Government of The Netherlands
Min. of Foreign Affairs/DGIS
Min. of Agriculture and
Fishery/DLO

International
Institute of Tropical
Agriculture (IITA).
Ibadan - Nigeria

# Wetland Utilization Research Project
West Africa

## Phase I
The Inventory

By: Ir. P. Hekstra
Ir. W. Andriesse
Ir. C.A. de Vries
Ir. G. Bus

Volume I: Main Report

April 1983



Institute for Land Reclamation & Improvement
Wageningen - The Netherlands

# WETLAND UTILIZATION RESEARCH PROJECT

West Africa



## Phase I

## The Inventory

By: Ir. P. Hekstra (editor) - Land and Watermanagement (ILRI)
Ir. W. Andriesse - Soil Survey and Landevaluation (STIBOKA)
Ir. C.A. de Vries - Agro-economy (KIT)
Ir. G. Bus - Sociology (KIT)



## VOLUME I: MAIN REPORT

(Summary, Conclusions and Recommendations)

International Institute
for Land Reclamation
and Improvement
ILRI - Wageningen

Soil Survey Institute
STIBOKA - Wageningen

Royal Tropical Institute
KIT - Amsterdam

CONTENTS Page

# FOREWORD

At the end of 1980, the International Institute of Tropical Agriculture (IITA) at Ibadan-Nigeria, requested the Government of The Netherlands for technical and financial assistance with its proposed Wetland Utilization Research Project (WURP). IITA officially submitted its proposal in 1981 comprising three phases:

- Phase I. The collection and evaluation of sufficient information for the identification of types and extent of wetlands and the assessment of the capabilities and constraints to the productive use of these wetlands. This should lead to the selection of a maximum of 3 representative benchmark sites, suitable for the implementation of Phase II;
- Phase II. The development of suitable technologies and methodologies of soil, water and crop management on 3 benchmark sites;
- Phase III. Assistance to those national governments or institutions, which desire to identify the wetland areas where improved or newly developed technologies and methodologies could be applied.

The objective of the project is to develop economically viable integrated (rice-based) farming systems on the soils of the topsequences of wetland areas and to identify or to develop a methodology by which the transfer of the new technology or certain elements of it, could be implemented with a high degree of success, ultimately aiming at the increase of the food production by smallholding farmers through the intensive utilization of wetland in tropical West Africa, based on village-level development without major imputs.

The implementation of the whole programme is proposed to be a joint effort of the IITA-Nigeria and the various land and water research institutions within the Dutch Ministry of Agriculture and Fishery/DLO. However, commitment by the Dutch Government has been made only to Phase I, yet.

This report presents the results of the study in respect of Phase I, the inventory. It provides a synthesis of available information about wetlands in West Africa, with the objective:

- to identify the different categories of wetlands and their potential and scope for development of rice-based smallholder farming systems;

- to select three representative benchmark sites for implementation of Phase II;
- to give the Dutch Government the necessary information so that it can evaluate the request from IITA and can decide upon the extent and degree of participation in the implementation of Phase II (and possibly of Phase III).

IITA will soon formulate a revised proposal WURP-Phase II, for presentation to the donor. Based on the findings of this inventory, the proposal will comprise the details of the research programme, estimates of the capital and operational expenditures and of the manpower requirements.
In anticipation of this proposal it may be said here that in West Africa present levels of rice yields are low and the costs of domestic rice production are relatively high.
Therefore the research should aim at maximizing returns to the scarce production factors, such as labour and other inputs. The research should be directed to appropriate technology developing techniques of rice production which fall significantly below current cost of domestic rice production and/or technologies that would significantly increase the rice production on smallholdings.
The large area of inland valleys of more than 10 million ha with potential for rice production, but presently marginally used, warrants that this research project can considerably contribute to improving the precarious food situation in West Africa.

# KEY-ISSUES

## 1. THE INVENTORY AREA

The inventory area has been confined to the area with a growing period of a minimum of 165 days to year round, allowing rainfed double cropping or more.

The total inventory area covers approximately 2.2 million $km^2$:
- the humid or Equatorial forest zone, (0.9 million $km^2$);
- the sub-humid or Guinea savannah zone, (1.3 million $km^2$).

It comprises, either partly or wholly, all coastal countries of West Africa from Guinea Bissau through Cameroon.

## 2. LAND REGIONS

Based on the geomorphology and geology, the inventory area has been divided into four land regions. These land regions are broad landscape units with recurrent physiography. They are:
- Coastal Plains: 100,000 $km^2$, or 4.6% of the inventory area;
- Interior Plains: 1,075,000 $km^2$, or 49.8% of the inventory area;
- Plateaux: 624,000 $km^2$, or 28.9% of the inventory area;
- Highlands: 361,000 $km^2$, or 16.7% of the inventory area.

The Interior Plains and the Plateaux are the most significant land-regions, comprising nearly 79% of the inventory area. Lithologically, the main differentiation within these two land regions is:
- Basement complex: 79.6% of the Interior Plains and Plateaux;
- Sedimentary deposits: 20.4% of the Interior Plains and Plateaux.

## 3. TYPES OF WETLAND AND DISTRIBUTION

The following four types of wetland have been distinguished in the inventory area (see Table 1):

a. Deltas, tidal and large inland swamps, estimated at 36,700 to 74,400 $km^2$ (1.7 to 3.5% of the inventory area).

b. River valleys:

   b.1 River floodplains (large floodplains) covering between 54,200 and 129,700 $km^2$ (2.5 to 5.9% of the inventory area)

   b.2 Overflow valleys (small floodplains) covering between 80,100 and 194,100 $km^2$ (3.6 to 9.0% of the inventory area)

   b.3 Streamflow valleys (small inland valleys) covering between 101,200 and 218,100 $km^2$ (4.7 to 10.0% of the inventory area).

The total wetland area has thus been estimated somewhere between 272,200 and 616,300 $km^2$, or 12.6 to 28.5% of the inventory area. Approximately one third of the total wetland area is occupied by streamflow valleys. Because of the objective of developing low-cost input technologies for smallholding farmers, this type of valley will be the main subject of the proposed research project. Within this type of valley, however, a great variation in morphological, hydrological and pedological characteristics has been reported.

4. POPULATION AND PRESSURE ON LAND

The average population density in West Africa is 19 $p/km^2$. This is low compared with most other regions in the world. However, in the inventory area (47 $p/km^2$) it is much higher than in the arid area to the north (6 $p/km^2$). Within the former area, Nigeria has the highest population density (83 $p/km^2$), followed by Ghana, Sierra Leone and Togo (48 $p/km^2$).

5. WETLAND RELATED DISEASES

There are two major wetland related human diseases. Schistosomiasis (bilharzia) is related to slowly flowing or stagnant water. Onchocerciasis (river blindness) is associated with aerated turbulently flowing water. Other wetland related diseases are dracunculiaris (guinea worm), malaria and trypanosomiasis (sleeping sickness). All these diseases may occur in any place in the inventory area with favourable vector habitat conditions. They form a great menace to the health of especially the rural population.

6. THE ROLE OF RICE IN FOOD SUPPLY

The average consumption of rice in West Africa is low (about 20 kg/capita/year), but differences between countries are large. In the inventory area, rice is a staple food only in Liberia and Sierra Leone (about 100 kg/capita/year). Consumption is substantial in Guinea, Ivory Coast and Guinea Bissau, but very low in Ghana, Cameroon, Benin, Togo and Nigeria (about 10 kg/capita/year). However, rice consumption has sharply increased in countries where it was very low in 1950. It has remained stable or declined in countries where it was relatively high (Liberia, Sierra Leone and Guinea).

Between 1950 and 1980 rice production increased substantially in all countries of the inventory area, except Guinea Bissau. On average, production could keep pace with the population growth. However, it could not keep pace with the consumption increase per capita, so that the self-sufficiency rate of rice production in the inventory area decreased from almost 100% in 1950 to 62% in 1980. In the arid area to the north the self-sufficiency rate in 1980 was even lower: 30%. Consequently, rice import has increased tremendously. In 1980, rice import (about 1.4 million tons) was only slightly less than domestic production (1.8 million tons). Present rice yields (paddy) in the inventory area and in West Africa as a whole, are rather low (1.3 ton/ha). The largest rice growing areas are found in Nigeria (over 600 000 ha), Ivory Coast, Sierra Leone and Guinea (over 300 000 ha). In West Africa rice is produced mainly by smallholders.

7. NATIONAL POLICIES

Government policies in West African countries are directed towards self-sufficiency in rice production. These policies are sustained not only by research, agricultural extension and development programmes to promote rice production, but in most countries of the inventory area also through subsidies on inputs, output, transport, processing, storage or marketing, or by a levy or quota system on rice import. These policies have saved much foreign currency. However, the negative aspect of the subsidies is that they increase the cost price at the national level, while the levy and quota system increases the consumer price. This is most serious in Nigeria and Ghana, substantial in Ivory Coast and Liberia and least in Benin, Sierra Leone and Togo.

8. RESEARCH NEEDS

Research on 'rice-based smallholder farming systems in wetlands in West Africa' is justified and urgently required because of:

- the sharp increase in rice demand,
- the continuous decrease in self-sufficiency in rice and in food supply as a whole,
- the high costs of food import.

The research should aim at maximizing returns to scarce production factors, such as labour (high cost and low productivity) but also other inputs.

Therefore, such research should be directed to appropriate technology, developing techniques of rice production which fall significantly below current cost of domestic rice production and/or technologies that would significantly increase the rice production on smallholdings. These technologies are related not only to the methods of production, but also to methods of land and water development.
The large area of inland valleys (over 10 million ha) with potential for rice production, but presently marginally used, warrants that this research project can considerably contribute to improving the precarious food situation in West Africa.
It is recommended that research in Phase II primarily directs itself to the following subjects (see IITA proposal, July 1981 for details):

- site characterization, incl. infrastructural and organizational requirements;
- site development;
- soil and water management (including upland)
- farming/cropping systems with attention to toposequential relationships;
- agro-socio-economic aspects, which should anyhow form the backbone of an appropriate research programme as well as the application of the results;
- characterization of the inland valleys (mainly streamflow valleys) and the set-up of a classification system.

It is noted that technologies of wetland management developed in Phase II can be transferred or extended to farmers through the on-farm adaptive research (OFAR) network now being established by IITA within the Farming Systems Programme. A major objective of the OFAR is to test the improved soil and crop management technologies on farmer's fields through a network involving IITA, national research and training institutions and World Bank and EC supported national agricultural development projects (ADP's). In the light of the above it is therefore recommended that a systematic physical and socio-economic inventory of wetlands in West Africa should constitute part of Phase III of the Wetland Utilization Research Project. Such a systematic inventory is aimed to provide specific information and technical assistance to those national governments or institutions which desire to identify areas where the improved wetland technologies could be applied.

9. SELECTION CRITERIA

For the selection of areas in which benchmark sites should be selected, the following criteria have been formulated.

(A) Physical criteria

a. Representativeness for sufficiently large parts of the inventory area, in terms of:
   - bioclimate: Equatorial forest and Guinea savannah zones,
   - land regions: the Interior Plains and the Plateaux,
   - geology: basement complex and sedimentary deposits.

b. Production potential of wetland soils for rice-based cropping systems:
   - low to medium production potential; viz. the soils on coarse grained sedimentary formations (sandstones) and on the acid to intermediate basement complex rocks (granites, quartzites and gneisses),
   - medium to high production potential; viz. the soils on fine grained sedimentary formations (shales and clays) and on the basic basement complex rocks (micaschists, greenstones and amphibolites) or possibly the soils on young volcanic formations and derived alluvium.

(B) Agro-socio-economic criteria

c. Population density: preference should be given to areas with a high rural population density.

d. Tradition for rice growing: rice should be a major crop in the farming system both for subsistence and cash.

Recommended areas in which the benchmark sites may be located are narrowed down by matching the areas selected on the physical as well as the agro-socio-economic criteria (see Map 5 of Volume IV). The recommended areas are:

1. (a) West Sierra Leone and (b) Southeast Sierra Leone in the Interior Plains on acid to intermediate basement complex rocks in the Equatorial forest zone with a pseudo-bimodal rainfall regime and with predominantly Ultisols and Oxisols.
2. West Ivory Coast (Man), in the Interior Plains on acid to intermediate basement complex rocks in the Equatorial forest zone with a bimodal rainfall regime and with predominantly Ultisols.

3.North Ivory Coast (Korhogo) in the Plateaux on basic basement complex rocks in the Guinea savannah zone with a bimodal rainfall regime and with predominantly Alfisols.

4.North Togo in the Interior Plains on coarse grained sedimentary deposits in the Guinea savannah zone with a monomodal rainfall regime and with predominantly Alfisols.

5.Benue trough - southeast Nigeria in the Interior Plains on coarse grained sedimentary deposits in the Guinea savannah/Equatorial forest transition zone, with a pseudo-bimodal rainfall regime and with predominantly Ultisols.

(C) Institutional framework and logistics

It is assumed that only three benchmark sites will be adopted. Areas where the benchmark sites will be located should ultimately be selected on the basis of close linkage and cooperation possibilities IITA has with national research, development and extension agencies. The areas finally selected should be approved by the national governments concerned.

10.BENCHMARK SITE CHARACTERIZATION AND SELECTION

Within the broad areas mentioned above, localities should be chosen, within which the actual benchmark site will be situated. It is recommended that the final selection of the benchmark site should be preceded by a survey to characterize the locality including the actual benchmark site. This survey, which is the start of WURP-Phase II should comprise the following elements:

- Valley morphology (shape and slopes).
- Hydrology (catchment description, run-off, erosion, location of the streamflow, groundwater table variations, flooding pattern, water retention and depletion).
- Soil conditions (depth, drainage class, texture, clay mineralogy, organic matter content, fertility, salinity and toxicities).
- Agro-socio-economic conditions (accessibility, existing farming systems, labour availability, marketing and processing facilities, farmers attitude to improved rice cultivation, water related health hazards, etc.).

# INTRODUCTION

## *Approach and presentation*

The activities for the WURP-Phase I, the collection and evaluation of existing information on wetlands, started in August 1982. In The Netherlands contributions were made by the STIBOKA (Soil Survey Institute) on the geological, geomorphological and pedological aspects, by the KIT (Royal Tropical Institute) on the agro-socio-economic aspects and by the International Institute for Land Reclamation and Improvement (ILRI) on the climatological and hydrological aspects. The ILRI also had the overall responsibility of coordination (Ir. J. de Wolf).

Various international documentation data bases in Europe and the U.S.A. were checked. Evidently, the physical aspects are more comprehensively documented than the agricultural, economic, and the sociological aspects. In general the quantity of information is abundant, but the quality is very much varying.

The first compilation of the inventory results was discussed with and commented by the International Institute of Tropical Agriculture (IITA) at Ibadan in Nigeria. Their comments have been incorporated in this final version, which therefore can be considered to include the opinions of IITA.

The report has been presented in four volumes.

- Volume I. The main report (this volume).
- Volume II. The physical aspects, comprising details of the climate, the geology, the geomorphology, the soils and the hydrology.
- Volume III. The agro-socio-economic aspects, comprising details of the population, the food supply, the utilization, the research and development of wetlands.
- Volume IV. The maps.

## *Area and subject of the inventory*

The area covered by this inventory is indicated on the maps of Volume IV. It has been chosen somewhat larger than the IITA-mandate area in West Africa. It covers the area where rainfed double cropping or more is possible.

This area consists of the Guinea savannah zone and the Equatorial forest zone, more or less corresponding with the subhumid tropics and the humid tropics of West Africa, respectively. The entire inventory area covers approximately 2.2 million $km^2$, comprising wholly or partly the coastal countries of West Africa from Guinea Bissau through Cameroon. Whenever applicable, comparisons have been made with situations in the Sudan and Sahel savannah zones (the semi-arid and arid zones north of the inventory area). In these cases reference to these areas has been made using the term 'arid area'.

Wetlands are lands having hydromorphic soils. Such soils have morphological characteristics associated with wetness and the resulting reduction during at least a part of the year. Wetland therefore is found where hydromorphic soils have been formed such as in deltas, tidal lands, inland depressions, river floodplains and the small inland river valleys. Because the WURP only comprises those wetlands which can be implemented, operated and maintained by smallholders having simple means only, the present study is restricted to the catenas of the small inland valleys (streamflow valleys). These valleys are formed on the upper part of the river catchments. They have a centrally located stream which is shallow and only a few meters wide, or which is not existing at all. They usually extend some 15 to 25 km downstream and have a width varying from 10 meters in their upper to about a few hundred of meters in their lower stretches. The catchment area ranges from at least 2 $km^2$ to some 100 $km^2$.

*This volume*

This volume comprises the summary of the physical (Volume II) and the agro-socio-economic (Volume III) aspects, the prospects of valley land development and research in rice-based smallholder farming systems and the recommendations for the WURP-Phase II.
In combination with the maps of Volume IV, this volume provides the reader a condensed review of the inventory relevant to the Wetland Utilization Research Project, the objective of Phase I.

# 1 PHYSICAL ENVIRONMENT OF WEST AFRICA

## 1.1 Climate

The climate is dominated by the interplay between two air masses with distinctly different moisture characteristics.

- The maritime (humid) airmass originating from the south Atlantic Ocean, associated with the southwest wind system, commonly referred to as the South-West Monsoon.
- The continental (dry) airmass originating from the African continent and associated with the northeast Harmattan windsystem (trade winds).

The frontal separation of these two airmasses is called the Inter Tropical Convergence Zone (ITCZ). Its location is determined by the seasonal position of the earth in relation to the sun. Consequently the main climatic parameters, such as the temperature, the sunshine duration, the solar radiation and the rainfall have a zonal pattern.

Based on the temporal and spatial variations in the precipitation, three climatic regimes are distinguished, as is shown on Map 1 of Volume IV.

*Monomodal (rainfall) regime,* which extends north of the 1,250 to 1,500 mm isohyets. In this regime, seasonal rainfall is characterised by one single peak. The rains gradually increase in frequency and quantity to reach a maximum in August, after which they rapidly decline to complete cessation. The humid period ranges between 2 months in the north and 5 months in the south.

The evaporation during the year shows 2 peaks of about 6 to 8 mm a day in March-April and in November. Evaporation minima of about 3 to 5 mm a day occur in January and during the rainy season. This regime is characterised by high solar radiation, conducive to high photosynthetic rates, high evapotranspiration rates (with occasional moisture stress) and irregularities in rainfall, especially at the onset and cessation of the rains.

Only the more humid part of this regime is found in the (north) of the inventory area.

*Bimodal (rainfall) regime,* which is found in the south-central part of West Africa extending south of the 1,250 - 1,500 mm isohyets and longitudinally restricted to between $7^{O}$W and $5^{O}$E. In this regime, the first rainfall peak occurs in June-July and the second one in September.

The total humid period is 5 to 9 months, except in the coastal region between Accra and Lomé. There is however, an intervening period of rainfall deficiency in late July and August, which constitutes a distinct break between the two seasons.
The evaporation is characterized by a maximum of about 7 mm a day in March and a minimum of 3 to 4 mm a day in August. During the intermediate periods the evaporation ranges between 3 and 7 mm a day.
Irregularities in rainfall, especially within the seasons, and relatively low solar radiation cause below optimum conditions for crop production.

*Pseudo-bimodal (rainfall) regime,* which extends east and west of the bimodal regime. In this regime, there is a continuous rainy season from March/April to November/December.
The evaporation generally is low throughout the year, ranging between 2 and 5 mm a day.
Relatively low solar radiation paired with relatively high air humidity cause below optimum conditions for crop production, with high incidences of pests and diseases, constituting additional yield limiting factors.

Based upon the length of the growth period as defined by TAMS/CIEH and FAO, four major bioclimatic zones are distinguished in West Africa. These zones are shown on Map 2 of Volume IV.

*Sahel savannah zone*, being the transition zone between Sahara desert and true savannah. The growth period is less than 90 days per year, roughly corresponding with less than 550 mm annual rainfall. There is a monomodal rainfall pattern. The vegetation cover is sparse. Nomadic agriculture is dominant. In the southern part the main crop is short season millet.

*Sudan savannah zone*, having a growth period between 90 and 165 days per year, roughly corresponding with 550 mm to 1,000 mm annual rainfall. There is a monomodal rainfall pattern. Fairly intensive crop production is possible. The drought hazard is relatively small and the high photosynthetic potential is relatively large.

*Guinea savannah zone*, having a growth period between 165 and 270 days per year, roughly corresponding with 1,000 to 1,500/2,000 mm annual rainfall. There is a monomodal rainfall pattern in the north gradually shifting into a bimodal pattern in the south, with two growth periods of unequal length. In the south drought hazards occur during the rainy seasons and the photosynthetic potential is relatively small.

*Equatorial forest zone*, having a growth period of 270 days and over per year, roughly corresponding with over 1,500/2,000 mm annual rainfall. There is a pseudo-bimodal rainfall pattern. Photosynthetic potential is relatively small and air humidity is relatively high. General crop production conditions are below optimum, with high incidence of pests and diseases.

With a growth period of 165 days to year round, only the latter two zones allow annual rainfed double cropping or more. For this reason the area of the inventory (WURP-Phase I) has been confined to the Guinea savannah zone (nearly 1.3 million $km^2$) and the Equatorial forest zone (nearly 0.9 million $km^2$).

## 1.2 Land regions

Based on differences in geomorphology and geology, the inventory area has been divided into four land regions. Land regions are broad landscape units with recurrent physiography. These land regions are shown on Map 3 of Volume IV. They are:

*Coastal Plains* (100,000 $km^2$, or 4.6% of the inventory area), comprising recent beach ridges, estuarine and deltaic tidal swamps and river plains (subregion 1.1) and dissected coastal terraces of older sedimentary deposits (subregions 1.2 and 1.3);

*Interior Plains* (1,075,000 $km^2$, or 49.8% of the inventory area), comprising the characteristic undulating to rolling peneplains of West Africa. Principally, these are Plio-pleistocene planation surfaces over Precambrian basement complex formations (granites, gneisses, schists, amphibolites etc.). They are further characterized by the occurrence of granitic inselbergs and hill ridges and flat, laterite-capped mesas (subregions 2.1, 2.2 and 2.3).

Interior Plains over sedimentary formations comprise those over Paleozoic, Cretaceous and Tertiary sandstones, shales, sands etc. (subregions 2.4, 2.5, 2.6, 2.7 and 2.8);

*Plateaux* (624,000 $km^2$, or 28.9% of the inventory area), consisting of undulating to rolling planation surfaces that are generally older (mainly Eocene) and occur at higher elevations than the Interior Plains. They mainly include peneplains over Precambrian basement complex formations with inselbergs, hill ridges and mesas (subregions 3.1 and 3.2). This land region also comprises Plateaux on Paleozoic and on Tertiary sedimentary formations (subregions 3.3 and 3.4);

*Highlands* (361,000 $km^2$, or 16.7% of the inventory area), comprising very steep and high (up to 2,000 m) mountain ranges of various lithology (subregions 4.1, 4.2 and 4.3) and dissected, high (over 1,500 m) sandstone Plateaux (subregion 4.4).

## 1.3 Soils

In general, the (upland) soils in the inventory area are well drained, moderately deep to deep, coarse to medium textured (loamy sands-light clays) and gravelly. Especially in the (subhumid) Guinea savannah zone, they may overlay shallow continuous hardpans of ironstone (laterite) or layers of ironstone aggregates, in particular on basic parent materials that are rich in iron (micaschists, greenstones, amphibolites).

The climate, geology and geomorphology have a pronounced effect on soil formation and soil characteristics.
Soil formation tends to be dominated by depletion processes, especially in the high rainfall zones. Ultimately these processes lead to the formation of soils with extremely low inherent fertility. Thus, the most depleted and chemically poorest soils with very low capacity to retain plant nutrients (Oxisols) are found in the southwest and in the southeast of the inventory area.
Ultisols are the main soils in the transition between the Guinea savannah zone and the Equatorial forest zone. They are less depleted than the Oxisols but they have low base saturation. In addition they are highly susceptible to erosion.
Alfisols are the somewhat better soils occurring in the northern part and in the centre of the inventory area (Guinea savannah zone) and on the more basic (richer) parent materials. They have relatively high base saturation and better inherent fertility than the Ultisols and Oxisols. Their main constraint is the low availability of soil moisture, in particular if profiles are shallow.

Soils developed in sedimentary material mainly contain residual, chemically poor minerals like quartz, kaolinite and gibbsite. Depending on the grain of the parent material they are coarse textured and of low inherent fertility (e.g. on sandstones) or clayey and of moderate fertility (e.g. on shales).

Within the formations of the basement complex, the basic metamorphic rocks (micaschists, greenstones, amphibolites) tend to weather into finer textured and more fertile soils than the acid and intermediate rocks (granites, quartzites, gneisses).

In the predominantly dissected, undulating to rolling landscape of West Africa, the characteristics of the soils also vary according to their position on the slope. Sedentary soils, developed in situ on the weathering rock, but subjected to erosion (planation), generally occur on the crests and upper slopes of the toposequences. On the lower slopes, colluvium from upslope forms (part of) the parent material. Soil profiles may be stratified and some sorting of the colluvium may have taken place, generally resulting in somewhat coarser textures than those of the upslope soils. The colluvium may include gravelly layers of quartz or ironstone concretions from the eroded higher profiles. The ironstone concretions may also have been formed in situ by irreversible hardening of plinthite. The latter is formed under the influence of groundwater. In the lowest part of the toposequence, the valley bottom, alluvium forms the parent material of the soils. Valley bottom soils vary widely in their characteristics within as well as between the valleys, but they have in common that they all show signs of periodic wetness (hydromorphic soils). Soil drainage may range from moderately well to poor and if flooded, submerged periods may last up to 5-6 months per year. Textures may range from sandy to clayey. The soils may be strongly stratified, contain gravel, iron concretions or plinthite and they may have low to moderate inherent fertility. In general however, it can be stated that in texture as well as in fertility the valley bottom soils reflect, to some extent, the characteristics of the surrounding upland soils and parent material.
The valley bottom soils are increasingly used for cultivation of rice. Their favourable hydrological regime makes the valley bottom soils better suited to wetland rice cultivation than the drier upland soils. Their main constraints to rice cultivation are the prevailing coarse textures and low fertility. Iron toxicity is reportedly widespread in rice cultivation in West African valley bottoms.

## 1.4 Wetland distribution and characteristics

The wetlands of the inventory area can be differentiated according to their relationship to the land drainage systems. Two broad groups have been distinguished.

a. The deltas, tidal (mangrove) swamps and large inland swamp (such as the bolis of Sierra Leone), with a total area estimated between 36,700 and 74,400 $km^2$, or 1.7 to 3.5% of the inventory area.
b. The river valleys, with a total area estimated between 235,500 and 541,900 $km^2$, or 10.9 to 25.0% of the inventory area.

The rivervalleys have been subdivided according to their position along the river, depending on which they have different flooding regimes.

*River floodplains* (large floodplains) along the main rivers, flooding every year. For the development of these plains, major engineering works are required, comprising river embankment, empoldering and often complete irrigation and drainage networks. Their total area has been estimated at between 54,200 and 129,700 $km^2$, or 2.5 to 5.9% of the inventory area.

*Overflow valleys* (small floodplains) along the smaller rivers and tributaries. They usually comprise plains of various sizes along one side of the river. The main source of water in these plains is from flooding. However, when the river does not flood, the plains suffer from drought. Their total area has been estimated at between 80,100 and 194,100 $km^2$ or 3.6 to 9.0% of the inventory area.

*Streamflow (French: 'marigot') valleys*, having been formed on the uppermost parts of the catchments. Generally they are narrow, varying from about 10 m in their upper to about 250 m in their lower stretches. The longitudinal slopes are up to 2.0% (in the Highlands up to 5.0%), with the highest values in the upper part of the valley. These valleys may stretch over a distance of up to 25 km, either continuously or interrupted. Apart from rainfall, the water regime in these valleys depends upon the surface and subsurface runoff from adjacent uplands. Their total area has been estimated at between 101,200 and 218,100 $km^2$ or 4.7 to 10.0% of the inventory area.

The distribution of the various categories of wetland over the land-regions and the bioclimatic zones is shown in Table 1. The area of the streamflow valleys is about one third of the total area of the wetlands. Streamflow valleys form the majority of the wetlands in the Interior Plains and Plateaux land regions, of both bioclimatic zones. Because of the objective of developing low-cost input technologies and methodologies for rice-based smallholder farming systems, this category of valleys will be the main subject of the proposed WURP-Phase II. Between and within these valleys however, variations in morphological, hydrological and pedological characteristics are great.

Depending on the lithology and geomorphology the streamflow valleys vary in shape, in terms of their longitudinal and cross-sectional profile. Longitudinally the valleys may be continuous and smooth or interrupted and stepped. The continuous valleys occur in rock formation with little structural variation, e.g. the sedimentary deposits. Stepped valleys occur in rock formations of the basement complex, where hard rocks (granites and quartzites) alternate with softer formations (schists and gneisses).

Cross-sectionally, three broad types of valleys can be distinguished:

- shallow and narrow V-shaped valleys, formed in relatively hard rock formations (granites, quartzites);
- deep and narrow U-shaped valleys with concave sides that gently transfer into the valley bottoms, formed in rocks of medium hardness/permeability (schists, gneisses);
- deep and wide U-shaped valleys with distinct bends between steep sides and flat bottoms, formed in relatively soft, permeable formations (sediments, amphibolites).

Due to increasing catchment area and subsequent increase in river discharges, the valleys become wider downstream. Also, the valleys widen at the confluence of streams.

Valleys to be developed for smallholder crop (rice) production should meet the following hydrological conditions.

A. Agronomic aspects:

- The crop water requirements should be covered during the entire growth period. This strongly depends on the amount of rainfall and the size of the catchment area. In the Guinea savannah zone it has been reported that 1 $km^2$ of catchment area provides the minimum requirements of roughly 0.8 to 3.0 ha of valley cultivation.

Table 1. Areas of various categories of wetland for the Equatorial forest and Guinea savannah zones for the land regions

| Land regions | | Wetlands | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Deltas, tidal swamps large inland swamps (incl. bolis etc) | | River valleys | | | | | | Total | |
| Name | Area | | | River floodplains | | Overflow valleys | | Streamflow valleys | | | |
| | 1000 km$^2$ | % | 1000 km$^2$ | % | 1000 km$^2$ | % | 1000 km$^2$ | % | 1000 km$^2$ | % | 1000 km$^2$ |
| I. EQUATORIAL ZONE | | | | | | | | | | | |
| 1. Coastal Plains | 100 | 25/40 | 25.0-40.0 | 1/5 | 1.0- 5.0 | 1/4 | 1.0- 4.0 | 1/3 | 1.0- 3.0 | 28/52 | 28.0- 52.0 |
| 2. Interior Plains | | | | | | | | | | | |
| - Basement complex | 376 | 1/2 | 2.5- 4.5 | 2/5 | 6.5-19.7 | 5/13 | 18.6-49.3 | 6/16 | 31.5-62.2 | 15/36 | 59.1-135.7 |
| - Sedim. deposits | 51 | 3/8 | 1.5- 4.1 | 5/10 | 2.6- 5.1 | 3/8 | 1.5- 4.1 | 1/6 | 0.5- 3.1 | 12/32 | 6.1- 16.4 |
| Total Int. Plains | 427 | 1/2 | 4.0- 8.6 | 2/6 | 9.1-24.8 | 5/12 | 20.1-53.4 | 7/15 | 32.0-65.3 | 15/35 | 65.2-152.1 |
| 3. Plateaux | | | | | | | | | | | |
| - Basement complex (= Total Plateaux) | 220 | - | - | 1/2 | 2.2- 5.5 | 2/7 | 3.8-14.8 | 2/7 | 3.8-14.8 | 4/16 | 9.8- 35.1 |
| 4. Highlands | | | | | | | | | | | |
| - Basement complex (= Total Highlands) | 118 | - | - | 1/4 | 1.2- 4.7 | 2/7 | 1.4- 8.3 | 5/10 | 5.9-11.8 | 7/21 | 8.5- 24.8 |
| Total Equatorial Zone | 865 | 3/6 | 29.0-48.6 | 1/5 | 13.5-40.0 | 3/9 | 26.3-80.5 | 5/11 | 42.7-94.9 | 12/31 | 111.5-264.0 |
| II. GUINEA ZONE | | | | | | | | | | | |
| 2. Interior Plains | | | | | | | | | | | |
| - Basement complex | 389 | 0/1 | 0.0- 3.5 | 5/8 | 17.9-29.5 | 7/12 | 28.3-47.4 | 3/11 | 13.4-41.6 | 15/31 | 59.6-122.0 |
| - Sedim. deposits | 259 | 3/8 | 7.7-20.7 | 5/10 | 13.0-25.9 | 3/8 | 7.7-20.7 | 1/3 | 2.6- 7.7 | 12/29 | 31.0- 74.0 |
| Total Interior Plains | 648 | 1/4 | 7.7-24.2 | 5/9 | 30.9-55.4 | 6/11 | 36.0-68.1 | 3/7 | 16.0-40.3 | 14/30 | 90.6-196.0 |
| 3. Plateaux | | | | | | | | | | | |
| - Basement complex | 374 | - | - | 1/5 | 3.7-18.3 | 1/5 | 3.7-18.7 | 8/13 | 31.2-49.9 | 10/23 | 38.6- 86.9 |
| - Sedim. deposits | 30 | 0/1 | 0.0- 0.3 | 2/7 | 0.6- 2.1 | 4/9 | 1.2- 2.7 | 4/9 | 1.2- 2.7 | 10/26 | 3.0- 7.8 |
| Total Plateaux | 404 | 0/0.1 | 0.0-0.3 | 1/5 | 4.3-20.4 | 1/5 | 4.9-21.4 | 8/13 | 32.4-52.6 | 10/23 | 41.6- 94.7 |
| 4. Highlands | | | | | | | | | | | |
| - Basement complex | 149 | 0/1 | 0.0- 1.5 | 3/8 | 4.5-12.0 | 8/13 | 12.0-19.4 | 3/8 | 4.5-12.0 | 14/30 | 21.0- 44.9 |
| - Sedim. deposits | 94 | 0/1 | 0.0- 0.9 | 1/2 | 0.9- 1.9 | 1/5 | 0.9- 4.7 | 6/11 | 5.6-10.3 | 8/19 | 7.4- 17.8 |
| Total Highlands | 243 | 0/1 | 0.0- 2.4 | 2/6 | 5.4-13.9 | 5/10 | 12.9-24.1 | 5/9 | 10.1-22.3 | 12/26 | 28.4- 62.7 |
| Total Guinea Zone | 1,295 | 0/2 | 7.7-26.1 | 3/7 | 40.7-89.7 | 4/9 | 53.8-113.6 | 5/10 | 58.5-124.2 | 12/27 | 160.7-348.1 |
| Total Inventory Area | 2,160 | 1.7/3.5 | 36.7-74.7 | 2.5/5.9 | 54.2-129.7 | 3.6/9.0 | 80.1-194.1 | 4.7/10.0 | 101.2-219.1 | 12.6/28.5 | 272.2-616.3 |

For the Equatorial forest zone this ratio is 1 $km^2$ for roughly 2.0 to 5.0 ha;

- Large (peak) floods may cause severe damage to the scheme infrastructure and the crops. Prolonged crop submersion will cause yield failure. Rice should not be allowed to be submerged longer than 48 hours (for most other crops this period is much shorter);
- Rice has shallow roots and is very drought sensitive. Especially the wetland varieties prefer water saturated conditions for an adequately long time during the growth period. To obtain a better insight in the performance of rice (and other crops) groundwater fluctuations in the valleys should be assessed. Such an assessment can be done on an annual basis for perennial crops as well as on a seasonal basis for annual crops. Valleys or parts thereof should be classified for their suitability to produce rice (or other crops).

B. Engineering aspects:

- The streamflow size should be neither too small nor too large. The size of the flow is related to the size of the catchment area. Generally the optimum range of the size of the catchments is between 4 and 70 $km^2$, depending on the annual amount of rainfall and environmental conditions of the catchment, in terms of vegetation and cover, slopes, soil depth, texture, structure and soil moisture content;
- The texture and structure of the valley bottom soils should provide sufficient stability for the water distribution structures, whilst seepage should be little;
- The length and the width of the valleys should be such that an optimum shape and size of the scheme can be obtained, which can be easily operated and maintained by the farmers or the community. The longitudinal slope should allow for adequate drainage, but should not exceed 0.1 to 0.2% to avoid overdrainage in sandy soils or heavy levelling.

Based on these criteria for the design, valleys may be classified according to their suitability to implement water control and distribution systems for the benefit of the production of rice or other crops.

For rice cultivation in the streamflow valleys the field layout should be based either on a system with contour bunds or on one with a retention/inlet structure.

- In the upper stretches of the valleys where the central stream is not (yet) existing, bunds should be made along the contours to spread the run off water evenly. The basins formed by these bunds should be levelled;
- In the lower parts of the valleys where a streamflow exists, a retention/inlet structure should be made across the stream. Such a structure should allow peakflows to pass, whilst in drier periods it should retain water, using stop logs. The obstructed water is forced through inlets into canals along the periphery of the valley floor. These feeder canals may also act as cut-off drains to intercept run off water and groundwater depletion flow from adjacent upland.

# 2 SOCIO-ECONOMIC ENVIRONMENT OF WEST AFRICA

## 2.1 Population

In 1980, the total population of subsaharan West Africa was 153.9 million persons, 122.4 million of whom lived in the countries of the inventory area. In the latter area the population has more than doubled during the 3 decades between 1950 and 1980 (increase 112%). This increase was lowest in Guinea Bissau (13%) and highest in Togo (320%). Recent highest annual growth rates were recorded for Ivory Coast and Liberia (3.5%) and Nigeria (3.3%).
The overall population distribution and densities, and the percentage of rural population in the inventory area is shown on Map 4 of Volume IV. The average population density in subsaharan West Africa is 19 $p/km^2$, but 47 $p/km^2$ in the inventory area. Of the latter, the eastern part is more densely populated than the western part. Very densely populated areas are found more often in the Equatorial forest zone than in the Guinea savannah zone. Country-wise highest population densities are observed in Nigeria (83 $p/km^2$), followed by Ghana, Sierra Leone and Togo (48 $p/km^2$).

In West Africa migration (internal as well as external) is substantial. The population movements are caused by the economic differences between, but also within countries. Generally countries with high population densities have or have had relatively strong economies. Although pressure on land in these countries is somewhat higher than in other countries, the rural population as a percentage of the total population is relatively low (in the order of 50 to 75%). A negative effect of the migration pattern is that it leaves the rural area with a relatively high proportion of old aged people, since many of the 15 to 35 year old people, both males and females, migrate to towns.

## 2.2 Role of rice in food supply

In 1970, the relative importance of rice expressed as a percentage of total food production in subsaharan West Africa was 6.7% and for the inventory area 6.8%. In 1980 this relative importance of rice had grown to 8.7% and 9.6%, respectively. For the arid area it had decreased to 5.2%.

In 1980/81, the total rice production in the inventory area was about 2.9 million tons, with the biggest producers being Nigeria (over 1 million tons), Sierra Leone and Ivory Coast (over 0.5 million tons) and Guinea and Liberia (over 0.25 million tons). The total production area was about 2 million ha, with the largest areas recorded in Nigeria (600 000 ha), Ivory Coast, Sierra Leone and Guinea (over 300 000 ha). Generally, low yields were recorded, averaging between 600 and 2,900 kg/ha (paddy). Countries having high yields were Cameroon and Nigeria. Both the acreage and the yield have increased during the 3 decades since 1950, resulting in an increased total production. This increase has kept pace with the increase of the population, but not with the increased consumers preference for rice.

The subsaharan countries show continuously decreasing rice self-sufficiency rates, from 98% in 1950 to 56% in 1981. For the countries of the inventory area, these rates are 98% in 1950 and 62% in 1981. Imports have increased substantially from 14,700 ton in 1950 to 1,397,100 ton in 1981 for the subsaharan countries and from 11,400 tons in 1950 to 969,000 tons in 1981 for the inventory area. If this trend is to continue, the self-sufficiency rate for the subsaharan countries will be 53% and for the countries of the inventory area 59% in 1990. This means that of the total rice consumption in 1990, over 40% is expected to be imported (estimated at about 1.8 million tons for subsaharan West Africa).

## 2.3 National policies

Because of the large proportion of rice to be imported to satisfy domestic demands, all West African countries have set policies towards self-sufficiency in rice production (and also for other staples). These policies are sustained by research, agricultural extension and development programmes. To this end 15 countries have founded the West African Rice Development Association (WARDA) to arrive at solutions for the problems of rice production.

At the national level, the governments' policies to promote rice production include subsidies to rice producers and/or rice consumers,

whilst imports may be restricted through levy or quota systems. Subsidies may be given at one or more phases of the production/marketing process, such as land development, inputs, output, transport, processing, storage or marketing (consumer price). The levy or quota system has saved much foreign currency, but the subsidies have caused the cost of rice production to increase at the national level and created a great diversity of prices in the various countries. In 1970 to 1974 the highest prices were paid to farmers in Nigeria (3 times as much as in Benin and 6 times as much as in Mali).
Generally, domestic rice is produced at costs far higher than average world market prices. Hence the difference is subsidized by the national governments. From the national economic point of view domestic rice production is only justified for on-farm and in-village consumption. Nationally, it may often be more profitable to produce other crops, mainly cash crops, but also maize.

## 2.4 Wetland related health aspects

Wetland related diseases are a great menace to the health of especially the rural population and have a great social and economic impact in West Africa. In the past the development of water resources has caused the spreading of these diseases into infestation-free areas. Therefore any effort to further develop land and water resources should comprise measures to prevent further hazards.

In the inventory area the major wetland related diseases are schistosomiasis (bilharzia) and onchocerciasis (river blindness). Other wetland related diseases are dracunculiasis (guinea worm), malaria and trypanosomiasis (sleeping sickness). In one way or another they all make human beings incapable to work for long or short periods. For example, guinea worm infection usually coincides at the beginning of the rainy (= planting) season often causing the loss of an entire cropping season.

Control and prevention of further spreading of the diseases concentrate on the environmental (or land and water) management, supported by chemical and biological measures to control the vectors (insects and molluscs). For river blindness, the vector (blackfly = *Simulium damnosum*) breeds at very specific locations, as the larves are dependent on well aerated, turbulent water. The most commonly tolerated velocity of the water ranges between 0.7 to 1.2 m/sec. Hence in development projects such conditions should be avoided and where they exist, they should be eliminated.

For bilharzia, the vectors (aquatic snails *Bulinus spp.* and *Biomphalaria spp.*) require nearly stagnant or very slowly flowing water. Such conditions should be eliminated by cleaning channels, filling unused ponds, channels, etc.

However, land and water management measures for these and other diseases to be effective must be sustained by improved community drinkwater supply, sanitation and housing facilities as well as health education, extension and community participation.

# 3 UTILIZATION OF INLAND VALLEYS

## 3.1 Traditional farming systems

Traditional smallholder farming systems are characterized by the need of farmers to avoid risks or to spread risks. These risks arise from constraints encountered by the farmers in their efforts to produce. These constraints may be of a physical, biological and socio-economic nature.

The physical constraints are set by the environmental situation, in terms of

- climate (rainfall quantities and distribution, drought and/or flood hazards, cloudiness and photosynthetic efficiency);
- soil (texture, inherent fertility, acidity and toxicities).

The biological constraints are related to

- quality of plant materials;
- crop pests and diseases and abundancy of weeds;
- human (such as river blindness, bilharzia, etc.) and animal diseases (e.g. trypanosomiasis);
- degradation of the bio-environment due to human interference.

The socio-economic constraints are related to

- increasing population pressure;
- poor infrastructure, processing and marketing facilities;
- unavailability of inputs or availability at high costs;
- high cost and low productivity of labour;
- poor financial structures (viz.: credit, commodity prices, incomes, etc.);
- lack of research and package approach to development and little effective extension services.

In West Africa the bulk of rice is produced either on upland soils or on hydromorphic soils of large floodplains, deltas and swamps, irrigated or not. However a substantial part of the rice is produced in small inland valleys (especially in the western part of the inventory area). All activities are basically done by hand. Fertilizers may or may not be applied. After planting or sowing the fields may be left untended till harvest time. Yields are low and range between 0.5 to 2.0 tons per ha depending on the soil conditions. If the farming system is improved, it usually applies to better water control and distribution, better varieties and some application of agro-chemicals. Under these conditions yields may be somewhat higher, ranging between 1.0 and 3.0 tons per ha.

## 3.2 Research and development

Earliest research on rice development in West Africa started in 1920. Nowadays several international institutes deal with it. At the national level most countries have their own rice research agencies. Presently, IITA within its Farming Systems Programme is establishing an on-farm adaptive research (OFAR) network for peasant crops, including rice. Initially it was thought that the 'Green Revolution' technology could be adopted for West Africa, but results have been disappointing. African farming systems are extremely complex and the development of suitable packages requires location specific research, to be supported by strong national research programmes on the staple foods of each country. Such programmes are presently conducted in Nigeria (National Agricultural Food Production Programme) and Sierra Leone (Coordinated Agro-economic Trials Programme). Investigations into the cost of developing land for rice cultivation, the cost of rice production and returns to farm income and labour in Sierra Leone, Liberia, Ivory Coast and Nigeria show that improving/developing rice-based smallholder farming systems should be approached very cautiously. The use of machinery should be avoided and capital investments should be kept to the bare minimum. Higher inputs aiming at higher yields are warranted only if the consequent higher risks are financially, economically and socially acceptable to the farmer and if the net family income and the return to labour are substantially increased. Hence research should be geared to low-cost inlet technology, both in land development and in crop production.

## 3.3 The impact of inland valley development

At the national level there are several economic incentives to improve and to increase rice production. The incentives to which smallholding farmers also may respond, are:

- the rapid increase of rice demand, especially in the low rice consumption countries;
- the decreasing self-sufficiency;
- the governments' policies to attain self-sufficiency in rice, thereby protecting domestic production and providing large amounts of subsidies;
- the large potential to increase rice yields, which are very low compared to yields in Asia and South America

In this context, the development of the streamflow valleys could make a considerable contribution to domestic rice production in West Africa. This is illustrated in the following calculation. If only 10% of the total area of streamflow valleys in West Africa (about 10 million ha) could be developed during the forthcoming decade, assuming a yield of 2 tons of paddy per ha and an average cropping intensity of 150%, total paddy production would be raised to 6 million tons. By the end of this decade the self-suffiency rate in West Africa would become 70 to 80%, which is substantially higher than the 53%, presently projected for 1990.

