a traditional long-cycle variety in widespread current use), TZPB-K81 (a long-cycle variety recommended by the Extension Service in North Cameroon), and CMS8501 (a short-cycle variety developed by SAFGRAD). The technologies compared for maize are: improved practices combined with use of fertilizer (from 75 to 105 kg/ha of nitrogen); improved practices and fertilizer combined with simple ridges (RID); and improved practices, fertilizer, and ridges tied at 2m (RIDGE).

Improved practices include lower planting density (62,000 plants/ha.), thinning plants to 1-2 plant/hill, weeding twice, seed treatment, and fertilization in two doses at planting or weeding.

Planting date is also a management technique. Because of labor scarcity during normal planting periods, labor constraints can be eased by staggering planting activities. However, yield penalties can be associated with planting early, eg. if early planting is followed by poor rainfall. By delaying planting, there may also be penalties because some yield is foregone if weather was good before planting, but with good enough weather, plants may "catchup".

Since weather-technology and weather-soil interactions may be different for different weather patterns, farm yield observations for each type of weather are regressed separately as functions of technology choices, planting dates and soil. Section C defines the weather classification method and probabilities of each for two agroclimatic regions of Cameroon.

To determine how yield is affected by technology for weather state ω, regressions are of the form:

$$(1) \qquad y^{\omega}_{ik} = y^{\omega}_{io} + \sum_{\ell} \alpha^{\omega}_{i\ell} D_{i\ell} + \alpha^{\omega}_{is} D_S + \epsilon^{\omega}_{ik}.$$

y^{ω}_{io}, the constant term, is the yield for average farmer with the traditional technology in weather state ω. $D_{i\ell}$ denotes a dummy variable indicating a nontraditional technology choice; a value of one means that the technology is applied whereas a value of zero means it is not applied: D_S indicates a dummy variable for soil type, a value of zero or one differentiates between soil types. The coefficient $(\alpha^{\omega}_{i\ell})$ of a factor (ℓ) tells how the application of a new technology will affect yield for the average farmer for weather state ω. By assumption the error term for the regression (ϵ^{ω}_{ik}) has a normal distribution with mean zero. The expected value of y^{ω}_{ik} in (1), taken over all farmers, is the yield $\bar{y}^{\omega}_{i}$ for the average farmer in weather state ω with the specified technology.

The method of moments is used because the error term in (1) does not satisfy the requirements of ordinary least squares. That is, the residual t is affected by weather and technologies. To emplement the method of moments, the squared residual obtained in (1) is regressed against the same explanatory variables in (1). The squared residual regression is of the form

(2) $$SR^{\omega}_{ik} = V^{\omega}_{io} + \Sigma\beta^{\omega}_{i\ell} D_{i\ell} + \beta^{\omega}_{is} D_s + \eta^{\omega}_{ik}$$

where the squared residual $SR^{\omega}_{ik} = (\epsilon^{\omega}_{ik})^2$. V^{ω}_{io} is the squared residual for the traditional technology and η^{ω}_{ik} is the error term. $\beta^{\omega}_{i\ell}$ shows how a technology (ℓ) affects the residual for weather state ω.

The method of moments then uses the standard error regresssion (2) to "correct" the regression (1) so that the error term in (1) will satisfy the assumptions of OLS. To do this, generalized least squares is used in which each observation is multiplied by the inverse of the square root of the corresponding squared residual.

Data obtained from SAFGRAD on-farm trials were analyzed using the regression techniques described above. Shown below are both the generalized least square results and the standard error regressions used to correct the initial OLS results. Separate regressions are presented for each of the three weather patterns to capture the interaction between technologies and weather.

The results for maize are described here to demonstrate interpretation of the methodology. The constant term in the yield regression is the yield for the average farmer with traditional technology, with weather held constant at the indicated level. Note that the traditional yield for maize increases as the weather improves. The effects of new technologies, planting date, and soil on yield are indicated by the coefficients of the corresponding dummy variables. Effects of combinations of technologies are obtained by adding the corresponding dummy variables.

Use of improved agronomic practices for maize increases the average yield from 1331 kg/ha to 2401 kg/ha for the driest rainfall pattern, but has no significant effect for other weather patterns. Use of low fertilizer in addition to improved practices increases yield to 4215 kg/ha in the driest weather. If the new variety CMS8501 was used in addition to improved practices and fertilizer in the driest weather, then yield was increased to 4726 kg/ha. No other technique had a significant effect on yield in the driest weather.

For intermediate weather, high fertilizer plus the new variety (TZPB) increases yield from the level of 2046 kg/ha with new technologies to 4590 kg/ha. For wet weather, yield increases from 2507 kg/ha to 4680 kg/ha by use of fertilizer, high fertilizer, and TZPB.

There were few observations of early planting in the data set; the indicated insignificant effect may not represent true effects. Planting late was shown to have a significant negative effect for intermediate weather. Soil type has a significant effect only for intermediate rainfall conditions for which yield is increased by having sandy soils.

The new varieties tested for maize have differing effects by weather pattern. TZPB significantly increases yield for intermediate rainfall conditions whereas CMS8501 increases yield for low rainfall conditions.

2. Regression Analysis

The data for the regressions come from the combination of data from FARMW and SAFTEC data files. A separate file was used for each crop (as described in Appendix B. Dummy variables were used to define treatment levels corresponding to experiments with yields in the SAFTEC file. Table B.1 shows the dummy variables for each experiment for maize. Tables 1.1 - 8.2 show the regressions for each crop.

Table B.1. Regression Dummy Variables for Maize Technology Experiments

Name	Variety	DFH	DFL	RID	RIDGE	DIP**
TRAD	mixed	0	0	0	0	0
M25	MEX .17	0	1 (manure)	1	0	1
MR25	MEX .17	0	1 (crop residue)	1	0	1
M100	MEX .17	1	0	1	0	1
M5T	MEX .17	0	0 (very low)	1	0	1
MFPR	MEX .17	0	0	1 (very simple)	0	0
MFLOT	MEX .17	1	0	0	0	1
MRID	mixed	1	0	1	0	1
M2RM	MEX .17	1	0	0	1	1
M3RM	MEX .17	1	0	0	1	1
MAX17	MEX .17	1	0	1	0	1
CMS501	CMS8501	1	0	1	0	1
TZPB	TZPB	1	0	1	0	1

**Plant 62,000 plants, 80 x 20 cm.

If fertilizer, use two does.

