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AGRICULTURAL RESEARCH CORPORATION

WESTERN SUDAN AGRICULTURAL RESEARCH PROJECT

RESEARCH PROGRAM FOR THE KORDOFAN REGION

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AGRICULTURAL RESEARCH CORPORATION
WESTERN SUDAN AGRICULTURAL RESEARCH PROJECT

The Government of Sudan
United States Agency for International Development
The World Bank
Consortium for International Development
Washington State University

RESEARCH PROGRAM FOR KORDOFAN REGION 1984 - 85

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FOREWORD

The research plans contained herein were drafted by the scientific and technical staff of the Kadugli and El Obeid, WSARP/ARC research stations.

The Kadugli proposals were reviewed by a joint meeting of the Station Research Committees (El Obeid and Kadugli) on January 28-29, 1984 in Kadugli. Dr. D.A. Dafalla, Director WSARP and, Dr. J.J. Riley, Senior Adivsor ARC, and Ms. Lili Martella, Assistant Agricultrual Development, Officer, U.S. Agency for International Development (Khartoum), also, were in attendance.

The El Obeid proposals were reviewed by the Project Director and a joint meeting of the El Obeid and Kadugli Station Research Committees on February 14, 1984. The Senior Advisor, ARC, also, was present.

The WSARP Systems Committee composed of:

Dr. Hassan Khalifa, Deputy Director General (Programmes) Agricultural Research Corporation, ARC

Dr. Mahmoud Adam Ali, National Research Coordinator for Pathology, ARC

Dr. Ahmed Nazr Balla, National Research Coordinator for Entomology, ARC

Professor Abdel Hamed Osman, Director, Institute for Animal Production, University of Khartoum

Mr. Morid Girgis Mansi, Statistician, ARC

Dr. Dafalla Ahmed Dafalla, Director WSARP

Dr. El Hag Hassan Abu El Gasim, Sedentary Systems Research Coordinator, WSARP

Dr. Babo Fadlalla Mohamed, Transhumant Systems Research Coordinator, WSARP

Dr. Richard H. Cook, Nomadic Systems Research Coordinator, WSARP

met in Kadugli on February 14, 15 and 16 to review the research plans of the Kadugli and El Obeid Stations. Dr. George Ghobrial, Plant Physiologist, USAID Khartoum and Dr. J.J. Riley, Senior Advisor, ARC attended as observers.

Dr. Stuart Marples, Livestock Production Specialist and Ms. Ingrid Foik, Agricultural Economist of the World Bank met with the Director, WSARP and the Research Committees of the El Obeid and Kadugli Stations in El Obeid, April 9, 1984 to review the research proposals. The Senior Advisor ARC also participated in the discussions.

The Project Advisory Committee met May 15, 1984 in Khartoum to give the final review of the proposed WSARP research program for 1984-85. The committee is composed of the following positions:

Director General ARC (Chairman)
Director WSARP (Secretary)
Deputy Director, WSARP
Project Coordinator, WSU
Senior Advisor to the Director General, ARC
Under-Secretary, Ministry of Agriculture and Irrigation, MOAI
Under-Secretary, Animal Resources, MOAI
Under-Secretary, Natural Resources, MOAI
Director, Western Savanna Development Corporation
Dean, Faculty of Agriculture, University of Khartoum
Dean, Faculty of Agriculture, University of Gezira
Director General, Mechanized Farming Corporation
Director Soil Conservation Department
Director, Council for Social and Economic Studies, NCR
Director General, Ministry of Agriculture and Natural Resources, Kordofan Region
Director General, Ministry of Agriculture and Natural Resources, Darfur Region
Representative(s), Consultative Group on International Agricultural Research
Deputy Director General (Programmes) ARC
Representative, Centro Internacional de Mejoramieto de Maiz y Trigo, CIMMYT
Representative, International Livestock Centre for Africa, ILCA

Representative, International Crops Reserach Institute for the Semi-Arid Tropics, ICRISAT

The Project is appreciative of the time taken and the excellent comments provided by the numerous individuals who have reviewed this work plan.

Dr. Dafalla Ahmed Dafalla
Director, WSARP

This manuscript was initially typed by the research scientists themselves. Revisions were typed by Ms. Rabia Ahmed El Ashei. The final draft was typed by Mrs. Gail Hebard.

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EXECUTIVE SUMMARY

SOUTHERN KORDOFAN

THE SEDENTARY PRODUCTION SYSTEM IN THE NUBA MOUNTAINS

The sedentary production system, which includes both an agronomic and a livestock component, is dominated by cropping activities based on a bush-fallow system of cultivation. Sorghum is the principal field and food crop with sesame, groundnuts and cotton the major cash crops. Intercropping is a common traditional practice, with sorghum frequently being cultivated with sesame or cowpeas. Agricultural practices require high labor inputs which are generally in short supply and of low productivity. Although soils are relatively low in fertility, improved and more efficient cultrual practices could substantially increase crop yields. More efficient utilization of agricultural resources should improve the welfare of traditional households and provide enhanced opportunities for investment and for market interactions to increase household incomes.

RESEARCH FOR THE SEDENTARY SECTOR

Objectives and Strategy

The long-term goal of the sedentary production system research program is to stabilize and improve the agronomic resource base of the traditional sedentary system to support the high development potential for mixed farming in the Nuba Mountains. The objectives of the present program are to; (1) stabilize and improve agricultural production; (2) improve the efficiency of labor; (3) improve the integration of crop and livestock activities; and (4) improve the

welfare and income of traditional households.

The strategy to accomplish these objectives basically involves the design and implementation of interventions which will increase the efficiency and utilization of land, labor and crop resources in a manner which will improve long term agricultural productivity. The five principal components of this strategy are: (1) increasing crop yields through the design and implementation of improved agronomic practices and introduction of improved varieties; (2) introducing food and forage legumes into a crop rotation system for improving the existing bush-fallow system of cultivation, while providing a harvestable crop of supplemental livestock feed; (3) introducing animal draft as a cost-effective, labor saving activity for expanding agricultural and household operations and as a means of marketing surplus food and/or cash crops outside the village domain, in areas where the return on crop sales is more profitable; (4) introducing the concept of conservation of native forage, and crop residues, at a time when their productivity and/or nutritive quality are high, as a cost-effective livestock supplement to be fed during the dry-season; and (5) evaluation of sedentary system dynamics, focusing on household consumption patterns and their interrelationships for crop and livestock activities (El Tighani's thesis research); and on the structure and organization of agricultural markets.

Activities

Improved Agronomic Practices

Insect pests and smut lower sorghum yields. The application of a combined fungicide and insecticide to the seed prior to planting reduces damage by both.

Most of the phosphorus in the cracking clay soils is chemically bound in a form not readily available to plants. Placement of phosphorus fertilizer in the soil with the seed at planting time is intended to stimulate seedling vigor and increase stand establishment.

Soil nitrogen is depleted by continuous cropping with cereal or oil seed crops. Adequate nitrogen is needed to sustain moderate to high yields. Crop response to several levels of nitrogen fertilizer will indicate level needed to maintain desired yields. Other studies will indicate the best means of providing nitrogen, either chemically or by including legumes in the cropping system.

The best yields will be achieved when both the nitrogen and phosphorus requirements of a crop are satisfied.

The yield of long duration sorghum cultivars native to the Nuba Mountains is diminished by drought, especially if it occurs during the grain filling stage. Late planting increases the probability of a crop maturing after the cessation of the rains. An earlier sowing date, introduction of shorter maturing cultivars and water conservation studies are aimed at reducing the incidence of water stress particularly in the later growth stages, in order to achieve higher more stable yields.

Labor is a serious constraint to crop production. Weeding is one of the most time consuming cultural practices, which often extends throughout the cropping season. Studies in other locales in Sudan, with similar environmental conditions as Kadugli, have shown that weeds must be removed early to effectively reduce competition for water and nutrients. Late weeding is not beneficial to crop productivity and wasteful of labor.

(1) <u>Effect of chemical seed dressing and phosphorus fertilizer on sorghum yields</u>

On-farm, farmer-managed, trial at 3 locations to confirm positive response to indicated inputs, last season, in on-

farm, researcher managed trials.

(2) Sorghum fertilizer trial

On-farm, researcher-managed, trials to verify response of traditional and introduced cultivars to application of phosphorus and/or nitrogen. Last season, on-station trials demonstrated marked response to phosphorus, but nitrogen without phosphorus had no significant effect on yield.

(3) Effect of timely practices and seed dressing on sorghum yields

On-farm, researcher-managed, trial to demonstrate advantages of early planting and weeding of short duration cultivar. Seed will be treated with combined insecticide and fungicide to reduce yield loss caused by insect pests and smut.

(4) Effect of delayed sorghum harvest on grain and forage losses

On-station, researcher-managed trial, to evaluate grain losses due to traditional practice of leaving crop in the field several months after it has reached maturity.

(5) Varietal screening trials

On-station, researcher-managed, trials to determine the potential of a limited number of promising lines of crops for introduction into the traditional cropping systems. Emphasis will be given to identifying higher yielding sorghum lines and legume crops which could be interplanted or rotated with sorghum. Possible entries for improving productivity of Near-farms and Housegardens, also will be tested.

(6) Soil and water management and conservation

On-station, researcher-managed, cultivation and mulching trials to increase crop water-use efficiency will be initiated.

Introduction of Food and Forage Legumes

In the bush-fallow cropping system practiced in the rainfed sector on traditional and mechanized farms, land is cleared of native vegetation, cropped continuously for several years with cereal or oil seed crops and then abandoned when the natural soil fertility will no longer support an acceptable level of crop production. While land is being rested, to regain its fertility, other land is cleared and cultivated. Thus, only a small portion of the land that has been cleared for farming is actually planted in a given year, while the remainder is subjected to wind and water erosion. Mechanization has made it possible to bring increasingly large tracts of land under bush-fallow cultivation. Traditional pastures and migration routes have been blocked or encroached upon. This has not only lead to an accelerated degradation of the land resources, but also a heightening of tensions between migrating pasturalists and sedentary farmers.

Legumes add nitrogen to the soil. Thus, the inclusion of legumes into the cropping cycle on mechanized or traditional farms should make it possible to maintain soil fertility and to continue cropping a given parcel of land indefinately. Farmers are reluctant to reduce the area planted to economically productive cereal or oil seed crops just to plant legumes. They must receive some economic return for planting legumes. Thus, forage and food legumes with potential economic value are being screened as sole crops for rotation or as intercrops with cereal or oil seed crops. The benefits of supplemental feeding of livestock with legume hay also is being evaluated.

(7) Varietal screening trials

On-station, researcher managed, screening of exotic and local legumes for adaptability to local growing conditions. Best lines will be evaluated in on-farm trials in the future.

Evaluation of crop rotation system

(8) On-station, researcher-managed, evaluation of food and forage legumes planted as sole crops or inte.cropped with sorghum or sesame.

(9) On-station researcher-managed, livestock feeding trial that will attempt to improve the nutritional quality of native roughages and crop residues by dietary supplementation with limited quantities of legume hay.

(10) On-farm, researcher-managed, long-term trial to evaluate the agronomic and economic advantages of incorporating legumes into the traditional cropping system as intercrops or in rotation with sorghum and sesame.

Increased use of Animal Draft

(11) On-farm, producer-managed, trials in two villages will be conducted in which the benefits of utilizing oxen drawn carts and planters will be evaluated.

Conservation of Native Forage-Evaluation of System Dynamics

(12) In-herd, researcher-managed, trial will be carried out to assess the benefits of feeding native grass hay to sedentary livestock.

(13) Consumption patterns and contribution of housegardens to consumption of sedentary households

In-village survey of 4-6 households in community participating in on-farm trials will be made to determine purchasing and food consumption patterns. Production requirements, as well as. nutritional and cash benefits of house-gardens will also be recorded.

(14) Input and output relationships for crop and livestock activities

In-village, researcher survey, using participant observation data collection method. (Ph.D. Dissertation research by WSARP staff member).

(15) Structure and organization of agricultural markets

A study of the basic characteristics of markets and marketing in the Nuba Mountains.

Staff Resource Requirements

Staff	Agronomy Section	Range/ Livestock	Soci-Economics	TOTAL
	----------person-years----------			
Senior Scientists	2	1	1	4.0
Research Assoc.	0	0	1	1.0
Senior Technicians	2	1.5	1	4.5
Junior Technicians	5	2.0	3	10.0
Assistants	10	3.0	3	16.0
Laborers	10	4.0	0	14.0

THE MIGRATORY PRODUCTION SYSTEM(S) OF SOUTH KORDOFAN

The migratory production system, which is dominated by an extensive livestock component, chiefly cattle, is characterized by a pattern of transhumance involving migrations of varying distances to arid, sandy ranges of the North during the rainy-season, returning to specific areas in the clay dominated ranges of the South during the dry-season. Cropping activities play a relatively minor role in this system, with sorghum, sesame and cotton representing the major crops grown on the cracking clays and millet and groundnuts on the lighter, sandier soils. Traditional livestock management practices have developed in response to the need for securing year-round sources of forage and water. During the dry-season, livestock depend on the previous season's forage, which is abundant on the cracking clays, although limited in availability due to inadequate sources of permanent water and the associated competition for forage in these areas. Early dry-season grazing attempts to exploit forages around temporary sources of water, resulting in a conservation of forage around permanent water sources for use later in the dry-season. Livestock productivity is generally rather low in traditional herds and flocks, chracterized by extended parturition intervals, poor neo-natal growth and survivability, low milk production and low yearly weight gains of all classes of livestock. Livestock disease poses less of a constraint on improving livestock productivity than does poor nutrition, which becomes increasingly more acute as the dry-season progresses. The most important constraint limiting livestock production in this system is the inability of pastoral producers to control and therefore, to efficiently

manage or utilize their natural resource base.

RESEARCH FOR THE MIGRATORY SECTOR

Objectives and Strategy

The objectives of the migratory production system research program are to: (1) increase the efficiency of resource utilization in a fashion compatable with sustained, long-term improvements in the productivity of the natural resource base; (2) stabilize and improve livestock production; and (3) improve the welfare and income of traditional households.

Strategies designed to increase livestock productivity in extensive pastoral systems have generally resulted in only limited success, primarily because these strategies focused on treating the symptomatic features of production constraints, rather than their causes. In this regard, addressing the problems associated with the control and management of natural resources are of paramount importance if stabilization and improvements in the long-term productivity of these systems are to be achieved. Accordingly, the strategy outlined for migratory livestock production systems in southern Kordofan and applicable to migratory production systems in other regions of Western Sudan, involves the design and testing of interventions which will improve the utilization and long-term productivity of the natural resource base and maximize the production potential of indigenous livestock species. This strategy has two basic components: (1) diagnostic activities aimed at evaluating and assessing the existing interrelationships within extensive pastoral system, focusing on: (a) the utilization of natural resources by the major species of domestic livestock and their impact on existing

range conditions and level of animal productivity and nutritional status; and (b) decision-making regarding managment and husbandry practices, disposition of livestock and livestock products and household consumption patterns; and (2) the design and testing of appropriate interventions aimed at improving the efficiency and rational utilization of the natural resource base and maximizing the level of livestock productivity in a manner which is compatable with both producer objectives and potentially available resources.