However, to develop such a large area of scattered and small valleys is an ambitious and tremendous exercise, which could considerable burden the services (and possibly drain resources) of the various national governments. The constraints are not only financial, or caused by lack of skilled technical staff or (inadequate) extension services, but also at the farmer's level. Within the prevailing social and economic situation in West Africa, smallholding farmers have little flexibility to alter their farming systems and to adopt new techniques. Hence, when national governments wish to promote rice production in small inland valleys, they have to enforce the capacity and skills of the extension services, including the establishment of local package research on rice-based smallholder farming systems in the wetlands.

# 4 RECOMMENDATIONS

## 4.1 Research needs

Research on rice-based smallholder farming systems in wetlands in West Africa is urgently required, because of:

- the sharp increase in rice demand;
- the continuous decrease in self-sufficiency in rice and in food supply as a whole;
- the high costs of food import;

The research should aim at maximizing the returns to scarce production factors, such as labour (high cost and low productivity) and other inputs.

It is strongly emphasized that this research should be directed to appropriate technology, developing new techniques of rice production which fall significantly below the current cost of domestic rice production and that also would significantly increase the rice production by smallholding farmers. Because of the large area of inland valleys (over 10 million ha), but presently marginally used, this research is warranted to contribute considerably to improving the precarious food situation in West Africa.

Evidently the agronomic, economic and sociological aspects form the basis of the appropriate research and of the monitoring and application of the results. However, in conducting research as proposed for the WURP-Phase II, the need to solve the problems arising from soil, land and water management are of great importance, since capital investments and production inputs are strongly related to the physical environment. Existing farming/cropping systems should be studied thoroughly, interlinking wetland and upland resources, to find solutions for the constraints in smallholder farming systems.

The research should comprise the following components.

A. Physical aspects

- land and water resources development, including low cost technologies for bushclearing, drainage, irrigation, etc.;
- land and water management, including water control and distribution systems with simple structures, field layout, land levelling, etc.;
- soil management, including tillage, fertilizer use, weed control, toxicity control etc.

B. Agronomic and socio-economic aspects

- agronomic quality of the land;
- size of the households and number of men, women and children available for farm work;
- degree to which household labour is supplemented with off-farm labour and the wages paid;
- farm size and identification of the crops and livestock comprising the farming systems and the relative importance of each in terms of land area, production, home consumption and market sales;
- description of existing production techniques estimating quantities of inputs, cost of purchased inputs, yields, total output and costs and returns for the major crops (enterprises);
- the agricultural calendar and the identification of peak demands for labour;
- major production constraints for principal crops, as viewed by the farmers.

An important component of the research programme should be to establish a system to characterize and to classify the various streamflow valleys, enabling the transfer of technologies (and methodologies) developed through the research project, to areas with similar valley conditions. Presently IITA is establishing within its Farming System Programme, a network of on-farm adaptive research (OFAR). A major objective of the OFAR is to test the improved soil and crop management technologies on farmer's field. This network involving IITA, national research and training institutions, World Bank and EC-supported national agricultural development projects (ADP's), can be used to transfer or extend technologies of wetland management to farmers, as is the main objective of the WURP-Phase III.

## 4.2 Criteria for benchmark site selection

### 4.2.1 Selection of areas

In selecting proper sites for the proposed WURP-Phase II, physical, agronomic and socio-economic criteria should be considered. Results from research should be applicable to areas larger than the selected sites only.
Therefore such larger areas should be selected first.

A. The main physical criteria are:

1. The representativeness for sufficiently large parts of the inventory area, in terms of:
   - bioclimate: Equatorial forest and Guinea savannah zones;
   - land regions: the Interior Plains and Plateaux;
   - geology/lithology: basement complex and sedimentary deposits.
2. The production potential of wetland soils for rice-based cropping systems:
   - low to medium production potential, viz.: the soils on coarse grained sedimentary formations (sandstones) and on the acid to intermediate basement complex rocks (granites, quartzites and gneisses);
   - medium to high production potential, viz.: the soils on fine grained sedimentary formations (shales and claystones), the basic basement complex rocks (micaschists, greenstones and amphibolites) and the soils on young volcanic formations and derived alluvium.

Based on these two main physical criteria benchmark sites may be selected in one or more of the following broad areas (see Map 5 of Volume IV):

- Sierra Leone - Liberia in the Interior Plains on acid to intermediate basement complex rocks in the Equatorial forest zone with a pseudo-bimodal rainfall regime and with predominantly Ultisols and Oxisols.
- South Ivory Coast in the Interior Plains on acid to intermediate basement complex in the Equatorial forest zone with a bimodal rainfall regime and with predominantly Ultisols.
- North Ivory Coast in the Plateaux on basic basement complex rocks in the Guinea savannah zone with a bimodal rainfall regime and with predominantly Alfisols.
- Central northeast Ghana - north Togo in the Interior Plains on coarse grained sedimentary deposits in the Guinea savannah zone, with a pseudo-bimodal ranging to a monomodal rainfall regime and with predominantly Alfisols.
- Benin - western Nigeria in the Interior Plains on acid to intermediate basement complex rocks in the Guinea savannah zone with a pseudo-bimodal rainfall regime and with predominantly Alfisols.
- Central Nigeria in the Interior Plains on coarse grained sedimentary deposits in the Guinea savannah zone with a pseudo-bimodal rainfall regime and with predominantly Ultisols.

- Southeast Cameroon in the Plateaux on basic basement complex rocks in the Equatorial forest zone with a pseudo-bimodal rainfall regime and with predominantly Oxisols.

Within these areas at least one benchmark site should be selected on the poor to medium and at least one on the medium to high production potential soils.

B. The main agro-socio-economic criteria are:

1. The population density. Preference should be given to areas with a high rural population density.
2. Traditional rice growing. In the selected areas, rice should be a major crop in the farming system, both for subsistence and cash, whilst the government policy should be actively favouring rice development.

Based on these agro-socio-economic criteria the benchmark sites may be selected in the following broad areas (see Map 5 of Volume IV):

- West central Guinea
- West Sierra Leone
- Southeast Sierra Leone
- West Ivory Coast
- North Ivory Coast
- North Ghana - north Togo
- North central Nigeria (Zaria-Kaduna)
- Benue trough - southeast Nigeria

To narrow down recommended areas in which benchmark sites should be selected, the areas selected on the physical as well as on the agro-socio-economic criteria are matched. The recommended areas are shown on Map 5 of Volume IV and are:

1a West Sierra Leone in the Interior Plains on acid to intermediate basement complex rocks in the Equatorial forest zone with a pseudo-bimodal rainfall regime and with predominantly Ultisol and Oxisols.

1b Southeast Sierra Leone in the Interior Plains on acid to intermediate basement complex rocks in the Equatorial forest zone with a pseudo-bimodal rainfall regime and with predominantly Ultisols and Oxisols.

2 West Ivory Coast (Man) in the Interior Plains on acid to intermediate basement complex rocks in the Equatorial forest zone with a bimodal rainfall regime and with predominantly Ultisols.

3 North Ivory Coast (Korhogo) in the Plateaux on basic basement complex rocks in the Guinea savannah zone with a bimodal rainfall regime and with predominantly Alfisols.

4 North Togo in the Interior Plains on coarse grained sedimentary deposits in the Guinea savannah zone with a monomodal rainfall regime and with predominantly Alfisols.

5 Benue trough - southeast Nigeria in the Interior Plains on coarse grained sedimentary deposits in the Guinea savannah/ Equatorial forest transition zone, with a pseudo-bimodal rainfall regime and with predominantly Ultisols.

C. Institutional framework and logistics

It is assumed that only three benchmark sites will be adopted. Areas where the benchmark sites will be located should ultimately be selected on the basis of close linkage and cooperation possibilities IITA has with national research, development and extension agencies. The areas finally selected should be approved by the national governments concerned.

### 4.2.2 Selection of the benchmark sites

Within the broad areas mentioned above, localities should be chosen, within which the actual benchmark site will be situated. It is recommended that the final selection of the benchmark site should be preceded by a survey to characterize the locality including the actual benchmark site. This survey should provide information on basis of which the research and monitoring programme has to be formulated. It is the start of the WURP-Phase II and should investigate the following aspects

- Accessibility to the site.
- Valley morphology (shape and slopes).
- Hydrology (catchment description, run off, erosion, location of streamflow, groundwater fluctuations, flooding pattern, water retention and depletion).
- Soil conditions (depth, drainage classes, texture, clay mineralogy, organic matter content, fertility, salinity and toxicities).
- Existing land and water management infrastructure.
- Marketing and processing facilities; stability of farm prices.

- Importance of rice within the local farming system and its comparative advantage to other crops.
- Labour and other bottlenecks which could become a hindrance to rice improvement.
- Farmers' interest in improving rice production (techniques).
- Potential conflicts or interferences between agricultural practices of rice production and practices of traditional pastoral farming, in the utilization of wetlands or water resources.
- Participation of women in rice production, processing and marketing.
- Site specific (wetland related) health problems (actual health situation - medical/epidemiological - assessing infection rates of onchocerciasis, schistosomiasis, guinea worm, malaria, trypanosomiasis, and other diseases; occurrence of the vectors (entomological, assessing populations of snails, blackflies, mosquitos, etc.).

The result of above investigation should form the criteria of the final selection of the actual sites within the pre-selected area. Generally, actual sites (1 or 2 valleys) should be selected where optimum conditions exist to conduct research and where the effects on the residing people will not be negative in any respect.

Government of The Netherlands
Min. of Foreign Affairs/DGIS
Min. of Agriculture and
Fishery/DLO

International
Institute of Tropical
Agriculture (IITA).
Ibadan - Nigeria

# Wetland Utilization Research Project
## West Africa

## Phase I
## The Inventory

## Volume II: The Physical Aspects

April 1983



Institute for Land Reclamation & Improvement
Wageningen - The Netherlands

WETLAND UTILIZATION RESEARCH PROJECT

West Africa



Phase I

The Inventory

By: Ir. P. Hekstra - Land and Watermanagement (ILRI)

Ir. W. Andriesse - Soil Survey and Landevaluation (Stiboka)

# VOLUME II: THE PHYSICAL ASPECTS



International Institute
for Land Reclamation
and Improvement
ILRI - Wageningen

Soil Survey Institute
STIBOKA - Wageningen.

CONTENTS Page

# INTRODUCTION

## *Approach and presentation*

The International Institute of Tropical Agriculture (IITA) at Ibadan - Nigeria, requesting the Government of the Netherlands for technical and financial assistance, submitted its proposal for the Wetland Utilization Research Project (WURP) in 1981. This proposal consists of three phases. The first phase is the inventory of existing information to identify the extent and categories of wetlands and to assess capabilities and constraints of using wetlands in rice-based smallholder farming systems, based on village-scale development without major inputs.

The activities for the WURP-Phase I, the collection and evaluation of available information started in August 1982. In The Netherlands contributions were made by the STIBOKA (Soil Survey Institute) on the geological, geomorphological and pedological aspects, by the KIT (Royal Tropical Institute) on the agro-socio-economic aspects and by the International Institute for Land Reclamation and Improvement (ILRI) on the climatological and hydrological aspects. The ILRI also had the overall responsibility of coordination, (Ir. J. de Wolf).

The report has been presented in four volumes.

Volume I The main report, with conclusions and recommendations
Volume II The physical aspects (this volume)
Volume III The agronomic, sociological and economical aspects
Volume IV The maps

## *Area and subject of the inventory*

The IITA prefers the WURP to be restricted to its mandate area, which in West Africa consists of the humid and subhumid tropics. This area is defined as the region having a positive (=surplus) rainfall over evaporation during a period of 5 months or more per year. This area is indicated on Map 2 of Volume IV.

However, this definition does not account for the possible total length of the growing season. The differentiation into bioclimatic zones as is done in Paragraph 1.4, is based on this criteria. In this option, the zones where rainfed double cropping or more is possible constitute the area adopted for the inventory of the WURP. This corresponds with the (sub-humid) Guinea savannah and the (humid) Equatorial forest zones and is somewhat larger than the IITA mandate area defined above. It comprises partly or entirely all coastal countries of West Africa from Guinea Bissau through Cameroon, covering an area about 2.2 million $km^2$.

Wetlands are lands having hydromorphic soils. Such soils have characteristics associated with wetness and unless artificially drained, with the resulting reduction during at least some period of the year. Evidently, hydromorphic soils are found in all types of land associated with wetness, such as there are the tidal lands, the deltas, the river floodplains, the inland depressions (e.g. the bolis in Sierra Leone) and the small inland river valleys.
In view of its objectives, the WURP is meant for those wetlands which can be developed simply and without major engineering works. The implementation, operation and maintenance of such schemes should be done by the farmer (or the farmer's community) himself, possibly with assistance from national extension services. Therefore, the present study is restricted to the small inland valleys (catenas). These valleys are formed on the uppermost part of the catchment and are the streamflow valleys mentioned in Paragraph 3.4.2.
They have a centrally located stream, which is shallow and only a few meters wide, or not existing at all. They have a width varying from about 10 meters in their upper to about a few hundreds of meters in their lower stretches. The catchment areas range from at least 2 $km^2$ to some 100 $km^2$.

*This volume*

Details of the climate, the geology, the geomorphology, the soils, the drainage and the hydrology of valleys are described in this volume. The inventory area has been differentiated in four landregions. Various types of wetlands have been quantified. This volume is concluded with recommendations for the selection of appropriate areas in which benchmark sites for the WURP - Phase II, should be selected. These recommendations are based on considerations of the physical aspects. Also the research needs and activities are indicated.

# 1 CLIMATE

## 1.1 General

The climate of West Africa, or parts of it, has been described in many publications, quite often as sectoral parts of surveys and studies. It has been treated most extensively by Walter and Lieth (1960), Rodier (1964), Landsberg and Griffith (1972) and Ojo (1977). The impact of the climate on the vegetation and on agricultural production has been described by Kowal and Kassam (1976), TAMS/CIEH (1976-1978), FAO (1978), Buddenhagen (1978), Lawson e.a. (1979) and Lauer and Frankenberg (1981).

The climate of West Africa is dominated by the interplay between two air masses with distinctly different moisture characteristics:

- the maritime (humid) air mass originating from the Atlantic Ocean, associated with the southwest wind system, commonly referred to as the South-West Monsoon.
- The continental (dry) air mass originating from the African continent associated with the northeast Harmattan wind systems (trade winds).

The frontal separation of these two air masses is called the Inter-Tropical Convergence Zone (ITCZ). Its seasonal migration, which follows the annual positional changes of the earth in relation to the sun, is shown in Figure 1 for Western Nigeria.

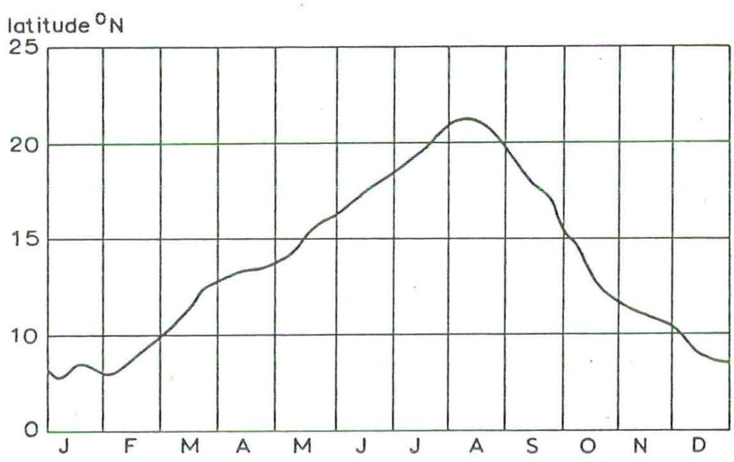



Figure 1. Mean monthly surface location of the ITCZ (Western Nigeria) 1956-1961.

Source: Ojo (1977), who shows the Inter-Tropical Discontinuity Zone. In the context of this inventory, this is considered to be the same as the ITCZ.

## 1.2 Parameters

### 1.2.1 Temperature

The distribution of the mean daily temperatures for the months of January, April, July and October is depicted in Figure 2.
Its pattern is more or less zonal. In January the temperatures on the whole decrease from south to north. The low temperatures in the north (Sahara) reflect the very low night temperatures and the relatively low day temperatures. This is associated with the Harmattan winds, which influence reduces towards the south.
In april the temperatures increase because of the more northerly position of the sun. In the north the temperatures rise more strongly than in the south.
In July, the greenhouse effect becomes evident, because of the increasing cloudiness. Highest temperatures are found just south of the Sahara (=Sahel/Sudan region). In the Sahara there is more outgoing radiation, whilst in the south there is less incoming radiation.
In October the cloud cover is withdrawing to the south. Lower temperatures are found in the coastal regions, mainly because of depletion of radiation.

Generally, the prevailing range of temperatures does not impose limitations to the production of crops usually grown in the region. If crops from more temperate regions are introduced, varieties must be selected which do not require a cold induced dormancy (chilling) period.

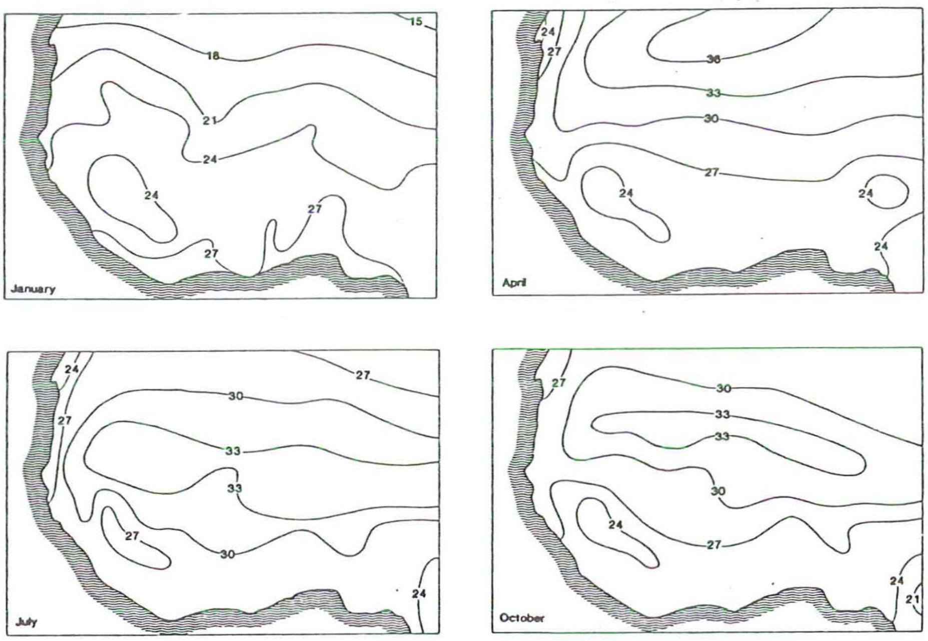



Figure 2. Distribution of mean daily temperature in °C, in West Africa.
Source: Ojo (1977), adapted for centigrades.

### 1.2.2 Sunshine and solar radiation

The amount of incoming radiation is a function of the number of hours of actual sunshine. The latter varies with the latitude, the season and the cloudiness. The cloudiness is related to the position of the ITCZ. Table 1 demonstrates that the northern latitudes receive roughly up to 50% more hours of actual sunshine than the southern latitudes. Also there is a marked dip in the number of hours of actual sunshine during the months of June to September, especially in the southern coastal regions. The net radiation, being the balance of incoming and outgoing radiation is shown in Figure 3. This balance is positive throughout the year and ranges between 65 and 100 Kcal/cm$^2$/year. The pattern is zonal. It is lowest in the coastal regions, followed by the Sahara region. It is highest in the Sahel/Sudan region lying in between the former two.

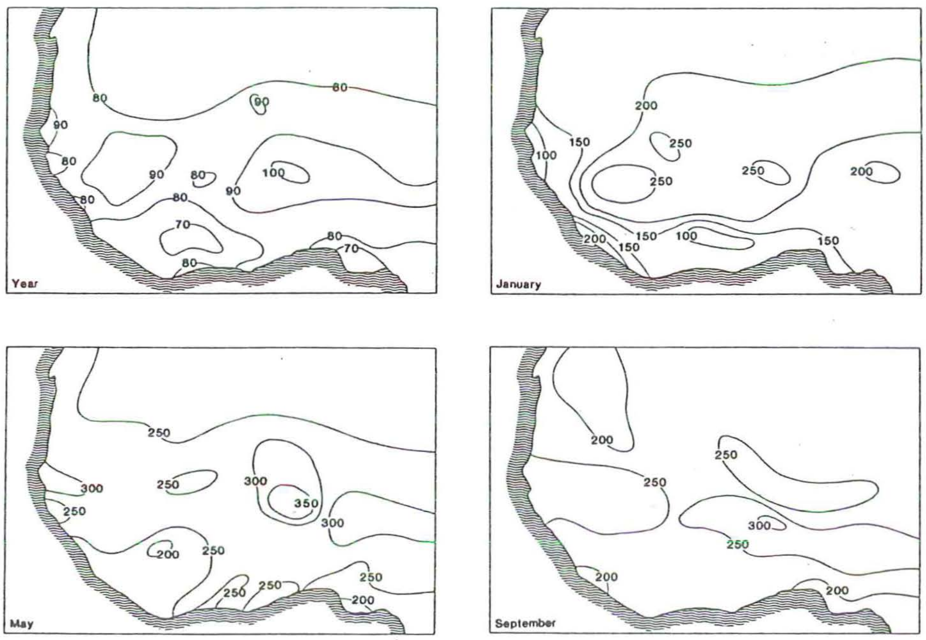



Figure 3. Distribution of net radiation in West Africa.
Year in Kcal/cm$^2$ per year
Months in cal/cm$^2$ per day
Source: Ojo (1977).

Table 1. Latitudinal and seasonal variation of actual sunshine hours per day in West Africa

| LOCATION | | J | F | M | A | M | J | J | A | S | O | N | D | Av. | Av. for latitude range |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North | | | | | | | | | | | | | | | |
| Port Etienne | Lat 17-21°N | 8.7 | 9.4 | 9.9 | 10.3 | 10.5 | 10.1 | 9.3 | 9.9 | 8.8 | 9.9 | 8.4 | 7.2 | 9.4 | |
| Bilma | Lat 17-21°N | 9.1 | 10.3 | 9.4 | 9.6 | 9.8 | 10.8 | 10.8 | 9.8 | 9.5 | 10.1 | 10.2 | 9.7 | 9.9 | 9.6 |
| Agadez | Lat 17-21°N | 9.8 | 10.3 | 9.4 | 9.3 | 9.4 | 9.4 | 9.2 | 9.0 | 9.1 | 10.0 | 10.0 | 9.8 | 9.6 | |
| Dakar | Lat 13-15°N | 8.0 | 8.5 | 9.6 | 10.6 | 9.7 | 8.6 | 7.1 | 6.2 | 7.3 | 8.5 | 8.9 | 7.1 | 8.3 | |
| Niamey | Lat 13-15°N | 9.5 | 9.9 | 9.0 | 8.6 | 8.8 | 8.9 | 7.2 | 6.5 | 7.2 | 9.1 | 9.6 | 9.5 | 7.9 | 7.9 |
| Ouagadougou | Lat 13-15°N | 8.7 | 7.9 | 8.9 | 7.1 | 7.9 | 6.5 | 6.9 | 5.5 | 6.7 | 8.2 | 9.1 | 7.7 | 7.6 | |
| Cotonou | Lat 5-7°N | 6.6 | 7.0 | 7.0 | 7.4 | 6.9 | 5.3 | 3.4 | 4.7 | 5.4 | 6.3 | 8.0 | 7.6 | 6.3 | |
| Accra | Lat 5-7°N | 6.8 | 7.2 | 7.0 | 7.2 | 7.8 | 5.2 | 4.5 | 4.5 | 5.7 | 7.1 | 8.1 | 7.6 | 6.6 | 6.2 |
| Abidjan | Lat 5-7°N | 5.0 | 7.2 | 6.8 | 6.7 | 5.9 | 3.7 | 3.4 | 3.6 | 4.7 | 6.0 | 7.4 | 6.8 | 5.6 | |
| South | | | | | | | | | | | | | | | |
| Average (seasonal effect) | | 8.0 | 8.6 | 8.6 | 8.5 | 8.5 | 7.6 | 6.9 | 6.6 | 7.2 | 8.4 | 8.9 | 8.1 | 8.0 | - |

In the south suboptimum radiation conditions prevail for agricultural production. Together with the generally high relative humidity, it causes a high incidence of plant diseases and pests. It also affects adversely the ripening of grains of legumes and especially of cereals, whilst the natural drying of grains is troublesome. Those crops therefore should be grown towards the end of the rainy season allowing ripening and drying during the dry season, with relatively higher solar radiation influx.

### 1.2.3 Rainfall

Like the other climatic parameters the rainfall distribution is zonal, as is shown by the isohyets on Map 1 of Volume IV. This north to south gradient is so striking that the mean annual rainfall has been expressed as a multiple regression equation with respect of the latitudinal and longitudinal position. This implies that the mean annual rainfall decreases towards the north by about 120 mm per 100 km, whilst longitudinally it decreases by about 70 mm for every 1000 km to the east.
The extreme southwest (Guinea Bissau, Guinée, Sierra Leona and Liberia) and the extreme southeast (southeast Nigeria and west Cameroon), are exceptions and rainfall largely exceeds 2500 mm per year. Another exception is the dry corridor of southeast Ghana, Togo and Benin, where the rainfall along the coast is less than 750 mm per year.
The tropical atmosphere holds large amounts of moisture. Rainstorms generally are intensive and heavy storms producing 50 mm or more and sometimes reaching 200 mm per hour over short periods, are not uncommon. They are rarely prolonged, with an average duration of 1 to 2 hours. This often results in rain splash, soil compaction, surface crusting and sheet or gully erosion.

Rainfall and its distribution pattern are the most striking features of the climates of West Africa. On this basis different climatic regimes have been distinguished and are discussed in Paragraph 1.3. Rainfall, rainfall distribution and the consequent soil moisture availability determine the vegetation growth and crop production. Based on the related length of the growth period, West Africa is divided into four different bioclimatic zones, which are discussed in Paragraph 1.4.

## 1.3 Climatic regimes

Three climatic regimes can be distinguished mainly based on the temporal and spatial variations in the precipitation and evaporation. This is shown on Map 1 of Volume IV.

a. The monomodal regime, this regime extends north of the 1250 - 1500 mm isohyets. The rainfall is characterized by one single peak. The rains gradually increase in amount and frequency to reach a maximum in August/September when the full effect of the ITCZ is felt. After this peak is reached the rains rapidly decline to complete cessation. The humid period (during which $R > ET_p$) ranges between 2 months in the north and 5 months in the south.
The evaporation during the year shows 2 peaks of about 6 to 8 mm a day in March/April and in November. The minima of about 3 to 5 mm a day occur in January and during the rainy season.
The main limitation to crop production is the deficiency in soil moisture, particularly in the beginning and at the end of the rainy season. The growth period is restricted to 180 - 200 days.

b. The bimodal regime, this regime is found in the south-central part of West Africa extending south of the 1250 - 1500 mm isohyets. Longitudinally, it is restricted roughly to the 7°W to the west and 5°E to the east. The rainfall distribution is characterized by two peaks. The first peak occurs in June/July and the second one in September. The total humid period is 5 to 9 months, except for the coastal region between Accra and Lomé. There is however, an intervening period with $R < ET_p$ in late July and August, which constitutes a distinct break between the two seasons. The evaporation is characterised by a well defined and pronounced maximum of about 7 mm a day in March and a corresponding minimum of 3 to 4 mm a day in August. A minor and diffuse maximum of 5 to 7 mm a day follows in October and November prior to an diffuse minimum of 3 to 5 mm a day in December to February.

Correspondingly the growth period consists of a major season of 4 months from April to July and a minor one from August to October. The main constraints to crop production are the irregularity in rainfall, especially within the seasons, and the suboptimum solar radiation.

c. The pseudo-bimodal regime, this regime extends east and west of the bimodal regime. Unlike the latter the decline in rainfall in July and August is not sufficiently pronounced to result a period of moisture deficit. The rainy season therefore is continuous from March/April to November/December.
The evaporation generally is low throughout the year, ranging between 2 and 5 mm a day.
The growth period ranges from about 200 days to year round in the extreme southwest and southeast. The main constraint to crop production is the suboptimum solar radiation, which in combination which the high air humidity causes a high incidence of pests and diseases.

## 1.4 Bioclimatic zones

Apart from the total amount of rainfall, the period during which vegetation growth and agricultural production are possible, is determined by the temporal distribution of rainfall and the consequent soil/moisture availability.
The length of this growth period has been defined by FAO (1978) and TAMS/CIEH (1976-1978) as follows:

- A continuous period during the year when precipitation is more than half the evaporation ($R > 0.5\ ET_p$) plus a number of days required to evaporate an assumed 100 mm of water stored in the soil after the rains have ceased. The growing season must exhibit a distinct humid period during which the precipitation is more than the evaporation ($R > 1.0\ ET_p$).

Based on the zonality of the annual rainfall, the length of the growth period and the resulting vegetational and agricultural potential, West Africa south of the Sahara, can be divided into four bioclimatic zones, as is shown on Map 2 of Volume IV. Each of these zones has specific prevailing ecological conditions.

a. The Sahel savannah zone is a transitional zone between the (Sahara) desert and the true savannah. The southern boundary roughly corresponds with the 90 days growth period isoline and the 550 mm annual isohyet. The vegetation cover is sparse. Nomadic agriculture is dominant. In the southern part millet can be grown, requiring a minimum growing season of 75 days. The Sahel savannah zone is not included in the area of the inventory.

b. The Sudan savannah zone extends south of the Sahel savannah zone, roughly between the 550 and the 1000 mm annual isohyets. Drought hazards are relatively low and a wide range of crops can be grown during a period of 90 to 165 days. Fairly intensive cultivation, is practised, particularly in Nigeria with almost continuous cultivation. The Sudan savannah zone is not included in the area of the inventory.

c. The Guinea savannah zone extends south of the Sudan savannah zone, roughly between the 1000 and the 1500/2000 annual isohyets. The growth period ranges between 165 and 270 days. Rainfall distribution is not uniform throughout the zone. In the northern part within the range of 1000 to 1300 mm per year the pattern is monomodal. Here, drought hazards are negligible and the photosyntetic potential is high. In the transitional southern part the rainfall has a bimodal pattern. The two rainy seasons are of unequal duration and rainfall is irregular. Drought hazards do occur here, whilst the photosynthetic potential is relatively low. Hence the bioclimatic conditions in the south are somewhat less favourable than in the northern part. The Guinea savannah zone is included in the inventory area within which it covers an area of nearly 1.3 million $km^2$.

d. The Equatorial forest zone extends southeast and southwest of the Guinea savannah zone. The annual rainfall is over 2000 mm per year, and increases rapidly towards the extreme southeast and southwest to 5000 mm per year or more.
The growth period exceeds 270 days, but the net solar radiation is low and the air humidity is high. Generally, these are suboptimum conditions for crop production. The Equatorial forest zone is included in the inventory area within which it covers an area of nearly 0.9 million $km^2$.

In contrast with the Sahel and Sudan zones, double or year round cropping is possible in the Guinea and Equatorial zones. This is especially so in the valleys of these zones, which usually have moist conditions over prolonged periods.
Because of this potential for double cropping, the Guinea and Equatorial zones have been adopted as the area subject to the Wetland Utilisation Research Project.

# 2 GEOLOGY/LITHOLOGY, GEOMORPHOLOGY AND SOILS

## 2.1 General

The following paragraphs present an outline of the geology, lithology and geomorphology of West Africa. Also, a general description is given of the main soils as well as a characterization of the soils occurring in the valley bottoms.
On the basis of a geomorphologic delineation of the inventory area, broad land regions could be distinghuished, as is shown on Map 3 of Volume IV. The land regions and their subdivisions group tracts of land with broadly similar characteristics with respect to land form, lithology and as a consequence, drainage. The land regions have been used as a basis for the inventory and characterization of the various types of wetlands occurring in the inventory area as is discussed in Chapter 3, Land drainage.

The geology and lithology have been described in a number of reports with accompanying maps. Coverage at scale 1:2.000.000 was available for almost all countries in the inventory area (Barrère and Slansky, 1965; Blanchot et al., 1973; Geol. Surv. Div., 1964; Nicklès and Hourcq, 1952; Dir. Overseas Surveys, 1960). For Guinea Bissau, use was made of the geological map at scale 1:1.000.000, included in the soil survey report by Da Silva Teixeira (1962). For Liberia such maps were not available. The geological information for this country was drawn from the Geological Atlas of the World at scale 1:10.000.000 (Unesco, 1976). For the whole region, use was also made of the descriptive text in Geology of Africa (Furon, 1963).
Additional detailed information was available for most countries, either in the form of specific geological studies and maps (Cameroon: Dir. des Mines et de la Geologie, 1953-59; Nigeria: Dir. Geological Surveys, 1962), or as sections in reports on soil surveys or land resources inventories.

The existing literature does not provide a comprehensive map coverage of the geomorphology. Therefore, the geomorphological information that underlies the division of the inventory area into land regions, by neccessity had to be derived mainly from the text and small sketch maps as presented in the various soil survey and land resources inventory reports for individual countries or parts thereof. The studies that were based on the so-called land system analysis proved very useful. Land systems (recurrent patterns of land form, soils and vegetation) are subdivided in their constituent units, the land facets. These are usually described in detail and illustrated in block diagrams. Information on specific land facets (e.g. valleyland) within a land system or on broad groupings of land systems (land regions) can be easily extracted from such reports and compiled for further elaboration. Land system analysis has been applied in Sierra Leone, in northwest Liberia, in large parts of Nigeria and in some parts of north Ivory Coast.

General information on the soils was obtained from such obvious sources like the 1:5.000.000 soil maps of Africa both by D'Hoore (1965) and by FAO-Unesco (1977), as well as Ahn's West African Soils (1970). More detailed soil data were gathered from reconnaissance and semi-detailed soil survey reports and maps of individual countries or parts thereof. For most of Liberia only a very small scale map (1:3.300.000) was available. The various sources of information used are listed in the references. As for the inland valleys, the main subject of the present inventory, details on their occurrence, distribution and characteristics were often difficult to obtain for areas surveyed by means of the French survey system. In this system emphasis is placed, in actual mapping as well as in the description of the map units, on the main soil of a mapping unit and its central concept in terms of soil classification. Inclusions, such as the valley lands generally are, due to their relatively limited extent and their scattered occurrence, receive little or no attention. Therefore, in francophone countries use had to be made frequently of information on similar land regions in adjacent (anglophone) areas.

## 2.2 Geology and lithology

In West Africa the most important geological unit is the basement complex comprising granites and associated metamorphic rocks of Precambrian age. The basement complex, which forms the African continental shield, underlies the whole inventory area. It appears in most of Guinea, Sierra Leone, Liberia, Ivory Coast, Togo, Benin, Nigeria and Cameroon, as well as in parts of Guinea-Bissau and Ghana.

The composition of the basement complex varies strongly. In south-eastern Guinea, Sierra Leone, Liberia, western Ivory Coast, central Togo, Benin and Cameroon, lower Precambrian rocks predominate. They are mainly granite-migmatite-gneiss complexes.
Middle Precambrian (Birrimean) rocks comprise mainly schists, quartzites and other metamorphic rocks, including micaschists, greenstone, amphibolites, arkoses, graywackes. These rocks crop out in northeastern and southern Guinea, in eastern Ivory Coast and in south Cameroon. They appear as NNE-SSW folded bands in the western part of Ivory Coast, in western Ghana and in the Atacora Range in Togo and Benin. Also of Birrimean age are the charnockites of the Man Massif (Ivory Coast). In southwest Ghana the Birrimean rocks also comprise basic and acid extrusives (lavas and tuffs). They occur in complexes with upper precambrian (Tarkwaian) rocks.
The Tarkwaian rocks were defined at Tarkwa in southwest Ghana and comprise folded conglomerates, (feldspathic) quartzites, sandstones and shales. These formations also occur locally in Ivory Coast.
Terminal Precambrian rocks (Buem series) are important in Togo and north Benin where, together with the Birrimean micaceous quartzites, they form the Atacora Range of high relief and topography. The Buem series includes shales, arkoses, sandstones, conglomerates and some volcanic rocks, mostly basalts and dolerites.
Precambrian rocks in Nigeria have not been well differentiated, but they include granites, gneisses, migmatites, micaschists and amphibolites with intrusions of 'Younger' granites. The latter form the core of the Jos Plateau in central Nigeria which has resisted various erosion cycles.

Precambrian intrusion phases have given rise to the occurrence of laccoliths, sills, dikes etc. In other parts of the inventory area, e.g. in Guinea, these formations comprise dolerites and gabbros.
Paleozoic (Cambro-ordovician) formations of sandstones, shales, mudstones and pebbly conglomerate beds occur in the central part of the Volta Basin and on the Sikasso Plateau (Mali, Upper Volta). Slightly older are the Infracambrian sandstones that form the upwarped fringes to the north, west and south of the Volta basin.
The high sandstone and shale plateaux constituting the Fouta Jallon and Manding Plateau in Guinea are also of Paleozoic age (Ordovician, Silurian and Devonian). However, these deposits have been uplifted subsequently over considerable heights. At present, altitudes in the Fouta Jallon exceed 1500 m locally.

It is thought that the African shield originally formed part of Gondwanaland, the ancient continent which comprised South America, Madagascar, India, Australia and Antarctica. During the Mesozoic era (lower Cretaceous) this continent broke up into the present blocks and drifted apart (continental drift). Concurrently and following the displacement of Gondwanaland, horizontal and vertical epeirogenic movements fractured the continent. These movements resulted in the formation of seas and lakes in basins like the Chad basin to the northeast of the inventory area and troughs likes the ones in which the Benue and Niger valleys are situated in Nigeria. These basins and troughs now comprise sedimentary rocks of corresponding age which are locally weakly metamorphosed. A wide variety of Cretaceaous marine and continental sandstones, shales and coal measures occurs in the Benue and Niger troughs (Nupe and Bima sandstone, Illo formation etc.). The Chad basin comprises Quaternary continental deposits which consist of unconsolidated clays, sandy clays and sands. Regionally, they occur as aeolian deposits (dunes etc).
During Tertiary and Mesozoic times volcanic intrusions and extrusions formed, among others, the Jurassic basalt flows and ash cones near Jos, the Cretaceous and Tertiary outcrops in the Benue trough and the Cretaceous basalt plateaux in west and central Cameroon (Mungo and Adamawa). Volcanic activity on the Jos plateau has continued into the Pleistocene. Mount Cameroon, still an active volcano near the Gulf of Guinea, is of Quaternary origin.

Tertiary sedimentary deposits, called the Continental Terminal, consist of weakly cemented sands, sandy clays, clays and marly clays . These deposits occur in fringes along the coast of Sierra Leone, Ivory Coast, Togo, Benin, Nigeria and Cameroon. They include the deposits that are locally known as Terres de Barre (Togo and Benin) and Coastal Plains Sand (Nigeria). The Kerri-Kerri formation west of the Gongola river in Nigeria also consists of continental sandstone deposits, whereas the low plains of Guinea Bissau and south Senegal comprise tertiary sedimentary deposits consisting mainly of unconsolidated sands with inclusions of sandstone shale, marl and clay.
Recent riverine and marine alluvial silts and clays occur in river plains (Volta, Oti, Niger and Benue rivers), delta's (Niger river) and estuaries (Rio Geba, Sierra Leone and Sassandra rivers). Elongated coastal sand bars (beach ridges) have been formed along most of the West African coastline.

In terms of soil formation in relation to lithology, it can be stated in general that in West Africa the soils derived from sedimentary material are chemically less fertile than those developed from Precambrian basement complex rocks. The latter contain silicate minerals that upon weathering, release nutrients. The sediments have been subjected to more than one weathering and erosion cycle and consist mainly of residual materials like quarts, kaolinite and gibbsite. Within the varied complex of sedimentary deposits, sandstones upon weathering give rise to very poor sandy soils. Shales tend to form more clayey soils, which to some extent are chemically richer.
Within the basement complex, the metamorphosed rocks (schists, amphibolites etc) tend to form relatively fine-textured soils (light clays) that are chemically richer than the soils formed over granitic material. In addition, the soils over granites have coarser textures (sandy clays, sandy loams, loamy sands and sands). The poorest basement complex soils are those over quartzites.
Generally, due to the prevailing climatic conditions (high temperature and precipitation), weathering processes have been intense and have caused deep soils, except in sloping and steep areas where erosion has resulted in shallow soils or even complete denudation of the rock.
Planation cycles, which during the various geologic eras have acted to form the typical (West) African plains and plateaux, have affected soil depth in large parts of the inventory area.

## 2.3 Geomorphology

### 2.3.1 General description

During the Jurassic era, preceding the lower Cretaceous disruption of Gondwanaland, the surface of the super continent was subjected to intensive erosion that caused the formation of a nearly level plain, the so-called Gondwana planation surface. Simultaneously, continental basins (e.g. the Congo basin) were filled with detritus from adjacent eroding areas. This sedimentation process further contributed to the smooth appearance of Precretaceous Africa. Relicts of the Gondwana surface can still be found in the inventory area. They include the high plateaux of the West Cameroon Mountain Range, the Jos Plateau in Nigeria and the summit of Mt. Nima in the Guinean Highlands.
The dislocation, fracturing and faulting of the African continent in the Cretaceous era caused a new erosion cycle to form the Post-gondwana planation surface. This surface comprises parts of the high plateaux surrounding Jos, portions of the Cameroon Highlands including the Adamawa Plateau and the crest of the Atacora Range in north Benin.
Associated with the Cretaceous faulting, volcanic activity started mainly in west Cameroon and in central Nigeria, locally forming extensive basalt plateaux.
Erosion cycles during the Eocene and Plio-pleistocene eras caused further planation (the African and Post-african planation respectively) and the formation of the extensive, remarkably level plains and plateaux that make up most of the inventory area. The various planation surfaces are commonly separated from each other by distinct scarps or by dissected transition zones of broken relief. Occasionally the transition is smooth and hardly discernable. Eocene planation surfaces comprise the high plains of Hausaland in Nigeria, which occur at altitudes of 600 to 1000 m above sea level (a.s.l.). Probably most of the plateaux in southern Cameroon (which have approximately the same elevation) belong to this planation surface too. The majority of the West African plains is of Plio-pleistocene age. They occur at elevations between 50 and 700 m a.s.l.

Most plains and plateaux have undulating relief. They are dissected to various degrees by streams and rivers, usually in a dendritic (non-orientated) drainage pattern. Locally, steep-sided remnants of older plateaux (mesas), granitic inselbergs and hill ridges arise from these plains. Granitic inselbergs and ridges have resisted ongoing weathering and erosion, due to their hardness.

They can be as high as 200 - 300 m. The mesas, which may stand about 10 - 100 m above the ground surface, have been formed due to the occurrence of ironstone hardpans (cuirasses, carapaces, duripans, laterite pans, etc.) at their surfaces. These hardpans have been formed through downward movement and subsequent accumulation in lower soil horizons of sesquioxides, notably iron oxides, under conditions of alternating wetness and drought. On the level planation surfaces formed by the various erosion cycles, massive sheets of iron accumulation could develop. The stripping of overlying soil material during new erosion cycles, caused by uplifting or other relative changes in the base level, has progressed down to the indurated iron pan, which now appears at or near the surface.

Geologic variations have locally caused pronounced relief in planation surfaces. For example, the Ashanti Hills in southwest Ghana comprise folded ridges of hard rocks (granites, quartzites, and diorite sills) and softer formations (conglomerates, sandstones, shales and phyllites) in a NE-SW alignment. Differential erosion has caused steep relief with slopes up to 35%, separating the relatively level remnants of former plains from wide, flat-bottomed valleys. Also in Ghana, the fringes of the Volta basin have been formed by uplifting, resulting in steep and deep, outward-facing scarps reaching down to the gently undulating plains to the north, west and south. The upturned edges rise to 400 m (the Gambaga scarp in the north) and 500 m (the Mampong scarp in the south) above the adjoining plains. These plains have an elevation of 100 - 200 m a.s.l. The plains between the Atacora Range (Togo and Benin) and the lower Niger valley (Nigeria) are distinctly stepped and warped. Locally they are nearly level to gently undulating; in other places successive planation cycles have caused a broken topography consisting of scarps and dissected areas.

The bolilands in Sierra Leone form a complex of seasonally flooded, wide and shallow depressions and low river terraces of negligible relief, associated with Precambrian sandy and clayey consolidated sediments. The low, nearly level plains in Guinea Bissau (and extending into Senegal and Gambia) are aggradation surfaces comprising the Continental Terminal deposits of mainly sandstones and sands. They have an elevation of approximately 20 to 50 m a.s.l. and are intersected by the valleys of the Coruba and Geba rivers and, outside the inventory area, by the Casamance and the Gambia river.

Most of the large rivers in West Africa have nearly level floodplains in which locally terraces have been formed. Extensive floodplains and terraces occur particulary along the Black Volta in Ghana, the Oti in northeast Ghana and north Togo, the Niger in Guinea and Nigeria and the Benue, also in Nigeria.