Thin to 1-2 plants/hill

Table 1.1 Effects by Weather, Red Sorghum Yield (kg/ha)

	Dry Weather		Inter. Weather		Wet Weather	
VARIABLE	Coeff	t-value	Coeff	t-value	Coeff	t-value
INTERCEP	1354.35	7.986	2155.93	7.251	3218	12.433
DE	-721.96	-3.870	-89.64	-0.368	.	.
DL	-217.43	-0.637	-964.64	-3.069	.	.
SD	554.75	3.190	-80.15	-0.268	.	.
R-SQUAR		0.241		0.373		
N-OBS		70		62		9

Table 1.2 Effects by Weather, Red Sorghum Residual

	Dry Weather		Inter. Weather		Wet Weather	
VARIABLE	Coeff	t-value	Coeff	t-value	Coeff	t-value
INTERCEP	634725	4.043	1119033	2.994	602916	1.715
DE	-433419	-2.366	-17973	-0.049	.	.
DL	461494	1.655	-973649	-2.374	.	.
SD	13126	0.072	-574872	-1.566	.	.
R-SQUAR		0.1887		0.1068		
N-OBS		70		62		9

Definition of Regression Variables for Red Sorghum:

DE - a dummy variable value of one indicates red sorghum planting before May 30.

DL - a dummy variable value of one indicates red sorghum planting after June 20.

SD - a dummy variable value of one indicates sandy soil (as opposed to clayey soil).

Table 2.1 Effects by Weather, Cotton Yield (kg/ha)

	Dry Weather		Inter. Weather		Wet Weather	
VARIABLE	Coeff	t-value	Coeff	t-value	Coeff	t-value
INTERCEP	1041.29	11.348	1305.00	16.228	1261.49	7.299
DE	-438.84	-1.869	-208.07	-1.185	-336.72	-1.751
DL	137.72	0.981	-506.04	-1.438	.	.
SD	-28.44	-0.254	172.11	1.107	705.71	3.184
DF	1223.67	9.502	1256.10	10.019	1175.45	6.606
R-SQUAR		0.595		0.6437		0.7822
N-OBS		73.000		80		19

Table 2.2 Effects by Weather, Cotton Residual

	Dry Weather		Inter. Weather		Wet Weather	
VARIABLE	Coeff	t-value	Coeff	t-value	Coeff	t-value
INTERCEP	83430	0.95	129204	1.85	91176	1.092
DE	-304818	-1.598	-69265	-0.435	-126503	-1.355
DL	94977	0.829	-194856	-0.919	.	.
SD	35497	0.356	358833	3.844	55682	0.553
DF	316951	3.225	116744	1.198	69025	0.854
R-SQUAR		0.1611		0.2177		0.1784
N-OBS		73		80		19

Definition of Regression Variables for Cotton:

DE - a dummy variable value of one indicates cotton planting before May 30.
DL - a dummy variable value of one indicates cotton planting after June 20.
SD - a dummy variable value of one indicates sandy soil (as opposed to clayey soil).
DF - a dummy variable value of one indicates fertilizer use.

Table 4.1 Effects by Weather, Groundnut Yield (kg/ha)

VARIABLE	Dry Weather Coeff	Dry Weather t-value	Inter. Weather Coeff	Inter. Weather t-value	Wet Weather Coeff	Wet Weather t-value
INTERCEP	1026.75	10.365	2060.19	12.167	2269.02	9.700
SD	-168.00	-1.467	332.95	1.371	1123.22	2.801
DE	70.46	0.609	-242.37	-0.683	-685.68	-2.435
DL	-57.85	-0.400	-500.13	-2.019	-637.83	-1.654
DK1	.	.	795.68	3.350	981.98	2.510
D28	.	.	844.37	3.826	789.73	2.289
R-SQUAR		0.041		0.3052		0.5942
N-OBS		66		97		42

Table 4.2 Effects by Weather, Groundnut Residual

VARIABLE	Dry Weather Coeff	Dry Weather t-value	Inter. Weather Coeff	Inter. Weather t-value	Wet Weather Coeff	Wet Weather t-value
INTERCEP	296556	5.782	561614	2.34	701226	3.958
SD	-159233	-2.508	558889	2.199	-367514	-1.448
DE	-94517	-1.142	-469067	-1.374	-522590	-2.474
DL	-100637	-0.951	-604087	-2.912	-38440	-0.16
DK1	.	.	-237989	-0.819	-322578	-1.239
D28	.	.	-393078	-1.353	-539430	-2.073
R-SQUAR		0.1337		0.1874		0.1842
N-OBS		66		97		42

Definition of Regression Variables for Groundnut:

- DE - a dummy variable value of one indicates groundnut planting before May 30.
- DL - a dummy variable value of one indicates groundnut planting after June 20.
- DK1 - a dummy variable value of one indicates use of new variety GK1.
- D28 - a dummy variable value of one indicates use of new variety G28.
- SD - a dummy variable value of one indicates sandy soil (as opposed to clayey soil).

Table 6.1 Effects by Weather, Cowpea Yield (kg/ha)

	Dry Weather		Inter. Weather		Wet Weather	
VARIABLE	Coeff	t-value	Coeff	t-value	Coeff	t-value
INTERCEP	760.00	5.438	2600.00	13.386	2640.00	16.682
DVX3	379.00	1.248	-1611.71	-6.651	-929.50	-4.241
DVYA	267.00	1.130	-1585.71	-6.343	-1161.50	-4.235
R-SQUAR		0.1825		0.7766		0.8086
N-OBS		13		18		9

Table 6.2 Effects by Weather, Cowpea Residual

	Dry Weather		Inter. Weather		Wet Weather	
VARIABLE	Coeff	t-value	Coeff	t-value	Coeff	t-value
INTERCEP	96457	2.156	120000	1.864	102400	2.359
DVX3	149058	1.825	-6228	-0.077	-88594	-1.091
DVYA	-35308	-0.432	38550	0.478	-36608	-0.451
R-SQUAR		0.3048		0.0305		0.166
N-OBS		13		18		9

Definition of Regression Variables for Cowpea:

DVX3 - a dummy variable value of one indicates use of new variety CVX3.
DVYA - a dummy variable value of one indicates use of new variety CYVA.

Table 5 Maskwari Yield (kg/ha) and Residual

	Dry Weather	Normal Weather	Wet Weather
Yield	1389.63	2146.15	.
Residual	39801.23	613784.6	.
N-OBS	9	26	.