Activities

Evaluation and Assessment of System Dynamics

(16) Production and consumption by gender and role among transhumants in the Western Sudan - the Baggara (Hawazma) of Kordofan

Conclusion of a two-year intensive study of a fariq (camp) based in the Nuba Mountains in the dry-season, to shed light on the importance of behavioral processes to the perpetuation of transhumance.

(17) Monitoring the productivity of sentinel herds

In-herd study of the comparative productivity of two Project owned sentinel herds, one kept year round on the cracking clays of southern Kordofan (researcher-managed) and the other maintained under traditional transhumant conditions (producer-managed).

(18) Evaluation of rangelands and resource utilization by transhumant livestock

On-range, researcher-managed, monitoring of the current conditions and productivity of major range communities as influenced by fire and seasonal grazing patterns.

(19) Nutritional factors affecting large and small ruminant production in South Kordofan

In-herd, researcher-managed, study of the consumption and productivity of transhumant cattle and sedentary goats and sheep.

(20) Range utilization/management and husbandry studies of camel production systems utilizing ranges in South Kordofan

Diagnostic surveys will be conducted to determine the current and potential impact of increased use of southern ranges by camel herds. An attempt will be made to identify possible interventions to increase seasonal resource utilization efficiency and herd productivity.

(21) Integration of improvements in rangeland productivity and utilization with agro-forestry practices

On-range, researcher-managed, study of woody vegetation with the aim of introducing control measures to improve overall range-use efficiency for crop, livestock and forestry production.

(22) The effects of a protein/phosphorus supplement during the dry-season on the productivity of transhumant cattle

In-herd, researcher-managed, trial to assess the benefits to transhumant producers of feeding sesame cake to adult cows during the dry-season.

(23) A feasibility study for improving the utilization of dry-season ranges in South Kordofan

A joint study between WSARP and the Kordofan Regional Government of the possibility of improving southern range utilization during the dry-season via the introduction of water sources with controlled grazing management.

Staff Resource Requirements

Staff	Agronomy Section	Socio-Economics	Range Livestock	TOTAL
	----------	person-years	----------	
Senior Scientists	0.1	0.80	2.0	2.9
Research Associates	0	1.0	0	1.0
Senior Technicians	0	0	2.0	2.0
Junior Technicians	0	0	3.7	3.7
Assistants	0	1.0	0	1.0
Laborers	0	0	5.0	5.0

NORTHERN KORDOFAN

THE SEDENTARY PRODUCTION SYSTEM

The sedentary production system in North Kordofan is largely dominated by production of field crops. However, there is considerable livestock component involved in this system. Vegetable and fruit crops are distributed in several locations along the 'khors' with individual holdings ranging from 1 to more than 30 hectares; the average size being 2 to 3 hectares. Holdings devoted to non-horticultural crops average under 15 hectares. However, producers are able to cultivate only about one half of their total landholdings in any given season and the production depends entirely on natural rainfall. All operations are carried out by human power utilizing traditional hand tools. Availability of labor is a serious constraint. Horticultural crops are somewhat better managed than field crops and occupy greater importance in certain areas of Northern Kordofan; especially in: Bara, Banjadeed, Er-Rahad and Umm Ruwaba.

RESEARCH FOR THE SEDENTARY SECTOR

Objectives and Strategy

The objectives of the sedentary production system research center around finding ways and means for increasing and stabilizing agricultural production and increasing the efficiency of utilization of natural resources. The strategy to be followed involves the following approaches:

1. Making better use of existing resources through finding effective ways of soil and water management and conserva-

tion coupled with improved cultural practices.

2. Increasing the yield potential through improvment of genetic stock by introduction, screening and breeding of improved varieties and strains.
3. Increase our understanding of the dynamics and characteristics of the sedentary livestock system and its constraints in order to develop appropriate interventions.
4. Promote proper use of available forage and crop residues to maintain livestock productivity in the sedentary system.

Activities

Soil and Water Management and Conservation

(24) Mulching and residue management for soil and water conservation

On-station and on-farm, researcher-managed, trials will be carried out to evaluate the effects of mulching on moisture conservation and crop growth.

(25) Trials on improving soil moisture supply in the seed zone

On-station, researcher-managed, evaluation of soil ammendments using locally available materials in conjunction with improved planting methods.

(26) Reclamation of Gardud soils

On-station, researcher-managed, trials to increase infiltration of rainwater and reduce runoff via tillage and/or imprintation coupled with sowing of legumes, including *Acacia*.

(27) Drip irrigation for vegetable and orchard farmers

On-farm and on-station demonstration trials will be established. The agronomic and economic advantages will be compared with traditional irrigation methods.

(28) Water harvesting on Goz soils to increase water supply in cropped fields

On-station, researcher-managed, trials will be carried out to increase runoff, via the application of hydrophobic substances (such as gum Arabic) to soil surface. The run-off water will be directed to adjacent crop production plots and the effect on crop yields will be recorded.

(29) Diagnostic investigations of soil physical and chemical properties in planning for soil and water conservation and fertility management

Complete analyses will be made of soil samples collected from 3 profiles at research sites on Goz and Gardud soils.

(30) Monitoring soil moisture regime

Seasonal variations in soil-water content of bare and cropped soils will be recorded at several sites on Gardud and Goz soils.

(31) Monitoring weather variables

The critical parameters affecting crop production will be recorded by a portable weather station placed near crop research plots.

Improved Cultrual Practices

(32) Spacing and population trials

On-station, researcher-managed, trials with field and horticultural crops will be conducted to determine optimal plant density for crop productivity and water-use efficiency.

(33) Fertilizer trials

On-station and on-farm, researcher-managed trials to determine yield response of horticultural and agronomic crops

to organic and/or chemical fertilizers will be conducted.

(34) Trials on seedbed preparation planting method and weeding

On-station and on-farm, researcher-managed, trials with groundnuts and selected horticultural crops will be conducted to determine optimal economic cultural practices.

(35) Intercropping

On-station, researcher-managed, trials with groundnuts, sorghum, millet and sesame intercropped with each other, cowpeas or one or more of the rainfed horticultural crops grown in the area (i.e. kerkadeh, watermelon and pumpkin) will be carried out to identify best combinations for risk adversion, reduced soil erosion and increased productivity.

(36) Varietal screening and development

On-station and on-farm, researcher-managed, screening trials of potentially more productive cultivars of the major crops grown in Northern Kordofan will be conducted to identify promising entries for more extensive on-farm testing.

(37) Varietal improvement through breeding

On-station, researcher-managed, trials to develop superior cultivars of millet and sorghum for traditional farmers will be continued. (The program includes collaboration with ICRISAT and INTSORMIL.) A breeding program with kerkadeh will be initiated.

(38) Observation plots of new crops

On-station, researcher-managed, preliminary screening trials of crops not currently grown in the area, which might productively fit into one of the cropping systems will be carried out.

Livestock Ecosystem Dynamics

(39) Study of the sedentary sheep production system and its constraints

Diagnostic surveys will be made to ascertain the basic characteristics of the system for raising desert sheep. This work will be coordinated with a study of the migratory livestock systems in Northern Kordofan (49).

(40) Desertification

Environmental changes and their affect on livestock and livestock producers will be studied. (Related to 50).

Forage and Crop Residue Production and Utilization

(41) On-farm, researcher-managed, trials will be conducted to determine constraints to production and utilization of crop residues.

(42) On-farm, researcher-managed, evaluation of the introduction of forage legumes into existing cropping systems to improve soil fertility and reduce soil erosion.

(43) On-farm, researcher-managed, study of the potential contribution of donkey pulled carts toward increasing the efficiency and productivity of traditional sedentary farmers.

(44) On-station, researcher-managed, screening of native and introduced forage legumes.

(45) On-station, researcher-managed, trials will be conducted to evaluate the response of forage legumes to the application of nitrogen and phosphorus fertilizers.

Agronomy Research in Relation to Animal Nutrition

(46) Grain and stover of major crops grown in the region will be collected from farms for analysis of their nutritive

value for livestock feeds.

Agro-Forestry Studies

(47) On-station, researcher-managed, trials of *Acacia senegal* and other native and introduced species will continue. Best species or combination of species for firewood, windbreaks, forage and improving soil fertility will be identified.

Staff Resource Requirements

Staff	Agronomy	Hort.	Soils/ Water	Range/ Livestock	Entom	Socio-Econ.	TOTAL
	----------person-years----------						
Senior Scientists	2.0	1.0	1.0	0.4	1.0	0.1	5.5
Senior Technicians	2.0	1.0	1.0	0.4	1.0	0	5.4
Junior Technicians	4.0	2.0	2.0	1.5	2.0	0	11.5
Assistants	7.0	3.0	3.0	3.0	4.0	0	20.0
Laborers	20.0	12.0	8.0	5.0	5.0	0	50.0

THE MIGRATORY PRODUCTION SYSTEM

The continuous use of rangelands in northern Kordofan and particularly the heavy grazing during the growing season by the sedentary system of North Kordofan and the mirgratory systems of both northern and southern Kordofan, lead to low forage productivity, depleted ground cover and severe wind and gully erosion. Range resource degradation is further aggravated by cultivation expansion, particularly in the sandy soil, creating an increasing grazing pressure on uncultivated areas by both the sedentary and the migratory herds, during the wet season and confining forage resource utilization during the dry-season to overgrazed areas where water is available for human and animal consumption. A combination of grazing and crop residue utilization is practiced by the sedentary system to ease the condition of forage unavailability during the long dry season. The migratory system undergoes southward movement, during the dry-season to southern Kordofan where the majority of grazing land is rested during the wet-season. Cattle, camels and goats are the livestock species involved in this activity.

RESEARCH FOR THE MIGRATORY SECTOR

Objectives and Strategy

The complexity of the interactions and the details of activities with regard to resource utilization by these systems is not as simple as earlier reports have indicated. Understanding the dynamics of the systems with regard to its plant, animal and human components will be of a priority in our program for 1984-1985 outlined in different sections as follows:

Activities

Characterization of Livestock Production Systems

(48) On-range monitoring of three sentinel herds of desert sheep kept by sedentary, transhumant and nomadic tribes will be used to ascertain the basic characters of sheep production systems in northern Kordofan. (Related to 40)

Dietary Habits and Consumption Patterns of Livestock Species

(49) On-range observations will be made of seasonal dietary composition and relationships to species and soil type for desert sheep. Competition and/or complementarity with goats and cattle will be noted. (Related to 41)

Staff Resource Requirements

Staff	Agronomy	Range/ Livestock	Socio-Economics	TOTAL
	------person-years			----------
Senior Scientists	0.1	0.6	0.1	0.8
Senior Technicians	0	0.6	0	0.6
Junior Technicians	0	1.5	0	1.5
Assistants	0	3.0	0	3.0
Laborers	0	5.0	0	5.0

THE 1984-85 RESEARCH PROGRAM

SOUTHERN KORDOFAN

INTRODUCTION

A fundamental constraint limiting both agricultural and livestock production for traditional producers in the Kordofan Region of Western Sudan is an inefficient, and at times inappropriate, use of their resource base to support production enterprises. The Kadugli Research Station proposes to implement a research program which addresses this constraint, with the objective of improving the efficiency of resource utilization while maintaining and improving the natural resource base. The implementation of such a research program appears to be a feasible strategy for achieving a measurable improvement in the livelihood of traditional producers.

This program has been developed to focus specific research activities in a manner which will exploit the relative economic and production advantages common to specific types of production systems. Such an approach should maximize the chances for developing a more efficient and stable set of production practices to support future improvements and diversifications in traditional production activities. For the sedentary production system in the Nuba Mountains, this strategy translates into an initial focus for on-farm and on-station research activities on improving existing agronomic practices, and on developing ways to more effectively exploit the

natural resource base for long-term, continuous cultivation. It is envisaged that a more efficient and productive agronomic base for this sedentary system could well support the future development of improved and more diversified cropping activities and the improved integration of livestock production and draft. In this regard, on-station research programs will examine new varieties in conjunction with improved crop rotation systems for sedentary cultivators and evaluate the potential for improving livestock nutrition utilizing these new varieties with traditional crop residues, both to be produced by the agronomy section in 1984 under researcher-managed, on-farm conditions.

For the migratory livestock production system, the initial focus of in-herd and on-range research activities will address the problem of rangeland utilization and the associated problems of dry-season livestock nutrition, health, and management. Efforts directed at improving the management of the natural resources. Fundamental problems arising from existing land-tenure, grazing management, and animal husbandry practices are addressed in order to develop the means for producers to more efficiently utilize available resources while conserving the natural resource base.

This research program has been developed within a systems' context, based on reconnaissance and diagnostic surveys and on the results of previous on-farm, in-herd, and on-station trials. Emphasis has been placed on off-station activities for the coming year to maximize researcher-farmer interations and to extend appropriate

technologies to producers in the shortest possible time. Such activities will focus on a limited, and identical group of representative producers from each system to more effectively integrate discipline-oriented activities in a complementary manner and to gain a more complete understanding and evaluation of production system dynamics, on-farm, in-herd, and on-range trials. This approach also strives to more efficiently utilize Research Station resources.

For each production system, research activities have been divided into four stages; (1) farmer-managed, on-farm trials; (2) researcher-managed, on-farm trials; (3) on-station trials; and (4) diagnostic activities. Implementation of this program requires that Research Station resources be prioritized to facilitate a maximum research effort, focusing on farmer-managed, and researcher-managed, on-farm trials for the sedentary agronomic system, and on researcher-managed, on farm trials and diagnostic activities for the migratory livestock system. On-station research activities have been prioritized to provide for both the direct, technical support of off-station trials and for evaluating anticipated future technological developments arising from current on-farm and in-herd activities.

THE SEDENTARY PRODUCTION SYSTEM IN THE NUBA MOUNTAINS

Crops and Livestock Raised

In the sedentary farming system of the Nuba Mountains the majority of households raise sorghum as the primary field and staple food crop. Numerous varieties of sorghum are raised that vary in grain size, maturity period, color and texture, which are used to prepare different types of foods or sold at market. Sesame is second to sorghum in area planted. The two crops are often intercropped. Cowpeas are also intercropped with sorghum, in smaller quantities, while cotton and groundnuts are generally grown as pure-stand cash crops.

In housegardens a wide variety of garden vegetables are grown including okra, cucumbers, squashes, tomatoes, melons eggplant and leafy vegetables, as well as, early maturing grains (eaten as vegetables); such as: maize, sorghum, millet, and sesame. Other crops grown on a smaller scale include kerkadeh, peppers, radishes, purslane, gourds and Jute mallow.

In irrigated areas onions, tomatoes and leafy greens, and in some areas, orchard fruits such as limes and mangos are grown.

The livestock include mainly cattle, goats, chickens, guineas, pigeons, and ducks and, ocassional sheep. In non-Muslim households pigs are also raised.

Patterns of Cultivation

Sorghum comprises about 56% of the cropped area of the Nuba Mountain Region. Sesame and cotton cover about 19% each, cowpea 16%

groundnuts 4% and millet 1%. Other crops such as maize, watermelon, cucumbers and kerkadeh total less than 1%.

Intercropping occurs on 34-45% of the area with the most prevalent being sorghum intercropped with either sesame or cowpea. Sometimes all three are found together.

Cotton is usually grown by traditional farmers in villages where a mechanized scheme provides sources of traction, seed, chemicals and a ready market.

