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INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

OUAGADOUGOU
UPPER VOLTA

SAVANNA REGIONAL WATER RESOURCES AND LAND USE

SAVANNA RESOURCES

VOLUME 4
STUDY PROPOSALS

CIEH-USAID
Grant Agreements
625-11-120-712
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TAMS
ADG
345 Park Ave.
New York 10022

This SAVANNA RESOURCES Study consists of 4 Volumes:

VOLUME 1. REPORT

VOLUME 2. MAPFOLIO

VOLUME 3. APPENDICES

VOLUME 4. STUDY PROPOSALS

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INTRODUCTION

One of the objectives of CIEH (Comité Interafricain d'Etudes Hydrauliques*) is to define general scientific and technical studies of common interest to its member states, to obtain funding for such studies, to execute them and assure dissemination of the results.

This Volume contains 22 study proposals. They were selected in the period 1975 to early 1978 and are designed to cover gaps in existing information and land use. The proposals constitute one of the outputs of the Savanna Regional Water Resources and Land Use Project. During the preparation of the synthesis of the Resources of the Savanna Region, presented in Volumes 1 to 3 of the present study, it became evident that there were numerous gaps in information. The studies necessary to eliminate these gaps were identified and all of them are listed in the Annex of this Volume. After a careful selection process, including review of each proposed study by several scientists, the most urgently needed were prepared for presentation in this Volume. One study proposal - the establishment of a regional remote sensing center - was already submitted to USAID for financing and implementation in June 1975 (AID Project N° 686 - 7709).

Execution of the full program of 22 studies presented herein will cost approximately US $ 2.2 million, or an average of US $ 100,000 per study at 1978 price levels.

The costs estimated for each study are based on the assumption that resident staff is available at CIEH to carry out the various assignments. Most of the studies are not designed for execution by individual consultants brought in from overseas. Several studies involve intermittent efforts with long gaps of inaction between active periods. It is therefore recommended that a series of studies be executed simultaneously. This would also allow for substantial savings in time and travel funds.

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*Interafrican Committee for Hydraulic Studies

Table I. Scientists assigned to identification of study proposals

Secretary General CIEH	: Mr. M. G. Gagara
Project Manager	: Dr. John Buursink
Hydrology	: Mr. P. W. Roark Mr. J. O. Robertson Mr. J. C. Henry Mr. A. Ballofet Mr. G. Williams
Hydrogeology	: Dr. M. A. Saint-Pé Mr. A. Ballofet Mr. J. O. Robertson
Water Resources Dev.	: Mr. J. O. Robertson Dr. M. A. Saint-Pé Mr. A. Ballofet Mr. P. W. Roark
Climatology	: Dr. J. M. Kowal Dr. P. Ahn
Land Use	: Dr. P. Ahn Mr. M. David
Documentation	: Mr. R. Koester

STUDY PROPOSALS: HYDROLOGY

INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

OUAGADOUGOU

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: HP 01

TITLE OF STUDY: Stream Flow Data

ESTIMATED COST: US $72,500

DATE OF PROPOSAL: November 1976, December 1977

Summary of the Problem

Existing stream flow records are not always adequate and/or accessible to allow definite conclusions to be drawn on the water resources of a West African river basin in a short time. Attempts to centralize data collection at one place such as CIEH have been successful, but gaps remain. These gaps are of three kinds:

a) data not collected

b) data collected, but not readily available

c) data collected and printed, but not available at CIEH

Nothing can be done about gap a), except to refer to documentation on neighbouring catchments, synthesize results from rainfall, and start the necessary measurements.

Gap b) refers to data which has been collected but requires processing and printing. Without the assistance of individuals having detailed knowledge, extending over many years, of the country concerned it is virtually impossible to overcome this gap.

Gap c) refers to the period prior to independence. In this case, some countries are not sure of the existence of all printed data within their orbit of responsibility, while others have the information but for certain reasons are not prepared to release it.

In other countries (Nigeria for example) we are aware of the existence of stream flow data but it is difficult to prove and to obtain.

In short, there is a need for a complete and conclusive check of all existing stream flow data, including the quality of such data, and subsequently to store this information in a center such as CIEH, with access given to all concerned.

Solution to the Problem

It is recommended that the following stream flow data be systematically collected, tabulated, quality checked and recorded on magnetic tapes,

with emphasis on current and recent material:

a) daily stage he:

b) stage-discharge measurements (rating curves)

c) peak floods- heights and flows

After detailed examination, older data, with comments on its quality would also be processed in a similar fashion.

The most complete record of hydrological observations for the francophone west-African region is maintained at the Hydrological Division of ORSTOM in Paris.

A CIEH hydrologist should visit ORSTOM and assess the quality of their data, identify and obtain data which are not now available at CIEH, and identify gaps in the data base.

Subsequently, for selected Francophone countries where data are suspected to exist that are not available at ORSTOM or at CIEH, a thorough carte-blanche search of the archives should be carried out. An investigation by a CIEH hydrologist accompanied by at least one local long-service employee is likely to reveal whether records exist or not.

As for such Anglophone countries as Nigeria and Ghana, use should be made of the services provided by local experts. Information concerning such local experts, their addresses and experience, is available at CIEH.

Cost of Study

In view of the unknowns which exist, only an approximate estimate of costs can be given.

Hydrologist	2 mo @ $8,000/mo	16,000
Jr. Hydrologist	6 mo @ $6,000/mo	36,000
Draftsman	2 mo @ $ 500/mo	1,000
Travel		6,000

Printing Reports	4,000
Unforeseen 15%	9,500
	US $ 72,500

This estimate is based on the assumption that individual countries will assist in locating missing data. If otherwise, the junior hydrologist's time will have to be increased to perhaps 18 months.

References

(1) Hydrological Year Books of member countries

(2) ORSTOM (1974-7) Monographies hydrologiques ORSTOM: n° 1 - Le bassin du fleuve Sénégal; n° 2 - Le bassin du fleuve Chari; n° 3 - Le bassin de la rivière Sanaga (Cameroun); n° 5 - Le bassin du fleuve Volta - Paris.

(3) TAMS (1978) Savanna Regional Water Resources and Land Use. Volume 1, Chapter 4, Ouagadougou, CIEH.

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: HP 02

TITLE OF STUDY: Water Quality

ESTIMATED COST: US $23,000

DATE OF PROPOSAL: March 1974, December 1977

Summary of the Problem

Basic water resource information implies a knowledge of water quality and sediment production. Sediment sampling and water quality analyses have been conducted in other parts of Africa over a period of many years. Apart from one or two isolated efforts at collecting data, for example by Grove in 1972[1], and ad hoc studies at the new lakes at Kainji, Volta and Kossou and of course Chad (Roche, Carmouze)[2], large gaps exist over extensive areas of the Savanna Region.

Fortunately, the situation is not so bad as appears at first sight. Generally, surface water in West Africa is of good quality with low salt content, low hardness and negligible pollution. Also, sediment load generally is light, with the exception of one or two isolated areas where runoff is high and vegetative cover is poor, for example on parts of the Jos plateau in Nigeria.

In spite of these favourable conditions, it would be unwise to dismiss the measurement of water quality and sediment load at key stations on a regular basis as merely a desirable but non-essential exercise. These historical records become valuable after a period of time, insofar as they indicate regional trends. Where nothing is done to maintain quality, the trend is inevitably retrograde. Such a trend will show up as for example, when more and more people cultivate fallow land unless rigorous steps are taken to prevent or reduce malpractices.

New water resource development projects cannot be started before a systematic sampling program has been established, but the results of analysed historical data can be used to advantage, even if they are only regional and not specifically applicable to the project. This study would enable this data to be collected and analysed for future use.

Solution to the Problem

The study would be concerned with (a) the collection of existing data, from which gaps would be readily identified, (b) the identification of facilities available at present for collecting and analysing data, and (c) the making of recommendations for upgrading existing arrangements.

The first two steps would involve obtaining information, by means of a form inquiry, from all countries concerned. This would be followed up by short visits to certain countries which require further investigation or have particularly difficult problems.

As for the last phase, recommendations will be made concerning:

1. The establishment of suitable laboratories where none exist at present. In some instances, it may be necessary to recommend setting up joint laboratories with hospital and police forensic departments.

2. The purchase of suitable field and laboratory equipment and identification of key sampling stations.

3. The training of field and laboratory staff.

The training of field technicians capable of taking "black box" readings on portable site instruments is a fairly straightforward matter. The training of analytical chemists might take several years.

The duration of the study would be about 6 months, allowing time for receipt of replies from member states.

Cost of Study

Hydrologist	- 1 month	@ 8,000/mo	8,000
Asst. Hydrologist	- 1 month	@ 6,000/mo	6,000

Travel to selected countries	4,000
Printing Report	2,000
Unforeseen 15%	3,000
Total	US $23,000

This cost estimate is based on the use of existing CIEH staff on an intermittent basis.

References

1) Grove, A.T. (1972) "The dissolved and solid load carried by some West African rivers: Senegal, Benue and Shari," Journal of Hydrology, 16, 4, p. 277-300.

2) Carmouze, J.P. (1976) "Les grands traits de l'hydrologie et de l'hydrochimie du lac Tchad," Cahiers ORSTOM, serie Hydrobiologie, 10, 1, p. 33-56.

3) Roche, M.A. (1973) Traçage naturel salin et isotopique des eaux du système hydrologique du Lac Tchad. Paris, ORSTOM.