High ranges in the inventory area comprise the Fouta Jallon in Guinea. This is an extremely dissected area of sandstone and shale plateaux at an elevation of 1000 to 1500 m a.s.l. Hard iron crusts (bowals) formed at the surface of these deposits, have contributed to their preservation. The deeply and steeply incised, fault-controlled valleys form a rectangular drainage pattern.
To the west the plateaux decline in a series of fault steps to the narrow coastal plain. In the east (Manding Plateau), a more gentle transition occurs towards the interior plains of Guinea and Mali (300 to 400 m a.s.1) in which the Niger has formed an extensive inland delta.
In sharp contrast to the high plateaux of the Fouta Jallon and the Manding Plateau are the rounded but steep hills and mountains of the Guinean Highlands (French: Dorsale Guinnéenne) comprising mainly granitic rocks, which rise to over 1900 m a.s.l. in the Loma Mountains of Sierra Leone. Mount Nimba on the border between Guinea, Ivory Coast and Liberia is 1752 m a.s.l. Further east is the Man Massif which attains heights up to 1400 m a.s.l.
The Atacora Range, east of the Volta basin, is a belt of parallel ridges trending NNE-SSW through south Ghana, Togo and north Benin. They rise to over 1000 m a.s.l. (Mt. Segou). The steep-sided and narrow valleys in between the mountains are locally more than 300 m deep.
In central Nigeria, the Jos Plateau consists of a granitic plateau with some volcanic hills and basalt flows up to 1600 m a.s.l. At its southern margin it is separated from the high plains of Hausaland by extremely deep and steep scarps of approximately 600 m. The West Cameroon Highlands comprise undulating to rolling plateaux formed in granite and basaltic lava flows at altitudes of 1500 m a.s.l. and more. Volcanic cones on these plateaux reach heights of more than 2500 m a.s.l. (Mts. Oku and Mba Kokeka and the Santa Peak). Stretching west of these highlands is the Yade Plateau in the Adamawa Range at an altitude of approximately 1200 m a.s.l. The Mandara Mountains further north also belong to the Cameroon Mountain Range. Mount Cameroon (4070 m a.s.l.) forms a spectacular, solitary dome to the south of the Cameroon Mountain Range. It is a still-active volcano.

The coastal plains in the inventory area comprise recent marine and riverine alluvial deposits occurring in coastal sand bars, beaches, lagoons, estuarine and deltaic swamps and riverplains.
At its mouth, the Niger has formed an extensive delta consisting of freshwater swamps, basins and levees in the central and inland parts. Mangrove swamps surrounded by tidal creeks prevail towards the coast. The coastline along most of the West African coast is formed by a series of sandy beach ridges.
Locally (Ivory Coast, Togo, Benin, Nigeria and Cameroon), the coastal plains include low plateaux of the Continental Terminal (Tertiary) deposits). These plateaux, have gently undulating relief. They have been upwarped slightly towards the interior, resulting in their separation from the interior plains by a distinct scarp which, in Ivory Coast, Togo and Benin, may attain several tens of meters in height. Rivers have cut steep-sided courses into the elevated parts of the coastal plains (Sassandra, Bandama and Komoe rivers in Ivory Coast, Sio and Haho rivers in Togo and the Ouème river in Benin among others). The Hollis Lama depression in Togo and Benin is a low-lying area of Eocene marly clays within the Continental Terminal plateau. It is probably formed by erosion of the soft marls.
In Nigeria, the transition between the coastal plateaux and the interior plains is formed by a zone of Tertiary and Cretaceous sandstones, shales, sands and coal measures of distinct dissection with high scarps (the Enugu Scarp is 350 m high) and dipslope features.

### 2.3.2 The land regions

For the purpose of the inventory and characterization of the small inland valleys, the inventory area has been divided into land regions, based on geomorphological differences described in Paragraph 2.3.1. Land regions are broad landscape units with recurrent physiography. Four land regions have been distinguished:

1. Coastal Plains covering an area of 100.000 $km^2$.
2. Interior Plains (1.075.000 $km^2$).
3. Plateaux (624.000 $km^2$).
4. Highlands (361.000 $km^2$).

These land regions are further subdivided according to geology, lithology and related features like degree of dissection, relief, occurrence of inselbergs, hill ridges and laterite-capped mesas. In total, 19 subregions have been distinguished.
Initially, these units were delineated on topographic maps at scale 1:1.000.000 on basis of information from various geological, soil and land resources surveys. The unit boundaries were then transferred to the present Map 3 of Volume IV at scale 1:5.000.000 (land regions).
The map units are briefly described in Table 2. More elaborate descriptions are included in the legend of the land region map.
This legend also shows the main soils occuring in the various subregions.

## 2.4 Soils

### 2.4.1 Upland soils

The distribution pattern of the soils in the inventory area shows that in general from the north to the south and from the centre to the west and east respectively, depletion processes become increasingly important in soil formation. These processes include the chemical weathering of primary minerals, their subsequent removal (leaching) and the formation of new and inert minerals. Ultimately these processes lead to the formation of soils with low inherent fertility. The distribution pattern of the soils coincides in general with the distribution pattern of present rainfall in the inventory area: precipitation increases towards the south, Sierra Leone, Liberia and Cameroon are the wettest countries and a 'dry corridor' exists near the coast of east Ghana, Togo and Benin (see also Chapter 1 and Map 2 of Volume IV). However, it should be noted that most land forms in West Africa are of Plio-pleistocene age and thus older than the present geo-climatic era. Therefore, there is no single causal relationship between present climate and soils.
The main soils of the inventory area are discussed below. Soil classification names refer to the USDA Soil Taxonomy.

Table 2. Land regions and subregions and summary descriptions

| Region | Map[1)] unit no | Area (km²) | PHYSIOGRAPHY | GEOLOGY AND LITHOLOGY | |
|---|---|---|---|---|---|
| COASTAL PLAINS | 1.1 | | Nearly level beaches, river plains, deltas, tidal swamps etc. | Recent sands, silts and clays | RECENT, TERTIARY AND CRETACEOUS SEDIM FORM |
| | 1.2 | | Slightly dissected, gently undulating coastal terraces | Tertiary weakly cemented sands to clays and marly clays | |
| | 1.3 | | Highly dissected, undulating to rolling coastal terraces | Tertiary and Cretaceous Sandstones, shales, sands and coal measures. | |
| | TOTAL | 100.000 | | | |
| INTERIOR PLAINS | 2.1 | | Slightly dissected, undulating peneplains with inselbergs, hill ridges and mesas | Undifferentiated granites, migmatites and gneisses | PRECAMBRIAN BASEMENT COMPLEX |
| | 2.2 | | - do - | Undifferentiated schists, quartzites and other metamorphic rocks | |
| | 2.3 | | Highly dissected, rolling to steep peneplains | Complex of metamorphics, sedimentary formations and volcanics | |
| | 2.4 | | Dissected and upwarped, undulating to rolling peneplains | Upwarped sandstones | PALEZOIC SEDIM FORMATIONS |
| | 2.5 | | Slightly dissected, nearly level peneplains | Sandstones, shales and mudstones | |
| | 2.6 | | Slightly dissected, gently undulating peneplains with mesas and volcanic cones | Marine and continental sandstones, shales coal measures and basalt-extrusions | CRETACEOUS SEDIM FORMATIONS |
| | 2.7 | | Sleeply dissected undulating peneplains | Continental sandstones and conglomerates | |
| | 2.8 | | Slightly dissected, nearly level aggradational plains | Sandstones and sands | TERT SEDIM FORM |
| | TOTAL | 1.083.000 | | | |
| PLATEAUX | 3.1 | | Slightly dissected undulating plateaux with inselbergs, hill ridges and mesas | Undifferentiated granites, migmatites and gneisses | PRECAM BASEM COMPLEX |
| | 3.2 | | - do - | Undifferentiated schists, quartzites and other metamorphic rocks | |
| | 3.3 | | Dissected, undulating to rolling plateau | Paleozoic sandstones | PAL SED |
| | 3.4 | | - do - | Tertiary sandstones | TERT SED |
| | TOTAL | 624.000 | | | |
| HIGHLANDS | 4.1 | | Highly dissected very steep mountain ranges with remnants of old planation surfaces | Undifferentiated granites migmatites and gneisses | PRECAM BASEM COMPLEX |
| | 4.2 | | do, but with rugged, rolling high plateaux | Complex of 'older' and 'younger' granites migmaties, gneisses and basalts | PRECAM JURAS CRET COMPL |
| | 4.3 | | do, but strongly foldes and faulted | Complex of sedimentary, metamorphic and extrusive formations | PRECAM BASEM COMPL |
| | 4.4 | | Steeply dissected, undulating high plateaux | Sandstones and shales | PAL SEDIM FORM |
| | TOTAL | 361.000 | | | |

1) Map unit numbers refer to the Land region map, Map 3 Volume IV.

a. Alfisols (Ustalfs) are the main soils in the north and in the centre of the inventory area (the Guinea savanna zone, including east Guinea, south Mali, southwest Upper Volta, north and east Ghana, Togo, Benin, west and central Nigeria). These scils are generally coarse to medium textured (sandy loams to light clays) with a clayey B-horizon. They have a favourable base status and acidity level (near neutral). These soils, which are mainly deep to moderately deep, may be very gravelly, especially if developed from parent material rich in quartz (granites, quartzites, some gneisses). The gravel may occur in layers or stonelines at shallow depth. Also, these soils may overlay continuous ironstone hardpans or sheets of ironstone aggregates at shallow depth (petroferric contact), especially in areas with parent materials that contain much ferro-magnesian minerals (e.g. amphibolites). These hardpans and aggregates have been formed by accumulation of sesquioxides, notably iron-oxydes, under conditions of alternating wetting and drying.
The Alfisols have relatively low organic matter contents. Their main constraint is the low availability of soil moisture, especially if profiles are shallow. The natural vegetation on these soils consists of open woodland grass savannah. The density of the tree cover varies, depending on local environmental conditions and on human activity. Traditionally these soils are used for the cultivation of crops including cassava, maize, sorghum, millet, groundnut and cotton, in shifting cultivation systems and for livestock grazing.

b. Ultisols (Ustults) are the dominant soils in the transition between the Guinea savannah zone and the Equatorial forest zone (Guinea, north Ivory Coast, central Ghana, east-central Nigeria). Like the Alfisols, they are mainly coarse to medium textured soils (sandy loams to light clays) with a clayey B-horizon. However, due to increasing depletion, they are acid and have a low base saturation (less than 50 percent). They may be gravelly and may contain ironstone hardpans or aggregate layers.
The main agricultural constraint of the Ultisols is their relatively low inherent fertility and their susceptibility to erosion. The natural vegetation on these soils is mainly tropical semi-deciduous rainforest. On these soils food crops such as cassava, maize, beans and upland rice are grown mainly in shifting cultivation systems. Also, cash crops such as coffee and cocoa are grown.

c. Ultisols (Udults) predominate in the southeast and the southwest of the inventory area. In the wettest parts (Sierra Leone, Liberia and Cameroon) Oxisols (Orthoxs) occur.
Udults are the Ultisols of the humid areas. They resemble the Ustults of the subhumid zone except for their relatively more humid soil moisture regime.
Orthoxs are strongly weathered and leached soils and consequently of very low inherent fertility, but with favourable although fragile soil structure. They are mainly medium textured (sandy clay loams - light clays) and deep. They may be gravelly.
Ironstone hardpans and aggregate layers do occur in these soils, but less common than in the Ustalfs and the Ustults. It is thought that under favourable paleoclimatic conditions these ironstone hardpans and aggregate layers have been formed extensively over the whole of West Africa, but that they have been largely disrupted in areas with a humid climate at present, e.g. the Equatorial forest zone and the southern fringe of the Guinea savannah zone. In these areas relief is also more pronounced.
Most Udults and Orthoxs in the inventory area are covered by tropical lowland rainforest, providing natural cover against erosion. Shifting cultivation is based on a short period (2-3 years) of cultivations of banana, cassava, yam, upland rice and maize, followed by fallow period (10-15 years). Plantation crops include rubber, oilpalm, cocoa and coffee.

Apart from climate, geology and geomorphology have a pronounced effect on the soil formation. Within the land regions and subregions mentioned in Paragraph 2.3.2, great variations of the main soils occur as is shown in the legend of Map 3 of Volume IV. The variations due to geological differences, are described below.

- Within the basement complex, the metamorphic rocks (schists, amphibolites and greenstones) tend to weather into relatively fine textured soils (light clays). Chemically rich soils develop in particular from the more basic rock types (amphibolites) that are rich in ferro-magnesian minerals like olivine, pyroxene and hornblende. However, the relatively high content in iron (and manganese) in these minerals also causes a high incidence of occurrence of continuous ironstone hardpans or sheets of ironstone aggregates.

In areas with relatively high groundwater levels or seepage water from sideslopes of valleys, formation of plinthite is common (Plinth-ustalfs, Plinthudults, Plinthaqualfs, Plinthaquults). Plinthite is an iron-rich and humus-poor mixture of clays and quartz. This mixture commonly occurs as reddish mottles in the soil profile. Upon repeated wetting and drying it changes irreversibly into ironstone, either in the form of a continuous pan, or as irregular aggregates.
Soils developed over intermediate (micaschists, gneisses) and more acid basement complex rocks (granites, quartzites) generally have coarse textures (sandy clays to sands) with medium to low fertility. They include Haplorthoxs, Tropudults and Ultic Tropudults in the humid climatological zones and Oxic Haplustalfs and Haplustults in the drier areas. Ironstone hardpans and concretionary layers are common in soils over intermediate and acid rocks, although less than in areas with rocks that are richer in ferro-magnesian minerals.

- The parent material of soils developed in sedimentary formations has been subjected to more than one weathering cycle. As a result, soils on these formations are chemically poor, as they mainly contain inert materials like quartz, kaolinite and gibbsite.
  The soils on the Cretaceous sedimentary formations occupying the Niger and Benue river troughs are mainly Ultisols. Depending on the grain of the parent material, they are coarse textured (on sandstones) ranging to clayey (on shales). In general these are deep soils with a 'stretched' B-horizon that shows signs of clay illuviation (Pale-ustults). Ultisols (Paleudults and Tropudults) are also the main soils of the coastal terraces. They are generally deep, sandy clay soils.
  Heavy cracking clay soils (Vertisols) have been formed in the marly sediments of the Hollis Lama depression in Togo and Benin.
  (Oxic) Haplustalfs and Plinthustalfs dominate on the sandstones of the Volta basin. Oxic Haplustalfs are Alfisols of the subhumid areas with low inherent fertility. Plinthustalfs contain plinthite within 125 cm of the surface. The occurence of continuous ironstone hardpans in the soils of the Volta basin is widespread.

### 2.4.2. Soils of valley catenas

Variations in soils do also occur because of geomorphological and hydrological differences along valley catenas (toposequences).

The predominantly dissected, undulating to rolling peneplain landscape of West Africa, has only few areas occupied by soils that have actually been formed in situ on the directly underlying rock. Planation cycles, in particular during the Plio-pleistocene era have removed much of the weathering mantle of the basement complex rocks and Cretaceous sedimentary formations (erosional stripping). As a result, soils have been rejuvenated and they are not extremely deep. However, real sedentary soils occupy specific positions of limited extent in the landscape: the summits and upper slopes of the toposequences.
In old landscapes the summits may consist of reworked, rather uniform material of former planation surfaces that may be associated with irontstone pans. On the lower slopes of the toposequences, colluvial deposits of material from upslope form the parent material of the soils. The colluvium may include gravelly layers with quartz or with ironstone concretions which either were formed in the higher profiles, or which were formed in situ. The extent of the colluvium depends largely on the relief. In the Equatorial forest zone relief is generally more pronounced, with relatively short and steep interfluves, than in the Guinea savannah zone where a gently undulating relief prevails.
In the lowest parts of the toposequences (the valley bottoms), alluvium is the parent material of the soils. These stratified materials originate mainly from areas further upstream. The soils of the valley bottoms differ widely in their characteristics, locally as well as regionally, but they have in common that they all show signs of periodic wetness.

### 2.4.3 Valley bottom soils

Valley bottom soils are hydromorphic soils. They have characteristics associated with wetness and, unless artificially drained, the resulting reduction during at least some period of the year. Hydromorphic processes include the mobilization and reduction of iron in the soil.
This causes the characteristic neutral grey colours under conditions of continuous saturation or mottling and possibly formation of iron concretions under alternating wet and dry periods. In sandy soils (periodic) wetness gives rise to the occurrence of uncoated sand grains. Under conditions of prolonged waterlogging, decomposition of plant remnants may be slow and humic topsoils may be formed which have higher contents in organic matter than adjacent higher and drier lands.

In soil classification (Soil Taxonomy; Soil Survey Staff, 1975) the concept of aquic soil moisture regime is used to distinguish hydromorphic soils. Aquic sub-orders have been distinguished in most of the ten Orders in this classification system, e.g. Aquents (Entisols), Aquepts (Inceptisols), Aqualfs (Alfisols), Aquults (Ultisols) etc. These soils are completely saturated for at least a few days per year. An aquic soil moisture regime implies reducing conditions in which little or no oxygen is available in the soil solution. Soils that have saturated horizons only below 50 cm in general, may be differentiated at the sub-group level of classification, e.g. Aquic Tropopsamments, Aquic Tropudults etc.

Valley bottom soils vary widely in their characteristics within valleys as well as between them. This is caused by their morphogenesis as stratified alluvial deposits, their occurrence in a wide range of valley shapes with different hydrological regimes and their varying lithologic origin. Texture of the soils of the valley bottoms may vary from sand to clay and drainage classes may be moderately well to very poor. The soils may be subject to floods of variable depth and duration. They may be strongly stratified and may contain gravel, iron concretions or plinthite. The inherent fertility may range from moderate to very low. It can be stated however, that in their texture as well as in their fertility, these soils in general reflect the characteristics of the surrounding upland soils and parent material. Thus, coarse texture and low fertility prevail in sandstone and quartzitic areas, coarse texture and moderate fertility mainly occur in granitic formations and medium to fine texture and moderate to high fertility are common on shales, siltstones and intermediate to basic rock formations.
To demonstrate the great variability of valley bottom soils within the land regions and within the valleys themselves, a number of descriptions of these soils is presented in Annex I of this Volume. These descriptions have been obtained from various soil surveys in West Africa. Where possible, descriptions of the valley morphology and of the land use on these soils have been included.

### 2.4.4 Soil constraints to rice cultivation in valleys

With a view to the proposed research on rice-based farming systems in the inland valleys of West Africa, the main soil factors affecting wetland rice cultivation on valley bottom soils are briefly discussed here.

Soil drainage. Rice being a semi-aquatic plant, poor to moderately well drainage conditions are best suited for rice growth and cultivation. Well and excessively drained soils carry a drought risk. Such a risk may be overcome by levelling and by the construction of bunds around the fields to retain the water. Soils that are continuously saturated are not suited for rice as some alternating oxidation and reduction of the (top)soils is required for good rice growth.

Texture. Coarse textured soils generally are less productive than soils with a fine texture. This is due to the lower inherent fertility of the former, but also because of their higher percolation rates, by which nutrients (including fertilizers) will easily leach below the root zone. On sandy soils therefore, fertilizers should be applied very carefully i.e. in several small doses, rather than in one or two large applications. The higher percolation rates of sandy soils imply that on these soils it is difficult to retain water on the field. In rice cultivation this would be desirable mainly for weed control purposes. Also, coarse textured soils lend themselves less well for the construction of bunds, dikes and drains than more clayey soils.

Soils with very high clay contents like Vertisols, have as their main constraint that land preparation is very difficult, often requiring mechanized draft power.

Structure. In wetland rice cultivation puddling, through intensive ploughing the wet soil is often practised to destroy the structure of the upper soil layers and to form a plough pan. The advantage of this practice is that a soft bed for seeding and/or transplanting is created, percolation losses are reduced and that weeds can be better controlled. Puddling is more difficult in fine textured soils which generally have a stronger structure than soils with a coarse texture, but it is more effective in decreasing percolation losses.

Inherent fertility. In general sandy soils have little capacity to supply nutrients to crops. In addition, they have a low capacity to retain nutrients applied through fertilizers. The cation exchange capacity (CEC) in sandy soils largely depends on the organic matter content. Under hydromorphic conditions the latter may be somewhat higher than in upland soils due to slow mineralization of organic matter under reduced conditions.

In clayey soils the CEC depends not only on clay and organic matter contents, but also on the clay mineralogy. Kaolinitic clays which dominate the clay fraction of alluvium derived from granitic basement complex rocks, have a low CEC compared with illite, vermiculite and smectite which are more abundant in alluvium derived from schists, greenstones and amphibolites.

Base saturation is a measure for the relative abundance of plant nutrients (bases). In general, a high base saturation is favourable for plant growth. However, a high base saturation is of limited relevance, if the total amount of bases available to the plant is low, i.e. if CEC is low, like in many of the valley bottom soils.

Soil reaction (pH) in the valley bottom soils ranges in general from extremely acid (4.0-4.5) to slightly acid (6.1-6.5). This is a suitable range for rice production, considering that upon reduction of the (top)soil following ponding and puddling, the pH tends to change toward neutral (6.5-7.0). Most plant nutrients are best available for uptake by roots in the slightly acid to near neutral reaction range.

Organic matter serves as a 'storage' for plant nutrients, contributing to the CEC of the soil. It also is a source of nutrients, mainly nitrogen, in itself. Further, it increases the water holding capacity of a soil, through its beneficial effect on the soil structure.

Salinity and toxicities. Valley bottoms in the northern part of the inventory area may have salinity problems in the dry season, due to capillary rise of groundwater. Upon evaporation of the water, salts may accumulate to harmful concentrations at the soil surface or in the rootzone. Usually, in the humid and subhumid regions, these salts are leached with the first rains of the subsequent rainy season, before cultivation.

Iron toxicity in rice has been reported from many West African countries although it has been little documented. Under reduced, acid conditions ferrous iron ($Fe^{++}$), which may either be present in situ in the soil profile from weathering primary minerals or that may be brought into the rootzone by subsurface flow from adjacent higher areas, affects the development of the rice crop in two ways:

a. by coating the plant roots with iron oxide and thus reducing the absorption capacity of the plant for other nutrients like P, K, Ca and Mg, ($Fe^{++}$-induced deficiency) and,
b. by direct iron toxicity through excessive $Fe^{++}$ absorption by the plant.

Iron toxicity in rice plants shows as a characteristic orange discoloration of the leaves (bronzing). It appears to occur mainly in areas dominated by Ultisols in the humid zones of the inventory area (Sierra Leone, Liberia, southeast Nigeria). Possible remedies, apart from the use of tolerant rice varieties, include seasonal drying of affected fields (oxidation of $Fe^{++}$ into insoluble $Fe^{+++}$) or interception of the subsurface water flow containing ferrous iron.

# 3 LAND DRAINAGE

## 3.1 General

TAMS/CIEH, during their study of the West African savannah from 1976 to 1978, collected and elaborated a substantial amount of information on the surface and subsurface water regimes in the area. Also Ativon (CIEH/WARDA, 1979) described the land drainage aspects of the inventory area. Catchments or sub-catchments have been described in varying detail by ORSTOM (1970) and Argoulon (1972) for the Niger basin, by Chauméņy (1972) and Reichhold e.a. (1978) for the Senegal basin, by Bertrand (1973) for the Casamance basin, by Girard e.a. (1971) for the rivers of Ivory Coast, by Quartey e.a. for the Volta basin, by Rodier and Sircoulon (1963), Moniod (1973) for the Ouémé basin, by Murdoch e.a. (1976) and Wall (1979) for the rivers of Southwest and central Nigeria and by Olivry (1976) and Casenave (1978) for the rivers of West Cameroon.
Significant work on the characterization of valleys has been done by IRAT (Kilian, 1972, Kilian and Teissier, 1973 and Gillet, 1973) in Benin, Ivory Coast and Upper Volta. Also the work done by Avenard (ORSTOM, 1971) in Ivory Coast, FAO (1979) in Sierra Leone, Murdoch e.a. (1976) and Savvides (1981) in Nigeria provides much insight in the diversity of the inland valleys.
The drainage systems in terms of pattern, and intensity (density and texture) have been characterized on the basis of information from semi-detailed soil surveys for selected sample areas, within respective land regions. Also estimates of the areas occupied by wetlands could be extracted from these reports and maps.
Details on the occurrence, the characteristics and the distribution of the inland valleys, were often difficult to obtain for areas surveyed under the French survey system. In this system (usually) only the main soils of the map units are described. Inclusions, such as the valley lands receive little attention. Therefore in the assessment of valley characteristics, extrapolations had to be made from information of similar land regions in adjacent (anglophone) areas.

### 3.2 Catchments

The large number of catchment areas (drainage basins) can be divided in two main groups.

a. The Sudan/Sahel rivers, comprising a small number of large rivers. These rivers initially flow in a northerly direction and then turn either to the west (the Senegal, Gambia and Casamance rivers) or to the east and subsequently to the south (the Niger and partly the Volta rivers).
   These rivers rise in the Fouta Jallon and associated mountain ranges in the western part of West Africa. They lie only partly within the inventory area, viz: the upper catchments of the Senegal, Gambia, Casamance and Niger rivers and the middle and lower catchments of the Volta and the Niger river systems. The Benue river, a tributary of the Niger river has a similar pattern but flowing from the Cameroon highlands to the north it turns to the west and south.
b. The coastal rivers comprising a large number of relatively small rivers. These rivers flow from the inland almost directly to the coast and generally have a north(east) to south(west) direction. Usually they have only few tributaries. They are short and hardly exceed a length of 500 to 600 km. They are all entirely located within the inventory area.

### 3.3 Drainage systems

The drainage systems can be characterized in terms of drainage pattern, density and texture. This kind of characterisation of the land drainage within the land regions and subregions is shown in the legend accompanying Map 3 of Volume IV.
The drainage pattern refers to the spatial arrangement of the drainage ways which may either or not be systematic due to variation in geology and relief.
In the lowlands of the Coastal Plains (subregion 1.1 in Table 2), estuarine and deltaic drainage patterns are obvious, and (tidal) swamps abound locally (Nigeria). Sedimentary stratification paired with slight dipslopes in the coastal terraces (subregion 1.2) has given rise locally to a trellis-like drainage amidst a predominantly dendritic pattern. Dendritic drainage patterns also prevail in the Interior Plains and the Plateaux (land regions 2 and 3).

Within the subregions of the Interior Plains and Plateaux comprising rock formations of the basement complex, (subregions 2.1, 2.2, 3.1 and 3.2) the more pronounced orientation of the sub-parallel and locally trellic drainage patterns is caused by the structural differences of underlying rock that may result in outcrops of more resistant formations (quartzitic bands, granitic hill ridges) amidst more weatherable rocks. The outer fringes of the Volta basin in Ghana (subregion 2.4) have been upwarped. Under the influence of the resulting inward overall slope a distinct sub-parallel drainage pattern has developed in this area. The rectangular drainage pattern occuring in the high sandstone and shale plateaux of the Fouta Jallon (subregion 4.4) is controlled by faults, along which streams have extended their courses by headward erosion.

The drainage density is the total length of all streams in a drainage basin and is expressed in km (waterway) per $km^2$ (basin). The drainage texture refers to the number of streams per unit area, expressed in number per $km^2$. The latter is closely related to relief and dissection. In general a high drainage density and fine texture occur on hard rock formations (such as granites and quartzites), that force precipitation water largely to run off superficially. On less hard and more permeable formations such as sedimentary deposits, more water can be discharged internally and the therefore density will be lower and the texture will be coarser.
The drainage texture is an indicator of the dispersion of the valleys. In combination with the drainage density, it also indicates the average length of the streams (the density divided by the texture). If this average is low, the streams generally are short and most likely the area comprises a relatively large number of streamflow (and possibly overflow) valleys. The valley characterization is discussed in paragraph 3.4.

Naturally, the drainage density of the land is also related to the amount of precipitation falling on it. This is reflected in the figures for drainage density as shown in the legend of Map 3 of Volume IV. These figures have been determined separately for the Equatorial forest zone (humid tropics) and for the Guinea savannah zone (sub-humid tropics). In the latter zone drainage density varies depending on the rock type from low to medium (0.3-1.2 $km/km^2$). In the Equatorial forest zone drainage density mainly varies from medium to high (0.6-2.4 $km/km^2$).

## 3.4 Valley characteristics

### 3.4.1 Morphology

Depending on differences in lithology and geomorphology, valleys vary in shape. The morphology of valleys can be characterized by their longitudinal cross-sectional profiles..
Longitudinally the valleys may be continuous and smooth, or interrupted and stepped. Continuous valleys occur in lithological formations with little structural variation, e.g. the sedimentary formations. Stepped valleys in the Interior Plains and Plateaux have been reported on the basement complex in Nigeria, Sierra Leone and Liberia. In the basement complex, hard rocks (granites, quartzites) alternate with softer formations (schists, gneisses). The flatter (and wetter) sections that develop on the more weatherable rock types are separated by short, relatively steep and narrow valleys in the resistant rock formations.
The overall longitudinal slope of the valleys in most of the Interior Plains and Plateaux is low (1 to 2%). It is steeper in the Highlands (up to 5%).

Shape and width determine the cross-section of the valley. Three broad types of cross-sections can be distinguished:

- shallow and narrow V-shaped valleys, formed in relativey hard rock formations (granites, quartzites)
- deep and narrow U-shaped valleys with concave sides that gently transfer into the valley bottoms, formed in rocks of medium hardness/ permeability (schists, gneisses)
- deep and wide U-shaped valleys with distinct bends between steep sides and flat bottoms, formed in relatively soft, permeable formations (sediments, amphibolites).

Due to increasing catchment area and subsequent increase in river discharges, the valleys become wider downstream. Also at the confluence of streams, the valleys are wider .
The morphology of valleys is important in view of their agronomic suitability. Particularly, the soil drainage and flooding regime are greatly influenced by the shape of the valley.

Concave valleys show a gradual transition from good drainage conditions on the valley sides through imperfect drainage on the lower colluvial slopes to somewhat poor to poor drainage in the valley bottom. If flooding occurs, then depth and duration vary widely according to the topography in the valley.
U-shaped valleys have an abrupt change in drainage conditions between the two main valley facets: the flat bottom lands have poor drainage, whereas the steep sideslopes are well drained. Groundwater tables or flood levels do not show much spatial variation over the whole of the valley bottom.

### 3.4.2 Position along the river

Depending on the position along the river, the valleys have different flooding regimes. Three main categories of valleys have been recognized, as is shown in Figure 4.
These categories are:

- The river floodplains along the (big) main rivers, which flood every year. Generally these plains cannot be developed without major engineering works, such as embankment of the river or empoldering. Often they require a comprehensive irrigation and drainage network.
- The river overflow valleys along the smaller rivers (i.e. main tributaries). Plains in these valleys are usually located on one side of the river and their sizes vary considerably. The main source of water is not from upland surface runoff or upland groundwater depletion flow, but from flooding of the river. If the river does not flood, the plains suffer from drought.
- The streamflow valleys (French: 'Marigots').
  These are formed on the uppermost part of the catchment and extend over a distance of up to 25 km and sometimes more. They have a width varying from 10 metres in their upper to about 250 metres in their lower stretches. The longitudinal slopes are in the order of up to 2.0%, in the Higlands upto 5%, with the highest values usually in the upper part. Their catchment area is at least 2 $km^2$. These valleys are not necessarily continuous and especially in areas underlain by basement complex formations, 'stepped' valleys occur commonly.


Figure 4. Example of the location of the various categories of river valleys

Source: Savvides (1981)

Apart from rainfall, water received from upland surface runoff and upland groundwater depletion is of great importance for the hydrology of the streamflow valleys. The more or less centrally located streamflows are shallow or, in the upper parts, not yet existing.

Of these three valley categories, the streamflow valleys are the prime subject of the proposed WURP. They are most appropriate for rice production in smallholder farming systems, without major inputs.

### 3.4.3 Distribution

The areas and distribution of the various categories of wetlands are shown in Table 3. These estimates have been derived from (semi)detailed and reconnaissance soil maps. For the entire inventory area it has been estimated that between 12.5 and 28.5 percent consists of wetland, corresponding with 27 to 62 million ha. This area includes all wetlands, such as deltas, tidal swamps, inland swamps (e.g. the bolis in Sierra Leone), river floodplains and inland valleys.

Table 3 shows the occurrence of these categories of wetlands in relation to the bioclimatic zones (Equatorial forest and Guinea savannah zones), the land regions and the main geological/lithological strata. This table shows that:

- the river floodplains are estimated to cover 2.5 to 6.0% of the inventory area, corresponding with 5.5 to 13.0 million ha;
- the overflow valleys are estimated to cover 3.5 to 9.0% of the inventory area, corresponding with 8.0 to 19.5 million ha;
- the streamflow valleys are estimated to cover 5.0 to 10.0% of the inventory area, corresponding with 10.0 to 22.0 million ha.

The distinction between the overflow and streamflow valleys on the available maps is often not clear, so that partly these two categories should be taken together. Nevertheless the size of the total area of the streamflow valleys, which are of main concern in the present inventory, may be estimated at approximately 10 million ha. They are mainly located in the Interior Plains (5.0 to 11.5 million ha) and Plateaux (3.5 to 6.5 million ha) land regions of the Equatorial forest (3.5 to 8.0 million ha) and the Guinea savannah (5.0 to 10,0 million ha) zones.

Table 3. Areas of the land regions and of the various categories of wetlands for the Equatorial forest and Guinea savannah zones

| | | Wetlands | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Area | Deltas, tidal swamps, large inland swamps etc. | | River valleys | | | | | |
| | | | | River floodplains | | Overflow valleys | | Streamflow valleys | |
| Landregions * | 1000 km$^2$ | % | 1000 km$^2$ | % | 1000 km$^2$ | % | 1000 km$^2$ | % | 1000 km$^2$ |
| I EQUATORIAL ZONE | | | | | | | | | |
| 1. Coastal Plains | | | | | | | | | |
| - 1.1 | n.d. | | | | | | | | |
| - 1.2 | n.d. | | | | | | | | |
| - 1.3 | n.d. | | | | | | | | |
| Total Coastal Plains | 100 | 25-40 | 25.0to40.0 | 1- 5 | 1.0to 5.0 | 1- 4 | 1.0to 4.0 | 1- 3 | 1.0to 3.0 |
| 2. Interior Plains | | | | | | | | | |
| - 2.1 | 253 | - | - | 1- 4 | 2.5to10.1 | 5-15 | 12.7to38.0 | 10-20 | 25.3to50.6 |
| - 2.1[a] | 15 | 15-25 | 2.5to 4.0 | 0- 1 | 0.0to 2.2 | - | - | - | - |
| - 2.2 | 60 | - | - | 5-10 | 3.0to 6.0 | 5-10 | 3.0to 6.0 | 4- 9 | 2.4to 5.4 |
| - 2.3 | 48 | 0- 1 | 0.0to 0.5 | 2- 7 | 1.0to 3.4 | 6-11 | 2.9to 5.3 | 8-13 | 3.8to 6.2 |
| Basement complex | 376 | 1- 2 | 2.5to 4.5 | 2- 5 | 6.5to19.7 | 5-13 | 18.6to49.3 | 6-16 | 31.5to62.2 |
| - 2.4 | n.d. | | | | | | | | |
| - 2.5 | n.d. | | | | | | | | |
| - 2.6 | n.d. | | | | | | | | |
| Sedimentary deposits | 51 | 3- 8 | 1.5to 4.1 | 5-10 | 2.6to 5.1 | 3- 8 | 1.5to 4.1 | 1- 6 | 0.5to 3.1 |
| Total Interior plains | 427 | 1- 2 | 4.0to 8.6 | 2- 6 | 9.1to24.8 | 5-12 | 20.1to53.4 | 7-15 | 32.0to65.3 |
| 3. Plateaux | | | | | | | | | |
| - 3.1 | 166 | - | - | 1- 2 | 1.7to 3.3 | 2- 7 | 3.3to11.6 | 2- 7 | 3.3to11.6 |
| - 3.2 | 54 | - | - | 1- 4 | 0.5to 2.2 | 1- 6 | 0.5to 3.2 | 1- 6 | 0.5to 3.2 |
| Basement complex (= Total Plateaux) | 220 | - | - | 1- 2 | 2.2to 5.5 | 2- 7 | 3.8to14.8 | 2- 7 | 3.8to14.8 |
| 4. Highlands | | | | | | | | | |
| - 4.1 Basement complex (= Total Highlands) | 118 | - | - | 1- 4 | 1.2to 4.7 | 2- 7 | 1.4to 8.3 | 5-10 | 5.9to11.8 |
| Total Equatorial Zone | 865 | 3- 6 | 29.0to48.6 | 1- 5 | 13.5to40.0 | 3- 9 | 26.3to80.5 | 5-11 | 42.7to94.9 |

Table 3. (cont.)

| | | | Wetlands | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | River valleys | | | | | |
| | | Area | Deltas, tidal swamps, large inland swamps etc. | | River floodplains | | Overflow valleys | | Streamflow valleys | |
| | Landregions * | 1000 km² | % | 1000 km² | % | 1000 km² | % | 1000 km² | % | 1000 km² |
| II | GUINEA ZONE | | | | | | | | | |
| 1. | Coastal Plains | - | | | | | | | | |
| 2. | Interior Plains | | | | | | | | | |
| | - 2.1 | 349 | 0- 1 | 0.0to 3.5 | 5- 8 | 17.5to27.9 | 8-13 | 27.9to45.4 | 6-11 | 12.2to38.4 |
| | - 2.2 | 40 | - | - | - | 0.4to 1.6 | 1- 5 | 0.4to 2.0 | 3- 8 | 1.2to 3.2 |
| | Basement complex | 389 | 0- 1 | 0.0to 3.5 | 5- 8 | 17.9to29.5 | 7-12 | 28.3to47.4 | 3-11 | 13.4to41.6 |
| | - 2.4 | n.d. | | | | | | | | |
| | - 2.5 | n.d. | | | | | | | | |
| | - 2.6 | n.d. | | | | | | | | |
| | - 2.7 | n.d. | | | | | | | | |
| | - 2.8 | n.d. | | | | | | | | |
| | Sedimentary deposits | 259 | 3- 8 | 7.7to20.7 | 5-10 | 13.0to25.9 | 3- 8 | 7.7to20.7 | 1- 3 | 2.6to 7.7 |
| | Total Interior plains | 648 | 1- 4 | 7.7to24.2 | 5- 9 | 30.9to55.4 | 6-11 | 36.0to68.1 | 3- 7 | 16.0to49.3 |
| 3. | Plateaux | | | | | | | | | |
| | - 3.1 | 332 | - | - | 1- 5 | 3.3to16.6 | 1- 5 | 3.3to16.6 | 9-14 | 29.9to46.5 |
| | - 3.2 | 42 | - | - | 1- 4 | 0.4to 1.7 | 1- 5 | 0.4to 2.1 | 3- 8 | 1.3to 3.4 |
| | Basement complex | 374 | - | - | 1- 5 | 3.7to18.3 | 1- 5 | 3.7to18.7 | 8-13 | 31.2to49.9 |
| | - 3.3 | n.d. | | | | | | | | |
| | - 3.4 | n.d. | | | | | | | | |
| | Sedimentary deposits | 30 | 0- 1 | 0.0to 0.3 | 2- 7 | 0.6to 2.1 | 4- 9 | 1.2to 2.7 | 4- 9 | 1.2to 2.7 |
| | Total Plateaux | 404 | 0-0.1 | 0.0to 0.3 | 1- 5 | 4.3to20.4 | 1- 5 | 4.9to21.4 | 8-13 | 32.4to52.6 |
| 4. | Highlands | | | | | | | | | |
| | - 4.1 | n.d. | | | | | | | | |
| | - 4.2 | n.d. | | | | | | | | |
| | - 4.3 | n.d. | | | | | | | | |
| | Basement complex | 149 | 0- 1 | 0.0to 1.5 | 3- 8 | 4.5to12.0 | 8-13 | 12.0to19.4 | 3- 8 | 4.5to 12.0 |
| | - 4.4 | | | | | | | | | |
| | Sedimentary deposits | 94 | 0- 1 | 0.0to 0.9 | 3- 2 | 0.9to 1.9 | 1- 5 | 0.9to 4.7 | 6-11 | 5.6to10.3 |
| | Total Highlands | 243 | 0- 1 | 0.0to 2.4 | 2- 6 | 5.4to13.9 | 5-10 | 12.9to24.1 | 5- 9 | 10.1to22.3 |
| | Total Guinea Zone | 1,295 | 0- 2 | 7.7to26.1 | 3- 7 | 40.7to89.7 | 4- 9 | 53.8to113.6 | 5-10 | 58.5to124.2 |
| | The Study Area | 2,160 | 1.7-3.5 | 36.7to74.4 | 2.5-5.9 | 54.2to129.7 | 3.6-9.0 | 80.1to194.1 | 4.7-10.0 | 101.2to219.1 |

* Land region symbols refer to Map 3 and its legend, in Volume IV.
n.d. = not differentiated

# 4 VALLEY HYDROLOGY

## 4.1 Valley hydrological regimes

The information on the hydrological regimes of the inland valleys in West Africs is sparse and rather erratic.
On flow sizes in small catchments significant investigations have been done by ORSTOM/CIEH for the francophone countries of Central and West Africa (Rodier 1964 and 1976 and Rodier and Auvray 1965).
Measurements and computations of the water balance (or components thereof) for individual or groups of valleys have been carried out by ORSTOM (Dubreuil 1966, Matthieu 1971, Molinier 1976, Lenoir 1978, Boulet 1978 and Collinet and Valentin 1979) in Ivory Coast and Upper Volta, by the Institute for Agricultural Research - Samaru (Kowal 1972 and Kowal and Omolokum 1972) in northern Nigeria, by IITA (Moormann 1973, Moormann and Veldkamp 1978, Moormann e.a. 1974 and 1977 and Veldkamp 1979) for south west Nigeria and by Ledger (1975) for an extremely wet catchment in south Sierra Leone.

In many respects the valleys are to be considered part of a catena system. Likewise there is an integrated sequential hydrological regime. A brief explanation of the processes involved in the valley hydrology is given in Annex II. Referring to the calculation models mentioned in this annex, the following general conclusions may be drawn.

- In the Sahel savannah zone rainfall is lost to evapotranspiration and especially to surface runoff during the rainy season. No upland groundwater replenishment and subsequent depletion flow occurs, except may be in a few rather flat areas, but this happens then only during the rainy season. Hence during the rains, the valley stream discharges are high, but very irregular. There is no prolongation of the growing period in the valleys. Although accumulation of water takes place, the valley bottom soils usually do not become completely saturated for long periods. This however, provides excellent conditions to grow a wide range of short season crops, mostly vegetables.
- In the Sudan savannah zone rainfall is not entirely lost to evapotranspiration and surface runoff during the rainy season. Some upland groundwater replenishment and subsequent depletion flow may occur in flat to rolling land. However, this occurs mainly during the rainy season. Hence discharges of the valley streams are high, but because of the presence of a baseflow, flows are somewhat more regular

than in the Sahel savannah zone. Nevertheless, the effect of the upland depletion flow on the prolongation of the growing season in the valley is too little to account for. Here again the valleys are best used for the cultivation of mainly vegetables, although the growing season is longer than in the Sahel savannah zone.

- In the Guinea savannah and the Equatorial forest zones groundwater levels both in the uplands and in the valleys rise considerably during the rains. The baseflow in the valley streams is substantial and continues after the rains. Although peakflows regularly occur, the valley streamflows generally have a more equable nature. Because of the continuing depletion flow from the uplands the growing period in the valleys is prolonged considerably.
  The chance that the soils of the valley bottoms are completely saturated is very great, especially in the Equatorial forest zone. Therefore, these valley bottoms are best suited to rice cultivation during the rainy season, either in double cropping or possibly followed by other crops grown on residual moisture from a gradually lowering groundwater table.

## 4.2 Valley suitability to rice production

Worldwide, hydromorphic soils are most extensively used for rice cultivation. In West Africa according to Le Buanec (1975) and Moorman and Veldkamp (1978), rice is still largely grown on upland (dry land) soils, although the use of hydromorphic soils is rapidly expanding. This rapid expansion, especially on inland valleys has been studied and described namely by Birie-Habas e.a. (1970), Bertrand (1973), Bertrand e.a. (1978), Kilian (1972), Moormann (1973) and Moormann e.a. (1976).
A large proportion of the hydromorphic soils (of the valleys) in the Guinea savannah and Equatorial forest zones have poor rice growing conditions (coarse textures and low fertility). Kilian and Teissier (1973) and Moormann (1978) however, state that the superior hydrological conditions in the valleys override these contraints.
A sandy soil would be unsuited for upland rice production, but this is not so under hydromorphic conditions. Many sandy valley soils are presently used for rice production in Nigeria, Ivory Coast, Liberia and Sierra Leone (Odell e.a. 1974).

There are two aspects to the suitability of valley bottom land for rice production by smallholders, viz: the agronomic and the engineering (water control and distribution) aspects. These aspects either singularly or combined have been studied and discussed by IITA (1973 and Annual Reports), Moormann e.a. (1974 and 1977), Veldkamp (1979), Okali e.a. (1979 and 1980), Juo and Moormann (1980), Savvides (1981), Barraud (FAO, 1963), Stiemer (SATMACI/FAO, 1968), SODERIZ (1976), Glemet (SATEC, 1975) Arrivets (1973) and AVV (1981).

### 4.2.1 Agronomic aspects

In spite of the sometimes very unfavourable health conditions (Paragraph 1.4 of Volume III), the valleys are increasingly used for rice production by smallholders. For a valley to be suitable for rice production under smallholder farming, it should meet a number of hydrological conditions.

Crop water requirements

The crop water requirements should be covered during the entire growth period of the crop. These requirements can be compensated by groundwater, (see below) and/or by water inflow. Apart from rainfall, this inflow is basically maintained by the upland surface runoff and the upland groundwater depletion flow. The latter, together with the valley groundwater depletion flow is the core of the baseflow in the valley stream. The size of the minimum flow is strongly related to the amount of rainfall and the size of the catchment area. In the Guinea savannah zone 1 $km^2$ of catchment area is needed to provide a minimum flow sufficient to cover crop water requirements for rice on a cultivated area of 0.8 to 3.0 ha in the valley. For the Equatorial forest zone this ratio is 1 $km^2$ for 2.0 to 5.0 ha.

Crop submersion

Peak discharges in the valley (stream) having a devastating nature and floods submerging the crop for long periods cause crop failures. To avoid such failures rice should be submerged not longer than 48 hours and other crops much shorter. The peak discharge is related to the absorption capacity of the catchment, the amount of rainfall, rainfall intensity and slope. The effects of the individual factors diminish with increasing size of the catchment area (area reduction factor). A computation model for peak discharges has been described by Rodier and Auvray (1965).

