PD-AAQ-268

Intsormil

INTSORMIL AGRONOMIC ACTIVITIES

IN

NORTH KORDOFAN, WESTERN SUDAN

by

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UNIVERSITY OF NEBRASKA

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University of Nebraska-Lincoln

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INTRODUCTION

On November 23, 1980, INTSORMIL entered into an agreement for cooperative work with the Agricultural Research Corporation (ARC) of Sudan and the Faculty of Agriculture of the University of Khartoum. One of the agreed upon areas of cooperative research was for INTSORMIL to start agronomic research at El-Obeid, North Kordofan Province. It was recommended that INTSORMIL provide a short-term staff for the 1982 cropping season with opportunities for long-term research in 1983. I arrived at El-Obeid town on June 17, 1982 to fill the short-term agronomist position.

This report summarizes my activities in the project area during June - October, 1982. The information contained in the report is from the following sources: 1) personal surveys, observations and findings, 2) persona interviews and discussions with farmers, 3) personal interviews and discussions with researchers, 4) reports of Messers Edward Reeves and Timothy Frankenberger, Department of Sociology, University of Kentucky (including personal discussions with them) and documented literature relevant to the project area.

With this report I aim to accomplish the following: 1) familiarize the reader with the project area - location, climate, soil etc, 2) provide information about the major field crops, their agronomy, production constraints and farmers compensatory strategies, 3) provide information about all 1982 agronomic research activities in the area and 4) provide a list of research priority areas under consideration for the 1983 cropping season.

Whenever necessary, tables, graphs and pictures have been included in the body of the paper. Additional information is made available in the appendix. A list of references is also included at the end of the report.

It is my earnest hope that this progress report will add something to the better understanding and improvement of the complex farming system in North Kordofan and also help to create a stronger cooperative research effort between INTSORMIL and ARC.

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1. THE PROJECT AREA

1.1 Location: the project area is located in Northern Kordofan Province Democratic Republic of Sudan (Fig. 1). North Kordofan Province lies between 12° 3' - 16° 30' N latitudes and 28° - 32° E longitudes. The present area of activity covers approximately a 50 kilometer (31 mile) radius from the center town, El Obeid (Lat. 13° 10' N, Long. 30° 14' E., Alt. 570 M.).

The whole project area is a flat plateau (elev. 300-900 M) of vast sand dunes with some sparcely and randomly distributed hills.

One of the most detailed sources of information about the area is the 1963-66 study series conducted by Doxiadis and Associates for FAO (FAO 1964, 1966).

1.2 Climate: the major climate of the area has been described as hot and semi-desert in the North to warm woodland savannah in the South. Four climatic seasons are recognized (Ibrahim 1977). These are: 1) the Rainy Season (June-September), 2) Retreat of Monsoon winds (October-November), 3) Cool Dry Winter (December-February) and 4) Hot Dry Months (March-May).

The agricultural environment in the area can best be described as very harsh, risky and very fragile. Even the most favorable parts of the area have to be regarded as marginal for crop production. Considering all the environmental factors (poor rainfall, poor soil, high temperatures, low relative humidity, high evapotranspiration, etc.), the area would be classified as "non-arable." However, the local people have somehow evolved a viable farming system that works reasonably well in spite of all the problems.

The following sections will deal with some of the environmental problems of the area.

1.2a Rainfall: Rainfall is one of the most important factors influencing crop yields in the area. (Ibrahim 1977, Jarrett 1979, Kassam 1979, Webster 1980). The rainy season is normally June to September and the rainfall is

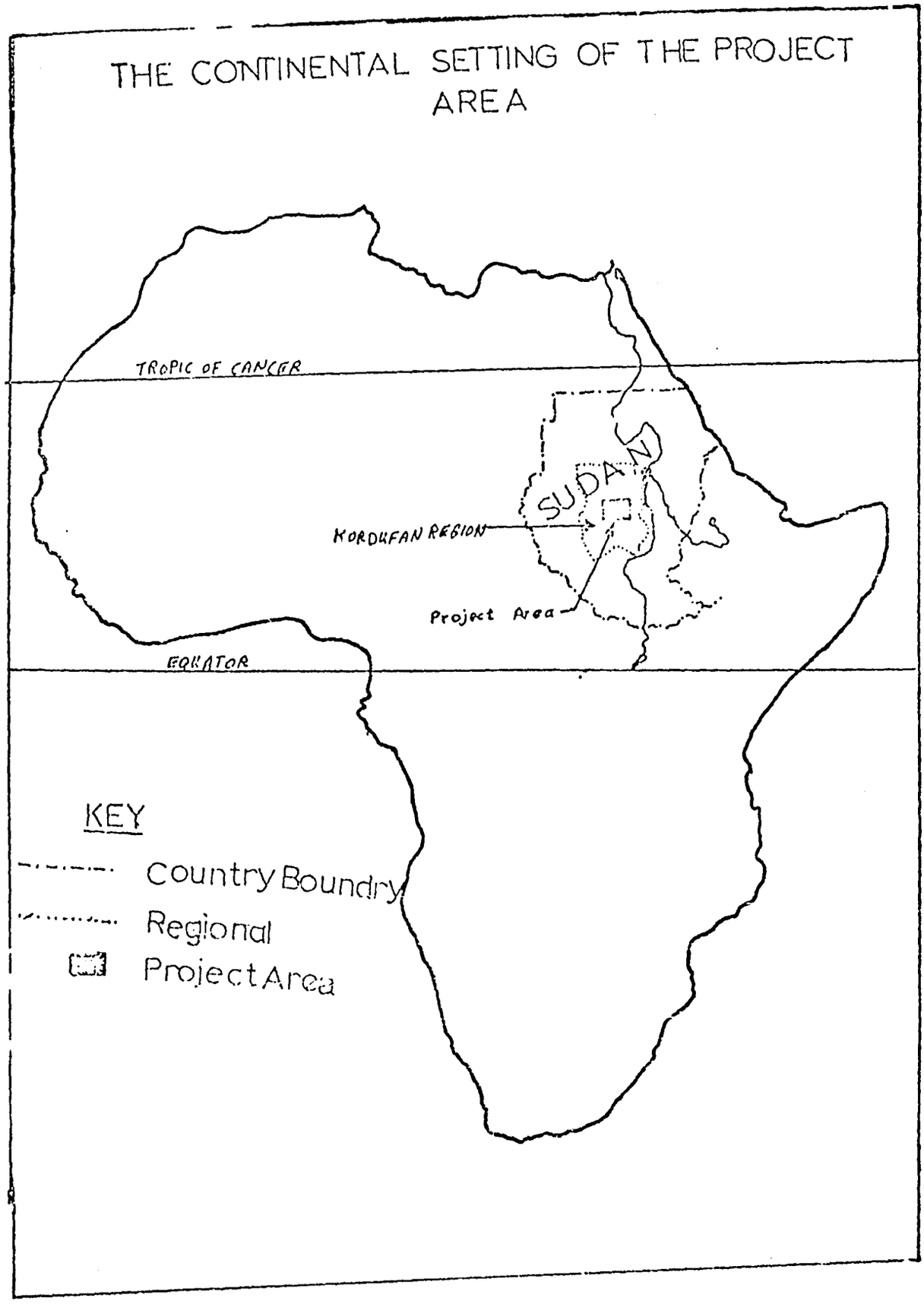

THE CONTINENTAL SETTING OF THE PROJECT AREA
TROPIC OF CANCER
SUDAN
KORDUFAN REGION
Project Area
EQUATOR
KEY
Country Boundry
Regional
Project Area

Figure 1

monomodal. Rainfall in the area is variable in the extreme. According to FAO reports (FAO 1964) annual rainfall varies between 75-300 mm (3-12") in the Northern part of the province to 300-450 mm (12-18") in the South. El-Obeid (center of project area) receives 200-450 mm (8-18") of annual rainfall and a slightly lower effective rainfall (Table 1).

Table 1. Effective and Annual Rainfall (mm) data for El-Obeid*

	Year								
Month	1941-70	1975	1976	1977	1978	1979	1980	1981	1982
June	27	8.5	6.0	4.3	9.5	13.1	40.0	30.3	0
July	113	87.2	176.8	72.9	130.5	50.2	138.0	112.0	112.5
August	143	59.1	135.2	210.4	164.1	154.3	75.4	65.4	118.0
September	68	42.8	89.2	7.6	77.1	31.2	87.5	46.0	13.0
October	19	tr	23.1	0.1	36.0	6.8	7.4	30.6	15.5
Effective Rainfall	370	197.6	430.3	295.4	417.2	255.6	348.3	284.3	259
Annual Rainfall	386	201.5	432.6	303.6	467.4	284.4	364.9	312.3	259

* (Source: Sudan Meteorology Department)

There is tremendous variation in annual seasonal and monthly precipitation (Figs. 2 and 3). There is also high irregularity within a season. According to Ibrahim (1977) the area suffers from 1) variation from year to year (contingent drought), 2) inadequacy of precipitation in one season, (seasonal drought), and 3) borderline inadequacy of rainfall from month to month (invisible drought). The rainfall is unrealiable in terms of total quantity, seasonal distribution, area of coverage and intensity. Usually the rains come in high intensity storms (Webster 1980). Sometimes, a rain that should be distributed over a month falls in one day (Min. of National Planning 1981). High intensity rains are undesirable in that they destroy soil crumbs, reduce infiltration and enhance run-off.