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: HP 03

TITLE OF STUDY: Review of the Hydrology of Large Watersheds

ESTIMATED COST: US $38,000

DATE OF PROPOSAL: March 1975, December 1977

Summary of the Problem

On many river basins in West Africa, rainfall records extend for longer periods than runoff records. If therefore, suitable rainfall-runoff models can be set up, it should be possible to establish reasonable runoff estimates for the "rainfall-only" years, and at the same time synthesize runs of rainfall and runoff over periods of 20, 50 and 100 years.

In the past, large rivers in West Africa have not been used extensively for irrigation, flood-control and hydro-electric power generation, as in other parts of the world, consequently there has been no great demand for basic hydrological data concerning these rivers. This situation is changing. Much development is now taking place, particularly on the Senegal River, the Upper Niger River, and others, therefore a pressing need to determine the main characteristics of these rivers has arisen, together with the underlying parameters which cause them.

In many cases long records, often exceeding 60 years, are available and much work has already been done in analysing mean and extreme-value flows, but much remains undone. For example, the quality of some of the data needs to be investigated, and the setting-up of a "black box" relationship between rainfall and runoff over daily, 10-day, monthly, and yearly periods should yield fruitful results, where these records exist.

Solution to the Problem

Map N° 4-3 of Volume 2 already presents much of the basic information, together with the computer print-outs from which it was prepared (Volume 3). In order to understand the runoff mechanism however, a study of rainfall-runoff relationships will be required, from which it should be possible to extrapolate extreme values where long-term rainfall is available and corresponding runoffs are only short term.

CIEH already has the estimated 25 and 100-year flood and drought flows on computer print-out. In addition, it will be useful to have a new map which will show these important parameters together with the mean flows as before.

With the use of modern techniques and equipment such as desk-top plotters, the effect of various actual rainfall distributions in time and space can be studied and the resultant runoff studied. If sufficient data is available on ground water recharge/abstraction and soil moisture flux, it should be possible to draw up a hydrological balance.

Much work has been done on the Senegal River, and further work on the Niger is scheduled by the Niger River Commission in their forthcoming diagnostic study. The present study will have the merit of providing an overall review within the Savanna Region, thus bringing out the salient differences and similarities within it.

Cost of Study

Hydrologist	1 month	@ $ 8,000/mo	8,000
Jr. Hydrologist	3 months	@ $ 6,000/mo	18,000
Draftsman	2 months	@ $ 500/mo	1,000
Travel			3,000
Printing reports and maps			3,000
Unforeseen 15%			5,000
		Total	US $ 38,000

References

1) ORSTOM (1974-77) Monograhies hydrologiques ORSTOM: no. 1 - Le bassin du fleuve Sénégal; no. 2 - Le bassin du fleuve Chari; no. 3 - Le bassin de la rivière Sanaga (Cameroun); no. 5 - Le bassin du fleuve Volta. Paris.

2) TAMS (1978) Savanna Regional Water Resources and Land Use, Volume 2, Chapter 4. Ouagadougou, CIEH.

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: HP 04

TITLE OF STUDY: Storage Required to Produce Different Rates of Regulated Flow

ESTIMATED COST: US $60,000

DATE OF PROPOSAL: March 1975, December 1977

Summary of the Problem

The rainfall regime over West Africa with its pronounced wet and dry seasons, produces concomitant fluctuations in river flows. For example the mean monthly flows on the Niger at Niamey in June and January are 106 and 1761 m^3/second respectively. This situation is unsatisfactory, insofar as insufficient water is available for navigation, second crop irrigation and hydro-power generation in the dry season, and excess water with a potential value of millions of dollars pours into the Gulf of Guinea during the wet season, and causes serious flooding in many places.

Some form of partial regulation is indicated, and the object of the study would be to identify "on-line" dam sites and "off-line" detention basins which would smooth out the peaks and the troughs of the annual hydrograph. Complete regulation would be grossly uneconomic.

To give some idea of the order of magnitude of cause and effect, a storage of 10% of mean annual flow near Niamey would reduce the above monthly extremes to 500 and 1500 m^3/second.

Solution to the Problem

Most of the data required to determine the storage necessary to produce different rates of regulated flow in the large West African rivers are now deposited at CIEH. The basic procedure would be to tabulate and/or plot mass curves of cumulative runoff from which the required storage for different rates of dependable flow can be computed. The final results would be plotted as storage-draft (regulated flow) curves. Generalized relations may then be developed in which storage can be expressed as a function of average flow. Because of the variability of annual natural runoff, it will be required to produce relatively small rates of dependable flow. In general, regulation for periods of more than one dry season will be impracticable, due in part to the large volumes of annual evaporation.

In some cases however, where economical storages are large, over-year storage may be practical. As an example, where the maximum depth stored is more than 50 m, the mean annual evaporation loss will usually be less than 10% of the total volume stored. This is reasonable, assuming a) seepage losses are small and b) the volume lost to evaporation is also small in relation to the mean annual inflow.

It is suggested that the study be split into 2 phases:

Phase 1. A basic survey covering the large rivers only eg., Upper Niger, Benue, Chari-Logone, Voltas, Senegal. Much work has already been done on the Niger, Volta and Senegal rivers (see References (1), (2), and (3)) and this survey based on long established data can start immediately. Phase I can be done by a junior hydrologist using conventional methods.

Phase 2. A more detailed survey embracing smaller rivers and tributaries. This second phase should be considered in the early 80's, when more adequate data will become available thus providing more meaningful results.

The repetitive work involved in Phase 2 indicates the use of computers and suitable programs to provide speedy solutions.

If Nigeria joins CIEH, one of the main priorities will be a flow regulation study of the Benue and smaller rivers such as the Kaduna and Sokoto. It is quite possible that much of this work has already been done by consultants to the Federal and State Governments of Nigeria. For example, the Shiroro gorge dam on the Kaduna River, and the Kiri dam on the Gongola River are now being built. Obviously, the necessary storage analyses were made before starting these and other projects.

Cost of Study

Phase 1:

Hydrologist	0.5 mo	@	$8,000/mo	4,000
Jr. Hydrologist	2 mo	@	$6,000/mo	12,000
Draftsman	0.5 mo	@	$ 500/mo	250

Printing report and maps		2,000
Unforeseen 15%		2,750
	Total US	$ 21,000

Phase 2.

The above named staff will be required for a longer period entailing a higher cost, say U.S.$40,000, for this phase.

References

1) Italconsult (1962) Etude sur les effets que la mise en exécution des principaux projets envisagés par les états riverains peut avoir sur le régime du Niger. Rome.

2) SOGREAH (1977) Etude comparative des differentes sites de barrages possibles sur la Volta Blanche et ses affluents dans la région de Bagre. Rapport final. Ouagadougou, Ministère du Développement Rural/A.V.V./Ministère du Plan.

3) OMVS (1976) Aménagement du bassin versant du Fleuve Sénégal. Dakar.

INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: HP 05

TITLE OF STUDY: Effect of Upstream Irrigation Development Upon the Flow Regime of the Niger River

ESTIMATED COST: US $42,000

DATE OF PROPOSAL: December 1977

Summary of the Problem

The Government of Mali has as an objective to bring one million hectares of land under irrigation by the year 2000. Water resources required for this vast undertaking will come from the Niger basin, where development of storage reservoirs is in progress in Mali and will continue in Guinea, on the Upper Niger tributaries.

The combination of irrigation consumptive use and storage is expected to have a marked effect upon the flow distribution pattern of the Niger river, with consequent repercussions in the downstream riparian countries of Niger and Nigeria.

It should be noted that prior to large-scale irrigation and storage development, about one half of the mean annual flow of the Niger river is lost to evaporation in the Interior Delta area in the north of Mali. It can therefore be expected that the reduction of water resources, due to irrigation consumptive use upstream, will to some extent be compensated by a reduction of the evaporation losses in the Delta area, as it can be seen from an examination of streamflow records that the Delta losses are proportional to the inflow into the area. Similarly, it is probable that evaporation losses at the storage reservoirs will be compensated in whole or in part, by a reduction of the flood areas since peak flows will be somewhat reduced.

As the future of irrigation extension in the Republic of Niger is almost wholly dependent upon use of Niger river water resources, it is of the utmost importance to base projects not on existing streamflow records but upon realistic estimates of future streamflow distribution. It is therefore urgent to undertake a study whose object is the quantitative evaluation of the contrary effects discussed above, in order to prepare reliable flow distribution diagrams for the Niger river downstream of the Interior Delta.

The possible effects of water management schemes upon Niger River flows were studied by Italconsult in 1962 under the sponsorship of the United Nations (see Reference (1)). At that time however, the irrigation plans of the Mali Government were much less extensive and the conclusions of the study must now be entirely reviewed in the light of present development objectives. These appear to be somewhat ambitious but nevertheless, not beyond the limits of modern technical achievement.

Solution to the Problem

It has been suggested to the Niger River Commission that a comprehensive mathematical model of the Niger basin should be set up in order to test different development and water management hypotheses. Although we believe that such a model can be a useful planning tool, it is felt that its formulation should not delay a preliminary evaluation of the problem which will yield the order of magnitude of the changes that can be expected and results of sufficient accuracy to enable planners to go ahead with prospective schemes in Niger.

The aim of the preliminary study will be to assemble all significant water use and storage project information for the area upstream of the Delta. On the basis of this information and with the assistance of the very long series of flow data available both upstream and downstream of the Delta, to prepare hypothetical flow distribution diagrams for different stages of Mali development, both storage and irrigation, and for various frequencies. These could be the median and the five and ten year wet and dry flows.

