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MAPPING OF THE SURFACE RESOURCES OF THE GAMBIA

A TECHNICAL REPORT

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GAMBIA CARTOGRAPHIC STUDIES PROJECT
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EXECUTIVE SUMMARY

Date - October 1986
Project - Gambia Cartographic Services
Project No. - 635-0203
Project Contract No. - 635-0203-C-00-6039-00
Project Duration - May 5, 1986 - September 30, 1986

PROJECT PURPOSE

1. To provide cartographic services to produce land classification cartography useful for resource planning and management.

2. To train Gambian resource planning technicians in basic map development and production procedures.

ACCOMPLISHMENTS

1. TRAINING

A two week training workshop on remote sensing and mapping of natural resources was offered in The Gambia from July 14 - 25, 1986. Fifteen resource scientists and technicians from five departments participated. Five Gambian resource planning technicians took part in a five week training program at the Office of Remote Sensing, South Dakota State University facility (July 23 - August 30, 1986). Detailed outlines of the training programs are included in the project's Monthly Reports for 12 July - 11 August, 1986 and 12 August - 11 September 1986.

2. AERIAL PHOTO INTERPRETATION AND FIELD SURVEY

Black and white, panchromatic aerial photos at a scale of approximately 1:50,000, collected by Markhurd in 1982 - 1983, were the interpretive base for the development of the updated planimetric maps and four thematic maps. Interpretation consisted of delineating various surface features including soils, cropland, and fallow lands, natural vegetation types and rangelands onto transparent overlays for each of 400 photographs. Short reconnaissance field surveys were conducted to identify and describe the different landscapes and cover types. An low level aerial survey provided an intermediate level of observation between the Markhurd aerial photos and ground-based survey.

3. PREPARATION OF MAPS

- Planimetric base - paper and transparency - 20 sheets at 1:50,000 and 4 sheets at 1:125,000 in black and white. This map base delineates villages, roads, road classification and identification, bridges, airports, hydrography including boreholes and wells, administrative and district delineations names and other features common to planimetric maps.

- Rangelands overlay - transparency - 20 sheets at 1:50,000 and 4 sheets at 1:125,000 in black and white. This overlay provides information on the land use aspects of Gambian vegetation resources with specific emphasis on forage for livestock. The legend contains data on dry season grazing values, wet season grazing values and principal species of grasses.

- Agricultural lands overlay - transparency - 20 sheets at 1:50,000 and 4 sheets at 1:125,000 in black and white. This overlay displays crop land and fallow land including rainfed and swamp and irrigated agriculture. Units are described according to dominant and subdominant crop associations.

- Forested lands overlay - transparency - 20 sheets at 1:50,000 and 4 sheets at 1:125,000 in black and white. This overlay is a map of the vegetation cover of The Gambia. Contained in the legend are physiognomic (structure) descriptions of vegetation cover and basic information on the floristic composition of the vegetation community.

- Landscape and soils overlay - transparency - 20 sheets at 1:50,000 and 4 sheets at 1:125,000 in black and white. This map overlay is a combined landscape and soil map. The legend is constructed using a physiographic approach and contains much information on landscape evolution asnd related soils.

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CHAPTER 1

SCOPE, OBJECTIVES, AND METHODOLOGY

1.1 INTRODUCTION

This technical report is submitted in compliance with Section F, Subsection 6-c of the contract agreement between the Engineering and Environmental Research Center, Office of Remote Sensing (formerly the Remote Sensing Institute) of South Dakota State University and the U.S. Agency for International Development for Gambia Cartographic Services, Gambia/635-0203-1. The objectives of the technical effort were to produce large and medium scale maps of The Gambia depicting various landuse/land cover themes to be used by administrators and planners of the Government of The Gambia (GOTG), and the various donor agencies for the planning and management of the country's natural resources. The map products delivered under this project are summarized in Section 1.2. This report summarizes the accomplishments of the survey and mapping work, the methods employed, recommendations for the use of the cartographic products, and the need for additional work.

1.2 SUMMARY OF MAP PRODUCTS

Map Themes: Five themes as follows:
1) Planimetric base
2) Rangelands overlay
3) Agricultural Lands overlay
4) Forested Lands overlay
5) Landscape and Soils overlay

Scale: 1) One set at 1:50,000
2) One set at 1:125,000

Number of Maps: 1) The first set (1:50,000) was divided into 20 sheets, each sheet consisting of a base plus four overlays. Total: 20 bases and 80 unique overlays.
2) The second set (1:125,000) was divided into 4 sheets, each sheet consisting of a base plus four overlays. Total: 4 bases plus 16 unique overlays.