Depth of groundwater level

Rice has shallow roots and is very drought sensitive, especially the wetland varieties. The latter prefer soils which are water saturated for an adequately long time during the growth period. For most other crops such a situation is of course a restraint.
In the Guinea savannah zone annual fluctuations of the groundwater level in the valleys are considerable, ranging between 1 and 5 metres and sometimes more. During the rains, the groundwater level may be at or above the soil surface, but this is not always so for every valley. In some cases the groundwater level may start lowering already before the end of the rainy season and may reach such a depth that crop production on residual moisture becomes not possible during (a part of) the dry season.
In the Equatorial forest zone annual fluctuations of the groundwater level in the valleys are relatively small, ranging from 0.5 to 1.5 metres. During the rains the groundwater level is at or above the soil surface, without many exceptions. The lowering of this level starts roughly 0.5 to 1.5 months after the rains have ceased. Crop production on residual moisture is possible throughout the dry season, which is short anyway.

The depth of the groundwater level and its fluctuation are of great influence on the crop performance and several researchers have endeavoured to make a suitability classification for rice on the basis of the depth of the groundwater level. From the literature on wetlands in valley catenas in West Africa three systems emerge. These are discussed below.

a. In the system by Moormann and Veldkamp (1978), three categories of rice land are distinguished in the valley catena. The differentiation is based on the degree of water accumulation and the topography (slope) and the consequent position of the free water table above or below the soil surface during the year.
In the pluvial zone (crest and upper slope of the catena) the groundwater level normally is out of range of the plant roots for most of the year. In the phreatic zone (lower slope) the groundwater level is within the range of the plant roots, but below the soil surface. In the fluxial zone (valley bottom) the waterlevel lies above or at the surface for part of the year. Depending on the concavity of the valleybottom, the central part (stream area) may remain wet for longer periods than the sides.

This classification has been adopted for experimental research on rice performance on the soils of a valley catena, conducted by IITA in Nigeria. The advantage of the system is that the three zones can be physically indicated in the field quite easily. A better rice production performance is likely to be achieved on the fluxial, followed by the phreatic lands, than on the pluvial lands. However, little can be said about the levels of production, because soil qualities have not been incorporated.

b. In the francophone countries Kilian and Teissier (1973) have developed another classification system. Primarily based on the groundwater regime, it also includes the soil texture, to qualify the soil suitability for rice production.

Class I: very good soils for rice; shallow groundwater level or slightly flooded; the soil texture is variable, but mainly medium to fine.

Class II: good soils for rice, deeper groundwater level or temporary inundation: the soil texture is variable, but mainly medium to very fine.

Class III: marginal soils for rice; deep or perched groundwater level with large fluctuations; the soil texture is variable, but mainly coarse to medium, often with colluvial cover.

Class IV: very marginal soils for rice; temporary perched groundwater level, inadequate water influx, risk of drought; the soil texture is coarse.

This system was tested for the soils of valleys in north Benin. Though provisionally, it is considered applicable for the Sudan/ Guinea savannah zone with ecological conditions comparable to those in north Benin, but it was recognised that the scope of applicability might be restricted.

Apparently, the classification does not provide for soils not suitable for rice production and does not comprehend all soils of the catena.

c. The third classification has been developed for conditions of the temperate climate, especially for pasture production in The Netherlands. It has been adopted and discussed by Veldkamp (1979) for conditions in West Africa. It is a general system on one hand but also refined on the other.

The groundwater level is assumed to fluctuate. The different classes are delineated by the variations of the fluctuations, that is by the

average highest and the average lowest groundwater levels. For annual crops these fluctuations are measured within the growing season, for perennial crops this is done during the year. A schematic example of such a classification is presented in Figure 5.
In this diagramme classes are grouped according to the depth of the average highest groundwater level. In group I the soils are flooded permanently (Ia) or during part of the year, or season. (Ib). For rice the most suitable hydrological conditions are grouped in class Ib (teporarily flooded) or in II with a shallow average lowest groundwater table. In subsequent groups the average highest groundwater level lies below the soil surface, but conditions become increasingly less suitable for wetland rice production. They may be better suited for other crops.
High values in the diagramme for the average lowest groundwater level make the conditions for rice hazardous because of droughts, even if the value for the average highest groundwater level is low (= a high groundwater level).

### 4.2.2 Engineering aspects

*Design*

When designing a water control and distribution system the following criteria are to be considered.

a. Hydrology. The size of the catchment co-determines the size of the minumum flow and the peak discharge. To secure a reasonable amount of water in the distribution system, the catchment area should be larger than 10 to 30 $km^2$ in the Guinea savannah zone and larger than 5 to 15 $km^2$ in the Equatorial forest zone, corresponding roughly with 15 to 30 ha of valley cultivation. If catchments are smaller, crops in the valley should be grown making use of contour bunds.
The maximum size of the catchment is set by the risk of floods and inundation/submergion damaging the crops and/or the water distribution system. In Upper Volta it was observed that unless dam reservoirs are envisaged, peak discharges and durations of inundation/submergion became prohibitive for rice in valleys with catchments over 250 $km^2$. In Central Ivory Coast it has been reported that catchments should not exceed 100 $km^2$ to allow for safe rice cultivation.

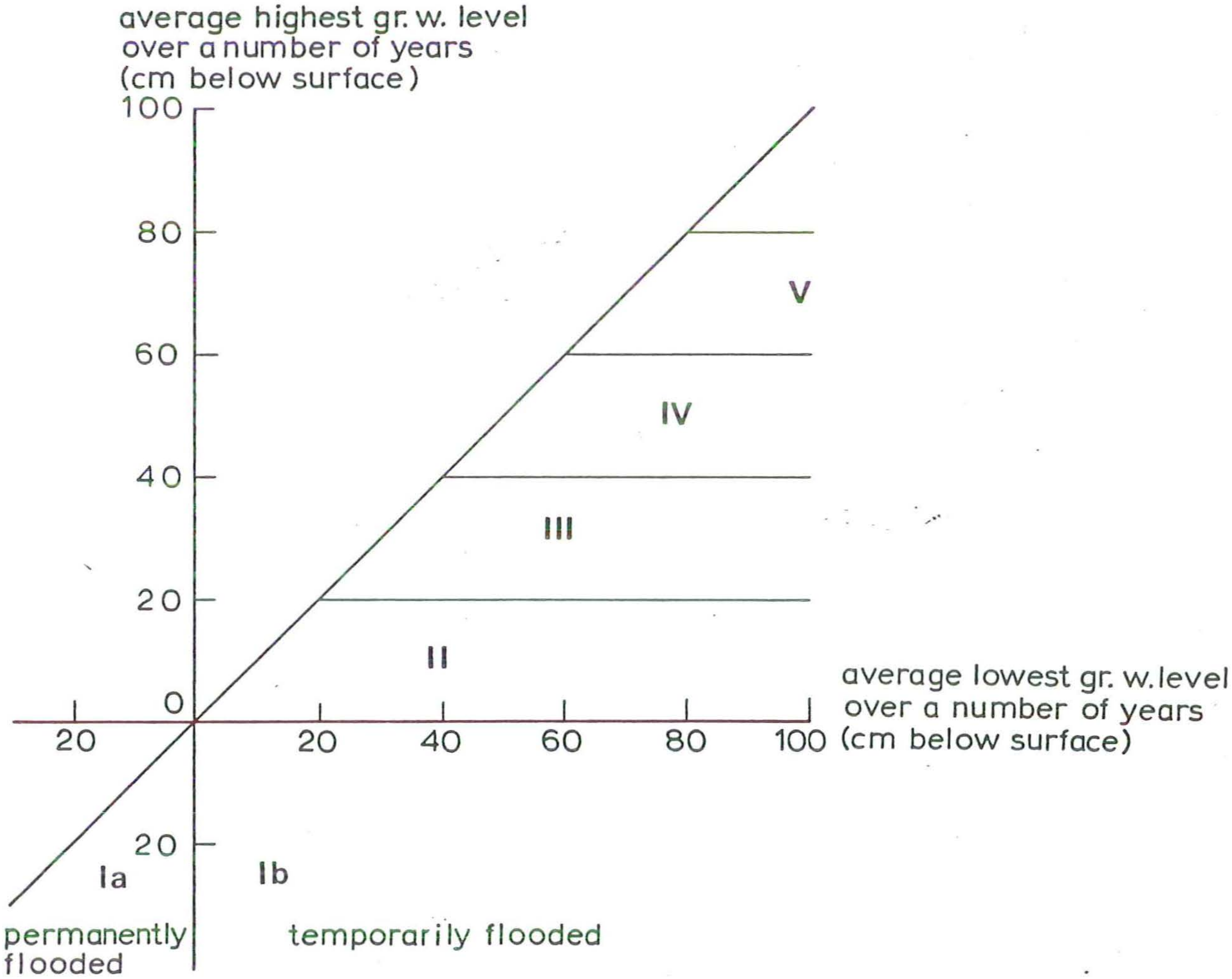



Figure 5. Groundwater classes
Source: Veldkamp (1979), revised

Generally the optimum range of the size of catchments is between 5 and 70 $km^2$. The interaction of the various hydrological processes results in a flow pattern, which may be used to qualify the valley stream.

- A stream with an open outlet, a regular flow or only slight inundation, does not present hydrological restrictions.
- A stream with an obstructed outlet or a very irregular flow and severe and prolonged inundations, presents many hydrological restrictions.
- A stream with a small flow or often falling dry is restrictive in such a manner that valleys should be bunded along the contours only.

b. Soils. The soil texture and structure are of great importance for the watercontrol (seepage) and the stability of the structures. Limitations due to soil texture can be indicated as follows:

- coarse texture : severe limitation
- medium : modest limitation
- fine to very fine: no limitation

c. Morphology. The shape (length and width) of the valley should be such that an optimum size of the scheme can be obtained, which can be operated and maintained easily by the farmers or the community. Very long and narrow valleys have the disadvantage of having an unfavourable ratio between the length of the channels and the cultivated area (maintenance problems).
The longitudinal slope should allow for adequate drainage, but should not exceed 0.1 to 0.2% to avoid heavy levelling and overdrainage (in sandy soils).

Using these criteria Kilian and Teissier (IRAT, 1973) have approximated a valley suitability classification, consisting of 6 classes for the development of valleys in Benin.

Class I + II: There are no morphological restrictions. The hydrological regime is favourable. The soil texture is fine to very fine (I) or medium (II). Usually the valleys are situated over schists (I) or largely over schists and partly over granites (II).

Class III + IV: There are no morphological restrictions. The hydrological regime is slightly unfavourable but soils have a fine to very fine texture (III), or it is favourable but with coarse textured soils (IV). These valleys are situated over fine textured granites with micas and they are often already under traditional rice cultivation (III) or they are situated over granites and many rock outcrops are found (IV).

Class V: There are morphological restrictions, but the unfavourable hydrological regime in combination with medium textured soils make them not suitable for development. These valleys are situated over schist-granite contact zones.

Class VI: Either the morphological conditions are unfavourable or the hydrological regime is unfavourable in combination with coarse textured soils. These valleys cannot be developed.

The applicability and the usefulness of this classification for all stream flow valleys in the Guinea savannah and Equatorial forest zones have to be tested. Most probably the classification has to be refined to include valleys on sedimentary deposits. The classification should also relate cropping intensities, crop yields and economic returns with respect to construction and maintenance costs.

*Layout*

The various types of water control and distribution systems presently used in streamflow (and possibly other) valleys in West Africa can generally be grouped as follows.

- Few contour bunds, eventually with levelled terraces, to spread the water more evenly in very small valleys with a non-existing stream flow or along the periphery of larger valleys.
- Retention/inlet structures in small valleys (generally the stream flow valleys), with two lateral irrigation canals, one along each side of the valley. These canals sometimes also act as cut-off drains to intercept upland runoff and groundwater depletion flow. The valley stream is used as the central drain and water buffer area.

- Dam-reservoirs with overflow, in larger valleys (generally the large streamflow and overflow valleys). Also in this system there may be two peripheral irrigation canals, which may act as cut-off drains. Usually the irrigation system is more intricate and basins may or may not be levelled.
  The valley stream is used as the central drain and buffer area, either embanked or not.

For the implementation of the benchmark sites to be used for Phase II of the WURP, two basic designs should be adopted.

a. The upper stretches of the valleys where the central stream is not yet existing, should be bunded along the contours to spread the surface water more evenly. The basins formed by the bunds should be levelled.
b. The lower parts of the valleys having a streamflow, should be provided with a retention/inlet structure in the stream. The structure is to be built in concrete across the full width of the stream, but with an orifice wide enough for peak discharges to pass unobstructed. Wooden stop logs should be used to retain the water. Upstream of the structure gated inlets to lateral canals along the periphery of the valley floor are to be made. The (preferably unlined) canals serve as the main irrigation feeders, but may also act as cut-off drains to intercept runoff and groundwater depletion from the upland. The cut-off drains may especially be useful in valleys where iron toxicity affects rice production. In this case the bottoms of the canals must be at bedrock level of the 'seepage zone' (Annex II). The 'seepage water' is collected and diluted with 'fresh' surface water.
   In this layout the streamflow is used as the central drain, either embanked or not. The rice is grown in basins which should be level.

# 5 SUMMARY AND CONCLUSIONS

## 5.1 The physical potential

The area of the inventory has been confined to the area having a growth period ranging from 165 days to year round, allowing rainfed double cropping, or more. This area consists of the Equatorial forest zone, roughly corresponding with the humid tropics and the Guinea savannah zone, roughly corresponding with the sub-humid tropics of West Africa. The total inventory area is approximately 2.2 million $km^2$, of which the Equatorial forest zone covers about 0.9 million $km^2$ and the Guinea savannah zone about 1.3 million $km^2$.

Generally, the climate of the area does not impose severe restrictions to the cultivation of tropical crops. In the monomodal rainfall area, the rainy season is about 5 months. The main limitation to crop production is the deficiency in soil moisture for a large part of the year. Solar radiation is high, favouring high photosynthetic energy conversion in crops. In the bimodal rainfall area, there is one rainfall peak in June to July and a second one in September. In this area the main limitations to crop production are the irregular rainfall, especially within the seasons and suboptimum solar radiation. In the pseudo-bimodal rainfall areas, there is a continuous rainy season from March/April to November/December. Here, the main limitations to crop production are the suboptimum solar radiation and the high air humidity. This combination causes a high incidence of diseases and pests.

Based on the geology and the geomorphology four land regions are distinguished in the inventory area. These land regions are broad landscape units with recurrent physiography:

- Coastal Plains : 100,000 $km^2$, or 4.6% of the inventory area
- Interior Plains : 1,075,000 $km^2$, or 49.8% of the inventory area
- Plateaux : 624,000 $km^2$, or 28.9% of the inventory area
- Highlands : 361,000 $km^2$, or 16.7% of the inventory area.

The Interior Plains and Plateaux comprising about 80% of the inventory area, are the most important land regions. Lithologically, the main differentiation within these two land regions is:

- Basement complex: 79.6% of the Interior Plains and Plateaux
- Sedimentary deposits: 20.4% of the Interior Plains and Plateaux.

Generally, the upland soils in the inventory area are gravelly and coarse to medium textured, have low water holding capacity and low inherent fertility. The best soils are formed over basic metamorphosed rocks of the basement complex (schists, amphibolites, greenstones, etc), or on fine grained sedimentary deposits (shales and claystones). Since soil weathering processes increase toward the southeast and southwest, the most depleted soils are found in these parts of the inventory area. Three main soil groups are distinguished:

- The Ustalfs in the Guinea savannah zone. With a clayey B-horizon, a favourable base status and near neutral acidity, they are the better soils. Very often however they have restricted soil depth due to the occurrence of ironstone hardpans or aggregate layers.
- The Ustults in the transition between the Guinea savannah and the Equatorial forest zones. They have a clayey B-horizon, but a low base status and they are acid. Ironstone hardpans and aggregate layers occur commonly in the Ustults.
- The Udults and Orthoxs in the Equatorial forest zone. Udults have clayey B-horizons, a low base status and are acid. Orthoxs are extremely weathered soils of very low inherent fertility, but with favourable physical characteristics. They are mainly medium-textured. Ironstone hardpans and aggregate layers do occur in the Udults and Orthoxs, but less common than in the zones comprising Ustults and Ustalfs. Very often they are gravelly.

The soils of the valley bottoms vary widely in their characteristics, in their texture as well as in their fertility. They generally reflect the characteristics of the surrounding upland soils and parent material. Coarse texture and low fertility prevail in valley bottom soils on sandstone and quartzite formations; coarse to medium texture and moderate fertility on granite formations and medium to fine textures and moderate to high fertility on shales, silt/claystone and basic rock formations. The soils of the valley bottoms have in common that they are hydromorphic. This condition makes them better suited to crop production (especially rice) than the adjacent upland soils.

The total wetland area is estimated somewhere between 272,000 and 615,300 $km^2$, or between 12.6 to 28.5% of the inventory area.
Four categories of wetland are distinguished.

a. Deltas, tidal and large inland swamps (including bolis): 36,700 to 74.400 $km^2$ or 1.7 to 3.5%.of the inventory area.

b. River valleys:

   b1. River floodplains (large floodplains): 54,200 to 129,700 $km^2$ or 2.5 to 5.9% of the inventory area.

   b2. Overflow valleys (small floodplains): 80,100 to 194,00 $km^2$ or 3.6 to 9.0% of the inventory area.

   b3. Streamflow valleys (small inland valleys): 101,200 to 218,100 $km^2$ or 4.7 to 10.0% of the inventory area.

About one third of the wetlands is occupied by streamflow valleys. Because of the objective of developing appropriate technologies for smallholding farmers, this category of valleys will be the main subject of the proposed WURP - Phase II.

## 5.2 Research needs

The need for rice-based smallholder farming research lies mainly in the agronomic and economic sphere (Volume III). However, in conducting such a research project, the need to solve problems of soil, land and water management is of importance, since capital investments and production inputs are strongly related to the physical aspects.
Research in the WURP-Phase II will be related to the entire valley catena and should comprise:

- physical site characterization, including monitoring of the (surface and subsurface) water regimes, erosion, soil degradation, etc.
- land and water development, including low cost technologies for bush-clearing, drainage and irrigation, etc.
- land and water management, including water control and distribution systems with simple structures, field layout, land levelling, etc.
- soil management, including tillage, fertilizer application toxicity control, etc.
- inland valley (mainly streamflow valleys) characterization and classification systems, for transferring technologies to areas with similar valley categories.

## 5.3 Criteria for benchmark site selection

### 5.3.1 Selection of areas

In selecting proper sites for the proposed WURP-Phase II, the following criteria should be considered.

a. The representativeness for sufficiently large parts of the inventory area, in terms of
   - (bio) climate: Equatorial forest and the Guinea savannah zones, also considering the different rainfall regimes;
   - geomorphology: the major landregions: are the Interior Plains and the Plateaux;
   - geology/lithology: basement complex and sedimentary formations.

b. The production potential of soils for rice cropping systems:
   - low to medium production potential, viz: the soils on coarse grained sedimentary formations (sandstones) and on the acidic to intermediate basement complex formations (granites and quartzites);
   - medium to high production potential, viz: the soils on fine grained sedimentary formations (shales and claystones) and on the basic basement complex formations (micaschists, gneisses and amphibolites) or the soils on young volcanic formations and derived alluvium.

It is assumed that ultimately 3 benchmark sites are selected. It is recommended that at least one site should be selected on low to medium and at least one site should be selected on medium to high production potential soil(s). From the physical point of view sites should be chosen so that they will be located within one of the following broad areas (See Map 5 of Volume IV):

- Sierra Leone - Liberia in the Interior Plains, on acidic to intermediate basement complex rocks in the Equatorial forest zone, with a pseudo bimodal rainfall regime and with predominantly Ultisols and Oxisols.
- South Ivory Coast in the Interior Plains, on acidic to intermediate basement complex rocks in the Equatorial forest zone, with a bimodal rainfall regime and with predominantly Ultisols.
- North Ivory Coast in the Plateaux, on basic basement complex rocks in the Guinea savannah zone, with a bimodal rainfall regime and with predominantly Alfisols.

- Central northeast Ghana - north Togo in the Interior Plains on coarse grained sedimentary deposits in the Guinea savannah zone, with a pseudo-bimodal ranging to a monomodal rainfall regime and with predominantly Alfisols.
- Benin - western Nigeria in the Interior Plains on acidic basement complex rocks in the Guinea savannah zone, with a pseudo bimodal rainfall regime and with predominantly Alfisols.
- Central Nigeria in the Interior Plains, on coarse grained sedimentary deposits in the Guinea savannah region, with a pseudo bimodal rainfall regime and with predominantly Ultisols.
- Southeast Cameroon in the Plateaux, on acid to intermediate basement complex rocks in the Equatorial forest zone, with a pseudo bimodal rainfall regime and with predominantly Ultisols.

### 5.3.2 Selection of sites

In harmony with the agro-socio-economic criteria (Volume III) in the above mentioned broad areas, localities should be chosen, within which the benchmark sites are to be situated.

The final selection of the benchmark sites should be preceded by a survey to obtain the physical characterization of the valley(s). This survey which should be the start of the WURP-Phase II, should investigate the following aspects.

- Valley morphology (shape and slope)
- Hydrology (catchment description, run-off, erosion, location of stream flow, groundwater fluctuations, flooding pattern, water retention and depletion).
- Soil conditions (parent material depth, drainage class, texture, clay mineralogy, organic matter content, fertility, salinity and toxities).
- Existing land and water development infrastructure.

## REFERENCES

### I CLIMATE

BUDDENHAGEN, I.W., 1978. Rice ecosystems in Africa. In: Buddenhagen and Persley, (eds): Rice in Africa. p. 11-27. New York/San Francisco/London, Acad. Press.

FAO, 1978. Report on the agro-ecological zones project - Vol. I. Methodology and results for Africa - World Soil Resources project no. 48.

KOWAL, J.M. and KASSAM, A.H., 1976. Agricultural ecology of savanna. A study of West Africa, Clarendon Press, Oxford.

LANDSBERG, H.E. and GRIFFITH, J.F., 1972. Climates of the world. In: World survey of climatology, Vol. 10 - Africa. Elsevier Publishing Co. Amsterdam/London/New York.

LAUER, W. and FRANKENBERG, P., 1981. Untersuchung zur Humidität und Aridität von Afrika. Das koncept einer potentiellen landschaftverdünstung. Bonner Geographischer Abhandlungen - Heft 66. Fred. Dümmlers Verlag, Bonn.

LAWSON, T.L., OGUNTOYINBO, J.S. and OJO, O., 1979. Agroclimatic conditions of West Africa. A paper presented at the IITA annual research conference on soil and climatic resources and constraints in relation to food crop production in W. Africa. Ibadan - Nigeria.

OJO, O., 1977. The climate of West Africa. Heineman Educational Books Ltd. London/Ibadan.

RODIER, J., 1964. Régimes hydrologiques de l'Afrique noire à l'ouest du Congo. ORSTOM, Paris. Mémoires No. 6.

TAMS/CIEH, 1976-1978. Savanna regional water resources and land use. Savanna resources. Comité Interafricain d'Etude Hydrologique. Ouagadougou, Haute Volta.

WALTER, H. and LIETH, H., 1960. Klima diagramm - Welt atlas. VEB-Gustav Fischer Verlag, Jena.

## II GEOLOGY, GEOMORPHOLOGY AND SOILS

AHN, P.M., 1961. Soils of the lower Tano basin, southwestern Ghana. (Map scale 1:250.000). Kumasi, Min. of Food and Agric. 266 pp.

AHN, P.M., 1970. West African Soils London. Oxford Univ. Press. 332 pp.

ASAMAO, G.K., 1968. Soils of the Ochi-Nakwa basin, Ghana. (Map scale 1:25.000). Kumasi, Ghana. Acad. of Sci., Soil Res. Inst. Mem. no. 4. 128 pp.

AVENARD, J.M., 1971. Aspects de la géomorphologie. In: Le milieu naturel de la Côte d'Ivoire. ORSTOM, Paris. Mémoires no. 50, p. 7-81.

BARNEVELD, G.W. van, 1980. Soils and soil conditions of the Zapi-est area, Eastern Province, Cameroon, and their capabilities and constraints to crop production, FAO Soil Resources Proj., Prelim. Working Paper No. 6. Ekona, Cameroon, 18 pp.

BARRÈRE, J. and SLANSKY, M., 1965. Notice explicative de la carte géologique au 2.000.000 de l'Afrique occidentale.Mem. du Bur. de Recher. Géol. et Min. No 29, Paris, 120 pp.

BAWDEN, M.G., and TULEY, P., 1966. The land resources of southern Sardauna and southern Adamawa provinces, northern Nigeria (Land system map at scale 1:500.000). Tolworth, Land Res. Div., Land Res. Study No. 2. 120 pp.

BAWDEN, M.G., CAROLL, D.M. and TULEY, P., 1972. The land resources of N.E. Nigeria. (Land system map at scale 1:500.000, geomorphological map and soil map at 1:1.000.000). Surbiton, Land Res. Div., Land Res. Study. No. 9, Vol. I. The environment, 183 pp. Vol. III. The land systems, 446 pp.

BLANCHOT, A., DUMAS, J.P. and PAPON, A., 1973. Carte géologique de la partie meridionale de l'Afrique de l'ouest à 1:2.000.000. Bur. de Rech. Géol. et Min., Paris.

BRAMMER, H., 1962. Soils: In: Wills, J.B., (Ed.) Agriculture and land use in Ghana. London, Oxford Univ. Press, p. 88-126.

BRAMMER, H., 1967. Soils of the Accra plains, Ghana. (Map scale 1:25.000). Kumasi, Ghana. Acad. of Sci., Soils, Res. Inst. Mem. no. 3. 146 pp.

CPCS, 1967. Classification des Sols. Commision de Pédologie et de Cartographie des Sols, édition 1967, ENSA, Grignon, 96 pp.

DABIN, B., LENEUF, N. and RIOU, G., 1960. Notice explicative de la carte pédologique de la Côte d'Ivoire au 1:20.000.000. ORSTOM, Paris/Abidjan, 31 pp.

DA SILVA TEIXEIRA, A.J., 1962. Os solos da Guine Portuguesa. (Map scale 1:500.000), Luanda, 397 pp.

D'HOORE, J.L., 1965. Exploratory monograph of the soil map of Africa. (Map scale 1:5.000.000). Comm. for Tech. Coop in Africa. Lagos, Nigeria. Joint project no. 11. Publ. no. 93. 209 pp.

DIEPEN, C.A. van, 1980. La degradation des sols en Republique Populaire du Benin. Proj. Agro-pédologique, Et. no. 229. Cotonou, 76 pp.

DIR. DES MINES ET DE LA GÉOLOGIE, 1953-59. Carte géologique de reconnaissance du Cameroon, à 1:500.000. Paris. (7 sheets available, no complete coverage of country).

DIR. GEOLOGICAL SURVEYS, 1962. Nigeria 1:250.000. Geological series (6 sheets available, no complete coverage of country).

DIR. OVERSEAS SURVEYS, 1960. Geological map of Sierra Leone. (Map scale 1:1.000.000).

ESCHENBRENNER, V. and BADARELLO, L., 1978. Etude pédologique de la région d'Odienne, Côte d'Ivoire. (Map scale 1:200.000). Paris, ORSTOM. Notice Explicative no. 74. 123 pp.

FAO, 1965. Land use survey in the Western Region of Nigeria. FAO/EPTA rep. no. 2108, Vol II. Rome, 227 pp.

FAO, 1968. Land and water survey in the upper and northern regions of Ghana. (Map scale 1:500.000). Rome, FAO, SF:31/GHA. Vol I: General, 118 pp; Vol. III: Soil survey, 111 pp. (Report includes semi detailed maps of selected areas at scale 1:30.000 and 1:50.000).

FAO, 1969. Soil and water resources survey of the Sokoto Valley, Nigeria. Final Report. Vol V. Soil survey and land classification. (Reconnaissance soil map at scale 1:250.000, semi detailed maps at scale 1:20.000). Rome FAO/SF: 67/NIR 3. 204 pp.

FAO, 1971. The evaluation of soil resources in West Africa. Rome, FAO. World Soil Resources Report No. 40. 166 pp.

FAO, 1979. Land in Sierra Leone: a reconnaissance survey and evaluation for agriculture. (Land systems map at scale 1:500.000). Rome, FAO AG: DP/SIL/73/002, Techn. Rep. 1. 246 pp.

FAO, 1981. Fourth meeting of the West African sub-committee for soil correlation and land evaluation. Banjul, The Gambia. Rome, FAO. World Soil Resources Report No. 53. 124 pp.

FAO/UNESCO, 1974. Soil map of the world. Volume I, legend Rome/Paris, 59 pp.

FAO/UNESCO, 1977. Soil Map of the World. Vol. VI. Africa. (Map scale 1:5.000.000). Rome/Paris. 299 p.

FANFANT, R., 1970. Report to the Government of the Liberia on soil survey. Rome, FAO TA/2845. 21 pp.

FURRON, R., 1963. Geology of Africa. London, Oliver and Boyd. 377 pp.

GEOLOGICAL SURVEY DIVISION, 1964. Geological map of Nigeria. (Map scale 1:2.000.000).

GREENLAND, D.J., (Ed.), 1981. Characterization of soils in relation to their classification and management for crop production: Examples from some areas in the humid tropics. Oxford, Clarendon Press. 446 pp.

HAWKINS, P. and BRUNT, M., 1965. The soils and ecology of West Cameroon. Report to the Government of Cameroon. (Map Scale 1:200.000). Rome FAO/PTA Report No. 2083. 285 pp.

HOWARD HUMPRIES & SONS, 1975. Projet Sucrier, Etude de pré-investissement, Rep. de Guinea, 87 pp.

HOWELER, R.H., 1973. Iron-induced oranging disease of rice in relation to physico-chemical changes in a flooded Oxisol. Soil Sci. Soc. Amer.Proc, Vol 37, 1973, p. 898-903.

JUNGERIUS, P.D., 1964. The soils of eastern Nigeria (Map scale 1:1.000.000). Luxembourg, Publ. Serv. Geol. du Luxemb. Vol XIV. p. 185-198.

JUO, A.S.R. and MOORMANN, F.R., 1980. Characteristics of two soil toposequences in southeastern Nigeria and their relation to potential agricultural land use. Soil Sci. Nig. Jnl. (1) 1, p. 47-61.

KANG, V.T. and JUO, A.S.R., 1981. Management of low activity clay soils in tropical Africa for food crop production. Paper presented at Fourth Int. Soil Class. Workshop, Kingali, Rwanda, 22 pp.

KILIAN, J. and TEISSIER, J., 1973. Methodes d'investigation pour l'analyse et le classement des bas-fonds dans quelques régions de l'Afrique de l'ouest. Propositions de classification d'aptitudes de terres à riziculture. L'Agronomie Tropicale Vol. 28(2), p. 156-171.

KING, L.C., 1967. Morphology of the earth. Edinburgh, Oliver and Boyd. 726 pp.

KLINKENBERG, K. and DE LEEUW. P.N., 1967. The soils of the Lau-Kaltungo area, Nigeria. (Map scale 1:100.000). Zaria, Soil Survey Bull. No. 36. 70 pp.

KOSAKI, T. and JUO, A.S.R., 1982. Selected profile data of hydromorphic soils from central and southeastern Niger. IITA Farming Systems Program, Ibadan. Mimeopgraph, 11 pp.

LAMOUROUX, M., 1969. La carte pédologique du Togo au 1:1.000.000. Paris, ORSTOM, Notice Explicative No. 34. 91 pp.

LÉVÈQUE, A., 1969. Les principaux évènements geomorphologiques et les sols sur le socle gneissique au Togo. Cah. ORSTOM. Sér. Géologique, Vol. 8(2), p. 203-223.

LÉVÈQUE, A., 1979. Pédogénèse sur le socle granito-gneissique du Togo. Trav. et Doc. de l'ORSTOM, No. 108. Paris, 224 pp.

MAIGNIEN, R., 1953. Etudes pédologiques en Guinée Française, Ann. Inst. des Fruits en Agrumes Col. no 5. p. 1-48.

MAIGNIEN. R., 1956. Le cuirassement des sols en Guinée. Dakar, ORSTOM. 239 pp.

MAIGNIEN, R., 1965. Notice explicative de la carte pédologique du Senegal au 1:1.000.000. Paris, ORSTOM, 63 pp.

MARTIN, D. and SEGALEN, P., 1966. Notice explicative de la carte pédologique du Cameroun oriental au 1:1.000.000. ORSTOM, Paris, 133 pp.

MARTIN, D., 1967. Géomorphologie et sols ferralitique dans le centre Cameroun. Cah. ORSTOM, Série Pédologique Vol. V, No. 2., p. 189-218.

MILETTE, G. and VIEILLEFON, J., 1965. Les sols de la région maritime et de la région des savannes. (Map scale 1:50.000). In: Etudes pédohydrologiques au Togo. Rome FAO/SF: 13/50, Vol II. 248 pp.

MOORMANN, F.R., 1973. General assessment of lands on which rice is grown in West Africa. WARDA. Seminar on rice soil fertility and fertilizer use. Monrovia, Liberia, 23 pp.

MOORMANN, F.R., 1981. Representative toposequences of soils in southern Nigeria and their pedology. In: Greenland, D.J., (Ed.): Characterization of Soils. Oxford Sci. Publ. p. 10-29 and Appendix 1: Profile locations, descriptions and analyses. p. 284-421.

MOORMANN. F.R. and VAN BREEMEN, N., 1978. Rice, soil, water and land. Int. Rice Res. Inst. Los Banos - Philippines, 185 pp.

MOORMANN, F.R., LAL, R. and JUO, A.S.R., 1975. The soils of IITA, Ibadan. IITA Techn. Bull. No. 3. 38 pp.

MOORMANN, F.R. and VELDKAMP, W.J., 1978. Land and rice in Africa: Constraints and potentials. In: Buddenhagen and Persley (eds.): Rice in Africa. London, Acad. Press. p. 29-43.

MORGAN, W.B., and PUGH, J.C., 1969. West Africa, Chapter 1.5. The major environmental factors, 176-249 and Chapter 1.6. Local factors in the environment, p. 250-309. London, Methuen and Co. 788 pp.

MOURIK, D. van, 1979. Land in western Liberia. A reconnaissance agricultural land evaluation of the Mano River Union project area. (Land system map at scale 1:500.000). Freetown, Mano River Union project. 98 pp.

MURDOCH, G., OJO-ATERE, J., OLOMU, E.I. and ODUGBESAN, E.M., 1976. Soils of the Western State savanna in Nigeria. (Land facets map at scale 1:125.000). Land. Res. Div., Surbiton. Land Res. Study No. 23. Vol. I, The Environment. 102 pp. Vol II. Description of basement comlex soil series: 115pp.

NICKLÈS, M. and HOURCQ, V., 1952. Notice explicative de la carte géologique de l'Afrique Equatorial Française et du Cameroun au 1:2.000.000. Direction des Min. et de la Geol. Paris, 109 pp.

ODELL, R.T., DIJKERMAN, J.C., VUURE, W. van, MELSTED. S.W., BEAVERS, A.H., SURRON, P.M., KURTZ, L.T. and MIEDEMA. R., 1974. Characteristics, classification and adaptation of soils in selected areas in Sierra Leone. Niala Univ. Coll. Bull. 4, 194 pp.

OKUSAMI, T.A., 1981. Land and pedogenetic characterization of selected wetlands in West Africa with emphasis for rice production, Ph. D. Thesis, Univ of Minesota, 360 pp.

OKUSAMI, T.A., RUST, R.H. and JUO, A.S.R., 1982. Properties, genesis and classification of selected alluvial soils in the Niger-Benue trough, Central Nigeria. IITA, Ibadan, Mimographs, 27 pp.

ORSTOM, 1970-78. Notices explicatives des cartes pédologiques de re-connaissance de la République Populaire du Benin. Not. Expl. Nos. 66(1-9). (Map scale 1:200.000), Paris.

ORSTOM, 1973-76. Notices explicatives des cartes pédologiques de re-connaissance du Cameroun. Not. Expl. Nos. 51, 53, 62. (Map scale 1:200.000, no complete coverage of country), Paris.

PERRAUD, A, 1971. Les sols. In: Le milieu naturel de la Côte d'Ivoire (Map scale 1:500.000). Paris. ORSTOM, Memoires No. 50, p. 265-391.

POSS, R., 1982. Etude morpho-pédologique de la région de Katiola, Côte d'Ivoire. (Map scale 1:200.000). Paris, ORSTOM. Notice Explicative No. 94, 142 pp.

PULLAN, R.A., 1969. The soil resources of West Africa. In: Thomas and Whittington (eds): Environment and land use in Africa. London, Methuen and Co, pp. 147-191.

REED, W.E., 1951. Reconnaissance soil survey of Liberia. (Map scale 1:3.300.000). Washington, USDA. Agric. Inf. Bull. No. 66. 107 pp.

ROOSE, E. and CHÈROUX, M. 1966. Les sols du bassin sédimentaire de Côte d'Ivoire. Cah. ORSTOM, Série Pédologique Vol. IV, No, 2, p. 51-92.

SEGALEN, P., 1967. Les sols et la géomorphologie du Cameroun. Cah. ORSTOM, Sér. Pédologique Vol. V., No. 2, p. 137-188.

SIVARAJASINGHAM, S., 1968. Soil and land use survey in the eastern province, Sierra Leone, (Map scale 1:200.000). Rome, FAO TA 2584, 73 p.

SMALL, R.J., 1972. The study of land forms. A textbook of geomorphology Cambridge Univ. Press. 486 pp.

SMITH, G.K., 1962. Report on soil and agricultural survey of Sene-Obosum river basins, Ghana. (Map scale 1:800.000). Washington, USAID. 168 pp.

SMYTH, A.J. and MONTGOMERY, R.F., 1962. Soils and land use in central western Nigeria. (Map scale 1:250.000). Ibadan. Min. of Agric. and Nat. Resources, 265 pp.

SOIL SURVEY STAFF (SSS), 1975. Soil taxonomy. Soil Conservation Service, USDA. Washington DC. Agric. Handbook no 436. 754 pp.

SOMASIRI, S., TINSLEY, R.L., PANABOKKE, C.R. and MOORMANN, F.R., 1978. Evaluation of rice lands in mid-country Kandi District, Sri Lanka. From: Soil resource inventory and development planning. Proc. of a workshop held at Cornell University. p. 97-122.

SOMBROEK, W.G. and ZONNEVELD, I.S., 1971. Ancient dune fields and fluviatile deposits in the Rima-Sokoto river basin, NW. Nigeria. (Geomorph. map at 1:500.000). Neth. Soil. Surv. Inst. Wageningen. Soil Surv. Papers no. 5, 109 pp.

THOMAS, M.F., 1974. Tropical geomorphology. A study of weathering and landform development in warm climates. London. McMillan Press. 332 pp.

UNESCO, 1976. Atlas géologique du monde au 1:10.000.000, Paris.

USAID & FAC, 1978. Resource inventory of North Cameroon. (Land systems map at scale 1:1.000.000). Washington, 189 pp.

VALLERIE, M., 1971. La carte pédologique du Cameroun occidental au 1:1.000.000. Notice Explicative No. 45. Paris, ORSTOM, 48 pp.

VALLERIE, M., 1973. Contribution à l'étude des sols du centre sud Cameroun. Types de differentiation morphologique et pédogénétique sous climat subéquatorial. Trav. et Documents de l'ORSTOM, No. 29. Paris, 111 pp.

VELDKAMP. W.J., 1979. Land evaluation of valleys in a tropical rain area. A case study. Thesis, Wageningen, 266 pp.

VELDKAMP. W.J., 1980. Soil survey and land evaluation in the Mano River Union area, E. Sierra Leone and W. Liberia. (Various small scale maps). Freetown, Mano River Union Project, 162 pp.

VOLKHOFF, B. and WILLAIME. P., 1963. La carte des sols de la République du Dahomey. (Map scale 1:1.000.000). Paris, ORSTOM. Notice Explicative, 67 pp.

VUURE, W. van, and MIEDEMA. R., 1973. Soil survey of the Makeni area, Northern Province, Sierra Leone. (Semi detailed soil association maps at 1:50.000, 1:25.000 and 1:5.000 scales). Njala Univ. Coll. 104 pp.

WALL, J.R.D., (Ed.), 1979. Land resources of central Nigeria. (Land system maps at 1:250.000). Land Res. Study, No. 29, 6 Vols. Surbiton, Land Res. Div.

YOSHIDA, S. M., 1981. Fundamentals of rice crop science. IRRI Los Banos, Philippines, 269 pp.

III HYDROLOGY

ARGOULON, J., 1972. Les surfaces potentièlles pour le dévéloppement de l'irrigation dans la vallée supérieure du Niger, S.C.E.T., Internationale, France. Séminaire international sur les perspectives pour l'irrigation en Afrique de l'Ouest. Université d'Ibadan, Nigeria.

ARRIVETS, J., 1973. Résultats de riziculture sans aménagement en zone Soudaniènne. l'Exemple de bas-fonds du centre d'Haute-Volta. IRAT, l'Agronomie Tropical Vol. 28(1), p. 34-53.

ATIVON, K., 1979. Les résources en eau de l'Afrique de l'Ouest et leur disponibilité pour l'agriculture. Seminaire sur la gestion de l'eau. CIEH-Ouagadougou, WARDA-Monrovia, Liberia.

AVENARD, J.M., 1971. Aspects de la géomophology, In: Le milieu naturel de la Côte d'Ivoire. ORSTOM, Mémoires No. 50, Paris, p. 71-81.

A.V.V., 1981. Synthèse des résultats de l'étude sur les possibilités de mise en valeur de la vallée de la Koulipele dans le bloc de Kaibo sud, 1977 à 1980. Authorité des Aménagements des Vallées de Volta, service expérimentation; Min. du Développement Rural - Haute Volta.

BARRAUD, J., 1963. Rapport au gouvernement du Togo sur les aménagements hydro-agricoles au Togo - FAO/Progr. Elargi d'Assistance Technique - No. 1609, Rome.

BERTRAND, R., 1973. Contribution à l'étude hydrologique, pédologique et agronomique des sols gris sableux hydromorphes du Casamance (Senegal). l'Agronomie Tropical 28(12). p. 1145-1192.

BERTRAND, R., SIBAUD, P., GARUY, F. and GUILLOBEZ, S., 1978. Rice cultivation under hydromprohic conditions on the sandy grey soils of the lower slopes in Senegal. In: Buddenhagen and Persley, (Eds), Rice in Africa, p. 249-256. London Acad. Press.

BIRIE-HABAS, J., AUBIN, J.P., SENE, D. and POSSON, C., 1970. Les récherches rizicoles au Sénégal. Doc. IRAT/IITA seminar on rice, IITA Ibadan, Nigeria.

BOULET, R., 1978. Toposéquences des sols tropicaux en Haute Volta. Equilibre et deséquilibre pédobioclimatique. ORSTOM, Paris, Mémoires no, 85.

CASENAVE, A., 1978. Etude hydrologique de basin de Sangué. Cah. ORSTOM. sér. Hydrologique, Vol. XV (1 et 2), p. 3 - 209.

CHAUMÉNY, J., 1972. The irrigation potential of the Sénégal river basin UNDP-Sénégal. International seminar on prospects for irrigation in West Africa. University of Ibadan, Nigeria.

COLLINET, J. et VALENTIN. C., 1979. Analyse des différents facteurs intervenant sur l'hydrodynamique superficièlle. Nouvelles perspectives - Applications agronomiques. Cah. ORSTOM, sér. Géologique, Vol. XVII (4), p. 283-329.

DUBREUIL, P., 1966. Les caractéristiqies physiques et morphologiques des basins versants. Leur détermination avec une précision acceptables. Cah. ORSTOM - ser. Hydrologiques no. 5.

FAO, 1979. Land in Sierra Leone: A reconnaissance survey and evaluation for agriculture. Rome, FAO AG/DP/SIL/73/002. Tech. Rep. 1.

GIGOU, J., 1972. Régularité des précipitations et cycles culturaux en Côte d'Ivoire. (Première esquisse). Sem. Int. sur les perspectives pour l'irrigation en Afrique de l'Ouest - Univ. d'Ibadan, Nigeria.

GILLET, N., 1973. Caractérisation et mise en valeur des petites vallées ou bas-fonds pour l'agriculture irriguée. IRAT: l'Agronomie Tropical 28(11), p. 1089-1099.

GIRARD, G., SIRCOULON, J. and TOUCHEBEUF, P., 1971. Aperçu sur les régimes hydrologiques. In: Le milieu naturel de la Côte d'Ivoire. ORSTOM, Paris, Mémoires no, 50.

GLEMET, D., 1975. l'Aménagement des bas-fonds, 1969-1976. SATEC, Min. du Développement Rural, Comité de Coordination des ORD-Haute Volta.

INSTITUTE FOR AGRICULTURAL RESEARCH, SAMARU, 1972. The hydrology of a small catchment basin at Samaru, Nigeria. Samaru Research Bulletin 149, Ahmado Bello University, Zaria, Nigeria.

I - Kowal, J., and Omolokum, A.O.,: seasonal fluctuations in the height of the groundwatertable

II - Kowal, J.,: Assessment of the main components of the water budget

III - Kowal, J.,: Assessment of surface runoff under varied land management and vegetation cover.

IV - Kowal, J.,: Assessment of soil erosion under varied land management and vegetation cover.

IITA, 1973. Farming Systems Programme. (Study on major soils in West Africa. Land suitability classification studies of a toposequence). International Institute of Tropical Agriculture, Ibadan, Nigeria.

IITA, 1972, 1974, 1975, 1976, 1978, 1979, 1980. Annual Reports. International Institute of Tropical Agriculture, Ibadan, Nigeria.

JUO, A.S.R. and MOORMANN, F.R., 1980. Characteristics of two soil toposequences in S.E. Nigeria and their relation to potential agricultural landuse. Journ. of Nigerian Soil Science Society. Vol. 1(1) p. 47-61.

KILIAN, J., 1972. Contribution à l'étude des aptitudes des sols à la riziculture des bas-fonds sans aménagement dans le Nord-Dahomey (Bas-fonds de Sirarou et Bagou). l'Agronomie Tropical 27(3), p. 323-375.