Although sorghum yields have been depressed in the past two years due to low rainfall, long term average sorghum yields range from about 450 kg/ha in the northern part of the region to about 700 kg/ha in the South. The average yield of sesame is about 450 kg/ha.

Three types of fields have been identified in the Nuba Mountains Sedentary production system. "Far farms" are located on clay soils, usually some distance from the household and produce medium to long-season sorghum, sesame, cotton and cowpea (lubia). "Near farms" are nearer the household on sandy soils and are planted to short to medium-season sorghum, groundnuts, millet and some lubia.

The "housegardens" are in the immediate vicinity of the households, on sandy to rocky soil, and are planted to short season sorghum, maize, millet, groundnuts and a wide variety of vegetable crops..

Almost all households have a housegarden; however, continued down-hill migration has caused some to abandon the area around the house compound and to begin the use of the "near farms" for this purpose. About half of the households had "near farms" and 70% had "far farms". Interestingly, it was found that only 17% of farmers interviewed in the Sedentary Production System Survey owned both near and far farms indicating a move toward some degree of specialization.

Field crops are usually grown continuously until soil fertility becomes depleted, or in case of sorghum, until Striga becomes so severe that further cropping is no longer feasible. The land is then left to bush-fallow for a number of years until soil fertility is restored and/or the Striga population is reduced. Systematic crop rotations are essentially non-existent. This bush-fallow cycle has been found to be shorter than previously believed with an average of 3½ years in crops and just over 4 years in fallow.

Planting of all crops in housegardens and nearby plots begins around June 1. Planting of all crops on far farms begins around June 15, but depends primarily on when the rainy season actually begins. Sorghum, because of its high priority as a food crop, is usually planted first. Planting is usually completed by August 1, unless rains are late.

If cropping is to begin following a fallow period, the land is cleared and burned to remove debris and/or burned following rains to remove weed growth. On land that was cropped the previous year, weeds are often removed with a push hoe (jeraia) prior to planting.

Most crops are planted by making a hole in the ground with a pointed tool (silukab). For sorghum, an over-abundance of seed is then thrown toward the hole and an attempt made to cover the seed with some soil using the foot, as the "planter" takes one step forward. No special attempt is made to plant in rows. Hills are made every step or pace, around 80 to 90 cm. Greater care is given to planting groundnuts and cotton and these particular crops are

usually planted in rows.

When intercropped, sesame is usually broadcast at the time of weeding sorghum. Sorghum and sesame are usually weeded twice and any thinning is usually done during the first weeding. Often weeding comes too late when early growth has already been depressed by weed competition. In spite of the high seedling rates, sorghum and sesame plant populations at harvest time are usually low. Groundnuts and cotton are usually weeded only once. Cowpeas are almost always intercropped and are usually planted and weeded at the same time as the major crop.

Buda (Striga hermonthica) is a most serious pest of sorghum. The denisty and severity of this parasitic weed increases with the number of years of continous sorghum. The land must then be left idle for a number of years to reduce this infestation. Other pests are stem borers (Chilo partellus, Busseola fusca, Sesamia cretica), army worms (Spodoptera exempta), and antat bugs (Agnoscelis versicolor). In certain areas the weaver birds (Quelea quelea) also pose a serious threat. The most serious sorghum disease is covered smut (Spacelotheca sorghi). Red rot (and perhaps rust) is so prevalent in dura that farmers do not recognize it as a problem, but consider it as a natural characteristic of the plants.

Sesame seems to have only a few pests and diseases, none of which are extremely serious. Webworm (Antigastra catalannis), gall midge (Asphandylia sesami), and sesame seedbug (Aphanus littoralis) are the most common pests. Leaf spot (Cercospora sesami) and bacterial leaf blight (Pseudomonas sesami) are the most common diseases. Cotton is attacked by a wide range of insects and

pests. Common among these are jassid (Empoasca lybica), white fly (Bemisia tabaci), aphid (Aphis gossypii), flea beetle (Podagrica puncticollis), and several types of bollworms. The most serious of these are the flea beetle in the early stages and bollworms in the later growth stages. Black arm is probably the most serious disease and all stalks by regulation, are to be uprooted and burned by May 21.

Groundnuts are thought to be relatively free of pests and diseases. However, some incidences of leaf spot (Cercospora arachidicola and Cercospora personata), stem rot (Macrphomina phaseoli), and root rot (Sclertium rolfsii) are known to occur. Termites and cutworms are the major insect problems. Cowpeas (lubia) are severely attacked by pollen beetles (coryn and mylabris), the giant coreid bug (Anoplocnemis curripes), and red and black bug (Llgaeus elegans). The stored seed is also subject to attack by Bruchidea spp.

Sorghum harvest begins between 90 and 130 days after emergence depending on the variety. All heads are usually cut by hand and stacked on the field. Threshing is by hand and the grain is stored in the home compound. The stover is occasionally harvested. Sesame harvest usually begins around mid-October. Either the whole plant is cut off or just the branches containing the pods and are left in a safe place for one to two weeks. Threshing is by tapping the dried plants or branches and letting seeds fall on a piece of cloth or plastic sheet. Cotton is harvested by hand normally from December through February. Yields averaged about 250 kg/ha during the past 10 years.

Hand pulling of peanuts usually begins in late September and continues into November. The harvested plants are stacked so that the nuts may dry. They are then stripped, cleaned, bagged and sold. Average yields probably are between 350 and 400 kg of unshelled nuts per ha. Groundnut stems and leaves are usually harvested, dried and stored for livestock feed.

Livestock Husbandry and Grazing Practices of Sedentary Farmers

Livestock are of only secondary importance to sedentary farming groups since the livelihood of these people is centered on the cultivation of crops. As a result, the care and herding of animals is generally entrusted to children and adolescents, particularly during the cropping season, when men and women are involved with various cultivation activities. The principal responsibility of herding at this time of year is to keep livestock from cultivated crops.

In general, animals belonging to several families are herded together in the interest of saving time and labor when moving them to and from forage and water. Small stock are rarely moved more than a few kilometers from individual homes, though cattle may travel as far as 10 km - 15 km in search of grazing at certain times of year. Sheep and goats are almost always herded separately from cattle because of their different behavorial and feeding characteristics. Goats in particular require little herding management once they are taken away from cultivated areas. Pigs are often kept close to the house compound where small rock shelters are built to

protect them from the sun, and to keep them out of the crops. In addition to grazing and scavenging, pigs are usually fed grain, crop residues, or remnants of meals. All animals have access to water every day, either from natural surface pools and streams, hand dug wells or hafirs depending on the time of year.

For cattle and small ruminants, the seasonal pattern of grazing involves the jebel and footslope vegetation during the rains and early dry-season, followed by the use of cracking clay plains later in the season, particularly after the main field crop harvest in December and January. In some areas such as Damba, Koya, Korungo, Baraka, and Teis, cattle are moved well into the hills during the rains where plentiful supplies of water and grazing are available. Here they may be kept in small enclosures at night and grazed in the surrounding region during the day. In other cases, more use is made of the footslopes where these are more extensive in size. A significant number of sedentary farms send their cattle North during the rainy season, as described in the following section regarding transhumants. This is accomplished by either attaching their livestock to a transhumant fariq or combining the livestock of 8-15 households and assigning several young men, from 12-25 years old, to manage the trek. In most cases some marketing of livestock is done during this period.

As the rainy season ends, animals are brought back from the North and out of the hills nearer to the permanent villages. Fodder from crop residues in the housegardens and nearby fields is often conserved for later use in the dry-season (eg. groundnuts), or it

is grazed on site soon after harvest (eg. maize, and short-maturing varieties of sorghum). Crop residues, particularly from sorghum and cowpeas, become an important source of food for livestock in the dry season.

Although every household owns some livestock the distribution is very uneven. Approximately 78% of households own goats, 50% own cattle and 11% own sheep. Some households own a few chickens. Most farmers indicate a desire to purchase more livestock.

Other Economic Activities

Many sedentary households are engaged in economic activities away from their farming enterprise. Some own and operate shops, others have family members with non-farm occupations such as gaffers, teachers, and government employees. Family members also obtain jobs on mechanized schemes during weeding, planting and land clearing seasons. Some households have members who have migrated to cities or irrigated farming areas and send money back to help support the household. Some gather wild seeds, fruits and vegetables for sale or consumption by the household. This year, due to reduced crop yields, significant numbers of farmers are seeking off-farm employment in order to sustain their families.

Organization of Households and Communities

The basic production and consumption unit among sedentary farmers in south Kordofan's Central Districts is the elementary family household or the compound family household. The unit typically consists of the male household head, his wife (or wives) un-

married children and immediate dependent kin such as siblings, a parent, etc. Farm households are divided into those in which the adults share farm work, such as most Nuba households, and those in which women are restricted to work around the house, as in most Arab households.

Juveniles engage in limited amounts of farm work, including planting field crops with parents. Adolescents generally do not work in the cracking clay fields; boys take care of livestock and girls perform household chores and carry water for domestic use. Among some Nuba tribes, mature boys are expected to devote most of their energy to physical culture and athletics, such as wrestling matches rather than farm work.

Heavy farm work is considered a male occupation, but women participate in planting, weeding, thinning and winnowing of grain crops. Women provide the management and labor for most of the house farms and garden plots near the village. Men retain control over land tenure and food stores.

Because of the emphasis on housefarms, known as "jubraka", compounds are dispersed within the village communities, rather than nucleated, and small livestock are kept inside the household compound and grazed on the housefarm soils. Common sources of peak season labor are communal work parties (nafirs) in which neighbors combine to weed or harvest a field for the sponsoring household in return for food and drink, reciprocated later on their land. Non-communal nafirs are also becoming popular where individuals join together into a work party and "hire out" to farmers in return for food and drink. In this case no reciprocal work is necessary.

Farmers in the Nuba Mountains region have progressed from being purely subsistence oriented to a partial market orientation. Most of the crops and livestock sold represent surplus production of traditional products and introduced cash crops, mainly cotton and peanuts.

Households can be separated into two types depending on the relative isolation and their cultural characteristics. One type is represented by households located near market towns, along all weather roads or in the vicinity of mechanized schemes. These households tend to be Islamic, have more market-oriented production systems and consumption patterns, concentrate production efforts on cropping activities, and have greater rates of out-migration.

The second type is characterized by isolation from market, subsistence oriented production systems that include greater numbers of livestock, participation in communal labor exchange, non-Muslim, inclusion of women in crop production, and less out-migration.

Despite the above tendencies, household types are not mutually exclusive as many display characteristics of both types. All produce similar crops and livestock (with the exception of pigs) using similar methods. Capital accumulation is limited and increased production is constrained by these production methods, shortage of resources and social pressures within the communities.

Factors Preventing Change in the Sedentary System

Farming remains the main source of subsistence for rural families in south Kordofan. The existing constraints on production op-

erate to limit the output of surpluses which would allow for more cash sales, keeping most farmers in a state of relative poverty. Rural isolation, inadequate knowledge and insufficient resources keep farmers in a primarily subsistence mode of production. Undeveloped infrastructures, especially roads and markets, also, hinder output. Other factors impose limited alternatives on farm households. These include poor access to credit or capital, few technological inputs including improved seeds, agricultural chemicals and fertilizers, and the absence of labor-saving devices.

Farmers lack knowledge of agronomic practices needed to maintain or increase soil fertility and production. They are inhibited from taking risks to produce more crops by adverse terms of trade, unreliable transportation and insecure land tenure. Seasonal labor scarcity also limits the extent and intensity of farming. Traditional labor such as communal work parties tend to keep production consistent across households rather than encourage more enterprising farmers to produce more. As population pressures increase, the slash-and-burn and bush-fallow system of cultivation requires the opening of new land or shorter fallow periods. Expansion of cash-crop oriented, mechanized farms has reduced planting of cracking clay soils by traditional farmers, further lowering production opportunities.

RESEARCH FOR THE SEDENTARY SECTOR

Objectives and Strategy

The long-term goal of the sedentary production system research program is to stabilize and improve the agronomic resource base of the traditional sedentary system to support the high developement potential for mixed farming in the Nuba Mountains. The objectives of the present program are to; (1) stabilize and improve agricultural production; (2) improve the efficiency of labor; (3) improve the integration of crop and livestock activities; and (4) improve the welfare and income of traditional households.

The strategy to accomplish these objectives basically involves the design and implementation of interventions which will increase the efficiency and utilization of land, labor, and crop resources in a manner which will improve long-term agricultural productivity. The five principal components of this strategy are: (1) increasing crop yields through the design and implementation of improved agronomic practices and introduction of improved varieties; (2) introducing food and forage legumes into a crop rotation system for improving the existing bush-fallow system of cultivation, while providing a harvestable crop of supplemental livestock feed; (3) introducing animal draft as a cost-effective, labor saving activity for expanding agricultural and household operations and as a means of marketing surplus food and/or cash crops outside the village domain, in areas where the return on crop sales is more profitable; (4) introducing the concept of conservation of native forage, and crop residues, at a time when their productivity and/or nutritive quality

are high, as a cost-effective livestock supplement to be fed during the dry-season; and (5) evaluation of sedentary system dyanamics, focusing on household consumption patterns and their interrelationships with housegarden productivity; on input-output relationships for crop and livestock activities (El Tighani's thesis research); and on the structure and organization of agricultural markets

Activities

Improved Agronomic Practices

Crop production may be increased by increasing yields or by cultivating more and. The first can be accomplished through improved agronomic practices, while the latter requires more capital and labor, both of which are major constraints for the traditional Nuba Mountain farmer. For the present and immediate future, the most logical way to increase production is to increase yields by improving or introducing new agronomic practices.

The agronomic research program for evaluating and introducing improved agronomic practices for the 1984 crop season will involve both on-farm and on-station activities.

(1) Effect of chemical seed dressing and phosphorus fertilizer on sorghum yields

This will be a nonreplicated, farmer managed on-farm trial at three locations to demonstrate the effects of seed dressing and a small application of phosphorus fertilizer on yields of improved and local sorghum varieties. The trial will consist of three plots or treatments: Improved variety, seed dressing and phosphorus fertilizer; local variety, seed dressing, and phosphorus fertilizer; and local variety with traditional practices.

(2) Sorghum fertilizer trial

On-station fertilizer trials in 1983 indicated marked yield responses of sorghum by small applications of triple superphosphate applied with the seed. Nitrogen without phosphorus had no effect. Additional trials are needed to determine if this phosphorus response occurs in other areas of the Nuba Mountain Region.

The proposed study will be researcher managed, on-farm trials involving an improved, short duration variety and a traditional

variety in a factorial experiment with 0 and 40 kg of N and P_2O_5 per ha in a RCBD with four replications. Cost-benefit analysis will also be made. Trials will be put out at three locations.

(3) Effects of timely practices and seed dressings on sorghum yields

It is the general consensus that sorghum is usually planted too late and is not properly weeded. Yields are often reduced by severe weed competition in the early stages and again when rains diminish or stop before maturation.
Researcher-managed, on-farm trials consisting of a package of practices, including an improved, short duration variety; early planting; timely weeding; and seed dressing will be evaluated against the traditional farmer practice at two locations.
Early planting will be after the accumulation of 50 mm of rain at the beginning of the rainy season. Timely weeding will be between 7-14 days after crop emergence for the first, and again after emergence for the second weeding.

