GARD REPORT #36

SOIL PHYSICS AND SOIL AND WATER MANAGEMENT

by

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I. INTRODUCTION

As specified in my terms of reference (Annex 1), the objective of this consultancy was to help the newly returned Soil Physicist develop a soil and water management and conservation research program that reflects the current needs of The Gambia. Specific charges were to:

1) Review the status of ongoing soil and water management research and review previous research results in The Gambia and neighboring countries.

2) Help the Soil Physicist develop a research program for presentation at the 1988 ARAB meetings.

These were accomplished by reviewing ongoing soil and water management and conservation research programs and visiting research stations in both The Gambia and Senegal. The programs and units visited included SWMU, Cluster Sites, GTZ (DWR), ISRA-Kaolack (Senegal), Inland Valley Monitoring, Cropping Systems/Resource Management Program, and the Jahaly-Pacharr Upland Irrigation Project.

The aforementioned Gambia-based groups have made good progress toward developing better management practices for The Gambia's most valuable resources, soil and water. As is often the case, however, there is a need for more research work in these areas. Areas needing more attention include 1) tillage, 2) upland runoff control, 3) lowland rice, 4) crop water use efficiency, and 5) alternative cash and double cropping systems. These are listed in order of priority, with number one being the area needing immediate attention. Future work in each of these areas should include some applied soil physics and soil and water management and conservation research. If this work is to be done, some basic equipment and laboratory space are needed. Some of these areas needing research were noted at the 1987 ARAB meetings (Land Management for Water Conservation, and Tied Ridges).

II. SOIL PHYSICS RESEARCH IN SENEGAL

Before discussing the soil physics research needs for The Gambia, I would like to review the status of this kind of work currently being conducted in Senegal, since many of the soils and weather patterns in Senegal are similar to those in The Gambia. We visited research sites and met with Soil Physicists in Senegal. The purpose of this visit was to establish contact and evaluate the potential for sharing research data between The Gambia and Senegal and to eliminate unnecessary duplication of basic soil physics research in this region of Africa. This would obviously result in savings for both countries.

The Soil Physicists with ISRA-Kaolack have a very progressive research program in applied soil physics and soil and water management and conservation. They have developed a good data base on soil erosion in different size watersheds. This data base covers a wide range of soil physical conditions (i.e., freshly tilled and surface crust) and storm characteristics. They have also measured many hydrological parameters of several soils. These data include hydraulic conductivity of saturated and unsaturated soil, and drainage and evaporation rates. In addition, they are developing a crop water use data base for groundnuts and other selected crops.

The Soil Physics Program in Senegal has been in existance for several years and is, therefore, much more advanced than the program in The Gambia. The Senegalese Soil Physicists have a well-organized and well-funded program with state-of-the-art equipment (i.e., neutron probe, gamma density probe, tensiometers, lysimeters, recording rain gauges, bulk density samplers, water stage height recorders, etc.). Their work on erosion control and water conservation, however, is in the infancy stages. In these areas, The Gambia is much farther along.

Researchers in Senegal are also evaluating different tillage systems for corn and groundnuts. These include chisel plowing, no-tillage, disking, and conventional animal-drawn plowing. They found little differences in yields between tillage systems except that where a dense pan was found, the chisel treatment caused higher groundnut yields. The profile water storage data for the different systems were not available.

III. TILLAGE

To assess the current status of tillage in The Gambia, we visited selected villages and ongoing tillage experiments at the Research Stations and Cluster Sites. Farmers in The Gambia use several techniques of tillage (spring-tooth harrow, ridger, moldboard plow, long-handled shovel - cayendako, and short-handled hoe - daba). The types of tillage vary quite widely between farmers. Farmers' choice of tillage is made with respect to the soils they farm and the type of crop grown, although the choices are not that great by developed-country standards. It was found that on a given farm, the type of tillage may vary between soil types and from one crop to another. Soils with sandy surface profiles are often tilled with hand tools, but soils with high silt and clay content in the plow zone are often mechanically tilled.

The Bowe soil (referred to as Dakh soil by some Wolof farmers) is an example of a soil with high clay content near the surface (within 30 cm). When dry, these soils are very hard, hence the draft requirements probably are quite high. Some alternative tillage and associated draft requirements for these problem soils should be determined because more of this kind of land is being farmed. With

the lower-than-normal rainfall, farmers are tilling more land (in many cases, unsuitable land that was in forest) to maintain their level of production. The Agricultural Engineering Unit has conducted research on draft requirements but not on these soils with a clayey plow layer.

