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WESTERN SUDAN AGRICULTURAL RESEARCH PROJECT

# SOIL AND WATER MANAGEMENT AND CONSERVATION PROGRAM, NORTH KORDOFAN

WSARP PUBLICATION NO. 35 FEBRUARY 1984

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THE GOVERNMENT OF SUDAN

UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

THE WORLD BANK

CONSORTIUM FOR INTERNATIONAL DEVELOPMENT

WASHINGTON STATE UNIVERSITY

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LALIT M. ARYA — SOIL AND WATER SPECIALIST

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LALIT M. ARYA

(SOIL AND WATER SPECIALIST)

FEBRUARY, 1984



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# SOIL AND WATER MANAGEMENT AND CONSERVATION PROGRAM, NORTH KORDOFAN

## SUMMARY

Water availability is the overriding problem in the region. It is a result of the combined effects of weather and soil conditions. Major elements of the soil and water management problems in North Kordofan are:

* Low and unreliable rainfall
* Relatively short rainy season
* High atmospheric evaporativity
* Poor water holding capacity and rapid water loss in qoz soils
* Rapid drying of surface zone in qoz soils leading to poor emergence and failure of emerged seedlings
* Excessive compaction and poor infiltration in gardud soils
* Low organic matter and absence of soil aggregation
* Poor soil fertility
* Weed competition for soil water and nutrients during the cropping season
* Inefficient use of irrigation water
* Severe wind erosion resulting in loss of soil and sandblasting of young seedlings
* Lack of information on soil properties and processes, fertility status, weather variables, crop/weather interactions, moisture balance and water loss patterns, and nature and magnitude of wind erosion
* Lack of awareness of soil and water problems and potential conservation practice

A program for soil and water management is proposed. The main emphasis is placed on maximizing soil water storage and minimizing non-useful losses. Field trials to be carried out are detailed in this paper.

# SOIL AND WATER MANAGEMENT AND CONSERVATION PROGRAM, NORTH KORDOFAN

LALIT M. ARYA

(SOIL AND WATER SPECIALIST)

## INTRODUCTION:

The Western Sudan Agricultural Research Project (WSARP) has established research stations for crop and livestock research for traditional producers in the rainfed sector of Western Sudan. One of the stations is located in El Obeid representing southern part of the North Kordofan Province. WSARP Kadugli serves the South Kordofan (or Nuba Mountain Region). WSARP El Fasher and WSARP Ghazala Gawazat serve the Darfur Region. The aim of the WSARP research program is to achieve an improvement in the livelihood of the traditional producers. A farming systems approach involving on-farm and on-station trials is being employed to address the constraints limiting agricultural production in the region. Reconnaissance and diagnostic surveys are being used continuously to identify constraints and formulate strategies for action. Several constraints relating to crop varieties, cultural practices, crop and animal diseases, marketing, storage, transportation, labor and agricultural supplies have been identified. Since the region is rainfed, availability of water remains a major management problem. Through continued neglect and poor management, soil deterioration has progressed to a point that the desired level of production cannot be sustained. Erosion, poor fertility, poor structure, and low water retention characterize most of the agricultural soils in the region.

A comprehensive presentation of WSARP work plan is available in WSARP Publications 13, 14, 15, 18, and 22. This document identifies and discusses major constraints relating to soil and water management in North Kordofan and presents

a research program for field testing and demonstration. Specific field trials to begin in 1984 are detailed out. Although the program is specific to North Kordofan, it can be extended to other regions with little modification.

## THE FARMING SYSTEM IN NORTH KORDOFAN

The agroclimatic environment in this region is characterized by poor soils and low and unreliable rainfall. Sorghum, millet, sesame, groundnut, kerkadi (Roselle), and watermelon are the chief crops. Vegetable and fruit trees are grown under irrigation in gardens distributed in the floodplains of seasonal streams (khors). Animals raised include: camels, cattle, sheep, and goats. The average annual precipitation around El Obeid is 350 mm, most of it falling between mid-June to mid-September. The pattern of precipitation within any given season is irregular, being marked by a few relatively heavy showers and several rainless periods of varying durations. The rainy season is preceded by several months of hot and dry weather. Relatively cool and dry weather prevails from December to February. The average annual free water evaporation is estimated around 2,400 mm.

The typical cropping cycle consists of land clearing, planting, weeding, and harvesting. Land clearing takes place in the period from January to April. Sorghum, sesame, and groundnuts are planted from June to early July. Millets are planted earlier, because the locally preferred varieties are long-maturing. Because of the necessity of synchronizing the crop growing period with a relatively short rainy season, farmers plant early in order to catch every available drop of rain for crop production. If the early plantings succeed, owing to arrival of rains as anticipated and if the moisture supply is regular, a successful harvest may be expected. Most often, however, there is a long gap between the first and the subsequent rains, which leads to a loss of emerged seedlings. Replanting becomes necessary, but the growing season is now shorter, so earlier maturing cultivars must be sown. Even if replanting succeeds in achieving an acceptable plant population, there are no guarantees against subsequent periods of drought.

Farmers recognize the importance of removing weeds from their fields. Most farmers try to weed at least twice, but, availability of labor is a serious constraint. Harvesting and threshing operations, in general, are carried out from October to November.

All work is done by hand tools and human power. The average landholding is 18 makhammas (32.4 acres). Most farmers, however, cultivate only about one-half of their total landholding. There is virtually no tillage; planting is done by dropping seeds dug by handtools at regular intervals. No chemicals or fertilizers are used and there is no evidence of any soil or water conservation practices. The way the soil fertility is traditionally maintained is by bush-fallowing.

Crop yields are very low by world standards. Average yields for sorghum, millet, sesame, and groundnuts (unshelled), reported in mid-1960, were 535, 470, 305, and 880 kg/ha, respectively. These averages are lower now. Water availability appears to be the main limiting factor. However, there appears to be potential for improvement, if sound conservation practices are adopted. Studies at the Central Arid Zone Research Institute in India showed that using a millet husk as a mulching material, the consumptive-use for millet was about 270 mm of water and yields over 1,700 kg/ha could be obtained. The 350 mm of rain around El Obeid is certainly more than the consumptive-use needed for a reasonably good yield of millet.

## WEATHER

Climatic normals for El Obeid are shown in the accompanying Figure 1, taken from Doxiadis Associates (Land and Water Use Surveys in Kordofan Province, The Sudan, 1967, Final Report, UNDP/FAO). The normals are based on weather data up to the mid-1960's. Examination of the data for the past several years shows that average annual rainfall has steadily declined and rainy season has shortened.