(4) Effect of delayed sorghum harvest on grain and forage losses

Although sorghum may reach physiological maturity by the end of October, it may not be harvested by the producer until the end of January. Even though the major threat of migratory bird damage is over by this time, there are still local birds, insects, and other animals that may destroy some grain. Stover quantity and quality undoubtly decrease considerably over this three month period. What is the total loss to the farmer of this delayed harvest?
A researcher-managed, on-station trial will be conducted to evaluate these losses. Two plots of sorghum, one a short duration, dwarf type, and the other a long duration, forage type, will be planted on the agromony research station. Grain and forage yield samples will be taken from each type at maturity, November 30, December 31, and January 31. Chemical analyses will be made on the stover to assess any changes in nutritive quality.

(5) Variety screening trials

Promising lines and varieties of sorghum, sesame, soybeans, cowpeas, sweet corn, sunflower, and forage legumes will continue to be evaluated in researcher-managed, on-station trials. Criteria for evaluating all crops will include; yields on low fertility soils; under low to moderate levels of fertilization; drought tolerance; maturity; and acceptibility for home consumption or in the market place. In addition, sorghum will be evaluated as to its resistance to *Striga* and quantity of stover; sesame on its resistance to shattering and oil content; soybeans and cowpeas on forage, as well as grain yields and the ability to compete with weeds; and sunflower for its oil content.

Soybeans, sorghum, and sunflower will be tested under different rates of fertilizer and at several plant populations. Some of the trials will be in association with international centers, ARC, or other agencies.

(6) Soil and water management and conservation

Cracking vertisols are the most important agricultural soils in southern Kordofan. These soils, because of their high clay content, have high nutrient and water holding capacity. However, because of deep and wide cracks they remain drought-prone. A significant portion of soil moisture is lost as direct evaporation from crack surfaces. As the soil continues to dry, it shrinks progressively and becomes increasingly impenetrable. The limited root growth which results does not permit plants to draw moisture from deeper layers. The overall effect is that crops suffer from moisture stress despite a soil with high mositure holding capacity and an average rainfall of 500 to 600 mm per year.

The central problem in management of cracking vertisols appears to be the management of cracks. Numerous fine cracks in place

of a few large cracks are more desirable. Fortunately, vertisols in South Kordofan do produce fine cracks in the surface which minimizes the need for surface cultivation. However, many large cracks also appear alongside. Management practices should aim at minimizing large cracks and preventing evaporative losses of soil moisture. Large cracks are believed to aid greatly in infiltration. It will be important to take this fact into account when attempting to modify cracking behavior or eliminate them altogether.

The program proposed aims at moisture conservation in cracking vertisols. The following practices will be tested in on-farm and on-station trials:

1. General mulching on surface.
2. Frequent surface cultivation to obliterate surface cracks.

Additional studies will include:

1. Diagnostic investigations of soil physical and chemical properties. Three profiles at the WSARP Agronomy Farm will be sampled for analyses.
2. Monitoring soil moisture regimes.

(see soil/water management and conservation, Northern Kordofan for details)

Introduction of Food and Forage Legumes

The primary objective for introducing legumes into the existing system of bush-fallow cultivation is to increase and stabilize crop yields on the crackling clays, while simultaneously providing a source of high quality forage for livestock during the critical part of the dry-season. With regard to the former, the maintenance or improvement of soil fertility should lead to an effective reduction in both the fallow period and the amount of land under fallow. The result should reduce the labor required in clearing new or long-abandoned land, and allow for the development of more productive and palatable forages in areas drawn out of the fallow system. Moreover, the scope for conflict between sedentary cultivators and migratory livestock producers would be narrowed by the increased stability of the cropping system and the greater control which can be exerted over crop land. The outcome will help minimize adverse consequences such as intentional burning and its harmful impacts in terms of forage losses and undesirable changes in the productivity and composition of rangeland vegetation.

Proposed procedures for introducing the use of legumes into the cropping system of the Nuba Mountains involve research on the station, as well as on-farm trials under researcher-managed conditions. These include the following:

(7) Variety screening trials

Promising exotic and local legumes (from general and species such as *Stylosanthes*, *Desmodium*, *Macroptilium*, *Crotolaria*, *Lablab*, *Dolichos*, *Indigofera*, *Leucaena*, *Canavalia*, *Phaseolus trilobus*, *Clitoria ternatea* and various cowpeas, pigeon peas, and soy beans) will be screened on the research station agro-

nomy farm to identify well-adapted species/varietes which are also vegetatively productive, well and actively nodulated, drought resistent, and good weed competitors. The best performing species will be selected for subsequent on-farm trials.

Evaluation of crop rotation system

(8) A number of crop rotation systems, involving suitable food and forage legumes, as sole crops, as well as inter-crops with sorghum and sesame, will be evaluated on the station farm. Criterial for evaluation will be based on improvements in crop yields, maintenance of soil fertility, and the amount and quality of forage produced for livestock feed.

(9) A second series of on-station trials concern experiments for improving the quality of native roughages and crop residues by supplementing limited quanities of legume hay to livestock during the dry-season. Since roughages of low nutritional value reduce intake, thereby accentuating already existing protein and energy deficiencies in livestock, supplements from specific legume crops grown on the research station will be fed to cattle to examine the biologic and economic benefits derived from anticipated improvements in the intake and digestability of native forages and crop residues. In addition, soil samples will be taken from several locations on the research station farm and from on-farm plots.

(10) Following the selection of an appropriate, representative village, a crop rotation system will be initiated on an acquired plot of land which has been cropped continuously for 5-8 years. With the possible exception of a forage legume, the rotation will use crops known by traditional farmers in the area. The crop sequence proposed will consist of: (a) sorghum, intercropped with cowpeas; (b) a forage legume, Phaseolus trilobus (phillipesara); (c) sesame, intercropped with cowpeas or pigeon peas; and (d) a food legume such as cowpeas. The trial will be conducted on approximately 8 feddans for a minimum of five years in order to complete a full rotation. Sole crops of food and forage legumes will be harvested, transported to a storage site

(see following section), and used as a supplemental feed to a selected group of animals during the dry-season. A cost benefit evaluation of the trials will be made during the course of, and at the termination of the trial.

(11) Increased Use of Animal Draft

Sedentary cultivators in the Nuba Mountain region experience critical labor shortages during the cropping season for many of their activities. These shortages act as a major contraint in limiting the types and efficiency of activities that are or could be conducted. Animal draft offers an opportunity to significantly reduce the high labor costs associated with many crop and livestock operations, and other household functions. In terms of agronomic practices, crop yields could be substantially increased through more timely and efficient planting and harvesting using appropriate animal-draft technology, would allow the expansion/diversification of enterprises, particularly in cultivating legume crops, and in securing greater quantities of harvested forages (crop residues, legume fodder, and native hay) to alleviate poor livestock nutrition late in the dry season. The acquisition of supplemental feeds can either be utilized by animals owned by the household, or sold to other livestock producers for added income.

In addition to improvements in planting and the transport of harvested grain and forage crops from distant field sites to secure storage areas, animal draft can be used to transport building material, charcoal, firewood, and water for various household needs. It also offers potential for households to market cash or surplus crops in areas where prices are more profitable.

Producer-managed on-farm trials will entail the placement of a pair of oxen with a planter, cart, and driver in each of two selected villages to facilitate the planting of crops (especially legumes), and the transport of various crop and household needs of 5-6 households in each village. The uses performed by the oxen and implements will be determined by the participating households and documented by research station staff. The trials will examine the extent to which labor can be utilized more efficiently in various activities through the introduction of relatively simple and inexpensive technology, and the mechanisms through which it could be effectively extended to other traditional households.

(12) Conservation of Native Forage

Much of the range vegetation produced on the cracking clays in the Nuba Mountains is not grazed by livestock until the dry-season when the available forage has declined sharply, both in quanity and nutritional value. In the absence of wet-season grazing, and given the poor nutritive value of vegetation during the dry-season, the harvesting and storing of native forage, at or prior to the flowering stage, could substantially improve the level of animal nutrition during critical periods of food shortage. The value of feeding such a forage, in terms of improved livestock condition and productivity, could be greatly enhanced by supplementing limited quanities of legume hay, in a manner similar to that described in a previous section (see section - evaluation of crop rotation systems).

A researcher-managed, in-herd trial will be conducted to assess the benefits of feeding native grass hay to sedentary livestock. A producer will be identified who owns a sufficient number of cattle

to enable the selection of two homogeneous groups of approximately 10 head. One group will be fed cut native hay, ad libitum, following the mid-day watering, replacing the traditional afternoon grazing period. The second group will be subject to traditional grazing practices, without supplementation. Changes in body weight and health status will be monitored during the course of the trial, in additon to the collection of data required for an economic evaluation of the practice. The feeding and supervision of the trial will be carried out by WSARP personnel in order to acquire accurate data. The trial will begin April 15th and terminate the end of June, 1984.

The results will be evaluated to determine the potential value and feasibility of harvesting native hay for supplemental feeding, and whether the benefits could be increased by the inclusion of small amounts of higher-quality legume hay.

Evaluation of System Dynamics

Although no extensive surveys are planned for the next few years in the Nuba Mountain area, there are several areas of interest in which additional information is needed. These areas are quite specific in nature and can be studied with a minimum investment of resources and time. The following activities are planned:

(13) Consumption patterns and contribution of housegardens to consumption of sedentary households

A group of 4-6 households will be selected in each of three villages in which on-farm trials are being conducted. Details will be gathered to assess the actual and desired consumption of food items, clothing, and durable items consumed and produced by the household. Input requirements of the housegardens will be studied in relation to output and cash generation.

(14) Input and output relationships for crop and livestock activities

Prior studies have shown that it is extremely difficult to determine input and output relationships of agricultural activities without using the participant observation method of data collection. Enumerators will be stationed in each of three villages to collect data from 3-4 farmers each. The study will be guided by El Tighani as part of his Ph.D. thesis research.

(15) Structure and organization of agricultural markets

This study will take place in selected sites throughout the Nuba Mountain area. Data and information will be collected to enable a more complete description of the structure, organization and operation of the agricultural markets of the area. Estimates will be made concerning supply, demand, and elasticities of major agricultural products to determine the effects on individual and household welfare resulting from increased agricultural productivity. An evaluation of the possibilities of establishing marketing co-operatives will also be made.

Resource Requirements

It is anticipated that 1-3 sedentary villages will be selected by an interdisciplinary team of scientists in which to conduct the on-farm and in-herd trials. The final number of villages will depend on the availability of research resources. Producers will be selected in each of these villages to act as co-operators, providing land and animal resources for trials. In addition, at least in one village, a plot of land, of approximately 8 feddans, will be acquired for a period of 4-6 years for researcher-managed crop rotation studies.

Supplies of seeds, chemical, fertilizers, animal health products, and other research supplies should be purchased and delivered to Kadugli. Sufficient animals should be available for feeding trials commencing in mid-1984. It is suggested that bicycles be provided to field technicians who are stationed in the villages to give then needed mobility to carryout their duties.

Personnel requirements for the sedentary production system research program are aggregated below:

Staff	Agronomy Section	Range/ Livestock	Soci- Ecomomics	TOTAL
	----------person-years----------			
Senior Scientists	2	1	1	4.0
Research Assoc.	0	0	1	1.0
Senior Technicians	2	1.5	1	4.5
Junior Technicians	5	2.0	3	10.0
Assistants	10	3.0	3	16.0
Laborers	10	4.0	0	14.0

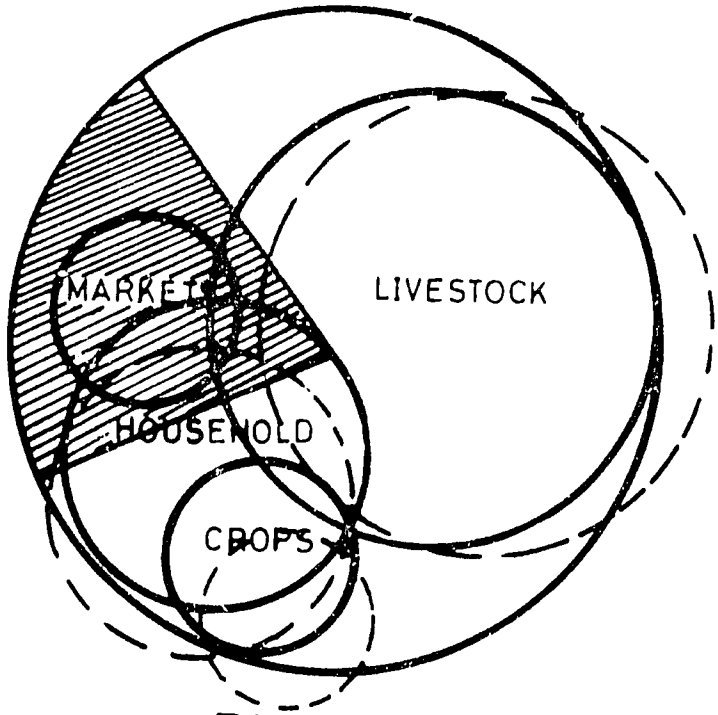
THE MIGRATORY PRODUCTION SYSTEM(S)

An understanding of pastoral production systems requires an appreciation of the dynamic interrelationships of the production system's components, their qualitative and quantitative characteristics, and how they are managed by households to achieve specific production objectives. Figure 1 illustrates the spacial relationships and relative spheres of influence for the major components of a "typical" pastoral system. The dominant components of this system are the natural resource base and livestock, where the natural resource base basically determines the species of livestock reared, as well as associated management practices and potential livestock productivity. Where land-use practices have led to environmental deterioration, the spheres of influence may partially fall outside the environmental resource base (indicated on this figure by the dotted circles). Under such conditions the long term stability and continued productivity of the system becomes jeopardized.

Alleviation of these unstable activities will be determined by the specific nature of the problems, but Figure 1 clearly illustrates that decreases in the spheres of influence, for example increasing livestock off-take for the livestock component, or increasing the integration among components, for example among house-livestock-markets to provide alternative sources of fuel or between households and livestock to improve grazing management and resource utilization, or any combination of these factors could lead to an improvement in the stability and long-term productivity of the system. For extensive pastoral systems the fundamental limitation on productivity is the natural resource base. Accordingly, the strategy adopted by the Kadugli Research Station for migratory livestock production systems in Southern Kordofan, and generally applicable to migratory livestock production systems in other regions of Western Sudan, ultimately focuses on the design and testing of interventions which will improve the utilization and long-term productivity of the natural resource base while maximizing the production potential of indigenous livestock species.

Research Station activities addressing migratory livestock production systems in South Kordofan have concentrated their attention on the Baggara-Hawazma system. The components of this system are <u>households</u>, represented by one or more consumption groups consisting of an adult male, one or more adult women and the immature and unmarried children; <u>livestock</u>, cominated by cattle but including small ruminants and chickens; <u>town and village markets</u>; and <u>limited cropping</u> conducted either on an opportunistic basis by the migratory household or on a sedentarized basis by urbanized relatives. The

FIGURE 1



PASTORAL
PRODUCTION SYSTEM

The characteristics of the environmental resource base are seasonally variable, depending on migratory patterns.