Table 8.1 Effects by Weather, White Sorghum Yield (kg/ha)

	Dry Weather		Inter. Weather		Wet Weather	
VARIABLE	Coeff	t-value	Coeff	t-value	Coeff	t-value
INTERCEP	406.67	0.748	1294.35	7.343	1933.33	2.573
DV	986.04	4.091	984.23	3.44	0.00	.
DL	73.33	0.178	-584.20	-1.595	0.00	.
SD	393.33	0.957	-609.87	-1.853	0.00	.
R-SQUAR		0.7644		0.3679		
N-OBS		13		30		2

Table 8.2 Effects by Weather, White Sorghum Residual

	Dry Weather		Inter. Weather		Wet Weather	
VARIABLE	Coeff	t-value	Coeff	t-value	Coeff	t-value
INTERCEP	-32088.89	-0.121	331230.10	4.006	1128888.89	.
DV	98495.85	0.837	140306.29	1.045	.	.
DL	32088.89	0.16	-399468.86	-2.325	.	.
SD	32088.89	0.16	30026.72	0.194	.	.
R-SQUAR		0.1265		0.2026		
N-OBS		13		30		2

Definition of Regression Variables for White sorghum:

- DV – a dummy variable value of one indicates use of new variety.
- DL – a dummy variable value of one indicates white sorghum planting after June 20.
- SD – a dummy variable value of one indicates sandy soil (as opposed to clayey soil).

Appendix B: CROP databases

<u>CROP1</u> (Red Sorghum; traditional only)

Variables	Units	Description
Year	1986-88	year of data collection
Sect	1-6	sector or locations of selected sites 1- Pitoa; 2- Bibemi; 3- Bould-Ibib; 4- Hamakousson; 5- Djalingo; 6- Hgoug
Farm	1-25	farmer's identification number
Areal	ha	area of red sorghum planted
Yieldl	kg/ha	yield of red sorghum per ha
WP	11, 13, 23	index of weather pattern 11- rainfall is low in both early and later growing period 13- rainfall is low in early and high in later growing period 23- rainfall is average in early and high in later growing period
SD	0 or 1	a dummy variable value of soil type 1- sandy soil; 0- clayey soil
DE	0 or 1	a dummy variable value. 1- red sorghum planted befor May 30; 0- red sorghum planted after May 30;
DN	0 or 1	a dummy variable value. 1- red sorghum planted during May 31 to June 20; 0- red sorghum planted before May 31 or after June 20
DL	0 or 1	a dummy variable value. 1- red sorghum

		planted after June 20; 0- red sorghum planted befor June 20;
PL1A1	1 to 31	date of red sorghum planted
PL1B1	1 to 12	month of red sorghum planted
QTIT1	kg	quantity of red sorghum harvested

CROP2 (cotton, traditional and improved practices)

Variables	Units	Description
Year	1986-88	year of data collection
Sect	1-6	sector or locations of selected sites 1- Pitoa; 2- Bibemi; 3- Bould-Ibib; 4- Hamakousson; 5- Djalingo; 6- Hgoug
Farm	1-25	farmer's identification number
Area2	ha	area of cotton planted
Yield2	kg/ha	yield of cotton per ha
WP	11 13 23	index of weather pattern 11- rainfall is low in both early and later growing period 13- rainfall is low in early and high in later growing period 23- rainfall is average in early and high in later growing period
SD	0 or 1	a dummy variable value for soil type 1- sandy soil; 0- clayey soil
DE	0 or 1	a dummy variable value. 1- cotton planted befor May 30; 0- cotton planted after May 30;
DN	0 or 1	a dummy variable value. 1- cotton planted during May 31 to June 20; 0- red sorghum planted befor May 31 or after June 20;

DL	0 or 1	a dummy variable value. 1- cotton planted after June 20; 0- cotton planted befor June 20;
DF	0 or 1	a dummy variable value for using fertilizer and improved practices. 1- fertilizer and improved practices used; 0- traditional practices
PL1A2	1 to 31	date of cotton planted
PL1B2	1 to 12	month of cotton planted
QTIT2	kg	quantity of cotton harvested

CROP3 (maize)

Variables	Units	Description
Year	1986-88	year of data collection
Sect	1-6	sector or locations of selected sites 1- Pitoa; 2- Bibemi; 3- Bould-Ibib; 4- Hamakousson; 5- Djalingo; 6- Hgoug
Farm	1-25	farmer's identification number
Area3	ha	area of maize planted
Yield3	kg/ha	yield of maize per ha
NAME		name of experiments
WP	11 13 23	index of weather pattern 11- rainfall is low in both early and later growing period 13- rainfall is low in early and high in later growing period 23- rainfall is average in early and high in later growing period
SD	0 or 1	a dummy variable value for soil type 1- sandy soil; 0- clayey soil
DE	0 or 1	a dummy variable value. 1- maize planted befor May 30; 0- maize planted after May 30
DN	0 or 1	a dummy variable value. 1- maize planted during May 31 to June 20; 0- maize planted befor May 31 or after June 20

DL	0 or 1	a dummy variable value. 1- maize planted after June 20; 0- maize planted befor June 20
DFL	0 or 1	a dummy variable value for using low fertilizer. 1- fertilizer was used less then 75 kg/ha; 0- fertilizer was not used or used more then 75 kg/ha
DFH	0 or 1	a dummy variable value for using high fertilizer. 1- fertilizer was used more then 75 kg/ha; 0- fertilizer was not used or used less then 75 kg/ha
RID	0 or 1	a dummy variable value for using rideges. 1- rideges were applied; 0- rideges were not applied
RIDGE	0 or 1	a dummy variable value for using tied rideges. 1- tied rideges were applied; 0- tied rideges were not applied
DIP	0 or 1	a dummy variable value for improved practices such as density of planting, weeding, and time of fertilizing. 1- improved pratices; 0- no improved pratices
DTZPB	0 or 1	a dummy variable value for usin new variety TAPB. 1- new variety TZPB was used; 0- new variety TZPB was not used

DCMS	0 or 1	a dummy variable value for using new variety CMS8501. 1- new variety CMS8501 was used; 0- new variety CMS8501 was not used
PPL1A3	1 to 31	date of maize planted
PL1B3	1 to 12	month of maize planted

CROP4 (Groundnut, traditional and improved)