Data collection will be limited to defining storage volumes and operation, type of irrigation and estimation of return flows from irrigation areas and whether double or single cropping is to be instituted. Details of any important hydro-power schemes will also be required since these involve a modification of the regime unless they are of the run-of-the river type.

Industrial water use need not be taken into account at this stage, however, it has to be considered after, say, the mid 80's. All abstraction and use of water should be governed by appropriate water rights legislation. All the hydrological data is already available at CIEH.

Cost of Study

Engineer-hydrologist	4 mo	@ $8,000/mo	32,000
Draftsman	1 mo	@ $ 500/mo	500
Travel to Mali			2,000
Printing Report and Maps			2,000
Unforeseen 15%			5,500
		Total	US $ 42,000

References

1) Italconsult (1962) Etude sur les effets que la mise en exécution des principaux projets envisagés par les états riverains peut avoir sur le régime du Niger. Rome.

INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: HP 06

TITLE OF STUDY: Reduction of Water Losses in the Inland Delta of the Niger River

ESTIMATED COST: US $34,000 (First Phase), US $8 million (Second Phase)

DATE OF PROPOSAL: March 1978

Summary of the Problem

At present up to half of the water which flows in at the top of the Niger delta is lost to evaporation. This is an enormous waste, therefore means to reduce it should be studied without delay. Even if only 1/3 is saved, the value of the water made available could be as much as US $ 300 million/year in the river and many times more than this at the head of irrigated fields.

Solution to the Problem

It is proposed that CIEH carry out a study of the Inland Delta in liaison with the River Niger Commission. Such a study would consist of two phases:

Phase 1. A reconnaissance study which would identify the problem and give some idea of the size of the parameters involved; and provide guidelines for a detailed study.

Phase 2. A detailed study, as was done on the Sudd swamps of the White Nile 25 years ago. This could take up to 5 years, but preferably would be curtailed to 1 year mobilization plus 2 years' study plus 6 months for write-up.

Cost of Study

Phase 1.

Engineering--hydrologist	3 mo @ $8,000/mo	24,000
Draftsman	1 mo @ $ 500/mo	500
Travel to Mali and Niger		3,000
Printing Report and Maps		2,000
Unforeseen 15%		4,500
	Total US	$34,000

Phase 2.

The actual detailed study is estimated to cost between 5 and 10 million US dollars.

Reference Jonglei Investigation Team (1954) The Equatorial Nile Project and its effect in the Anglo-Egyptian Sudan. London, Sudan Government.

STUDY PROPOSALS: HYDROGEOLOGY

GENERAL INFORMATION AND RECOMMENDATIONS

Availability of Groundwater Data

Groundwater data are relatively abundant throughout the Savanna Region, however some areas are not well provided. The western and central parts of the Savanna area are rather well known while the eastern one is not so.

Countries with sufficient basic groundwater data include:

- Senegal, except the Casamance and the southeastern regions;
- Mali, except the part to the south of Bamako, and the area bordered by the Niger River, parallel 15° and meridian 0° (region to the southeast of Timbuctou);
- Upper Volta, except the southwest and the east;
- Ivory Coast
- Togo
- Benin, except the central part
- Mauritania, except the southeastern part
- Niger except the eastern part
- Ghana
- Nigeria
- Cameroon, especially the northern part
- Chad, the central part

Countries with insufficient basic groundwater data (or countries for which groundwater data available at CIEH is limited) include:

- Central African Empire
- The Gambia
- Guinea Bissau
- Mauritania, southeastern part
- Sierra Leone
- Guinea
- Chad, other than central part

Hydrogeologic Information Needed for CIEH Member States

It would be desirable for each country to have in addition to the national geologic map, a hydrogeologic map at similar scale (1:2,000,000 to 1:500,000 according to the size of the country) showing the main hydrogeologic characteristics of each series, formations and rock types. It is also recommended that each country prepare a hydrogeologic synthesis presenting each aquifer, as well as the groundwater situation in each region, including a text, map and sections. Finally all available data should be summarized in a groundwater data catalog listing inventoried wells (keyed to a location map) with their main characteristics, i.e. geographic coordinates, type, depth, diameter, aquifer utilized, static water level, pumping water level, yield, transmissivity, storage coefficient, water quality, water use and so forth.

Subsequently, on a regional level within each country, regional hydrogeologic maps at appropriate scale (1 : 500,000 to 1 : 100,000) should be prepared. Above all, the yearly groundwater use should be estimated and monitored each year (by aquifer and usage, namely domestic-rural, livestock, municipal and industrial agriculture, irrigation). In addition, a monitoring water level network should be installed in each country. In the future, information from the observation well network and groundwater data catalog would be the basis for groundwater data banks. Finally an annual groundwater report should be prepared regularly to summarize the groundwater situation, the progress made, and the needed studies, investigations and development programs and projects.

This information would provide the basis for efficient utilization of the groundwater resources of the Savanna Region.

Promising areas for groundwater irrigation (500,000- 1,000,000 sq km) should be investigated further in Senegal, Niger, Nigeria, Chad and Mali.

Country-specific Hydrogeologic Investigations Suggested

Below is a listing of studies and investigations which are needed for each country:

1. Benin: ascertain groundwater resources in the northern sedimentary basin and monitor any possible sea water intrusion in the coastal basin.

2. Cameroon: conduct pumping tests (100-200 m/h) in the Plio-Quaternary and Continental Terminal; explore deep aquifers down to 700 m in depth.

3. Chad: complete the national water well inventory; study groundwater resources in the basement (Mayo Kebi) and in the Koros region; study the underflows in Ouaddai; study groundwater resources in the north including exploratory drilling.

4. Central African Empire: study, including exploratory drilling, the Continental Terminal; and the Continental Intercalaire; check if it is feasible to meet the municipal water needs of the following towns from groundwater: Berberati, Bozoum, Bossangoa, Mbaiki, Birao, Ndele.

5. The Gambia: study, including geophysics and exploratory drilling, the Continental Terminal and Maestrichtian aquifers, including actual and/or potential sea water intrusion problem(s).

6. Ghana: study the Northern Region and the Paleozoic sandstone-quartzite.

7. Guinea: study the Paleozoic sandstone-quartzite.

8. Guinea Bissau: study the Maestrichtian, including exploratory drilling and any possible actual and/or potential sea water intrusion problem(s); study the Infra-Cambrian sandstone.

9. Ivory Coast: prepare the hydrogeologic synthesis of the Savanna part of the country.

10. Mali: synthesize all the hydrogeologic work done so far; study, including photo-geology, field geology, and exploratory drilling, the Gourma dolomite; study the Infra-Cambrian sandstone, including photo-geology and exploratory drilling up to 200-300 m and pumping tests, the Bandiagara and Sikasso sandstone; study, including exploratory drilling up to 200-300 m and pumping tests, the Continental Intercalaire, Nara and Vallée du Serpent area; study the phreatic aquifer in southeastern Mali; study the Niger River valley; study the Taoudeni basin in northern Mali.

11. Mauritania: study, including drilling and tests, the southwestern sedimentary basin (Maestrichtian, Trarza region, R'Kiz area); study the alluvium of the Senegal River and tributaries (Karakoro and Gorgol for instance) and the dune sand in Assaba; study the Paleozoic sandstone of Aioun; study the Hodh pellites (contacts with dolerites; fractures should be water yielding), including wells up to 300 m in depth; study the Assaba sandstone (Paleozoic); improve the well intakes for Aouker dunes aquifer development to plan the development of the Dahr de Nema aquifer in the southeast (good yields from the Continental Intercalaire).

12. Niger: study, including exploratory drilling and tests, western Niger, the Tegama (Continental Intercalaire aquifer), the Lake Chad area, northern Niger, the Continental Terminal and Cretaceous in the Nigeria bordering region; prepare a country-wide hydrogeologic synthesis report.

13. Nigeria: study further as needed, including exploratory drilling and tests, and prepare hydrogeologic synthesis reports of the following areas: northwestern Nigeria (Sokoto basin), northeastern Nigeria (Lake Chad basin); Niger and Benue river basins, from Jebba to Lokoja and from Yola to Lokoja, respectively.

14. Senegal: study, including exploratory drilling and tests, the Casamance region (Continental Terminal, Miocene, Maestrichtian), including any possible actual and potential sea water intrusion problem(s). This last point should also

be studied in Sine-Saloum, in the Mbour area (Paleocene limestone) and to the north of Dakar to Mauritania; prepare the synthesis of the Continental Terminal and of the hydrogeology of the Dakar-Thies area; study southeastern Senegal; review, analyze and prepare a synthesis (including well inventory) of the hydrogeologic work of the Senegal river area in view of a long-term groundwater development program.

15. Sierra Leone: prepare a hydrogeologic synthesis of the country.

16. Togo: study, including drilling and tests, the Dapango sandstone (check if pores and/or channel porosity), the Paleocene limestone (to the northeast of Lomé, at Lebé, and Agoréké), the Cretaceous-Maestrichtian at Angouévé and Kpogamé.

17. Upper Volta: study, including photo-geology and exploratory drilling, the Gourma dolomite (see Mali); study the Infra-Cambrian sandstone in the West and the Bobo-Dioulasso springs (inventory of wells, topographic levelling, piezometric mapping, exploratory drilling and tests); study the confined groundwater in dolomite under the Continental Terminal; study the basement in the East.

INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

OUAGADOUGOU

UPPER VOLTA

SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: GP 01

TITLE OF STUDY: Construction of Wells and Boreholes and Installation of Pumps in West Africa

ESTIMATED COST: US $95,500

DATE OF PROPOSAL: August 1977, March 1978

Summary of the Problem

There exists throughout the Savanna Region a potential need for a large number of wells and related facilities to provide for (a) a dependable, safe and cost-efficient water supply to millions of (primarily rural) people, and (b) irrigated agriculture development and food production.