Although five major migration routes have been identified for this transhumant group, the major route utilized by producer groups who spend the dry-season in central, South Kordofan is called the Western Route and involves more or less permanent fariqs in the Nuba Mountain area during the dry-season, from November through June (depending somewhat on the commencement of the rains). This migration route generally follows the paved road from Kadugli, through Dilling, to Dubibat, and then northwards to the qoz areas around Abu Haraz. Reasons for undertaking this seasonal pattern of migration are complex, but include the followig factors: (1) to escape the insect, disease, and mud problems in the southern cracking clay areas which intensify with the onset of the rains; (2) to take advantage of better quality grazing on the northern ranges and (3) to take advantage of opportunities to strengthen linkages with urbanized relatives. The factors determining selection of particular migratory route are also somewhat complex, but for this Baggara-Hawazma group, the socio-economic resource base such as the attraction to cheese factories and livestock markets appears to play a dominant role.

It is estimated that over 50% of traditional Hawazma pastoralists have sedentarized during the past 80 years, adopting professions such as sedentary cultivators, merchants/tradesmen, and government workmen. Accordingly, migratory households have many established kinship ties with urbanized relatives, living in towns and villages between the Nuba Mountains and El Obeid. The maintenance of these ties has brought the traditional pastoral sector into repeated con-

tact with urbanized environments during seasonal migrations, and as infra structures have developed within these urban areas, these traditional pastoralists have increasingly made use of services such as markets, education, medical care, and local political organizations. These conditions have likely made socio-economic considerations important in modifying migratory patterns.

This is not to suggest that the necessity for securing year-round sources of forage and water do not play the dominant role in decision-making regarding migrations. The timing of northern migrations is closely correlated with the onset of the rains and the establishment of seasonal ranges and sources of water in the North. During migrations, emphasis is placed on utilizing ephemeral pools and hafirs associated with gardud soils. This practice has several functions. It reduces the high labor costs of drawing water by hand from wells for watering livestock, and it avoids mud problems for both people and livestock during the rains, particularly in the vicinity of the fariq. It also provides better quality forage at the start of the rains because of the earlier flush and greater diversity of vegetative growth on these soils relative to the cracking clays. The latter is especially true for small ruminants and camels, but cattle require a denser and higher sward of herbaceous growth to satisfy their intake requirements. As a result, when the ground cover is short and sparse early in the wet season, cattle also utilize the abundant previous season's growth of vegetation on the cracking clays when these soils are not wet. However, as plant growth becomes more significant, the ratio of dry to green forage selected by cattle steadily changes in favor of the higher

quality green vegetation. At the end of the wet season the depletion of forage and water forces the return migration south. During this period, attempts are made to maximize the use of abundant high quality grazing in areas with adequate supplies of water. For this particular Baggara group, sites for grazing and watering livestock are frequently selected in proximity to mechanized transport and markets. The dry season settlement of fariqs is influenced by these factors, and by the availability of schools and medical facilities, but the areas grazed by livestock are ultimately determined by opportunities to secure optimum amounts of forage and water.

For traditonal households in this Hawazma system income is generated almost exlusively through the sales of livestock and livestock products. It appears that milk sales may represent approximately 35 to 40% of total household income, being maximized during the rainy-season when milk is sold to cheese factories in the North. Milk sales are the prerogative of women, who through their control of the management of milking cattle, the purchase of supplemental feeds, and the occasional sale of small ruminants and chickens generate roughly half of the total subsistence income of the household, as well as, income for purchasing clothing and personal items for dependent children. The remainder of household income is generated through livestock sales controlled by men. Information collected to date suggests that subsistence income is derived primarily from the sales of milk, milk products, chickens, and small ruminants. Cattle sales are generally reserved for major purchases such as the purchase of sorghum (approximately 30% of total household expenditures), payment of school fees, and the purchase of additional and/

or replacement livestock.

The livestock component of this system is dominated by cattle, although substantial numbers of small ruminants, sheep and goats are also kept. Within the Hawazma there is a large spectrum in household livestock holdings, with sedentarized households owning small herds, which are frequently entrusted to migratory relatives to manage. A few nomadic Hawazma have herds in excess of several hundred head, while the majority of transhumant households own herds averaging approximately 100. The proportion of small ruminants to cattle is approximately 2:3. Traditional herd demographics reflect a relatively high proportion of adult male cattle with the ratio of females to males over 30 months of age about 3:1. Under local management systems cows are available for service throughout the year. Calving percentages range from approximately 55 - 60% with calving interval of approximately 20-24 months. Under open breeding conditions as exist under traditional management practices, age at first calving is the result of first oestrus and occurs at approximately 4-5 years of age. Calf mortalities appear relatively low, with less than 15% dying before weaning, however, calf growth and nutrition appear quite poor with 14-20 month old animals generally weighing less than 150 kgs. Overall herd losses resulting from culling and deaths range from 15-20%, with most culls involving adult female cattle with either reproductive problems and/ or farcy.

Very little data has been developed regarding market interations with tradtional Hawazma producers. As already discussed, the

sale of milk during the rainy-season represents a substantial percentage of household income. However, sales and purchases of livestock and estimates of annual off-take are lacking.

Cropping activities play a relatively minor role in the production activities of the traditional Hawazma system. Sorghum, sesame, and cotton represent the major crops grown on the cracking clays, and millet and groundnuts on the lighter, sandier soils. It is estimated that migratory households produce approximately 1/5 to 1/6th of their yearly requirements of cereal grains, the remainder having to be purchased. Occasionally, however, livestock and crop production activities are shared between extended families, with urbanized members undertaking cropping activities while migratory members undertake livestock management.

The primary constraint limiting improvements in livestock productivity for the traditional Hawazma system is the inability to manage or control their natural resource base, resulting in intense competition for available grazing and water sources. On a production basis this competition for limited natural resources severely restricts the time spent in the Northern grazing areas, limiting animal productivity and the opportunity for marketing milk and milk products. In South Kordofan grazing is limited by the unavailability of water and widespread burning. The scenario is poor livestock production resulting from poor nutrition, a condition which becomes increasingly more acute as the dry-season progresses. In addition, the poor nutritional status of transhumant livestock, especially during the latter stages of the dry-season, is frequently aggravated by disease and parasitic infestations. Acute disease problems, eg. anthrax, haemor-

rhagic septicemia, blackquarter, and CBPP chronic problems such as farci, stredtotrichosis and generalized deuodex are endemic in South Kordofan, while ecto- and endo-parasitic infestations severely limit seasonal production, especially for young stock.

RESEARCH FOR THE MIGRATORY SECTOR

Objectives and Strategy

The objectives of the migratory production system research program are to: (1) increase the efficiency of resource utilization in a fashion compatable with sustained, long-term improvements in the productivity of the natural resource base; (2) stabilize and improve livestock production; and (3) improve the welfare and income of traditional households.

Strategies designed to increase livestock productivity in extensive pastoral systems have generally resulted in only limited success, primarily because these strategies focused on treating the symptomatic features of production constraints, rather than their causes. In this regard, addressing the problems associated with the control and management of natural resources are of paramount importance if stabilization and improvements in the long-term productivity of these systems are to be achieved. Accordingly, the strategy outlined for migratory livestock production systems in Southern Kordofan, and applicable to migratory production systems in other regions of Western Sudan, involves the design and testing of interventions which will improve the utilization and long-term productivity of the natural resource base and maximize the production potential of indigenous livestock species. This strategy has two basic components.

(1) diagnostic activities aimed at evaluating and assessing the existing interrelationships within extensive pastoral system, focusing on: (a) the utilization of natural resources by the major species of domestic livestock and their impact on existing range conditions and level of animal productivity and nutritional status; and (b) decision-making regarding management and husbandry practices, disposition of livestock and livestock products, and household consumption patterns;

(2) the design and testing of appropriate interventions aimed at improving the efficiency and rational utilization of the natural resource base and maximizing the level of livestock productivity in a manner which is compatable with both producer objectives and potentially available resources.

Activities

Evaluation and Assessment of System Dynamics

The objective of these studies is to relate existing range and livestock conditions to management, husbandry, and livestock behavioral patterns, and clarify household decision-making patterns on resource utilization.

Factors associated with declining livestock and rangeland productivity resist swift and simple solutions. Significant increases in livestock productivity are possible, but require improvements in the range and forage base, which must be accompanied by more efficient resource utilization, improved livestock husbandry and management practices, disease control, and marketing facilities and incentives to promote off-take. When properly evaluated and understood, improvements in pastoral system productivity offer the opportunity to efficiently and effectively utilize both non-arable land resources, as well as arable resources in a compl mentary manner with existing cultivation, to make a significant impact on the welfare of traditional producers. The starting point in this development exercise is to identify the causalities for many of the apparent symptomatic constraints limiting productivity in extensive systems, and then undertake to design and test interventions which will overcome these causal problems. The design of such interventions requires a clear understanding of existing management prac-

tices and how these practices impact on the natural resource base through livestock utilization patterns. Specifically, livestock feeding habits, diet quality and composition, and voluntary intake are important in order to assess; (1) whether existing livestock numbers and/or mix of livestock species are well-balanced with respect to both existing vegetation communities and total herbage production; (2) whether or not available indigenous forage and browse species are providing an adequate level of nutrient intake for maintaining an acceptable level of productivity; and (3) the potential, seasonal carrying capacities, both in terms of numbers and mix of livestock species, for specific ecological areas. Interrelating such data with management and husbandry practices, disease incidence, and household resource utilization patterns, then gives a more integrated picture of the system's present and future production potential. Such studies should examine all livestock species and relate their seasonal resource utilization patterns, on a location-specific basis, to the existing and potential primary productive capacity. A number of existing, and several planned activities, address these questions for both Southern and Northern Kordofan.

(16) Production and consumption by gender and role among transhumants in the Western Sudan. The Baggara (Hawazma) of Kordofan.

Among the Baggara, analysis has identified two operational ideologies: (1) an ecomonic ideology; and (2) a genealogical or kinship ideology. The Baggara economic ideology is focused on the value of cattle management and preference for transhumence through the independent household. The kinship ideology stresses the importance of the patrilineal group and of close cousin marriage. An additonal aspect of both of these ideologies is male dominance over cattle and women.

The research objective of this study is to explain these interlinked ideologies in terms of actual behavior. Actual behavior includes; (1) the organization of several households into permanent camps for livestock production and crop raising; (2) widespread evidence of bilateral kinship ties which create multiplex links binding several households together; and (3) evidence of relatively autonomous management roles for women in such activities as household managment, cattle ownership, milk and milk-product marketing and consumer purchasing.

The major hypothesis is that these behavioral processes contribute to the perpetuation of transhumance as a viable economic mode, while allowing flexible movement between sedentarization and nomadization by individual householders in response to situational production strategies and constraints. These behavioral processes will be studied within the context of the ecological zones exploited, and the socio-cultural context which includes traditional sedentary Nuba populations and urbanized populations of Baggara, Nuba, and other ethnic groups.

There are indications that transhumant production, consumption, and herd management units are not necessarily the same. Nor are all herd or farm managment decisions made by a single individual within the production/consumption unit(s). Management decisions may be gender- and age-defined, or be made at different levels, ie., household or fariq. Management decisions may be based on the availability of inter-unit (eg., fariq/household resources and support. On-going studies are attempting to define which production/consumption decisions (in regard to livestock, crops, food consumption, purchase of consumer goods, acquistion of housing materials, sale of products such as meat, milk, skins, manure) are made in each of the gender, age, and organizational level catagories. On-going studies also include investigation of household budgets;

the impact/contribution of wage labor to the transhumant system; marketing patterns; and cultivation activities.

Planned studies include: (1) Investigation of the demographic compostion of households and camps in order to understand the population dynamics requisite to the transhumant system. The impact of such factors as birth/death rates, disease, and water quality will be considered; (2) investigation of social networks, both kin- and nonkin-based, in order to understand how social networks facilitate or retard production, strengthen group solidarity, maintain either nomadization or sedentarization, or allow for movement between these two economic modes; (3) investigation of patterns of inheritance and redistribution of agricultural resources institionalized in gifting, blood money payments, circulation of cattle between transhumant and sedentary households, sacrifical rituals, farmland division, and how these patterns help to maintain the transhumant system or affect the decision-making of a household to nomadize or sedentarize. The objective is to understand how these customs encourage productive off-take or limit livestock sales, or otherwise affect production/consumption patterns; and (4) investigation of transhumant Baggara relationships to wider society, including response to social services (health care and education); veterinary and agriculatural services and policies; courts and politics; and military service. These studies will also consider historical factors such as the development of cheese factories as outlets for milk sales and access to lorry transportation.

(17) Monitoring the productivity of sentinel herds

The long-term objectives of these studies are to assess; (1) the possibilities for increasing the efficiency of utilizing cracking-clay plains for livestock production; and (2) decrease the early wet-season grazing pressures on traditional grazing areas in Northern Kordofan. Specifically,

these studies are evaluating production constraints in two sentinel herds, one maintained on a year-round basis on the cracking clays and the other maintained under traditional transhumant practices.

These activities were initiated in August, 1982, when the Station purchased two herds of cattle, demographically similar to traditional herds. Data are being collected on productivity parameters, such as; changes in liveweight, milk yield, services, return to oestrus, birth weights, disease incidence and mortalities. Data collection will be continued until December, 1984, after which a decision will be made about future status of these herds. At present, it is felt that, if continued on the long-term, the mangement of the research station herd should be substantially improved to reflect the best possible productivity to be expected from Baggara cattle maintained on the cracking clays. The migratory herd may continue for sometime so that more data can be collected on cattle managed under traditional, transhumant practices.

(18) Evaluation of rangelands and resource utilization by transhumant livestock

The principal objective of this research is to assess the current conditions and productivity of major range communities as influenced by factors such as the incidence of fire and the seasonality and intensity of grazing. An accurate assessment of range conditions necessitates a sound understanding of land-use practices, grazing patterns, and other disturbing influences which may function to maintain or depress the quality and carrying capacity of rangelands below their potential. Similarly, resource utilization patterns of livestock under traditional management should be adequately understood to ensure a clear identification of the key constraints affecting livestock productivity.

Emphasis during the current work plan in this area is being given to transhumant cattle because they are the most important and numerous class of livestock in South Kordofan. Although considerable information has been compiled on the major range communities and their use in this Province, information is lacking on seasonal food preferences of cattle. This information is essential from an ecological context, as well as from a nutritional one, since it identifies the relative importance of different plants to different species of livestock on a seasonal basis. The results can greatly assist in carrying-capacity determinations, and in designing management practices to increase the abundance of valuable forage plants over undesirable or less palatable species.

In addition to these activities, seasonal monitoring of permanent exclosures and transect lines will be conducted to assess changes in primary productivity and species composition as affected by the presence or absence of grazing and fire.

(19) Nutritional factors affecting large and small ruminant production in South Kordofan

The objectives of these studies are to assess resource utilization patterns of large and small ruminants and to relate these utilization patterns to nutritional status and productivity. The present series of studies have been undertaken with migratory livestock to more clearly assess the problems in forage and water availability, common dry-season constraints for Baggara livestock, and their effects on voluntary intake, diet quality, and diet composition. These studies will address cattle, sheep and goats, with regard to these parameters. Since all three species utilize virtually the same natural resource base, it is important to evaluate the potential competition and/or complementarity among these species in terms of resource utilization.