Grand Total: 24 bases plus 96 overlays.

Map Duplication: 4 copies of each planimetric base were furnished in transparency form (B&W).
8 copies of each planimetric base were furnished on a stable paper base.

8 copies of each overlay were furnished on a stable transparent film material.

Sheet Totals: 4 x 24 planimetric bases (transparencies) = 96
8 x 24 planimetric bases on paper = 192
8 x 96 transparent overlays = 768

Size of Map Sheets: Variable, conforming to the 1:50,000 scale photo maps published by the Directorate of the Overseas Surveys (DOS), and the 1:125,000 scale maps from the Land Resource Study 22 (Dunsmore et al., 1976). Sheets did not exceed 30" x 40".

Form of Maps: Black and white pattern/number/letter combinations. Stable paper base with four transparent overlays for each base.

Projection of Maps: Universal Transverse Mercator

1.3 THE REMOTE SENSING SURVEY

Remote sensing is defined as the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation (Lillesand and Kieffer, 1979).

In conducting the survey of the surface resources of The Gambia, remote sensing data in the form of 1:50,000 scale black-and-white panchromatic aerial photographs were used. These were acquired by Markhurd in 1982, and they formed the basis of most of the work. Also consulted were the slightly older (1980) Teledyne infrared photographs at 1:25,000 scale which were available through the Gambia Mixed Farming and Resource Management Project 635-0203. Finally, a set of Landsat satellite images, acquired in January and April 1986, were used as a general reference and as training material for the workshops conducted by the Project.

All of the map units which appear on the thematic map overlays were drawn from interpretation of the Markhurd aerial photographs. Interpretation consisted of delineating such surface features as soils, croplands, natural vegetation cover types, and rangelands onto transparent overlays for each of the approximately 400 photographs. Conventional interpretation techniques were employed, making use of photo features (tone, texture, pattern, shape, size, association, etc.) and relating them to the various land surface formations.

During the interpretation, an effort was made to maintain a standard level of detail over the whole country. The minimum mapping unit was set at approximately 10 hectares, although this varied somewhat according to the shape of the map unit (linear units tended to have a smaller minimum size).

Each land cover or land use type was identified and coded with reference to a provisional legend. The legends and coding systems were finalized upon completion of the interpretation effort. The interpretation was performed by the team while in The Gambia.

1.4. FIELD SURVEYS

Three short reconnaissance surveys were conducted to identify and describe the various landscapes and cover types, and to formulate the basic mapping units. These took place between June 8 and July 22, 1986. A number of specific observations were made on soils, agricultural land use, vegetation cover, range conditions, and cultural features. Due to the limited time available in-country, a systematic approach to collecting field data was not possible. Specific field data on the various resource themes were derived from previous field surveys completed by other investigators (see Bibliography).

1.5. AERIAL SURVEY

The entire length of the country was viewed from a light aircraft on June 26, 1986. Slides (35 mm) were systematically taken from both sides of the aircraft and correlated to a topographic map. The slides, whose scale is between that of the field observation and that of the Markhurd aerial photographs, offer an intermediate level of observation. Analysis of the oblique views offered by the slides provided valuable data on further characterization of the surface features previously delineated on the overlays. Flight altitude ranged from 300 to 1000 feet AGL.

1. MAP PRODUCTION

This section summarizes the major steps in the map production effort which were common to all five map themes.

The map production phase of the project was conducted at South Dakota State University, using the existing base maps and interpretation overlays prepared by the team in The Gambia. The major steps in the cartographic process are summarized as follows:

a. The air photo interpretation overlays were used to prepare worksheets of each final map sheet for each of

the five map themes. This was done through optical projection of the interpretations onto translucent worksheets registered to the existing basemaps. Each air photo interpretation had to be carefully scaled and registered to the basemap before the delineations could be transferred.

b. The final lay out of the map features was prepared. Detailed annotations and other map format requirements were made.

c. The final drafting of the maps began with the updated planimetric basemaps. All drafting of linear map features was done on large (30" x 40") scribe sheets, using rigid and swivel gravers to produce the map artwork in negative form. Linear features to be printed in different shades of gray had to be engraved (scribed) on separate sheets, one for each shade.