Presently, the cost of well construction is very high, ranging from US $ 80 (small diameter) to $ 730 (large diameter) per meter, and averaging $ 250 per meter for drilled wells and generally from $ 300 - 400 per meter for large dug wells. Likewise pumps are costly: US $ 400 - 2,800 for a handpump, $ 1,600 for a locally developed windmill, $ 8,000 - 12,000 for an electric pump and engine, $ 25,000 - 120,000 for a solar pumping plant.

With so many different ways available of sinking a well and the variety of pumps available on the market and presently in use in the region, broad guidelines on the best ways of developing wells and installing pumps, preferably adapted to each sub-region, are needed. Such guidelines would be flexible in view of local spatial variations and continuing technological development.

Solution to the Problem

The purpose of the study is to determine the types of wells and pumps best suited to the region and to compile and publish installation instructions in the form of small hand books for the use of field staff.

The technical, economic, and social aspects of well construction and selection and installation of pumps will be examined. The study will not be concerned with aspects of administration, departmental structure and staff training.

There is a great deal of literature on the subject, and the first phase of the study would consist of a review of this, together with consultation with various government departments and local private firms in order to ascertain their views on the construction of wells and installation of pumps in their respective areas. A good example of the co-operation required, would be

permission to use the forthcoming report of the Ghana Upper Region Water Supply Project. Subsequently, the study would be concerned with work in progress (i.e., unpublished) and such matters as assessing the possibilities and capabilities of new equipment, e.g. the revolutionary Ingersoll-Rand percussion drill and variants which may be developed from it.

Special attention will be given to the desirability of (a) standardization of drilling and pumping equipment with the widespread use of a few basic types and (b) fostering the establishment of privately-owned water well drilling companies.

The choices of certain wells and pumps may have important socio-economic consequences, especially when effective utilization of wells require the relocation of people. Therefore, as part of the study, special attention will be given to types and placement of wells which will:

1) serve the special needs of the people in different sub-regions
2) effectively serve the large and scattered population
3) be consistent with the desires of the beneficiaries for location of their homes and villages.

Cost of Study

Sr. Hydrogeologist/Engineer	1 mo @ $8,000	8,000
Jr. Hydrogeologist/Engineer	4 mo @ $6,000	24,000
Engineer	1 mo @ $8,000	8,000
Junior Engineer	2 mo @ $6,000	12,000
Rural Planner	2 mo @ $8,000	16,000
Sociologist	1 mo @ $8,000	8,000
Travel	(5 trips)	5,000
Printing Report		2,000
Unforeseen 15%		12,500
	Total US	$ 95,500

The work of the hydrogeologists would focus on construction of wells and boreholes, that of the engineers on the installation of pumps in wells and boreholes.

The cost may be reduced considerably if the country reports of the USAID mission on Water Supply to the Rural Poor in West Africa (Mission to be fielded sometime in 78) are made available to CIEH.

INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

OUAGADOUGOU

UPPER VOLTA

SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY:	GP 02
TITLE OF STUDY:	Operation and Maintenance of Wells and Boreholes and Pumps in West Africa
ESTIMATED COST:	US $43,700
DATE OF PROPOSAL:	August 1977, March 1978

Summary of the Problem

The life of wells and especially pumps is short in the Savanna because of poor operation practices and lack of maintenance. This is due in part to lack of personnel to train users, which often is the result of lack of funds. Thus the potential of significant investments in well programs is usually not realized.

It is also known that well yields are generally low over most of the pre-Cambrian. This results in scattered villages that can support only limited numbers of people. The logistics of maintaining and operating a multiplicity of pumps over such a vast area becomes extremely difficult. Information must be made available as to methods and types of equipment best adapted to the region.

Solution to the Problem

Drawing on experience gained in the Savanna Region, as well as other countries, an assessment will be made of the performance, from the point of view of maintenance and operations, of existing wells and pumps. As there is a great deal already written on this subject, an analysis and consolidation of this information is clearly indicated and long overdue. This would be followed by a continued monitoring for an extended period of time of new developments.

In order to reduce the proliferation of scattered wells (and maintenance problems), and take sound decisions on the desirability of abandoning low yield wells where they have become inoperative, potential alternative sources of water supply (e.g. regulated surface storage or springs) must also be considered. Also to be considered would be the feasibility of providing more centralized water supplies (and other basic services) for the rural population.

The major effort of this study will be an evaluation of the performance of existing wells and pumps, followed by extended trials of new and

untried models of pumps and new methods of sinking wells, from the operation and maintenance viewpoint. Recommendations will be developed as to procedures and the types of equipment which will enable a reduction in maintenance problems and expenses.

To investigate new developments, input will be required, on an intermittent basis, over a period of two years or longer. This study will be complementary to Study Proposal GP 01 (Construction of Wells and Boreholes and Installation of Pumps in West Africa).

Cost of Study

Sr. Engineer	1 mo @ $8,000	8,000
Jr. Engineer	4 mo @ $6,000	24,000
Travel		4,000
Printing Report		2,000
Unforeseen 15%		5,700
	Total	US $ 43,700

References

1) Pacey, A. (1977) Hand-pump maintenance in the context of community well projects. London, Intermediate Technology Publications.

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3) Mcjunkin, F.E. (1977) Hand pumps for use in drinking water supplies in developing countries. (Technical Paper no. 10) The Hague, International Reference Centre for Community Water Supply.

4) Pacific Consultants (1978) West Africa rural water supply and sanitation pre-project analysis; study carried out November 4 - December 15, 1977 sponsored by AID/Washington. (restricted circulation.) Washington, D.C.

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UPPER VOLTA

SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: GP 03

TITLE OF STUDY: Observation Well Network

ESTIMATED COST: US $169,000

DATE OF PROPOSAL: August 1977, October 1977

Summary of the Problem

At present, there is no systematic network of observation wells in the West African Savanna Region. This means that the movement of groundwater levels and quality is not well known, hence it is not possible to ascertain extraction and losses, and recharge to aquifers, with any degree of confidence.

Solution to the Problem

This study will establish criteria and guidelines for the design and operation of a regional network of observation wells. It should be carried out in conjunction with study GP 04.

The network would be worked out with the help of the member countries of CIEH, several of whom already have some wells under surveillance at present. This will result in a homogeneous regional network tailored to the peculiar situation of each country. The density of the network would fit the importance of the aquifers under consideration, with a higher density in problem areas and stressed aquifers.

As far as possible, certain existing holes would be taken over as monitor wells which would be sounded at regular intervals. A small proportion of these would be fitted up with water-level recorders. Obviously, wells in active use could not be used for this purpose.

In some remote areas, new holes will have to be sunk. In these areas, it will be better to sink two wells at each location, one for "production" and one for continuous recording.

It is unlikely that sufficient technicians will be available to carry out the necessary observations and attend to routine matters such as chartchanging, so teams of these people will have to be trained by the hydrogeologist in charge of the operations. Observations should include analysis of the water quality (including trace elements).

The data are expected to be processed in the various countries concerned and the results sent to CIEH.

Cost of Study

Sr. Hydrogeologist	2 mo	@ $ 8,000	16,000
Jr. Hydrogeologist	6 mo	@ $ 6,000	36,000
Recording equipment (part financed by member states, part by CIEH)			70,000
Travel			20,000
Printing Report and Maps			5,000
Unforeseen 15%			22,000
		Total	US $ 169,000

INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

OUAGADOUGOU

UPPER VOLTA

SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: GP 04

TITLE OF STUDY: Development and Management of Savanna Groundwater Reservoirs

ESTIMATED COST: US $111,500

DATE OF PROPOSAL: August 1977, October 1977

Summary of the Problem

The principal aquifers in the sedimentary basins of the Savanna Region have been studied, but much more work has to be done on them before one can arrive at firm conclusions concerning their exploitation. The following figures indicate the size of the main basins:

Lake Chad Basin (Chad, Cameroon, Niger, Nigeria)	150,000-300,000 km^2
Senegal-Mauritania-Gambia Basin	150,000-250,000 km^2
Niger Basin (West) in Niger and northwest Nigeria	100,000-150,000 km^2
Lower Niger Basin (including Benue River)	50,000-100,000 km^2
Upper Niger Basin, Mali	50,000-100,000 km^2

While the western and central basins are relatively well known, the eastern ones generally are not. For instance, the Continental Intercalaire and Cretaceous aquifers in Niger, and the Continental Terminal, Pliocene and Quaternary aquifers in Chad are insufficiently understood.

Also, data on the relationships between major rivers and shallow aquifers in the sedimentary basins is too scarce to provide meaningful recharge information, which is essential for hydrological analysis of aquifers located near the river beds. In general, natural groundwater recharge, on a regional basis, is not well enough known to allow optimum aquifer management. Similarly, the information on groundwater level fluctuations is insufficient, although some research has been carried out especially on shallow aquifers.

The Savanna groundwater reservoirs offer a great potential for domestic and agricultural use. Detailed information on the extent, thickness

and characteristics of the aquifers is necessary for optimum exploitation and management and for the preparation of regional and local pre-investment plans for groundwater basin and regional development.

Solution to the Problem

The purpose of this study will be to define the best ways and means to develop as quickly as necessary the vast largely untapped reservoirs of groundwater of the West and Central Savanna Region.