For studies with cattle, five bulls, which were previously used

for studies on the research station farm were moved to the migratory sentinel herd, given a period of adaptation, following which total fecal output was analyzed for a 7 day period. This will be repeated four times a year, commencing in February 1984. Diet quality will be determined by the diet-simulation technique of Wallace et al (1972) as applied by Short (1977). Samples will also be used to determine in vitro digestability and proximate analysis. Voluntary intake will be calculated from a relationship between digestability and total fecal output per 24-hour period.

In order to initiate studies with small ruminants, flocks of both sheep and goats are required, containing at least 25 breeding females of each species. These flocks will be used for monitoring productivity. In additon, five rams and five male goats will be used to evaluate feeding habits, diet quality, and total voluntary intake. Production monitoring will include; weight changes, oestrus, service, return to oestrus, number of offspring, and parturition interval.

(20) Range utilization/management/and husbandry studies of camel production systems utilizing ranges in South Kordofan

Increasing pressures on rangelands in the Northern areas of Kordofan Region due to several successive years of low rainfall and inappropriate land-use practices for the production of both crops and livestock, are leading to increased competition among different pastoral groups for resources in South Kordofan. Preliminary diagnostic activities are planned to address camel production systems with respect to seasonal resource utilization patterns.

The objectives of this study will be to evaluate current range/forage conditions in terms of available plant cover and composition, livestock foraging patterns and food preferences, diet quality and composition, total voluntary intake, and management/husbandry practices. Socio-economic evaluations of decision-making and resource utilization by households will be inter-

related with livestock production data in an attempt to quantify pastoral system productivity/resource utilization. An assessment will be made of the potential improvements in productivity which may be possible through adoption of interventions designed to more efficiently utilize the natural resource base and maintain its long term productivity.

(21) Integration of improvements in rangeland productivity and utilization with agro-forestry practices

The primary objective of this study is (1) to evaluate woody vegetation in terms of its value and impact on land-use practices, and (2) to determine how the density and composition of this resource can be manipulated to achieve the integration of grazing, cultivation, and forestry practices with the long-term productivity and utilization of the resource base. This study was initially undertaken to examine measures for controlling the density of problem species in areas where forage productivity, quality, and availability are impaired by bush encroachment. The study has been expanded to include results from evaluations and patterns of resource use (see above) with regard to the woody component. The importance of woody vegetation is demonstrated by its wide range of uses and stabilizing influence on the environment. In northern zones increasing pressures on this resource are precipitating a need for land-use planning and improved agro-forestry practices. Although woody vegetation in South Kordofan is more abundant and resilient to land-use pressure, future demands for wood products will increase. Certain species with low fire-tolerance and regenerative ability are already declining in areas of high population density, usually on course-textured soils where the diversity and proximity of trees attract cutting. In contrast, vegetation on cracking clays shows high fire-tolerance and rapid regenerative capibilities following both cultivation and grazing. Bush problems here hinder livestock movements and reduce the biomass and quality of the herb layer. This study attempts to identify ecologically expedient measures

for controlling the density of Acacia seyal and Dichrostachys cinerea to more desirable levels, while encouraging the growth of species such as Balanites aegyptiaca, Ziziphus spina-christi, Combretum aculeatum, and Capparis tomentosa. The measures used must operate selectively in order to maintain the wood vegetation at a density which maximizes multi-use characteristics (e.g., improvements in the herb component with more diverse browse plants and shade for people and animals; enhanced soil fertility, nutrient cycling, and moisture conservation; provision of food and other products such as fuel, building material, gum, and medicinal properties). The results may also provide a potential mechanism to divert tree-cutting, away from fragile plant-soil communities, to areas of higher resilience and regenerative capacity. The effect will serve to improve the productivity and utilization of land and vegetative resources, while ensuring the conservation and stability of the environment.

Improving the Efficiency of Livestock Productivity

In-herd and on-range, researcher-managed trials for the coming year, and beyond, will focus on two primary areas for the migratory production system of South Kordofan; (1) improvements in the level of nutirition for cattle during the dry-season, specifically protein and phosphorus; and (2) improvements in utilization of range resources in grazing practices, and in disease control, for transhumant livestock during the dry-season. In additon, preliminary analyses are planned to examine breeding and production records of the Gezira Research Station in an attempt to define the heritable production traits of Kennana and Kennana-class cattle, which might be exploited in the West under improved semi-intensive management.

(22) The effects of a protein/phosphorus supplement during the dry-season on the productivity of transhumant cattle

The objective of this researcher-managed, in-herd trial is to assess the cost/benefit for transhumant producers of the introduction of a protein-phosphorus supplement for adult, female cattle during the dry-season. Experimentally, this trial will assess the seasonal phosphorus status of adult cattle, and its interaction with a protein-phosphorus supplement as determined by changes in the productive performance over a period of two calving intervals.

The primary justification for this trial lies in its economic analysis, since sesame cake is presently fed, on a limited basis, to adult cattle by traditional producers. In addition, circumstantial evidence exists for the presence of phosphorus deficiency in cattle resident in South Kordofan, and this trial is intended to provide seasonal, quantitative data on this subject. The principal production parameters to be evaluated in this trial relate to changes in the reproductive efficiency and productivity of adult cows, and therefore, it is intended to collect data over a period of at least three years.

Semi-intensive forms of livestock husbandry are almost invariably associated with sedentary systems where the agronomic resource base is capable of supporting high levels of livestock productivity through the supply of high quality supplemental feeds. Improved cross-bred animals generally require such management systems in order to achieve levels of production greater than that found in traditional, unimproved herds. Within such a system there exists considerable scope for improving productivity through selective-breeding and cross-bred breeding programs, based on utilizing indigenous breeds.

In this regard, several breeds, indigenous to the Sudan, Kenanna and Butanna, offer potential for the development of an improved cross-bred animal suitable for semi-intensive, mixed farming systems. It is planned to have a Project graduate student, presently studying for an M.Sc. in the United States, undertake to evaluate breeding/production data from the Kenanna herd of the Gezira Research Station for his thesis topic. The objective of this analysis will be to establish genetically-linked production parameters and relate this data to Station management/husbandry practices.

(23) <u>A feasibility study for improving the utilization of dry-season ranges in South Kordofan</u>

Evaluations into rangeland productivity and patterns of resource use by the existing livestock biomass in South Kordofan indicate that only 6-10% of the net primary production is consumed by livestock on an annual basis. Relative to other regions in Africa where this percentage reaches 25-35%, the use of grazing lands in South Kordofan is clearly inefficient. This is attributed to factors related to the availability and quality of forage, such as the timing and distribution of grazing, water availability, plant palatability, and forage losses from fire, natural decomposition, wind, and herbivory by small mammals and invertebrates.

With regard to migratory livestock, which account for 70-80% of the ungulate biomass in the province, grazing in the South is confined to the dry-season, coinciding at the outset with a dramatic reduction in forage abundance and quality immediately after the growing season. Declining conditions at this time are exacerbated by limited water supplies which lead to localized high concentrations of livestock, and intense competition for grazing. The outcome is a steady depletion of available forage in radiating arcs from water points as the dry-season progresses. This forces animals to travel greater distances to water and graze, causing increased energy expenditures and reduced food intake. Fires further aggravate the problem of decreasing forage supplies by annually consuming up to 30-40% of the net primary production, while also inducing undesirable changes in the vegetation. The results are collectively manifested in poor animal growth and productivity, as well as greater susceptibility to disease and mortality.

These conditions, coupled with land-use conflicts posed by expanding cultivation and the increasing inability of pastoralists to control their resource base, limit the options available for improving the productivity of migratory livestock in South Kordofan. A strategy which shows high potential for achieving this objective is the introduction of water in appropriate dry-season ranges which are currently unutilized due to the absence of water. It is estimated that as much as 30% of the rangelands in South Kordofan are unavailable for grazing because of the lack of dry-season water, and the fact that insects, disease, and mud prevent their use during the growing season. Thus, the strategic development of water offers the potential of a sound ecological and socio-economically acceptable approach for (1) improving the productivity of livestock and the efficiency of resource utilization in areas currently uninhabited and receiving little or no agriculatural use; (2) providing alternative sources of grazing for migratory livestock under conditions where resource competition and land-use conflicts are minimized;

and (3) developing land-use plans, in cooperation with regional and national governments, for the future integration of livestock and crops whereby the productivity and stability of these regions are optimized.

In view of the resource deterioration frequently associated with water developments, the nature of the environment and the use to which it will be subjected are critical to the long-term success of such a program. The types of areas proposed are characterized by extensive plains of cracking clays where annual rainfall averages 750-800mm. These areas are not only capable of supporting high year-round land-use pressures, but the incidence of insects, disease and mud during the rains currently precludes occupancy by both people and livestock at this time. Unless some relief from these problems is provided, which is unlikely in the near future, the use of these areas will be confined almost exclusively to dry-season grazing, when physiological damage to plants is negligible. In the event that habitation by people and animals is made possible during the wet-season, the range communities here are such that moderate to high grazing pressures in the growing season would tend to favor improvements in species composition, with little or no risk of resource deterioration. An important implication of animal-health control measures is the possible indirect effect for alleviating pressures on wet-season ranges in the more fragile North, though the attraction among producers for securing a more stable source of forage in the South.

Based on the potential for substantially improving livestock productivity and resource utilization in South Kordofan, the Kadugli Research Station is proposing a feasibility study with the regional government for introducing water on a limited, pilot-trial basis to increase the availability of dry-season grazing. Such a trial would be accompanied by an improved system of grazing management with strategic measures for animal-disease control The latter will involve efforts to reduce the

incidence of ecto- and endo- parasitic infestations which have been shown to significantly affect the productivity of livestock under both migratory and sedentary conditions.

The initial stage of the feasibility study will require (1) in-depth discussions with regional government for coordination and assistance, (2) extensive, multi-discipline oriented surveys in the evaluation of potential sites, sources of water, and the pastoral group(s) to be involved, (3) an assessment of the resorces associated with potential sites in terms of the number of households and livestock which can be supported on a seasonal and year-round basis, and (4) an evaluation of the logistical and technical inputs necessary for effective implementation and monitoring.

Staff Resource Requirements

Staff	Agronomy Section	Socio-Economics	Range/ Livestock	Total
	----------person-years----------			
Senior Scientists	0.1	0.80	2.0	2.9
Research Associates	0	1.0	0	1.0
Senior Technicians	0	0	2.0	2.0
Junior Technicians	0	0	3.7	3.7
Assistants	0	1.0	0	1.0
Laborers	0	0	5.0	5.0

THE 1984-85 RESEARCH PROGRAM

NORTHERN KORDOFAN

INTRODUCTION

Agricultural production (both crops and livestock) in Northern Kordofan is dominated by traditional farming methods, depending mainly on rainfall, which averages about 350mm/year. Availability of water is the most important limiting factor for crop and livestock production. The rainy season usually extends from July through September. A bush-fallow system is practiced with *Acacia senegal* (gum arabic) being the main tree crop in the system. The major crops grown include pearl millet, sorghum, sesame, groundnuts, kerkadeh (roselle), watermelon and a variety of other minor crops. Vegetable crops and fruit trees are mainly produced under irrigation in the several thousands of gardens distributed in the floodplains of the seasonal streams (khors) where shallow wells have been dug in order to provide irrigation water. The main animals raised include camels, cattle, sheep and goats.

Two major types of soils exist in the region, namely, the stabilized sands or "goz" soils and the clayey sand soils locally known as "gardud" soils. The goz soils account for more than 70 per cent of the area. Water and nutrient holding capacity of these soils is very low. They are highly susceptible to wind and water erosion. The gardud soils, on the other hand, have varying amounts of finer materials that gives than a sandy clay to clayey texture. Thus they have a better potential for retaining water and nutrients. However, their compacted state allows very little infiltration of water.

Much of the rainfall is lost as runoff. Additionally, because of their hard structure they are difficult to cultivate using traditional hand tools. Thus, despite their potential, the gardud soils remain unproductive. They are only partially utilized. In comparison, the goz soils are easy to cultivate using hand tools and as a result much of the traditional production activities are practiced on these soils. This has resulted in exhaustion of the soil and deterioration of the landscape. Crop yields are very low compared to world standards.

Agricultural production in North Kordofan is constrained by a variety of natural and socio-economic factors. The more easily identifiable constraints are listed below.

(a) Unavailability of water and low and unreliable rainfall.

(b) Poor soil fertility.

(c) Poor genetic stock.

(d) Poor cultural practices and lack of management and conservation of natural resources.

(e) Losses due to pests and diseases and lack of proper control measures.

(f) Transportation difficulties that limit the availability of agricultural inputs (seeds, fertilizers, chemicals, etc.) and restrict access to major markets.

(g) Various other infra-structure problems and social and economic factors.

El Obeid station research program is designed with the objective of attempting to find solutions to some of the constraints. On-station and on-farm research programs are being proposed that

would, hopefully, lead to interventions useful to the traditional producers both in the sedentary and the migratory systems of production.

The WSARP Research Farm, at the station site near El Obeid is on goz soil. Field crop experiments, also are planted at Kaba, 10 km south of El Obeid on gardud soil. Horticultrual trials are conducted on farmers fields in Banjadeed. These will soon be supplemented with additional plantings on the Horticultural Research Farm being developed at Beno.

THE SEDENTARY PRODUCTION SYSTEMS*

The rural population is dispersed in villages that vary in size from five or six households to 1,000 or more. The number of villagers that occupy a village varies with the season. The population is greatest during the rainy, cropping season and lowest during the dry-season. The average household numbers between seven and eight members. Nuclear family residence seems to be preferred but extended families, matrifocal families and other household arrangements are fairly common. Whereas, the household is the basic unit of consumption, agricultrual production is typically in the hands of more than one decision-maker in the household. A common pattern is for husband and wife to manage separate farms. Unmarried sons and daughters who are old enough are also given land to manage, if it is available. Besides farming, virtually every household has members who work in secondary occupations, usually on a seasonal basis. Two-thirds of the household members are productive in some way during a part of the year. The usefulness of children as producers and income-earners is well understood by parents.

The average rainfed cultivated landholding of a household head is 18 makhammas, (32 feddans). Most farmers are cultivating more than one-half of their total land holdings, a fact that supports the

*A WSARP social scientist has not been posted in El Obeid. However, INTSORMIL, The Sorghum and Millet Collaborative Research Support Program, assigned two anthropologists, Dr. E.B. Reeves and Mr. T. Frankenberger to study farming systems in Northern Kordofan during 1981-82. This section is drawn from their summary of their main findings. Reference: Reeves, E.B. and T. Frankenberger, 1982 Farming Systems Research in North Kordofan, Sudan, Report No. 2, Depts. of Sociology and Anthropology, University of Kentucky, Lexington, Kentucky, USA.

view that soil fertility in the region is steadily declining due to insufficient fallowing. One-third of all cultivated lands are rented rather than owned by farm managers. Most of the rented land is leased by better-off farmers from farmers who are poorer than average. Because labor is the key constraint on cultivating land and because poorer farmers lack the equity to hire labor, they gain an income from idle land that they own by renting it to others.

The four most common field crops are millet, sorghum, sesame and groundnuts. The cereals are primarily subsistence crops though surpluses are sold to other farmers and at local markets. Millet is the preferred staple of the rural diet, and the stalks of the millet plant are ubiquitously used as a building material. Thirty-eight percent of the cultivated lands are cultivated in millet, while 95 percent of the households grow it. Sorghum is not nearly as important a crop although about three-quarters of the farmers do grow some sorghum. Local varieties (milo type, red and white) are frequently seen intercropped (in the same hole) with sesame. White sorghum is preferred for making bread and porridges. Red sorgum is used to make beer. Sorghum is also an important animal fodder and both the seed and the stover are used for this purpose.