KILIAN, J. et TEISSIER, J., 1973. Methodes d'investigation pour l'analyse et le classement des bas-fonds dans quelques régions de l'Afrique de l'Ouest, proposition de classification d'aptitudes des terres à la riziculture. IRAT. l'Agronomie Tropical, 28(2), p. 156-171. This paper was preceeded by an English version presented to the International Seminar on Prospects for Irrigation in West Africa. University of Ibadan, Nigeria: Methodes of investigation for the analysis and classification of swales in some areas of W. Africa, by Kilian, J., and Teissier, J., in 1972.

LE BUANEC, B., 1975. La riziculture pluviale en terrain drainé. Situation, problèmes et perspectives. l'Agronomie Tropical 30(4) p. 350-381.

LEDGER, D.C., 1975. The waterbalance of an exceptionally wet catchment area in West Africa. Journ. of Hydrology Vol. 24 p. 207-214.

LENOIR. F., 1978. Rélations entre le dynamique et la composition chimique d'une nappe d'arène en Côte d'Ivoire, Cah. ORSTOM, sér. Géologique Vol X. (2), p. 209-236.

MATTHIEU, Ph., 1971. Erosion et transport solide sur un basin versant forestier tropical (Basin de l'Amitioro, Côte d'Ivoire). Cah. ORSTOM, sér. Géologique Vol III (2). p. 115-144.

MOLINIER, M., 1976. Qualité des eaux de surface en zone forestière équatoriale de Côte d'Ivoire. Cah. ORSTOM, sér. Hydrologique, Vol VIII, (1), p. 7-24.

MONIOD, F., 1973. Régime hydrologique de l'Ouémé (Dahomey). Cah. ORSTOM, série Hydrologique Vol X (2), p. 171-183.

MOORMANN, F.R., 1973. General assessment of lands on which rice is grown in West Africa. WARDA. Seminar on rice soil fertility and fertilizer use, Monrovia, Liberia.

MOORMANN, F.R., CURFS. H.P.F. and BALLAUX, J.C., 1974. Classification of conditions under which rice is grown in the tropics, with special reference to mechanisation in West Africa. IITA/FAO/Neth. Govt: Exp. Consultation Meeting on the mechanization of rice production, IITA, Ibadan, Nigeria.

MOORMANN, F.R., PEREZ, A.T. and VELDKAMP. W.J., 1976. Potential of hydromorphic rice cultivation in Nigeria. NAFPP workshop paper. IITA, Ibadan, Nigeria.

MOORMANN. F.R. and VELDKAMP, W.J., 1978. Land and rice in Africa, constraints and potentials. In: Buddenhagen and Persley. (eds), Rice in Africa. London Acad. Press, p. 29-43.

MOORMANN, F.R., VELDKAMP, W.J. and BALLAUX J.C., 1977. The growth of rice on a toposequence. A methodology. Plant and Soil no. 48, p 565-580.

MURDOCH, G., OJO-ATERE, J., COLBORNE, G., OLUMU, E.I. and ODUGBESAN. E.M., 1976. Soils of the Western State savanna in Nigeria. Land Res. Study, No. 23, Vol I. The environment. Land. Res. Div. Surbiton.

ODELL, R.T., DIJKERMAN, J.C., VAN VUURE, W., MELSTED, S.W., BEAVERS, A.H., SUTTON. P.M., KURTZ, L.T. and MIEDEMA. R., 1974. Characteristics, classification and adaptation of soils in selected areas in Sierra Leone, Njala Univ. Coll. Bull 4. Sierra Leone.

OKALI, C., OBENG, D., OJO-ATERE, T. and LAWSON, T., 1979. An evaluation for farmer's knowledge and use of hydromorphic toposequences in the Western State of Nigeria: findings from selected areas in Oshun River Basin, IITA discussion paper No. 4/79, Agric. Economics.

OKALI, C., OBENG, D. and OJO-ATERE, T., 1980. The management and use of hydromorphic toposequences in the Ogun River Basin: the case of traditional farmers in the Ofada area of Ogun State, IITA discussion paper No. 5/80, Agric. Economics.

OLIVRY, J.C., 1976. Régimes hydrologiques en pays Bamiléke (Cameroun) Cah. ORSTOM, Sér. Hydrologique, Vol. VIII (1), p. 37-71.

ORSTOM, 1970. Monographie hydrologique du basin du Niger. Comité Interafricain d'Etudes Hydrologique, Ouagadougou, Haute Volta. 3 parties: Partie I: Le Niger supérieur et le Bamie; Partie III: Le Niger moyen.

QUARTEY-PAPAFIO, H.K. and KEMEVOR, E.D., ?. Land and Water resources for irrigation in the Volta Basin.

REICHOLD, W., BLECKMAN, E.G., MAYER. R. and PARIS-TEYNAC, J., 1978. Der Senegalstrom, Lebensader dreier Nationen. IFO-Inst. für Wirtschafstforschung München, Afrika Studien 102. Weltforum Verlag.

RODIER, J., 1964. Régimes hydrologiques de l'Afrique noire à l'ouest du Congo, ORSTOM, Paris, Mémoires no. 6.

RODIER, J., 1976. Estimations des débits de crues décennales pour les petits basins forestiers en Afrique tropicale. Etude préliminaire. Cah. ORSTOM, Sér. Hydrologique Vol. VIII (4), p. 243-268.

RODIER, J., 1976. Evaluation de l'écoulement annuel dans les regions tropicales sèches de l'Afrique occidentale. Cah. ORSTOM, sér. Hydrologique, Vol. XIII, (4), p. 269-306.

RODIER, J. et AUVREY, C., 1965, Estimation des débits de crues décennales pour des basins versants de superficie inférieure à 200 km$^2$ en Afrique occidentale. ORSTOM-Paris/CIEH Ouagadougou. This paper has been translated into English by Herridge, W.E, 1965. Publ. Works Dept. Ghana.

RODIER, J. and SIRCOULON, J., 1963. Monographie de l'Ouémé supérieure. ORSTOM Paris 2 Volumes.

SAVVIDES, L., 1981. Guidelines to improving valley swamps (fadamas). Bida Agricultural Dévelopment Project in Nigeria.

SODERIZ, 1976. Project Bouaké Nord. Rapport de synthèse prévenu dans le cadre du contract d'Assistance Technique TA/984 entre le Fond Européene de Dévèloppement et Grontmij International.

STIEMER, D., 1968. Aménagement hydro-agricoles dans le nord de la Côte d'Ivoire. FAO/SATMACI, Operation Riz, Korhogo.

TAMS/CIEH, 1976-1978. Savannah regional water resources and land use. Savannah resources. Comité Interafricain d'Etude Hydrologique, Ouagadougou, Haute Volta.

VELDKAMP, W.J., 1979. Land evaluation of valleys in a tropical rain area. A case study. Thesis, Wageningen, The Netherlands.

WALL, J.R.D., (Ed.), 1979. Land Resources of central Nigeria. Land Resources Study no, 29. 6 Vols. Land Res. Div. Surbiton.

ANNEX I

DESCRIPTIONS OF SOME VALLEY BOTTOM SOILS IN WEST AFRICA

Land region 1 - Coastal Plains.

U-shaped valleys in the Continental Terminal sandstone deposits of the coastal terraces (subregion 1.2) in south Togo comprise soils of the Yovor series in their lowest parts. These are deep, poorly drained, gray (loamy) sands of very low inherent fertility: CEC (Cation Exchange Capacity) is 1-3 me/100 g soil; base saturation is 30-40 percent and pH water is 5.5-6.0. The Yovor soils can be classified Typic Tropaquepts, sandy/coarse loamy.
In similar U-shaped valleys in sandstone formations in the Bende area in southeast Nigeria, deep, very poorly drained, gray sandy loams of slightly better fertility status occur. Their effective CEC (e CEC) is 5-8 me and base saturation is 70-80 percent of eCEC. pH-water is low: 4.0-4.6. They are classified Tropaquents, coarse loamy.
Both the above soils are largely still under natural swamp forest. Patches of land are being used for wetland rice cultivation.
The sandstone formations in the Bende area overlay Tertiary shales which upon exposure in the valleys weather into clayey soils of relatively high fertility. They have been described as deep, imperfectly drained, mottled clays. Effective CEC is approximately 30 me, base saturation (of eCEC) is almost 100 percent due to high contents in exchangeable Ca, and pH-water is 5.4-5.7. These soils are classified Aquic Eutropepts. They are increasingly being developed for wetland rice cultivation.

Land region 2 - Interior Plains.

In the Interior Plains on acid to intermediate rocks of the basement complex in Sierra Leone (subregion 2.1) inland valley bottoms vary in width from several tens to several hundreds of meters. They are occupied mainly by associations of soils comprising the Masuba, Panlap and Mankane series. In this order these soils occupy increasingly low positions in the valley bottoms.

The Masuba soils comprise moderately well drained, deep, gravelfree sandy clay loams with dark topsoils, over yellowish brown, prominently mottled subsoils in which plinthite is being formed. They have very low CEC (3-6 me) and low base saturation (10-20%) and pH-water (4.6-4.8). They are not subject to flooding. These soils are classified 'Plinthic Udoxic' Dystropepts, fine.

The Panlap soils are somewhat poorly drained, deep, gravel-free sandy loams and loamy sands with dark humic topsoils over gray mottled subsoils with plinthite. They are flooded during 3 to 4 months per year. They have very low CEC (2-4 me), relatively high base saturation (30-60%) and pH-water between 4.5 and 5.0. They are classified Aeric Plinthic Tropaquepts, coarse loamy.

The Mankane soils resemble those of the Panlap series but they are poorly drained and their flooded periods last longer (5-6 months). They have slightly lower base saturation. They are classified Plinthic Tropaquepts, coarse loamy.

Most valley bottoms in Sierra Leone have grasses and reeds in natural vegetation with some raphia palm and wild oil palm. The valley bottoms are increasingly developed for wetland rice cultivation.

In valley bottoms of the Interior Plains in Liberia (Subregion 2.1) the Dalia soil family comprises poorly drained, dark brown sandy loams which overlay gray, coarse sandy gravel at shallow depth. These soils have low inherent fertility: CEC is less than 4 me, base saturation 25-35% and pH-water 5.0-5.5. They are classified 'Psammentic Dystric' Tropaquents, loamy over sandy-skeletal.

Valley bottoms in Ivory Coast have been described as to have heterogenous textures generally overlaying coarse sands within 100 cm of the surface. Textures in the upper soil horizons in southern Ivory Coast (Equatorial forest zone, subregions 2.1 and 2.2) are mainly coarse to medium. They are medium to fine in the Guinea savannah zone towards the north of this country (subregions 3.1 and 3.2) where the 'bas-fonds' are generally more extensive than in the south. Fertility of the valley bottom soils reflects a related pattern: it is relatively low in the south and it is medium to high in the north.

As an example of a valley bottom soil on granites in the southern part of Ivory Coast (Subregion 2.1) may serve the description of a 'Sol hydromorphe mineral à gley de profondeur sur material alluvio-colluvial issu de granite' occurring in a 200 m wide valley.

It is a poorly drained, deep sandy clayloam with a dark humic topsoil over a light gray subsoil which overlays coarse sand at 100 cm. CEC is 17 me in the topsoil, and ranges from 4 to 10 me in the lower horizons. Base saturation is 20-40%, pH-water is 4.7-5.4, This soil may be classified Typic Tropaquept, coarse loamy.
In the same area, valley bottom soils developed in alluvium/colluvium from schists (subregion 2.2) occur as 'Sols hydromorphes mineraux à gley de profondeur sur material alluvio-colluvial issu de schistes'. An example of such a soil, occupying a slightly elevated position near the fringe of a valley bottom was described as a moderately well drained, deep, light clayey soil with a dark humic topsoil over a mottled gray clayloam subsoil. CEC is 12-17 me throughout the profile. Base saturation is 60-80 percent and pH-water is 6.0-6.7. This soil may be classified Aquic Eutropept, fine loamy.
Natural vegetation in the valley bottoms in southern Ivory Coast is swamp forest with raphia palm.

In the Interior Plains in Niger, the Matako soils have been described in valley bottoms in micaschist rocks (representative for subregion 2.2) in the Guinea savannah zone. These poorly drained soils have dark, humic, sandy topsoils (mollic epipedon) over mottled gray sandy loam subsoils. Due to a relatively high organic matter content (over 4.5 percent), CEC of the topsoil is high: 17 me. CEC is low in the subsoil: 1-5 me. Base saturation (78-100 percent) and pH (5.6-8.3) are high throughout the profile, mainly because of the high content in exchangeable sodium. The Matako soils are classified Fluvaquentic Haplaquolls, sandy. Vegetation is mainly grass savannah and some bush regrowth after shifting cultivation.

Ofin and Firam soil series occupy valley bottoms in the Interior Plains over upper Birrimean rocks in Ghana (subregion 2.3). The poorly drained Ofin soils are subject to flooding. They have a thin humic sandy loam topsoil over pale gray sands or loamy sands. They have low CEC and base saturation, and their pH is between 4 and 5. Ofin soils may be classified Typic Tropaquepts, sandy. Firam soils are slightly better drained, have finer texture and thicker humic topsoils than the Ofin soils. They are Aeric Tropaquepts, fine loamy.

In central Ghana, in the Interior Plains on sandstones and shales (subregion 2.5) soils in the valley bottoms belong to the Sene-Denteso association. Denteso soils occupy the higher positions in the valley bottoms. They are developed in collo-alluvial material and consist of deep, moderately well drained, pale coloured sands with plithite, overlying hard ironstone pans. They are saturated in the wet season and dry during the dry period. CEC is very low (1-3 me), base saturation is relatively high (50-60%) and the pH ranges from 5.2-5.6. They can be classified Aquic Plinthic Tropopsamments, sandy.
The lower member of this soil association comprises the Sene soils. These are deep, poorly drained, sandy loams over strongly mottled sandy clays with plinthite. They are flooded annually. They have low CEC (6-10 me), relatively high base saturation and subsoils tend to be alkaline (pH 6.6-9.0). They are Plinthaquepts or Plinthic Tropaquepts, fine.

Also in subregion 2.5, but more to the north, Volta and Lima soil series have been distinguished in the valley bottoms in sandstone formations. The Volta series comprises somewhat poorly drained soils with dark coloured, silty clayloam topsoils over brownish mottled, silty clay subsoils. The CEC of the (sub-)soils is 10-17 me and base saturation and pH are relatively high as well (60-95% and 5-7 respectively). Lima series soils occupy slightly higher positions in the landscape. They are moderately well drained and they have lighter surface textures.
The valleys in this subregion have been described as to be somewhat shallower and wider than those in the adjacent plains on granitic rock formations to the northwest (subregion 2.1). Also, the texture of the sandstone-derived alluvium is coarser than that of the granites. In the dry climate prevailing in this area, salinity problems do occur.

The soils formed in valley bottoms in the Cretaceous sediments in the Niger and Benue trough of Central Nigeria (subregion 2.6) vary strongly due to variations in parent material, which ranges from sandstone to shale, and in drainage conditions.
Near the middle stretches of the Benue river, in a sandstone area, stratified, moderately well drained, brownish sandy loams with dark sandy topsoils of low fertility have been described. Cation exchange capacity (eCEC) is 0.4-3.0 me, base saturation (over eCEC) is 73 percent in the topsoil and 17-28 percent in the deeper horizons. pH water is 4.1-4.8. These soils are classified Aquic Ustifluvents, coarse loamy.

They are generally not cultivated but overgrown by shrubs, grasses and trees.

In an area in the Benue trough dominated by claystone sediments, finer textured soils occur: Fluvaquentic Ustropepts, fine clayey. A typical profile has been described as moderately well drained and deep with a dark brown loamy sand topsoil over a brownish mottled clayey subsoil. These soils have somewhat better fertility characteristics than the soils over sandstone described above. eCEC is 8-10 me and base saturation (over eCEC) ranges from 40 to 55 percent throughout the profile. pH-water is 4.2 in the topsoil and between 5.2 and 5.4 in the subsoil. Rainfed rice and sugarcane are grown on these soils, on high ridges.

In both the Niger and the Benue troughs plinthite is locally being formed in the soils of valley bottoms. An example of a plinthitic soil has been described in the Niger trough. It is a moderately deep, somewhat poorly drained silt loam with a topsoil of loamy sand and signs of clay translocation in the subsoil. From about 60 cm below the surface the soil is strongly mottled white and yellowish brown and concretionary. The plinthite has hardened below 90 cm depth, to form an impenetrable cemented ironstone hardpan. This soil has low inherent fertility. eCEC is about 4.5 me in the upper horizon, decreasing to 1.7 me in the subsoil. Base saturation ranges from 50 to almost 100 percent (topsoil). pH-water is 5.5 in the topsoil and increases to 6.5 at 90 cm depth. The soil can be classified Oxic Plinthaquult, coarse loamy. Vegetation on this soil is mainly grasses and shrubs.

Non-plinthitic soils in valley bottoms of the Niger through have been described near Bida as comprising deep, somewhat poorly drained, concretionary brownish light clays with pale coloured loamy topsoils. eCEC in the topsoil is low (2-4 me) and increases in the finer textured subsoils to 16 me. Base saturation (of eCEC) is about 70 percent in the top of the profile and 100 percent in the lower horizons, due mainly to high contents is Ca and Mg. pH similarly increases from 4.7 to about 8 at a depth of 130 cm. This soil can be classified Aeric Tropaquept, fine loamy. The soils are used for rainfed rice cultivation with grass fallow.

Land region 3 - Plateaux

In southeast Guinea, deep, somewhat poorly drained, light clays with dark topsoils over light gray mottled subsoils have been observed in valley bottoms of the Plateaux on granitic basement complex formations. (subregion 3.1).
They have low to moderate fertility: CEC is 20-25 me in the surface horizons and 7-15 me in the subsoils. Base saturation is 15-30%, pH-water 5.0-5.5. Their classification is Aquic (Oxic) Dystropepts, loamy/fine clayey.
In the Odienne area in north Ivory Coast (subregion 3.1, Plateaux on granitic basement complex formations) poorly drained valley bottom soils include those with very dark brown humic sandy loam topsoils over mottled gray sandy clayloams over sandy strata between 40 and 200 cm (Typic Tropaquepts, fine loamy or fine loamy over sandy-skeletal). The variability of these soils may be illustrated by analytical data on 20 'Sols hydromorphes mineraux' in this area, which show that the CEC in the topsoils ranges between 2 and 30 me (13) and between 2 and 14 (6) in the subsoils. Base saturation varies from 4-85% (37) and from 1-100% (37) in the surface and in the deeper horizons respectively. pH-water ranges from 4.2 to 6.5 throughout the profiles. (Figures between brackets refer to average values).
In south-central Cameroon, valley bottom soils in the Plateaux (subregion 3.2) have been classified Tropaquents and Tropic Fluvaquents. Locally some peats occur as well (Tropofibrists). The mineral soils have mainly humic topsoils and gray, stratified loamy, sandy clay and clayey subsoils. They have moderate to high fertility: CEC ranges between 20 and 30 me, base saturation is 25-40% and pH-water is between 4.5 and 5. The valley bottoms in this area are generally narrow (50-100 m). The valleys are deep and have steep sides (10-20%). V-shaped and U-shaped valleys occur both.

Land region 4 - Highlands

Valley bottom soils occurring in the Highlands are not specified here. Within the framework of the present inventory they are of little relevance as they occupy a limited total area only (Table 2) and because they occur mainly under rather specific environmental conditions (specific geology/lithology; high elevation) which are representative for very small parts of the inventory area only.

ANNEX II

HYDROLOGICAL PROCESSES IN VALLEYS

1 Tropical valleys have drawn attention because of their more humid appearance than the adjacent upland, sometimes over prolonged periods, providing opportunities to grow crops beyond the rainy season. Whether and for how long these valleys can be used for crop production depends on the extent of occurrence of:

- the normal and peak discharges of the valley streamflow;
- the amount and duration of subsurface water influx from adjacent upland during, but especially after the rainy season;
- the height and duration of the high groundwater level during, but especially after the rainy season.

For an accurate assessment of the extent and dimensions of these features recordings and measurements should be done at site. This would be absolutely necessary for the benchmark sites of Phase II of the WURP to be implemented. Each valley namely, has specific physical and environmental conditions and some of them are not constant in time.

2 For a better understanding and to enable an evaluation of the moisture regime of the valleys a brief explanation of the hydrological processes is given below:

All hydrological processes (or components thereof) are interrelated and have a dynamic (non-steady) nature. They can roughly be divided in the above-surface and subsurface processes.

2.1 The above-surface processes may be approximated by a steady state model of the water balance, which can be expressed in a general form as follows:

Supply - Losses = Change in amount of groundwater

This model enables the calculation of quantities of water involved, if the various components are known. However, it does not allow for the computation of the time involved.

For the uplands (u) the waterbalance is:

$$P - E_u - R_u = \Delta H_u$$

For the valleys (v) the waterbalance is:

$$P + (\Delta H_u + R_u) \frac{\text{Area upland}}{\text{Area valley}} . - E_v - R_v = \Delta H_v$$

All components in these equations are expressed in mm, they are:

P = Precipitation. This is the average annual rainfall as obtained from the nearest rainfall recording station or for larger areas as prevailing in the various climatological or ecological zones.

E = Evapotranspiration. This is the average evapotranspiration, distinguished respectively in $E_1$ for the evapotranspiration during the growing season and in $E_2$ for the non-growing season. Eventually $E_v$ is larger than $E_u$ because of the wetter conditions in the valley.

R = Surface runoff. This is a fraction (runoff coefficient) of the total supply of water, for the upland of the rainfall and for the valley of the rainfall plus inflow from upland.
The runoff coefficient depends on a large number of factors, such as rainfall in terms of quantity, intensity and duration, the size and shape of the catchment area, the vegetational groundcover, the soil texture, the infiltration capacity and the degree of saturation of the soil.
Because of these variable factors the surface run off coefficient may range between almost 0% to almost 100% for different areas and for different times.
Usually the upland surface runoff is smaller then the valley surface runoff. Surface runoff is highest when the soil is completely saturated (ground water level at or above surface).

This may often occur in the valleys, but rarely on the uplands. If rain falls at the time that saturated conditions exist, peak discharges are likely to occur. The stream discharge will return to baseflow, if the stream is fed by groundwater only, or if the surface runoff from upland into the valley is nil.

$\Delta H$= Change of the amount of groundwater
Water that has not run off or evaporated from site will add to the groundwater reservoir causing its level to rise. In turn this raised water level is the driving force causing the groundwater to flow internally to lower lying areas (from upland to valley bottom to lower lying (larger) valleys or rivers), resulting in the fall of groundwater level. This continuous changing of the groundwater level is exemplified in Figure $A_1$ for a valley in central south Ivory Coast.
At the end of the annual hydrological cycle $\Delta H$ = nil.
This means that the groundwater reservoir built up during the supply period is depleted because of sub-surface water movement to the lower lying areas. Usually $\Delta H_u$ is depleted quicker than $\Delta H_v$, implying that the valley stays wet longer than the upland.

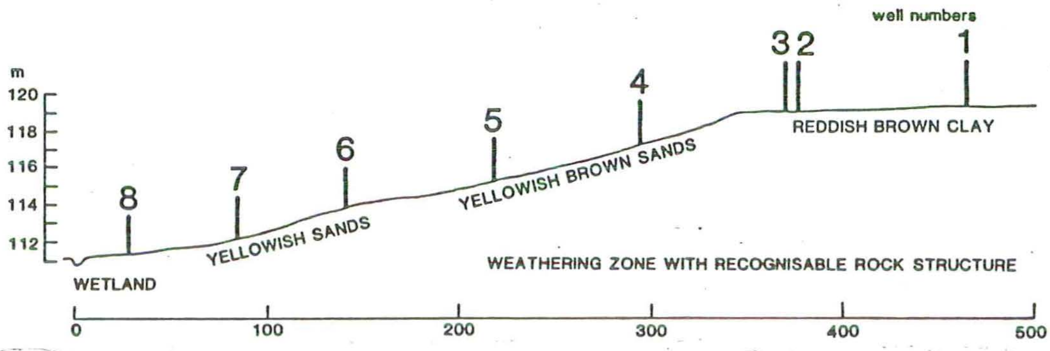
2.2 The subsurface water movement is governed by a number of inter related variables. Their values can only be assessed on site and at time.

- The hydraulic gradient (i) depends on the location and changes with time. It is the difference in height between two points on the groundwater level divided by the distance between these points. The position of the groundwater level depends on the fill and depletion of the groundwater reservoir and the position and slope of the impermeable bedrock or layer.
- The hydraulic conductivity (K) is a resistance coefficient. It depends on the soil texture and structure. For a uniform soil mass K is near constant under completely saturated conditons. If the water flows through a stratified soil, the overall hydraulic conductivity is the weighed average of the water carrying soil layers.

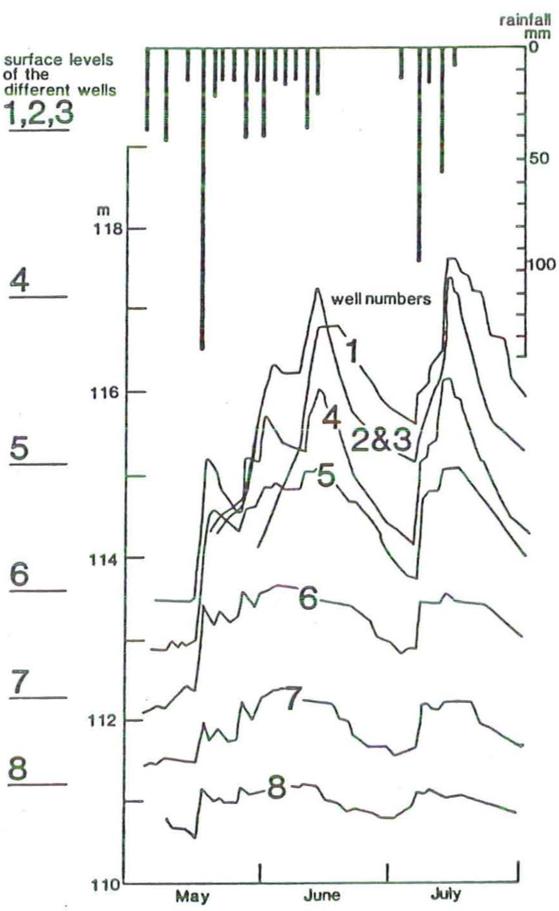
- The thickness of the water carrying layer (D) changes with the fill and depletion of the groundwater reservoir. It is the depth of the groundwater from its upper level to the impermeable (bedrock) layer.

  The combined KD value determines the transmissivity of the soil. It differs at places and changes in time.

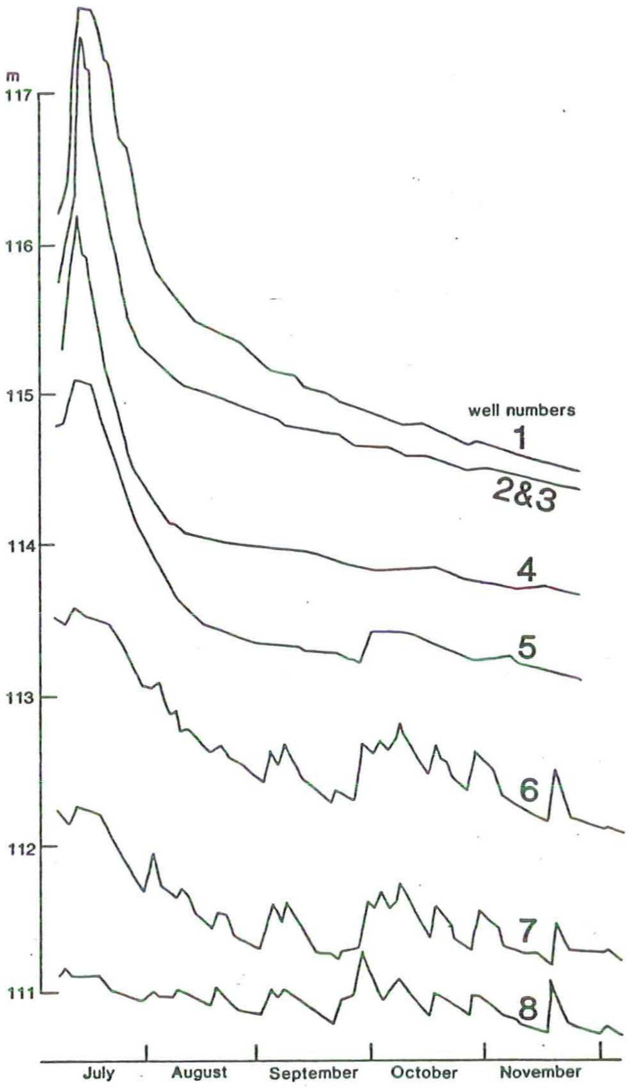
At the transition zone of the valley slope to the valley bottom, groundwater often appears at the soil surface during and after the rains. This is often refered to as seepage and the area is refered to as the seepage zone. If this phenomenon occurs, it means that the soil on top of the impermeable (bedrock) layer is too shallow (or contracted) to accommodate the KD value of the moment. Once the KD value has decreased or the hydraulic gradient has increased (= faster flow) because of the lowering of the (ground) water level in the valley bottom, seepage will stop, although subsurface flow will continue until D has become nil.
The subsurface flow of both the upland and the valley bottom provide the water of the baseflow of the valley stream or river. The baseflow gradually decreases and becomes nil if subsurface flow has ceased before the next rainy season.




a. Location of piezometer wells on the toposequence, on granite




b. Climbing groundwater levels




c. Declining groundwater levels

Figure A1. Example of groundwater fluctuations in a valley catena in central Ivory Coast, 1975.

Source: Lenoir (1978)

Government of The Netherlands
Min. of Foreign Affairs/DGIS
Min. of Agriculture and
Fishery/DLO

International
Institute of Tropical
Agriculture (IITA).
Ibadan - Nigeria

# Wetland Utilization Research Project
# West Africa

## Phase I
## The Inventory

## Volume III: The Agronomic, Economic and Sociological Aspects

April 1983



Institute for Land Reclamation & Improvement
Wageningen - The Netherlands

WETLAND UTILIZATION RESEARCH PROJECT

West Africa



Phase I

The Inventory

By: Ir. P. Hekstra (editor) - Agronomy (ILRI)
Ir. C.A. de Vries - Agro-economy (KIT)
Ir. G. Bus - Sociology (KIT)

The information about health aspects was compiled by Ir. Linklaen Arriëns (ILRI). The assistance given by Dr. Lucassen is gratefully acknowledged.

VOLUME III: THE AGRONOMIC, ECONOMIC AND SOCIOLOGICAL ASPECTS

International Institute
for Land Reclamation
and Improvement
ILRI - Wageningen

Royal Tropical Institute
KIT - Amsterdam

CONTENTS

# INTRODUCTION

## *Approach and presentation*

The International Institute of Tropical Agriculture (IITA) at Ibadan - Nigeria, requesting the Government of The Netherlands for technical and financial assistance, submitted its proposal for the Wetland Utilization Research Project (WURP) in 1981. This proposal consists of three phases. The first phase is the inventory of existing information to identify the extent and the categories of wetlands and to assess capabilities and constraints of wetland utilization in rice-based smallholder farming systems, based on village-scale development without major inputs.

The activities for the WURP-Phase I, the collection and evaluation of available information, started in August 1982. In The Netherlands contributions were made by the STIBOKA (Soil Survey Institute) on the geological, geomorphological and pedological aspects, by the KIT (Royal Tropical Institute) on the agro-socio-economic aspects and by the International Institute for Land Reclamation and Improvement (ILRI), on the climatological and hydrological aspects. The ILRI also had the overall responsibility of coordination, (Ir. J. de Wolf).

The report has been presented in four volumes:

| | |
|---|---|
| Volume I. | The main report, with conclusions and recommendations. |
| Volume II. | The physical aspects. |
| Volume III. | The agronomic, sociological and economic aspects, (this volume). |
| Volume IV. | The maps. |

## *Area and subject of the inventory*

The inventory area is indicated on the maps of Volume IV. It has been chosen somewhat larger than the IITA-mandate area in West Africa. It covers the area where rainfed double cropping or more, is possible.

This area comprises the Guinea savannah zone and the Equatorial forest zone, more or less corresponding with the subhumid tropics and the humid tropics of West Africa respectively. The entire inventory area covers approximately 2.2 million $km^2$, comprising partly entirely the coastal countries of West Africa from Guinea Bissau through Cameroon.
Wetlands are lands having hydromorphic soils. Such soils have morphological characteristics associated with wetness and the resulting reduction during at least a part of the year. Wetland therefore is found where hydromorphic soils have been formed, such as in delta's, the tidal lands, inland depressions (e.g. the bolis of Sierra Leone), river flood-plains and inland valley bottoms.
Because of its objectives the WURP will be restricted to those wetlands which can be implemented, operated and maintained by smallholders having simple means only. Therefore the present inventory directs itself mainly to small inland valleys (streamflow valleys). These valleys are formed on the upper part of the river catchments. They have a centrally located stream which is shallow and only a few meters wide, or which is not existing at all. They have a width varying from about 10 metres in their upper to a few hundred of metres in their lower stretcher. The catchment area ranges from at least 2 $km^2$ to some 100 $km^2$.

*This volume*

Under rainfed conditions in West Africa, most rice is produced on upland soils, although an increasing proportion is grown in the wetlands of small inland valleys and swamps. If cultivated by smallholding farmers having their plots on valley catenas, rice is very often part and parcel of intricate farming and cropping systems, comprising a range of different crops grown on upland and wetland soils. Decisions to be made by these farmers in relation to their crop production are always related to the agro-socio-economic environmental circumstances.
Therefore this volume presents the results of the inventory of literature in respect of the socio-economic and agronomic context in which rice is grown by smallholding farmers and the research activities done to improve rice production.

Also, criteria are formulated for the selection of areas, in which benchmark sites could be located. Research needs and activities are indicated, based on the agro-socio-economic aspects related to smallholder's wetland rice production, for the proposed WURP - Phase II.
Because of the interrelationship between the sociological, but especially the economic aspects, in this volume comparisons are made between the countries of the inventory area and the countries of the semi-arid and arid tropics (the Sahel and Sudan savannah zones) of West Africa. Hereafter these latter areas will be referred to as the 'arid area', whenever applicable.

# 1 DEMOGRAPHY AND HEALTH

## 1.1 General

West Africa is more urbanized than East Africa, but less than other African regions. About 25 to 50% of the population lives in urban centres. Apart from Lagos and Ibadan, (both in Nigeria), there are no cities with more than one million people.

The overall population density of West Africa is low. However, the distribution of the population is strongly determined by the economic strength and stability of the individual countries (or parts thereof) and changes in the economic situation often result in movements of large numbers of people. The countries of the inventory area are very heterogeneous in respect of economic growth as well as population growth. In 1980 the highest population growth was recorded in Ivory Coast, whilst the lowest growth was found in Guinea Bissau. In 1973 the highest per capita G.N.P. was found in Ivory Coast (US$ 380), but the economic growth was sharpest in Togo (4.4% during 1960-1973). More recently the growth of the G.N.P. was largest in Nigeria, because of the oil boom which attracted large numbers of people from neighbouring countries. In 1983, with the turn of the economic (oil) events, millions of them have been sent back to their homelands, especially Ghana.

Based mainly on data from the United Nations, the World Bank and Zacharia and Condé (IBRD/OECD, 1981), the two major demographical aspects (population and migration) are discussed in the subsequent paragraphs.

## 1.2 Population

The population of the inventory area consists of a great variation of peoples, both in numbers and customs. The population numbers for the various countries in 1950, 1963, 1970 and 1980 are presented in Table 1 together with the population increase during the period 1950 to 1980. The total population increase for West Africa, including both the inventory and the arid area, was 109% between 1950 and 1980.

Table 1. Population numbers and increage 1950-1980 (x 1000) and percentage rural population 1980.

| | 1950 | 1963 | 1970 | 1980 | % increase (1950-1980) | rural population 1980 (%) |
|---|---|---|---|---|---|---|
| Inventory area | | | | | | |
| 1. Benin | 1571 | 2233 | 2720 | 3530 | 125 | 45.9 |
| 2. Cameroon | 3921 | 5009 | 6780 | 8444 | 115 | 80.7 |
| 3. Ghana | 5191 | 7345 | 8610 | 11679 | 125 | 50.8 |
| 4. Guinea | 2247 | 3465 | 3920 | 5014 | 123 | 80.1 |
| 5. Guinea Bissau | 507 | 524 | 490 | 573 | 13 | 82.2 |
| 6. Ivory Coast | 2612 | 3925 | 5310 | 8034 | 208 | 79.3 |
| 7. Liberia | 860 | 1041 | 1340 | 1967 | 129 | 69.7 |
| 8. Nigeria | 37606 | 55150 | 56350 | 77082 | 105 | 53.3 |
| 9. Sierra Leone | 2004 | 2305 | 2690 | 3474 | 73 | 65.1 |
| 10. Togo | 1190 | 1563 | 1960 | 2625 | 320 | 67.9 |
| Sub-total | 57709 | 82560 | 90170 | 122422 | 112 | 58.6 |
| Arid area | | | | | | |
| 11. Chad | 2665 | 3210 | 3640 | 4455 | 67 | 83.6 |
| 12. Gambia | 263 | 317 | 460 | 603 | 129 | 78.6 |
| 13. Mali | 3440 | 4307 | 5050 | 6940 | 102 | 87.0 |
| 14. Mauretania | 840 | 1017 | 1243 | 1634 | 95 | 92.8 |
| 15. Niger | 2417 | 3422 | 4020 | 5318 | 120 | 87.9 |
| 16. Senegal | 2482 | 3329 | 4270 | 5661 | 128 | 74.4 |
| 17. Upper Volta | 3676 | 4551 | 5380 | 6908 | 88 | 81.4 |
| Sub-total | 15783 | 20153 | 24063 | 31519 | 100 | 85.7 |
| Total West Africa | 73492 | 102713 | 114233 | 153941 | 109 | 64.1 |

Source: UN-Demographic Yearbooks

This increase was slightly higher in the inventory (112%) than in the arid area (100%). During this period population increase was very low in Guinea Bissau (13%) whilst it was very high in Togo (320%) and Ivory Coast (208%). However, more recently the population growth rate in Guinea Bissau has been increasing. The highest annual rates are presently (1975-1980) found in Ivory Coast (3.5%), Liberia (3.5%) and Nigeria (3.3%) as is shown in Table 2.

The overall population density in the inventory area (47 persons per $km^2$) is much higher than in the arid area (19 persons per $km^2$). Within the inventory area Nigeria is the most populous country (83 persons per $km^2$) and Guinea Bissau the least (16 persons per $km^2$). The regional variations in population densities are shown on Map 4 of Volume IV. Generally, the eastern part of the inventory area is more densely populated than the western part.

Table 2. Population, growth rates and densities

| | Population x 1000 1980 | Population growth rate % year 1970-78[1] | 1975-80 | Area km² | Density p/km² |
|---|---|---|---|---|---|
| Inventory area | | | | | |
| 1. Benin | 3,530 | 2.9 | 2.8 | 112,622 | 32 |
| 2. Cameroon | 8,444 | 2.2 | 2.5 | 475,442 | 18 |
| 3. Ghana | 11,679 | 3.1 | 3.0 | 238,537 | 48 |
| 4. Guinea | 5,014 | 2.9 | 2.6 | 245,857 | 20 |
| 5. Guinea Bissau | 573 | 1.6 | 1.8 | 36,125 | 16 |
| 6. Ivory Coast | 8,034 | 5.8 | 3.5 | 322,463 | 25 |
| 7. Liberia | 1,967 | 3.4 | 3.5 | 111,369 | 17 |
| 8. Nigeria | 77,082 | 2.5 | 3.3 | 923,768 | 83 |
| 9. Sierra Leone | 3,474 | 2.5 | 2.7 | 71,740 | 48 |
| 10. Togo | 2,625 | 2.6 | 2.6 | 56,785 | 48 |
| Sub-total | 122,422 | | | 2,594,708 | 47 |
| Arid area | | | | | |
| 11. Chad | 4,455 | 2.2 | 2.3 | 1,284,000 | 4 |
| 12. Gambia | 603 | 3.1 | 2.8 | 11,295 | 53 |
| 13. Mali | 6,940 | 2.5 | 2.6 | 1,240,000 | 6 |
| 14. Mauretania | 1,634 | 2.7 | 2.8 | 1,030,700 | 2 |
| 15. Niger | 5,318 | 2.8 | 2.9 | 1,267,000 | 4 |
| 16. Senegal | 5,661 | 2.6 | 2.6 | 196,192 | 29 |
| 17. Upper Volta | 6,908 | 1.6 | 2.6 | 274,200 | 25 |
| Sub -total | 31,519 | | | 5,303,387 | 6 |
| Total West Africa | 153,941 | | | 7,898,095 | 19 |

1) Source: World Bank 1980 Atlas.

Source: Demographic Yearbook 1980

Highest population densities (20 to 49 persons per km² and over) are found in the Equatorial forest zone and the southern part of the Guinea savannah zone, especially around the capitals and other administrative centres. In the northern part of the inventory area the population density is mainly below 20 persons per km².

However some areas have higher densities. These are the Fouta Jallon in central Guinea (Haute Guinée) with 20 to 100 persons per km², the region of south Upper Volta - north Ghana, also with 20 to 100 persons per km² and most important, northern Nigeria with over 50 persons per km² in the Sokoto-Zaria-Bauchi region to more than 100 persons per km² near Kano.

Evidently, in those densely populated areas not all people are employed in agriculture and exert pressure on land. In Nigeria, Benin and Ghana, the rural population is roughly half the total population, in other countries about three quarters. The rural population density in the inventory area is highest in Nigeria (over 50 persons per km²) and lowest in Liberia, Guinea Bissau and Guinea, Benin and Cameroon (less than 20 persons per km²).

## 1.3 Migration

West Africa is one of the few regions in the world where relatively large-scale free movement of people accross international borders still takes place. Where once movement was compulsory because of wars, slave trade and forced labour, in recent years it has become a free migration of individuals and families, as part of an effort to improve their economic conditions.

For West Africa, Zacharia and Condé (1981) report that, expressed as a percentage of the national population, Ivory Coast (21.3%) and Gambia (10.6%) have the highest, whilst Mali (1.7%) and Upper Volta (1.9%) have the lowest numbers of foreign nationals.
Nevertheless the overall external migration is only half of the internal migration. The overall direction however, is the same: towards the south, from the interior to the coastal areas. There is an overall negative relation between emigration and internal migration and an overall positive relation between immigration and internal migration. Immigration rates have been high in Ghana and still are for Ivory Coast. More recently these rates increased for Nigeria, at the expense of those of Ghana. They are low for Benin, Togo, Guinea and Guinea Bissau. Principal areas of in-migration are the capital cities which are mainly located along the coast. Secondary areas of in-migration usually are the main administrative centres.

Differences in population density do not explain the migration movements. These movements are mainly caused by the economic differences between or within the countries. People move from countries or regions with weak economies to those with a stronger one. The number of people involved in these movements is relatively large and the economic and social consequences are substantial. In Ivory Coast only 35% of the population is living in the localities where it was born.
The economic impact of these movements is most evident from the size of the migrant labour force in the destination countries and the amount of migrant workers' remittances sent to their countries of origin. In 1975, about 11% of the total labour force in West Africa was immigrated, whilst 17.5% was internally migrated. The total external remittances during 1970 to 1974 amounted to 7.4% of the average annual export earnings of the receiving countries.

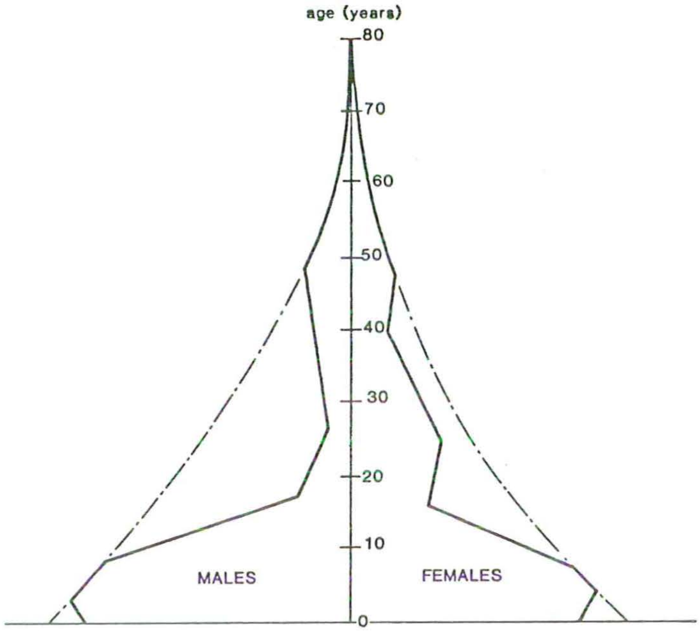



Figure 1. Population structure of a rural area, indicating out-migration (Interrupted line shows a typical population structure for total counts in developing countries).
Source: Baseline survey Ilorin Agricultural Development Project, covering 400.000 inhabitants over 11.775 $km^2$. (Ay, 1981).

Migrants include a relatively large proportion of young adults. Women are more inclined to migrate when they are young or when the distance is short. The overall age differential is larger with the external migrants than with the internal migrants, whilst unmarried persons usually are more mobile than the married ones.
Figure 1 illustrates the rural population structure in the Ilorin area in Nigeria. Ay (1981) states that the same situation was observed in the rural areas of Ivory Coast and that in the rural areas of West Africa, the age group between 15 and 35 years is lagging behind the normal pattern, somewhat more for males than for females, due to emigration to urban centres. This causes a heavy drain on the labour force in the agricultural sector.

There is an increasing tendency of migrants to settle in the host country or area of in-migration. Generally, the external migrants are less educated than the internal migrants. Employment rates are higher amongst the migrants than amongst the non-migrants.
In Ghana and Nigeria most of the migrants find low status occupations. Many are employed as hired labourer in agriculture, as casual labourer in towns, or in mining.
In the agricultural sector, immigration has had a great influence on the development of especially the industrial crops, but also on the introduction of rice production in the Equatorial forest zone. Usually the immigrants were hired for work on commercial plantations and sometimes by residential farmers. If the immigrants were used to rice in their diet, they often started to grow rice using their own traditional methods. In this way migration has contributed to the dispersion of rice growing and in some places rice production has become common now.