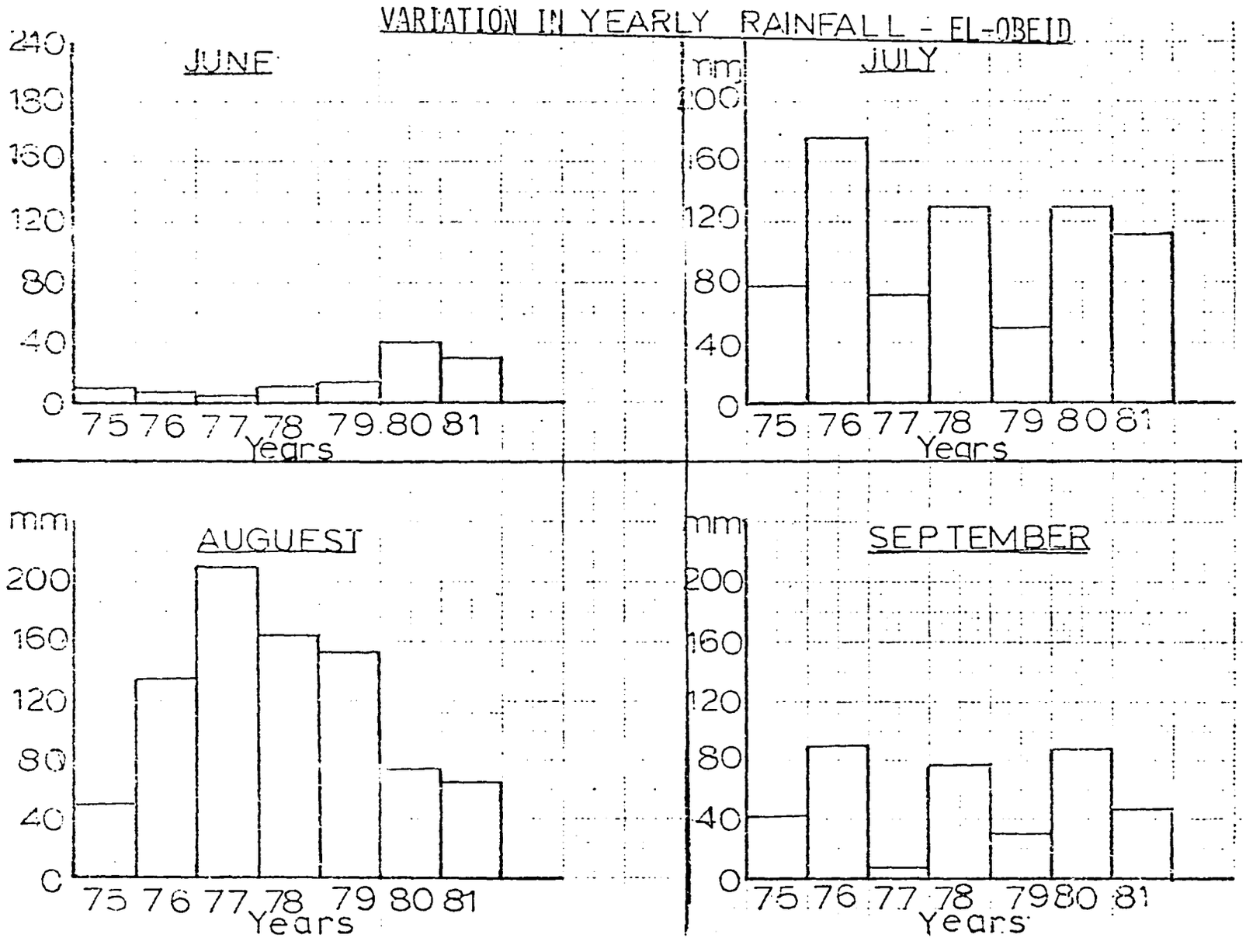

VARIATION IN YEARLY RAINFALL - EL-OBEID
JUNE
JULY
AUGUEST
SEPTEMBER
mm
240
180
160
120
80
40
0
200
75 76 77 78 79 80 81
Years

Figure 2

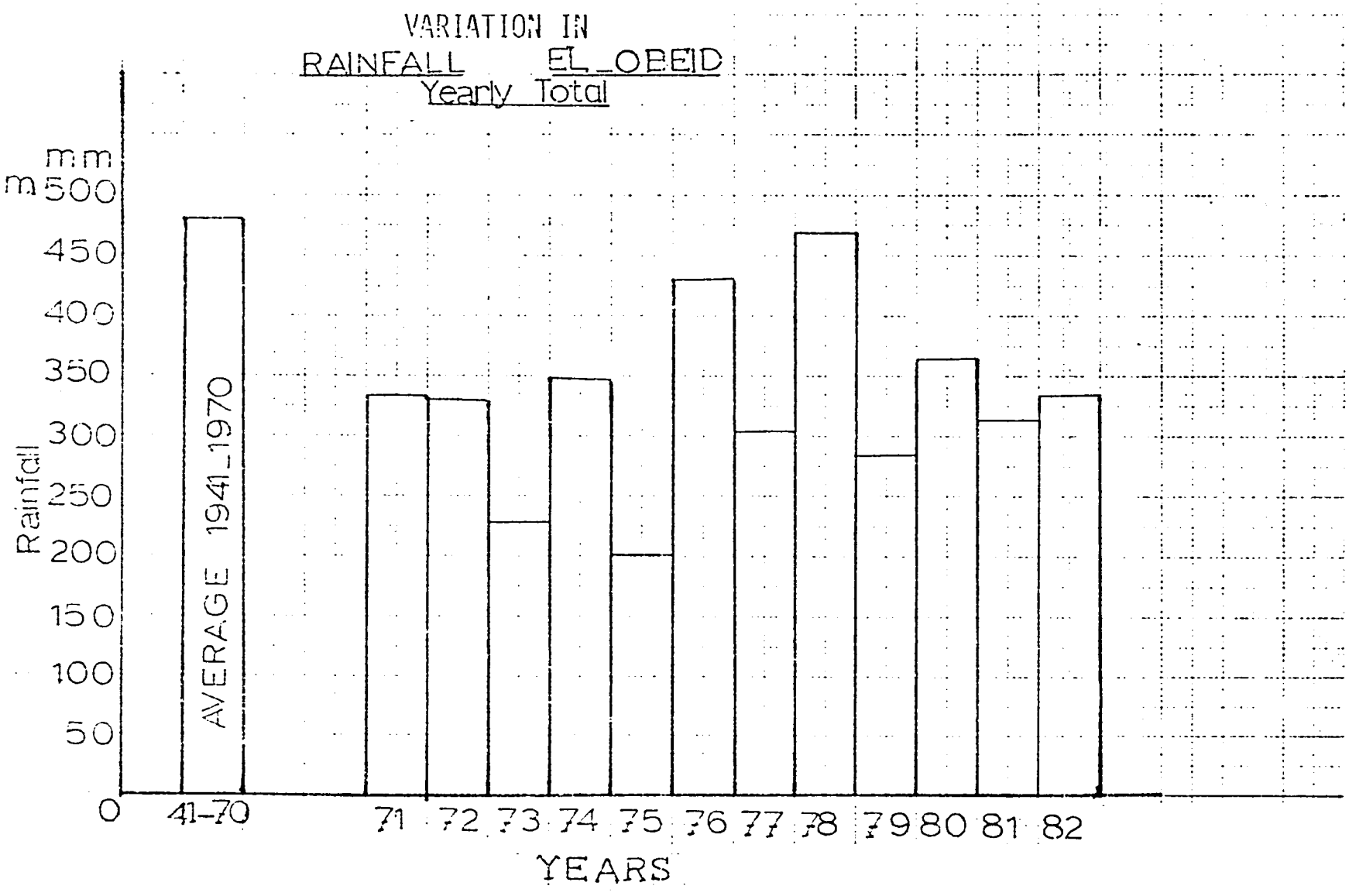

VARIATION IN
RAINFALL EL_OBEID
Yearly Total
mm
m 500
450
400
350
300
250
200
150
100
50
0
Rainfall
AVERAGE 1941_1970
41-70
71
72
73
74
75
76
77
78
79
80
81
82
YEARS

Figure 3

Variation in rainfall has a big effect on crop yields. Kamball (1978) estimated that a difference of more than 20% in production levels can be accounted for by the yearly variation in rainfall. In fact this is a very conservative estimate as compared to the yield differences reported by the Extension Department and shown on Table 2.

Table 2. Effect of Weather Variability on Crop Yields (Abulgassim 1980/81)

	Crop Season		
	1976/77	1977/78	
Crop	Rainfall (433 mm) Yield (Tons/Feddan)*	Rainfall (302 mm) Yield (Tons/Feddan)	Yield Reduction
Millet	0.200	0.037	18.3 %
Sorghum	0.120	0.070	58.3 %
Sesame	0.015	0.014	9.3 %
Groundnut	0.400	0.185	46.3 %

* 1 Feddan ≃ 1 acre

The rains usually fall in middle or late afternoon when evaporation and evapotranspiration are favored. As a result, precipitation exceeds potential evapotranspiration for only one month in the North and two months in the South (Ibrahim 1977). Positive balance is obtained usually during the months of August and early September. Analysis of 1941-70 El-Obeid climatological data showed that precipitation exceeds 0.5 PET only from mid-July to mid-September.

Rainfall also influences the types of crops grown in the area. North of El-Obeid (low rainfall) millet and sesame are grown. South of El-Obeid (higher rainfall) the predominant crops are sorghum and groundnuts.