Forty-eight percent of the rainfed cultivated land is planted in sesame, while 93% of the farmers grew sesame in their fields. Sesame is often intercropped with sorghum, cowpeas, watermelon or roselle (kerkadeh). Some farmers sow varieties of sesame which mature at different rates in order to avoid the labor bottlenecks that can occur during the busy harvest season. Since sesame is threshed by hand, it must have the characteristic of shattering

easily. Sesame is the primary cash crop. Most of it is sold at regional markets and is destined for processing into oil which is consumed in the urban centers. Market prices of sesame tend to be stable and predictable. Ten percent of the cultivated land was planted in groundnuts during the 1980-1981 season. Barberton variety is grown exlusively and seed quality is said to be very poor. Groundnuts are grown primarily for the export market where wild price fluctuations have occurred in recent years. Price instability makes this a high-risk crop for farmers.

Besides these four major field crops, a variety of lesser-important crops are grown under rainfed conditions. Roselle is usually sold for cash or traded in kind. Cowpeas and okra are intended for domestic consumption, but may also be sold or traded. Watermelon is grown as a water source and fodder for livestock during the dry-season. It is also consumed domestically and sold in local markets. These minor crops are frequently interplanted with sesame and sorghum on the rainfed fields.

The cropping cycle begins in the period of January to April with land clearing. Then, between April and August all four major crops are planted. Millet is planted earliest because the locally preferred variety is long-maturing. If the early plantings succeed in germinating owing to an early arrival of the rains the crop will mature before the season in which insects and birds usually attack the immature candles. If the early plantings of millet do not germinate the farmer may replant after a month. Alternatively he may switch to a shorter maturing crop, like sesame or an early maturing sorghum. Regular plantings of sesame, groundnuts and sorghum gener-

ally occur in June and early July. These crops, too, may have to be replanted if rains are insufficient for germiation or if sandstorms kill the seedlings.

According to an ideal expressed by farmers, every crop should be weeded at least twice. Although wealthy farmers can afford to hire labor for a third and even a fourth weeding of groundnuts, poor farmers are forced by their need for cash to hire their labor to other farmers and thereby neglect an adequate weeding of their own fields.

Harvesting operations are spread out over the period of late August to January, with the most activity occurring in October and November. All threshing operations are accomplished with hand labor.

Next to the vagaries of the climate, labor is the most important constraint on the cropping system. For many farmers the cost of hiring agricultural laborers is the largest input expenditure that they make. The rate of return to labor is highest for millet, followed by groundnuts, sesame, and sorghum. Sesame's popularity among farmers, although its rate of return is lower than either millet or groundnuts, can be attributed to risk-aversion. Millet is relatively a greater risk to plant than sesame because of its higher susceptibility to pest attack, while unstable prices and high outlay for the labor input limits the planting of groundnuts.

Animals play an important role in this farming system. The availability of drinking water, first and pasture during the dry-season, second are the central-most constraints on livestock raising. Crop residues, as well as commercial sorghum are an important source of fodder for working animals, but herd animals subsist largely on

the pasture that lies beyond the village's zone of cultivated lands. Most farm families own a donkey and several goats. Better-off families are able to invest in sheep and cattle. The largest herd of cattle recorded was 60, but the average herd size was only 6. Similarly, the largest herd of sheep was 120, but the average herd was also about 6.

Nearly every farm household supplements its income through off-farm activities. The latter include dry-season migration for a wage, charcoal manufacture, water-hauling, tailoring, carpentry, metal-working, itinerant marketing, and the operation of such capital-intensive enterprises as village shops, bakeries, flour mills, oil presses, cisterns, and trucks. Monetary gifts from relatives living elsewhere is another important source of income for about one-fourth of the farm households.

Farming in this region is <u>not</u> subsistence-oriented. Farm households purchase foodstuffs at village shops each day, or several times per week at least. These goods are paid for either in cash or in kind. In the latter case a crop is usually offered to the merchant as payment, the price of the crop having been determined by the schedule of prices prevailing among all crop buyers in the village. To obtain a cash income from agriculture, farmers may sell their crops (primarily sesame, groundnuts, roselle, and gum arabic) to a variety of buyers, including the shopkeeper, the urban crop merchant's agent who buys at rural crop markets, and jobbers and truck owners who are prepared to haul the purchase immediately to the urban market.

We identified a number of important marketing instituions including the village shop, periodic vendors attending weekly markets,

the government administered crop market, and the government administered livestock market. Two kinds of crop marketing systems were found. The most prevalent is the system in which the crop's price is determined in auction, after which the farmer's produce is weighed. The government prefers this procedure because the tax rate is precisily assessed. The other kind of system relies on an estimation of the weight and price of the crop according to a formula set by the district council. This procedure results in a lower tax estimation than the weighing and auction system, but it appears to be well suited to small, isolated markets where the extra incentive of reduced taxes encourages crop buyers to visit the market. Illegal conveyance of certain crops, particularly sesame, from the farm gate to crop buying agencies in El Obeid without the full assessment of taxes - is believed to be a widespread practice.

Millet, the subsistence crop, is supplemented by the importation to the region of sorghum (feterita) grown principally on the mechanized farming schemes at Habila, Southern Kordofan. Only the wealthier households are able to satisfy the ideal of eating from their own millet stores throughout the year. This is because only they have enough equity to purchase the labor to cultivate a large field of millet. Alternatively, they buy millet from farmers who are in need of cash. Most families buy feterita at least during the dry-season in order to save their millet for rainy-season consumption. A prevailing belief is that feterita is an undesirable food for the rainy season. During this period of hard physical labor, only millet can provide the required nutriment. Information from the sample of forty households suggests that the typical farm family sup-

ports itself on its own millet for only about four months in the year. The rest of the time it buys feterita.

A preliminary analysis of crop marketing channels revealed a number of incentives and constraints for the participants. For example, farmers whose production is small or who lack equity are typically unable to hold their crops off the market until the post-harvest rise in prices occurs. They have to begin selling their crops immediately after the harvest to pay their consumption bill. Better-off farmers, on the other hand, may be able to reserve their crops several months in anticipation of a rise in prices.

From government records of livestock sales it is possible to gauge the dramatic effect which the seasonal presence of nomads is having at a large rural market. A conclusion to be drawn is that the relation between nomad and farmer, who are frequently in conflict over access to forage and water, is complementary when it comes to livestock marketing.

Although the sedentary production system in Northern Kordofan is largely dominated by production of field crops, there is considerable production of vegetable and fruit crops in several locations along the "khors". Individual holdings ranging from 1 to more than 30 hectacres; the average size being 2 to 3 hectares. Horticultural crops are somewhat better managed than rainfed field crops and occupy greater importance in certain areas of Northern Kordofan; especially in Bara, Banjadeed, Er-Rahad and Umm Ruwaba.

RESEARCH FOR THE SEDENTARY SECTOR

Objectives and Strategy

The objectives of the sedentary production system research center around finding ways and means for increasing and stablilizing agricultural production and increasing the efficiency of utilization of natural resources. The strategy to be followed involves the following approaches.

1. Making better use of existing resources through finding effective ways of soil and water management and conservation coupled with improved cultural practices.
2. Increasing the yield potential through improvement of genetic stock by introduction, screening, and breeding of improved varieties and strains.
3. Increase our understanding of the dynamics and characteristics of the sedentary livestock system and its constrains in order to develop appropriate interventions.
4. Promote proper use of available forage and crop residues to maintain livestock productivity in the sedentary system.

Activities

Soil and Water Management and Conservation

Water unavailability appears to be the overriding problem in Northern Kordofan. The average annual precipitation around El Obeid is about 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 serveral rainless periods of varying duration. The rainy season is preceded by several months of hot and dry weather. The average annual free water evaporation is estimated around 2100 mm. As a result of high evaporation during the dry months, there is virtually no stored water to carry over from the previous season. If crops are planted early, stand is usually poor because of uncertainty of rainfall. If planting is delayed until sufficient moisutre has been received, growth period extends beyond termination of rains and crops experience stress at their reproductive stage. Water conservation, therefore, appears to be of utmost significance. The management practice should aim at maximizing the intake of water in the soil profile and then make the most efficient use of the stored water.

On the goz soils where infiltration is rapid, the problem is to conserve water against evaporative losses and weed transpiration. Studies at the Central Arid Zone Research Institute in India show that with millet husk as a mulching material consumptive use of millet is about 270 mm of water and yields over 1700 kg/ha can be obtained. The 350 mm of rain around El Obeid is certainly more than the consumptive use needed for reasonable yield. The infiltration of rain water is rapid in the sandy goz soils, and if trapped to full extent, can support a good crop yield. However, under the prevailing soil and climatic conditions drying of the seed zone is very rapid. This affects seriously the seed emergence and seedling growth and eventually crop stand as a whole. Although a potential water supply may exist in the subsoil and below, plants with a small root system are unable to obtain it. Therefore, improving moisture sup-

ply in the seed zone during the critical stages of emergence and seedling establishment appears to be another key management problem.

On the gardud soils the problem is very low infiltration rate due to excessive compaction. Rehabilitation of gardud soils would involve both the improvement of physical condition and moisture conservation. These soils are a potential alternative to goz soils, and if made productive, pressure from the more fragile goz soils can shift.

Irrigation is practiced in areas where water is available. However, the supply is limited. There is a need to introduce a system of irrigation that is more efficient in use of available water. Production of horticultural crops depends on irrigation to a large extent.

Under the soil and water management program a series of suggested solutions will be tested in both the on-station and on-farm trials. Some studies will involve only on-station and laboratory research. The proposed trials include the following:

(24) Mulching and Residue Management for Soil and Water Conservation:

Both on-station and on-farm trials will be carried out to evaluate and demonstrate the effects of mulching on moisture conservation and crop growth. Keeping the land surface covered with dead organic residue not only prevents evaporative loss of water, it also improves soil structure, prevents runoff, increases infiltration, prevents erosion, supresses weed growth, and keeps the soil surface relatively cooler.

(25) Trials on Improving Soil Moisture Supply in the Seed Zone:

This effort will involve treating the planted hills with materials that have the potential for improving soil moisture retention. Locally available materials such as saw-dust, crushed

charcoal, clay soil, and chopped straw will be evaluated. Also, planting methods in which seed zone microenvironment is modified by creating seed cradles and furrows will be tested. A combination of soil amendments and planting methods will also be evaluated.

(26) Reclamation of Gardud Soils

Hand operated imprinters will be designed and used to create macroroughness (several inch deep impressions) in gardud soils. The objective is to reduce runoff and maximize infiltration. The imprints will be seeded with forage legumes and *Acacia*. It is hoped that increased water intake will help establish the legumes and the *Acacia*. The natural root growth should help create a more open structure. Additionally, nitrogen fixation should improve soil fertility. *Acacia* has been found to grow roots rapidly and produce a rather massive root system in a relatively short time. It can grow under unfavorable soil environment.

Deep plowing is an effective means of loosening compact soils. However, availability of suitable machinery and energy costs make it impractical for the traditional farmer at the present. It may be feasible on government managed lands and lands under the control of mechanized schemes. Plowing trials will be attempted on a limited basis. Previous work has shown that if plowing is not continued gardud soils fall back to their original density. In our trials *Acacia* and forage legumes will be planted in the plowed field with the hope that root system of these plants will help stabilize the open structure created by plowing. This will be an on-station trial.

(27) Drip Irrigation for Vegetable and Orchard Farmers

Drip is the most efficient method of water application. There is almost 50 per cent reduction in water usage. Pumping cost is reduced accordingly. Water is delivered to the plants only

and dissolved fertilizers can be fed to the plants directly via drip outlets. Between-row spaces are always dry so that weed growth is supressed and farm operations such as staking, picking, and pruning, etc. continue uninterrupted.

Several demonstration sets of drip system will be established on farmers' fields and on the WSARP Horticultural Research Farm at Beno. Farmers who irrigate have pump and water available. PVC pipes and a variety of fittings are available locally. Drip hoses and some specialized drip components will have to be imported.

Once the system becomes operational farmers will be provided with the information as to the timing and amount of irrigation.

(28) Water Harvesting on Goz Soils to Increase Water Supply in Cropped Fields:

This will be carried out as an on-station, preliminary observation trial at first. Certain portion of the field upslope will be sprayed with a hydrophobic substance to induce runoff. The runoff will be collected in the field downslope to increase moisture supply. A system or ridges and furrows in the field downslope will be utilized to keep the incoming water in place.

Initial tests with diluted solutions of gum arabic have shown that it has the potential for creating hydrophobic surfaces. It also has soil binding property and may be effective in controlling soil movement due to wind action.

(29) Diagnostic investigations of soil physical and chemical properties important in planning for soil and water conservation and fertility management: Three soil profiles at each of the experiment sites will be sampled for analyses. The experiment sites are: WSARP Research Station, El Obeid (goz soils, Kaba (gardud soils). 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 depth

intervals. Each sample will be analysed for:

- pH
- electrical conductivity
- total soluble salts
- total and organic carbon
- total and available N, P, K, S, Mo, B and Zn
- exchangeable Ca, Mg, K, Na, Fe, and Al
- percentages of particles less than 1, 2, 5, 20, 50, 100, 250, 500, 1000 and 2000 microns

Bulk density will be measured by in-situ sampling of undisturbed cores. Infiltration rates will be determined by on-site tests using double ring infilterometers. Moisture chracteristics and hydralic conductivity will be obtained from prediction models that utilize as inputs particle size distribution, bulk density and organic matter.

(30) Monitoring soil moisture regime: Moisture balance data are needed to understand the nature of moisture loss problems and to form basis for proposed solutions of water conservation and improved cropping practices, etc. These data will also aid in selecting crop varieties and planning for planting strategies. Both the bare and the cropped fields will be monitored by a combination of neutron scattering and gravimetric sampling. Profile mositure distribution will be determined at weekly intervals throughout the year. Crop growth and yield data will also be obtained. Data will be analysed to reflect crop performance in relation to variation in soil mositure regime. It will also be possible to delineate the most critical periods. Data on soil moisture regime are also necessary to evaluate effectiveness of management practices.

(31) 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. 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 will be extremely useful as inputs to crop growth and yield models which are now being used as surrogate to field experiments.

A portable weather station has been ordered. The variables to be monitored are:

- rainfall
- maximum and minimum air temperatures
- soil temperature
- relative humidity
- wind run

- solar radiation
- pan evaporation

Improved Cultural Practices

An opportunity to increase productivity lies in improved cultural practices such as spacing and plant population, fertilizer application, planting method, intercropping and rotations, etc. The trials proposed involve the following aspects, tested singly or in combination.

(32) Spacing and Population Trials:

These trials will include the major field and horticultural crops specially sorghum, millet, groundnuts, cowpeas, sesame, kerdadeh, tomato, eggplant, sweet pepper, okra and watermelon.