## 1.4 Wetland related health aspects

The high incidence of many diseases has a great social and economic impact, especially on the rural population of the inventory area. Several diseases are related to the wetland conditions as they occur naturally in the humid and subhumid tropics of the Equatorial forest and the Guinea savannah zones The development of the water resources may have further negative implications for the public health situation. In the past such developments have led to the spread of diseases into areas which were disease-free, as favourable habitats were created for the vectors of parasitic diseases, such as schistosomiasis (bilharzia), onchocerciasis (riverblindness), dracunculiasis (guinea worm), trypanosomiasis (sleeping sickness) and malaria.
These various wetland related diseases, their distribution, epidemiology, impact and control are discussed in more detail in Annex 3 of this volume.

The major wetland related diseases in West Africa are schistosomiasis and onchocerciasis. They may occur almost everywhere in the inventory area, like guinea worm and malaria, two other wetland related diseases. Trypanosomiasis actually is an animal (cattle)disease, that may also affect man.

To diminish the occurrence and to prevent further spreading of the diseases, the transmission must be halted. Usually this is done through integrated programmes to control and eradicate the breeding sites of the vectors. The measures include:

- chemical control (through water) e.g. larvaecides, molluscides.
- biological control e.g. natural predators
- environmental management, especially water management.

The emphasis in disease control should primarily be on management of the environment including water and should be supported by chemical control (e.g. using abate) at localized sites. Biological control measures are still in an experimental stage.
The environmental and water management vector control measures for the various diseases are discussed in Annex 3. In this annex it is strongly suggested that such measures should be included in the proposed research project WURP-Phase II, because of:

- the very widespread occurrence of the wetland related diseases in West Africa and their specific relationship with water management;
- the considerable social impact, causing economic losses, especially in farming communities.

The distribution and incidence of these diseases however, are not only related to water management for agricultural cropproduction, but also to the quality of community drinkwater supply, sanitation and housing facilities as well as to (re-)settlement and migration aspects.
In the prevention and control of the wetland related diseases, the extent and quality of education and community participation as well as an intersectoral coordination with national and district health authorities, are essential.

# 2 THE ROLE OF RICE IN FOOD SUPPLY

The place of rice amongst the other food crops in the various countries of West Africa is reflected in the trends of production, cultivation area, yields, imports, supply, consumption and the rate of self-sufficiency over the period 1950 to 1980. The data presented in the subsequent paragraphs are derived from the Production and Trade Yearbooks of the F.A.O. As far as possible three or five years averages are used. The 10 countries of the inventory area are compared with 7 countries of the arid area and with the whole of West Africa.
The general trend has been that rice production, in terms of both area and yield, has expanded. This expansion however, has been too little to cover the increase in consumption due to growth of population and change of food preference. This resulted in a decreasing self-sufficiency rate and increasing quantities of rice imports. This situation is observed in all countries of West Africa.

## 2.1 Production and trends of staple food crops

The relative importance of production of the major staple food crops in the various countries of the inventory and of the arid area are indicated in Table 3.

Around 1970, the relative importance of rice production (expressed as a percentage of total food production) in the inventory area (6.8%) was about the same as in the arid area (6.2%).
Between 1970 and 1981 this percentage increased to 9.6% in the inventory area while it decreased to 5.2% in the arid area.
In 1981, the relative importance of rice production was largest in Sierra Leone (75.6%), followed by Liberia (63.2%), Guinea (42.6%), Guinea Bissau (27.7%), and Ivory Coast (26.5%), all belonging to the inventory area. However, between 1970 and 1981 in all these important rice producing countries except Ivory Coast, rice production relatively decreased. On the other hand, relative importance of rice production increased in most of the countries where rice production was relatively small, except in the arid area countries Gambia, Mali, Senegal and Upper Volta.

Table 3. Importance of rice production in relation to other foodcrops (x 1000 tons)

| Country | Maize | | Millet | | Sorghum | | Tubers*) | | Pulses | | Groundnut | | Rice | | Total | | % Rice | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | '69/71 | '81 | '69/71 | '81 | '69/71 | '81 | 69/71 | '81 | '69/71 | '81 | '69/71 | '81 | '69/71 | '81 | '69/71 | '81 | '69/71 | '81 |
| Inventory area | | | | | | | | | | | | | | | | | | |
| 1. Benin | 201 | 349 | 6 | 11 | 52 | 80 | 379 | 600 | 32 | 54 | 47 | 60 | 4 | 16 | 721 | 1170 | 0.6 | 1.4 |
| 2. Cameroon | 355 | 500 | 343 | 400 | - | - | 562 | 827 | 71 | 115 | 206 | 120 | 13 | 55 | 1550 | 2017 | 0.8 | 2.7 |
| 3. Ghana | 417 | 420 | 120 | 73 | 147 | 142 | 1224 | 1117 | 13 | 11 | 88 | 90 | 55 | 79 | 2064 | 1932 | 2.7 | 4.1 |
| 4. Guinea | 68 | 63 | - | - | 8 | 5 | 216 | 261 | 36 | 32 | 74 | 83 | 364 | 330 | 766 | 774 | 47.5 | 42.6 |
| 5. Guinea Bissau | 2 | 4 | 6 | 6 | 3 | 5 | 12 | 13 | 2 | 2 | 36 | 30 | 30 | 23 | 91 | 83 | 33.0 | 27.7 |
| 6. Ivory Coast | 257 | 300 | 31 | 48 | 14 | 35 | 764 | 1077 | 7 | 8 | 42 | 54 | 335 | 550 | 1450 | 2072 | 23.1 | 26.5 |
| 7. Liberia | - | - | - | - | - | - | 101 | 120 | 2 | 3 | 2 | 3 | 184 | 216 | 289 | 342 | 63.7 | 63.2 |
| 8. Nigeria | 1215 | 1580 | 2792 | 3230 | 3632 | 3835 | 8338 | 9592 | 849 | 903 | 1660 | 580 | 352 | 1241 | 18838 | 20961 | 1.9 | 5.9 |
| 9. Sierra Leone | 10 | 14 | 6 | 9 | 6 | 11 | 39 | 43 | 27 | 32 | 20 | 20 | 474 | 400 | 582 | 529 | 81.4 | 75.6 |
| 10. Togo | 160 | 137 | 121 | 107 | - | - | 292 | 334 | 22 | 21 | 20 | 35 | 18 | 21 | 633 | 655 | 2.8 | 3.2 |
| Sub-total | 2685 | 3367 | 3425 | 3884 | 3862 | 4113 | 11927 | 13984 | 1061 | 1181 | 2195 | 1075 | 1829 | 2931 | 26984 | 30535 | 6.8 | 9.6 |
| Arid area | | | | | | | | | | | | | | | | | | |
| 11. Chad | 12 | 15 | 615 | 580 | - | - | 101 | 132 | 56 | 62 | 95 | 110 | 42 | 47 | 921 | 946 | 4.6 | 5.0 |
| 12. Gambia | 4 | 13 | 40 | 38 | - | - | 3 | 2 | 3 | 3 | 129 | 130 | 39 | 33 | 218 | 219 | 17.9 | 15.1 |
| 13. Mali | 67 | 80 | 784 | 930 | - | - | 27 | 39 | 33 | 36 | 144 | 190 | 161 | 142 | 1216 | 1417 | 13.2 | 10.0 |
| 14. Mauretania | 4 | 6 | 81 | 67 | - | - | 2 | 3 | 20 | 26 | 2 | 4 | 1 | 6 | 110 | 112 | 0.9 | 5.4 |
| 15. Niger | 2 | 9 | 974 | 1117 | 262 | 273 | 63 | 85 | 115 | 280 | 223 | 100 | 34 | 38 | 1673 | 1902 | 2.0 | 2.0 |
| 16. Senegal | 42 | 55 | 539 | 750 | - | - | 58 | 12 | 22 | 26 | 794 | 900 | 118 | 120 | 1573 | 1863 | 7.5 | 6.4 |
| 17. Upper Volta | 60 | 100 | 352 | 400 | 528 | 750 | 34 | 40 | 153 | 175 | 68 | 77 | 35 | 29 | 1230 | 1571 | 2.8 | 1.8 |
| Sub-total | 191 | 278 | 3385 | 3882 | 790 | 1023 | 280 | 313 | 492 | 608 | 1455 | 1511 | 430 | 415 | 6941 | 8030 | 6.2 | 5.2 |
| Total W-Africa | 2876 | 3645 | 6810 | 7766 | 4652 | 5136 | 12215 | 14297 | 1463 | 1789 | 3650 | 2586 | 2259 | 3346 | 33925 | 38565 | 6.7 | 8.7 |

*) dry tubers (= 1/3 of fresh tubers), including cassava, yam, sweet potato and taro

## 2.2 Trends in rice production

The level of rice production in the various countries in 1950, 1963, 1970 and 1980 and the relative change between 1950 and 1980 are presented in Table 4. The area of rice production is presented in Table 5, whilst the yield levels of rice in kg per ha obtained in these countries in 1950, 1963, 1970 and 1981 are presented in Table 6.

### 2.2.1 Total production

Table 4 shows that between 1950 and 1980 rice production in West Africa increased with an average of 130%, which is slightly more than the population increase of 109% over the same period, (see Paragraph 1.2).

Table 4. Rice production 1950 - 1980 (x 1000 tons)

| | 1950[1)] | 1963[2)] | 1970[3)] | 1980 | % increase 1950-1980 |
|---|---|---|---|---|---|
| Inventory area | | | | | |
| 1. Benin | 0.4 | 1 | 4 | 16 | 3900 |
| 2. Cameroon | 5 | 10 | 13 | 55 | 1000 |
| 3. Ghana | 23 | 35 | 55 | 62 | 170 |
| 4. Guinea | 208 | 318 | 364 | 350 | 68 |
| 5. Guinea Bissau | 100 | 126 | 30 | 23 | - 77 |
| 6. Ivory Coast | 104 | 220 | 335 | 511 | 391 |
| 7. Liberia | 178 | 161 | 184 | 243 | 37 |
| 8. Nigeria | 250 | 348 | 352 | 1090 | 336 |
| 9. Sierra Leone | 274 | 336 | 474 | 513 | 87 |
| 10. Togo | 7 | 19 | 18 | 24 | 243 |
| Sub-total | 1149.4 | 1574 | 1829 | 2887 | 151 |
| Arid area | | | | | |
| 11. Chad | 12 | 27 | 42 | 45 | 275 |
| 12. Gambia | 20 | 33 | 39 | 34 | 70 |
| 13. Mali | 148 | 173 | 161 | 125 | - 16 |
| 14. Mauretania | - | - | 1 | 4 | - |
| 15. Niger | 3 | 11 | 34 | 32 | 967 |
| 16. Senegal | 52 | 102 | 118 | 59 | 13 |
| 17. Upper Volta | 11 | 34 | 35 | 29 | 164 |
| Sub-total | 246 | 380 | 430 | 328 | 33 |
| Total West Africa | 1395.4 | 1954 | 2259 | 3215 | 130 |

1) average of 5 years (1948/53)

2) average of 5 years (1961/65)

3) average of 3 years (1969/71)

Rice production increase was highest in Benin, Cameroon and Niger. Rice production decreased in Guinea Bissau and Mali. In 1980, rice production was highest in Nigeria (over a million tons), followed by Sierra Leone and Ivory Coast (over 500 000 tons) and Guinea and Liberia (over 200 000 tons). In the arid area only Mali produced more than 100 000 tons.

### 2.2.2 Cultivated area

Table 5 shows that between 1950 and 1981, the rice area in West Africa increased by 56%, in the inventory area by 58% and in the arid area by 46%. During this period, the rice area increased almost at the same rate as the rice yield (54%) as is indicated in Paragraph 2.2.3. In 1981 the largest rice areas were found in Nigeria (600 000 ha), followed by Ivory Coast, Sierra Leone, Guinea (over 300 000 ha) and Mali (over 150 000 ha). The relative distribution of rice areas is shown on Map 5 of Volume IV.

Table 5. Rice cultivated area (x 1000 ha)

| | 1950[1)] | 1963[2)] | 1970[3)] | 1981 |
|---|---|---|---|---|
| Inventory area | | | | |
| 1. Benin | 2 | 2 | 3 | 12 |
| 2. Cameroon | 6 | 11 | 16 | 23 |
| 3. Ghana | 20 | 34 | 55 | 83 |
| 4. Guinea | 340 | 258 | 411 | 380 |
| 5. Guinea Bissau | 73 | 67 | 30 | 37 |
| 6. Ivory Coast | 202 | 249 | 286 | 475 |
| 7. Liberia | 261 | 214 | 154 | 180 |
| 8. Nigeria | 171 | 220 | 272 | 600 |
| 9. Sierra Leone | 316 | 273 | 331 | 400 |
| 10. Togo | 11 | 23 | 25 | 20 |
| Sub-total | 1402 | 1351 | 1583 | 2210 |
| Arid area | | | | |
| 11. Chad | 10 | 25 | 44 | 46 |
| 12. Gambia | 11 | 26 | 28 | 40 |
| 13. Mali | 182 | 178 | 158 | 172 |
| 14. Mauretania | ? | ? | 1 | 2 |
| 15. Niger | 4 | 9 | 16 | 23 |
| 16. Senegal | 57 | 78 | 91 | 80 |
| 17. Upper Volta | 12 | 47 | 40 | 40 |
| Sub-total | 276 | 363 | 378 | 403 |
| Total West Africa | 1678 | 1714 | 1961 | 2613 |

1) average of 5 years (1948/53)

2) average of 5 years (1961/65)

3) average of 3 years (1969/71)

### 2.2.3 Yields

Table 6 shows that between 1950 and 1981, the average rice yield in West Africa increased by only 54%, in the inventory area by 62% and in the arid area by 16%. The present average rice yield (1281 kg/ha) is still very low.

In 1981, rice yields varied from 622 to 2857 kg/ha. Countries having low yields (less than 1000 kg/ha) were Guinea Bissau, Upper Volta, Mali, Gambia, Guinea and Ghana. Countries having high yields (over 2000 kg/ha) were Mauretania, Cameroon and Nigeria.

However, yields vary strongly: in 1970 the yields in Cameroon (844 kg/ha) and Mauretania (1008 kg/ha) were low, while the yield in Niger (2090 kg/ha) was relatively high.

Table 6. Rice yields (kg/ha)

| | 1950 1) | 1963 2) | 1970 3) | 1981 |
|---|---|---|---|---|
| Inventory area | | | | |
| 1. Benin | 190 | 450 | 1372 | 1345 |
| 2. Cameroon | 880 | 930 | 844 | 2391 |
| 3. Ghana | 1150 | 1030 | 1000 | 952 |
| 4. Guinea | 610 | 1230 | 886 | 868 |
| 5. Guinea Bissau | 1360 | 1870 | 994 | 622 |
| 6. Ivory Coast | 510 | 890 | 1168 | 1158 |
| 7. Liberia | 680 | 75' | 1194 | 1200 |
| 8. Nigeria | 1460 | 1580 | 1293 | 2068 |
| 9. Sierra Leone | 870 | 1230 | 1431 | 1000 |
| 10. Togo | 680 | 810 | 709 | 1050 |
| Sub-total | 820 | 1165 | 1155 | 1326 |
| Arid area | | | | |
| 11. Chad | 1180 | 1100 | 963 | 1022 |
| 12. Gambia | 1880 | 1280 | 1414 | 825 |
| 13. Mali | 820 | 970 | 1017 | 823 |
| 14. Mauretania | - | - | 1008 | 2857 |
| 15. Niger | 660 | 1190 | 2090 | 1665 |
| 16. Senegal | 900 | 1320 | 1293 | 1500 |
| 17. Upper Volta | 870 | 710 | 869 | 725 |
| Sub-total | 891 | 1047 | 1138 | 1030 |
| Total West Africa | 832 | 1140 | 1152 | 1281 |

1) average of 5 years (1948/53)

2) average of 5 years (1961/65)

3) average of 3 years (1969/71)

Figure 2 illustrates that, while cereal yields in Asia and Latin America have increased since 1965, those of Africa have remained stagnant and low.

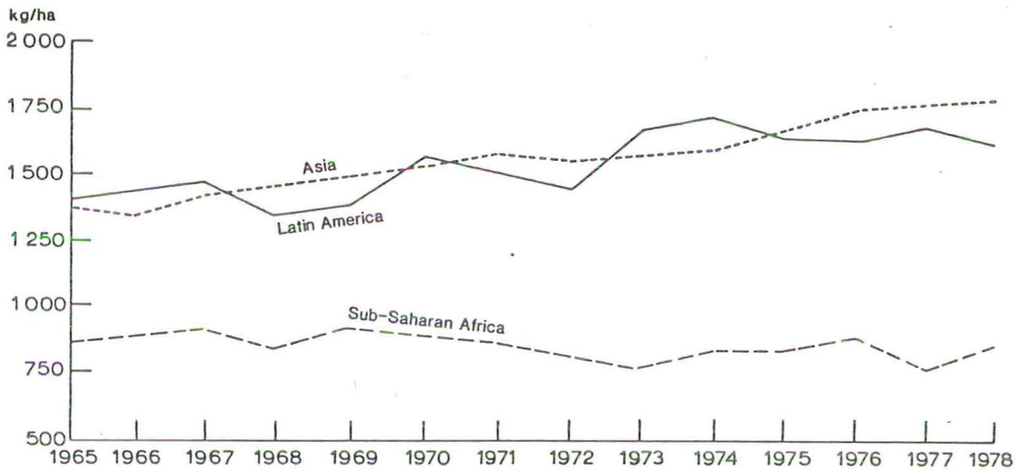



Figure 2. Trends in cereal yields 1965 - 1978.
Source: USDA (1981). Food problems and prospects in Sub-Saharan Africa.

## 2.3 Trends in rice import and self-sufficiency

Quantities of rice imports and their changes during the 3 decades of 1950 to 1980 for the various countries are presented in Table 7. The rate of self-sufficiency in rice production over the same period is given in Table 8.

### 2.3.1 Import

Table 7 shows, that between 1950 and 1980, the rice import in West Africa increased tremendously, from less than 15 thousand to almost 1.4 million tons (an increase of more than 9000 %).
Countries which imported over 100 000 tons in 1980 were Nigeria, Senegal, Ivory Coast and Guinea.

Table 7. Rice imports 1950 - 1980 (x 1000 tons)

| | 1950[1] | 1963 | 1970 | 1980 | % increase |
|---|---|---|---|---|---|
| Inventory area | | | | | |
| 1. Benin | - | 4.3 | 7.6 | 20 | 365[2] |
| 2. Cameroon | 3.2 | 3.5 | 7.8 | 18[3] | 463 |
| 3. Ghana | 3.5 | 26.8 | 53.1 | 34 | 871 |
| 4. Guinea | 1.2 | 20.0 | 11.7 | 128 | 10,500 |
| 5. Guinea Bissau | - | 3.1 | 13.3 | 12 | 287[2] |
| 6. Ivory Coast | - | 25.6 | 78.8 | 230 | 800[2] |
| 7. Liberia | 2.7 | 35.9 | 49.0 | 87 | 3,122 |
| 8. Nigeria | 0.3 | 1.3 | 1.8 | 387 | 130,000 |
| 9. Sierra Leone | 0.2 | 21.2 | 86.9 | 41 | 20,400 |
| 10. Togo | 0.3 | 3.0 | 3.1 | 12 | 3,900 |
| Sub-total | 11.4 | 144.7 | 313.1 | 969 | 8,400 |
| Arid area | | | | | |
| 11. Chad | - | 0.2 | - | 2.4 | 1,100[2] |
| 12. Gambia | 3.3 | 8.2 | 14.2 | 26 | 688 |
| 13. Mali | ? | ? | ? | 18 | - |
| 14. Mauretania | - | - | 15.8 | 50.7 | - |
| 15. Niger | - | 2.1 | - | 27 | 1,186[2] |
| 16. Senegal | - | 100.5 | 119.2 | 275 | 174[2] |
| 17. Upper Volta | - | 3.1 | - | 29 | 835[2] |
| Sub-total | 3.3 | 114.1 | 149.2 | 428.1 | 12,873 |
| Total West Africa | 14,7 | 258,8 | 462.3 | 1397.1 | 9,404 |

1) average of 5 years (1948/53)

2) increase between 1963 and 1980

3) in 1980 Cameroon imported 20,700 tons and exported 2,800 tons

Rising food imports are attributed to many factors such as population growth, lagging domestic production, availability of food aid, overvalued local currency exchange rates which often make imported cereals cheaper than domestic supplies, increasing urbanisation and the accompanying shift of consumer preference from cassava, yams, millet and sorghum to rice and wheat.

### 2.3.2 Self-sufficiency

Table 8 shows, that not one country in West Africa is self-sufficient in rice production. Total rice import in 1980 (about 1.4 million tons) was only slightly less than domestic rice production (1.8 million tons). Self-sufficiency was lowest in Mauretania and Senegal, followed by Benin, Upper Volta, Niger, Gambia and Ghana, where import of rice was equal or higher than domestic production.

Table 8. Rates of self-sufficiency[1]) in rice production 1950 - 1981 (%)

| | 1950[2]) | 1963 | 1970[3]) | 1981 |
|---|---|---|---|---|
| Inventory area | | | | |
| 1. Benin | 100 | 11 | 23 | 31 |
| 2. Cameroon | 46 | 61 | 48 | 59 |
| 3. Ghana | 78 | 42 | 36 | 50 |
| 4. Guinea | 99 | 90 | 95 | 60 |
| 5. Guinea Bissau | 100 | 96 | 55 | 51 |
| 6. Ivory Coast | 100 | 83 | 70 | 55 |
| 7. Liberia | 97 | 71 | 67 | 61 |
| 8. Nigeria | 100 | 99 | 99 | 61 |
| 9. Sierra Leone | 100 | 90 | 75 | 87 |
| 10. Togo | 92 | 78 | 77 | 52 |
| Sub-total | 98 | 86 | 76 | 62 |
| Arid area | | | | |
| 11. Chad | 100 | 99 | 100 | 91 |
| 12. Gambia | 77 | 69 | 60 | 42 |
| 13. Mali | ? | ? | ? | 79 |
| 14. Mauretania | ? | ? | 3 | 4 |
| 15. Niger | 100 | 74 | 100 | 40 |
| 16. Senegal | 100 | 36 | 35 | 11 |
| 17. Upper Volta | 100 | 86 | 100 | 36 |
| Sub-total | 98 | 65 | 61 | 30 |
| Total West Africa | 98 | 81 | 73 | 56 |

1) Self-sufficiency rate is calculted as domestic paddy production less 10% losses and 5% seed, times 65% conversion rate, devided by total rice supply (domestic production plus import).
2) Average of 5 years (1948/52).
3) Average of 3 years (1969/71).

Self-suffuciency in rice was highest (over 80%) for Chad and Sierra Leone. Between 1950 and 1980, the self-sufficiency for West Africa deteriorated from almost 100% to 56%. The situation is worse in the arid area (30%) than in the inventory area (62%).

## 2.4 Trends in rice supply and consumption

The rice supply, comprising domestic production and import, and its changes during the period 1950 to 1980 in the various countries are presented in Table 9, whilst the per capita consumption of rice and its changes are presented in Table 10.

### 2.4.1 Supply

Table 9 shows, that between 1950 and 1980 the rice supply in West Africa increased by over 300%, in the arid area by 338% and in the inventory area by 297%. Only in Guinea Bissau the rice supply decreased. Increases were highest (over 500%) in Benin, Senegal, Ivory Coast, Cameroon, Upper Volta, Nigeria and Togo. Increases were relatively small (less than 200%) in Mali, Sierra Leone, Liberia, and Guinea.

Table 9. Rice supply[1]) 1950 - 1980 (x 1000 tons)

| | 1950[2]) | 1963 | 1970 | 1980 | % increase 1950-1980 |
|---|---|---|---|---|---|
| Inventory area | | | | | |
| 1. Benin | .22 | 4.9 | 9.8 | 28.8 | 13000 |
| 2. Cameroon | 6 | 9.0 | 15 | 48.4 | 707 |
| 3. Ghana | 16.2 | 46.1 | 83.5 | 68.3 | 322 |
| 4. Guinea | 116.1 | 195.7 | 212.8 | 321.4 | 177 |
| 5. Guinea Bissau | 55 | 72.7 | 29.9 | 24.7 | -55 |
| 6. Ivory Coast | 57.5 | 147.2 | 263.9 | 512.3 | 791 |
| 7. Liberia | 101 | 124.9 | 150.7 | 221.3 | 119 |
| 8. Nigeria | 138.4 | 193.6 | 196.3 | 989.2 | 615 |
| 9. Sierra Leone | 151.6 | 206.8 | 348.8 | 324.4 | 114 |
| 10. Togo | 4.2 | 13.5 | 13 | 25.3 | 502 |
| Sub-total | 646.4 | 1014.3 | 1323.6 | 2564.1 | 297 |
| Arid area | | | | | |
| 11. Chad | 6.6 | 15.1 | 23.2 | 27.3 | 314 |
| 12. Gambia | 14.4 | 26.4 | 35.7 | 44.8 | 211 |
| 13. Mali | 82 | 95.6 | 89.0 | 87.1 | 6 |
| 14. Mauretania | - | - | 16.4 | 52.9 | - |
| 15. Niger | 1.7 | 8.2 | 18.8 | 44.7 | 253 |
| 16. Senegal | 28.7 | 156.9 | 184.4 | 307.6 | 972 |
| 17. Upper Volta | 6.1 | 21.9 | 19.3 | 45 | 638 |
| Sub-total | 139.2 | 324.1 | 475.8 | 609.3 | 338 |
| Total West Africa | 785.6 | 1338.4 | 1799.4 | 3173.4 | 304 |

1) Rice supply is domestic rice production (less losses and seed) plus import. Export is negligible

2) Average of 5 years (1948/52)

### 2.4.2 Consumption

Table 10 shows, that rice consumption per capita in West Africa differs widely. In most West African countries, rice consumption is not large. The main staples in the inventory area are cassava, yam or maize, and in the arid area millet or sorghum.

Rice is a staple food only in Liberia and Sierra Leone, while in Gambia it shares the place with millet, in Guinea with cassava, in Ivory Coast with maize and cassava, and in Guinea Bissau with groundnut.
In 1980, rice consumption per capita in Nigeria, Ivory Coast and Togo was roughly 3 times the amount in 1950, in Cameroon and Upper Volta roughly 4 times, in Senegal roughly 5 times, and in Niger and Benin even more.

Table 10. Rice consumption in West Africa 1950 - 1980
(in kg per capita per year)

| | 1950 | 1963 | 1970 | 1980 | % increase 1950-1980 |
|---|---|---|---|---|---|
| Inventory area | | | | | |
| 1. Benin | 0.14 | 2.2 | 3.6 | 8.2 | 6000 |
| 2. Cameroon | 1.5 | 1.8 | 2.2 | 6.1 | 307 |
| 3. Ghana | 3.1 | 6.3 | 9.7 | 5.8 | 86 |
| 4. Guinea | 52.0 | 56.5 | 54.3 | 64.1 | 23 |
| 5. Guinea Bissau | 108.0 | 139.0 | 61.0 | 43.1 | -60 |
| 6. Ivory Coast | 22.0 | 37.5 | 50.0 | 63.8 | 190 |
| 7. Liberia | 117.0 | 120.0 | 112.0 | 112.5 | -4 |
| 8. Nigeria | 4.0 | 3.5 | 3.5 | 12.8 | 220 |
| 9. Sierra Leone | 76.0 | 90.0 | 130.0 | 93.4 | 23 |
| 10. Togo | 3.5 | 8.6 | 6.6 | 9.6 | 174 |
| Sub-total | 11.2 | 12.3 | 14.7 | 21 | 88 |
| Arid area | | | | | |
| 11. Chad | 2.5 | 4.7 | 6.4 | 6.1 | 144 |
| 12. Gambia | 55.0 | 83.0 | 78.0 | 74.3 | 35 |
| 13. Mali | 24.0 | 22.0 | 17.6 | 12.6 | -48 |
| 14. Mauretania | - | - | 13.2 | 32.4 | - |
| 15. Niger | 0.7 | 2.4 | 4.7 | 8.4 | 1100 |
| 16. Senegal | 11.6 | 47.0 | 43.2 | 54.3 | 368 |
| 17. Upper Volta | 1.7 | 4.8 | 3.6 | 6.5 | 282 |
| Sub-total | 8.8 | 16.1 | 19.8 | 19.3 | 119 |
| Total West Africa | 10.7 | 13.0 | 15.8 | 20.6 | 93 |

For the whole of West Africa rice consumption per capita almost doubled between 1950 and 1980. Generally, rice consumption sharply increased in countries where it was very low in 1950, but it remained stable or declined slightly in countries where it was relatively high in 1950 (Liberia, Sierra Leone, Gambia and Guinea).
The sharp increase of rice consumption in some countries is likely due to urbanisation. Rice, being a convenience food, can more easily be traded, stored and prepared than maize, sorghum or millet, (which first have to be ground) or tubers (which cannot be stored for long).

The levelling off of the relatively high rice consumption rates is likely due to the increased competition in towns, but also in villages, of bread made of imported wheat, which does not need further preparation at home.

Mali and Guinea Bissau are exceptions. In Guinea Bissau the decrease of the consumption rate since 1950 is due to political disturbances and the departure of many Portuguese. In Mali, the consumption rate decreased because of the doubling of the population between 1950 and 1980, whilst the production remained almost the same, i.e. 148,000 tons in 1950 and 125,000 ton in 1980. The latter figure is the production in 1980, but should be compared with the 3-years average over 1979 to 1981 of 148,000 tons.

# 3 POLICIES AND PROSPECTS

Worldmarket prices for rice fluctuated considerably and were unprecedentedly high in 1974. The high price and ever increasing imports have led to the goal of self-sufficiency in the West African countries. To attain this goal various measures have been taken. Internationally, 15 West African countries have formed the West African Rice Development Association (WARDA, or in French ADRAO).
Nationally, various forms of subsidies are extended to rice producers and consumers. In the subsequent paragraphs the prospects of self-sufficiency, the marketing and price policies and the possible impact of valley development will be discussed. Generally, the prospect of self-sufficiency is rather bleak, whilst the costs of the various production factors do not enhance rice production in many West African countries, although the physical potential of valley development is large.

## 3.1 Prospects of self-sufficiency

The WARDA (1980) projections of the annual growth rates of population, per capita income and rice consumption, together with the annual income elasticity for rice over the period upto 1990, are presented in Table 11.

For these projections the 1974 to 1978 data have been extrapolated to 1990. Assumptions of the rates of growth of population and annual real per capita income are based on World Bank, WARDA and governmental statistical documents. Estimates of income elasticities of demand are based on studies in West Africa and elsewhere.
On the basis of the projections mentioned in Table 11, WARDA has made projections of the rice demand, the production and the self-sufficiency in 1990, for its member states. They are presented in Table 12.
For the 9 countries Gambia, Ivory Coast, Liberia, Mali, Mauretania, Niger, Senegal, Sierra Leone and Upper Volta, rice production in 1990 is estimated by WARDA on the basis of assumed capacities to further expand rice production in the 1980's.

Table 11. projected annual growth rated of population, per capita income and rice consumption, and income elasticity for rice (1974/78 to 1990).

| | Population growth rate (%) | Income growth rate (%) | Income elasticity | Rice consumption growth rate (%) |
|---|---|---|---|---|
| Inventory area | | | | |
| 1. Benin | 2.0 | 1.0 | 0.7 | 2.7 |
| 2. Cameroon | 2.5[1] | 2.8[2] | 0.8[3] | 4.7 |
| 3. Ghana | 2.7 | 1.0 | 0.6 | 3.3 |
| 4. Guinea | 2.2 | 1.0 | 0.4 | 2.6 |
| 5. Guinea Bissau | 2.2 | 1.0 | 0.4 | 2.6 |
| 6. Ivory Coast | 4.0 | 2.0 | 0.3 | 4.6 |
| 7. Liberia | 3.0 | 1.5 | 0.4 | 3.6 |
| 8. Nigeria | 2.6 | 5.5 | 0.8 | 7.0 |
| 9. Sierra Leone | 2.1 | 1.0 | 0.3 | 2.4 |
| 10. Togo | 2.6 | 2.0 | 0.7 | 4.0 |
| | | | | |
| Arid area | | | | |
| 11. Chad | 2.3[1] | - 0.6[2] | 0.6[4] | 1.9 |
| 12. Gambia | 2.4 | 5.0 | 0.4 | 4.4 |
| 13. Mali | 2.5 | 1.0 | 0.5 | 3.0 |
| 14. Mauretania | 2.6 | 3.0 | 0.6 | 4.4 |
| 15. Niger | 2.8 | 1.0 | 0.6 | 3.4 |
| 16. Senegal | 2.6 | 1.0 | 0.4 | 3.0 |
| 17. Upper Volta | 2.0 | 1.0 | 0.6 | 2.6 |

Source: WARDA Occasional Paper Nr. 1, 1980

[1] Demographic Yearbook 1980. Annual rate of increase 1975-80

[2] World Bank 1980 Atlas. Annual growth rate GNP/capita 1970-1980

[3] Assumed the same as for Nigeria

[4] Assumed the same as for Niger.

For the other 6 countries the production is projected on the assumption that the average annual growth rate achieved during the 14,5 year - period 1960/64 to 1975/78 is maintained during the 1980's.

WARDA (1980) computed a self-sufficiency rate for its member states of 0.68, based on the production and import data in the period 1975 to 1978. As is shown in Table 12, WARDA expects this rate to grow slightly to 0.70 in 1990.

Table 12. Projections of demand, productionm trade position and self-sufficiency rate of rice for 1990 (x 1000 tons)

| | Demand | Production | Trade position | Self-sufficiency rate |
|---|---|---|---|---|
| Inventory area | | | | |
| 1. Benin | 28.8 | 32.1 | -3.3 | 1.12 |
| 2. Cameroon[1)] | 81.4 | 76.3 | 5.1 | .94 |
| 3. Ghana | 134.0 | 75.0 | 59.0 | .64 |
| 4. Guinea | 366.4 | 339.9 | 26.5 | .92 |
| 5. Guinea Bissau | 52.1 | 51.6 | 0.5 | .99 |
| 6. Ivory Coast | 599.7 | 394.0 | 205.7 | .66 |
| 7. Liberia | 299.2 | 224.0 | 75.2 | .75 |
| 8. Nigeria | 1301.4 | 513.8 | 787.6 | .40 |
| 9. Sierra Leone | 496.4 | 541.0 | - 44.6 | 1.09 |
| 10. Togo | 33.9 | 10.7 | 23.2 | .32 |
| Sub-total | 3393.3 | 2258.4 | 1134.9 | .67 |
| Arid area | | | | |
| 11. Chad[1)] | 33.0 | 40.6 | -7.6 | 1.23 |
| 12. Gambia | 78.4 | 50.0 | 28.4 | .64 |
| 13. Mali | 196.7 | 291.0 | - 94.3 | 1.48 |
| 14. Mauretania | 74.2 | 35.0 | 39.2 | .47 |
| 15. Niger | 37.3 | 41.4 | -4.1 | 1.11 |
| 16. Senegal | 400.8 | 211.3 | 189.5 | .53 |
| 17. Upper Volta | 49.7 | 53.7 | -4.0 | 1.08 |
| Sub -total | 870.1 | 723.0 | 147.1 | .83 |
| Total West Africa | 4263.4 | 2981.4 | 1282.0 | .70 |

Source: WARDA Occasional Paper Nr. 1, 1980

1) Non-WARDA members: data derived from Table 11 and production figure of 1980 and trends 1950 - 1980 from Paragraph 2.2.

However, from Table 8 (Paragraph 2.3.2), it can be learned that this would imply a very drastic change in the trend of the past. If the trend of the past (1950 to 1980) continues, then the situation in 1990 will be as is presented in Table 13, showing a substantially lower self-ufficiency rate (0.53) in 1990, then projected by WARDA (0.70).

Table 13. Projections for production, import supply and self-sufficiency in 1990, based on trends of the past (x 1000 tons)

| | | 1950 | 1970 | 1990 |
|---|---|---|---|---|
| Inventory area | production | 635 | 1010.5 | 1600 |
| | import | 11.4 | 313.1 | 1111 |
| | supply | 646.4 | 1323.6 | 2711 |
| | self-sufficiency rate | 0.98 | 0.76 | 0.59 |
| Arid area | production | 135.9 | 237.6 | 410 |
| | import | 3.3 | 149.2 | 665 |
| | supply | 139.2 | 386.8 | 1075 |
| | self-suffciency rate | 0.98 | 0.61 | 0.38 |
| West Africa | production | 770.9 | 1248.1 | 2010 |
| | import | 14.7 | 462.3 | 1776 |
| | supply | 785.6 | 1710.4 | 3786 |
| | self-sufficiency rate | 0.98 | 0.73 | 0.53 |

## 3.2 Rice marketing and price policies

Only about 4% of the world's rice production is traded in the free market. The majority of this amount comes from the United States (23%). Thailand (18%) and China (15%), with smaller contributions from Japan (7%), Burma (7%), Egypt (5%), Italy (5%) and Pakistan (5%) (WARDA, 1975). Thus the world market price is dependent upon production in a few countries and is subject to considerable fluctuation, The latter is demonstrated in Table 14, showing a relatively low world market price during 1970 and an unprecendently high price in 1973/1974.

Table 14. Fluctuations in world market prices of rice (US$ per ton)

| Year | Thai 5% broken f.o.b. Bangkok | Texas no. 2 f.o.b. Houston |
|---|---|---|
| 1970 | 143 | 222 |
| 1973 | 299 | 700 |
| 1974 | 543 | 486 |
| 1976 | 255 | 354 |
| 1981 | 484 | 565 |

With regard to the demand, rice will become increasingly important in most West African countries. It is not only the urban high income consumer who demands rice, but also institutions such as schools, hospitals, military establishments and hotels.
The Governments' policy to promote domestic rice production includes in most cases a subsidy to rice producers, adding to the diversity of rice prices in the various West African countries, as is shown in Table 15.

Table 15. Average producer price 1970 - 1974 in US$ per ton of paddy (= unhusked rice)

| | | | |
|---|---|---|---|
| Benin | 144 | Gambia | 168 |
| Ghana | 310 | Mali | 80 |
| Ivory Coast | 260 | Mauretania | 240 |
| Liberia | 264 | Niger | 140 |
| Nigeria | 480 | Senegal | 166 |
| Sierra Leone | 150 | Upper Volta | 180 |
| Togo | 160 | Arid area | 162 |
| Inventory area | 253 | West Africa | 211 |

(Source: WARDA Rice Statistics Yearbook 1975).

N.B. Producer price in Cameroon in 1975 was $ 130 and in 1977 $ 157 per ton paddy (Baudet, 1981).

Table 15 shows that in 1970 to 1974, the by far lowest farmers' (=producers') price for paddy was paid in Mali (US$ 80/ton), followed by Niger, Benin and Sierra Leone. The average farmers' price in the arid area (US$ 162/ton) was substantially lower than in the inventory area (US$ 253/ton). The highest price was paid in Nigeria (US$ 480/ton) followed by Ghana, Liberia, Ivory Coast and Mauretania.

Only in Mali was the farmers' price substantially below the world market price for rice. To compare the farmers' price for paddy with the world market price for rice, the following calculation is made.
The farmers' price (= paddy price) of US$ 80/ton (as for Mali) is equivalent to a rice price of US$ 123/ton (outturn 65%). Including milling and distribution costs of US$ 85/ton, the wholesale price for rice becomes US$ 208/ton.

During the period 1970 to 1974, the average world market price for Thai white long grain 5% broken f.o.b. Bangkok was US$ 252/ton and for Texas long grain no. 2 f.o.b. Houston was US$ 390/ton (Table 14). Hence, none of the countries of West Africa except Mali, were able to compete with the world market and this situation has remained so. At the national level it appears that importing rice is cheaper than producing domestically.

This is illustrated by the example of the producers' price in Ivory Coast as presented in Annex I. In this annex the producers' price is dealt with in more detail. Between the various rice production techniques in Ivory Coast, the net private profitability (NPP = farmers' profit) ranges from 8.0 to 58.8 FCFA/kg milled rice and the net social profitability (NSP = profitability at national level) from - 44.6 to + 8.5 FCFA/kg milled rice. This implies that the Ivorian government heavily subsidises domestic rice production, which costs are far higher than average world market prices. Nationally domestic rice production is only justified for on-farm and in-village consumption.
Compared with other crops, rice production in Ivory Coast has the highest resource/cost ratio. At the national level it is economically more profitable to produce coconuts, cocoa, pineapple, coffee, palmoil, maize, cotton and groundnuts, as is shown in Annex I.
Compared with Ivory Coast, the situation is better in Benin, Sierra Leone and Togo, about the same in Liberia and worse in Ghana and Nigeria.

## 3.3 Potential of inland valley development

In Volume II, Paragraph 3.4.3, the area of streamflow valleys has been estimated at over 10 million ha (between 4.5 and 10% of the inventory area). These valleys are suited to rice production. At present this potential is little used for rice growing. However, if only 10% of the streamflow valleys be developed up to 1990, assuming a yield of 2 tons paddy per ha and a cropping intensity of 150%, paddy production would increase with 3 million tons to about 6 millions tons of paddy, equivalent to about 3.5 million tons of rice. In this case the self-sufficiency rate in West Africa would become about 0.78 in 1990. This is much more than the projection shown in Table 13, (0.53) and higher than the WARDA projection in Table 12, (0.70).

The above example suggests that the development of streamflow valleys would have a considerable impact on rice production in West Africa. However, the development of such large areas of scattered valleys is an ambitious and tremendous exercise.
There are many constraints, not only in terms of financing, insufficient technical manpower or inadequate extension services, but also at the farm level. These farming system constraints are discussed in Paragraph 4.2. If the national governments wish to promote rice production in inland valleys, they have to enforce the capacity and skills of the extension services, including the establishement of local research facilities on rice-based smallholder farming systems in the wetlands.

# 4 UTILISATION OF INLAND VALLEYS

## 4.1 General

The Guinea and Equatorial zones have a natural vegetation cover related to the subhumid and humid tropical climates respectively. The high rainfall savannah of the Guinea zone consists of a deciduous to evergreen tree park landscape interspersed with tracts of grassland. The Equatorial zone has an evergreen forest, which originally was very dense. Due to human interference the climax vegetation in both zones has largely been lost and it has given way to a sub-climax (or derived) vegetation and cultivated land.
Generally, scarcity of land is not (yet) a restriction to crop production. Although local variations exist, valley land if not included in development schemes, is generally in use-ownership of the community. The right of occupation by individuals is usually decided upon by the community and its leaders.

Accurate data on the area and production of rice on the hydromorphic soils of inland valleys (streamflow and partly also overflow valleys) are not available. In West Africa rice is mainly grown:

- on the well drained uplands by smallholders in areas where rainfall exceeds roughly 1300 mm per year (most of the inventory area).
- under irrigation in vast areas of hydromorphic soils (riverplains, deltas and swamps) in schemes adopting high levels of technology.

National statistics showing rice production in quantity and area, if available, are usually not specific on valley rice production. It is therefore not possible to indicate the area of stream flow valleys used for rice cultivation and the yields.

Nevertheless, some general remarks can be made.

a. Land including valley land, is hardly ever unused. If not cultivated, valley land is used for livestock production (especially in the more arid areas) or it provides collected food, or material for industrial activities such as housebuilding, basket work etc. Often, inland valleys or parts thereof (mostly the peripheries) are used for growing some vegetables or staples (including rice) not much different from the crops also grown on the upper parts of the catena.

In the eastern part of the inventory area (from Ivory Coast to Cameroon), cash crops such as cocoa and oilpalm are often grown in a traditional way in the valleys or along their periphery.

b. In the western part of West Africa rice has been grown by smallholders in the inland valleys for longtimes especially in the Guinea savannah zone, where rice has been an important staple crop. According to Mohr (1969) this area comprises the upper catchments of the Casamance and Gambia rivers, south Mali - Upper Volta, north and west Ivory Coast (Korhogo and Man), Guinea, north Liberia - Sierra Leone and Guinea Bissau. In this region valley rice cultivation is still wide- spread. East of Ivory Coast rice is not a main staple, but it used to be grown in the valleys of the Oti and Mono basins in Togo, the Alibory basin in north Benin and around the population centres of north Nigeria i.e. Kano, Zaria and Bida. In the past, rice production has declined here, but it has been re-encouraged by the governments, very recently.

In the climatically less suitable Equatorial forest zone (see Volume II, Paragraph 2), rice production is of rather recent date and is not widely practised. It has usually been introduced by immigrants. In this way rice cultivation started in central, southwest and southeast Ivory Coast, in southwest and southeast Ghana and southeast Nigeria and west Cameroon. For example, settlers and migrant labourers started the cultivation of rice in the valleys of Cross River near Abakaliki in southeast Nigeria as recently as the 1940's. At present, rice production in this area has developed into a flourishing industry, despite of the (almost sacral) preference for yam by the original people.

c. Governments encourage rice production. During World War II this was done to raise food for the armies. More recently governments are aiming at self-sufficiency. Although rice development programmes are more often found in non traditional farming systems on the hydromorphic soils of the large tracks of wetlands, they include smallholding farmers in the streamflow and overflow valleys.