1.2b Temperature: The project area has a frost free season throughout the year. Temperature varies from cool to warm to hot according to the movement

of the air masses. Four seasons are recognized. These are: 1) warm rainy summer (June-September), 2) retreat of Monsoon (October-November), 3) cool dry winter (December-February) and 4) hot dry period (March-May). (Pachecho and Dawoud 1976, ARC 1981, Min. of Natl. Plan. 1983). Temperature data presented on Table 3 and Appendix A reveal that in most of the months, the temperatures are well above the level at which one can comfortably work. This influences the working schedule of farmers who perform most of their field activities only from 7-11 in the morning and 3-6 in the afternoon (Reeves and Frankenberger 1982).

High variation in temperature in different places create areas of high and low pressures which in turn creates the local dust storms (Haboobs). Haboobs cause a lot of damage to crops.

The following is a short summary of a few facts about the temperatures in the area.

- Hottest months: May and April, 39-40° C (maximum)
- Coldest months: December and January, 12-14° C (minimum)
- Hottest month: May - Maximum (40° C), Minimum (24° C)
- Coldest month: January - Maximum (31° C), Minimum (13° C)
- Mean annual maximum temperature = 34 ± 5° C
- Mean annual minimum temperature = 13 ± 5° C
- Highest maximum temperature recorded = 44.3° C
- Lowest minimum temperature recorded = 4.4° C

Evidently, the high temperatures cause evapotranspiration rates of crops also to be very high.

Comparison of annual minimum, maximum and mean temperatues for the years 1975-1980 with the mean of 1941-70 reveal that there has been an increase of 0.5 to 1.5° C (Appendix C).

Table 3. Mean Monthly Temperatures (°C) at El-Obeid *

Month	Year 1941-70	1975	1976	1977	1978	1979	1980
January	22.1	20.8	22.1	21.3	21.4	22.6	21.9
February	22.9	25.9	23.8	24.3	24.8	26.7	24.1
March	27.0	2.78	2.91	26.3	27.7	27.7	2.85
April	29.7	29.1	30.7	29.2	31.8	32.1	31.8
May	31.5	32.2	32.6	31.5	31.6	31.0	32.3
June	30.8	30.9	30.9	30.9	31.5	30.5	31.1
July	28.1	28.6	28.1	28.4	27.5	29.2	27.9
August	26.7	27.5	28.2	29.6	28.7	29.2	28.1
September	27.7	27.5	28.2	29.6	28.7	29.2	29.6
October	28.7	29.5	29.9	28.3	29.8	30.2	30.6
November	25.7	26.9	30.0	25.1	24.1	27.9	26.8
December	22.5	21.9	25.2	22.1	23.5	21.1	23.4

*(Source: Sudan Meteorology Department)

1.2c Other Climatic Factors: In addition to the two major weather factors, rainfall and temperature, other climatic normals available for the area include: number of rainy days, relative humidity (RH) pitch evaporation, wind direction and speed, cloud cover, and bright sunshine hours. Monthly means averaged over a 30 year period (1941-70) are presented on Table 4.

Table 4. Climatological Normals for El-Obeid (1941-1970)*

	CLIMATIC FACTOR						
Month	No. of Rainy Days	Pitch Evap. (mm)	RH (%)	Cloud Cover (0-8 Rating)	Bright Sunshine Hours	Wind** Direction	Wind** Speed (MPH)
January	0	15.6	23	2.3	10.4	N	8
February	0	17.9	18	2.5	10.6	N	9
March	0.1	20.7	15	3.1	10.0	N	8
April	0.5	21.1	17	3.1	10.3	N	7
May	1.8	18.9	27	3.9	9.7	N	8
June	4.0	15.2	41	4.8	8.5	SSW	9
July	8.9	9.7	60	5.7	7.0	SSW	9
August	11.5	5.8	70	5.7	6.9	SSW	7
September	6.6	7.3	60	5.2	8.4	SW	6
October	2.3	13.2	37	3.8	9.4	N	7
November	0	16.8	24	3.2	10.3	N	8
December	0	15.0	24	1.9	10.6	N	8

*(Source: Sudan Meteorological Department)

**10 year average

Some facts about the climatic factors:

- Cloud cover reaches maximum (50-60%) during the rainy season (June-September) and is usually 20-30% for the rest of the year.
- Relative humidity is high in the morning, low at mid-day and again high in the evening. It reaches 60-70% in July, August, and September but falls below 40% for the rest of the year.
- Wind direction is SW to SSW during the rainy months and N for the rest of the year.

- Average wind speed is about 9 miles/hr throughout the year. However, there are dust storms (quite often) whose speeds may exceed 25 miles/hr.
- Mean monthly pitch evaporation is quite high (6-21 mm) because of the high temperatures.
- The project area is close to the equator and therefore the days are short. Bright sunshine hours range from 7 to 10.5.
- The low figures in the number of rainy days/month indicate that rains fall in high intensities and that rainfall distribution is poor.

1.3 Soils: Soils of the project area consist of two main broad categories: the Goz (Qoz) and the Gardud (Gardood). The Goz soils are wind transported and later stabilized sand dunes while the Gardud have been formed in situ (FAO 1964). The Goz soils occupy about 70% of the area and the Gardud soils 25%. A third group of soils called "Sils" occupy about 5% of the area. These are silty clays that are found along valleys and river beds.

The following is a compiled general characterization of the two main soil types.

Goz	Gardud
Sandy	Hard red clay (compact)
Highly permeable	Very low permeability
Susceptible to leaching	Not susceptible to leaching
Very little surface drainage	Very susceptible to run-off
Neutral to alkaline in pH	Strong alkaline
Allow hand tool cultivation	Difficult to cultivate
Low inherent fertility	Better than Goz in fertility

Properties Common to Both Soil Types

Deficient in N and P; K status good
Low organic matter
Low cation exchange capacity (low Ca and Mg)
Low in fertility
Low in moisture

Farmers recognize two types of Goz: Goz ahmar which means red Goz and Goz abyad (white Goz). About 60% of the Goz area has 20 cm top layer. The rest (40%) has no top layer (truncated soil) or has much less than 20 cms.

Only a very small portion of the Gardud soil is presently used for crop production. The Soil Conservation and Management Department has a Gardud soil reclamation research underway south of El-Obeid.

2. THE CROPPING SYSTEM

2.1 Types of Crops Grown: Crops are grown either for food or for cash. The main subsistence cereals grown are pearl millet, locally known as "Dukn" (*Pennisetum americanum*) and sorghum (*Sorghum bicolor*). Cash crops include: sesame (*Sesamum indicum*) and groundnuts (*Arachis hypogaea*). Other crops of less importance that are grown either for home consumption or for cash include cowpeas (*Vigna unguiculata*), watermelon (*Cucumis* sp.) Kerdede (*Hibiscus sabdariffa*) and Okra (*Abelmoschus esculentus*).

One of the most common ways farmers identify types within each crop is by maturity. The word "Baladi" means late and identifies crops in the 90-120 day maturity range. Hence, a late maturing millet is "Dukn Baladi", a late maturing sorghum is "Mareeg Baladi" or "Zunnari Baladi", and a late maturing sesame is "Simsim Baladi." Similarly, the word "Hirehree" means early and therefore by replacing the word Baladi by Hirehree one identifies types that mature in 70-80 days. There is no common word for intermediate types (80-100 day maturity even though they exist. Examples of intermediate types are: Eesh Bornu in millet, Feterita in sorghum and Jaborouk in sesame.

If rains come early and the season is good for crops the late types (Baladis) predominate. If rains come late then the early types (Hirehrees) occupy a larger area. Usually, farmers plant varieties of different maturity groups in order to spread their planting period, harvesting period and also as a safeguard against crop failure.

2.2 Farm Size, Acreage and Yields: A farm size survey (Reeves and Frankenburger 1982) showed that 35% of the farmers cultivate 10 acres or less, 43% cultivate 11-20 acres and 23% over 20 acres. Considering the fact that all farming operation is manual using simple hand tools[1] the farms seem to be too large to manage. However, farmers manage to farm large areas because 1) a lot of family and/or hired labor is practiced, and 2) very wide spacings are used between hills and rows to make up for poor soil fertility.

Total acreage and yield data for all crops grown in North Kordofan province during 1974-80 are presented in Table 5. A summary of these data is also presented in Table 6. The summary reveals that out of the 3.7 million Feddans, millet occupied the largest area (28.5%) followed by sesame (26.4%). Groundnuts occupied a third place with 19% and sorghum ranked fourth (14.4%). In Reeves and Frankenberger (1982) report, 38% of land was under millet and 48% under sesame in 1981.

It should be noted that acreage under each crop varies from village to village and from season to season. For instance, in El-Kharta and El-Geifil villages where rainfall is usually low, 50-60% of the area is sown under sesame (Reeves, and Frankenberger, 1982). In seasons when rains are late, millet is replaced either by sorghum or sesame.

Average yields of all crops are very low and usually represent only one-fourth to one-third of the maximum yield potential possible in the area (Ibrahim 1977). Variation in weather accounts for 20% of yield reduction (Kamball 1978) and pests and diseases account for another 50-60% reduction in yield (Abdel-Ghaffar 1976). These facts suggest that there is a lot of room for yield improvement in the area.

[1]Farm tools are described in Reeves and Frankenberger (1982).