The study, leading to actual implementation of groundwater development projects, will be carried out in several phases and on a long term basis with CIEH providing technical advice and coordinating the various national efforts.

In the first phase of the study a series of representative sample areas will be selected in the major sedimentary basins listed above and a detailed program of work and cost estimate will be prepared and specifications for contracts in geophysical exploration, well drilling and surveying will be made. It is expected that this can be done in close cooperation with national government authorities in a relatively short period of time, of say, 6 months.

In the second phase emphasis will be on field work in the sample areas. Work will include, but not necessarily be limited to, an exploration program involving a geophysics and drilling (and pumping tests) campaign aimed at providing knowledge of the geometry and hydrology of the aquifers and of the realizable pumping rates.

For the study of river-aquifer relationship, the sample areas will be selected in the following river stretches:

a) The Gambia from Simenti to the estuary (250-300 km)

b) Senegal from Bakel to Saint-Louis (500 km)

c) The Niger River from Segou to Gao (800 km) and as needed down 1500 km to Lokoja in Nigeria, especially within the reach between Jebba and Lokoja (250 km).

d) The Benue River at relevant sections along a 600 km. stretch.

e) The Chari and Logone Rivers from Sahr and Lai to N'Djamena (400 km) and as needed around Lake Chad (10,000 sq. km).

The piezometric elevations of the aquifers will be mapped at an appropriate scale, involving detailed mapping in areas where immediate exploitation may be envisaged. For the case of the shallow aquifers connected to open water bodies, this mapping will be done at the end of the rainy and dry seasons and will require well levelling.

For analysis of groundwater level fluctuations, also to be carried out at representative sites, measurements will be made to ascertain seasonal and interannual changes of the groundwater levels.

For evaluation of natural groundwater recharge representative watersheds will be selected for which runoff, rainfall and evapotranspiration measurements are available or will be measured in order to compute the estimated recharge. Also base flow should be estimated from existing records at as many gauging stations as possible.

Consideration should be given to the technical and economic feasibility of routine use of new methods such as the technique of shallow ground temperature surveying. In 1973 this method was tried out in Upper Volta to determine where to drill or dig wells and its application on a larger scale was recommended.

Based on knowledge and experience gained in the sample areas, and with the help of national personnel trained during that phase, CIEH's groundwater specialists would continue to provide guidance and assistance to member states. This third phase should be conceived of as a long-term effort (20-50 years), during which member states will be actively engaged in continued investigation and exploitation of their precious groundwater reservoirs with CIEH providing a management and coordination input for such investigations as required for feasibility studies and project design.

Cost of Study

Below, a cost estimate of only the first phase of this study is given since the costs of subsequent phases will be one of the outputs of this first

phase. Substantial cost information is already at hand at CIEH.

It is estimated that the first phase of the study can be carried out in a six month period allowing for consultation with Government Departments concerned and the checking/definition of sample areas selected.

Sr. Hydrologist	6 mo @ $ 8,000/mo	48,000
Jr. Hydrologist	6 mo @ $ 6,000/mo	36,000
Travel		8,000
Printing Reports and Maps		5,000
Unforeseen 15%		14,500
	Total	US $ 111,500

STUDY PROPOSALS: WATER RESOURCES DEVELOPMENT

INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

OUAGADOUGOU

UPPER VOLTA

SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: WP 01

TITLE OF STUDY: CIEH Regional Multi-Purpose Water Data Bank

ESTIMATED COST: US $61,000

DATE OF PROPOSAL: June 1977-October 1977

Summary of the Problem

Data relating to all aspects of water resources, climatology, hydrogeology and hydrology are being collected at an ever-increasing rate, with the result that conventional storage and retrieval methods--documentation stacks, filing cabinets, and map cases--are becoming increasingly incapable of coping with the large quantity of data which continually accrues. Because of the decentralized nature of the data now available, access to it is usually haphazard, time-consuming, and costly. Integrated planning for regional water resources development can proceed only with access to a central data facility which would permit near-instantaneous data retrieval and manipulation. At present plans exist for the creation of a hydrological and meteorological data bank at the headquarters of the Agrhymet Center in Niamey, Niger. This project is limited in two ways: 1) its scope encompasses only the Sahelian member states of CILSS, 2) it will not deal with groundwater data.

Solution to the Problem

A data storage and retrieval systems requirements and design study is called for. This study would be concerned with the advantages and disadvantages of the different systems available for the integration of the data collected under the following headings:

- Agroclimatology--meteorology, records, forecasting, soil moisture
- Surface water--rating curves, current meter records, water use and needs etc.
- Ground water--water levels, fluctuations, yields, quality, etc.
- Research and Development--storage, ground and surface water, drafts, etc.

Basically, the study would concern systems requirements and design with a view towards rapid and reliable data retrieval and reproduction in any desired format. The study would recommend one or two alternative designs.

The data bank itself would function according to modern concepts of data management, designed to rectify problems inherent in the traditional

program/file approach. These concepts were realized with the introduction of third generation computers, large capacity direct-access storage devices, remote terminals, and improved communication networks in the late 1960's and early 1970's.

Such an approach would provide:

1) Control of data storage and retrieval with one generalised software system.
2) Multiple data access methods that are highly independent of file structures.
3) Storage of related data in a single integrated data base that serves many functions and users simultaneously.

Such an arrangement pre-supposes the shared use of a central computer in Ouagadougou, although with improved telecommunications, there is no reason why computer facilities at Abidjan would not be used part of the time if the need arose.

In addition to receiving "metric" inputs from Francophone member states, the bank would have to deal with the processing of non-metric inputs from the Anglophone countries such as Nigeria and Ghana, should these countries decide to change their present Observer status to that of full CIEH member.

The study would be done by a team consisting of a water resources engineer, one expert from one of the field disciplines, an information specialist and a systems analyst.

Cost of Study

Water resources engineer	2 mo @ $ 8,000/mo	16,000
Other water expert	1 mo @ $ 8,000/mo	8,000
Information specialist	1 mo @ $ 8,000/mo	8,000
Systems Analyst	2 mo @ $ 8,000/mo	16,000
Travel (including 2RT Europe/US)		4,000
Printing Report		1,000
Unforeseen 15%		8,000
	Total US	$ 61,000

INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

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UPPER VOLTA

SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: WP 02

TITLE OF STUDY: Model Master Plans for Water Resources Development

ESTIMATED COST: 2 x US $15,500

DATE OF PROPOSAL: December 1977

Summary of the Problem

The need for preparing both regional and national Water Resources Plans would appear to be obvious, and most Governments realize that without proper planning at both levels no real progress can be made.

It is proposed to deal with national and regional plans separately. Unfortunately, sometimes the existence of strong opposing political forces is likely to pre-empt any meaningful discussions taking place, let alone allowing decisions to be made. On the other hand, one can quote examples of development based on sound and lasting agreements (reference 2 below) to support the hypothesis that planning and mutual understanding may produce concrete results in the end.

Solution to the Problem

This study will develop model Master Plans for National and Regional Water Resources Development and give estimates of cost required to actually compile and produce them.

National Plan.

Several detailed work plans are available for modification, therefore very little base work will be required in drawing up a Model National Master Water Plan for West African countries. The assumption is made that permission to use all or some of the existing plans will be granted to CIEH by the various Governments concerned.

Broadly speaking, such a master plan covers economical, technical, legal and administrative aspects of the following principal activities:

Storage

Irrigation

Hydro-power generation

Navigation

Fisheries, national and artificial
Pollution
Industrial abstraction and use
Domestic abstraction and use
Agricultural processing and use
Soil conservation
National and Regional Water Authorities
Drafting of legislation, implementation, etc.

Based on a standardised national master plan as developed by CIEH, each of its member states can then prepare its own national plan geared to its specific needs. The scope and cost for country specific plans will vary enormously but would be in the order of magnitude of 0.25 to 2 million dollars.

Cost of Study--National

Hydrologist Planner	0.5 mo @ $ 8,000/mo	4,000
Jr. Hydrologist	1 mo @ $ 6,000/mo	6,000
Draftsman	1 mo @ $ 500/mo	500
Travel		2,000
Printing Report		1,000
Unforeseen 15%		2,000
	Total	US $ 15,500

Regional Plan.

While National Plans are limited by artificial boundaries, contiguous states must recognise the needs of other country users downstream of their own territory to avoid uneven and inequitable development. By drawing attention to regional development such potential defects can be seen and presented in time and the only way of achieving this is to prepare regional plans.

The Savanna Region can be divided into several well-defined sub-regions by considering the principal river basins, namely:

The Senegal in the northwest

The Gambia, Casamance and others in the west

The Niger in the center

The Ivory Coast rivers in the south (Comoe, Sassandra, etc.)

The Volta in the south

The Benue

The Chari-Logone in the east

The Bangui in the southeast (north or right-bank tributaries)

As in the case of National Plans, a few suitable existing regional plans can be adapted for use in West Africa, so there will be no need for prolonged base work in preparing a model regional master plan, again assuming that existing plans will be accessible.

Cost of Study--Regional

The cost of setting up a detailed standardised regional plan over a period of 2 months is estimated to cost as much as the national plan: $15,500, and require similar staffing.

References

1) El-Shibini, F.Z. and J.R. Rydzewski (1977) "Towards an optimal utilization of the water resources of the Nile basin," Proceedings of the Institution of Civil Engineers, Part 2, 63, p. 35-47.

2) Governments of Egypt, Sudan, Ethiopia, Uganda, Kenya, Tanganyika (1929, 1959), Nile water agreements of 1929, 1959.