## 4.2 Farming systems

A farming (or farm or agricultural) system has been defined by Okigbo (1979) as consisting of an enterprise or business in which sets of inputs or resources are uniquely orchestrated by the farmer in such a way as to satisfy needs and to achieve desired objectives in a given environmental setting. In West Africa, the farming system comprises the activity of one or more individuals, usually a family unit, with some or all members of the family participating for part or most of the time in farm work. A cropping system refers to the kinds, combinations and/or sequences of activities in time and space, in addition to the practices and technologies, used in the production of the crop(s) in a specified area to satisfy the needs of growers and users. Consequently, Okigbo (1979) considers cropping systems as equivalent to or components of farming systems. Farming systems in West Africa are described in Annex II. In smallholder farming, differences in systems are basically determined by the need of farmers to avoid risks or, if that is not possible, to spread risks. These risks arise from the constraints encountered by the farmers in their efforts to produce. The constraints may be of physical, biological and socio-economic nature. For the inventory area they are:

a. Physical constraints (see also Volume II).
   - Unreliability of rainfall and unpredictability of periods of drought and floods.
   - Cloudiness and reduced photosynthetic efficiency.
   - Poor soil conditions, because of intensive weathering (due to high temperature and humidity), low inherent fertility (low cation exchange capacity, low organic matter content, nutrient deficiencies, high P-fixation, etc), acidity, toxicities and low water storage capacities.

b. Biological constraints.
   - Unimproved crops (and livestock), usually associated with low yield potentials.
   - High incidence of crop (and livestock) diseases and pests and abundancy of weeds, due to unfavourable environment.

- Deterrence of human diseases, such as the wetland related river blindness, bilharzia, guinea worm and malaria.
- The impossibility to use animal traction due to the prevalence of the tse-tse fly, in some areas, spreading sleeping sickness.
- Degrading effects of changes in the environment (erosion and loss of fertility).

c. Socio-economic constraints.

- Land fragmentation related to increasing population pressure on land.
- Poor infrastructure in terms of road and transport systems, marketing and milling facilities, resulting in high transport costs and low farmers' prices.
- Unavailability at the time required and/or the high costs of modern inputs, such as improved seeds, fertilizer, insecticides and machinery (both animal and mechanical traction). Repair facilities for the latter are often inadequate.
- High cost and low productivity of labour.
- Lack of credit, poor pricing structures and low incomes.
- Lack of research and package approach to technology development and use.
- Little effective technology transfer through extension services, often resulting in inappropriate inputs.

Within a given environment the farmer has adapted his farming system to the constraints encountered by him. Changes in these constraints will lead to the farmer altering his farming system.
However, this is a very slow process, due to the very little flexibility such systems usually has. This is mainly because of the inherently meagre financial resources, but often also because of the economically (and socially) inadequanteness of new techniques and inputs offered to the farmer.

## 4.3 Rice cultivation on valley land

### 4.3.1 Traditional husbandry

The indigenous rice species *Oryza glabberima* (together with its close relative *O. breviligulata*) has been grown for many centuries in the Gambia to Sierra Leone region, the highlands of Guinea - Liberia and in the inland delta of the Niger river (Mali).

This culture was very primitive and stagnant. Recent efforts to expand rice production have concentrated on *O. sativa*, introduced from Asia. According to Buddenhagen (1978) the latter is grown under widely differing ecological conditions and on all kinds of soils, though some are frequently, others are rarely used.
The bulk of rice is produced either on upland soils or on hydromorphic soils of large floodplains, deltas and swamps, irrigated or not.
Rice production in the smaller inland valleys has received attention by research workers and development agencies during the last 20 to 40 years. Here, production has increased substantially (mainly because of areal expansion), although this increment is hardly quantifiable.

According to Chabrolin (1977) bush clearing and tillage of the wet soil by hand hoeing or shallow ploughing with draught animals, is followed by broadcasting of the seed at a rate of 70 to 100 kg/ha. Sometimes transplanting is done, but not in rows. During the seedling stage the rice is usually competing with many weeds. Weeding may be done, once or twice by hand, but often not at all, because it is a long and tiring job or rice fields are too far from the villages. Fertilizers are very little applied, if at all. Quite often the fields are left untended when they become flooded until harvest time. Yields under these conditions are very low and range from 0.5 to 1.0 ton per ha on the poor, coarse textured soils overlying sedimentary sandstones and basement complex granites. On the finer textured and more fertile soils overlying sedimentary claystones and shales and basement complex schists and gneisses, yields range from 1.0 to 2.0 ton per ha. In good years yields may reach up to 3 ton/ha.
Typical for the traditional systems of rice cultivation is the wide choice of varieties available to the farmers. Varieties of different length of growing period, but also of different stalk length may be grown in one farmer's field, thus spreading the risks of damage by flooding and/or drought (wetland and upland varieties).
Under 'improved' traditional management the most significant improvements are better water control and distribution, adapted varieties, pest and disease control and fertilizer application. If mineral fertilizers are used, the effect may be very disappointing on coarse textured soils.

The fertilizers are easily leached out of reach of the plant roots and yields tend to remain low, i.w. in the order of 1.0 to 2.0 ton/ha. the effect of the fertilizer on the fine textured soils is relatively high and yields may be in the order of 3 to 5 ton/ha, if appropriate varieties are used.

4.3.2 Scope of rice production improvement

Moormann and Veldkamp (1978) conclude that considerable land areas in West Africa are suitable for rice cultivation to a varying degree from the point of view of soil and hydrological conditions. However, few soils of the uplands in the Guinea savannah and Equatorial forest zones lend themselves to a system of permanent cropping. the prospects for the development of such cropping systems are considerable better on the hydromorphic soils, of which over 10 million ha are found in the small inland (or streamflow) valleys in West Africa. Rice is the only major annual food crop (with the partial exception of avoids) which thrives on land which is water saturated or even inundated during part of all of the growing cycle of rice.

Economically, the main incentives to improve and to increase rice production in West Africa are:

- the rapid increase of rice demand in the low rice consuming countries;
- the decreasing self-sufficiency rate in all West African countries except Cameroon;
- the large potential to increase rice yields (which are much lower than in Asia or Latin America);
- the large area of small inland valleys (10 to 20 million ha) suitable to rice production which are a virtually untapped source upto now;
- the Governmental objective to attain self-sufficiency in rice, thereby providing large amounts of subsidies in most West African countries (except Mali and Sierra Leone) to promote domestic rice production.

Provided that economically (and socially) adequate techniques and inputs are timely made available, the farmers will respond to the incentives metioned above. Because of the meagre financial resources it will be a slow process (Paragraph 4.2).

The logical sequence of development will be from the simple, non-improved utilization of unland valleys with sufficient additional water over and above the water provided by rain, towards the improvement of such valleys by levelling, bund and in a later stage, controlled irrigation. This development sequence can already be seen at present in various parts of West Africa. While most small inland valleys and other hydromorphic areas are still undeveloped with regard to land and water management, there is a definite trend towards their better utilization. Many of these lands are now continuously in use for rice (and other crops) without fallowing.

Winch and Kivunja (1978) concluded that the ability of farmers to respond to the incentives mentioned above and to increase the supply to the market, will depend primarily upon the:
- quantity of labour, suitable land and capital under their control;
- existing production techniques;
- existing production constraints;
- access to additional resources and techniques;
- relative profitability of rice as compared to crops in their farming system;
- possibility and cost of reducing present rice production constriaints;
- perceived risk associated with new planting material and techniques.

An additional constraint related specificially to the development of the streamflow valleys is their scattered and very diverse pattern. Resulting in relatively small rice areas with numerous different and complex farming systems.

# 5 RESEARCH AND DEVELOPMENT

## 5.1 Present research

### 5.1.1 Programmes

Rice research in West Africa began in the 1920's with Moor Plantation in Ibadan, Nigeria.
The oldest rice research station in West Africa is Rokupr in Sierra Leone which started in 1934. The rice research station at Badaggi in Nigeria was established in 1953. Rice research was conducted at Kumasi and Kpong in Ghana, at Harbel and later at Suakoko in Liberia and at Spu in Gambia.
Rice research in West Africa benefitted from the findings by the International Rice Research Institute (IRRI) in the Philippines, the International Institute of Tropical Agriculture (IITA) established at Ibadan, Nigeria in 1967, and the West Africa Rice Development Association (WARDA) established at Monrovia, Liberia, in 1971.

The Rice Improvement Programme of IITA has close cooperation with IRRI, WARDA and IRAT (the research institute on tropical agriculture in francophone African countries) and with the national rice improvement programmes of Nigeria, Sierra Leone and Liberia.
The major objective of IITA's Rice Improvement Programme is to develop varieties adapted to the major African rice ecosystems, with stable and high yields and adequate quality. The specific crop properties differ with the constraints in each eco-system. For wetland irrigated rice, resistance to fungi (which become damaging under unbalanced nutrition), resistance to high iron concentration levels and resistance to unbalanced Fe, Mn, K and P levels, are all factors influencing rice breeding efforts. Modern rice varieties need to be high-yielding, fertilizer responsive, improved plant types resistant to diseases and insects, tolerant to soil toxicities and to have acceptable grain quality (Vermani et al., 1978). Presently, IITA within its Farming Systems Programme (F.S.P.) is establishing an on-farm adaptive research (OFAR) network. A major objective of the OFAR is to test the improved soil and crop management technologies on farmers' field through a network involving IITA, national research and training institutions, and World Bank and EC supported national agricultural development projects (ADPs).

WARDA was established to assist the 15 member countries (Benin, Gambia, Ghana, Guinea, Guinea Bissau, Ivory Coast, Liberia, Mali, Mauretania, Niger, Nigeria, Senegal, Sierra Leone, Togo and Upper Volta) to attain self-sufficiency in rice (Will, 1978).
Rice research at Rokupr in Sierra Leone showed that a major factor depressing rice yield is weed infestation. Weed control trials have centred around the screening of herbicides since hand weeding is time consuming and costly (Jones et al., 1978).
At the national level, important rice research is being done by the National Agricultural Food Production Programme (NAFPP) in Nigeria and the Coordinated Agro-economic Trials (CAT) programme in Sierra Leone.

### 5.1.1 Results

Some 20 years ago, foreign advisers were optimistic about transferring the Green Revolution technology to Africa. Through this, African states could make use of high yielding food grain varieties, developed in international agricultural research centres in Mexico, the Philippines and other parts of the world. After two decades of experimentation the results are disappointing. Because the constraints were considered to be mainly of physical and technical nature, improved (highly yielding) varieties and (often high input) technologies have been developed by research institutions in West Africa. However, Eicher (1982) concludes that African farming systems are extremely complex and that the development of suitable packages requires location specific research by multidisciplinary research teams, which are supported by strong national research programmes on the staple foods of each country, to make the results socially and economically acceptable.

Present, ongoing research in Nigeria (NAFPP) and Sierra Leone (CAT) has provided important information, which may be relevant to all countries in West Africa, intending to conduct similar projects:

a On-farm trials are essential to test the adequacy of research findings and to identify economically viable packages of practices.
  The results should enable governments to decide whether or not to launch accelerated production campaigns, based on available knowledge and expertise.

b On-farm trials provide researchers with feed back to determine their research priorities. This is probably one of the most valuable aspects of the on-farm testing and promotion conducted to date. These trials effectively link researchers, extension workers and farmers.

c Progressive farmers are provided opportunities to test on their farms the recommended cultural practices developed at research stations. In turn they themselves serve as agents of change in disseminating field-proven cultural practices to other farmers.

d To assure the success of farm trials at many sites, there is a need for good planning, organizational and budget support, and above all, political support and commitment.

e On-farm testing research should be developed, financed and controlled by a research organization and not be dependent upon multi-organizational agreements and committees.

f The degree of success in obtaining accurate results depends upon the agricultural extension workers being well-trained and dedicated, and upon close supervision by the state and national staff. In addition, extension workers must be able to devote full attention to the project. As was experienced, most extension workers were not assigned on a fulltime basis and most were responsible for many projects at the same time. Thus, trials were often poorly supervised.

g Intensive crop-oriented training courses are a necessary component of on-farm trials. They must include some theory as well as practical details on how to conduct trials and to record data.

With these provisions, a successful programme becomes a feasible proposition. This will result in higher national rice production and higher yields per ha. (Perez and Mahapatra, 1978).

## 5.2 Development costs and economic returns

Pearson e.a. (1981) investigated the capital investments for developments involving land clearing and irrigation and the rates at which these developments were subsidized in Ivory Coast. Their findings are shown in Table 16.

Table 16. Development costs for irrigation and clearing in Ivory Coast

| Land investment | Initial cost (FCFA/ha) | Total market cost per crop (FCFA/ha) | Subsidy per crop (FCFA/ha) | Subsidy per crop (FCFA/mt paddy) | Subsidy rate (percent of total market cost) |
|---|---|---|---|---|---|
| Lowland irrigation, forest zone | 365,000 | 35,800 | 22,645 | 6,470 | 63 |
| Lowland irrigation, forest zone suitable for power tillers | 420,000 | 43,839 | 22,645 | 5,661 | 52 |
| Lowland irrigation, savannah | 365,000 | 42,309 | 26,762 | 7,646 | 63 |
| Pump installation and irrigation network | 1,243,000 | 79,627 | 79,627 | 28,955 | 100 |
| Dams and irrigation network | 1,703,000 | 85,633 | 77,313 | 19,328 | 90 |
| Winch clearing, upland, savannah | 12,744 | 3,785 | 2,804 | 1,558 | 74 |
| Mechanized clearing, upland, savannah | 130,000 | 28,398 | 23,398 | 11,699 | 82 |

Also for Ivory Coast, Pearson e.a. (1981) investigated the costs components of rice production in various production systems. This is shown in Table 17.

Table 17. Production costs of rice in different farming systems in Ivory Coast.

| Production technique | Yield (t/ha) | Labour (Man-days) | Development cost (x1000FCFA/ha) | Inputs ( x1000FCFA/ha) | Extension service (x1000FCFA/ha) | Mechan. cost (x1000FCFA/ha) |
|---|---|---|---|---|---|---|
| Forest zone | | | | | | |
| F1 upland | 1.3 | 120 | 13.5 | 3.9 | 0 | 0 |
| F2 upland | 2.2 | 121 | 18 | 24.7 | 7.8 | 0 |
| F3 lowland | 3.5 | 240 | 365 | 32.7 | 15.7 | 0 |
| F4 lowland | 2.4 | 209 | 365 | 3.3 | 0 | 0 |
| F5 lowland | 4.0 | 202 | 420 | 32.3 | 15.7 | 23.6 |
| F9 irrigated | 2.75 | 34 | 1,243 | 46.9 | 15.7 | 72.0 |
| Savannah zone | | | | | | |
| F10 upland | 0.89 | 85 | 7 | 4.1 | 0 | 0 |
| F11 upland | 1.5 | 97 | 7 | 25.2 | 7.8 | 0 |
| F12 upland | 1.8 | 90 | 12.7 | 25.2 | 7.8 | 7.7 |
| F13 upland | 2.0 | 30 | 130 | 25.2 | 7.8 | 43.1 |
| F15 lowland | 3.5 | 237 | 365 | 33.3 | 15.7 | 0 |
| F16 lowland | 2.4 | 206 | 365 | 3.3 | 0 | 0 |
| F17 irrigated | 4.0 | 247 | 1,703 | 33.3 | 15.7 | 0 |
| F18 irrigated | 2.7 | 211 | 1,703 | 3.3 | 0 | 0 |

Evidently, mechanization both for land development and for rice production increases the farmers' price of rice. Consequently, higher subsidies are required for rice to be competitive.
Djibril (1978) compared the cost of mechanized and manual land clearing in Ivory Coast, Sierra Leone, Gambia and Senegal. He observed that the development costs are as high as US$ 10,000 per ha when land clearing was done using heavy machinery, whilst they are only US$ 1000 per ha, when land clearing was done by the people themselves in community development projects.

The management aspects of smallholders' farms have been studied by Ruthenberg (1980) from samples in Sierra Leone, Liberia and Ivory Coast. Table 18 demonstrates the low return from rice to family income and labour. In Sierra Leone where (upland) rice constituted over 90% of the cropping system, the average family income was US$ 205 and the return to labour only US$ 0.11 per man hour.
In Ivory Coast where (upland) rice constituted only 32% of the cropping system, these values were US$ 1518 and US$ 0.65, respectively.

In the Bida area in Nigeria, Ward (1981) compared the crop budgets of rice grown in an unimproved valley (with traditional farming methods) and in an improved valley (with improved techniques). He found that, because of the improved techniques, the rice yield increased with about 30% to 3.5 ton per ha, the net family income with about 9% to Naira 1314.20 and the return to labour with about 9% to Naira 11.63 per manday.
Obviously the yield of rice has been raised, but the return to family income and labour has not risen proportionally and probably does not sufficiently warrant the added risks of higher imputs in bad years.

From the different examples mentioned above, it may be concluded that improving/developing rice-based smallholder farming systems should be approached very cautiously. The use of machinery should be avoided and capital investments should be kept to the bare minimum. Higher inputs aiming at higher yields are warranted only if the consequent higher risks are financially, economically and socially acceptable to the farmer and if the net family income and the return to labour are substantially increased.

Table 18. Farm management data on rice cultivation in Sierra Leone, Liberia and Ivory Coast

| | Sierra Leone | Liberia | Ivory Coast |
|---|---|---|---|
| Rainfall (mm) | 2500 | 1900 | 1750 |
| Year | 1971-72 | 1972 | 1974-75 |
| Number of samples | 22 | 20 | 30 |
| Persons per household | 8.4 | 7.2 | 6.9 |
| Labour force (ME)[1)] | 5.2 | 2.7 | 3.2 |
| Land claimed (ha) | 25 | 16 | 12.20 |
| Upland rice | 1.74 | 1.34 | 1.74 |
| Swamp rice | - | 0.40 | - |
| Other food crops | 0.16 | 0.68 | 0.40 |
| Sugar-cane | - | 0.12 | - |
| Coffee and cacao | - | 0.20 | 3.30 |
| Total crop area | 1.90 | 2.74 | 5.44 |
| Cropping index (%) | 8 | 17 | 24 |
| Yield (t/ha), rice | 1.23 | 1.12 | 1.74 |
| Yield (t/ha), coffee | - | 0.20 | 0.22 |
| | | | |
| Economic returns | | | |
| ($ per holding) | | | |
| gross return from crops | 220 | 480 | 1580 |
| Purchased inputs | 15 | 12 | 62 |
| Income | 205 | 468 | 1518 |
| | | | |
| Productivity | | | |
| Gross return $/ha total land | 9 | 30 | 130 |
| " " crop land | 116 | 175 | 290 |
| " $/ME | 42 | 178 | 494 |
| Income $/ha crop land | 108 | 171 | 279 |
| Income $/ME | 39 | 173 | 474 |
| Labour input (manhours) | 1919 | 1975 | 2340 |
| Income $ per man hour | 0.11 | 0.24 | 0.65 |
| Manhours per family ME | 369 | 731 | 731 |

1) ME = man equivalent

Note: (1) paddy prices were $ 109.90 in Liberia, $ 94 in Sierra Leone, and $ 254 in Ivory Coast

(2) total agricultural work at 5 hours per day in Liberia, 6 hours per day in Sierra Leone and Ivory Coast.

## 5.3 Research outlook

Rice preferably grows on land which is water saturated or even flooded. This means that the major constraints and potentials of rice cultivation in inland valleys cannot be seen separate from the use and manipulation of water. This, the African farmer basically being a dryland farmer, has been and still is handicapped with regard to the development of wetland rice production.
Wetland rice-based smallholder farming research should be geared appropriate technology, with inland development and crop production (Paragraph 5.2.). This restricts the proposed WURP-Phase II project to the stream-flow valleys where land can be developed and hydrological conditions can be controlled by simple and cheap interventions, by the farmers' community itself.

As mentioned in the Paragraphs 4.2 and 4.3, increasing the output of rice depends on the flexibility farmers having in altering their cropping systems. This flexibility is related to the available resources at farmlevel, the opportunity cost of the resources particularly to labour and the possibility to acquize additional resources and techniques at socially and economically acceptable levels of risk. From the farmers point of view, the relative profitiability of rice will depend upon cash expenditures, the labour requirements for each crop in his cropping system, relative market prices (or value to him for home consumptions) and consequently the new income of each crop.
Concluding is can be said that a research programme to improve and increase rice production through smallholder farming systems, should be orientated not only to the physical and biological constraints, but also to the socio-economic constraints as encountered by the farmers. Improved techniques and methodologies should be geared to their appropriateness and the acceptability by the farmers, in terms of risks, profitability and social preferences. Research should be directed to appropriate technology, developing techniques which fall significantly below the current cost of domestic rice production.
In finding solutions for or in alleviating the constraints, research can contribute considerably to the increase in rice production by small holding farmers and ultimately contribute to the improvement of the precarious food situation in West Africa.

# 6 CONCLUSIONS AND RECOMMENDATIONS

## 6.1 The socio-economic aspects

The average population density in West Africa including the arid area (19 p/$km^2$), is low compared with most other regions in the world. However, it is much higher in the inventory area (47 p/$km^2$) than in the arid area (6 p/$km^2$). Among the countries of the inventory area, the highest population density is found for Nigeria (83 p/$km^2$), followed by Ghana, Sierra Leone and Togo (48 p/$km^2$).
During the period 1950 to 1980, the population of the inventory area has doubled (112% increase), with Ivory Coast having the largest (208%) and Guinea Bissau the smallest (13%) increase. Most of this increase has been effectuated in the big capital and administrative centres, for a large part through migration. This resulted in high total population (urban and rural) densities in large parts of the Equatorial forest zone and in few areas of the Guinea savannah zone of countries with relatively strong economies. In these countries the rural population is about 50 to 75% of the total population and the density is about the same as in the adjacent rural areas. A negative effect of the migration is that it leaves the rural areas with a relatively aged population.

In 1980 the average consumption of rice in West Africa was low (about 20 kg per capita/year), but differences between countries are large.
In the inventory area, rice is a staple food only in Liberia and Sierra Leone (about 100 kg/capita/year). Consumption is substantial in Guinea, Ivory Coast and Guinea Bissau, but very low in Ghana, Cameroon, Benin, Togo and Nigeria (about 10 kg/capita/year). However, rice consumption has sharply increased in countries where it was very low in 1950, while it remained stable or declined slightly in countries where it was relatively high (Liberia, Sierra Leone and Guinea).

Between 1950 and 1980 rice production increased substantially in all countries of the inventory area, except Guinea Bissau. On average, it could keep pace with the population growth.

However, it could not keep place with the consumption increase per capita, so that the self-sufficiency rate of rice production decreased from almost 100% in 1950 to 62% and 30% in 1980, respectively in the inventory area and the arid area. Consequently, rice import has increased tremendously. In 1980 rice import (about 1.4 million tons) was only slightly less than domestic production (1.8 million tons).
The present yields are rather low (1.3 ton/paddy/ha). The largest rice areas are found in Nigeria (600 000 ha), Ivory Coast, Sierra Leone and Guinea (over 300 000 ha) but mainly as upland rice. Rice in West Africa is largely produced by smallholding farmers.

The big shortages and the higher costs of import have led to the general policy of all West African countries to become self-sufficient, not only in rice, but in all food production. This policy is sustained not only by research, agricultural extension and development programs to promote rice production, but in most countries of the inventory area also through subsidies on inputs, output, transport, processing, storage or marketing, or by a levy or quota system on rice import. This policy has saved much foreign currency. However, the negative aspect of the subsidies is that they increase the cost price at the national level, while the levy and quota system increases the consumer price. This is most serious in Nigeria and Ghana, substantial in Ivory Coast and Liberia and least in Benin, Sierra Leone and Togo.

## 6.2 Research needs

Research on rice-based smallholder farming systems in wetlands in West Africa is urgently required, because of:
- the sharp increase in rice demand,
- the continuous decrease in self-sufficiency in rice and in food supply as a whole,
- the high costs of food import,

The research should aim at maximizing the returns to scarce production factors, such as labour (high cost and low productivity) and other inputs.

It is strongly emphasized that this research should be directed to appropriate technology (developing new techniques of rice production which fall significantly below the current cost of domestic rice production), that would significantly increase the rice production by smallholding farmers.

Because of the large area of small inland valleys (over 10 million ha), but presently marginally used, the research is very likely to contribute considerably to improving the precarious food situation in West Africa.

The proposed WURP - Phase II, apart from the land and watermanagement aspects mentioned in Volume II, should include the agro-socio-economic aspects. The latter form the basis for proper research and for the application of the results. Existing farming/cropping systems should be studied thoroughly, interlinking wetland and upland resources, to find solutions for the constraints in smallholder farming systems. The basic knowledge that is to be acquired comprises:

- agronomic quality of the land
- size of the household and number of men, women and children available for farm work;
- degree to which household labour is supplemented with off-farm labour and the wages paid;
- farm size and identification of the crops and livestock composing the farming systems and the relative importance of each in terms of land area, production, home consumption and market sales;
- description of existing production techniques estimating quantities of inputs, cost of purchased inputs, yields and total output and costs and returns for the major crops (enterprises);
- the agricultural calendar and the identification of peak demands for labour;
- major production constraints for principal crops, as viewed by the farmers.

## 6.3 Criteria for benchmark site selection

### 6.3.1 Selection of areas

In selecting proper sites for the proposed WURP - Phase II, a number of agro-socio-economic criteria should be considered. Generally, it can be said that the research results should have a ready applicability to larger areas than the selected sites only.

Therefore such larger areas should be selected first on the basis of the following agro-socio-economic criteria.

a. The population density. Preference should be given to the high rural population density areas.
b. Traditional rice growing. In the selected areas, rice should be a major crop in the farming system both for subsistance and cash, whilst the government policy should be actively favouring rice development.

Based on these two main agro-socio-economic criteria the potential benchmark sites should be located within the following broad areas: (See Map 5 of Volume IV):

- West Central Guinea
- West Sierra Leone
- Southeast Sierra Leone
- West Ivory Coast
- North Ivory Coast
- North Ghana - north Togo
- North Central Nigeria (Zaria - Kaduna)
- Benue trough southeast Nigeria

### 6.3.2 Selection of sites

In harmony with the physical criteria (Volume II) in the above mentioned broad areas, localities should be chosen within which the benchmark sites are to be situated.

The final selection of the benchmark sites should be preceded by a survey (or surveys). The latter will not only cover physical characteristics, but will deal also with the agro-socio-economic aspects and should provide the information on basis of which the research and monitoring programme can be formulated.

This survey, which should be the start of the research project of Phase II, should investigate the following conditions.

- Accessibility to the site;
- Marketing and processing facilities; stability of farm prices;
- Importance of rice within the local farming system and its comparative advantage to other crops;
- Labour and other bottlenecks which could become a hindrance to rice improvement;

- Farmers' interest in improving rice production (techniques);
- Potential conflicts or interferences between agricultural practices of rice production and practices of traditional pastoral farming, in the utilisation of wetlands or water resources;
- Site-specific health problems, such as river blindness, bilharzia, etc;
- Participation of women in rice production, processing and marketing.

The results of these investigations should form the criteria of the selection of the actual sites within the areas mentioned in Paragraph 6.3.1.
Generally, actual sites (1 or 2 valleys) should be selected where the conditions to conduct research are optimal or where effects on the residing people will not be negative. With respect to the health conditions, a disease-free situation seems to be a positive factor in relation to rice production. However, in the past the interference in the existing water regimes has proven to spread river blindness and bilharzia to non-infested areas.
This may lead to the conclusion that preferably sites should be chosen, which have high incidences of these diseases, since the situation can not be worsened, but may be improved somewhat.

The results of the above mentioned surveys should form the basis of the research programme. The research results should be tested continuously in on-farm situations. This approach provides the opportunity to monitor and to evaluate the results in view of their wider applicability, not only within but also outside the selected sites. The latter aspect is one of the main objectives of Phase III the WURP.

REFERENCES

AY, P., 1981. Rural population crisis and research priorities. In draft, IITA-Ibadan, Nigeria.

BAUDET, J.L., 1981. Cameroon: towards self-sufficiency in rice. The Courier no. 66, March-April 1981, p. 75-77.

BERTRAND, R., 1973. Contribution à l'étude hydrologique, pedologique agronomique des sols gris sableux hydromorphes du Casamance (Senegal). L'Agronomie Tropicale 12, p. 1145-1192.

BOUTRAIS, J., 1978. Deux études sur l'élévage en zone tropicale humide. Cameroun, Orstom, Paris.

BUDDENHAGEN, I.W., and PPERSLEY, G.J. (eds.), 1978. Rice in Africa. Academic Press, London, 356 p.

BYERLEE, J. and FATOO, H., 1976. Rural-urban migration in Sierra Leone: Determinants and policy implications. Afr. Rural Ec. Paper no. 13.

CHABROLIN, R., 1977. Rice in West Africa. Chapter 2 in Foodcrops of the lowland tropics, by Leakey, C.L.A. and Wills, J.B., (Editors). Oxford Univ. Press.

DJIBRIL, A.W., 1978. Rice development strategies in Africa. In: Rice in Africa (Buddenhagen and Pearsley). p. 69-74.

DUE, J.M. and KARR, L., 1973. Strategies for increasing rice production in Sierra Leone. Afr. Studies Review. Vol. XVI (1) April.

EICHER, C.K., 1982. Facing up to Africa's food crisis. Foreign Affairs, Fall. p. 151-174.

FAO, Production Yearbook, 1981, Vol. 35.; 1970, Vol. 24.; 15.; 1962, Vol. 16.; 1961, Vol. 15.; 1960, Vol. 14.

FAO, Trade yearbook, 1980, Vol. 34; 1971, Vol. 25,; 1961, Vol 15.

FAO, 1969. Report to the Government of Sierra Leone: Problems related to land use, FAO.

FRESSONS, S., 1978. Public participation on village level irrigation perimeters in the Matam Region of Senegal. OECD. Occasional papers No. 4.

HAAS, A.W., 1974. Diffusion of innovations in Sierra Leone, W. Africa. First report of the introduction and diffusion of a new rice farming method among Koranko farmers in Alikalia, Koinadugu District. A study on human communication. Institute of Cultural and Social Studies, Leiden State University.

IRAT, 1981. Rice research in the ACP countries. The courier no. 66., March/April 1981, p. 65-68.

JONES, M.J, and WILD, A., 1975. Soils of the West-African savanna. Technical Communication No. 55, Commonwealth Bureau of Soils, Harpenden. Commonwealth Agricultural Bureaux, England, 246 p.

JONES, R.A.D., MATIAPATRA, I.C. and RAYMUNDO S.A., 1978. Rice research in Sierra Leone. In: Buddenhagen and Persley. Rice in Africa. Proc. Conf. IITA, March 1977. London Acad. Press, P. 223 - 230.

KASSAM, A.H., 1976. Crops of the West African semi-arid tropics. International Crops Research Institute for the Semi-arid Tropics, Hyderabad, India, 154 p.

KORTENHORST, L.F., 1980. Factors affecting the viability of smallholders' irrigation. ILRI Wageningen, Report no 20.

LANG, (?)., The economics of rainfed rice cultivation in West Africa. The case of the Ivory Coast. Socio-economic studies on rural development, No. 35. p.234.

LAWSON, T.L., JUO, A.S.R. and AY, P., 1982, Methodology for farming systems research. Environmental description and resource evaluation IITA, Ibadan, Nigeria.

MAIGA, I.D., 1979. Organisation paysanne et gestion de périmètre. Le riz en Afrique de l'ouest, perspectives de l'autosuffisance. In: Warda, seminaire sur la gestion de l'eau, Sept. 1979.

MAY-PARKERS, I., 1974. Problems of rice marketing in Sierra Leone. In the Sierra Leone Agricultural J. Vol. 3(1).

MOHR, B., 1969. Die Reiskultur in West Afrika. IFO-Institut für Wirtschaftsforschug, Afrika Studien 44 - Weltforum Verlag, München.

MOORMANN, F.R., PEREZ, A.T. and VELDKAMP, W.J., 1976. Potential of hydromorphic rice cultivation in Nigeria. National Agricultural Food Production Programme (NAFPP) Workshop Paper, 8 p., IITA, Ibadan, Nigeria.

MOORMANN, F.R. and VELDKAMP, W.J., 1978. Land and rice in Africa: Constraints and potentials. In: Buddenhagen and Persley (eds.). Rice in Africa. Proc. Conf, IITA, March 1977. London Acad. Press.

NELSON, N., 1981. African women in the development process. J. Dev. Stud. v. 17(3), p. 152.

ODELL, R.T., DIJKERMAN, J.C., van VUURE, W., MELSTED, S.W., BEAVERS, A.N., SUTTON, P.M., KURTZ, L.T. and MIEDEMA, R., 1974. Characteristics, classification and adaptation of soils in selected areas in Sierra Leone, West Africa. Njala Univ. Coll. Bull. 4, Sierra Leone, 194 p.

OKALI, C., OBENG, D., OJO ATERE, T. and LAWSON, T., 1979. An evaluation of farmer's knowledge and use of hydromorphic toposequence in the Western State of Nigeria. Findings from selected areas in the Ashun River Basin. IITA-Ibadan Nigeria. Discussion paper No. 4/79.

OKALI, C., OBENG, D. and OJO ATERE, T., 1980. The management and use of hydromorphic toposequence in the Ogun River Basin. The case of traditional farmers in the Ojada area of Ogun State. IITA - Discussion paper No. 5/80.

OKIGBO, B.N., 1979. Cropping systems in the humid tropics of West Africa and their improvement. IITA, Ibadan, Nigeria. Paper presented at the IITA Research review 1979.

PEARSON, S.R., STRIJKER, J.D. and HUMPHREYS, C.P. et al. (1981). Rice in West Africa. Stanford Univ. Press, Stanford, 482 p.

PEREZ, A.T. and MAHAPATRA, I.C., 1978. Technology transfer in Nigeria and Sierra Leone. In: Buddenhagen and Persley (eds). Rice in Africa, p. 231-241.

RUTHENBERG, H., 1980. Farming systems in the tropics. Clarendan Press, Oxford, 424 p.

UNITED NATIONS, New York, Demographic yearbook 1979.

USDA, 1981. Food problems and prospects in sub-Saharan Africa.

VALTLEON, A.P., 1979. Evaluation of a rice-farming project in Alikalia, Sierra Leone, W. Africa. Research report. Institute of Cultural and Social Studies, Leiden State University p. 40.

VALLEE, G. and VUONG, H.H., 1978. Floating rice in Mali. In: Buddenhagen and Persley. Rice in Africa, p. 243-248.

VELDKAMP, W.J., 1979. Land evaluation of valleys in a tropical rainfall area - a case study. Thesis Wageningen, The Netherlands, 266 pp.

VERNON, R.D. and BARRY, L., 1979. Essays on the economic anthropology of Liberia and Sierra Leone. Philadelphia Institute for Liberian Studies, 283 pp.

VIRMANI, S.S., OLUFOWOTE, J.O. and ABIFARIN, A.O., 1978. Rice improvement in tropical anglophone Africa. In: Buddenhagen and Persley. Rice in Africa, p 101-116.

WADE, R., 1979. The social response to irrigation: and Indian case study. J. Dev. Stud. 16(1): 3-26, WARD, K., 1981. A profile of rice cultivation within the Bida A.D.P. area. Bida A.D.P. Monitoring and evaluation section - Nigeria.

WARDA, 1975. Rice statistics yearbook 1975. West African Rice Development Association, Monrovia. Liberia.

WARDA/ADRAO, 1979. La politique rizicole en Sierra Leone. Adrao/SD/79/8 Rice Development Strategies.

WARDA, 1980. Prospects on self-sufficiency in rice in W. Africa. Warda, Occasional Paper, No. 1.

WARDA, 1981. Rice development in West Africa. The courier no, 66. March/April 1981, p. 70-72.

WEINTRAUB, L., 1973. Introducing agricultural change: The inland valley swamp rize scheme in Sierra Leone. Unpublished Ph.D. Theses Un of Wisconsin, Madison.

WESTPHAL, E., 1981. L'Agriculture autochtone au Cameroun. Les techniques culturales, les sêquentes de culture, les plantes alimentaires et leur consommation. L.H. Wageningen. Misc. Papers 20. Veenman & Zonen, B.V., Wageningen - The Netherlands.

WHITTAKER, V.A., 1971. The economics of mechanical cultivation of rice lands in Sierra Leone. University Microfilm International, An Harbor, Michigan, USA. Degree date.

WILL, H., 1978. The research programme of the West African Rice Development Association (WARDA). In: Buddenhagen and Persley. Rice in Africa, p. 215-223.

WINCH, F.E. and KIVUNJA, C.D., 1978. Relative importance of rice in tropical Africa and the need to increase the farm level economic data base. In: Buddenhagen and Persley (eds.). Rice in Africa. p. 75-98.

ZACHARIA, K.C. and CONDÉ, J , 1981. Migration in West Africa. Demographic aspects. A joint World Bank - OECD study. Publ. by Oxford Univ. Press. p. 130.

ANNEX I

## THE STRUCTURE OF THE PRODUCERS' PRICE FOR RICE.

An example from Ivory Coast.

Within the group of countries of the inventory area, Ivory Coast is nearest to the average producer price. Therefore, the build-up of the producer price in Ivory Coast is dealt with more extensively here.

In Ivory Coast, government incentives to promote domestic rice production include trade control (restricting rice imports), domestic price support, subsidies on recurrent inputs and investments financed from public funds.
Since 1975, the consumer price was maintained by trade policy at 100 FCFA (approximately US$ 0.37) per kg rice, which resulted in 1976-1977 in a subsidy of 50 FCFA per kg rice as follows:

| | |
|---|---|
| official cost of paddy (rice equivalent) | 114 FCFA |
| estimated cost of rice, delivered at Abidjan | 136-138 FCFA |
| official selling price of rice to wholesalers | 87 FCFA |
| approximate deficit | 49- 51 FCFA |

The estimated cost of rice is based on a purchase price of paddy at state mills of 75 FCFA and a milling outturn of 0.66. The deficit is covered by heavily subsidizing both the milling and the distribution costs.
In addition, also inputs are subsidized, (Table A1). Inputs such as improved seed, fertilizers and insecticides, along with extension services and the maintenance of water distribution systems, are delivered as a package. Mechanization is delivered as a service. Investments for oxen and implements, are subsidized by the government. In return, the farmer is charged a fixed fee for the input package or service.

Table A1. Farm level subsidies on inputs, in FCFA (1975-76)

| | Market costs per ha | Net farm-level subsidy | | | Subsidy rate (%) |
|---|---|---|---|---|---|
| | | per ha | per ton paddy | per ton rice | |
| modern inputs | 37,129-63,119 | 17,745 | 7,094 | 10,748 | 33-40% |
| power tillers | 24,170 | 6,580 | 1,645 | 2,492 | 28% |
| animal traction | 9,165 | 1,885 | 1,047 | 1,586 | 21% |
| tractors and harvesters | 43,600-72,929 | 14,940 | 5,975 | 9,053 | 18-30% |

Another kind of Government policy to provide incentives for domestic paddy production is public financing of land development. According to Pearson e.a. (1981), investment costs in such projects are subsidized at rates ranging between 52 and 100%.

Also according to Pearson e.a. (1981), between the various rice production techniques in Ivory Coast, net private profitability (NPP = farmers' profit) ranges from 8.0 to 58.8 FCFA/kg milled rice, and net social profitability (NSP = profitability on national levels) from -44.6 to 8.5 FCFA.

Private production costs of rice in the Guinea savannah zone are 10 to 20% lower than in the Equatorial forest zone due to significantly lower wages.

Apparently only on-farm and in-village consumption of traditional (upland) rice production (rainfed, manual land preparation, no improved seeds, no fertilizer, no pesticides in the Guinea savannah zone) have a positive NSP.

Compared to other crops, rice production in Ivory Coast has the highest resource - cost ratio:

| | |
|---|---|
| coconuts | 0.4 |
| cocoa and pineapples | 0.45 |
| coffee and oilpalm | 0.5 |
| maize, cotton and groundnuts | 0.8 - 1.0 |
| rice, savannah | 1.5 - 2.5 |
| rice, forest | 2.0 - 2.5 |

At national economic level the commodities with a resource - cost ratio of less than 1.0 are more profitable than the ones with a ratio of more than 1.0.

Moreover, with regard to food supply, preliminary estimates suggest that both cassava and plantain bananas (and not yams) are more efficient than rice in providing calories to substitute for rice import.

Hence, for Ivory Coast, Pearson e.a. (1981) conclude that improved rice production reduces national growth: compared to the price of rice imports, the costs of domestic production are too high, resulting in a waste of resources and in a potential loss of foreign exchange. The failure of the government policy has two main causes: the rice sector cannot compete efficiently with imports and wage rates are relatively too high, in relation to the low population density and the area of unused arable land.

It is concluded that in Ivory Coast domestic rice production is heavily subsidized, rice production costs are far higher than average world market price, and that from the viewpoint of net social profitability, domestic rice production in Ivory Coast is only justified for on-farm and in-village consumption.

ANNEX II

FARMING AND ASSOCIATED CROPPING SYSTEMS IN WEST AFRICA.

A general characterisation based on work by Okigbo, 1979.

A simple model of traditional farming would consist of a concentric pattern of fields on which are practised various methods of fertility maintenance, clearing systems and production systems. The latter comprise varying numbers of crop species, cropping patterns and sequences, according to prevailing practices, customs and needs of the farmer. A general description of characteristics of traditional farming systems in the region is as follows:

a. Farm sizes are small (in southern Nigeria over 80% of the farms are just 2 ha or less). Large scale tree crop plantation or monoculture occur in countries such as Ivory Coast and Cameroon, but smallholder tree crop plantations predominate in Ghana and Nigeria.
b. Farming is predominantly based on human labour and simple tools especially in areas where tse-tse flies and trypanosomiasis prevent the use of cattle for traction.
c. Farming systems are diverse and range from 'true' shifting cultivation (where the settlement is moved) to permanent cultivation. Although 'true' shifting cultivation is reported to be restricted to parts of Ivory Coast and Cameroon, it is very likely that long term fallows where a temporary settlement is built, have replaced it.
d. The centre of activity from where roads or paths radiate to all field systems, is the compound farm or homestead garden on which permanent cultivation is practised. Permanent cultivation also occurs in the terrace agriculture on steep hill slopes such as at Maku in the Anambra State of Nigeria and on overcrowded high population density areas of southeastern Nigeria in parts of Anambra, Imo and Cross River States.
e. The compound farm is the most widespread feature of agriculture of the region. It is the most intensive farming system in which the largest number (up to 60 species) of crops are grown for food, fibre, condiments or spices, masticants, drugs, fibres, structural materials, animal feed, demarcation of boundaries, firewood, ornaments, shade and protection of homestead, religious and social functions and various other uses.

Its development is related to (i) the division of labour between the sexes in which women, responsible for cooking, grow enough vegetables, condiments and spices in the compounds to enhance regular harvesting, minimize storage problems and purchase from the local market and (ii) the use of the compound for growing various useful plants which are fast disappearing from the forest due to frequent clearing or for growing exotic and other useful plants.

Soil fertility for permanent cultivation is maintained with household and kitchen refuse, ashes, farm residues, animal pen manure, human waste, etc. Annual staples, vegetables and other food plants are grown with perennial trees and shrubs (planted in certain characteristic locations or patches) and complex intercropping mixtures forming a multi-storied structure approximating a tropical forest ecosystem. Studies of traditional farming systems indicate that the objective of most small farmers is not necessarily to maximize production and returns of any given commodity, but to produce reasonable stable yields of a range of crops to satisfy subsistence requirements and eventually increasing the cash needs of farmers.

f. Next to the compound farm and on its periphery are 1 to 2 year short term fallow rotations, in which tree crops are cultivated or protected in mixtures with annual staples and other crops. However, the agro-ecosystem rarely attains the complexity of the compound farm.

g. On other fields farming systems are practised consisting of bush fallows of short or long duration depending on population pressure. They are characterised by (i) the length of the fallow period (which is decreasing with increasing population pressure and nearness to the compound farm), (ii) the dominant crop species (consisting mainly of staple food, some vegetable crops and some protected wild, but useful plants, (iii) the use of either natural fallows or purposely planted fallows, (iv) the conventional slash and burn landclearing techniques and the heavy pruning of trees and shrubs to stumps of 1.5 to 2.5 m and (v) the use of the short stumps for staking of climbing or twining crops such as yams and pumpkins and hanging for desicating hard to kill weeds.

h. Preplanting cultivations may be on flat land with minimum cultivation, or on mounds, beds and ridges of various sizes.

i. Intercropping of various kinds (mixed, row, patch and relay patterns) and sequences is common in all field systems. Row intercropping is not much used since neither animals nor tractors are used for ploughing.

j. Growing crops in pure stand (sole cropping) is most common for plantation crops and commercial crops such as cotton and groundnuts. Rotational sequences of sole crops are rare, but there is a definite order of certain crops in the sequence during the cropping phase. For example, important staples such as yams, maize and associated vegetables in intercropping systems, are planted first after bush clearing, while others such as cassava which is adapted to marginal soils are often the last in the sequence just before the fallow (often for a number of years). The diversity of mixtures encountered in tropical agriculture are not only due to the range of crops at the disposal of the farmer or the range of ecological conditions in which they can be grown, but also depends on the objective for mixing.
The commonest objectives for mixing is to spread risks and to ensure constant harvests. Sometimes crops of the same species or plant types are grown to mature at difference times.
k. Most cropping patterns depend on the prevailing rainfall regime, unless there is supplementary irrigation which is uncommon in the humid and subhumid tropics of Africa.
l. Traditional cropping systems take advantage of local topographic features, such as toposequences, micro relief and other related peculiarities. Unfortunately, not much advantage has been taken of hydromorphic soils, except for sugarcane and vegetable crop production close to urban centers.
Some new cropping systems are developing on embankments along highways.
m. In almost all farms limited numbers of small livestock (chickens, goats, sheep and pigs) are kept, either restricted to pens in the compound during the year or cropping season, or on the free range or in fields not far from the homestead. Small livestock is important as (i) a source of meat (ii) thrifty scavengers converting farm, compound and kitchen waste to food, (iii) source of manure for maintaining soil fertility and adequate levels of soil organic matter and (iv) a sort of savings which yield cash in emergencies. Sometimes, livestock tenancy is important in spreading risks among relatives and friends.

ANNEX III

# WETLAND RELATED HEALTH ASPECTS IN WEST AFRICA

CONTENTS

# 1 INTRODUCTION

Wetland related health aspects have been investigated, studied and described by a large number of researchers. Major references used for this inventory are: Ansari (1973), Feachem e.a. (1977), Hunter e.a. (1966), Laird (1981), Mcjunkin (1975), N.C.A.E. (1982), Quélennec e.a. (1968), Stanley and Alpers (1975), WHO (1976, 1980 a, 1980 b and 1982 a, 1982 b) and Worthington (1979).