Variables	Units	Description
Year	1986-88	year of data collection
Sect	1-6	sector or locations of selected sites 1- Pitoa; 2- Bibemi; 3- Bould-Ibib; 4- Hamakousson; 5- Djalingo; 6- Hgoug
Farm	1-25	farmer's identification number
Area4	ha	area of groundnut planted
Yield4	kg/ha	yield of groundnut per ha
NAME		name of experiments
WP	11 13 23	index of weather pattern 11- rainfall is low in both early and later growing period 13- rainfall is low in early and high in later growing period 23- rainfall is average in early and high in later growing period
SD	0 or 1	a dummy variable value of soil type 1- sandy soil; 0- clayey soil
DE	0 or 1	a dummy variable value. 1- groudnut planted befor May 30; 0- groundnut planted after May 30;
DN	0 or 1	a dummy variable value. 1- groundnut planted during May 31 to June 20; 0- groundnut planted befor May 31 or after June 20;

DL	0 or 1	a dummy variable value. 1- groundnut planted after June 20; 0- groundnut planted befor June 20;
DK1	0 or 1	a dummy variable value for using new variety GK1. 1- new variety GK1 was used; 0- new variety GK1 was not used
D28	0 or 1	a dummy variable value for using new variety G28. 1- new variety G28 was used; 0- new variety G28 was not used
PL1A4	1 to 31	date of groundnut planted
PL1B4	1 to 12	month of groundnut planted
QTIT4	kg	quantity of groundnut harvested

CROP5 (Muskwari, traditional)

Variables	Units	Description
Year	1986-88	year of data collection
Sect	1-6	sector or locations of selected sites 1- Pitoa; 2- Bibemi; 3- Bould-Ibib; 4- Hamakousson; 5- Djalingo; 6- Hgoug
Farm	1-25	farmer's identification number
Area5	ha	area of maskwari planted
Yield5	kg/ha	yield of maskwari per ha
WP	11 13 23	index of weather pattern 11- rainfall is low in both early and later growing period 13- rainfall is low in early and high in later growing period 23- rainfall is average in early and high in later growing period
SD	0 or 1	a dummy variable value of soil type 1- sandy soil; 0- clayey soil
PL1A5	1 to 31	date of maskwari planted
PL1B5	1 to 12	month of maskwari planted
QTIT5	kg	quantity of maskwari harvested

CROP6 (Cowpeas, traditional and improved)

Variables	Units	Description
Year	1986-88	year of data collection
Sect	1-6	sector or locations of selected sites 1- Pitoa; 2- Bibemi; 3- Bould-Ibib; 4- Hamakousson; 5- Djalingo; 6- Hgoug
Farm	1-25	farmer's identification number
Area6	ha	area of cowpea planted
Yield6	kg/ha	yield of cowpea per ha
NAME		name of experiments
WP	11 13 23	index of weather pattern 11- rainfall is low in both early and later growing period 13- rainfall is low in early and high in later growing period 23- rainfall is average in early and high in later growing period
SD	0 or 1	a dummy variable value of soil type 1- sandy soil; 0- clayey soil
DVX3	0 or 1	a dummy variable value for using new variety CVX3. 1- new variety CVX3 was used; 0- new variety CVX3 was not used
DVYA	0 or 1	a dummy variable value for using new variety CVYA. 1- new variety CVYA was used; 0- new variety CVYA was not used
PL1A6	1 to 31	date of cowpea planted
PL1B6	1 to 12	month of cowpea planted
QTIT6	kg	quantity of cowpea harvested

CROP8 (White sorghum, traditional and new varieties)

Variables	Units	Description
Year	1986-88	year of data collection
Sect	1-6	sector or locations of selected sites 1- Pitoa; 2- Bibemi; 3- Bould-Ibib; 4- Hamakousson; 5- Djalingo; 6- Hgoug
Farm	1-25	farmer's identification number
Area8	ha	area of white sorghum planted
Yield8	kg/ha	yield of white sorghum per ha
NAME		name of experiments
WP	11 13 23	index of weather pattern 11- rainfall is low in both early and later growing period 13- rainfall is low in early and high in later growing period 23- rainfall is average in early and high in later growing period
SD	0 or 1	a dummy variable value of soil type 1- sandy soil; 0- clayey soil
DN	0 or 1	a dummy variable value. 1- white sorghum planted during May 31 to June 20, 1- white sorghum planted befor May 31 or after June 20
DL	0 or 1	a dummy variable value. 1- white sorghum planted after June 20; 0- white sorghum planted befor June 20

DV	0 or 1	a dummy variable value for using new varieties. 1- new variety was used; 0- new variety was not used
PL1A8	1 to 31	date of white sorghum planted
PL1B8	1 to 12	month of white sorghum planted
QTIT8	kg	quantity of white sorghum harvested

C. Weather Patterns

1. Definition of Weather Categories

Above, yield effects of technologies were described by weather condition. Alternative weather conditions were classified as being "dry", "intermediate", and "wet" in terms of rainfall for critical periods of the growing season. To develop this weather classification, early season was represented by cumulative rainfall for the period from April/May to June 10 and mid-season weather was represented by cumulative rainfall through July 20. Rainfall patterns for the two periods were then grouped as shown below, to designate "low", "medium", and "high" rainfall conditions.

Growing Period Rainfall (mm)

Early (before June 10)		Later (before July 20)	
low	≤ 150	low	≤ 250
medium	151 - 230	medium	251 - 350
high	≥ 231	high	≥ 351

Classsification of Rainfall Conditions
as Related to Early/Later Rainfall

dry:	low/low; low/medium; medium/low
intermediate:	medium/medium; low/high; high/low
wet:	high/high; medium/high; high/medium

2. Rainfall Data and Probabilities of Weather Conditions

As indicated elsewhere, the study area is divided into agroclimatic zones. Namely Sahelian, Sudan, Northern Guinea, Savanna zones, having annual rainfall of less 600, 600-800 and 800-1000 min/year respectively. The data file RAINHIST described below contains historical rainfall data for 1965 through 1988 for six representative sites. The rainfall sites selected are: Sector 9 - Yaguoua, Sector 2 - Bizdar, Sector 3 - Kaiele for the Sahelian-Sudan-Savanna, Sector 1 - Pitoa, Sector 4 - Hiramambak, and Sector 5 - Sanguere for the Guinea Savanna.

Sectors 2, 3, and 9 represent drier weather than sectors 4, 5, and 9.