Table 5. Areas Cultivated With Traditional Crops and Their Yield, N. Kordofan Province, Sudan

Crops	1974-75		1975-76		1976-77		1977-78		1978-79		1979-80	
	Area F +	Aver. Prod. T ±	Area F	Aver. Prod. T	Area F	Aver. Prod. T	Area F	Aver. Prod. T	Area F	Aver. Prod. T	Area F	Aver. Prod. T
Groundnuts	578,380	.318	894,000	.249	418,753	.400	855,881	.400	741,714	.185	771,782	.108
Sesame	1,423,800	.0320	951,000	.0746	898.587	.015	957,617	.014	950,547	.014	724,266	.06
Millet	1,450,000	.0775	257,000	.490	1,353,051	.200	1,140,000	.150	1,350,000	.037	818,158	.069
Sorghum	647,000	.0804	329,000	.164	631,262	.120	609,209	.115	630,251	.070	395,643	.375
Karkade	47,481	.013	44,090	.013	20,276	.010	22,300	.015	62,054	.020	78,444	.16
Watermelon Seeds	410,430	.097	372,718	.097	389,885	.090	369,225	.080	370,230	.100	417,361	.12
Total	4,557,091		2,847,808		3,711,814		3,964,242		4,104,796		3,195,654	

+F = Feddan

±T = Tons

Table 6. Mean Acreage and Mean Yields for Crops Grown in N. Kordofan, Sudan During 1974-80.

Crop	Mean Acreage (Feddans)*	% of Total	Mean Yield (Tons/Feddan)
Millet	1,063,034.8	28.5	0.17
Sesame	984,302.8	26.4	0.05
Groundnuts	710,085.0	19.0	0.28
Sorghum	538,729.2	14.4	0.16
Watermelon	388,308.2	10.4	0.10
Karkade	45,774.2	1.2	0.04
Okra	not reported	----	not reported
Total	3,730,234.2	99.9	

*1 Feddan ≃ 1 acre

2.3 Farming Operations: The main farming operations include: land clearing, planting and replanting, weeding (usually twice), harvesting and thresing. Timing of each activity is dependent on the weather, specifically rainfall. Figure 4 was constructed from survey data of Reeves and Frankenberger (1892) to show the range (represented by lines) and peak (represented by rectangles) periods of activity for each crop and operation. Usually there are overlaps between activities. Of all the activities weeding is the most arduous and most expensive. It takes as much as 50% of the operation expense (Manger 1981). According to Reeves and Frankenberger's (1982) findings, groundnuts are the most expensive to produce (also give highest return) and sorghum is the least expensive to grow. Cost of production comparisons are provided in Table 7.

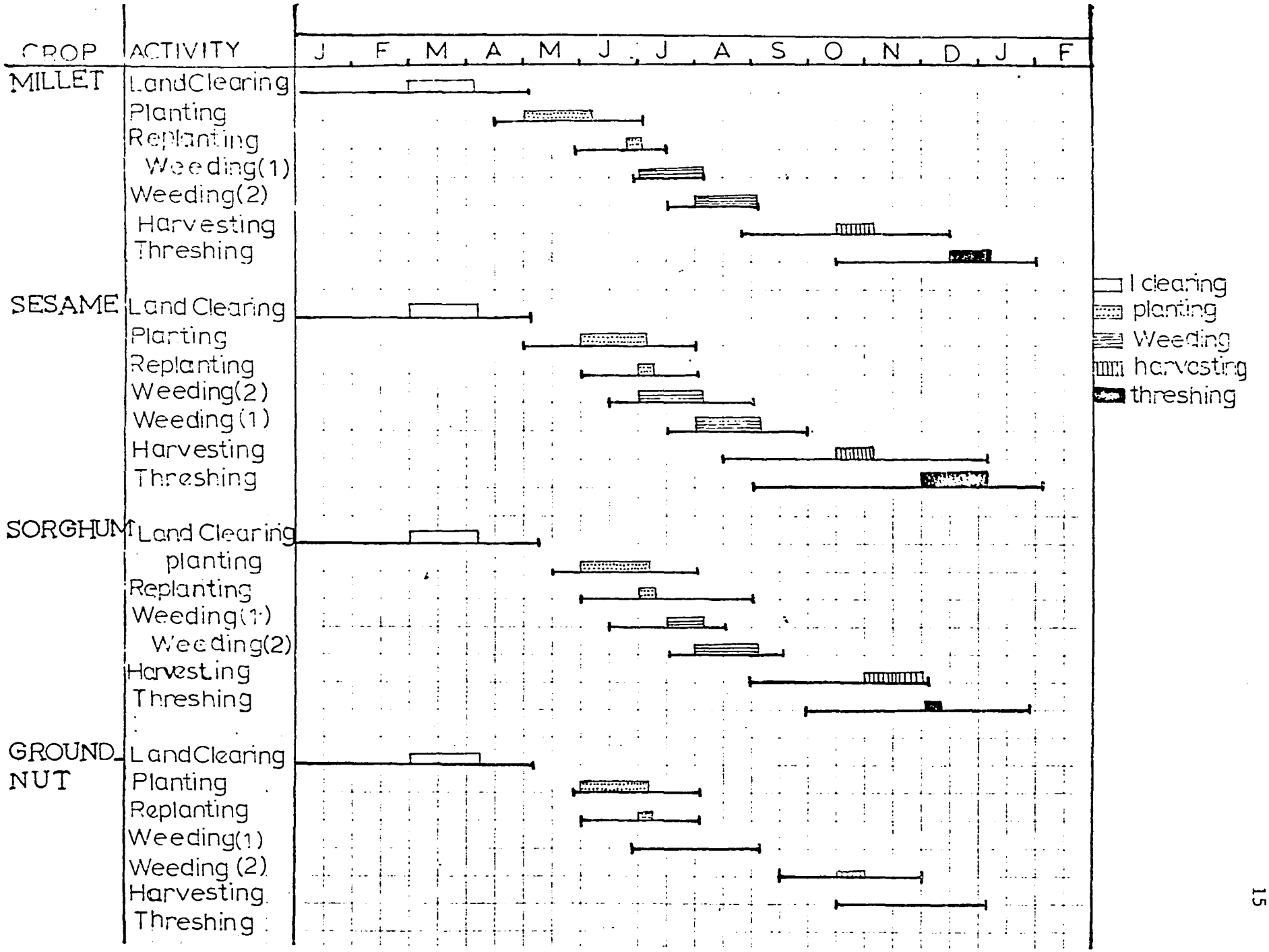

CROP
ACTIVITY
J F M A M J J A S O N D J F
MILLET
Land Clearing
Planting
Replanting
Weeding(1)
Weeding(2)
Harvesting
Threshing
SESAME
Land Clearing
Planting
Replanting
Weeding(2)
Weeding(1)
Harvesting
Threshing
SORGHUM
Land Clearing
planting
Replanting
Weeding(1)
Weeding(2)
Harvesting
Threshing
GROUND NUT
Land Clearing
Planting
Replanting
Weeding(1)
Weeding (2)
Harvesting
Threshing
l clearing
planting
Weeding
harvesting
threshing

Figure 4.

Table 7. Yield, Cost of Production and Net gain from Crop Production in N. Kordofan, Sudan. (Source: Reeves and Frankenberger (1982)

Crop	Av. Yield (Sacks/Makhamas)[1]	Yield Range	Labor Cost	Net Profit (L.S)[2]
Millet	1.14	0-3	21	18
Sesame	1.06	0.04-2.10	21	13.65
Groundnut	5.58[3]	1.67-15.83	33	25.11
Sorghum	1.09	0.14-3.00	21	4.40

[1] 1 Makhamas = 1.73 Feddan = 1.8 acre

[2] L.S = Sudanese Pounds

[3] Unshelled

2.4 Production Constraints and Farmers' Compensatory Strategies: Instead of enumerating production constraints in the project area it would have been much simpler to enumerate factors that favor crop production. The reason is very simple. There are none. Agriculture exists in the area as a means of survival. Since the will to survive is very strong, farmers of the area have developed ingenius compensatory strategies to the countless constraints and have developed a farming system in an otherwise impossible environment.

The production constraints discussed here are only those related to agronomy. A more comprehensive list is found in Reeves and Frankenberger (1982).

2.4a Inadequacy and Unreliability of Rainfall: Farmers have a number of strategies to tackle this very frequent production constraint.

1) They cultivate drought tolerant crops (millet, sorghum, sesame, groundnut, cowpea).

2) They recognize and use different maturity groups and drought resistant types within each crop.

3) They start planting before the oncoming of rains to take full advantage of the first good shower(s).

4) They plant within two days after a good rain.

5) They plant the most drought tolerant crop (pearl millet) first.

6) They cultivate millet and sesame to the north and east of the project area (low rainfall) but sorghum and groundnuts to the south and southwest (higher rainfall).

7) If first rains are insufficient for crop establishment, the fields are replanted. If rains come very late, either very early varieties are used or another crop is substituted. Usually a millet field will be substituted by sorghum in the south and by sesame in the north.

8) Some farmers make small water catchments around each hill of plants.

9) They spend a lot of time and money combating weeds that compete for moisture.

10) Farmers of the project area increase their success of having a crop by planting several crops (up to six) in the same hole (hill). Usually, at least one or two of the crops will make it.

2.4b Poor Soil Fertility: Most of the farmers recognize the poor fertility condition of their soils. Hence, they do practice (though in haphazard fashion) certain cultural practices which to some extent alleviate the problem.

1) Farmers use wide spacing and cultivate a larger area to make up for poor soil fertility.

2) They leave the land fallow or planted with *Acacia senegal* (legume) for a number of years until fertility is restored. If a farmer has access to other lands, the fallow period can extend up to 10 years or more. Otherwise, the fallow period may be as short as 3 to 4 years. With increase in population less land is available for cultivation. As a result, the 3 to 4 year fallow practice is becoming more dominant. Increase in the production of cash crops (sesame and groundnut) is also a factor in this.