3) Senghor, Adrien (1977) Communication...devant l'Assemblée Nationale sur la politique de l'eau, Dakar, le 14 janvier, 1977. 2 vols. Dakar, Ministère du Developpement Rural et de l'Hydraulique.

4) TAMS (1976) Kenya national master water plan: detailed work plan. Nairobi/New York

5) United Nations Development Program (1978) Stratégie d'aménagement des eaux de Togo, premières phase. Lomé.

INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

OUAGADOUGOU

UPPER VOLTA

SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: WP 03

TITLE OF STUDY: Water Conservation in the Savanna Region

ESTIMATED COST: US $69,000

DATE OF PROPOSAL: March 1978

Summary of the Problem

A basic problem in large areas of the Savanna Region is to find suitable ways and means of retarding and retaining surface runoff. Much has already been achieved in this respect through construction of dams and reservoirs and in some instances terracing of slopes in small river basins. Some existing techniques (sub-surface dams, smoothing of watersheds, water harvesting catchments, piping of springs) are for various reasons not applied. Other, newer techniques, such as the reduction of evaporation using polystyrene rafts are not well enough known. In countries such as Upper Volta where there are over 300 small dams with a mean storage of just over 1 million m^3, representing a considerable outlay, the reduction of 1/3 to 1/2 of the total water lost to evaporation and seepage would represent a significant saving.

Solution to the Problem

This study will identify which water conservation techniques can be best applied and which areas of the West Africa Savanna Region are most suitable, bearing in mind that choice of techniques is usually limited to only one or perhaps two in specific areas. For example, development of springs is only possible where geology favouring this mode exists e.g., at Banfora in south-west Upper Volta, and in the Atacora Mountains (Togo and Benin). Such areas make up less than 1% of the total Savanna Region, nevertheless they are important by virtue of the high quality and in a few cases, the large quantity of water available. A case in point is the dry-weather flow of the Kou River (Banfora). This is largely fed from springs and exceeds 250,000 m^3 per day, which can be compared with the peak demand of Ouagadougou of 15,000 m^3/day.

The study will list the advantages and disadvantages of various possibilities, according to, for example, climatic zone or the nature of the land and its geology. Constraints in applying various techniques will be analysed (including socio-economic aspects) and specific guidelines and

recommendations given as how best to retain surface water for the dry season.

It is suggested that CIEH undertake this study in collaboration with one of the universities in the southwest U.S.A., where similar problems exist and where solutions have been found or work is in progress to solve such issues as specifying suitable materials for catchment construction, etc.

It is also recommended that this work be carried out not only as a desk exercise but that facilities be provided for experimentation and demonstration under field conditions.

Summing up, there is little point allowing surface water to run away if a small fraction can be captured and retained at sub-surface depths. The alternative is laborious extraction from ground-water.

Cost of Study

1 hydrological engineer	3 mo	@	$8,000/mo	24,000
1 Jr. hydrological engineer	4 mo	@	$6,000/mo	24,000
Travel	4 trips		$1,000	4,000
Printing and Report/Maps				3,000
Material for demonstrations--sum				5,000
Unforeseen 15%				9,000
			Total US	$ 69,000

INTERAFRICAN COMMITTEE FOR HYDRAULIC STUDIES

OUAGADOUGOU

UPPER VOLTA

SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: WP 04

TITLE OF STUDY: Appraisal of Hydro-Agricultural Schemes Implemented in the Recent Past

ESTIMATED COST: US $24,000

DATE OF PROPOSAL: March 1978

Summary of the Problem

A wide range of agricultural projects, irrigation schemes, hydro-electric plants have been implemented in the West African Savanna Region. After the establishment of such schemes, little is (publicly) made known about their continued performance/production, whether the project is to be considered a success or failure in terms of the original expectations or in terms of today's views on project performance. As a consequence little understanding is gained that could be applied to new projects.

Solution to the Problem

A post-project evaluation is required for a selected number of water resource development projects that were conceived and implemented in the period 1965-1975. A report will outline reasons for failure and apparent success of such projects that would help in the design of new projects.

The net time spent is likely to be about 2 months, spread over a period of about 1 year. No specific travel will be involved, the exercise being one of critical desk review. Each project will be studied critically, using official reports, press releases and reports by independent observers.

Cost of Study

1 Engineer or Agriculturalist	1 month $8,000	8,000
1 Junior Agriculturalist	2 months $6,000	12,000
Printing, etc.		1,000
Unforeseen 15%		3,000
	Total US	$ 24,000

STUDY PROPOSALS: CLIMATE/LAND USE

CLIMATE AND FOOD PRODUCTION

In order to determine how much water needs to be allocated to irrigation in the Savanna Region two basic issues need to be resolved: (1) estimation of market demand for food/fiber/industrial crops, and (2) estimation of food production in non-irrigated areas (taking into consideration expected improvements of rainfed agriculture). The difference between (1) and (2) will be the agricultural production which must be made up by imports or irrigated production.

The following eight study proposals are primarily presented to better define what can be produced under rainfed agriculture. Here, the emphasis is not on how to attain this production since it is felt that this is better left with the specialized national and regional agricultural organizations.

The upper limits to agricultural production are set by:

(a) the climate, particularly rainfall and temperature. Where water is not the limiting factor, production limits are set by potential photosynthesis which depends on total net radiation.

(b) the availability of suitable soils in which plants can grow.

(c) the ability of crops and varieties to convert the resources of the climate (water, net radiation, etc.) to useful end products. This can be expressed in terms of their energy and water use efficiencies.

(d) man's knowledge of (a), (b) and (c) above, and the economic and sociological factors affecting the practical application and exploitation of this knowledge.

The study proposals therefore call for:

1. Delineation and elaboration of the basic resources of climate and soils.
2. Quantification of yield potential of crops and crop varieties matched to the local climate.
3. Definition of the practical potential productivity of each bioclimatic area.
4. Comparison of practical potential productivity with present land use and quantitative definition of the gap between the two.
5. Recommendations to overcome constraints in order to narrow this gap.

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UPPER VOLTA

SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: CP 01

TITLE OF STUDY: **Climatic Variability (Confidence Limits) in the Savanna Region in relation to Agriculture**

ESTIMATED COST: US $124,000

DATE OF PROPOSAL: **July 1977, September 1977**

Summary of the Problem

Agricultural planning and the rational evaluation of alternative agricultural strategies is now limited by the lack of sound statistical analyses of climatic data, particularly as regards year to year climatic variations expressed as probabilities (confidence limits). Climatic parameters expressed in terms of stated probabilities are essential for the scientific matching of specific crop varieties to local growing seasons, and this is the only rational approach to the solution of problems created by the variability of climatic events about the mean.

Solution to the Problem

The purpose of the study is to analyse statistically the probability (confidence limits) of selected climatic parameters affecting annual and perennial crops as well as pasture and forestry activities in the Savanna of West Africa.

This project assumes parallel or prior work on the setting up of the CIEH water data bank (see Study Proposal WP 01). It involves (a) the careful selection of all those climatic parameters held to influence crop adaption and crop development at various stages of the plant growth cycle, and (b) their statistical analysis. This will require the services of an agroclimatologist working in consultation with specialists in such related fields as soil physics, agronomy and crop physiology. The choice of parameters to be analysed will be based on known crop requirements and normally will involve the statistical analysis of temperature and other requirements for a specified length of growing period in order to make choices between crop variety alternatives or assess the probabilities of the occurrence of unfavourable conditions. To the extent that the requirements of different crops and crop varieties can be quantified it is then possible to calculate the risks attached to the growing of a specific variety in a specific location in terms of the percentage of years that crop failure due to climatic variability can be expected. Without this information, the selection of varieties adapted to local climates and growing seasons is at best only guesswork based on empirical hit or miss methods.

The duration of the project is estimated at 6 months and expected outputs include a series of maps which will, on a regional basis, express the confidence limits attached to those climatic parameters selected as capable of affecting crop production, as well as range and forestry activities.

Cost of Study

Agroclimatiologist	6 mo @ $8,000	48,000
Consultants in related fields	6 mo @ $8,000	48,000
Cartographic Services		2,000
Travel		5,000
Printing Report/Maps		5,000
Unforeseen 15%		16,000
	Total US	$ 124,000

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: CP 02

TITLE OF STUDY: Dry Season Climatic Resources of the Savanna Region in relation to Irrigation

ESTIMATED COST: US $153,000

DATE OF PROPOSAL: July 1977, September 1977

Summary of the Problem

Potential crop yields under irrigation, as determined by climatic factors of the dry season, are largely unknown. To date, most studies of the Savanna Region have been focused on the wet season and the rainfed agriculture associated with it. The dry season lasts from about three months in the south to about ten months of the year at the 400 mm isohyet in the north, and during these periods both land and farmers are traditionally relatively idle. Irrigation projects can be expected to modify this situation, but in planning irrigation development during the dry season in the various West African bioclimatic zones, precise information on potential productivity is needed, and this in turn will necessitate greater knowledge of the bioclimatic factors affecting crop growth. These bioclimatic factors include, but are not limited to: (1) net radiation and photosynthetic potential, which are generally high because of low cloud cover; (2) the dry, dust-laden harmattan winds and their effects; (3) the very high evapotranspiration rates likely from small irrigated areas because of the advective energy of winds, and (4) high daytime soil temperatures, low night temperatures, low average dry season temperatures and wide diurnal ranges of temperature.