To obtain probabilities for each of the two climatic regions for 1965-1988, probabilities of "dry", "intermediate", and "wet" conditions, were based on frequencies of the above conditions (see Table C.1). Region 1 includes sectors 1, 4, and 5 and Region 2 includes sectors 2, 3, and 9.

Probabilities of Rainfall Conditions by Weather Region.

	Dry	Intermediate	Wet
Region 1:	.3055	.3472	.3472
Region 2:	.6528	.3194	.0278

Note that the probability distribution for rainfall conditions is not normal in either region. The distribution for region 2 is heavily skewed toward low rainfall, whereas for region 1, it is skewed toward medium to high rainfall conditions.

Table C.1. Calculation of Weather Probabilities by Region

weather pattern	Region 1 sect 1 freq.	sect 4 freq.	sect 5 freq.	prob.	Region 2 sect 2 freq.	sect 3 freq.	sect 9 freq.	prob.
ll	1	3	1	.0694	5	6	10	.2917
lm	5	6	4	.2083	6	10	10	.3611
lh	9	6	4	.2639	5	3	2	.1389
mm	1	1	3	.0694	2	2	0	.0555
ml	1	1	0	.0278	0	0	0	0
mh	2	3	5	.1389	4	0	1	.0139
hh	1	3	5	.1250	0	0	0	0
hm	4	0	2	.0833	0	3	1	.0139
hl	0	1	0	.0139	1	0	0	0

Appendix C. RAINHIST database

Name	Unit	Description
sect	1, 4, 5, 2, 3, 9	sectors-locations of rainfall observation sites from 1965 to 1988
month	1 to 12	month for which rainfall is recorded
decade	1, 2, 3	ten days interval
X65	mm	rainfall in millimeters for 1965
		"
		"
through		
		"
		"
		"
		"
		"
		"
		"
		"
		"
		"
		"
		"
		"
		"
X88		" for 1988

STAFF PAPER

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·46

DOCUMENTATION OF RESEARCH FOR FARMING SYSTEMS IN NORTHERN CAMEROON, 1986-1988

by

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Vol. II

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D. Optimization Modeling

Separate optimization models will be built for regions of different soil and weather, defined as follows:

type I: wetter weather/sandy soil (sector 1)

type II: wetter weather/clayey soil (sectors 4, 5, 6)

type III: dry weather/sandy soil (sectors 2, 3).

For a family size of about five in each type of area, acres planted in each crop were observed (see Table D.1). Not surprisingly, the agroclimatic area with the best conditions used the least land to meet family requirements! Actual cropping pattern are the basis for constraints in the optimization problem.

1. Activities, prices, and costs

Activities, or choice variables for optimization, are defined by acres planted in each crop/technology combination by planting date. Prices used for each crop are market prices in U.S. dollars; see Table D.2. The technology combinations and their variable costs per acre are given in Table D.3. These variable costs include seed, fertilizer, and other chemicals but exclude labor. Variable costs and prices were obtained from another part of the SAFGRAD study.

Six planting dates were available for each crop except muskwari. Maize variety CMS8501 had a later seventh period also available. Early, normal, and late planting dates by crop are listed in Table D.4.

2. Means and variances by crop/technology [to be inserted later]

3. Labor constraints

Labor constraints for each crop/technology were based on activities for each crop. For each activity, total labor spent by farm was averaged; primary data given in the data base FARM17. The labor by crop and activity is reported in Tables D.6. Oxen requirements are treated similar to labor requirements. Table D.7 reports periods for which labor is constrained and the number of hours available for family labor and oxen.

4. Other Constraints

Minimum consumption constraints per year are as follows for a family of five.

$Q_{\text{Red Sorghum}} \geq 520$ kg

$Q_{\text{Maize}} \geq 520$ kg

$Q_{\text{Cowpea}} + Q_{\text{Groundnut}} \geq 500$ kg

$Q_{\text{Muskwari}} + Q_{\text{White Sorghum}} > 600$ kg

Cash is also constrained; currently, credit repayment and cash needs are about $300; current income levels are about $1300. Land (up to 8 ha/farm) is available and is also restricted in terms of the crops which can be grown on different types of land:

45% good land - for maize and cotton

40% secondary land - suitable for cowpea, groundnut, and sorghum

15% available for muskwari where wet soils are present.

8. Preliminary Optimization Results

A preliminary optimization model of the expected utility form was run using MINOS. The form of the model is:

$$\underset{x_{ij}}{\text{Max}} \quad \Sigma u(\pi(x_{ij}); W_k) \rho_k$$

$$\pi^{\cdot} = \sum_{i,j} [p_i y_{ij}^k - vc_{ij}] x_{ij} - wL_h$$

$$A x \leq L_f + L_h$$

$$\sum_j y_{ij}^k x_{ij} \geq \bar{Q}_i, \text{ each crop i for each weather state k}$$

where B is the input-output matrix, x_{ij} is the acres planted in crop i and technology/planting date j, ρ_k is the probability of weather state k, $\pi^{\cdot}$ is profit in weather state k derived from the set of activities, y_{ij}^k is yield in weather k for crop i and technology/planting date j, L_f is family labor, and L_h is hired labor. $\bar{Q}$ is the minimum consumption vector. Yield for each crop/technology combination was predicted from the yield regression models. The form of the utility function used is

$$u(\pi) = -e^{-r\pi}$$

where r is the Pratt-Arrow risk aversion coefficient.

Preliminary results are attached for a farm in agroclimatic type I. Note that compared to the observed traditional cropping patterns, less red sorghum, no cotton, more groundnut, and much more maize is grown. Because of the restrictive cash constraint, mostly traditional practices are chosen.

Future research efforts will improve the model. A base case, in which new technologies are not available, should be defined in terms of constraints and risk aversion levels; this base case should be made to match the cropping patterns observed for traditional farms. Then, when new technologies are introduced, the same risk aversion levels and constraints as in the base case will be used. Other types of preference models, such as mean-variance and MOTAD, should also be tested to see the effects of these on technology recommendations. Other types of models will use the same constraints but the form of the objective function will change.