3) They include legumes either in mixed cropping or in rotation. Rotation with a legume is not common north of El-Obeid where the practice is mostly millet - sesame - millet. In the south however, a sorghum (or millet) - groundnut - sorghum rotation is practiced.

4) Farmers plant millet if the land is very poor whereas they plant sorghum and sesame if the land is fertile.

5) Farmers encourage cattle, sheep, goats, etc. to graze on residue after harvest so that the animals leave their droppings on the field.

2.4c High Wind and Duststorms (Haboobs): Wind speeds of 20-25 miles per hour are quite frequent throughout the year. During the off-season when the ground is bare and dry, a lot of the topsoil and sand are blown away or truncated around bushes and shrubs. High winds during the crop season expose seeds and seedlings, uproot seedlings and plants, and damage or kill leaves (especially those of sesame and groundnuts). To minimize wind damage farmers practice the following strategies:

1) They plant a mixture of crops in one hole - eg. sorghum is planted with sesame. Sorghum roots stabilize the soil for sesame.

2) Farmers plant a large amount of seed in each hole in order to create a bush and thus minimize wind damage.

3) Farmers leave bushes and shrubs uncut until crop is well established (1st weeding).

4) They leave cut bushes, weeds and crop residue during the off-season.

2.4d Pests and Diseases: The failure or reduced production of crops in the area is many times wrongly blamed on the weather. Pests and diseases are one of the biggest major production constraints in the area. An annual yield loss of 60% is considered a conservative estimate (Abdul-Ghaffar 1976). Ibrahim (1977) studied the probability of occurrence of farm hazards in the eastern part of North Kordofan and found a 33% probability of occurrence for wind and bird damage, 55% for rat damage and 90% for damage by insects and diseases. Striga alone accounts for 5-10% annual yield reduction in sorghum and millet. Sometimes yield can be reduced to zero (Kamball 1978).

North Kordofan farmers conduct certain direct and indirect farm operations that tend to reduce pest damage. Some of these are:

1) Millet, the crop with the most pest problems is planted very early. If planted and established early, the crop has a chance of maturing before insect peak cycle.

2) The practice of mixed- and inter-cropping helps in keeping pest and disease levels low.

3) They use Aldrex-T for seed-dressing. Salt or DDT are also placed around harvested head piles to keep off ants and termites.

4) Fallowing and rotation help in the control of pests such as striga.

5) They weed sesame first because it is a very poor weed competitor.

6) Farmers of N. Kordofan store their produce in underground pits called "Matmuras". These storage pits are excellent in that they keep storage insects off. The only problems observed with storage insects were with merchants who store their grain in burlap sacks above ground.

2.4e Unavailability of Improved Seed: All varieties of millet, sorghum, sesame and cowpeas (lubba) are land cultivars. The groundnut variety "Barbeton" is a long time introduction with no improvement effort on it since then. According to Reeves and Frankenberger (1982) farmers obtain seed from their own field, from fellow farmers and from merchants. Only groundnuts are sometimes bought from a government seed source. From these facts, it is evident that farmers do not have much choice in terms of seed supply. Sometimes farmers practice selection of best heads and saving the seed for planting in the following year.

3. 1982 AGRONOMIC ACTIVITIES IN THE PROJECT AREA

3.1 INTSORMIL

3.1a Knowing the Area: In order to identify the major production constraints, pick out priority areas for agronomic research and make plans for the next crop season, it was necessary for me to get firsthand information about the area, its people, the crops and agronomic practices.

About 80% of my time was spent in travelling to various villages, observing crops and production practices, and talking to farmers. Visits to agricultural institutions and researchers, obtaining relevant literature and reading occupied about 10%. The remaining 10% was used to run errands such as obtaining fuel, car repair, banking, etc.

3.1b Millet Demonstration Plots: On arrival at the project area I found that Mr. Timothy Frankenberger INTSORMIL, University of Kentucky and Mr. Bekit Musa, Plant Breeder, Regional Ministry of Agriculture had cooperatively initiated millet demonstration plots in three villages. On arrival, I took the follow-up responsibility. A second millet demonstration trial was prepared and sent by Dr. R. P. Jain, ICRISAT Millet Breeder. This trial was conducted in four villages. The details of the demonstration trials were as follows.

Trial 1:

a) Objective: to compare the performance of "Ughandi", a newly released variety with two local varieties "Baladi" a long maturing variety and "Hirehree" a short maturing variety. All comparison to be made under farmers' own practices.

b) Trial locations: Geffil, 35 Km E of El-Obeid
Um Ramaad 30 Km SW of El-Obeid
El-Kharta 20 Km N of El-Obeid
(See Figure 5 for relative location of villages)

c) Plot area: 1 Feddan = 1 acre/variety/location

Trial 2:

a) Objective: to compare the performance of a new promising line "ICMS 7817" with "Ughandi" and a local variety "Baladi".

b) Trial locations: all three locations listed on Trial 1b plus Ban Jedid (30 KM S).

c) Plot area: 500 M^2/variety/location

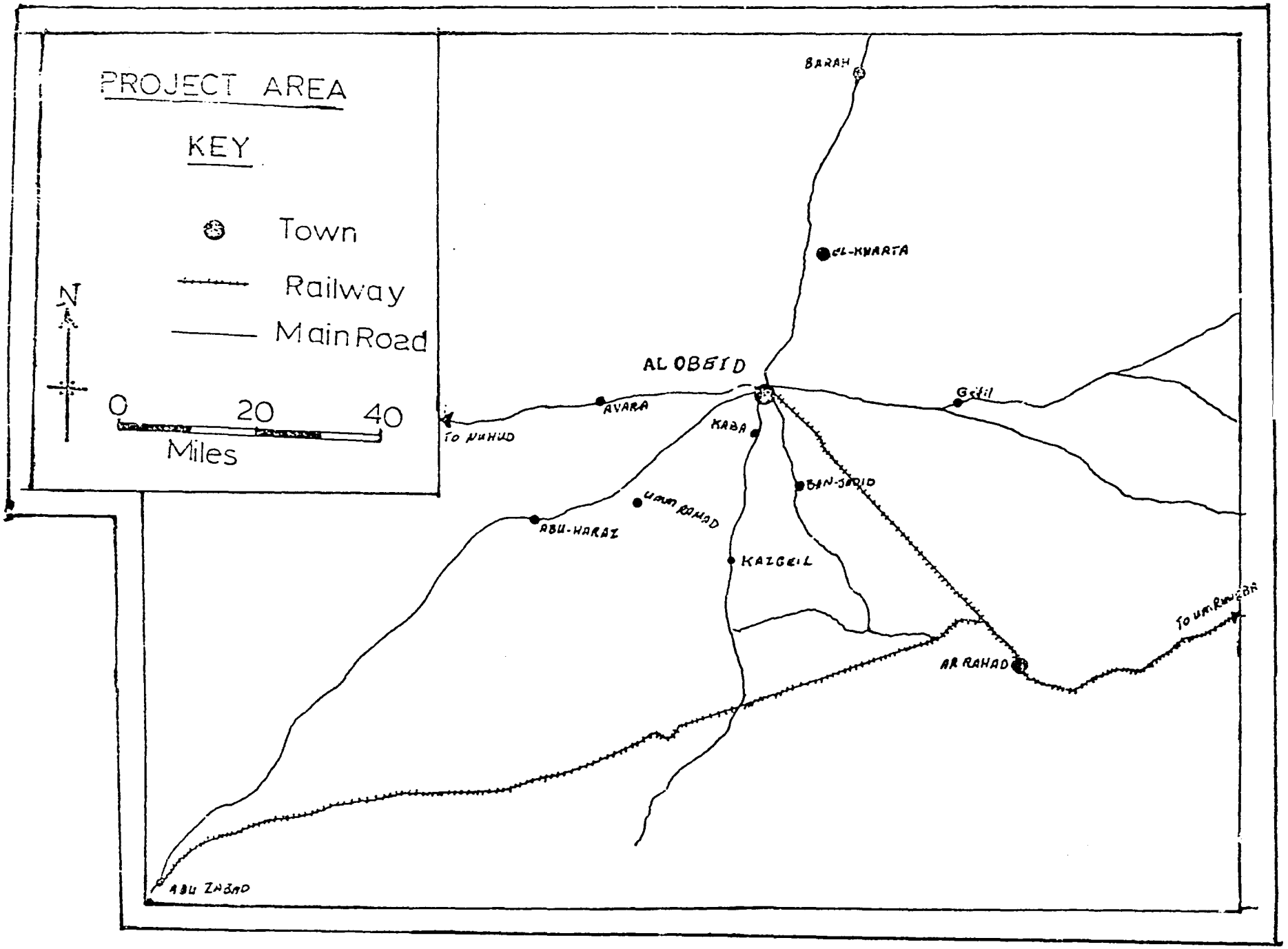

PROJECT AREA
KEY
Town
Railway
Main Road
N
0
20
40
Miles
BARAH
EL-KHARTA
AL OBEID
AVARA
TO NUHUD
KABA
Gefil
BAN-JADID
UMM RAMAD
ABU-HARAZ
KAZGEIL
AR RAHAD
TO UM RUWEBA
ABU ZABAD

Figure 5

3.1c Chickpea Adaptation Trial: Chickpea (*Cicer arietinum*) was tested for adaptation. If found adaptable, it could be used as an alternative legume both for rotation and consumption. People are very familiar with the legume and hence no consumer preference or market problems are anticipated.