It should also be noted that other tillage work has been conducted (Cropping Systems/Resource Management Program, Sapu) but again, this was on soils with more sandy surface horizons. Current tillage research on tied-ridging is also being conducted on soils with sandy surface horizons.

Farmers in the village of Pallol, MacCarthy Island Division (ODA economists have conducted surveys in this village), use a millet/groundnut/fallow rotation on these Dakh soils. They indicated that they would grow groundnuts yearly but find it difficult to harvest their crop if a monoculture system (continuous groundnut) is used. They also noted that these soils are very productive; thus it is worth the extra hard work to grow groundnuts occasionally. The Dakh soils in this village seem quite different (more clay in the plow layer) than those at the Cluster Sites and research stations.

As the population increases, and with lower rainfall, more of this kind of land which in the past was left in forest is being cultivated. Thus tillage research should be conducted on this kind of land. It may be necessary to establish a satellite research station on this Dakh soil.

Recommendations

1. Tillage research is needed to determine the lowest draft requirement for land preparation and groundnut harvest for Dakh soils. Moldboard plowing could be used for both land preparation and harvesting. I suggest that ridge tillage experiments be evaluated using the mold-board plow. The end of the rows should be connected together to enhance profile water recharge. Conventional tillage practices should be used as a control.

2. The draft requirements for the different treatments should be measured. This can be done in cooperation with the Agricultural Engineering Unit.

3. The Soil Physicist should work with Agronomists on current tied-ridging research to estimate profile water recharge, depletion, drainage rates and, if possible, crop water use.

Methods and Materials

The soil bulk density should be measured at least twice during the growing season for each treatment. These data should be taken for the plow zone after planting and prior to harvesting. Soil water content should also be monitored throughout the growing season. These measurements should be taken at the soil surface and to a depth of at

least 1 m or below the root zone. (NOTE: Some of these data are already available for the tied-ridging study.) Cone penetration resistance measurements should also be evaluated after planting and prior to harvesting.

The equipment needed for this study include a bulk density sampler, moisture measuring meter (neutron probe or time domain reflectrometer), and a recording penetrometer.

Summary and Anticipated Results[1]

The initial ridges will be difficult to construct unless it is done when the soil moisture content is at optimum (about 1/3 bar is optimum water content for tillage). Subsequent ridging will be less difficult because less energy is needed to turn existing ridges. Unlike level land, a ridge has no horizontally opposing force. Groundnut harvesting and ridging for the following year can be done at the same time. One pass with the plow will lift the nuts and, after removal of the crop, a second pass will establish the ridge.

A second phase of management for these soils is to improve their structure by growing a dry season crop that has a high root mass. An early maturing variety of groundnut should also be considered.

IV. UPLAND RUNOFF CONTROL BERMS

With the current lower-than-normal rainfall in The Gambia, it is important that runoff of rainwater be kept to an absolute minimum. In many developed countries, conservation or minimum tillage is being promoted as a management technique to reduce runoff. In The Gambia, minimum to zero tillage is conventional, yet there is considerable runoff during the rainy season. Therefore, some other management technique is needed to reduce runoff and soil erosion. The SWMU has constructed upland berms to reduce runoff and soil loss. This is probably a good practice but the benefits have not been documented.

There is no need to do runoff and soil erosion work since this has been well documented in Senegal for soils and tillage systems similar to those in The Gambia. As previously noted, The Gambia is much farther ahead of Senegal in the application of water conservation techniques and this is where research efforts should focus.

Recommendation

The Soil Physicist should evaluate upland contour berms to determine how these structures affects soil profile water recharge.

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1 This summary and anticipated results section apply to recommendations 1 and 2.

Methods and Materials

The best way to evaluate the effectiveness of upland contour berms is to do a paired watershed study where two watersheds with similar soils, slope, cropping history and land formation are evaluated. Berms should be installed on one watershed while the other is unchanged. Profile water recharge should be monitored at several locations in the two watersheds with a moisture meter and/or tensiometers during the rainy season.

Summary and Anticipated Results

A comparison of soil water before and after a storm event will elucidate the effectiveness of upland berms. The advantage of a paired watershed study is that only one or at most two years are needed to evaluate the effectiveness of upland berms because each storm event can be treated as a separate data set.