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Table 3. Optimum Solution for Farming Decision

ACTIVITY	UNIT	OPTIMUM SOLUTION RISK-0.0005	OPTIMUM SOLUTION RISK-0.0007	OPTIMUM SOLUTION RISK-0.0009
NET REVENUE /DRY WEATHER	S	4908.61	4950.89	4955.85
NET REVENUE /NORMAL WEATHER	S	10113.23	9570.34	9463.91
NET REVENUE /WET WEATHER	S	9029.61	8838.97	8799.60
GROUDNUT-D28 PLANT MAY 10	ha	1.28		
GROUDNUT-D28 PLANT MAY 30	ha	0.18	[illegible]6	1.46
MAIZE-TZPB PLANT JUNE 10	ha	0.12	0.02	
TRAD-MAIZE PLANT JUNE 20	ha	0.70	2.38	
TRAD-MAIZE PLANT JUNE 30	ha	2.28	0.70	2.40
RED SORGHUM PLANT JULY 10	ha	0.41	0.41	0.70
TRAD-COWPEA PLANT JULY 10	ha	0.90	0.56	0.41
COWPEA-TVX3236 PLANT JULY 10	ha			0.50
COWPEA-TVX3236 PLANT JULY 30	ha		0.34	0.05
MUSKWARI PLANT OCTOBER 30	ha	0.75	0.75	0.35
TOTAL PLANTING AREA	ha	6.62	6.62	0.75
AVERAGE NET REVENUE	S	8395.87	8154.10	6.62 / 8104.99

Table 4. The Constriants Activity and Showdown Price

OBJECTIVE VALUE	-32.2604107	CERTAINTY EQUIVALENCE	6867.82895
RISK COEFFICIENT	0.0005	EXPECTED NET REVENUE	8395.86796

CONSTRIANTS	STATE	ACTIVITY	SLACK AVTIVITY	LOWER LIMIT	UPPER LIMIT	DUAL ACTIVITY	SHOWDOWN PRICE
LAND FERTILE	UL	3.10	0.00	NONE	3.10	0.77	48.57
LAND LESSFERTILE	UL	1.46	0.00	NONE	1.46	19.24	1814.41
LAND POOR & SANDY	UL	0.90	0.00	NONE	0.90	9.21	671.94
LAND WATER LOGGED	UL	0.75	0.00	NONE	0.75	16.99	1496.08
CASH FLOW	UL	300.00	0.00	NONE	300.00	0.10	5.97
LABOR 4/1-4/20	BS	34.46	48.04	NONE	82.50	0.00	0.00
LABOR 4/21-5/10	BS	176.87	103.63	NONE	280.50	0.00	0.00
LABOR 5/11-5/30	BS	72.38	208.12	NONE	280.50	0.00	0.00
LABOR 5/31-6/20	UL	297.00	0.00	NONE	297.00	0.02	1.09
LABOR 6/21-7/20	UL	429.00	0.00	NONE	429.00	0.02	1.04
LABOR 7/21-8/20	BS	116.46	329.04	NONE	445.50	0.00	0.00
LABOR 8/21-9/30	BS	398.99	178.51	NONE	577.50	0.00	0.00
LABOR 10/1-11/10	BS	416.46	161.04	NONE	577.50	0.00	0.00
LABOR 11/11-12/20	BS	382.28	178.72	NONE	561.00	0.00	0.00
LABOR 12/21-3/21	BS	112.80	629.70	NONE	742.50	0.00	0.00
RED SORGHUM SUBSISTENCE/DRY	BS	199.09	-43.09	156.00 *	NONE	0.00	0.00
RED SORGHUM SUBSISTENCE/NORMAL	LL	156.00	0.00	156.00 *	NONE	0.00	0.00
RED SORGHUM SUBSISTENCE/WET	BS	388.55	-232.55	156.00 *	NONE	0.00	0.00
GRUNDNUT+COWPEA SUBSISTENCE/DRY	BS	2786.94	-2372.94	414.00 *	NONE	0.00	0.00
GRUNDNUT+COWPEA SUBSISTENCE/NOM	BS	6511.22	-6097.22	414.00 *	NONE	0.00	0.00
GRUNDNUT+COWPEA SUBSISTENCE/WET	BS	5501.54	-5087.54	414.00 *	NONE	0.00	0.00
MAIZE SUBSISTENCE/DRY	BS	1375.64	-1195.64	180.00 *	NONE	0.00	0.00
MAIZE SUBSISTENCE/NORMAL	BS	2446.89	-2266.89	180.00 *	NONE	0.00	0.00
MAIZE SUBSISTENCE/WET	BS	2373.01	-2193.01	180.00 *	NONE	0.00	0.00
MUSKWARI SUBSISTENCE/DRY	BS	746.04	-520.04	226.00 *	NONE	0.00	0.00
MUSKWARI SUBSISTENCE/NORMAL	BS	1155.13	-929.13	226.00 *	NONE	0.00	0.00
MUSKWARI SUBSISTENCE/WET	BS	1155.05	-929.05	226.00 *	NONE	0.00	0.00

* dollar values (times price)

Table 4. The Constriants Activity and Showdown Price (continue)