Two market samples were tested in three planting dates (early August, late August and early September). The test sites were: Geifil (35 Km E.), Um Ramad (30 Km SW), El-Kharta (20 Km N), Banjedid (20 Km S), Kaba Station (7 Km S) and Ayara (30 Km W). Tests were conducted both on Goz and Gardud soils. Each market sample was planted in a $20M^2$ (2m x 10m). Spacing was 50 cm between rows and 20 cms between hills. Seed rate was 2-3 seeds/hole. Seeds were planted dry (Treatment 1) and pre-soaked overnight (Treatment 2). Aldrex-T was used as seed-dressing.

3.1d Plant Spacing and Plant Population Survey: Farmers in the project area use different spacings for the different crops they grow. Planting space is widest in millet and closest in groundnuts. Since spacing is determined by each farmer's footsteps, there is a lot of variation within a crop in different farms. Spacing is usually closer in fertile soils and wide in poorer soils. Crop spacing measurements conducted on 10 random farms within the project area are presented in Table 8. Based on that, estimated final plant populations grown are presented in Table 9. It should be noted though, that farmers put 10-20 times more seed per hill than is necessary for the final stand. This is to guarantee a stand after drought, wind, insects and other hazards have taken their share.

Table 8. Crop Spacing (cms)* Practices by Farmers in North Kordofan, Sudan-A Sample Survey

	CROP				
Sample #	Millet	Sorghum	Sesame	Groundnut	Okra
1	153 X 137	114 X 106	121 X 192	55 X 50	57 X 74
2	131 X 136	88 X 107	120 X 106	40 X 48	74 X 67
3	121 X 170	125 X 109	141 X 91	45 X 49	85 X 101
4	124 X 144	127 X 125	147 X 105	37 X 49	93 X 87
5	138 X 166	108 X 127	97 X 77	52 X 55	100 X 113
6	128 X 121	109 X 112	71 X 84	36 X 53	97 X 112
7	121 X 119	79 X 94	76 X 65	43 X 47	114 X 125
8	97 X 102	103 X 107	100 X 96	41 X 35	81 X 84
9	123 X 110	129 X 113	138 X 131	41 X 43	100 X 113
10	144 X 137	138 X 131	102 X 96	61 X 59	95 X 102
$\overline{X}$	128 X 134	112 X 113	110 X 95	45 X 48	90 X 98

*Each farm sample spacing is a mean of 10 sub-samples

Table 9. Estimated Per Hectare Plant Populations Planted by Farmers in North Kordofan, Sudan

		CROP				
Spacing*	Plants/Hill	Millet	Sorghum	Sesame	Groundnut	Okra
Wide	1	4,771	5,828	5,828	27,778	7,017
	3	14,313	17,423	17,423	------	21,053
	5	23,855	29,140	29,140	------	35,085
	7	33,397	40,796	40,796	------	49,119
$\overline{X}$	4	19,084	23,296	23,296	27,778	28,068
Medium	1	5,831	7,899	9,569	46,296	11,338
	3	17,493	23,697	28,708	------	34,014
	5	29,155	39,495	47,845	------	56,690
	7	40,817	55,293	66,983	------	79,366
$\overline{X}$	4	23,324	31,596	38,276	46,776	45,352
Narrow	1	10,000	13,405	20,242	69,444	23,697
	3	30,000	40,214	60,729	------	71,090
	5	50,000	67,025	101,215	------	118,485
	7	70,000	93,835	141,694	------	165,879
$\overline{X}$	4	40,000	53,620	80,970	69,444	94,792
Overall $\overline{X}$	4	27,469	36,171	47,514	47,999	56,071

*Wide = widest spacing for each crop in sample survey

Average = mean spacing for each crop in sample survey

Narrow = Closest spacing for each crop in sample survey

3.1e Pest and Disease Problem Assessment: The pest problem in the project area cannot be emphasized enough. Out of the many pest and disease problems that are reported to be common in the area (Appendix B) a number of them caused very serious losses in the 1982 crop season (Table 10). Of all the pests and diseases, Sinta (*Cryptocamentha* sp.) is the most serious. It causes a complete loss by eating every grain from all millet heads. Other insects that were observed to be serious in several places were Nafasha (*Eublema brachygonia*) and grasshoppers. Millet striga (*Striga hermonthica*) was serious in several villages. Long smut (*Tolyposporium* sp.) was present in the whole area but only serious around Kasgail. Downy Mildew (*Sclerospora* sp.) was also present but not serious.

Table 10. 1982 Pest and Disease Problem Assessment* in Project Area

	PEST					DISEASE	
Village	Striga	Nafasha	Sinta	Grass-hopper	Borer	L. Smut	D. Mildew
Hamadiya (20 km E)	3	2	0	0	0	1	1
Um Kitiera (25 Km E)	0	2	0	0	0	1	1
Geifil (35 Km E)	3	2	3	0	3	1	1
Banjedid (28 Km S)	3	3	1	2	3	2	1
Um Ramad (35 Km SW)	1	1	3	0	1	1	1
Rahad (20 Km SW)	0	0	2	2	0	0	0
El-Kharta (20 Km N)	3	2	0	2	1	1	1
Jelabiya (10 Km W)	1	2	2	3	1	1	1
Ayara (25 Km W)	0	3	1	3	1	1	1
Kaba (7 Km S)	0	2	0	2	0	1	1
Zerab Gallo (20 Km S)	1	3	0	1	0	2	1
Um Shidera (35 Km S)	3	3	1	2	1	3	1
Kasgail (50 Km S)	3	3	0	2	0	3	1

*0 = none observed, 1 = observed but not serious
2 = serious, 3 = very serious

3.1f Study of Seed Size and Density in Relation to Stand Establishment:

One of the major problems farmers in the project area face is how to obtain good seedling establishment and early plant vigor. It was mentioned earlier that farmers plant 10-20 times more seed per hole than would be necessary under normal circumstances. There is a need for improving the situation.

Seed size and density are known to have a positive influence on germination, early seedling vigor, and plant establishment. In order to take advantage of this, Mr. Bekit Musa, Agronomist, regional Ministry of Agriculture and myself have cooperatively initiated a study in this line. The plan of the experiment is as follows:

- Crops to be studied: millet and sorghum
- Genotypes: Millet 1. Ughandi - a newly released variety
  2. ICMS 7817 - a promising line
  3. Baladi - local variety

  Sorghum 1. P9898012 - drought tolerant selection which is under increase
  2. IS9830 - striga tolerant and early
  3. Zunnrari hirehree - some striga tolerance
  4. SRN-39 - striga tolerant
- 1982: study the effect of reducing sink size on seed size and density by removing 1/3, 1/2 and 2/3 of head after flowering. Treatments to be compared both under rainfed and irrigated conditions.
- 1983: study the influence of each treatment on stand establishment.

3.1g Germplasm Collection: Many fields of millet have been observed to contain a high number (up to 70%) of mixtures of unharvestable wild and intermediate types. A mass selection improvement program was started this season by collecting the following types.

- 279 heads of Baladi (Kordofani)
- 84 heads of Hirehree
- 79 heads of Esh Bornu

In making these composite collections, particular effort was made to select for compactness of heads (resistance to Nafasha), long smut resistance, striga tolerance, seed set, etc.

3.1h Other Activities: In addition to the main activities discussed up to here, I also participated in part or whole in the following:

- helped Dr. R. P. Jain, ICRISAT millet breeder in the evaluation of his breeding and advanced materials.
- located two areas where irrigation water and facilities are available. The areas are near each other and about 15 kms south of El-Obeid. One belongs to a farmer and has five wells each with a capacity of 3,600 gallons/hour. The other one has only one well and a storage tank and belongs to the Soil Conservation Department.
- located striga sick fields of millet and sorghum where striga seed collection can be made (Mr. Bekit Musa will be in charge) and striga tolerance experiments can be conducted.
- made some pest collections for Dr. Farouk Abdel-Ghaffar, Entomologist.
- participated in a village self-help school building program. Messers. Edward Reeves and Timothy Frankenberger had procurred 5,000 Sudanese Pounds from the U.S. Embassy to buy school construction material. However, they had to leave before delivering the materials to the village. Mr. James Stearns of CARE and myself were able to coordinate the delivery of the school materials to Geifil. Mr. Timothy Frankenberger again requested us to apply for more funds from the U.S. Embassy and coordinate a similar school building program for Um Ramad village. I had to leave Sudan before the completion of this project but Mr. Miles Todder (USAID) and Mr. James Stearns (CARE) will handle it.

3.2 ICRISAT

A large number of millet and sorghum experiments were planted at Kaba Experiment Station (7 Kms south of El-Obeid). These included: millet germplasm, segregating materials, advanced materials, variety trials, and striga tolerance screening trials. Unfortunately, most of the experiments failed due to lack of rain. Anyway, Dr. R. P. Jain and myself went through all the experiments and made the following observations.

- Nafasha, stemborer and long smut were present and quite serious in Kaba.
- from the segregating and advanced materials, some entries were selected because of desirable traits such as earliness, good stand, good seed set, compactness, bristling, etc.
- Ughandi, the newly released variety, which was included as check in most trials showed superiority in stand establishment, earliness and seed set.

3.3 Regional Ministry of Agriculture

3.3a Department of Agronomy: The Department of Agronomy whose head is Mr. Bekit Musa had the following experiments at Ayara (30 Km W).