(33) Fertilizer Trials:

These trials include N, P, K applications in groundnuts, sesame, tomato, eggplant, sweet pepper and onion. Nitrogen application trials will also be carried out with vegetable root crops (radish, beet and carrot). Nitrogen fixation, Calcium and micro-nutrients (Mo, B) application will be studied with groundnuts. The effect of farmyard manure on watermelon and okra will also be tested. (The INTSORMIL agronomist will be conducting fertilizer trials with sorghum and millet)

(34) Trials on Seedbed Preparation, Planting Method and Weeding:

The effect of shelling, seed size, seed treatment (Aldrex T) and planting depth will be investigated on groundnuts. Aldrex T seed dressing will also be tried on okra. Seedbed preparation (ridge vs. flat), planting method (direct seeding vs. transplanting), and irrigation interval effects will be studied on onion. Weeding and seedbed preparation effects on radish, beet and carrot will also be investigated.

(35) Intercropping:

Intercropping is a common practice in the region. Intercropping gives small farmers some sort of insurance against total crop failure due to uncertain weather conditions. It may even increase total productivity per unit area. If properly practiced, it should contribute towards decreasing hazards of erosion and loss of soil fertility. Interventions involving intercropping require less dramatic changes on the part of the farmer's cropping system. We propose to evaluate the following crop combinations and arrangements:

- Groundnut intercropped with sesame, millet, sorghum kerkadeh, watermelon and pumpkin
- Sorghum intercropped with cowpea and watermelon.
- Millet intercropped with cowpea and pumpkin.
- Sesame intercropped with cowpea

(36) Varietal Screening and Development

Local varieties grown by farmers in the region are of poor performance and low yield potential. There is a substantial scope for improving yields through varietal development and/or introduction. Varietal screening trials will include sorghum, millet, groundnuts, sesame, cowpea, guar and a number of vegetable crops viz. tomato, eggplant, sweet pepper, hot pepper, okra, watermelon, pumpkin and onion. (An ICRISAT pearl millet breeder is scheduled to be posted in El Obeid beginning this season. He'll work closely with WSARP staff in developing millet varieties suitable for traditional farmers.)

Some cultivar trials will be conducted on fruit crops. Contacts have been made with horticulturists at Sennar and Hudeiba Research Stations in order to help in providing seedlings of fruit cultivars available at these stations. Cultivar trials will be es-

tablished at El Obeid and other locations (mainly Abu Gubeiha and Bara). Fruit crops suggested for testing, in order of importance, are mango, citrus (lime, grapefruit, orange) and guava. With regard to mango, priority will be given to the extension of harvest season by introduction of cultivars with a wide range of maturities and to determination of optimal planting density. In citrus priority will be given to the selection of suitable root stocks for the region and the identification and propagation of virus free bud wood.

Fruit crops which might be introduced or more widely evaluated, in order of importance are papaya, custard apple, sapodilla, date palm (Phoenix sp.), and avocado (Persea americana).

Collaboration of the pomologist at Hudeiba Research Station will be very useful especially with the identification of virus free citrus bud wood.

(37) Varietal Improvement Through Breeding:

Breeding programs aiming at development of high yielding adapted strains of millet and sorghum will be continued. A breeding program for the improvement of kerkadeh will be initiated. This will start with the collection of local genetic stocks from the different regions growing the crop. This will be followed by identification and selection of the different agronomic types or strains and testing of their performance.

(38) Observation Plots of New Crops:

Observational plots for the preliminary evaluation of the performance of crops that are new to Kordofan environment will be grown. These newly introduced crops will include various legumes, horticultural and other miscellaneous crops.

Livestock Ecosystem Dynamics

The main emphasis in this field will be collection of information to increase our understanding of the production systems and their effects on the ecosystem. Studies will include:

(39) Study of the sedentary sheep production system and its constraints:

The details of this study are outlined within the migratory system.

(40) Desertification:

The emphasis in this field will be on understanding the phenomenon and study of indicators to determine the degree of desertification on both sandy and gardud (clayey sand) soils. Information will be collected with regard to:

1. Study of biological and edaphic indicators to isolate one or more valuable indicators to help in determining the degree of desertification in the semi-arid region of Kordofan.
2. Determination of nutritive value and digestibility of major plant species within the sandy and the gardud soils.
3. Determination of diet composistion of sheep, goats and cattle and their ecological relationships with regard to diet overlap and complementarity.

Forage and Crop Residue Production and Utilization

One major constraint to livestock production in Northern Kordofan is unavailability of forage during the dry season. This is greatly affecting the sedentary livestock production system, which is lacking the advantage of mobility exercised in the transhumant and the nomadic systems. The approach to improve forage production and

utilization will focus on:

On-farm trials:

(41) To study the system of crop residue production and utilization. It is assumed that certain limitations or constraints occur during the crop residue harvest, transport, storage and utilization. Understanding and evaluating the effects of these constraints will help in designing studies to test interventions that will increase the efficiency of utilization of this resource.

(42) Introduction of forage legumes in fallow land with objectives of reducing fallow periods by restoring soil fertility, reducing soil erosion and providing the farmer with another resource (forage) for his livestock use or sale.

(43) Use of animal power (donkeys) to increase hay supply to towns during the dry season, from areas which are not utilized by livestock due to lack of water. Introducing donkey-pulled carts is expected to double the hay supply and increase the farmer's income.

Research farm trials:

These will be conducted on the station research farm focusing on the following:

(44) Variety screening trial on forage yield of native and introduced forage legume species.

(45) Effect of fertilizer application (nitrogen and phosphorous) on yield of certain forage legumes.

Results of these studies will be utilized in designing forage legume studies on farmers fields.

(46) Agronomy Research in Relation to Animal Nutrition

Studies will involve the collection of samples of all cultivars of crops grown in the region that have a contribution to animal nutrition as residues or grain. Samples will be analysed for

chemical composition, particularly crude protein at maturity. High quality varieties will be recommended for further agronomy research for production of dual purpose crop for both forage and grain yield.

(47) Agro-forestry Studies

A major activity in Northern Kordofan in which local and international agencies are involved, is the rebuilding of the *Acacia senegal* belt for economic returns, as well as control of desertification and soil erosion. This activity will involve most of the *Acacia senegal* savannah belt, which is the major vegetation zone, area wise, in Northern Kordofan. Studies will be directed to determine the optimum *Acacia senegal* density which will allow a reasonable herbaceous vegetation biomass production within the planted areas for livestock (small ruminants) use within the sedentary livestock production system in a way not to harm gum crop production. Trials with other native and introduced tree species will be continued, with emphasis on selection of best combination of species for firewood production, windbreaks, forage and improvement of soil fertility.

Staff Resource Requirements

Staff	Agronomy	Hort.	Soils/ Water	Range/ Livestock	Entom.	Socio- Econ.	TOTAL
	person-years						
Senior Scientists	2.0	1.0	1.0	0.4	1.0	0.1	5.5
Senior Technicians	2.0	1.0	1.0	0.4	1.0	0	5.4
Junior Technicians	4.0	2.0	2.0	1.5	2.0	0	11.5
Assistants	7.0	3.0	3.0	3.0	4.0	0	20.0
Laborers	20.0	12.0	8.0	5.0	5.0	0	50.0

THE MIGRATORY PRODUCTION SYSTEM:

The continuous use of rangelands in Northern Kordofan and particularly the heavy grazing during the growing season by the sedentary system of North Kordofan and the migratory systems of both Northern and Southern Kordofan, lead to low forage productivity, depleted ground cover and severe wind and gully erosion. Range resource degradation is further aggravated by cultivation expansion, particularly in the sandy soil, creating an increasing grazing pressure on uncultivated areas by both the sedentary and the migratory system, during the wet season and confining forage resource utilization during the dry-season to overgrazed areas where water is available for human and animal consumption. A combination of grazing and crop residue utilization is practiced by the sedentary system to ease the condition of forage unavailability during the long dry-season. The migratory system undergoes southward movement, during the dry-season to Southern Kordofan where the majority of grazing land is rested during the wet-season. Cattle, camels and goats are the livestock species involved in this activity.

RESEARCH FOR THE MIGRATORY SECTOR

Objectives and Strategy

The complexity of the interactions and the details of activities with regard to resource utilization by these systems is not as simple as earlier reports have indicated. Understanding the dynamics of the systems with regard to its plant, animal and human com-

ponents will be of a priority in our program for 1984-1985 outlined in different sections as follows:

Activities

(48) Characterization of Livestock Production Systems:

Research work will focus on understanding the livestock production systems in North Kordofan and their constraints. Work will start by sheep production systems. As long as desert sheep is generally the only livestock species that utilizes North Kordofan all year round, we expect it to have the major impact on the ecosystem, within North Kordofan, compared to cattle, camels and goats within the transhumanc and the nomadic systems that spend part of the dry-season in South Kordofan. The sedentary (Gawama), the transhumant (Hamar) and the nomadic (Shanabla) systems will be studied using sentinel herds under the previously stated tribes selected to represent each system due to their contribution to sheep production in relation to quantity and quality for both local and export markets, based on informal surveys.

The three herds will be used in collecting information about:

1. The animal husbandry and range resource utilization
2. Weight gain through season.
3. Lambing rates.
4. Mortality rates among both adult and young animals.
5. Annual offtake.
6. Animal health in relation to retardation of growth, productivity and mortality rates (in collaboration with the Vet. Res. Dept. in El Obeid and Dr. R. Cook).

This study is expected to increase our understanding of these systems and their constraints and help in designing interventions in joint programs to improve production condtions.

(49) Dietary Habits and Consumption Patterns of Livestock Species

Dietary habits studies are very important in: understanding vegetation changes in relation to grazing activity, management decisions, herbivores ecological relationships and animal nutrition studies. Seasonal diet compostion of sheep will be studied in connection with the sheep production systems study. Another study is linked to the desertification study where diet compostion of sheep, goats and cattle will be determined in relation to soil type (sandy and Gardud soils). Information on diet compositon will be used in determining the extent of competition and complementarity between herbivores to particular plant species and also in understanding the annual or seasonal nutritional deficiency that needs to be corrected.

Staff Resource Requirements

Staff	Agronomy	Range/ Livestock	Socio-Econ.	TOTAL
	----------	person-years	----------	
Senior Scientists	0.1	0.6	0.1	0.8
Senior Technicians	0	0.6	0	0.6
Junior Technicians	0	1.5	0	1.5
Assistants	0	3.0	0	3.0
Laborers	0	5.0	0	5.0

WSARP SENIOR STAFF AS OF FEBRUARY 1984

Khartoum

Project Director.....Dr. Dafalla Ahmed DAFALLA
Chief Administrative Officer.....John B. HANNUM
Administrative Associate.....Shirley A. HIGGINS
Assistant Director - Administration.....Osman Abdalla MOHAMED
Personnel Officer.....Salah Hag ARABI
Inspector of Accounts.....Mohamed Yousif BAKRI
Purchasing Officer.....Abbas Hassan EL NOUR
Storekeeper.....Musa Abdel Gafar MUSA
Administration Officer.....Sayed Gasim EL-SAYED
Project Engineer.....Dr. David T. HIGGENS
Senior ARC Advisor.....Dr. James J. RILEY
Senior Project Architect.....Henry P. BERGMAN
Aircraft Pilot.....Tom "Curley" MILLS

El Fasher

Resident Engineer.....Hassan EL TOM
Research Scientist (Forestry).....Mohamed El Mukhtar BALLAL

El Obeid

Head of Research Station*
(Gum Arabic Research Officer).....Zakaria Abdalla SAAD
Forestry Research Officer*.....Farouk Mohamed AL HADI
Soil-Water Specialist.....Dr. Lalit M. ARYA
Horticulturist.....Dr. Osman Adam OSMAN
Asst. Research Officer.....Kamal HAMAD
Plant Breeder (Millet), Acting Station
Director and Sedentary Systems Coordinator.Dr. El Hag H. Abu EL GASIM
Agro-Breeder (Groundnuts).....Abdelrahman El Khidir OSMAN
Range Scientist (Range Ecology).....Hashim Khider MUKHTAR
Clerk of the Works.....Yousif SULAIMAN
Senior Forest Ranger.....Abdul Aziz Ahmed IBRAHIM
Inspector (H.Q.).....Ahmed Khalid ABU BAKER
Accountant.....Ahmed ABDULSEED

Ghazala Gawazet

Clerk of the Works.....El Jack MURAT

Kadugli

Director of Research Station.....Mukhtar KENANI
Administration Officer.....Ali Mohana MUDEER
Range Management Specialist.....Dr. W. Trent BUNDERSON
Social Scientist.....Mohamed Azim ABU SABAH
Animal Nutritionist.....Dr. Babo Fadlalla MOHAMED

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* In Training

Kadugli (continued)

Agronomist.....Dr. Joe R. GINGRICH
Agronomist*.....Ibrahim Mohamed Daw MEDINA
Assistant Agronomist*.....Babiker Abdalla IBRAHIM
Agricultural Engineer*.....Makki Abdelatif OMER
Senior Technician (Agronomy).....Ahmed Kehir ES-SEID
Aricultural Economist.....Dr. Neil A. PATRICK
Asst. Social Scientist.....Mahmoud Awad MEKKI
Agricultural Economist*.....Tigani Mirghani EL AMIN
Agric. Economics Specialist.....Abdul Aziz Abdul EL FATAH
Asst. Range & Livestock*.....Abdel Gadir A. AGGEB
Livestock Production Specialist.....Dr. Richard H. COOK
Associate in Research (Anthropology).....Barbara MICHAEL
Maintenance Officer.....Antonio B. CENIDOZA
Asst. Scientist, Agricultural Economics*...Sid Ahmed Hassan Sid Ahmed BETEIK

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* In Training

LIST OF WSARP PUBLICATIONS

Publication No.	Title	Date
1	WSARP General Outline of Early Planning and Implementation Requirements	1979
2	Scope of Work for Intitial WSARP Activities	1980
3	Consultant Report on Range Livestock by Dr. D. Dwyer	1980
4	First Annual Report	1980
5	Summary of WSARP Planning Meeting October - November 1980 including Consultants Report	1980
6	The Horticultural Resources of the Kordofan Region of Sudan	1982
7	Second Annual Report	1981
8	Consultants Report on Research Station Development by Mr. D. Meinhart	1980
9	Consultant Report on Livestock Production by Dr. T. Wilson	1981
10	Annual Report on Range Research by Dr. W.T. Bunderson	1981
11	WSARP Social Perspectives on Agricultural Research and Development in the Sourthern Kordofan, Sudan: Systems of Agricultural Production Among the Nuba by Dr. F.P. Araujo	1981
12	Consulting Report on Range Research by Dr. D. Dwyer	1981
13*	Work Plan, Volume I, General Research Program and Plans	October 1982
14*	Work Plan, Volume II, Project History and Functional Structure	October 1982
15*	Work Plan, Volume III, Research Plan for the Kadugli and Other Stations	October 1982
16	Review of Seed Program in Sudan	October 1983
17	Report of Visit to Sudan to Review Fruit Tree Research Program and Related Factors by Dr. A. H. Krezdorn, Consultant	May 1983

*Constitute Third Annual Report

Publication No.	Title	Date
18	Work Plan, Volume IV, Initial Research Proposals -- Kadugli Research Station	August 1983
19	Fourth Annual Report	August 1983
20	A Summary of the Darfur and Kordofan Regional Planning Workshops	April 1983
21	Report of Visit to Sudan to Review the Organization and Development of Research Support for the WSARP Experiment Stations	February 1983