Solution to the Problem

The purpose of this study is to assess and interpret climatic parameters affecting dry season crop production under irrigation in the various bioclimatic zones of the Savanna. Information on all West African experience of irrigation so far will be collected and analysed in relation to climate, but will also be supplemented by information on relevant experience elsewhere, outside the region, which might act as a guide to the climatic parameters of most relevance to dry season crop production in the Savanna.

The study will be facilitated by, and follow on from, the studies concerning the water data bank (see Study Proposal WP 01) and the statistical analysis of climate (see Study Proposal CP 01). It will require the services of

specialists in the fields of climatology/agroclimatology, with subsidiary inputs from agronomists and crop physiologists. The duration of the study is estimated at 9 months.

Cost of Study

Sr. agroclimatologist	9 mo @ $8,000		72,000
Short term consultants in agronomy, crop physiology	6 mo @ $8,000		48,000
Cartographic services			3,000
Travel			6,000
Printing Report/Maps			4,000
Unforeseen 15%			20,000
		Total US	$ 153,000

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: CP 03

TITLE OF STUDY: **The Two-Peak Rainfall Regime of the Southern Savanna Region and its Agriculture**

ESTIMATED COST: US $247,000 (Phase I)

DATE OF PROPOSAL: **July 1977, September 1977**

Summary of the Problem

The Southern Guinea Climatic Zone, which has a two peak rainfall regime, is underutilized and population densities remain relatively low in comparison with much of the rest of West Africa. There is as yet no concensus as to the real reasons for this underutilization, or ways to tackle it.

The Southern Guinea Zone has rainfall maxima in June and September with a relatively dry August which, particularly in the southern part of the area, divides the rainy period into two wet seasons. In planning for dryland farming, it has proved more difficult to match crops and cropping systmes to these two relatively unreliable wet seasons than it has been to match them to the single, better defined wet season of the Sudan Savanna to the north or to the wetter areas of the forest zone to the south. Potential net photosyntesis is lower than in the Savanna areas to the north, and the longer wet season appears to favour pests and diseases of both crops and livestock. These areas include parts of the so-called "middle belts" of Ghana and Nigeria noted for their low population densities. The relatively low ratio of people to land suggests underutilization. This underutilization and consequent apparent potential for further agricultural development was emphasized, in the case of Nigeria, by the FAO report "Agricultural Development in Nigeria, 1965-1980" (FAO , 1966). Any development plan however will first have to identify the climatic and other restraints and show how they can be overcome.

Solution to the Problem

The purpose of this study is to (1) identify those climatic factors which impede agricultural development in the two-peak rainfall areas of the Southern Guinea Zone, and (2) to work out solutions to overcome these climatic constraints. This can be achieved through a two-phase approach. In Phase 1, a systematic study of all aspects of the agroclimatology of the currently little used bioclimatic area is required in order to clarify and quantify the extent to which climate itself is limiting, and to form the basis of a more scientific

approach to the matching of crops with climate. The first phase is thought of as lasting about nine months. It will involve specialists in the fields of agroclimatology and soil science, with subsidiary inputs from specialists in agronomy, plant physiology and pathology, range management, etc.

A second phase is needed to provide viable development strategies. A widening of the field of research is called for to form an integrated consideration of climate, cropping, soil, livestock, human and economic problems of a zone which has long been something of a problem area for farmers, climatologists, agronomists and geographers. The second phase will therefore include the identification of a wider range of specialists, and the commissioning of individual studies, in order to arrive at a broader based assessment of the potential of the two-peak rainfall Savanna areas and to assist in identifying development possibilities. In a workshop or conference organised by CIEH, possibly in cooperation with another international agricultural organization, specialists in relevant fields will be brought together to focus attention on the problems and possibilities of the zone, and the various viewpoints and approaches published.

Cost of Study

Phase I.

Agroclimatologist	9 mo @ $8,000	72,000
Soil Scientist	6 mo @ $8,000	48,000
Consultants	9 mo @ $8,000	72,000
Cartographic and Computer Services		5,000
Travel		8,000
Printing Report/Maps		10,000
Unforeseen 15%		32,000
	Total US	$ 247,000

Phase II.

The costs of this phase can be estimated upon completion of Phase I. Phase I is estimated to last about 9 months, Phase II to last about 12 months with an additional 3 months for report editing and publication by CIEH. Total project duration is therefore about 24 months.

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: TP 01

TITLE OF STUDY: Soil Fertility-Climate Relationships in the Savanna Region

ESTIMATED COST: US $176,000

DATE OF PROPOSAL: September 1977

Summary of the Problem

One of the factors involved in increasing crop production under dry land farming is an improved knowledge of the basic properties of the soil in different bioclimatic zones.

The soils of West Africa are closely related to climate and vegetation belts. Their systematic study and utilization is helped by an appreciation of the relationships between soil characteristic and productivity on the one hand and climate on the other. To some extent these relationships and their effects can be quantified. A systematic study and interpretation of these fundamental relationships is now possible by the increase in our knowledge of both West African climate and of soils in the last few years.

Solution to the Problem

The purpose of this study is to define the basic soil/climate relationships in West Africa on a regional basis, which, in addition to explaining soil characteristics, affect the behaviour of the soil under cultivation, and the extent to which fertilizer nutrients can be expected to move in the soil or be lost by leaching to lower horizons. The fate of added organic residues and the extent to which humus levels can be built up, best understood in relation to humus equilibrium levels, will also be taken in consideration.

The main relationships involved appear to be:

(a) the relationships between total rainfall, length of growing season, amount and type of vegetation and the organic matter content of the soil. The organic matter content in turn influences the structure of the soil, its water storage and cation exchange capacities, and the liberation of plant nutrients due to humus mineralisation, and is therefore fundamental to soil productivity.

(b) the relationship between the seasonal surplus of rainfall over evapotranspiration in various bioclimatic areas and the role of this water in parent material weathering and the removal of substances in suspension and in solution within, or right out of, the soil profile. Soil reaction and the movement of nutrient ions are much affected by the extent of wet season leaching, which varies greatly between bioclimatic areas.

The investigation will include the examination of the extent to which this general relationship is modified locally by differences in soil parent material and in drainage.

The duration of the study is expected to be nine months. A senior soil scientist working for the duration of the project will coordinate activities and draw upon subsidiary inputs of a junior soil scientist and consultants in climatology and soil science responsible for local data collection and interpretation within the general framework agreed upon.

Cost of Study

Sr. Soil Scientist	9 mo @ $8,000	72,000
Jr. Soil Scientist	6 mo @ $6,000	36,000
Consultants	4 mo @ $8,000	32,000
Cartographic and Computer Services		5,000
Travel		5,000
Printing Report/Maps		3,000
Unforeseen 15%		23,000
	Total	US $176,000

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: TP 02

TITLE OF STUDY: **Soil Erosion-Climate Relationships in the Savanna Region**

ESTIMATED COST: US $152,000

DATE OF PROPOSAL: **September 1977**

Summary of the Problem

A realistic assessment of practical crop production potentials and of the steps necessary to achieve them in the different bioclimatic zones of the Savanna Region requires comprehensive and up-to-date information on the physical characteristics of the soils and in particular on the erosion hazard.

A number of useful erosion studies have been carried out on agricultural stations, particularly by Francophone workers at Sefa, Senegal and at Adipodoume, Ivory Coast, but these are very localized and a more systematic study is needed of the basic factors responsible for erosion, their effects and control.

Erosion occurs as widespread sheet erosion, removing progressively the upper layers of the soil, and as gullies. Although gullies are the more spectacular form, sheet erosion is the more widespread type of erosion, and it is particularly damaging because its presence and effects are not so immediately striking and obvious as gully erosion. Many of the more heavily cultivated areas of the Savanna Region have their productivity sericusly reduced by widespread topsoil removal and this is particularly damaging where a relatively fertile topsoil overlies a poor gravelly subsoil, as is the case of many ferruginous soils of the Savanna Region.

Erosion is important because of (a) the very erosive nature of the West African rainfall, characterised by many heavy storms with high rainfall intensities, drops of large size and high kinetic energy loads, and (b) the fact that annually cultivated ground is usually bare at the beginning of the wet season.

Solution to the Problem

The purpose of this study, a logical corrolary of proposal TP 01, is to synthesize available information on soil erosion on a regional basis in relation to climate. The study will include investigations on:

- the erosivity of the climate
- the erodibility of the soils
- the extent of erosion to date and its effects on agricultural production
- remedial measures practicable and future prospects of soil conservation

The extent to which the erosion hazard as defined by the erosivity of the climate and the erodibility of the soil actually results in physical erosion depends on the gradient and length of slope (easily quantifiable) and the cultural practices and erosion control measures adopted by the farmer concerned. The last are the main variables. The degree and type of erosion control necessary to reduce erosion to negligible or at least acceptable limits can be indicated from the study of the other parameters involved, thus providing a logical and scientific approach, rather than a merely empirical one, to the problems of erosion control.

The main results of this study will be specific recommendations, on a regional basis, for erosion control measures thought best suited to the local erosion hazard as defined by climate, soil and slope, as well as an indication of what losses are estimated to be if current local agronomic practices are not suitably modified to provide better protection. (It should be noted that erosion control measures recommended in other areas of the world are not necessarily applicable to the Savanna, because of differences in cultural practices and rainfall intensities.)