Experiment 1. Groundnut spacing study

Experiment 2. Sesame variety trial

Experiment 3. Sesame spacing study

Experiment 4. Effect of undersowing legumes on cereal yield

Experiment 5. Seed propagation. Seventeen acres of seed increase for Ughandi and 9 acres for P9898012 sorghum. Because of drought and pests (sinta, grasshoppers, Nafasha) results will not be obtained from any of the experiments. The sorghum line P9898012 was found to be very drought tolerant and some seed will be harvested from the increase plot.

3.3b Soil Conservation Department: There were a number of good experiments at the Gardud Soil Reclamation Station, near Banjedid (25 Km S). Mr. Abulgassim Amir Abudik (Head) and Mr. Abdella Azibier Abu Allama (Agronomist) are in charge. The experiments were:

1. Effect of mulching and/or legume undersowing on improving Gardud soil. Cereal: Sorghum local variety Um Benin (early). Legume: greengram. Planting method: ridge vs flat.
2. Plant population (spacing) study on sorghum (entry P9898012). Planting method: ridge vs flat.

In early observations it was evident that mulching alone or with a legume had distinct advantage over control plots. Ridge planting also looked better over flat. This area was also hit by drought and hence final results are very unlikely.

3.4 Agricultural Research Council: Dr. M. B. El Ahmadi, National Groundnut Breeder at Wad Medani had variety trials at Kaba Station consisting of:

1. Early maturing types
2. Drought tolerant types
3. Resistant to *Aspergillus flavus* types. Results are pending. Many have been affected seriously by drought.

3.5 Others:

1. *Rhizobia* inoculation study on groundnuts by Mr. Hadad, Sudanese student at Iowa State University. Results - pending.
2. Screening sorghum for striga tolerance - Dr. M. O. Khidir, Khartoum University. Result: Drought affected plus no striga in experimental field.

4. RESULTS OF INTSORMIL TRIALS

4.1 Millet

Because of the drought and serious pest problems only one of the 3-acre demonstration plots (El-Kharta village) was successful. The demonstration plot was planted on June 26 and received good rain on July 2. From this

demonstration plot it was learned that at early stages, the local varieties, Baladi and Hirehree, looked much better than the newly released variety, Ughandi. However, at flowering and onwards, Ughandi showed a comparative advantage over the others. The following observation is presented for comparison.

Table 11. Maturity comparison of Ughandi with Hirehree and Baladi

Variety	Number of Days to Flower	Milk Stage	Maturity
Ughandi	45	55	65
Hirhree	60	67	75
Baladi	67	75	90

The fact that Ughandi reached the milk stage 10 days earlier than Hirhree and three weeks earlier than Baladi means a lot to the farmers of the area. This means that they will have food (Ferrik) available earlier. It also means that Ughandi can mature much earlier and hence avoid peak season of Sinta and other pests. Besides earliness, Ughandi has a large head and long bristles which reduce bird and grasshopper attack. Ughandi is also resistant to long smut. Farmers around El-Kharta are very excited about it and have requested more seed.

The only weak points observed on Ughandi were that it does not tiller much and it is weaker in stand establishment than Baladi and Hirehree. Closer spacing may compensate for tillering in Ughandi.

There were fair to good stands of the demonstration plots at Um Ramad and Geifil. Stand establishment comparisons of the four varieties were as follows: ICMS7817 (very poor), Ughandi (poor), Hirehree (fair), Baladi (good). Yield comparisions will not be possible because sinta and Nafasha were very serious this year in addition to drought.

4.2 Chickpea

All the chickpea trials were also a failure because of drought. Only one trial at Banjedid (Gardud soil) reached flower formation stage after which the plants died because of lack of moisture. With more drought tolerant types, chickpea may have some adaptation on the Gardud soils but not on Goz.

5. CONCLUSIONS AND RECOMMENDATIONS

Up to the present farmers of North Kordofan have maintained a viable farming system in an almost impossible environment. However, with changing conditions, that farming system has reached a critical stage. An increase in human and animal populations has resulted in uncontrolled deforestation in overgrazing and cropland overutilization. The results of these have been decreasing rainfall and increasing temperature trends. There is an immediate need for extensive applied agronomic research first to stabilize the existing farming system and second to make some improvements on it. A simultaneous and coordinated research is also needed in the following areas: plant protection, range and pasture management, soil and water conservation and forestry (reforestation, shelter belts, etc.)

Based on the facts and figures presented in this report, the major factors that reduce crop yields are the abiotic factors - erratic rainfall and poor soil fertility - and on the biotic side - pests and diseases. Out of the three constraints, I consider the pest and disease problem as number one which should be given immediate attention. Unless this problem is solved first, all other breeding or agronomic efforts will be futile. Breeding and selection for resistance and the practice of using cultural practices that minimize pest incidence will be emphasized in the INTSORMIL/ICRISAT millet and sorghum cooperative program. However, with the present pest situation, this will not be sufficient unless additional chemical control measures are used.

As a partial solution to the production constraints in the region, the following are considered priority areas for agronomic research in the 1983 crop season.

1. Seedling establishment and early vigor
   - selection of genotypes (local and exotic)
   - study effect of seed size and density

2. Drought tolerance - selection of genotypes that withstand or escape drought (earliness)

3. Pests and diseases
   - breeding and selection for resistance (bristles, compactness, etc.)
   - developing cropping systems (mixed and inter-cropping) that minimize pest populations
   - crop rotation

4. Soil fertility
   - rotation of cereals with legumes
   - intercropping of cereals with legumes

5. Local and exotic germplasm
   - evaluation of already available germplasm
   - collection of more germplasm (millet, sorghum, cowpeas)
   - introduction of more germplasm (erect and drought tolerant cowpeas, other drought tolerant legumes)

REFERENCES

Abu-El-Gassim, A. 1981-82. Extension annual programmes of Northern Kordofan (unpublished).

Abdel-Ghaffar, A. Farouk. 1976. Major pests of farm crops in Northern Kordofan (unpublished). 4 p.

Ahmed, K. M. and El-Tigani M. El-Amin. 1976. Field pests of groundnuts (Arachis hypogaea) and millet (Pennisetum typhoides) in Sudan with special reference to Kordofan province (unpublished). 13 p.

Agricultural Research Council. 1981. The Horticultural Resources of the Kordofan Region of Sudan. A report of an ARC review mission. Feb. 28 - Mar. 7, 1981. Khartoum, Sudan.

El-Taiyib, G. El-Din. 1972. Forestry and land use in the Sudan. Khartoum Univ. Press. 58 p.

FAO, 1964. Land and water use survey in Kordofan province of the Republic of the Sudan: Agronomic investigations during the 1963 season. Document: DOX-Sud-A25. 232 p.

. 1966. Land and water use survey in Kordofan Province of the Republic of the Sudan: Agronomic investigations - concluding report on the crop trials and their implications for improving land use. Document: DOX-Sud-A24. 81 p.

1977. Report on the Agro-ecological Zones Project, Vol. 1. Methodology and results for Africa. World Soil Series Report. pp. 31-40.

Ibrahim, M. Babiker. 1977. Peasant farmers' response to drought hazard at East Kordofan. Diploma of Physical Environment of the Tropics. Univ. of Khartoum, Geography Department.

ICRISAT. 1980. Annual report of the Sudan cooperative sorghum and millet program. Report #4.

1981a. Annual report of the Sudan cooperative sorghum and millet program. Report #5.

-- 1981b. The pearl millet improvement program: objectives, organization and progress. PM-53. ICRISAT, INDIA. 31 p.

Jarrett, H. R. 1979. Africa. The new certiciate geography series, advanced level. 5th ed. Macdonald and Evans Plymouth, PL6 7PZ. 58 p.

Kambal, A. E. 1979. A report on striga research in the Sudan. Technical progress report No. 1. Agricultural Research Council, Wad Medani and Faculty of Agriculture, Shambat. 101 p.

Kambal, A. E. 1980. Sorghum production in the Sudan. 15 p.

Kassam, A. H. 1979. Multiple cropping and rainfed productivity in Africa. FAO/UN FPA Project INT/75/P13 Land Resources for population of the future. Consultants working paper No. 5. 23 p.

Khidir, M. O. 1981. Striga research in the Sudan. Technical report #2. Agricultural Research Corporation, Wad Medani and Faculty of Agriculture, Shambat. 30 p.

Manger, L. O. 1981. The sand swallows our land: overexploitation of production resources and the problem of household viability in the Kheiran - a Sudanese oasis. African savannah studies - occasional papers in social anthropology No. 24. University of Bergen. 137 p.

Miguel, Angel A., C. A. Francis, Aart V. S. and J. D. Doll. 1978. A review of insect prevalence in maize (Zea mays L.) and bean (Phaseolus vulgaris L.) polycultural systems. Field Crop Research 1:33-49.

Ministry of National Planning, the Democratic Republic of the Sudan. 1981. Gum arabic development phase II. Project design study - Northern Kordofan. Final Report. 237 p. GITEC Consult GMBH, Duesseldorf, Fed. Rep. of German

Musa, B. M. 1980. Breeding sorghum cultivars for resistance to Striga hermonthica. Masters Thesis, Faculty of Agriculture, Univ. of Khartoum. 148 p

. 1981. Variety trial in two local sesame cultivars grown in the sandy soils of North Kordofan (unpublished). Regional Ministry of Agriculture and Natural Resources, El-Obeid.

Obeid, M. and A. S. El-Din. 1971. Ecological studies of the vegetation of the Sudan, III. The effect of simulated rainfall distribution at different isohytes on the regeneration of Acacia senegal (L.) Willd. on clay and sandy soils. J. Appl. Ecol. 8:203-209.