I anticipate that research will show that upland berms are very effective in controlling runoff, thus reducing soil erosion, and that profile water storage is increased with the berms.

V. LOWLAND RICE

Lowland rice production in The Gambia has been significantly increased with the construction of anti-salt and water retention structures by SWMU and GTZ. There is still potential, however, to further increase the total hectares of rice in these areas. This will require close cooperation between SWMU, GTZ and the Research Units.

Rice variety research trials are being conducted on both sides of the river. This is much needed research and should be continued.

Some preliminary ground water quality and elevation data are being collected and should be continued, but this work should be expanded and input from the Soil Physicist is needed. Very little is known about the ground water in these areas. A better understanding of the flow patterns and water quality of these shallow water table aquifers is needed to direct future reclamation work. This work should include determining the effect of The River Gambia on these aquifers [i.e., is the ground water recharged from the river during the dry season, what are the weekly, seasonal, or yearly variations in water table elevation and salt concentrations?].

Both the SWMU and GTZ are constructing water control structures, although they have taken different approaches. The SWMU constructs both anti-salt and water retention dikes, whereas GTZ structures are solely for water retention. The SWMU structures are primarily placed across Bolongs, while those of GTZ's are placed parallel to the Bolongs with much smaller catchment areas. In addition, GTZ includes

water control gates in all their recent structures. Although they are currently used to control water level, these gates may also be used to flush salt from the catchment area behind newly constructed structures or, if necessary, at the beginning of each growing season.

Barren areas, with high salt content at the soil surface, have been noted along the fringes of some reclaimed lowland sites. The origin of this salt is not known.

It would be a useful exercise to estimate the total number of hectares of lowland that could be reclaimed and brought under production if one or more of these structures were installed and to estimate the expected increase in total rice production. It might be possible to make such an estimate using remote sensing techniques.

Recommendations

1. Expand the water quality research to include an evaluation of the variation in salt concentration with depth and ground water flow patterns. This is needed to determine if salt is being added to the soil by subsurface flow during high tide in the dry season.

2. Determine the cause of the barren areas along the edge of some reclaimed lowlands. It may also be necessary to determine the leaching requirements and infiltration rate for these barren areas if they are to be reclaimed.

3. Evaluate the potential benefit of water level control gates for water retention dikes constructed across Bolongs.

Methods and Materials

The ground water flow patterns and salinity concentrations with depth should be monitored. A portable salinity meter will be needed to measure the ground water salt concentration *in situ*. Ground water elevation and flow patterns can be measured with piezometers and wells. In addition to the existing wells, which are placed across the valley, a nest of piezometers should be placed across and up the valley. Within a given nest of piezometers, at least one piezometer should be in each major soil horizon. This will allow the researchers to determine the vertical and horizontal flow patterns and determine if a layer in the profile restricts water flow.

The wells and piezometers can be constructed from PVC pipe and installed with a soil auger. It may be necessary to seal around the piezometers with clay approximately 20 cm from the bottom depending on the thickness of the layer, to prevent a pseudo-hydraulic connection between layers. False hydraulic connections between stratigraphic units often develop during installation of monitoring equipment.

VI. CROP WATER USE EFFICIENCY

Water use efficiency data for the different cropping systems used in The Gambia are needed to help researchers determine the best cropping system for the most efficient water use. These data may be already published for many of the cropping systems and crop varieties. If this is the case, the Soil Physicist should, in consultation with the Agronomists, identify and make recommendations for those systems with optimum water use efficiency. If these data are not available, some research is needed.

Gravimetric soil water measurements are being made for some research studies, but little attempt is made to determine the water use efficiency (WUE) of various cropping systems. Since water is one of the biggest constraints for crop production in The Gambia, there is a need for WUE data for different cropping systems. In the case where soil water data are collected, most of the sampling is done after the rains stop. If WUE is to be evaluated, soil water measurements need to be made throughout the growing season on closely spaced intervals and the values should be expressed on volume basis. Soil physical data needed include evaporation, infiltration and drainage rates. Rainfall rates and amounts are needed. Some of the soil physical data are already available (Williams, 1979 and others). Total rainfall is being collected in some of the existing research sites, but rainfall intensities may not be as readily available.

Recommendation

The Soil Physicist should work closely with the Agronomists to establish a WUE data base for the major cropping systems and crop varieties used in The Gambia.