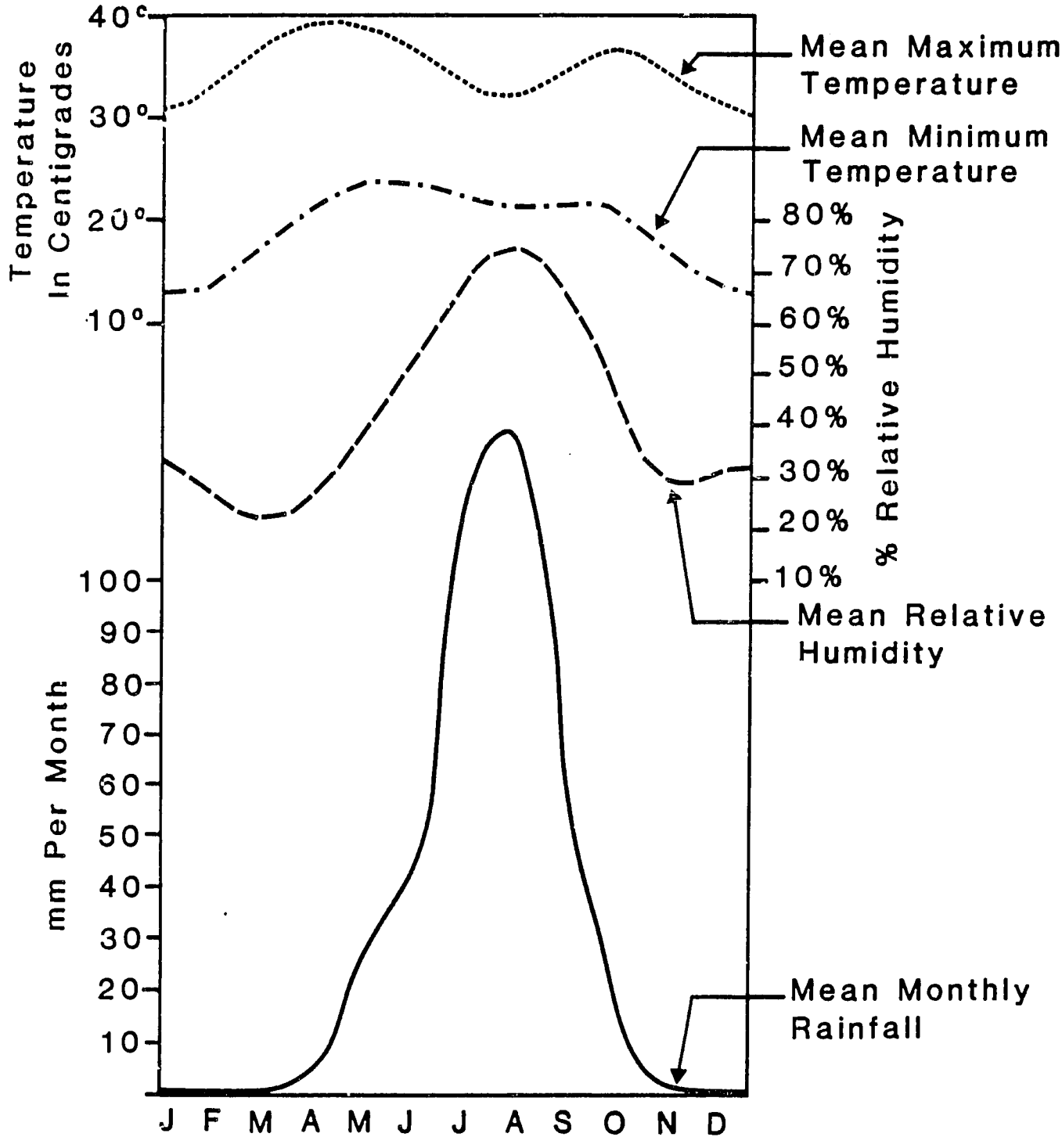



Figure 1. Climatic Normals At El Obeid

Source: D-SUD-A1316
Doxiadis Associates

Nevertheless, climatic normals show the period most favorable for crop production. During the dry months, weather conditions are conducive to high evaporation. As a result, there is virtually no stored water to carry over from the previous season. The early rains are uncertain and light in amount. This affects crop production in an important way. If crops are planted early, stand is usually poor because of insufficient soil moisture. If plantings are delayed until sufficient moisture has been received, growth period extends beyond the termination of rains and crops experience stress at their reproductive stage. Both the early and late rains are insignificant. The short season makes it difficult to crop long-maturing varieties that may be otherwise desirable. Water conservation, therefore, appears to be of utmost significance. If conservation practices are adopted to maximize soil water storage, it may be possible to delay sowing dates, since stored water would be available to crops beyond the point when rains cease. It should be noted that temperature conditions following the rainy season are still quite good for crop growth.

## SOILS

There are two major soil types in the region. The stabilized sand soils, locally called "Qoz" account for 70 percent of the area. Its water and nutrient holding capacity is very low and it is highly susceptible to wind and water erosion. The second major soil is "GARDUD", which consists of varying amounts of finer materials giving it a sandy clay to clayey texture. In many instances, the surface of gardud soil is covered with 20 cm, or so, of sand. Gardud soil is highly compacted and very difficult to cultivate with traditional hand tools and human power. Water infiltration in gardud soils is very poor and root growth is highly restricted. As a result, its surface is only sparsely covered with vegetation and is exposed to erosion. Consequently, little or no organic matter is added to the soil and natural soil fertility is very low and there is no soil structure. Thus, despite their potential for better water and nutrient holding capacity, gardud soils are not cultivated by traditional farmers. In their present state, they are unproductive. There is evidence, however, that these soils can be rehabilitated. Deep plowing and disking trials by Doxiadis Associates in early 1960's showed significant improvements in crop production on

these soils. However, if plowing was not continued, the open structure fell back to its original density. Apparently, plowing and other management practices are needed to create and stabilize an open structure. Additionally, water conservation and fertility management practices are needed to ensure continued productivity.

The qoz soils, on the other hand, are easy to cultivate with traditional hand tools. As a result, much of the traditional crops are grown on these soils. Local cropping practices on qoz soils involve clearing the land of all vegetation, planting without any tillage, and then clearing the land again after the crop is harvested. These practices expose the land to wind and water erosion causing deterioration of an already fragile landscape. Because these soils are deep sands with poor water and nutrient holding capacity, crop yields are very low. Expert opinion suggests that the best use of these soils would be to preserve them under forest and natural vegetation, but this appears to be difficult at the present time. Although, gardud soils appear to be potentially productive, their present state does not permit them to be easily utilized without rehabilitation, which may take time. If cropping on qoz soils is to continue, sound management practices have to be evolved and adopted. Observations made during the 1983 cropping season revealed sparse stands as a widespread feature on cropped qoz lands. It is, obviously, a result of poor emergence and/or loss of emerged seedlings. The problem appears to be related to moisture deficiency in the surface zone. The intake of rainwater is rapid in these soils, and if tapped to full extent, can support a reasonable crop yield. However, under the prevailing soil and climatic conditions, drying of the surface zone (or the seed zone) is very rapid. This affects, seriously, seed emergence and seedling growth and eventually the crop stand. Although a potential water supply exists in the subsoil and below, plants with a shallow root system are unable to use it. Poor crop cover allows a significant amount of infiltrated water to be lost to direct evaporation. Thus, on qoz soils, conservation of soil moisture and improving moisture supply in the seed zone during the critical stages of emergence and seedling growth appear to be key to improved management.

## IRRIGATION:

Although the region is largely rainfed, irrigation is practiced where water is available. Irrigated areas exist in the floodplains of seasonal streams (khors). The orchards and vegetable gardens in these areas are an important source of fruits and vegetables for the region. Water in these areas comes from a perched water table and is limited in amount. The present method of conveying water via open channels and irrigating fields by flooding is highly wasteful and labor intensive. The amount of water applied is generally much in excess of what is actually needed. Excess water fosters the development of crop diseases, promotes weed growth, causes leaching of nutrients and interferes with farm operations. Given that the water supply is limited, the need for an efficient system of irrigation is obvious. Providing farmers with the information on when to irrigate and how much water to apply plus a controlled system of water application should be a rewarding effort.

## STATUS OF RESEARCH:

Much of our current understanding of soil and water problems in the region is based on reconnaissance surveys, visual observations, and impressions gathered from discussions with professional agronomists, administrators, and farmers. Factual data on soil properties and processes, soil moisture regimes, fertility status, and crop/weather interactions are lacking. For example, the characteristics of gardud soils that are responsible for its present condition are not understood. Understanding its mechanical and chemical composition, structure, hydrologic properties, and layering sequence is important in identifying the constraints to agricultural production and recommending suitable soil and water conservation practices. There are no data on crop water-use and field water balance. A continuous or frequent monitoring of soil moisture regimes in both the gardud and the qoz soils is important for determining the nature of water loss problems and to form basis for proposed solutions of water conservation and improved cropping practices etc. Monitoring weather variables is also important in planning management strategies. Wind erosion is a very serious problem in

the region, but, its nature and magnitude remain unknown. A system of monitoring wind erosion on a year-round basis should be helpful in identifying and evaluating management practices.

PROPOSED RESEARCH PROGRAM:

From the preceding discussion, it is possible to summarize readily identifiable elements of soil and water management problems in North Kordofan. These are:

* Low and unreliable rainfall
* Relatively short rainy season
* High atmospheric evaporativity
* Poor water holding capacity and rapid water loss in qoz soils
* Rapid drying of surface zone in qoz soils leading to poor emergence and failure of emerged seedlings
* Excessive compaction and poor infiltration in gardud soils
* Low organic matter and absence of soil aggregation
* Poor soil fertility
* Weed competition for soil water and nutrients during the cropping season
* Inefficient use of irrigation water
* Severe wind erosion
* Lack of information on soil properties and processes, fertility status, weather variables, crop/weather interactions, moisture balance and water loss patterns, and nature and magnitude of wind erosion
* Lack of awareness of soil and water problems and potential conservation practices

Water availability appears to be the overriding problem in the region. It is a result of the combined effects of low rainfall and poor soil conditions. Since there is nothing that can be done to alter the rainfall, management practices should aim at maximizing the intake of water in the soil profile and then making the most efficient use of the stored water.

On the qoz soils, where infiltration is rapid, the problem is to conserve the water against evaporative losses and weed transpiration. Mulching and leaving crop residue in the field are effective means of controlling evaporation and suppressing weed growth. Adequate moisture supply in the seed zone on these soils is very important for seedling emergence and stand establishment.

On gardud soils the problem is restricted root growth and very low infiltration due to excessive compaction. Rehabilitation of gardud soils would involve both the improvement of physical condition and moisture conservation. If water infiltration in gardud soils can be improved, the natural wetting-drying cycle will play an important role in improvement of soil structure. Creating surface roughness by land imprinting and plowing should prove useful. However, the soil structure must be stabilized by cropping and addition of soil amendments.

Water harvesting could be employed to make better use of the limited rainfall for field crop production. By a combination of surface treatment and land shaping, rainfall received over a large area can be concentrated over a smaller area to increase total water storage and chances for successful crop production. A system of cultivation in which micro-catchments are provided for growing plants should help young seedlings. Planting in cradles or furrows has been shown to be effective in conserving moisture and seedling establishment.

Steps should also be taken to reduce risk of erosion. Wind erosion on qoz soils is a serious problem. Spraying the surface with soil-binding substances could be an effective means of reducing soil movement due to wind action. Stabilized ridges and furrows should also reduce soil movement. Additionally, shelterbelts

and windbreaks should be considered in overall planning for soil and water conservation. The key to both soil and water conservation is to keep the land surface covered as much as possible.

The following programs for soil and water conservation are being proposed for testing, demonstration, and on-farm evaluation. Details of field trials for some of the programs are presented in the Appendix.

A. Mulching and residue management for soil and water conservation: Both the on-station and on-farm trials should be carried out to demonstrate and evaluate the effects of mulching on moisture conservation and crop growth. Keeping the land surface covered with dead organic residue not only minimizes evaporative loss of water, it also improves soil structure, reduces runoff, increases infiltration, reduces erosion, suppresses weed growth, and keeps the soil surface relatively cooler. Mulching materials could include dry grasses and crop residue from the previous crop, collected and stored for use at the beginning of a cropping season. Alternatively, stalks from the previous crop could be left standing in the field and chopped to bring them to the ground level when it's time to plant the next crop. During the crop season, weeds that are removed could also be left drying between the crop rows. The demand for crop residues for use as a thatching material and forage for cattle is a point to consider. However, it is hoped that increased vegetative growth from conserving moisture would alleviate the pressure to some extent. Farmers' realization of the significance of moisture conservation is, perhaps, the most important issue. A demonstration of the method and its results should be the first step towards educating farmers.