Pacheco, R. and H. A. Dawoud. 1976. Exploratory soil survey on North and South Kordofan based on low intensity survey and LANDSAT Imagery Interpretation. Ministry of Agriculture and Natural Resources, Democratic Republic of the Sudan. Wad Medani Soil Survey Report, No. 81. 108 p.

Rachie, K. O. and J. V. Majmudar. 1980. Pearl millet. Penn. State Univ. Press.

Reeves, E. B. and T. Frankenberger. 1981. Socio-economic constraints to the production, distribution and consumption of millet sorghum and cash crops in North Kordofan, Sudan. Report No. 1. INTSORMIL Contract No. AID/DSAN-G-0149. Department of Sociology, College of Agriculture, Univ. of Kentucky. 72 p.

------ and ------. 1982. Socio-economic constraints to the production, distribution and consumption of sorghum, millet and cash crops in North Kordofan. Report No. 2. INTSORMIL Contract No. AID/DSAN-G-0149. Department of Sociology College of Agriculture, Univ. of Kentucky.

Webster, C. C. and P. N. Wilson. 1980. Agriculture in the tropics. William Clowes and Sons Limited, London and Beccles. 640 p.

APPENDICES

Appendix A. Monthly Maximum, and Minimum Temperatures (°C) for El-Obeid (Source: Sudan Meteorology Department)

Month	Year													
	1941-70*		1975		1976		1977		1978		1979		1980	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Jan.	30.6	13.5	28.6	12.9	30.5	13.7	29.5	13.0	29.9	12.9	20.9	14.3	30.8	13.0
Feb.	31.1	14.6	33.7	18.0	32.0	15.5	32.7	15.8	33.3	16.3	35.4	17.9	32.5	15.6
Mar.	35.7	18.3	36.3	19.2	37.2	21.0	34.4	18.2	36.6	18.8	36.3	19.1	37.0	19.9
Apr.	38.3	21.1	33.6	21.6	38.7	22.6	37.7	20.6	39.7	23.8	40.1	24.0	40.1	23.4
May	39.0	24.0	39.4	24.9	39.9	25.3	38.7	24.3	40.1	25.0	39.3	24.6	40.3	25.2
June	37.3	24.3	37.3	24.4	37.3	24.4	37.1	24.7	38.1	25.1	36.5	24.5	37.5	24.7
July	33.4	22.9	33.8	23.4	33.3	22.8	33.7	23.0	32.6	22.3	35.1	23.3	33.1	22.6
Aug.	31.4	21.9	31.9	22.1	32.4	22.3	31.5	21.9	32.1	22.2	33.7	23.2	33.2	22.9
Sep.	33.8	21.6	33.0	22.6	34.7	21.7	36.2	22.9	34.9	22.4	35.4	23.0	36.1	23.0
Oct.	36.2	21.3	36.8	22.2	37.3	22.4	35.5	21.1	36.7	22.8	37.1	23.2	38.2	22.9
Nov.	33.9	17.5	34.4	19.3	34.9	19.0	33.1	17.1	31.9	16.3	35.4	20.4	34.4	19.2
Dec.	30.9	14.2	29.6	14.2	33.1	17.3	29.6	14.5	31.4	15.6	29.0	13.2	31.2	15.5

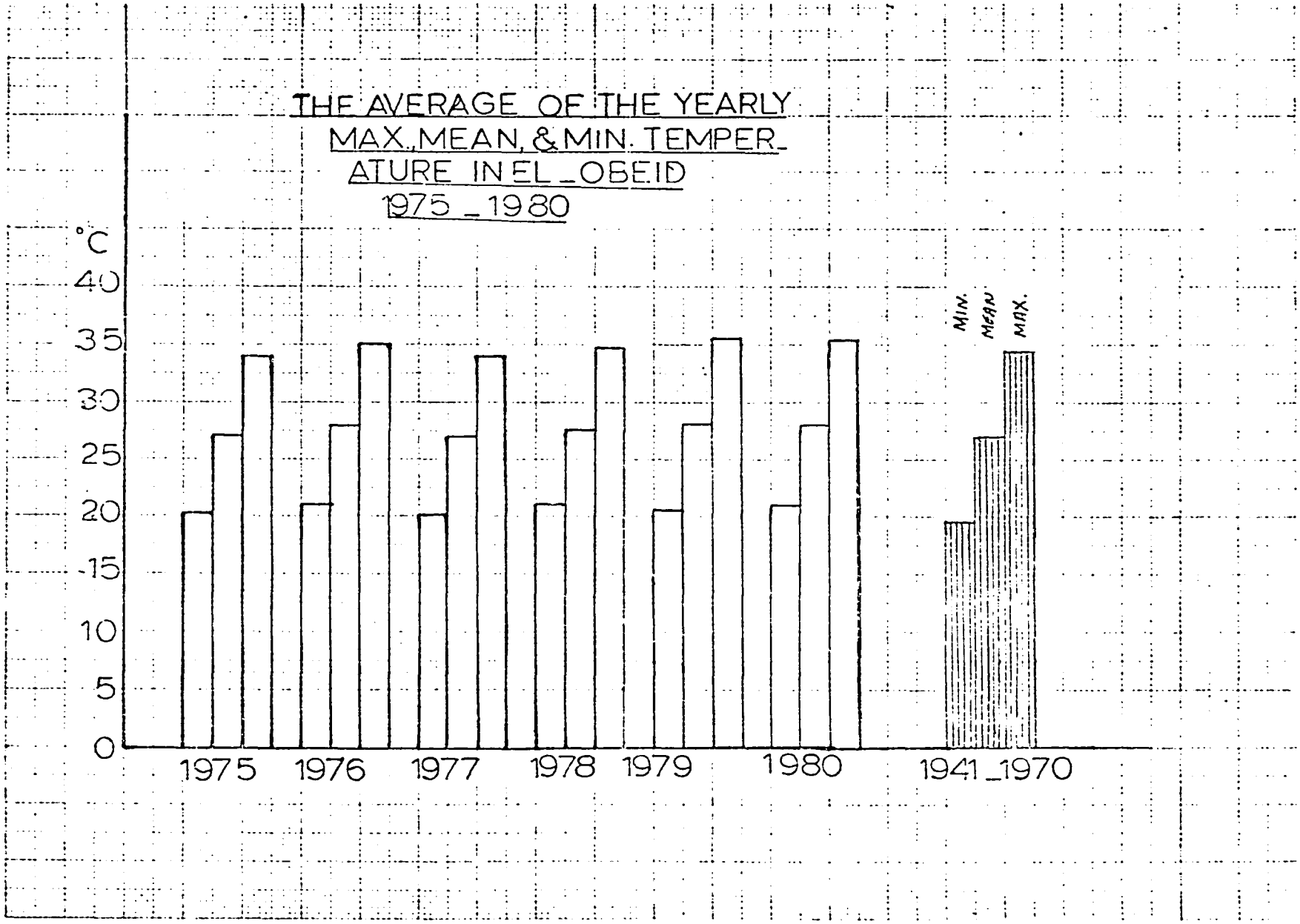
*30 year average

Appendix B. Common Pests and Diseases in North Kordofan, Sudan

Pest	Host*			
	Millet	Sorghum	Sesame	Groundnut
Sinta (*Cryptocamenta* ssp.)	X			
Quelea birds	X	X		
Crows and Doves	X	X	X	X
Nafasha (*Eublema brachygonia*)	X			
Locusts & Grasshoppers	X	X	X	X
Joraan (small black beetle)		X		
Abu Dagig (a type of moth)	X			
Buuda (*Striga hermonthica*)	X	X		
Caterpillars (Rauuma)			X	
Millipedes (Surfa)	X	X	X	X
Ants and Termites	X	X	X	
Field rats (Faar)	X	X	X	X
Ground squirrels	X	X	X	X
Shootfly (*Atherigonia* ssp)	X	X		
Sorghum midge (*Contarina sorgicola*)		X		
Grubs (*Schizonycha cibrata*)				X
Thrips (*Caliothrips* spp).				X
Dura stem-borer (*sesamia eretica*)	X	X		
Spotted stalk borer (*Chilo narfiblus*)	X	X		
Butterfiles and moths	X	X		
Andat (*Agnoscelis pubescus*)	X	X		
Sesame webworm (*Antigasta catalauralis*)			X	
Bugda (*Pachnoda* ssp.)	X	X		
Elasomolus sordidus			X	
Diseases				
Long smut (*Tylosporium* ssp.)	X	X		
Downy mildew (*Schlerospora* ssp.)	X	X	X	
Asperigillus flavus				X

*host crops indicated by the letter X

Appendix C


THE AVERAGE OF THE YEARLY
MAX., MEAN, & MIN. TEMPER-
ATURE IN EL-OBEID
1975 - 1980
°C
40
35
30
25
20
15
10
5
0
1975
1976
1977
1978
1979
1980
1941-1970
MIN.
MEAN
MAX.

Appendix D. Agronomic characteristics of the three local millet types - Baladi, Hirehree, Esh Bornu - and a newly released variety, Ughandi (Abu Suf) in the 1982 crop season

	Agronomic Trait		
	Plant height (cms)	Ear length (cms)	Ear girth (cms)
Baladi - range	1.25-2.25	20-37	9-12
- mean	1.90	29.0	10.5
Hirehree - range	90-2.00	20-29	7-9
- mean	1.63	26.0	8
Esh Bornu - range	1.20-2.20	25-40	7-8
- mean	1.74	33.0	7.5
Ughandi - range	1.00-2.25	25-35	9-12
- mean	1.82	30.0	11