Methods and Materials

Soil water content (volumetric) for the crop rooting depth throughout the growing season should be measured. Crop growth parameters (biomass, growth rate, and yield) should be measured. A soil moisture measuring meter is needed to measure the soil water content. A bulk density sampler will be needed to measure the soil bulk density and convert existing gravimetric water content data to volumetric. The aforementioned soil physical data are needed. If this data cannot be obtained from the literature, a ring infiltrometer, mini-lysimeter (Boast and Robertson, 1982) and tensiometers should be purchased or constructed. All the necessary soil physical property data can be obtained using this equipment. A recording rain gauge is needed for some of the study sites.

VII. ALTERNATIVE CASH AND DOUBLE CROPPING SYSTEM

The groundnut is the most widely-grown cash crop in The Gambia. It could almost be regarded as The Gambia's national crop. At the

risk of being considered aggressive, however, I suggest alternative cash crops be evaluated. Some work on sesame is being done now and this is a good alternative crop given its drought tolerance. This crop will work well into the current farming systems in The Gambia. For example, in the Tandako rice cropping system, it may be possible to plant sesame when the rice is nearing maturity (also after harvest, as the rice straw could be used as a mulch to reduce evaporation) and there are other places that this crop may mesh well with current practices.

The Tandako rice research seems like an interesting project, and as previously mentioned, there is a possible potential for double cropping with this farming system. The use of different tree species to add organic matter and nitrogen to the soil is a good idea. It would be beneficial if similar practices could be used to increase organic matter with other cropping systems.

Recommendation

The Soil Physicist should work with the Agronomists to evaluate the water remaining after harvest under different cropping systems and determine the potential for double cropping, using the residual water to grow the second crop during the dry season.

Methods and Materials

This study can be conducted with the same equipment noted for crop water use efficiency work (i.e., a soil moisture measuring meter and a mini-lysimeter; Boast and Robertson, 1985).

Summary

I appreciate that some double cropping work is being done, but little is done by way of estimating the residual moisture following the primary crop. The Soil Physicist should work with the Agronomists to establish residual moisture for double cropping systems such as millet/cowpea, maize/sesame and rice/sesame.

VIII. INFRASTRUCTURE

Sapu

Laboratory (including equipment and supplies) and office space should be made available for the Soil Physicist at the station and adequate transportation provided to and from research sites. As previously noted, it may be necessary to develop a satellite research station (similar to the Tandako site) on the Dakh soils so that the proposed tillage study can be conducted.

Laboratory and Field Equipment Needed

1. Hydrometer
2. Sedimentation flasks
3. Top-loading balances, electronic and beam
4. Augers
5. Tensiometers
6. Neutron probe or time domain reflectrometer
7. Bulk density sampler
8. Recording rain gauges
9. Soil sieves
10. Portable salinity meter
11. Recording penetrometer
12. General glass and plastic ware (i.e., buchner funnels, beakers, pipettes and etc.)
13. Soil moisture cans
14. Data logger
15. Soil moisture resistance cells
16. Constant temperature bath
17. Drying oven (forced air)

This is the minimum equipment needed to start a soil physics program in The Gambia. Additional equipment will need to be purchased as the program develops.

Yundum

The scientists at this station are conducting good quality research, but they are rightly concerned about the uncertainty of the office and field experimental site.

The soils laboratory is non-functional and is seriously in need of attention.

IX. SUMMARY

I suggest that the Soil Physicist and other scientists keep current with research being conducted in surrounding countries with similar soils and climate as The Gambia. Gambian scientists should also be encouraged to keep abreast of research publications from other areas, publish their work whenever possible, and write yearly progress reports.

X. ACKNOWLEDGMENTS

I wish to than Mr. Katim Touray for planning my itinerary and Mr. Junkung Ceesay for teaching me much about the soils in The Gambia. I also thank all who made my visit very enjoyable.

ANNEX 1

TERMS OF REFERENCE

NAME: Birl Lowery

DATES: October 20 - November 11, 1987

SPECIALIZATION: Soil Physics/Soil and Water Conservation

COUNTERPART: Mr. Katim Touray

BACKGROUND:

Rainfall in The Gambia during the past 15 years has been about 30 percent lower than during the twenty years following World War II. The majority of this rainfall deficit occurs in August, resulting in occasional dry spells during the cropping season and less recharging of the soil profile for subsequent crop growth on residual moisture in October when the rains end. Farmers' response to these changes have been no-till, direct seeding for early planting dates and the adoption of short-cycle varieties. Neither of these interventions directly addresses the problem of soil moisture deficit during the cropping season or immediately after the rains end. Both attempt rather to avoid (escape) drought stress.