B. Improving soil moisture supply in the seed zone in sandy soils: This effort should involve treating the soil with amendments that have the properties of improving soil moisture retention and/or reducing evaporation. Both the general treatment of the land, as well as of the planted hills or rows should be evaluated. Hydrophilic colloids such as "AGROSOKE" and "SUPER SLURPER" have been shown to be highly effective in increasing moisture

retention in sandy soils. However, cost and importation problems make their use in Sudan highly improbable. Locally available materials such as gum arabic and clay soils appear to have a potential and should be evaluated. Partial mulching (of planted hills and rows) as opposed to general mulching with cropped straw appears to be another alternative. Also, planting methods in which seed zone microenvironment is modified by planting seeds in depressions and furrows should be effective in increasing water collection in the seed zone and reducing evaporation. A combination of amendments and planting techniques may be even more effective. An on-station trial to evaluate the effectiveness of these methods under the local soil and climatic conditions should be carried out at first.

C. Water harvesting to increase water supply in cropped fields: Water harvesting is taking rain that falls on a given area and diverting it to a portion of this area. The objective is to increase the availability in a limited area. Water harvesting has been used with success in other arid and semi-arid countries. Sloping land is best suited for these purposes. Treating the contributing area with a hydrophobic material or compacting it with a roller decreases infiltration and induces runoff. Some land shaping may be necessary. A system of ridges and furrows should be provided in the receiving area in order to contain the incoming runoff. It is suggested that land be prepared for water harvesting at the onset of the rainy season.

Locally produced Gum Arabic has been tested for its soil sealing properties. A spray of this material or application in powdered form could be used for inducing runoff. Since this will be the first trial of its kind, an on-station trial is recommended. Optimum rate of application, application methods, and persistence of gum in the soil need to be studied. Efforts should be made to make an economic evaluation of this technology.

D. Rehabilitation of gardud soils: Field trials should be carried out to evaluate deep plowing and chiseling as a means of loosening gardud soils. Previous work has indicated that if plowing is not continued in gardud soils, the open structure created by plowing falls back to its original density. Apparently, there is a need for methods to stabilize soil structure. Ridges and furrows should help increase infiltration and help maintain looseness of the soil. Cropping with crops that produce extensive and deep root systems should have a stabilizing effect. The benefit would come primarily from addition of organic matter, compression of soil into aggregates, and establishment of water conducting channels left by decaying roots. Addition of amendments such as farmyard manure and gypsum might also be helpful. An on-station trial should be carried out to measure the effects of plowing and cropping treatments on soil resistance, infiltration, and moisture regime. Persistence of the effects of plowing should also be studied.

Availability of suitable machinery and energy costs make deep plowing somewhat impractical for the traditional farmer in Western Sudan. It may be feasible on government-managed lands and lands under the control of mechanized schemes. There may be merit in exploring the feasibility of animal-drawn implements. A simpler alternative would be to test land imprinting as a means of reducing runoff and increasing infiltration. Imprints are several inch deep depressions created by driving into the soil metal cones or wedges. The depressions act as microcatchments for water, reduce runoff, and increase water intake. The depressions could also be seeded with grasses and forage legumes to help improve soil condition. The success of this technique has been demonstrated by USDA researchers in Arizona (USA). An on-station trial should be carried out to measure the effects of various densities of the imprints. A comparison of land imprinting and plowing effects on water intake and other relevant soil properties should also be made.

E. Drip irrigation for horticultural production: Horticultural production in North Kordofan is dependent on availability of irrigation water. Critically low supplies and wasteful methods of irrigation make it important that efforts begin to educate farmers in new technologies of irrigation. Drip system is the most efficient method of water application. There is almost 50 percent reduction in water usage. Pumping cost is reduced accordingly. Labor requirement to maintain open earthen channels is eliminated. Water is delivered to the plants directly and dissolved fertilizers can be fed to the plants via drip outlets. Between row spaces are always dry so that weed growth is minimal and farm operations such as staking, picking, and pruning continue uninterrupted. Earthwork to move water from one end of the field to another is completely eliminated.

It is proposed that a few demonstration sets of drip system be installed on farmers' fields. Farmers who irrigate have pumps and water available. PVC pipes and a variety of fittings are available locally. Importation of drip hoses and some specialized drip components will be necessary. If the necessary components are available, it should be fairly simple to install an operational system. Efforts should be made to develop irrigation schedules to advise farmers on when to irrigate and how much water to apply. Weather data and information on crop water-use are necessary inputs to developing irrigation schedules. Information developed elsewhere could be modified for use in the beginning.

The success of the drip system and demand for it will not be known until the system is introduced and benefits evaluated. If there is sufficient demand, an interest in importation and/or manufacturing of drip components on the part of the local businesses should be expected.

F. Use of shelterbelts and windbreaks for soil and water conservation: Shelterbelts and windbreaks reduce the wind velocity and thereby decrease wind erosion as well as evapotranspiration. Closely planted rows of acacia or other local species at regular intervals (500 ft or so) can form an

effective shelterbelt. Crops planted between the rows of acacia should benefit. It is, however, difficult to find existing plantations in the configuration of a shelterbelt. Plantings that are under the control of the forestry department may be of no benefit to an individual farmer. The problem of wind erosion and the need for moisture conservation, however, is serious enough that a program must start now. Large areas should be covered to develop shelterbelts of desired density and geometry. It could be a regional program and WSARP could provide technical assistance. Where individual farmers are concerned, they may be encouraged to plant acacia as permanent windbreaks around their fields.

Because of the land tenure system, present land-use patterns, and the need to cover large areas, a program of this nature does not seem feasible for WSARP. WSARP could, however, focus on developing cropping systems in which tall-growing crops are used as windbreaks or shelters for short-growing crops. As an example, groundnuts, cowpeas, and watermelons could be planted between rows of tall varieties of sorghum, millet, and pigeon peas. Intercropping is practiced in the region and some field trials have shown beneficial effects. However, no trials have been designed from the standpoint of water conservation. Field trials should be carried out to determine most useful crop combinations and planting geometry. Soil moisture regime, crop water-use, and crop yield should be monitored as indicators of the effectiveness of a system.

G. Monitoring wind erosion: Wind erosion is a serious problem in the region. Not only the fertile top soil is lost, sandblasting of young seedlings leads to poor crop stand. However, the nature and magnitude of erosion problems remain unknown. There is need for quantitative characterization of wind erosion. A knowledge of spatial and temporal variations of wind erosion could be very useful in identifying the most susceptible locations and the times when the problem is most serious. Factors contributing to erosion need to be isolated and quantified. Quantitative data are needed for developing management strategies. Soil and water conservation programs

that are proposed in this document are expected to reduce soil erosion. However, effectiveness of the practices cannot be ascertained without quantitative measurements.

It is proposed that a wind erosion measurement program be started in a collaborative mode with research centers where wind erosion programs exist and measurement techniques have been perfected.

H. Investigations of soil physical and chemical properties: There are hardly any data on physical and chemical properties of the soils of the region. Quantitative data are needed for isolating soil factors and analyses of soil processes basic to identifying constraints and formulating management practices. Also, evaluation of management practices would require quantitative measurements on a continuing basis.

It is proposed that a program of measurement of soil physical and chemical properties be started. As a first step, three profiles at each of the WSARP experiment sites, representing major soil types, could be analysed. Eventually the program must expand to include other locations. A well-equipped laboratory and technical staff are needed. WSARP does not have laboratory facilities at the present time. It is, therefore, proposed that the initial samples be sent to established laboratories elsewhere for analysis on a hire basis.

I. Monitoring soil moisture regime: Western Sudan is a semi-arid region where water availability is the most serious problem. Understanding moisture loss problems is a must. Field moisture balance data are needed on a temporal basis to develop an inventory of the water resources. These data will aid in forming the basis for solutions of water conservation and improved croppping practices etc. Selection of crop varieties, delineation of critical periods, and planting strategies can be based on the field moisture data.

Although monitoring the soil moisture regime is identified as a program in this document, a separate activity is not intended. The measurements could be carried out as part of the other programs that are proposed. The only requirement is that measurements of moisture content be made as a function of time and depth under various management practices. In addition, soil hydrologic properties needed for moisture balance analysis should also be measured. Depth of soil monitored should conform to crop rooting zone.

J. Monitoring weather variables: Weather data are needed to characterize the agroclimatic environment. They are important for computing atmospheric evaporativity and evaluation of field moisture status. Irrigation schedules have to be based on the weather data. Crop types and varieties can be better selected if weather variables are known. Planting dates can be better specified and sound basis for management practices can be evolved. Additionally, data should be useful as inputs to crop growth and yield models. The information gained from models will augment data gathered from field experiments and accelerate our understanding of crop/environment interactions.

It is proposed that weather stations be installed on each of the WSARP experiment sites and following variables be monitored on a daily basis.

* Rainfall
* Maximum and minimum air temperatures
* Soil temperature
* Relative humidity
* Wind run
* Solar radiation
* Pan evaporation

# APPENDIX

## SPECIFIC RESEARCH PROPOSALS FOR SOIL AND WATER CONSERVATION PROGRAM, NORTH KORDOFAN

## SPECIFIC RESEARCH PROPOSALS

### A. FIELD TRIALS ON MULCHING AND CROP PRODUCTION UNDER THE SEMI-ARID CONDITIONS OF NORTH KORDOFAN.

Mulching is an effective method of soil and water conservation. Keeping the land surface covered with dead organic residue not only minimizes evaporative loss of water, it also improves soil structure, reduces runoff, increases infiltration, reduces erosion, suppresses weed growth, and keeps the land surface relatively cooler.

BEGINNING DATE: 1984 cropping season (June-July 1984)

OBJECTIVE: To evaluate and demonstrate the effectiveness of surface mulch on soil water storage, efficiency of crop water use, and crop production.