OBJECTIVE VALUE	-3.72700372	CERTAINTY EQUIVALENCE	6213.5007316
RISK COEFFICIENT	0.0009	EXPECTED NET REVENUE	8104.99268

CONSTRIANTS		STATE	ACTIVITY	SLACK AVTIVITY	LOWER LIMIT	UPPER LIMIT	DUAL ACTIVITY	SHOWDOWN PRICE
LAND FERTILE		UL	3.10	0.00	NONE	3.10	0.35	110.79
LAND LESSFERTILE		UL	1.46	0.00	NONE	1.46	3.83	4018.59
LAND POOR & SANDY		UL	0.90	0.00	NONE	0.90	1.80	732.61
LAND WATER LOGGED		UL	0.75	0.00	NONE	0.75	3.28	2348.34
CASH FLOW		UL	300.00	0.00	NONE	300.00	0.02	6.47
LABOR 4/1-4/20		BS	34.46	48.04	NONE	82.50	0.00	0.00
LABOR 4/21-5/10		BS	38.39	242.11	NONE	280.50	0.00	0.00
LABOR 5/11-5/30		BS	200.42	80.08	NONE	280.50	0.00	0.00
LABOR 5/31-6/20		UL	297.00	0.00	NONE	297.00	0.00	0.09
LABOR 6/21-7/20	A	UL	429.00	0.00	NONE	429.00	0.00	0.00
LABOR 7/21-8/20		BS	199.33	246.17	NONE	445.50	0.00	0.00
LABOR 8/21-9/30		BS	311.21	266.29	NONE	577.50	0.00	0.00
LABOR 10/1-11/10		BS	417.27	160.23	NONE	577.50	0.00	0.00
LABOR 11/11-12/20		BS	382.56	178.44	NONE	561.00	0.00	0.00
LABOR 12/21-3/21		BS	112.80	629.70	NONE	742.50	0.00	0.00
RED SORGHUM SUBSISTENCE/DRY		BS	199.09	-43.09	156.00000	NONE	0.00	0.00
RED SORGHUM SUBSISTENCE/NORMAL	A	LL	156.00	0.00	156.00000	NONE	0.00	0.00
RED SORGHUM SUBSISTENCE/WET		BS	388.55	-232.55	156.00000	NONE	0.00	0.00
GRUNDNUT+COWPEA SUBSISTENCE/DRY		BS	2899.18	-2485.18	414.00000	NONE	0.00	0.00
GRUNDNUT+COWPEA SUBSISTENCE/NOM		BS	5961.35	-5547.35	414.00000	NONE	0.00	0.00
GRUNDNUT+COWPEA SUBSISTENCE/WET		BS	5305.79	-4891.79	414.00000	NONE	0.00	0.00
MAIZE SUBSISTENCE/DRY		BS	1310.63	-1130.63	180.00000	NONE	0.00	0.00
MAIZE SUBSISTENCE/NORMAL		BS	2347.43	-2167.43	180.00000	NONE	0.00	0.00
MAIZE SUBSISTENCE/WET		BS	2338.75	-2158.75	180.00000	NONE	0.00	0.00
MUSKWARI SUBSISTENCE/DRY		BS	746.04	-520.04	226.00000	NONE	0.00	0.00
MUSKWARI SUBSISTENCE/NORMAL		BS	1155.13	-929.13	226.00000	NONE	0.00	0.00
MUSKWARI SUBSISTENCE/WET		BS	1155.05	-929.05	226.00000	NONE	0.00	0.00

Table 4. The Constriants Activity and Showdown Price (continue)

OBJECTIVE VALUE	-10.6893057	CERTAINTY EQUIVALENCE	6483.5878549
RISK COEFFICIENT	0.0007	EXPECTED NET REVENUE	8[illegible]54.0995

CONSTRIANTS	STATE	ACTIVITY	SLACK AVTIVITY	LOWER LIMIT	UPPER LIMIT	DUAL ACTIVITY	SHOWDOWN PRICE
LAND FERTILE	UL	3.10	0.00	NONE	3.10	0.35	48.11
LAND LESSFERTILE	UL	1.46	0.00	NONE	1.46	8.36	2175.08
LAND POOR & SANDY	UL	0.90	0.00	NONE	0.90	3.78	622.97
LAND WATER LOGGED	UL	0.75	0.00	NONE	0.75	7.56	1753.72
CASH FLOW	UL	300.00	0.00	NONE	300.00	0.04	5.98
LABOR 4/1-4/20	BS	34.46	48.04	NONE	82.50	0.00	0.00
LABOR 4/21-5/10	BS	38.12	242.38	NONE	280.50	0.00	0.00
LABOR 5/11-5/30	BS	200.73	79.77	NONE	280.50	0.00	0.00
LABOR 5/31-6/20	UL	297.00	0.00	NONE	297.00	0.01	0.89
LABOR 6/21-7/20	UL	429.00	0.00	NONE	429.00	0.01	0.82
LABOR 7/21-8/20	BS	198.71	246.79	NONE	445.50	0.00	0.00
LABOR 8/21-9/30	BS	315.12	262.38	NONE	577.50	0.00	0.00
LABOR 10/1-11/10	BS	417.14	160.36	NONE	577.50	0.00	0.00
LABOR 11/11-12/20	BS	382.52	178.48	NONE	561.00	0.00	0.00
LABOR 12/21-3/21	BS	112.80	629.70	NONE	742.50	0.00	0.00
RED SORGHUM SUBSISTENCE/DRY	BS	199.09	-43.09	156.00000	NONE	0.00	0.00
RED SORGHUM SUBSISTENCE/NORMAL	LL	156.00	0.00	156.00	NONE	0.00	0.00
RED SORGHUM SUBSISTENCE/WET	BS	388.55	-232.55	156.00000	NONE	0.00	0.00
GRUNDNUT+COWPEA SUBSISTENCE/DRY	BS	2881.23	-2467.23	414.00000	NONE	0.00	0.00
GRUNDNUT+COWPEA SUBSISTENCE/NOM	BS	6049.28	-5635.28	414.00000	NONE	0.00	0.00
GRUNDNUT+COWPEA SUBSISTENCE/WET	BS	5337.10	-4923.10	414.00000	NONE	0.00	0.00
MAIZE SUBSISTENCE/DRY	BS	1323.62	-1143.62	180.00000	NONE	0.00	0.00
MAIZE SUBSISTENCE/NORMAL	BS	2365.93	-2185.93	180.00000	NONE	0.00	0.00
MAIZE SUBSISTENCE/WET	BS	2346.82	-2166.82	180.00000	NONE	0.00	0.00
MUSKWARI SUBSISTENCE/DRY	BS	746.04	-520.04	226.00000	NONE	0.00	0.00
MUSKWARI SUBSISTENCE/NORMAL	BS	1155.13	-929.13	226.00000	NONE	0.00	0.00
MUSKWARI SUBSISTENCE/WET	BS	1155.05	-929.05	226.00000	NONE	0.00	0.00

Table D.1 . Hectares in each crop, traditional farms for family size of five

	Type I	Type II	Type III
Red sorghum	.69	.69	.99
Cotton	.49	1.9	1.06
Maize	.44	1.01	.81
Groundnut	.25	.98	.52
Muskwari	.46	.56	.40
Cowpeas	.17	.37	.37
White sorghum	.46	.37	.37

Table D.2. Market Prices by crop

	Prices
Red sorghum	$.25
Cotton	.40
Maize	.30
Groundnut	.33
Muskwari	.32
Cowpeas	.37
White sorghum	.20

Table D.3 Variable costs for crop technologies

	Variable Cost ($/ha)
Red Sorghum	
Traditional (RST)	$ 16.67
Cotton	
Traditional (CT)	$107.17
Improved Practices (CP)	$187.90
Groundnut	
Traditional (GDT)	$ 50.00
Improved Variety (GK1)	81.97
(G28)	72.00
Muskwari	
Traditional (MSK)	7.20
Cowpeas	
Traditional (CPT)	20.67
Improved variety VYA (CPY)	55.17
TVY (CTV)	55.17
White Sorghum	
Traditional (WST)	16.67
Improved (WS35)	34.51
Maize	
Traditional (MZT)	50.67
MEX17 + Improved Practices + low fert. + Rid (MZ25)	76.97
(MEX17 + Improved Practices + high fert. + Rid (MRD)	162.13
TZPB + Improved Practices + high fert. (MZPF)	165.13
TZPB + Improved Practices + high fert. + Rid (MZPR)	165.13
CMS + Impr. Prac. + high fert. (MZ5F)	165.82
CMS + Improved Practices + high fert. + Rid (MZ5)	165.82
CMS + Improved Practices + high fert. + Ridge (MZ5R)	165.82

Table D.4. Planting dates for crops.