To complement the current recommendations for early seeding and short-cycle varieties it is necessary to develop cultivation practices that conserve moisture, permitting crops to better utilize current rainfall. Good cultivation practices or engineering structures (contour berms) will help keep the rainfall on the land and limit soil erosion.

The objective of this consultancy will be to help the newly-returned Soil Physicist develop a soil and water conservation research program that reflects the current needs of The Gambia.

SPECIFIC ACTIVITIES:

1. Review the status of ongoing soil/water management research and review previous research results in The Gambia and neighboring countries. This activity will be accomplished by visiting ongoing research and conservation efforts here in The Gambia (SWMU, Inland Valley monitoring, tied-ridges) and in neighboring Senegal (ISRA-Kaolack).

2. Help the Soil Pnysicist develop a research program for presentation to the 1988 ARAB meetings. For a soil water management research project to integrate into the Cropping Systems/Research Management Program it will be necessary for individual research themes to address the particular problems posed by topography, soil types, and dominant cropping systems in The Gambia.

ANNEX 2

Itinerary for Dr. Girl Lowery

(October 20 - November 11, 1987)

Tues. October 20		Arrival at Yundum International Airport.
Wed. October 21	8:30 a.m.	Meeting with Elon Gilbert (COP), Sompo-Ceesay, Asst. Dir. Research, and Sankung Janneh, Director.
	9:15 a.m.	Cape Office Staff: Bintu Nying, Joan Robertson & Connie Tucker.
	11:00 a.m.	Meet with David Gibson & Mile 7 Staff.
Thurs. October 22	8:00 a.m.	Depart for Sapu with: K. Touray J. Ceesay
	3:00 p.m.	Visit Cluster Site at Giroba Kunda (URD)
Fri. October 23	9:30 a.m.	Attend Research Staff Meeting (Sapu). Discuss Soil-Water Research Priorities.
	10:00 a.m.	Visit Jahaly-Pacharr irrigation.
	2:00 p.m.	Meet with ODA economist.
Sat. October 24	9:00 a.m.	Visit Kuntaur Cluster Site (NBC) and Pallol.
Sun. October 25	9:00 a.m.	Visit SWMU contour berms at Sare Ngai.
Mon. October 26	9:00 a.m.	Visit Sapu Research Station.
	4:00 p.m.	Return to Mile 7.
Tues. October 27	8:00 a.m.	Visit Jarrol with: S. Jarju H. Metz
Wed. October 28	8:00 a.m.	Visit Kwinella with SWMU Staff.

Thurs. October 29	8:00 a.m.	Visit Yundum Station.
	8:45 a.m.	Meet with Station Officer and J. Posner
	9:00 a.m.	Agronomy Lab., Soils Lab., Tandako, Site 3, East Paddock.
	1:00 p.m.	Visit SWMU
Fri. October 30	8:00 a.m.	Visit to Bakindik Cluster Area.
Sat. October 31	10:00 a.m.	Meet with Elon Gilbert.
Sun. November 1		Write report.
Mon. November 2	9:00 a.m.	Visit with M. Van Krimpen, Dept. of Water Resources & Environment.
Tues. November 3	8:00 a.m.	Visit to Jiramba & Somita with SWMU Staff.
Wed. November 4		Agric. Engineering (Yundum). Horticulture Unit (Yundum).
Thurs. November 5		Maouloud Holiday.
Fri. November 6	9:00 a.m.	Day Trip to Nioro Du Rip - Senegal.
Sat. November 7		Report writing.
Sun. November 8		Report writing.
Mon. November 9	9:00 a.m.	Visit with Tom Hobgood, U.S.A.I.D. Banjul.
	1:00 p.m.	Seminar.
		Exit visit with COP & Asst. Director for Research.
Tues. November 10		Free day.
Wed. November 11		Return to Madison.

ANNEX 3

References

Boast, C. W., and T. M. Robertson. 1982. A "micro-lysimeter" method for determining evaporation from bare soil: description and laboratory evaluation. Soil Sci. Soc. Am. J. 46:689-696.

Williams, J. B. 1979. Soil water investigation in The Gambia. Tech. Bulletin 3, Land Resources Development Centre, Ministry of Overseas Development, England.

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