EXPERIMENT 1:

Effects of surface mulch on soil water storage, crop water use, and sorghum and millet yields in sandy qoz soils.

METHODOLOGY:

There will be one on-station trial and one on-farm trial. A single layer of dry millet stalks will be spread on the trial plots just before the rains are expected. Crops will be planted after the first 10 mm rain has been received. Planting will be carried out by opening the layer of mulch just enough to prepare the hill and drop the seeds. A preplanting basal dose of fertilizer (40 Kg N and 80 Kg $P_2O_5$/ha) will be given. Five seeds per hill will be planted and thinned to one plant per hill after germination.

On-Station Trial:

The trial will be carried out on the WSARP Agronomy Farm, El Obeid.

(a) Experimental Design:

A split plot design with 2 treatments (mulch and no mulch), 2 crops (sorghum and millet), and 4 replications.

| | | | | |
|---|---|---|---|---|
| Rep I | MMI | MS | CMI | CS |
| Rep II | CS | CMI | MMI | MS |
| Rep III | MS | MMI | CMI | CS |
| Rep IV | CMI | CS | MS | MMI |

M = mulch; C = no mulch; S= sorghum;
MI = millet

(b) Planting Pattern (sorghum and millet both):

8 rows, 12 m long. Row to row spacing - 75 cm. Plant to plant spacing - 20 cm. Plot size - 72 $m.^2$ Plant population - 66,667/ha.

(c) Observations:

Four middle rows will be used for observation. Data to be recorded include: emergence, plant population, plant height and number of leaves per plant, days to flowering, days to maturity, total biomass at harvest (grain yield + stover), weed growth, and weekly soil moisture status.

(d) Resources Required:

* Approximately 1500 $m^2$ of qoz land
* 15 trailerloads of millet stalks
* 2 Kg sorghum seeds and 1 Kg millet seeds
* 15 Kg urea and 30 Kg triple superphosphate
* 1 measuring tape, 100 stakes, 2 marking pens, 1500 ft of string/rope, 200 plastic bags (1 Kg capacity), 100 moisture cans, 2 oakfield augers, meter sticks, weighing balance, and drying ovens.
* Senior technician - 32 technician days
* Junior technician - 32 technician days
* Laborers - approximately 65 laborer days
* Vehicle and driver - as needed
* Scientist - 16 scientist days

On-Farm Trial:

The objective of this trial is to demonstrate the benefits of mulching to the traditional producers of sorghum and millet. Detailed observations on plant growth and moisture regime are not intended. Only yield data will be taken to compare production with and without mulch.

The trial will be carried out in collaboration with Dr. Tareke Berhe of INTSORMIL in a village where he already has ongoing trials. Mulching material, fertilizer, and seeds will be supplied by WSARP. Millet and sorghum will be planted in 20m X 20m plots in the same way as for the on-station trial. This will be an unreplicated trial. For comparison, adjacent plots without mulch will be planted using farmer's planting method. Frequent visits will be made to the village to observe crop growth and development. Yield data will be obtained in the same manner as for the on-station trial.

a) Resources Required:

* Approximately 1600 $m^2$ of farmer's land
* 2 Kg sorghum seeds and 1 Kg millet seeds
* Vehicle and driver for 10 round trips of 20 km each
* 6 trailerloads of millet stalks
* Measuring tape, string/rope, and stakes
* Painted signboards
* Laborers - approximately 15 laborer days
* Technician - approximately 10 technician days
* Scientist - approximately 8 scientist days
* 20 Kg urea and 40 Kg triple superphosphate

EXPERIMENT 2:

Demonstration of the effects of straw mulch on irrigation requirement and vegetable production in the Bangdeed region of North Kordofan.

BEGINNING DATE:

March - April 1984

METHODOLOGY:

This will be a researcher-managed on-farm trial. The WSARP horticulturist is already conducting field trials on two farms in Bangdeed. The same farms will be utilized for the mulching trials. Soils in this region are clayey. Cracking is extensive and is believed to be the cause of rapid moisture loss. First trials will be carried out with eggplants. Eggplants have been chosen because other crops do not do well during the hot summer months. The trial will be repeated with other crops as the growing season becomes more favorable.

Farmers grow vegetables on a ridge-furrow bed; furrows being utilized for irrigation. The proposed trial will be carried out on the same kinds of beds. Eggplant seedlings will be planted on the slopes of the ridges after a pre-planting irrigation. Fertilizers (50 kg N and 100 kg $P_2O_5$/ha) will be applied as dressing at three stages of growth. A layer of straw mulch sufficient to cover the soil completely will be spread in the plots receiving mulch treatment. Mulch will be applied before the seedlings are planted. Water will be applied at three irrigation frequencies (5, 10, and 15 day intervals). Amount of irrigation water cannot be controlled at this time. The farmer will be allowed to apply the amount of water he usually applies in a given irrigation. A schedule of irrigation will be provided and a WSARP technician will be on site to guide the farm manager with regard to irrigation frequency. Cultural operations will be carried out following farmer's own practices.

(a) Experimental Design:

A split-plot design with 2 mulch treatments (mulch and no mulch), 3 irrigation frequency, and 3 replications

| REP I | | | | | | REP II | | | | | | REP III | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NM | M | NM | M | M | NM | M | NM | NM | M | M | NM | NM | M | M | NM | NM | M |
| (10) | (10) | (5) | (5) | (15) | (15) | (5) | (5) | (10) | (10) | (15) | (15) | (15) | (15) | (5) | (5) | (10) | (10) |

M = Mulch; NM = No mulch; 5 = 5 day irrigation interval; 10 = 10 day irrigation interval; 15 = 15 day irrigation interval.

(b) Planting Pattern:

6 rows, 5 m long. Row to row spacing - 75 cm. Plant to plant spacing - 50 cm. Seedlings will be planted midway on the slopes of the ridges. Plot size - 22.5 $m^2$. Number of plants/plot -60.

(c) Irrigation:

There will be a preplanting irrigation, possibly three days before planting. The second irrigation will be applied immediately after planting. Frequent light irrigation will continue until seedling establishment. This will be based purely on visual observations of seedling condition. After seedlings have established, irrigation will be applied at 5, 10, and 15-day intervals as outlined in the experimental design.

(d) Observations:

Two middle rows in each plot will be used for observation. Data to be recorded include plant growth and yield, soil moisture, weed growth, and cracking. Additional information will include labor used for weeding, pumping cost, and amount of irrigation water used.

(e) Resources Required:

* Approximately 450 $m^2$ of farmer's land
* Irrigation water, conveyance system, and pump
* Eggplant seedlings, about 1200
* Straw mulch for 250 $m^2$ land
* Measuring tape, string/rope, and stakes
* Soil moisture sampling tools - moisture cans, auger, balance, and drying oven
* 10 kg urea and 20 kg triple superphosphate
* Vehicle and driver for 15 trips of 40 km each
* Laborers - approximately 50 laborer days
* Technician - approximately 40 technicians days
* Scientist - approximately 15 scientist days

B. TRIALS ON IMPROVING SOIL MOISTURE SUPPLY IN THE SEED ZONE IN SANDY QOZ SOILS IN NORTH KORDOFAN.

Under the prevailing climatic conditions, drying of the surface zone in the sandy qoz soils is very rapid. This affects seriously the seed emergence, seedling establishment, and eventually the crop stand as a whole. Although a potential water supply may exist in the subsoil and below, plants at the seedling stage are not able to benefit from it. Surface zone moisture supply is critical for seedling establishment. Soil amendments that improve moisture retention and planting methods in which seedling microenvironment

is modified by creating seed cradles and ridge-furrow beds will be evaluated in field trials. Surface mulching is also effective in conserving moisture, and a field trial has already been proposed.

BEGINNING DATE:

1984 cropping season (June-July 1984)

OBJECTIVE:

To improve seed emergence and seedling establishment by accumulating more water in the seed zone and reducing evaporative losses.

EXPERIMENT 1:

Effects of planting methods on seed zone soil moisture, seed emergence, seedling survival, and crop yield in a sandy qoz soil.

METHODOLOGY:

This will be an on-station trial. Three methods of planting will be evaluated with sorghum and millet as test crops.

1. Planting in seed cradles:

Seed cradles will be created by forcing a cone-shaped imprinter in the surface to a depth of 10 cm. The imprinter will be rotated several times in order to stabilize the sides of the cone-shaped seed cradle. A preplanting basal dose of fertilizer (40 kg N and 80 kg $P_2O_5$/ha) will be applied. Seeds will be planted in the bottom of the cradle and covered with 3 cm of soil. Six seeds per cradle will be planted and thinned to 2 plants per cradle after emergence. It is expected that seed cradles will accumulate more water and provide some protection against evaporative action of wind and solar radiation.

2. Planting on a ridge-furrow bed:

Ridges and furrows will be created by digging and moving the soil by hand tools. Ridge to ridge space will be 80 cm and ridge height will be 20 cm. Seeds will be planted at the bottom of the furrow. A preplanting basal dose of fertilizer (40 kg N and 80 kg $P_2O_5$/ha) will be applied in the furrows. Six seeds per hill will be planted and thinned to 2 plants per hill after emergence. Ridges and furrows are expected to effect greater water accumulation and reduction in evaporation by providing partial shading and protection against wind action. Ridges (when stabilized) should also act as a barrier against wind erosion.

3. Regular planting on a flat surface:

Planting will be carried out in the way the farmers plant, except that the spacing and the seed rate will be the same as for the seed cradle and ridge-furrow system. This method of planting will serve as a control. A preplanting basal dose of fertilizer (40 kg N and 80 kg $P_2O_5$/ha) will be applied by broadcasting. Six seeds per hill will be planted and thinned to 2 plants per hill after emergence.