Crop	Planting Dates		
	Early	Normal	Late
Red sorghum	May 10	June 10	June 30
	May 30	June 20	July 10
Cotton	May 10	June 10	June 30
	May 30	June 20	July 10
Groundnut, traditional and improved	May 10	June 10	June 30
	May 30	June 20	July 10
Cowpeas, traditional and improved	--	July 10	--
	--	July 30	--
White sorghum, traditional	May 30	June 10	June 30
	--	June 20	--
White sorghum, improved	May 30	June 10	June 30
	--	June 20	July 10
Muskwari	--	October 1	--
Maize, traditional	May 10	June 10	June 30
	May 30	June 20	July 10
Maize, improved TZPB	May 10	June 10	June 30
	May 30	June 20	July 10
Maize, improved CMS8501	May 10	June 10	June 30
	May 30	June 20	July 10
	--	--	July 20

Table D.5. Cost of Hired Labor and Hired Oxen by constraint period

Period	rate ($/day) labor	oxen
April 1 - April 20	3.4	27.78
April 21 - May 10	4.2	27.78
May 11 - May 30	7.1	30.86
May 31 - June 20	12	30.86
June 21 - July 20	12	30.86
July 21 - August 20	12	27.78
August 20 - Sept. 30	7.1	19.21
Oct. 1 - Nov. 10	10	15.74
Dec. 21 - March 31	8	15.74

Table D.6.i Labor requirements for maize technologies

	Trad.	IZPB, CMS8501	Trad, low fert, Rid	Trad, high fert, Rid	Trad, high fert, no Rid
Bush clearing	16	17.7	17.7	17.7	17.7
Soil preparation					
with hoe and	40.6				
with oxen	27.4	40.1	40.1	40.1	40.1
1st Planting	48.4	54.1	54.1	54.1	54.1
1st Fertilizing	2.5	6.9	3.0	6.9	6.9
Replanting	7.1	3.0	7.1	7.1	7.1
1st Weeding	63.9	55.0	63.9	63.9	63.9
Ridging trad. or	10	--	--	--	10
Ridge or	--	16.5	16.5	56	--
Tied Ridge	--	56	--	56	--
2nd Fertilizing	--	13.5	--	13.5	13.5
2nd Weeding	20.8	25.0	25.0	25	25
Harvesting	71.7	60.18	60.18	60.18	60.18
Transport	14.2	23.4	23.4	23.4	23.4

Table D.6.ii Labor Activities, Cotton

	Cotton, trad.	Cotton, improved
Bush clearing	17.7	17.7
Soil Prep.		
with hoe and	37.6	--
with oxen	25.0	40.1
1st planting	58.5	58.5
1st fertilizing	12	12
Replanting	3.8	3.8
1st weeding	96.12	75.6
Ridging	26.9	16.5
2nd fertilizing	--	15
2nd weeding	31	
Spraying	12.2	20
Harvesting	162.3	
Transport	19.1	

Table D.6.iii Labor Activities, Sorghum

	Red Sorghum	White Sorghum	White Sorghum, improved	Muskwari
Bush clearing	37.1	37.1	34	37.1
Soil Prep.	39.5	60	57	40.1
1st planting	50.4	50.4	46.1	50.4
1st fertilizing	--	--	--	6
Replanting	7.0	7.0	--	7.0
1st weeding	161.1	161.1	63.5	161.1
Ridging	--	--	--	16.5
2nd weeding	46.4	79.4	19.6	46.4
Harvesting	118.4	118.4	124.5	118.4
Transport	18.2	26	25.9	26

Table D.6.iv Labor Activities, Groundnut

	Groundnut, traditional	Groundnut, GK1
Bush Clearing	23.6	23.6
Soil Prep.		
hoe and	45	--
oxen	30	46
1st planting	77.6	77.6
Fertilizing	--	6
Replanting	8	8
1st weeding	156.4	156.4
2nd weeding	42.7	42.7
Harvesting	173.4	173.4
Transport	49.2	49.2

Table D.6.v Labor Requirements, Cowpeas

	Cowpeas, traditional	Cowpeas, VYA
Bush clearing	30.1	20
Soil prep.		
hoe and	38	--
oxen	24	26
1st planting	40	25.6
1st fertilizing	--	6
Replanting	--	5.6
1st weeding	93.8	60
2nd weeding	79.4	20
Spraying	--	6
Harvesting	64.2	54.21
Transport	12.4	12.4

Table D.7. Periods and Constraints by Period: family size = 5, pair of oxen

Period	Acronym	# Days	Family labor (hrs) supply	Draught power (hrs) supply	Major farm operations
April 1 - April 20	LABAPR20	5	82.5	20	Bush cleaning
April 21 - May 10	LABMAY10	17	280.5	68	Bush cleaning, soil prep.
May 11 - May 30	LABMAY30	17	280.5	85	Bush cleaning, soil prep., early planting
May 31 - June 20	LABJUN20	18	297	90	Bush cleaning, soil prep. normal planting
June 21 - July 20	LABJUL20	26	429	130	Weeding, late planting, ridging
July 21 - Aug. 20	LABAUG20	27	445.5	135	Weeding
Aug. 21 - Sept. 30	LABSEP30	35	577.5	175	Second weeding, spraying insecticides
Oct. 1 - Nov. 10	LABNOV10	35	577.5	175	Start harvesting
Nov. 11 - Dec. 20	LABDEC20	34	561	170	Harvesting & transport
Dec. 21 - March 31	LABMAR31	45	742.5	225	Harvesting late planted crops and cotton & transport