The development of water resources in the tropics has important implications for public health. In recent decades, many water resources development projects have caused significant increases in occurrence of water related diseases, the outstanding example being schistosomiasis (bilharzia). The spread of this disease, especially on the African continent, is still dramatic to any standard, causing both human disablement and suffering, and subsequent decreased economic productivity.

In the inventory area, next to bilharzia, onchocerciasis (river blindness) together with some other water related diseases, constitutes another major hazard to public health.
The proven relationship between water resources development and the distribution of water related diseases calls for a study of the health aspects whenever water resources are to be developed.
A preliminary inventory of the health aspects in the context of the Wetland Utilization Research Project is given in the following paragraphs, in terms of occurrence, epidemiology and control of the major wetland related diseases.
It is stressed that the distribution and incidence of wetland related diseases are not only related to irrigated agriculture but also to the level of community water supply, sanitation and housing facilities, and to the degrees of (re)-settlement and migration of population. Therefore, in the prevention and control of wetland related diseases, education and community participation, as well as an inter-sectoral coordination with national and local health authorities, are essential.

## 2 OCCURRENCE AND IMPACT

### 2.1 Onchocerciasis

Figure A1.A gives an indicative distribution of onchocerciasis in West Africa.
The vector, Simulium (blackfly), is common in the whole of West Africa, but the percentage of infected flies varies per area. All turbulent water locations ('white' water) however, are potential breeding foci. Onchocerciasis is a disabling but not necessarily lethal disease (to infected persons). Blindness may occur in the case of prolonged infection in older adults, disabling them to contribute to the economic process. Presently WHO is conducting the Onchocerciasis Control Programme (OCP), comprising seven countries with headquarters at Ouagadougou, Upper Volta. The OCP area includes the northern parts of some of the countries of the inventory area. Within the OCP area, transmission of onchocerciasis has reportedly been halted.

### 2.2 Schistosomiasis

Schistosomiasis occurs in slow flowing or stagnant water in the whole of Africa. Figure A1.B roughly indicates the areas of increased prevalence in West Africa.
An atlas on schistosomiasis distribution is presently being prepared by WHO and will be available by the end of 1983.
In general, schistosomiasis causes fatigue and lassitude in infected persons, making them less active.

### 2.3 Other diseases

Figure A1.C roughly shows the principal foci of trypanosomiasis in West Africa. The tse-tse fly habitat consists of trees and shrubs alongside rivers, providing shade and humid conditions. Trypanosomiasis may be lethal. A 0.1% of flies being infected may cause meso- or hyper-endemicity.

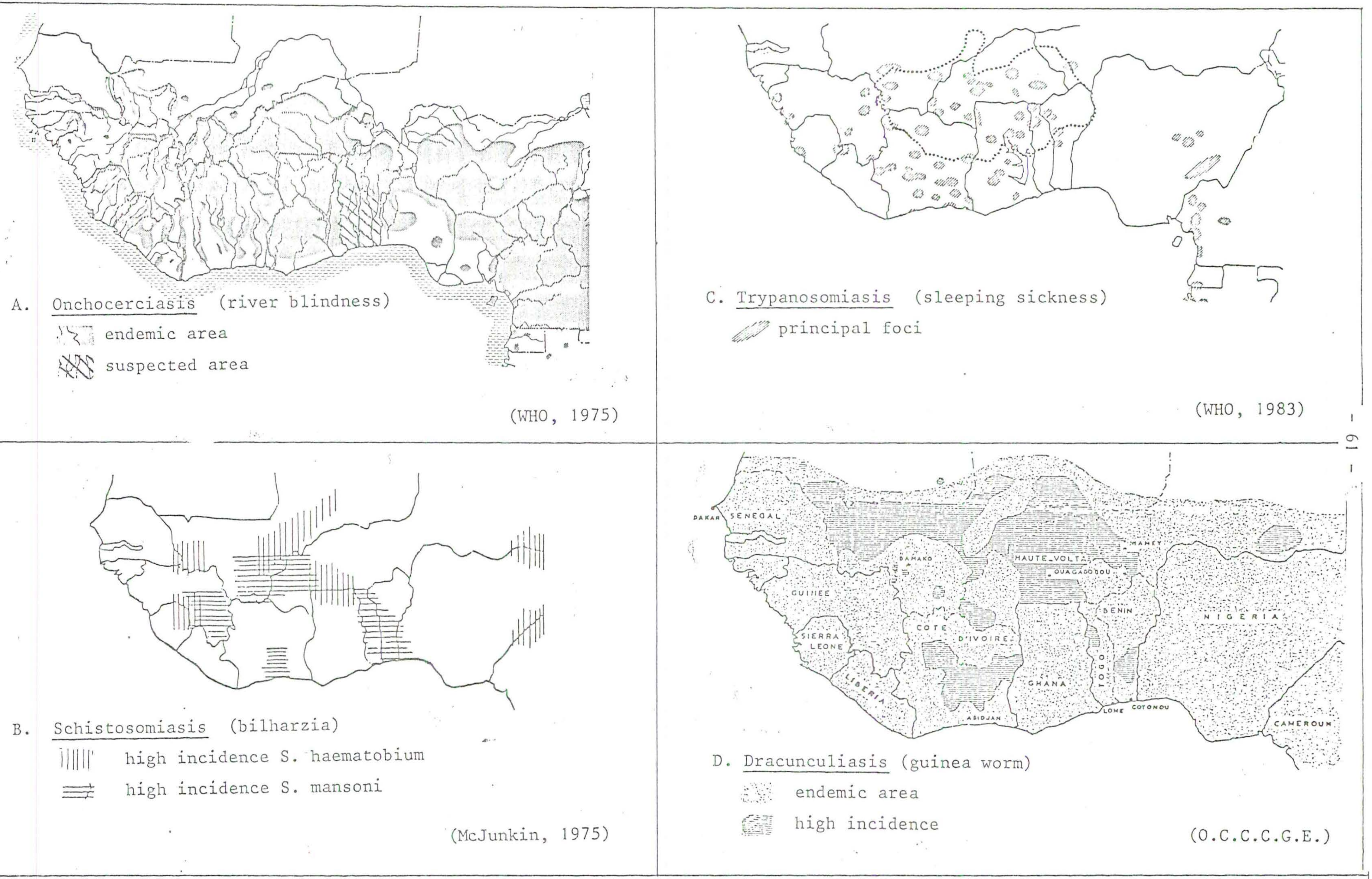



Figure A1. Distribution of major wetland - related diseases in West - Africa

Figure A1.D roughly gives the distribution of guinea worm. The infection causes disablement for several weeks coinciding with the planting season, causing considerable economic losses.

Malaria may be considered holo-endemic (uniform prevalence) in the inventory area.

# 3 EPIDEMIOLOGICAL FEATURES

## 3.1 Onchocerciasis (river blindness)

Onchocerciasis is a vector-borne infection caused by *Onchocerca volvulus*, a nematode worm. The adult parasites live mainly in subcutaneous tissues of the human host, where they may form visible nodules in which one or more worms are coiled up. The female worm discharges innumerable microfilariae during its life span of approximately 15 years. The mobile microfilariae are found in the skin of the entire body, but may also penetrate the eyes, causing blindness.
In some affected villages up to a quarter of adult persons may be blind.

The infection is transmitted by certain species of blackflies (*Simuliidae*): in the inventory area mainly *Similium damnosum*, whose bites are painfully. The simulium vector, breeds in rapidly flowing, well-aerated water. The adult blackfly is usually found close to its breeding site, but can fly considerable distances (50 km of more in case of supporting winds). This ability to fly long distances has significant consequences for the spread of infected areas and the planning of control programmes (re-infestation hazard).

## 3.2 Schistosomiasis (bilharzia)

Schistosomiasis, in contrast to onchocerciasis, is a disease of slowly flowing waters, and constitutes a major hazard of irrigation.

The schistosomes (*Schistosoma haematobium* and *S. mansoni* in the inventory area) may cause damage to the urinary tract, destruction of one or both kidneys, bladder cancer, and liver fibrosis. Severity of the disease is related to worm load, in turn depending on the intensity of transmission. Aquatic snails (mostly *Bulinus spp.* and *Biomphalaria spp.*) are the intermediate host in the life cycle of the parasite. The snail also provides a transportation vehicle for the spread of the disease, whereas some snail species are drought tolerant, enabling the parasites to overcome intermittent drying out of irrigation canals, or even the whole dry season.

## 3.3 Other diseases

Malaria is caused by a number of parasites, of which *Plasmodium vivax* and *P. falciparum* are the main species. It can be a rapidly fatal disease. *P. falciparum* parasites can cause blood clotting in the small vessels of the brain. *P. vivax* malaria is less dangerous but tends to relapse. The destruction of blood cells can lead to severe anaemia, and each bout of fever of course implies disablement. Malaria is transmitted by mosquitoes (*Anopheles spp.*) Mosquito breeding usually takes place in stagnant or slowly flowing water.

Guinea worm disease (dracunculiasis or dracontiasis) concerns infection with a small helminth (*Dracunculus medinensis* or guinea worm). The disease causes infective arthritis of joints adjacent to the active worm. It effectively disables those infected for several weeks, which, because of the timing of the infection, coincide with the (short) planting season. The required time for maturing in the human host is one year. Infection occurs when drinking water is ingested with infested *Cyclops*, a minute crustacean. Worms up to 70-80 cm in length develop in the subcutaneous tissue of the feet or legs of the human host, and larvae are liberated to renew the cycle when an infected individual steps into a well or pond (from which others may draw drinking water). Infection is markedly seasonal because of a) the influence of the climate on the types of water source and b) the development cycle of the parasite.

Trypanosomiasis (sleeping sickness) may effect both human and animal health. *Trypanosoma gambiense* is prevalent in West Africa. The infection is characterized by enlarged lymph-glands. Later stages of the disease involve the spread of the infections to the brain. Extreme lethargy is the result. The patient does not eat and seems to sleep himself to death.
Trypanosomiasis is transmitted by tse-tse flies (*Glossina palpalis* along rivers, and *G. morsitans* in the savannahs). Both vector species need shady and relatively humid conditions.

# 4 OPTIONS FOR CONTROL

## 4.1 General

Regarding the control of wetland related diseases the following options exist:

1 curative treatment

2 preventive measures
   - chemical, e.g. larvaecides, molluscides
   - biological, e.g. natural predators
   - environmental, e.g. water management

Curative treatment is not within the scope of the WURP. As for the preventive measures (a combination of the three types is nowadays denoted as integrated control), emphasis should be on environmental management. Table A2 lists various options in this respect, directed at vector control. Limited chemical measures can be supportive in vector control. Biological control is still in its research phase.
Measures necessary to control the various diseases are outlined in the Paragraph 4.2 to 4.4 of this annex. For all these measures to be effective, it should be appreciated that improved community water supply, sanitation and housing facilities, as well as health education, extension, training and community participation are essential.

## 4.2 Onchocerciasis

Environmental management for control of the Simulium fly, the vector of onchocerciasis, is focused on turbulent water locations. The development of larvae is dependent on well-aerated, turbulent water. These conditions may occur at spillways, bridges, rapids, cascades or wherever streams face temporary obstructions e.g. from debris.
The breeding sites are thus very specific and isolated. They may occur at various unanticipated locations. WHO (1980) indicates that the water velocity enabling attachment of larvae and pupae to concrete spillways, bridge pilons, stones or vegetation just under or above the water surface, ranges from 0.5 to 2.0 m/s. The most commonly tolerated velocities range from 0.7 to 1.2 m/s.

Table A2. Environmental management for vector control

| | Malaria (Anopheles mosquitos) | Schistosomiasis (Aquatic snails) | Onchocerciasis (blackfly) | Trypanosomiasis (tse-tse fly) | Dracontiasis (Cyclops) |
|---|---|---|---|---|---|
| Modification | | | | | |
| Drainage (all types) | ++ | + | - | - | - |
| Total earth filling | ++ | + | - | - | - |
| Deepening and filling | ++ | ++ | - | - | - |
| Land grading | ++ | + | - | - | - |
| Velocity alteration | + | + | + | - | - |
| Impounding | - | - | ++[a] | - | - |
| Manipulation | | | | | |
| Bush clearing and burning | + | - | - | ++ | - |
| Shading or exposure to sunlight | + | - | - | - | - |
| Water level fluctuation | + | + | - | - | - |
| Sluicing for flushing | + | + | + | - | - |
| Aquatic vegetation control | + | + | - | - | - |
| Salinity regulation | ++ | + | - | - | - |
| Human habitation control | | | | | |
| Water supply and sewerage | + | ++ | + | - | ++ |
| Screening and bednets | + | - | - | - | - |
| Refuse collection and disposal | + | - | - | - | - |
| Land use restriction | + | + | + | + | - |
| Improved housing | + | - | - | - | - |

Key: - little or no directly demonstrated effect, or not applicable

+ partially effective (some species)

++ Primarily effective (most species)

a Small dams = adverse effect; large dams = good effect

Source: WHO (1980).

Large dams have a beneficial effect on Simulium control because of lowered flow velocities in a relatively large area upstream.
Small dams and structures however, do not have this benefit. Their effect is adverse, because they enlarge the number of potential new breeding sites.

Quélennec e,a, (1968) has tested various types of spillways on their unsuitability for larvae and pupae attachment. He concluded that stepped spillways (gabions) are most unsatisfactory in this respect, because they provide excellent breeding sites. Increased inclination of the spillway plane causes a reduction in potential breeding time. Vertical or overhung spillways provide most unfavourable breeding conditions to Simulium. In regions where Simulium is not found, a dam with sluice gates and syphons for periodic flushing and drying is desirable.
When turbulent conditions cannot be avoided as may be the case for larger irrigation structures, covering the turbulent water should be considered, possibly in combination with manual removement and chemical control.
Manual removement of Simulium larvae and pupae from structures using steel brushes, is a possibility, but it has to be carried out frequently.
Chemical control at breeding sites may be considered because of the limited amounts of the agent (e.g. abate) needed. The turbulent conditions will help ensure the required mixing.
In general, the unanticipated and unnoticed creation of new breeding foci through all sorts of (temporary) obstructions in waterways remains a problem because of the rapid development of simulium, sometimes requiring only 5 days.

## 4.3 Schistosomiasis

Figure A2 shows the transmission cycle of the parasite with possible entries for control.
Eggs in the excreta perish unless they promptly reach water. This can be prevented by sanitation facilities. Improved sanitation diminishes the necessity for human contact with the cercariae.
Reduction of snail populations may be achieved through chemical control (expensive and repetitive, McJunkin, 1975), or appropriate canal construction and maintenance.

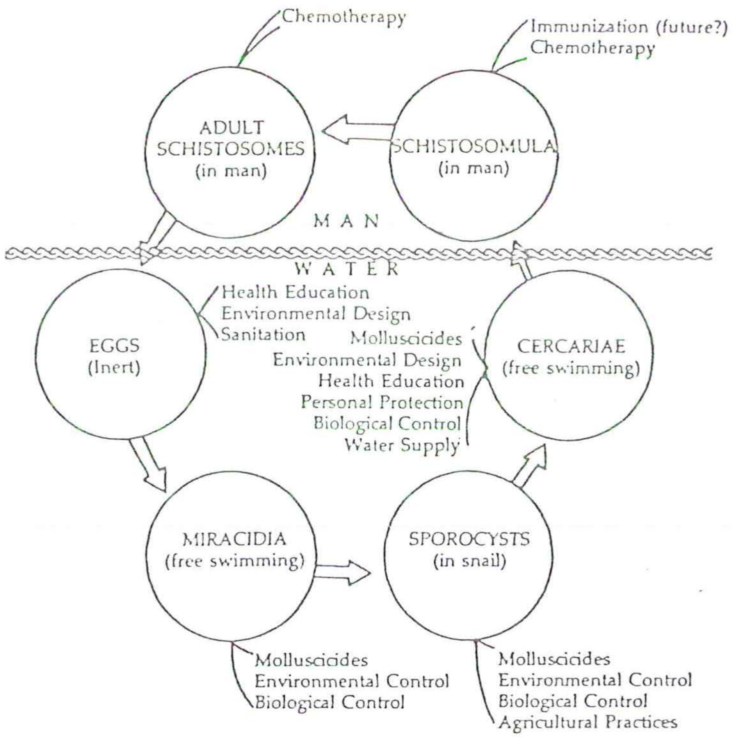



Figure A2. Transmission cycle of Schistosomiasis with possible entries for control.

Source: McJunkin, 1975.

Table A3 lists mean velocities immobilizing a snail vector. Further increase of velocity eventually leads to dislodgement of the snail.

Table A3. Mean velocities in trapezoidal channels for control of *Australorbis glabratus*

| Discharge | | Immobilizing Mean Velocity | |
|---|---|---|---|
| ($m^3$/sec) | (cfs) | (cm/sec) | (fps) |
| 1 | 35 | 58 | 1.90 |
| 5 | 175 | 67 | 2.20 |
| 10 | 350 | 71 | 2.33 |
| 20 | 700 | 75 | 2.40 |
| 30 | 1000 | 78 | 2.60 |
| 50 | 1750 | 81 | 2.66 |

Source: Jobin and Ippen (1964).

Canal lining provides a smooth surface which is less attractive to snails. Vegetation in canals harbours snails and lowers the velocity. Improved canal maintenance, especially of the drainage network is therefore beneficial. The effect of intermittent operation depends on the ability of the snail vector to survive in the absence of free water. This ability varies between species. If the periods of drought are sufficiently frequent or sufficiently prolonged, a snail population may be greatly reduced or even eliminated, especially in the case of lined canals. Water level fluctuation has proven to be beneficial but generally this is less applicable in the case of small inland valley development with smallholder farming systems. Storage reservoirs, including night storage reservoirs constitute a hazard with respect to increased snail population and therefore, should be avoided.

In general, the following measures are beneficial: clearing and re-grading of canals; backfilling, grading, draining or fencing of borrow pits, neighbouring low grounds and unused canal branches; periodically flushing of canals and seepage control on canal banks.

## 4.4 Other diseases

Major malaria control options are listed in Table A2. In general, the increased availability of water, especially stagnant or with low velocity, provides extra breeding potential to Anopheles mosquitoes.

Such conditions prevail in rice fields, canals, borrow pits, pools and ponds, containers, etc. Regarding rice cultivation, intermittent water application and field drainage may reduce breeding facilities. Drainage canal maintenance stands out as important.
Borrow pits and stagnant ponds have to be closed. Velocity increase inhibits breeding for some Anopheles species. Improved water supply, sanitation and housing facilities are beneficial.

Control of guinea worm infection (dracunculiasis) can be achieved through improved sanitation facilities (e.g. closed wells), with possible aid from chemical control e.g. abate (Lyons, 1973).

In the case of trypanosomiasis, environmental manipulation in the form of vegetation clearing has been practised, but is only advisable in the absence of detrimental effects on environment (e.g. erosion, sedimentation).
Landuse restrictions are widely practised in West Africa, also with respect to onchocerciasis. 'Dry belting' of wet rice cultivation areas, whereby a buffer zone surrounding the village is restricted to dry crops such as pasture, is also based on landuse restriction.

# 5 RECOMMENDATIONS

The IITA intends to carry out on-farm research to develop or improve rice production in small inland valleys in systems of smallholder farming. When considering the subject of wetland related diseases, one can scarcely imagine a more ominous combination of terms than West Africa, wetland rice cultivation and smallholders. Unless therefore, the research locates at least one or two of its benchmark sites in disease ridden areas, its findings can hardly be considered realistic.
A meso- or hyper- endemic area is particularly of interest because of:
- the very widespread occurrence of these diseases in West Africa and their specific relationship with water and water management;
- the considerable economic and social impact, especially in farming communities.

The areas with high incidences of onchocerciasis and schistosomiasis, for which the relation with water management is most evident, are roughly indicated in Figure A1.

It is recommended that the WURP - Phase II should include a survey at site to cover:
- the actual health situation (medical/epidemiological), to asses infection rates of onchocerciasis, schistosomiasis, guinea worm, malaria, trypanosomiasis and maybe other diseases like yellow fever;
- the occurrence of the vectors (entomological), to assess the populations of snails, blackflies, mosquitoes, etc.

This survey should form the basis of the monitoring during the project, regarding:
- public health (medical/epidemiological)
- vector populations (entomological)

Vector control measures should be incorporated in irrigation and drainage network design, construction, operation and maintenance. Emphasis should be on environmental control and supported by chemical control.

In the context of future land and water development in the inventory area, the improvement or safeguarding of public health will also depend on improvements in the field of community water supply, sanitation and housing, not in the least through increased community participation and health education.
Environmental vector control measures can be incorporated in the scope of the WRUP. The medical and epidemiological surveillance necessitates institutionalised cooperation with national and local authorities (health, public works, housing, etc.).

REFERENCES

ANSARI, N., 1973. Epidemiology and control of schistosomiasis. Karger.

FEACHEM, R., McGARRY, M., MARA, D., et al., 1977. Water, wastes and health in hot climates. Wiley & Sons, Chichester, 400 p.

HUNTER, J.M., REN, L. and SCOTT, D., 1979. Disease control and prevention in water development schemes. Assignment report, PDP/SCH. WHO, Geneva.

JOBIN, W.R. and IPPEN, A.T., 1964. Ecological design of irrigation canals for snail control. Science, 145, 1964, pp. 1324-1326.

LAIRD, M. (ed.), 1981. Blackflies: the future for biological methods in integrated control. Academic Press, London. 400 p.

LYONS, G.R.L., 1972. Guinea worm infection in the Wa district of north-western Ghana. WHO Bulletin 47, p. 601-610.

McJUNKIN, F.E., 1975. Water, engineers, development and diseases in the tropics. USAID, Washington, 180 p.

NATIONAL COLLEGE OF AGRICULTURAL ENGINEERING, 1982. Irrigation and dams, their impact on public health. Course notes 22-25 June 1982, NCAE, Silsoe, Bedford, U.K.

QUELENNEC, G., SIMONKOVICH, E. and OVAZZA, M., 1968. Recherche d'un type de déversoir de barrage défavorable à l'implantation de Simulium damnosum. WHO Bulletin, 38, pp. 943-856.

STANLEY, N.F. and ALPERS, M.P. (eds.), 1975. Man-made lakes and human health. Academic Press, London, New York, San Fransisco.

WHO, 1969. African Trypanosomiasis. Techn. Rep. Ser. No. 434. Geneva.

WHO, 1976. Epidemiology of onchocerciasis. Tech. Rep. Ser. no. 597, Geneva.

WHO, 1980a. Epidemiology and control of schistosomiasis. Technical Report Series 643, Gevena.

WHO, 1980b. Environmental management for vector control. WHO Technical Report Series 649, WHO, Geneva.

WHO, 1982a. Water resources development and health: a selected bibliography, by Deom, J., Geneva, PDP/82.2.

WHO, 1982b. Manual on environmental management for mosquito control; with special emphasis on malaria vectors. WHO offset publ. No. 66. Geneva, 280 p.

WHO/FAO/UNEP, 1981. PEEM, Report first meeting, Geneva 22-29 Sept. 1981. WHO, Geneva.

WHO/FAO/UNEP, 1982. PEEM, Report of second meeting, Nairobi, 14-20 Sept. 1982. Geneva, VBC/82.2.

WORTHINGTON, E.B., 1979. Some ecological problems concerning engineering and tropical diseases.

Government of The Netherlands
Min. of Foreign Affairs/DGIS
Min. of Agriculture and
Fishery/DLO

International
Institute of Tropical
Agriculture (IITA).
Ibadan - Nigeria

# Wetland Utilization Research Project
# West Africa

## Phase I
## The Inventory

Volume IV: The Maps

April 1983



Institute for Land Reclamation & Improvement
Wageningen - The Netherlands

# WETLAND UTILIZATION RESEARCH PROJECT

West Africa



## Phase I

## The Inventory

By: Ir. P. Hekstra - Land and Water Management (ILRI)
Ir. W. Andriesse - Soil Survey and Landevaluation (STIBOKA)
Ir. G. Bus - Sociology (KIT)
Ir. C.A. de Vries - Agro-Economy (KIT)

## VOLUME IV: THE MAPS



International Institute
for Land Reclamation
and Improvement
ILRI - Wageningen

Soil Survey Institute
STIBOKA - Wageningen

Royal Tropical Institute
KIT - Amsterdam

CONTENTS

## INTRODUCTION

### *Approach and presentation*

The International Institute of Tropical Agriculture (IITA) at Ibadan-Nigeria, requesting the Government of The Netherlands for technical and financial assistance, submitted its proposal for the Wetland Utilization Research Project (WURP) in 1981. This proposal consists of three phases. The first phase is the inventory of existing information to identify the extent and the categories of wetlands and to assess capabilities and constraints of wetland utilization in rice-based smallholder farming systems, based on village-scale development without major inputs.

The activities for the WURP-Phase I, the collection and evaluation of available information started in August 1982. In The Netherlands contributions were made by STIBOKA (Soil Survey Institute) on the geological, geomorphological and pedological aspects, by the KIT (Royal Tropical Institute) on the agro-socio-economic aspects and by the International Institute for Land Reclamation and Improvement (ILRI) on the climatological and hydrological aspects. The ILRI also had the overall responsibility of coordination (Ir. de Wolf).

The report has been presented in four volumes:
- Volume I. The main report;
- Volume II. The physical aspects;
- Volume III. The agronomic, sociological and economic aspects;
- Volume IV. The maps (this volume).

### *Area and subject of the inventory*

The area of the inventory is defined as the area where rainfed double cropping or more, is possible. It is somewhat larger than the IITA - mandate area in West Africa. It comprises the Guinea savannah zone and the Equatorial forest zone, more or less corresponding with the subhumid and humid tropics of West Africa, respectively. The entire inventory area is approximately 2.2 million $km^2$, comprising partly or wholly all coastal countries of West Africa from Guinea Bissau through Cameroon.

Wetlands are lands having hydromorphic soils. Such soils have characteristics associated with wetness and the resulting reduction during at least a part of the year. Evidently, hydromorphic soils are found in all types of land associated with wetness, such as there are the tidal lands, the deltas, the river floodplains, the inland depressions (such as the bolis of Sierra Leone) and the small inland river valleys.
In view of its objectives, the WURP is meant for those wetlands which can be developed simply and without major engineering works. The implementation, operation and maintenance of such schemes should be done by the farmer himself (or the farmer's community), possibly with assistance from national extension services. Therefore, the present study is restricted to the small inland valleys (streamflow valleys). They are formed in the upper part of the catchments. They have a centrally located stream, which is shallow and only a few meters wide, or which is not existing at all. They have a width varying from about 10 meters in their upper to a few hundreds of meters in their lower stretches. The catchment area ranges from at least 2 $km^2$ to some 100 $km^2$.

*This volume*

The maps and their legends presented in this volume are illustrative to subjects in the Volumes II or III. They can also be read in combination with the Main Report of Volume I.


# WETLAND UTILIZATION RESEARCH PROJECT - WEST AFRICA

Phase I - THE INVENTORY

Map 5 Recommended areas for benchmark site selection

Project coordination (Phase I):
International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands
Cartography: Soil Survey Institute, Wageningen, The Netherlands

Map scale 1 : 5 000 000

0 100 200 300km

Date: March 1983

Legend

Representative areas based on climatological, geological, geomorphological, hydrological and soil criteria (see Volume II)

Representative traditional rice growing areas with relatively dense population (see Volume III)

(4) Recommended areas for benchmark site selection ( for numbers see Volume I)

5.6 Rice cultivation area - 1981 (% of whole country)
400 Total rice cultivation area of the whole country - 1981 (x 1000 ha)

KEY

Boundary of inventory area

International boundary

# WETLAND UTILIZATION RESEARCH PROJECT - WEST AFRICA

| Phase I - THE INVENTORY | Map 4 Population distribution and density. |
|---|---|

Project coordination (Phase I):
International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands
Cartography: Soil Survey Institute, Wageningen, The Netherlands

| Map scale 1 : 5 000 000 (0 – 100 – 200 – 300 km) | Date: March 1983 |
|---|---|


Legend

2.6 — Total population of the whole country - 1980 (x $10^6$)
67.9 — Rural population - 1980 (% of total population)

- 0 - 9 persons per $km^2$
- 10 - 19 persons per $km^2$
- 20 - 49 persons per $km^2$
- 50 - 99 persons per $km^2$
- > 100 persons per $km^2$

KEY

- Boundary of inventory area
- International boundary

830044 - 2644789

# WETLAND UTILIZATION RESEARCH PROJECT - WEST AFRICA

| Phase I - THE INVENTORY | Map 3 - LAND REGIONS |
|---|---|

Project coordination (Phase I):
International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands
Cartography: Soil Survey Institute, Wageningen, The Netherlands

| Map scale 1 : 5 000 000 (0, 100, 200, 300km) | Date: March 1983 |
|---|---|


FOR DESCRIPTIVE LEGEND SEE OVERLEAF

KEY

- Land region boundary
- Subregion boundary, major geologic distinction
- Subregion boundary, minor geologic distinction
- Boundary of inventory area
- International boundary

| LAND REGION | MAP UNIT NO. | SUBREGION GEOMORPHOLOGY/TOPOGRAPHY[1][2] | GEOLOGY/LITHOLOGY | MAIN SOILS[3] | DRAINAGE SYSTEM Pattern | Density $(km/km^2)$[4][5] | Texture $(no/km^2)$[6] |
|---|---|---|---|---|---|---|---|
| COASTAL PLAINS | 1.1 | Beach ridges, alluvial plains with levees and basins, estuarine and deltaic tidal swamps and lagoons. Nearly level-gently undulating (0-5%); e: 0-80 m; a: 0-10 m. | Recent coastal sands and alluvial silts and clays, some peats | Beach ridges: Quartzipsamments, Tropohumods. Alluvial plains: Tropaquepts, Trop-/Fluv-aquents, Tropofluvents. Tidal swamps: Trop-/Fluv-/Sulfaquepts, Trop-/Hal-/Sulfaquents (including saline and sodic phases), some Histosols. | Swales; Meandering/ estuarine/ deltaic; Swamps | — | — |
| | 1.2 | Slightly dissected coastal terraces with slight dipslope and scarps. Nearly level-gently undulating (0-5%); e: 25-150 m; a: 5-15 m. Scarps up to 80 m. | Tertiary sedimentary deposits of weakly cemented sands (Coastal Plains Sands, Nigeria), sandy clays and clays (Terres de Barre, Togo/Benin), marly clays (Hollis Lama depression, Togo/Benin) | Sierra Leone, Liberia, Ivory Coast, East Nigeria, Cameroon: Haplorthoxs Togo, Benin, west Nigeria: Paleustults, Haplustalfs. Pellusterts in Hollis Lama depression. | Dendritic/ trellic | — | — |
| | 1.3 | Highly dissected coastal terraces with distinct dipslope features and scarps. Undulating - gently rolling (5-15%); e: 50-400 m; a: 10-100 m. Scarps up to 350 m (Enugu scarp) | Cretaceous and Tertiary sedimentary deposits: sandstones, siltstones, sands, shales and coal measures (south-central Nigeria) | Pale-/Hapl-/Plinthustults, locally with petroferric contact. | Dendritic/ trellic | — | — |
| INTERIOR PLAINS | 2.1 | Slightly dissected peneplains with common granitic/quartzitic inselbergs and hill ridges and common mesas with ironstone hardpans; locally highly dissected. Undulating (5-10%), locally rolling (10-20%); e: 50-500 m; a: 10-50 m. Inselbergs, hills up to 300 m, mesas up to 100 m high. | Lower Precambrian (Archean) undifferentiated granites, migmatites and gneisses | Sierra Leone, Liberia, Cameroon: (Plinthic) Hapl-/Umbriorthoxs and Trop-/Plinthudults, locally with petroferric contact. Ivory Coast: (Plinthic) Tropudults, Plinthudults and (Oxic) Dystropepts, partly with petroferric contact. Togo, Benin, Nigeria: Hapl-/Pale-/Plinthustalfs and some Pale-/Plinthustults, partly with petroferric contact. Chromusterts in south Togo/Benin. | Dendritic/ subparallel/ trellic | E: high<br>G: low to medium | E: fine<br>G: very coarse |
| | 2.1.a | Non-dissected association of large drainage depressions and low terraces. Nearly level (0-2%); e: 20-50 m; a: 0-3 m. Seasonally flooded. | Lower Precambrian (post Archean) consolidated unfossiliferous sandy and clayey sediments. (Bolilands, Sierra Leone) | (Plinthic) Tropaquepts and Paleaquults | Dendritic/ meandering/ sineous | E: medium | E: very coarse |
| | 2.2 | Slightly dissected peneplains with few to common granitic/quartzitic inselbergs and hill ridges and common to many mesas with ironstone hardpans; locally highly dissected. Undulating (5-10%), locally rolling (10-20%); e: 50-400 m; a: 10-50 m. Inselbergs, hills up to 300 m, mesas up to 100 m high. | Middle Precambrian (Birrimean) undifferentiated schists, quartzites and other metamorphic rocks (micaschists, amphibolites, greenstones, arkoses, graywackes. | Ivory Coast: Trop-/Plinthudults, some (Oxic) Dystropepts, mainly with petroferric contact. Guinea: Pale-/Rhod-/Haplustalfs, mainly with petroferric contact. | Dendritic/ subparallel | E: high<br>G: high | E: medium<br>G: medium |
| | 2.3 | Highly dissected peneplains comprising rolling (10-20%) remnants of former peneplains with steep (30-35%) sideslopes and relatively flat (2-5%) valley bottoms; e: 50-400 m; a: 25-150 m. | Complex of upper Precambrian (Tarkwaian) folded conglomerates, quartzites, schists, sandstones and shales and middle Precambrian (Birrimean) schists, quartzites, other metamorphic rocks, lavas and tuffs (Ashanti hills, Ghana). | Tropudults, locally (over Tarkwaian rocks) Paleudalfs | Dendritic | G: medium | G: medium |
| | 2.4 | Dissected and upwarped peneplains with steep outward-facing scarps. Undulating - gently rolling (5-15%) and very steep (> 35%: scarps); e: 200-700 m; a: 25-50 m. Scarps up to 400-500 m (Gambaga scarp, Mampong scarp). | Paleozoic (Infracambrian) upwarped sandstones (Volta basin, Ghana). | (Oxic and Lithic) Haplustalfs, partly with petroferric contact | Subparallel | G: low | G: very coarse |
| | 2.5 | Slightly dissected peneplains. Nearly level (0-2%); e: 80-200 m; a: 5-10 m. | Paleozoic (Cambro-Ordovician) sandstones, shales, mudstones and pebbly conglomerates (Volta basin, Ghana). | (Oxic and Lithic) Hapl-/Plinthustalfs, mainly with petroferric contact. | Dendritic/ meandering (Oti river) | G: low | G: very coarse |
| | 2.6 | Slightly dissected peneplains with some basalt cones and common mesas with ironstone hardpans or concretionary surfaces. Nearly level - gently undulating (0-5%); e: 50-300 m; a: 5-10 m. Basalt cones up to 300 m high, mesas up to 20 m. | Mesozoic (Cretaceous) complex of marine and continental sandstones, shales and coal measures (Niger and Benue river troughs, central Nigeria/north Cameroon). | Niger river trough: Paleustults and some Hapl-/Plinthustults and Hapl-/Plinthustalfs. Benue river trough: Plinthustalfs (north of B. river) and (Oxic) Haplustalfs (south of B. river) and some Hapl-/Paleustults, partly with petroferric contact. Pellusterts in upper B. river trough. | Dendritic/ meandering (Niger and Benue rivers) | E: low<br>G: low | E: coarse<br>G: very coarse |
| | 2.7 | Deeply dissected peneplains. Undulating (5-10%) with very steep (> 35%) canyon-like slopes down to valley bottoms; e: 300-500 m; a: 25-50 m (peneplains), 100-150 m (canyons). | Mesozoic (Upper Cretaceous) continental sandstones and conglomerates (Grès de Kandi, north Benin, Illo formation northwest Nigeria). | (Oxic) Haplustalfs, Pale-/Haplustults. | Dendritic/ meandering (Niger river) | G: low | G: very coarse |
| | 2.8 | Slightly dissected aggradational plains. Nearly level-gently undulating (0-5%); e: 20-50 m; a: 0-10 m. | Tertiary sandstones and sands with inclusions of shale, marl and clay (Continental Terminal, Guinea-Bissau/Senegal). | (Oxic) Haplustalfs with some Orthents and Psamments | Dendritic/ meandering | G: low | G: very coarse |
| PLATEAUX | 3.1 | Slightly dissected plateaux with common granitic/quartzitic inselbergs and hill ridges and common mesas with ironstone hardpans; locally (mainly at transition zones to interior plains) highly dissected with scarps. Gently undulating (2-5%), locally rolling (10-20%); e: 350-850 m (up to 1000 m in Nigeria and Cameroon); a: 10-50 m (up to 100 m in highly dissected areas). Inselbergs, hills up to 300 m, mesas up to 100 m high. | Lower Precambrian (Archean) undifferentiated granites, migmatites and gneisses. | Sierra Leone, Guinea, Cameroon: (Plinthic) Haplorthoxs, (Oxic) Trop-/Paleudults, locally with petroferric contact. Ivory Coast, northwest Ghana: (Oxic) Hapl-/Paleustults and some Hapl-/Paleustalfs, partly with petroferric contact. Nigeria: (Oxic) Hapl-/Plinthustalfs, partly with petroferric contact. Orthents and Psamments in northern part. | Dendritic/ subparallel/ trellic | E: high<br>G: low to medium | E: very fine<br>G: very coarse |
| | 3.2 | Slightly dissected plateaux with few to common granitic/quartzitic inselbergs and hill ridges and common to many mesas with ironstone hardpans; locally highly dissected. Gently undulating (2-5%), locally rolling (10-20%); e: 350-850 m; a: 10-50 m (up to 100 m in highly dissected areas. Inselbergs, hills up to 300 m, mesas up to 100 m high. | Middle Precambrian (Birrimean) undifferentiated schists, quartzites and other metamorphic rocks (micaschists, amphibolites, greenstones, arkoses, graywackes). | Ivory Coast: (Oxic) Hapl-/Pale-/Plinthustalfs, mainly with petroferric contact. Cameroon: Haplorthoxs, Tropudults. | Dendritic/ subparallel | E: high<br>G: medium | E: fine<br>G: medium |
| | 3.3 | Dissected plateau with steep outward scarps. Undulating - gently rolling (5-15%); e: 400-600 m; a: 25-50 m. Scarps up to 150 m. (Falaise de Banfora). | Paleozoic (Cambro-Ordovician) sandstones (Sikasso plateau, Mali/Upper Volta). | (Oxic) Haplustalfs, mainly with petroferric contact. Some Orthents and Psamments. | Dendritic | G: low | G: coarse |
| | 3.4 | Dissected plateau with deeply incised valleys. Undulating-rolling (5-20%); e: 300-600 m; a: 25-100 m. | Tertiary (Paleocene) sandstones (Kerri Kerri formation, central Nigeria). | Paleustults | Dendritic | G: low | G: coarse |
| HIGHLANDS | 4.1 | Highly dissected mountain ranges with remnants of old planation surfaces. Very steep (> 35%), locally rolling (10-20%); e: 600-900 m; a: 100-1000 m. | Lower Precambrian (Archean) undifferentiated granites, migmatites and gneisses (Guinean Highlands, West Cameroon Highlands, Mandara Mountains, Adamawa Range). | Guin. Highlands: (Lithic) Haplorthoxs, Tropudults and Dystropepts. West Cam. Highlands: (Lithic) Haplorthoxs, Pale-/Tropudults, Palehumults, Haplohumoxs and Orthents. | Subparallel/ rectangular/ dendritic | E: medium | E: coarse |
| | 4.2 | Complex of highly dissected mountain ranges with very steep slopes (> 35%); rolling-steeply sloping plateaux (10-35%) and very steep and deep scarps (> 50%); e: 600-2000 m; a: 300-1000 m. Scarps south of Jos plateau up to 600 m. | Complex of Precambrian 'older' granites, migmatites and gneisses, Jurassic 'younger' granites and Cretaceous and more recent basalts. (Jos plateau, Nigeria; high plateaux in West Cameroon Highlands and Adamawa Range). | Jos plateau: (Oxic and Lithic) Haplustults and Haplustalfs, Plinthustults. West Cam. Highlands, Adamawa Rg: (Lithic) Haplorthoxs, Pale-/Rhod-/Hapludults, Palehumults, Eutrandepts. | Subparallel/ dendritic | G: medium | G: coarse |
| | 4.3 | Complex of highly dissected, folded and faulted mountain ridges with very steep slopes (> 35%), very steep and deep scarps (> 50%) and some rolling (10-20%) remnants of old planation surfaces; e: 300-1000 m; a: 100-500 m. | Complex of terminal Precambrian (Buem) folded and faulted shales, arkoses, sandstones, conglomerates, basalts and dolerites and middle Precambrian (Birrimean) folded and faulted micaceous quartzites. (Atacora Range, southwest Ghana/ Togo/North Benin). | (Lithic) Hapl-/Paleustalfs, Paleustults, Ustorthents. | Subparallel/ dendritic/ rectangular | G: medium | G: coarse |
| | 4.4 | Deeply dissected high plateaux. (Gently) undulating (2-10%) with very steep (> 50%) scarps down to narrow nearly level (0-2%) valley bottoms; e: 500-1500 m; a: 10-50 m (plateaux), 100-500 m (scarps). | Paleozoic (Ordovician, Silurian, Devonian) uplifted and faulted sandstones and shales, locally with intrusions of dolerites and gabbros (Fouta Jallon/Manding plateau, Guinea). | Haplustults, Dystropepts, mainly with petroferric contact, (Lithic) Ustorthents. | Rectangular dendritic | G: medium | G: coarse |

1) Slope classes:

| | |
|---|---|
| nearly level | 0-2 percent |
| gently undulating | 2-5 |
| undulating | 5-10 |
| gently rolling | 10-15 |
| rolling | 15-20 |
| steep | 20-35 |
| very steep | >35 |

2) e: elevation above sea level.
a: amplitudo of local relief.

3) Soil classification names refer to the USDA Soil Taxonomy (SSS, 1975). General descriptions of the main soils in the inventory area are given in Volume II, Chapter 2.

4) Drainage density classes:

| | |
|---|---|
| very low | 0-0.3 $km/km^2$ |
| low | 0.3-0.6 |
| medium | 0.6-1.2 |
| high | 1.2-2.4 |
| very high | > 2.4 |

5) E: Equatorial forest zone
G: Guinea savannah zone

6) Drainage texture classes:

| | |
|---|---|
| very coarse | 0-0.5 $streams/km^2$ |
| coarse | 0.5-1.0 |
| medium | 1.0-2.0 |
| fine | 2.0-3.0 |
| very fine | > 3.0 |

**WETLAND UTILIZATION RESEARCH PROJECT - WEST AFRICA**

| Phase I - THE INVENTORY | DESCRIPTIVE LEGEND OF Map 3 - LAND REGIONS |
|---|---|
| Project coordination (Phase I): International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands<br>Cartography: Soil Survey Institute, Wageningen, The Netherlands | |
| Map scale 1 : 5 000 000 | Date: March 1983 |


# WETLAND UTILIZATION RESEARCH PROJECT - WEST AFRICA

Phase I - THE INVENTORY

Map 2 Bioclimatic zones and lenghts of growth periods.

Project coordination (Phase I):
International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands
Cartography: Soil Survey Institute, Wageningen, The Netherlands

Map scale 1 : 5 000 000
0 100 200 300km

Date: March 1983

Legend

210 Isoline of length of growth period

Boundary of bioclimatic zones and isoline of length of growth period

IITA - mandate boundary (Isoline of 5 - months humid period)

## SAHEL - SAVANNAH ZONE

Transition zone between Sahara desert and true savannah. The growth period is less than 90 days per year, roughly corresponding with less than 500 mm annual rainfall. Monomodal rainfall pattern. Vegetation cover is sparse. Nomadic agriculture dominant. Main crop: short season millet.

## SUDAN - SAVANNAH ZONE

Growth period between 90 and 165 days per year, roughly between 550 mm and 1000 mm annual rainfall. Monomodal rainfall pattern. Fairly intensive crop production possible. Relatively low drought hazards and relatively high photosynthetic potential.

## GUINEA - SAVANNAH ZONE

Growth period between 165 and 270 days per year, roughly between 1000 mm and 1500/2000 mm annual rainfall. Monomodal rainfall pattern in the north gradually shifting into a bimodal pattern in the south, with two growth periods of unequal length. In the south drought hazards occur during the rainy seasons and the photosynthetic potential is relatively low.

## EQUATORIAL - FOREST ZONE

Growth period over 270 days per year, roughly over 1500/2000 mm annual rainfall. Pseudo bimodal rainfall pattern Photosynthetic potential relatively low and air humidity relatively high. General crop production conditions are below optimum, with high incidence of pests and diseases.

Key

Boundary of inventory area and north boundary of Guinea savannah zone

International boundary

830042 - 2644789


# WETLAND UTILIZATION RESEARCH PROJECT - WEST AFRICA

Phase I - THE INVENTORY

Map 1 Climatic (rainfall) regimes and annual rainfall distribution.


Project coordination (Phase I):
International Institute for Land Reclamation and Improvement, Wageningen, The Netherlands
Cartography: Soil Survey Institute, Wageningen, The Netherlands


Map scale 1 : 5 000 000

0 100 200 300km

Date: March 1983

Legend

1250 — Rainfall isohyet 1250 mm

(April - October) Main period of rainfall

I — Monomodal (rainfall) regime. 2 to 5 humid months, characterised by high evapotranspiration rates (with occasional moisture stress) and irregularities in rainfall, especially at the onset and cessation of the rains.

II — Bimodal (rainfall) regime. A major humid period of 4 months (mid March to mid July) and a minor one (late August to early November). The intervening period of moisture deficit constitutes a distinct break between the two seasons - Irregularities in rainfall, especially within the seasons and relatively low solar radiation, cause below optimum conditions for crop production.

III — Pseudo - bimodal (rainfall) regime. Continuous humid period from March/April to October/November. Relatively low solar radiation paired with relatively high air humidity cause below optimum conditions for crop production, with high incidences of pests and diseases, constituting additional yield limiting factors.

KEY

Boundary of inventory area

International boundary

830041 - 2644789