Weeding for all plantings will be carried out by hand as and when required.

(a) Experimental Design:

A randomized complete block design with 3 methods of planting and 3 replications. Both sorghum and millet will be treated as two different experiments and will be planted in separate blocks.

```
  REP I                    REP II                REP III
---------------        ----------------      ---------------
|    |    |   |        |    |    |    |      |   |    |    |
|    |    |   |        |    |    |    |      |   |    |    |
| RF | SC | F |        |  F | RF | SC |      | F | SC | RF |
|    |    |   |        |    |    |    |      |   |    |    |
|    |    |   |        |    |    |    |      |   |    |    |
|    |    |   |        |    |    |    |      |   |    |    |
|    |    |   |        |    |    |    |      |   |    |    |
---------------        ----------------      ---------------
```

RF = Ridge-furrow; SC = Seed cradle; F = Flat surface

(b) Planting Pattern:

8 rows, 12 m long. Row to row spacing - 80 cm. Plant to plant spacing - 50 cm. Plot size - 76.8 $m^2$. Plant population - 50,000/ha.

(c) Observations:

Four middle rows will be used for observation. Data to be recorded include: emergence, plant population, plant height and number of leaves per plant, days to flowering, days to maturing, total biomass at harvest (grain yield + stover), and weekly moisture status. Additional information will include labor and cost for the three planting systems.

(d) Resources Required:

* Approximately 1500 $m^2$ of qoz land (sorghum and millet both)
* 2 kg sorghum seeds and 1 kg millet seeds
* 15 kg urea and 30 kg triple superphosphate
* Measuring tape, string/rope, and stakes
* Hand operated soil imprinter
* Marking pens, plant labels, and plastic bags
* Soil moisture measuring equipment - moisture cans, auger, balance, and drying oven
* Senior technician - 32 technician days
* Junior technician - 32 technician days
* Laborers - 65 laborer days
* Scientist - 20 scientist days
* Vehicle and driver - as required

EXPERIMENT 2: Field evaluation of gum arabic as an evaporation retardant.

The loose sandy surface in qoz soils permits excessive evaporation. The surface few inches of the soil becomes very dry, soon after a rain. This creates an unfavorable environment for emerging seeds and young seedlings. A certain binding of the sand might be useful in slowing down the drying rate. Preliminary pot tests indicate that small quantities of powdered gum arabic does, in fact, retard evaporation. Four day evaporation from pots treated with 0, 5, 10, 15, and 20 g gum arabic were found to be 548, 442, 394, 370, and 340 ml of water, respectively. Larger quantities of gum have the effect of producing a surface seal of low permeability and high mechanical resistance. There appears to be a possibility that gum arabic might also be useful in reducing wind erosion and treating the land for water harvesting. Most of the gum arabic produced in Sudan at the present time is exported, at relatively cheap prices. Its value should increase if

it is found useful in soil and water conservation programs. Additionally, an incentive to increase gum production should result in increased planting of acacia. This, in itself, will be a step towards soil conservation.

METHODOLOGY:

This will be a preliminary on-station trial with sorghum as a test crop. Two methods of applying gum arabic will be tested.

1. Spot treatment:

   Planted hills will be treated with varying quantities of gum arabic. The treatment will be applied at the same time as the seeds are planted. The dose will be 0, 5, and 10 g of gum arabic per hill.

2. General application:

   Powdered gum arabic will be applied by broadcasting at the rate of 0, 50, 100 and 300 kg/ha. The soil surface will be raked to ensure mixing of the gum with the soil. For purposes of broadcasting, the gum powder will be mixed with soil in the ratio of 1 to 3.

   A preplanting basal does of fertilizer (40 kg N and 80 kg $P_2O_5$/ha) will be applied for both the methods.

   For each case, six seeds will be planted per hill and thinned to 2 plants per hill after emergence.

(a) Experimental Design:

A randomized complete block design with 3 levels of gum treatment for the spot treatment and 4 levels of gum treatment for the general application and 3 replications for each. Both the methods of application will be treated as separate experiments and will be planted in separate blocks.

Spot treatment

| REP I | | | REP II | | | REP III | | |
|---|---|---|---|---|---|---|---|---|
| 5 g | 10 g | 0 g | 0 g | 5 g | 10 g | 10 g | 0 g | 5 g |

General application

| REP I | | | | REP II | | | | REP III | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 50 kg | 0 kg | 100 kg | 300 kg | 100 kg | 50 kg | 0 kg | 300 kg | 0 kg | 100 kg | 300 kg | 50 kg |

(b) Planting Pattern:

8 rows, 12 meter long. Row to row spacing - 80 cm. Plant to plant spacing - 50 cm. Plot size - 76.8 $m^2$. Plant population - 50,000/ha.

(c) Observations:

Four middle rows will be used for observation. Data to be recorded include: emergence, plant population, plant height and number of leaves per plant, days to flowering, days to maturity, total biomass at harvest (grain yield + stover), weekly soil moisture status, infiltration rate, and persistence of gum in the soil. Additional information will include cost of gum arabic and labor for grinding and application.

(d) Resources Required:

* Approximately 1700 $m^2$ of qoz land
* 2 kg sorghum seeds
* 15 kg urea and 30 kg triple superphosphate
* 25 kg powdered gum arabic
* Measuring tape, string/rope, and stakes
* Marking pens, plant labels, and plastic bags
* Soil moisture measuring equipment - moisture cans, auger, weighing balance, and drying oven
* 3 double ring infiltrometers
* Facilities for analyzing organic carbon content of the soil
* Senior technician - 32 technician days
* Junior technician - 32 technician days

* Laborers - 65 laborer days
* Scientist - 20 scientist days
* Vehicle and driver - as required

## C. WATER HARVESTING FOR CROP PRODUCTION IN NORTH KORDOFAN

When rainfall is below a critical minimum, crop production is not feasible. However, if the rainfall received on a given area is diverted to a portion of this area, the effective moisture storage of the portion receiving the diverted rainfall may be increased and a successful harvest may be obtained. This is the whole idea of water harvesting. Water harvesting may be effected by treating the soil to reduce infiltration or it may be covered by some impervious material to promote maximum runoff. Channel terraces or ditches may be used to divert the runoff to leveled areas for crop production.

There appears to be a potential for exploiting water harvesting techniques for crop production in North Kordofan. It is a better idea to crop a smaller area with adequate moisture than to crop a larger area with inadequate moisture.

BEGINNING DATE:

1984 cropping season (June-July 1984)

OBJECTIVE:

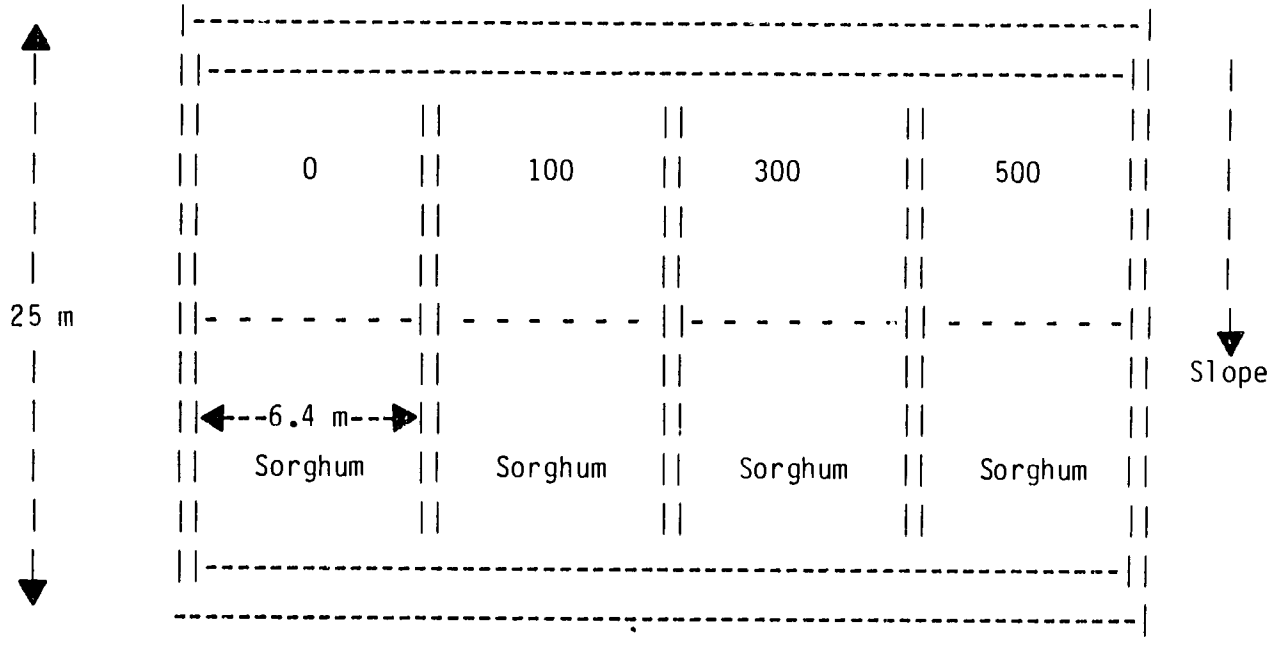
To increase soil moisture supply for crop production.

EXPERIMENT 1:

A preliminary trial on water harvesting on qoz lands in North Kordofan.

METHODOLOGY:

This will be an unreplicated on-station trial. A gently sloping area will be selected and divided into two sections along the slope. The upslope half of the field will be treated with powdered gum Arabic at the rate of 100, 300, and 500 kg/ha and compressed by passing a roller several times. This operation will be completed soon after the first 10 mm rain has been received. A dike will be created around the experimental plots so as to keep the water from flowing sideways. The downslope half of the field will be planted in sorghum. See figure for a suggested layout. A rain gauge will be installed in order to monitor the rainfall. Apart from plant growth and yield measurement, a periodic measurement of soil moisture in both the treated and untreated portions of the field will be carried out. Fertilization and seeding will be as for other sorghum experiments.