Cost of Study

Sr. Soil Scientist	6 mo @ $8,000	48,000
Jr. Soil Scientist	6 mo @ $6,000	36,000
Geomorphologist	2 mo @ $8,000	16,000
Climatologist	1 mo @ $8,000	8,000
Agronomist	2 mo @ $8,000	16,000
Draftsman	2 mo @ $ 500	1,000
Travel		4,000
Printing Report/Maps		3,000
Unforeseen 15%		20,000
	Total US	$152,000

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: TP 03

TITLE OF STUDY: Rainfed Crops of the Savanna Region - their Adaptability and Yields

ESTIMATED COST: US $170,000

DATE OF PROPOSAL: September 1977

Summary of the Problem

The Savanna wet season is as long as nine months in the southern savanna areas but as little as about two months at the northern limit of cropping corresponding to the 250 mm isohyet. Changes in length of dry season are associated with changes in total rainfall. This diversity of climate within a single region requires a diversity of crops and crop varieties to give an acceptable matching of crops grown to local moisture regimes. The scientific matching of crops to climate requires an analysis of the climate, preferably in terms of confidence limits, and a comprehensive knowledge of the climatic and soil requirements of individual crop varieties, particularly water needs at different stages of growth and the effects of variations in day length and total net radiation.

Increased crop production in the Savanna Region requires better information on the wide range of climatic factors involved and the cropping possibilities and strategies possible.

Solution to the Problem

The purpose of this study is to provide for:

(a) a more systematic knowledge of the exact soil and climate needs of crop varieties, and of their potential yields under optimum conditions;

(b) the systematic matching of these known needs to the soil and climatic resources of the Savanna with the rational selection of alternative crops and cropping systems.

Work on these main themes will be undertaken essentially by coordinating the efforts of a number of consultants engaged to investigate well defined aspects of the study, since as a whole it extends over too many crops and areas to be carried out by a single person in reasonable time. The matching of crop needs to climate will primarily be the task of an agroclimatologist working

in consultation with agronomists. The soil requirements of West African crops are not usually particularly narrow but can be defined in broad terms and an indication given of the extent of soil limitations in each climatic zone otherwise suitable can be given by a soil scientist. The most difficult part of the study will concern the limited amount of exact knowledge as to the climatic needs of specific crops and crop varieties and here the cooperation of agronomists and plant physiologists will be needed.

Cost of Study

Project manager - Agroclimatologist	9 mo @ $8,000	72,000
Consultants	8 mo @ $8,000	64,000
Travel		10,000
Printing Report		2,000
Unforeseen 15%		22,000
	Total	US $ 170,000

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SAVANNA REGIONAL WATER RESOURCES AND

LAND USE PROJECT

STUDY PROPOSAL

NUMBER OF STUDY: TP 04

TITLE OF STUDY: Irrigated Crops of the Savanna Region - their Adaptability and Yields

ESTIMATED COST: US $170,000

DATE OF PROPOSAL: September 1977

Summary of the Problem

Irrigation agriculture is as yet practiced only to a very limited extent in the Savanna Region. However, vast irrigation projects are being designed and will be executed in the near future. Relatively little is known about the crops and crop varieties best suited to irrigation and to the climatic conditions prevailing in the Savanna dry seasons.

The assessment of dry season climatic conditions in relation to plant growth has been proposed as Study Proposal CP 02. The collection and analysis of information on crop varieties adapted to dry season climates with irrigation, and their potential yields, is a logical complementary task.

The greater diurnal range of temperature associated with the season and low night temperatures affect crop selection and performance. Water needs of crops may be much higher than anticipated if not grown in blocks large enough to overcome the wind fetch effect, which can extend across 60-75 meters.

Solution to the Problem

As in the case of study Proposal TP 03, the purpose of this study is to provide for (a) a more systematic knowledge of the exact soil and climatic needs or tolerances of crop varieties, and their potential yields when these conditions are satisfied and water is not a limiting factor, and (b) the systematic matching of these needs to the dry season climatic conditions of the Savanna assuming the availability of irrigation water.

The inputs needed and the type of specialist consultant services required will be comparable to those enumerated for study Proposal TP 03, and some advantages would be obtained by having the two studies carried out at the same time.

Cost of Study

Project Manager- Agroclimatologist	9 mo @ $8,000	72,000
Consultants	8 mo @ $8,000	64,000
Travel		10,000
Printing Report		2,000
Unforeseen 15%		22,000
	Total	US $170,000

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STUDY PROPOSAL

NUMBER OF STUDY: TP 05

TITLE OF STUDY: Potential Crop Production in the Savanna Region

ESTIMATED COST: US $174,000

DATE OF PROPOSAL: September 1977

Summary of the Problem

As stated in the introductory section to this group of study proposals dealing with climate, soils and agriculture, an estimate of practical potential food production under rainfed farming is needed to arrive at a better allocation of water for irrigation.

CIEH is currently undertaking a study of present land use and production levels of the Savanna Region. Knowledge on what can be produced in each of the Savanna Region bioclimatic zones in agriculture needs to be synthesized. Then a comparison of present and potential crop production can be made to show how production can be increased.

Solution to the Problem

The purpose of this study is to determine for each bioclimatic zone, and for defined areas within zones, the practical potential level of the major food crops. Practical potential production can be thought of as the production level which appears practicable using known and proved techniques. A realistic assessment of practical production potential must avoid vague or unproved assumptions. Practical production potentials will vary considerably between bioclimatic zones, and according to the relative importance given, in alternative development strategies, to agriculture, forestry and range management.

Practical potential production refers to what is attainable at different, realistic levels of management, not theoretical upper limits ignoring practical restraints or based on unproved assumptions. An indication of practical potential production is given by what the best varieties produce with good management, and this potential is not static, but will tend to increase as new varieties and techniques are introduced. A calculation of practical potentials as advocated here in no way suggests or assumes that traditional practices of agriculture can or should be swept aside in favour of other systems as yet unproved, but it does seek to quantify what is practicable in terms of present knowledge and proved experience.

The study will, it is assumed, follow on and draw upon the results of the previous seven proposals in this series.

In an additional phase of the study, alternative ways of increasing production and of narrowing the gaps between present and potential production levels will be considered, and the relative merits of each will be indicated.

This strategy can be put forward as a practical proposition only because, and to the extent that, we now have knowlege of basic climate and soil resources, and of the nature and intensity of current land use in the Savanna Region. The strategy therefore makes use of, and builds on, the data presented in the other three volumes of this report and the Land Use Map, completed in 1978 as part of the Savanna Regional Water Resources and Land Use Project.

The present study will require inputs from the same fields as earlier study proposals.

Cost of Study

Project manager- Agronomist	9 mo @ $8,000	72,000
Consultants in agroclimatology, soils, agronomy, ag. economics, etc.	8 mo @ $8,000	64,000
Travel		10,000
Printing Report/ Maps		5,000
Unforeseen 15%		23,000
	Total	US $ 174,000

ANNEX

List of Study Proposals

Below is a list of all study proposals prepared during the synthesis of the Savanna Resources report. A detailed description of each proposal is available for reference at CIEH. Studies marked with an asterisk are included in this volume.

*HP 01 - Stream flow data

*HP 02 - Water quality data

- Hydrology of small watersheds

*HP 03 - Hydrology of large watersheds

- Short duration rainfall intensities
- Area-depth of rainfall relation
- Areal extension of rainstorms

*HP 04 - Storage required to produce different rates of regulated flow

*HP 05 - Effect of upstream irrigation development upon the flow regime of the Niger River

*HP 06 - Reduction of water losses in the inland delta of the Niger River

- Trends and persistence in natural phenomena
- Lack of climatological and hydrological data on anglophone countries#
- Aspects of surface water measurement

*GP 01 - Construction of wells and boreholes and installation of pumps in West Africa

*GP 02 - Operation and maintenance of wells and boreholes and pumps in West Africa

- Artificial recharge to groundwater
- Aquifer modelling applicability

*GP 03 - Observation well network

*GP 04 - Development and management of Savanna groundwater Reservoirs

- Groundwater data bank#
- Applicability of shallow ground temperature surveying to well siting
- Groundwater level fluctuations analysis
- Natural groundwater recharge evaluation
- Pump experiments in N. Ghana

*WP 01 - CIEH regional multi-purpose water data bank

*WP 02 - Model master plan for water resources development

*WP 03 - Water conservation in the Savanna Region
- Water-spreading in the Savanna Region
- Low cost rainfall catchments
- Subsurface dams
- Use of ox-scoops for the construction of small earth dams and terraces
- Piping of springs

*WP 04 - Appraisal of selected hydro-agricultural schemes implemented in the recent past
- Trans-Africa electricity supply network
- Establishment of a climatic data bank for West Africa at CIEH#

*CP 01 - Climatic variability in the Savanna Region in relation to agriculture

*CP 02 - Dry season climatic resources of the Savanna Region in relation to irrigated agriculture

*CP 03 - The two-peak rainfall regime of the Southern Savanna Region and its agriculture

*TP 01 - Soil fertility-climate relationships in the Savanna Region
- Fertilizer responses in the Savanna Region in relation to soils, climate and vegetation
- The use of locally produced rock phosphate in the Savanna

*TP 02 - Soil erosion-climate relationships in the Savanna Region
- Soil survey coverage and interpretation in the Savanna

*TP 03 - Rainfed crops in the Savanna Region - their adaptability and yields

*TP 04 - Irrigated crops in the Savanna Region - their adaptability and yields

- Shifting cultivation in the Savanna in relation to soils and climate
- Range management and pasture improvement in the Savanna in relation to soils and climate
- Reaforestation possibilities in the Savanna in relation to soils and climate

*TP 05 - Potential crop production in the Savanna Region

- West African regional remote sensing center##
- Regional gaps in CIEH information
- Agro-economic analysis of sample areas

See Study Proposal WP 01 - CIEH regional multi-purpose water data bank

Already submitted to USAID for financing and implementation