This is an exploratory trial. Several modifications of the suggested plan are possible. For example, it may be necessary to create ridges and furrows in the receiving portion of the field. Also, spraying gum arabic

solution may be more efficient than applying a powdered form of gum arabic. We may set up another trial to evaluate the effectiveness of the two methods of land treatment.

(a) EXPERIMENTAL DESIGN:

Unreplicated trial. See figure for layout.

(b) PLANTING PATTERN:

8 rows, 12 m long. Row to row spacing - 80 cm. Plant to plant spacing - 50 cm. Plot size - 76.8 $m.^2$ Plant population -50,000/ha.

(c) OBSERVATIONS:

Four middle rows in each plot will be used for observation. Data to be recorded include: emergence, plant population, plant height and number of leaves per plant, days to flowering, days to maturity, total biomass at harvest (grain yield + stover), rainfall over the experimental area, and periodic soil moisture status in both the treated and untreated plots. Additional information will include cost of gum Arabic and labor required for land treatment.

(d) RESOURCES REQUIRED:

* Approximately 650 $m^2$ of qoz land
* 21 kg sorghum seeds
* 8 kg powdered gum Arabic
* 1 spreader
* 1 sprayer
* Measuring tape, string/rope, stakes, plant labels, and plastic bags
* 1 raingauge

* Soil moisture measuring equipment - auger, moisture cans, weighing balance, and drying oven
* 1 kg urea and 2 kg triple superphosphate
* Senior technician - 15 technician days
* Junior technicians - 15 technician days
* Laborers - 30 laborer days
* Scientist - 15 scientist days
* Vehicle and driver - as required

## D. REHABILITATION OF GARDUD SOILS IN NORTH KORDOFAN

Gardud soils have sandy clay to clayey texture. They are highly compacted, allow very little infiltration of water, and offer severe resistance to root penetration. Much of the rainwater is lost as runoff and the land surface is eroded. The need to rehabilitate these soils is based on the view that these soils, because of their finer texture, have a better potential for water and nutrient retention and could become an alternative to the more fragile qoz soils. Deep plowing and chiseling have been shown to be effective in increasing water infiltration in gardud soils. However, if the plowing is not continued, the open structure created by plowing falls back to the original density. Apparently, there is a need for methods to stabilize the soil structure created by plowing. Root action resulting from continued cropping; addition of organic matter and crop residue; addition of chemical soil amendments, such as gypsum; and wetting-drying cycle resulting from increased infiltration of water should lead to structural stability.

BEGINNING DATE: 1984 cropping season (June-July 1984)

OBJECTIVE: To increase productivity of gardud soils by improving water infiltration and soil structure.

EXPERIMENT 1:

Effects of land preparation methods and crop type on water infiltration and soil structure in gardud soils.

METHODOLOGY:

This will be an on-station trial on the Kaba site of the WSARP Experiment Station. Three methods of land preparation will be combined to observe the effects on water infiltration and persistence of soil structure. The proposed treatments are as follows:

| LAND PREPARATION | CROPPING |
|---|---|
| 1. Shallow harrowing, flat surface | bare, sesame, watermelon, clitoria (clitoria ternatea) |
| 2. Deep plowing, and harrowing, flat surface | bare, sesame, watermelon, clitoria |
| 3. Deep plowing and harrowing, ridge-furrow system | bare, sesame, watermelon, clitoria |

The crops have been chosen for their root density effects and drought tolerance. It is intended to use higher than normal planting density in order to achieve a higher root density. It is hoped that root growth and subsequent decay of roots, along with wetting-drying will produce a structure stabilizing effect. Some addition of organic matter should also be expected.

A basal dose of fertilizers (40 kg N and 80 kg $P_2O_5$/ha) will be applied by broadcasting before the harrowing operation.

Four to five seeds of each crop will be planted per hill and thinned to one plant per hill after emergence.

(a) Experimental Design:

A split plot design with 3 methods of land preparation, 4 crops (including bare land), and 3 replications.

| | DPRF | SH | DPF |
|---|---|---|---|
| REP I | B C S W | C B S W | S B W C |
| | SH | DPRF | DPF |
| REP II | W S B C | C S B W | W B S C |

```
                DPF                    SH                    DPRF

          |---------------|      |---------------|      |---------------|
          |   |   |   |   |      |   |   |   |   |      |   |   |   |   |
          |   |   |   |   |      |   |   |   |   |      |   |   |   |   |
REP III   | W | C | B | S |      | W | C | B | S |      | B | C | S | W |
          |   |   |   |   |      |   |   |   |   |      |   |   |   |   |
          |   |   |   |   |      |   |   |   |   |      |   |   |   |   |
          |---------------|      |---------------|      |---------------|
```

DPF - deep plowing, flat; DPRF - deep plowing, ridge-furrow;
SH - shallow harrowing; B - bare; C - Clitoria; S - sesame;
W - watermelon.

(b) <u>Planting Pattern</u>:

Because of planting in ridge-furrow beds, row to row spacing for all crops for all the methods of land preparation will be the same as the ridge to ridge spacing. The plant to plant spacing within the row will be varied to achieve the desired planting density. The ridge to ridge spacing is expected to be 80 cm. It is desired to use a plot size of 15 m x 8 m with 10 rows in each plot. Suggested planting pattern for the various crops are:

| | | |
|---|---|---|
| Clitoria | - | 80 cm x 10 cm |
| Sesame | - | 80 cm x 10 cm |
| Watermelon | - | 80 cm x 30 cm |

It should be noted that the intention in this trial is to achieve the maximum root mass in the soil.

(c) Observations:

Four middle rows will be used for observation of plant biomass. Moisture regime, infiltration rate, and penetration resistance data will be taken from replicated random locations in each plot. Infiltration and penetration resistance measurements will continue through the following dry season. Additional information will include cost of land preparation.

(d) Resources Required:

* Approximately 4500 $m^2$ of gardud land
* Tractor with deep plow, harrow, and ridger
* 3 kg clitoria, 1 kg sesame, and 2 kg watermelon seeds
* 50 kg urea and 100 kg triple superphosphate
* 4 sets of double ring infiltrometers
* Truckborne water, 200 gallon for each date of observation
* 1 set of proctor penetrometer
* Soil moisture measuring equipment - moisture cans, augers, weighing balance, drying ovens
* Measuring tape, string/rope, stakes, marking labels
* Senior technician - 50 technician days
* Junior technician - 50 technician days
* Laborers - 60 laborer days
* Scientist - 30 scientist days
* Vehicle and driver - as required

EXPERIMENT 2:

Evaluation of land imprinting as a method of increasing infiltration in gardud soils.

Although plowing is effective in breaking up the compact soil layers, availability of suitable machinery, lack of know how, and energy costs will most certainly make it impractical for the traditional farmer in North Kordofan. There is a need to explore simpler techniques. Land imprinting appears to have a potential for adaptation by traditional farmers. It is a technique in which small depressions (3 to 4 inches deep) are created on the land surface, using a cone or wedge-shaped device which is pushed into the soil by human power or hammered in. A rough surface is created and the rainwater collects in the depressions. The result is reduced runoff and increased infiltration. Such techniques have been used successfully by R. M. Dixon of ARS/USDA in improving arid rangelands in Arizona.

METHODOLOGY:

This will be an unreplicated on-station trial on Kaba or Bano site of the WSARP Experiment Station. Cone-shaped imprinters of 4 inch height and 5 inch base diameter will be driven into the soil surface to create a network of depressions. Three imprint densities will be evaluated.

1. Imprints on a 1 meter square grid
2. Imprints on a 1.5 meter square grid
3. Imprints on a 2 meter square grid

Plots of 18m x 12m will be used. Imprinting will be completed before the start of the rains.

Periodic soil moisture profiles to a depth of 1 meter will be compared with the moisture profiles in the control plots.

(a) Experimental Design:

Unreplicated trial with three imprint densities and control.

(b) Planting Pattern:

No crop

(c) Observations:

Periodic soil moisture profiles to a depth of 1 meter. Additional information will include cost of imprinters and labor and time required for land imprinting.

(d) Resources Required:

* Approximately 900 $m^2$ of gardud land
* 4 cone-shaped imprinters with 4 inch height and 5 inch base diameter
* Sledge hammer (16 lbs)
* Measuring tape, string/rope, and stakes
* Soil moisture measuring equipment - augers, moisture cans, weighing balance, drying ovens
* Senior technician - 25 technician days
* Junior technician - 25 technician days
* Laborers - 30 laborer days
* Scientist - 15 scientist days
* Vehicle and driver - as required

## E. INTRODUCTION, DEMONSTRATION, AND DEVELOPMENT OF DRIP SYSTEM OF IRRIGATION FOR HORTICULTURAL PRODUCTION IN NORTH KORDOFAN

Water availability is one of the most limiting factors for agricultural production in North Kordofan. In some localities, however, a limited supply of underground water is available. This water is utilized for irrigating horticultural crops. Farmers pump water from open wells and irrigate by flooding. Most often the wells run dry after a few hours of pumping and a waiting period is usually necessary to get the wells recharged. The present method of conveying water via open chanels and irrigating fields by flooding is highly wasteful. A significant amount of water is lost to seepage and direct evaporation. Digging channels and maintaining them and conveying water to all parts of the field is labor intensive. The amount of water that is applied is usually much in excess of what is actually needed. This causes crop diseases, promotes leaching of nutrients, and interferes with farm operations. Weeds are a serious problem, which not only occupy much of the labor force to control them, but also, detract nutrients and water which would otherwise be available for plant growth.

There is, thus, a need for an efficient method of irrigation. With the drip system of irrigation, both the water conveyance and application are highly controlled. There is almost 50 percent reduction in water usage. Pumping costs are reduced accordingly. Water is delivered to the plants directly and dissolved fertilizers can be fed to the plants via drip outlets. Between row spaces are always dry so that weed growth is minimal and farm operations such as staking, picking, and pruning continue uninterrupted. Earthwork to move water from one end of the field to another is usually eliminated.

BEGINNING DATE:

1984 cropping season (June-July 1984). Although this is the beginning of the rainy season, irrigation is required during rainless periods of long duration. The system, once installed, should continue to function over the following dry season.

OBJECTIVE:

To introduce and develop an efficient method of utilizing the limited amount of water that is available for horticultural production.

METHODOLOGY:

The number of irrigation sites depends on resources available. However, it is our hope that at least two sites will be on farmer's fields, one in Bangdeed and another in Bara or Kheiran, and two on the WSARP horticultural research farm at Banou. The actual design will depend on the crop type and the size and shape of the field to be irrigated. For the purpose of this document, we give only a typical example. Farmers who irrigate have pumps and water available. PVC pipes and a variety of fittings are available locally. Drip hoses and some specialized drip components have been ordered from the USA. A typical layout of the system is shown in Figure 2.

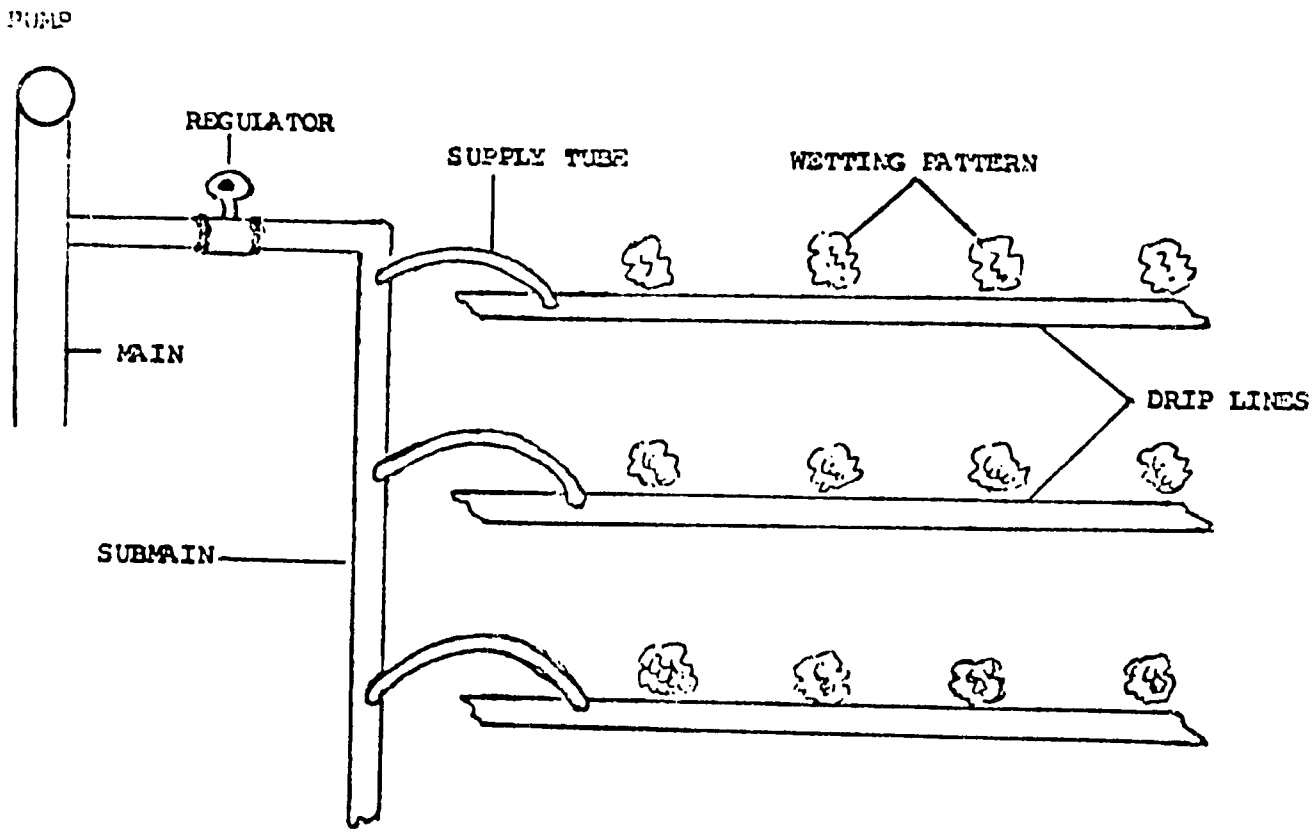



Figure 2. A schematic layout of the drip system of irrigation

EXAMPLE:

Crop - tomato
Plot size - 0.25 hectare (50m x 50m)
Row to row spacing - 80 cm
Plant to plant spacing - 45 cm (limited by the spacing of drip outlets on the hose)
Number of rows - 63
Number of plants per row - 111
Total number of plants - 6,993

Irrigation Scheduling:

Soil, crop, and climatic data needed for irrigation scheduling are unavailable. However, efforts will be made to base irrigation on the estimates of the variables needed.

Estimates of potential and actual evapotranspiration.

| Month | Monthly Potential Evapotranspiration* (mm) | Daily Rate (mm) | AET/PET** |
|---|---|---|---|
| January | 178.7 | 5.8 | - |
| February | 188.1 | 6.7 | - |
| March | 230.1 | 7.7 | 0.22 |
| April | 227.2 | 7.6 | 0.60 |
| May | 244.6 | 7.9 | 0.88 |
| June | 223.9 | 7.5 | 0.88 |
| July | 192.6 | 6.2 | 0.75 |
| August | 162.2 | 5.2 | 0.50 |
| September | 169.0 | 5.6 | 0.30 |
| October | 199.7 | 6.4 | - |
| November | 187.4 | 6.3 | - |
| December | 174.8 | 5.8 | - |

* Estimates are for El Obeid, Sudan. Taken from S. A. Awadalla, 1983. Potential evaporation over the Sudan, an application of Penman's model over a dense spatial pattern. Scientific Note No. 3, Sudan Meteorological Department.

** AET/PET ratios are for a tomato crop in the San Joaquin Valley, California. Similar data are available for other crops. See Vegetative Water Use in California, 1974. Bulletin No. 113-3, State of California, Department of Water Resources

Month by month ratios of actual evapotranspiration to potential evapotranspiration for California will hardly be comparable to those in Sudan. However, since these ratios vary with the stage of crop development, expressing them as a function of growing season should be more appropriate if the data are to be used at another location. The basis for this transformation is that if the potential evapotranspiration is high, so should be the actual evapotranspiration, given adequate water supply. Figure 3 shows variation of AET/PET ratios as a function of percent of growing season. We propose to use this graph for irrigating tomatoes in the vicinity of El Obeid. It is our hope that local data will develop as the program progresses. Data similar to those in the table and in Figure 3 are available for other localities and other crops.

(a) Irrigation Timing:

Two alternatives.

(1) Based on tensiometer readings:

Dial gauge tensiometers will be installed at 15, 30, 45, and 60 cm depths. Irrigation will be applied when the tensiometer reading shows 0.7 on the dial gauge. We propose to use the 15 cm depth for the first 1/4 of the growing season, the 30 cm depth for the second 1/4, the 45 cm depth for the third 1/4, and the 60 cm depth for the fourth 1/4.

(2) Daily irrigation:

Based on daily PET rate and AET/PET ratio for the stage of growing season.

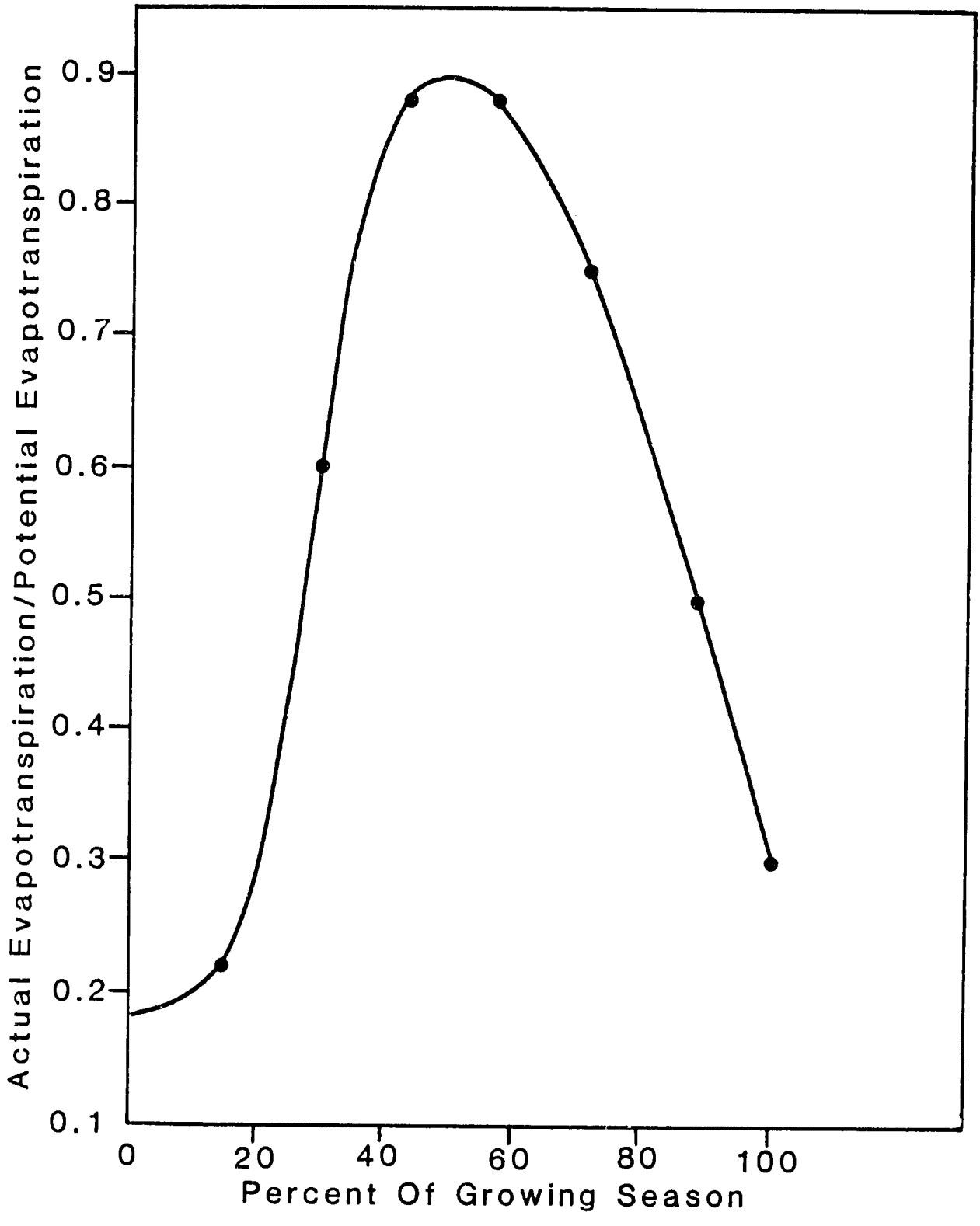



Figure 3. Variation of actual evapotranspiration/potential evapotranspiration ratios with the growing season for tomatoes. Data for North Kordofan are not available. Ratios presented in this figure are based on data for San Joaquin Valley, California (USA).

(b) Irrigation Amount:

Will depend on the method of timing irrigation.

(1) Daily irrigation:

Suppose on the day of irrigation the growing season is 30 percent completed. We obtain an AET/PET ratio of 0.62 from Figure 3. If the month is November, we have a daily PET of 6.3 mm. The AET for the purpose of irrigation on that day is 3.91 mm. The total AET over the field (50m x 50m) will be 9775 liters (= 2583 US gallons). This is the amount of water that should be applied on the day in question.

For our example of tomatoes (45 cm within row spacing) we will use CHAPIN WATERMATICS' twin-wall hose #35-5735. This hose, with a pressure of 8.5 PSI delivers 0.34 gallons per minute per 100 feet. We have a total of 3150m (=10,335 feet) of drip line. Assuming 100 percent uniformity, this length of drip line will deliver 35 gallons per minute. Therefore, in order to deliver 2,583 gallons, the system must be operated for a period of 74 minutes.

(2) Based on tensiometer readings:

If the irrigation is based on the tensiometer readings, there will be a number of days between the previous irrigation and the time indicated by the tensiometer. In that case, the total amount of irrigation water can be determined by accumulating the daily values as for the daily irrigation. The duration of operation of the system can be determined by dividing the total amount by the delivery rate.

OBSERVATIONS:

Cost of drip system components and installation cost will be determined. Data will be obtained on the amount of irrigation water used, pumping costs, and weeding operations. Uniformity of delivery rates will be obtained. Problems encountered in system operation will be studied. Additional data will include water-use patterns and crop growth and yield.

RESOURCES REQUIRED:

* 0.25 hectare land
* Water and pump (capacity 2000 gallons/hour)
* Drip system components - drip hoses, supply tubes, mains and submains, pressure regulator, flowmeter, valves, plumbing accessories, pressure gauges
* Fertilizer tank and fittings
* Tensiometers
* Soil moisture measuring equipment - auger, moisture cans, weighing balance, drying ovens
* Tomato seedlings - 8000
* Soluble fertilizers
* Measuring tapes, string/ropes, stakes
* Stop watch, buckets, and volumetric cylinders
* Senior technician - 32 technician days
* Junior technicians - 32 technician days
* Laborers - 35 laborer days
* Scientist - 30 scientist days
* Vehicle and driver - as required

## F. INVESTIGATIONS OF SOIL PHYSICAL AND CHEMICAL CHARACTERISTICS IMPORTANT IN PLANNING FOR SOIL AND WATER MANAGEMENT

Much of our current understanding of soil and water management problems in Kordofan region is based on reconnaissance surveys, visual observations, and impressions gathered from discussions with professional agronomists, farmers, and administrators. Factual and quantitative data on soil properties and processes are lacking. For example, characteristics of gardud soils that are responsible for its present condition are not understood. Understanding its mechanical and chemical composition, structure, and hydrologic properties should enable us to identify the constraints to agricultural production and recommend suitable soil and water management practices. Similarly, a quantitative understanding of hydrologic properties and processes in qoz soils should enable one to determine the nature of water loss problems and to form the basis for proposed solutions of water conservation and improved cropping practices, etc. Quantitative data on nutrient status of the soils of the region are needed for formulating and recommending fertility management practices. Data are also needed to evaluate effectiveness of recommended management practices.

BEGINNING DATE:

March - April 1984 and to continue for several years.

OBJECTIVE:

To obtain quantitative information on soil characteristics so as to form the basis for solutions of soil and water management practices.

METHODOLOGY:

Three soil profiles at each of the WSARP experiment stations will be sampled for analyses of soil physical and chemical characteristics. The sites are: (1) WSARP Experiment Station, El Obeid (qoz soils), (2) WSARP Experiment Station, Kaba (gardud soils), (3) WSARP Experiment Station, Banou (gardud soils), and (4) WSARP Experiment Station, Kadugli (cracking vertisols).

Samples will be drawn from 0-5, 5-10, 10-20, 20-30, 30-45, 45-60, 60-75, 75-90, 90-105, 105-120, 120-135, and 135-150 cm depths. Each sample will be analysed for

* pH
* Electrical conductivity
* Total soluble salts
* Total and organic carbon
* Cation exchange capacity
* Total and available N, P, K, S, Mo, B, and Zn
* Exchangeable Ca, Mg, K, Na, Fe, Mn, and Al
* Percentages of particles less than 1, 2, 5, 20, 50, 100, 250, 500, 1000, and 2000 microns

Bulk density will be determined by in-situ sampling of undisturbed soil cores. Infiltration rates will be determined by on-site tests using double ring infiltrometers. Moisture characteristics and hydraulic conductivity will be estimated from prediction models that utilize as inputs particle size distribution, bulk density and organic matter data.

Efforts to obtain soil samples using an auger have not been successful, chiefly because of excessive hardness of the soil at this time of the year. On the qoz soils, the loose sand could not be retained in the auger bucket.

Consequently, it has been decided to dig pits and obtain samples from individual layers. Work has already begun and three pits at WSARP Horticultural Experiment Station, Banou have been completed.

WSARP does not have an analytical laboratory, as yet. Samples will be sent to Washington State University for analyses requiring laboratory procedures. Standard procedures, as outlined in Methods of Soil Analysis parts I and II, Agronomy No. 9, American Society of Agronomy, Madison, Wisconsin are recommended.

It is hoped that the program of soil analyses will be carried over beyond the WSARP experiment sites and will be a continuing program.

RESOURCES REQUIRED:

* Analytical laboratory - hire basis
* Soil core and core sampler
* Digging tools - spades, forks, knives
* Hammers, mixing pans, buckets
* Measuring tapes, meter rules, labels, sample bags
* Soil sieves
* Infiltrometers and hook gauges
* Supply of water - truckborne
* Moisture cans, augers, weighing balances, drying oven
* Senior technician - 30 technician days
* Junior technician - 30 technician days
* Laborers - 30 laborer days
* Scientist - 20 scientist days
* Vehicle and driver - as needed

## G. MONITORING WEATHER VARIABLES IN NORTH KORDOFAN

Weather data are needed to characterize the agroclimatic environment. A program of soil and water conservation and improved cropping practices must take into account environmental conditions. Weather data are important for computing atmospheric evaporativity and evaluating soil moisture status. An understanding of crop/weather interactions is needed in order to select suitable crop type and varieties. Planting dates can be better specified and a sounder basis for management practices can be evolved. Irrigation schedules cannot be determined without weather data. Additionally, weather data are important inputs to soil moisture and crop growth models, which are now being used as surrogate to field experiments. If computing facilities are available, such models can be applied to analyzing and evaluating agricultural production in the Kordofan region. It should save costs incurred in field experimentation.

BEGINNING DATE:

June - July 1984 and to continue.

OBJECTIVE:

To characterize the agroclimatic environment in Kordofan region.

METHODOLOGY:

A portable weather station consisting of a number of sensors has been ordered from Campbell Scientific, Logan, Utah. This station will be installed in a fenced area at the WSARP Experiment Station, El Obeid.

A similar station is recommended for the other sites. Daily measurements of the following variables will be made.

* Rainfall
* Maximum and minimum air temperatures
* Soil temperature at 0, 5, 15, 25, 50, and 100 cm depths
* Relative humidity
* Wind run
* Solar radiation
* Pan evaporation
* Soil moisture under bare ground
* Soil moisture under well watered grass

RESOURCES REQUIRED:

* Portable weather station
* Standard Class A USDA pan with a hook gauge
* Supply of water and irrigation system
* Metal posts and chainlink fence
* Neutron probe and accessories
* Laborers - 2 to 3 laborer days per month
* Technician - 2 hours per day
* Scientist - occasional