d. Lettering plates were prepared for each map. Type styles and point sizes were selected for all lettering to appear on the maps. All textual material, codes, figures, etc. were typeset, photographically converted into negatives, reproduced as film positives, manually affixed to transparent flaps, and finally reprinted onto large negative plates for use in printing the final products.

e. Each of the thematic resource maps had to be scribed onto separate sheets, all in precise registration to the previously scribed basemaps.

f. Peelcoats, or open-window negatives used for applying tints and patterns to areal map features, were exposed and etched from the appropriate scribe sheets. Each peelcoat was then masked to remove extraneous linework, and finally "peeled".

g. Several phases of proofing of the artwork were required, including careful editing of the thousands of map units to ensure that each had the proper code.

h. All artwork in negative form, of which there were over 500 unique sheets, was photographically combined into composite negatives, one for each map sheet and theme.

i. The composite negatives were used to print the final map products. The full set of basemaps and overlays comprises 120 unique map sheets.

1.7 TECHNICAL PROBLEMS

Many of the project operations had to be conducted simultaneously due to the shortness of time allowed by the contract (120 unique map sheets had to be prepared in less than 120 working days). The following is a summary of the problems encountered which have a bearing on the technical quality of the products.

The MarkHurd aerial photographs have a nominal scale of 1:50,000, but the scales were found to range from 1:50 000 to 1:60,000. Thus, the interpretation made from these photos had to be slightly enlarged on a frame-by-frame basis, using an optical projection system which introduced a certain amount of distortion. Furthermore, an intermediate set of worksheets had to be hand-drawn from the projection system, introducing some line generalization. The final drafting (scribing) of all linework is therefore two generations removed from the original interpretation. This is not the case with the updated planimetric maps, since intermediate worksheets were not part of their preparation.

The alternative to using the MarkHurd photographs would have been the use of the 1:25,000-scale color infrared photographs supplied by the Gambia Mixed Farming and Resource Management Project. Although they were consulted, they did not form the basis of our work because they did not represent the most recent aerial coverage of The Gambia, and because there were four times as many photos, effectively quadrupling the amount of time required to complete the interpretation and worksheets.

No adequate basemaps at 1:125,000 scale were available for use in preparing the final 1:125,000 scale products. The approach taken was to photographically enlarge the existing The Gambia 1:250,000 Scale Map published by the Directorate of Overseas Surveys (DOS). In transferring the resource data from our worksheets to the enlarged base, some discrepancies were found with comparison to the 1:50,000 scale basemaps. These were generally limited to minor inconsistencies in the international border and in drainage systems. As a result, the transferring of map units to the small-scale sheets was more complicated than anticipated. The photo-reduction process required in preparing the small-scale maps also contributed to slight distortions in the linework.

The location accuracies of the map unit boundaries relative to the true position of the units is estimated to generally fall within plus or minus 1 mm (equivalent to plus or minus 50 m at the 1:50,000 scale). Positional errors of plus or minus 2 mm may occur in some areas (equal to plus or minus 100 m at 1:50,000).

Similar positional errors occur on the 1:125,000 scale maps, corresponding to ground distances generally within plus or minus 125 m, and in some areas plus or minus 250 m.

CHAPTER 2

PHYSICAL AND CULTURAL DESCRIPTION OF THE GAMBIA

2.1 INTRODUCTION

The small West African country of The Gambia is entirely surrounded by Senegal except for the Atlantic coast on the west. It lies between 13° and 14° N latitude, ranges from 24 to 48 km wide, and extends approximately 320 km eastward from the coast on either side of the Gambia river. The surface area of approximately 10,370 km^2 lies on a gently sloping, poorly dissected plain of low relief.

2.2 CLIMATE

The Gambia lies within the Sahelo-Sudanian climatic zone. It is characterized by a dry season from late October through May and a wet season from June through September. During the dry season, the dry, hot Harmattan winds, which originate over the Sahara, are the major climatic factor. These are pushed northward by the warm, humid, seasonal air masses of the South Atlantic anti-cyclones, which initiate and sustain the wet season. In general, the resulting dynamic interface between these conflicting air masses produces short, intense, often local storms during early and late portions of the wet season with longer duration, more extensive and less intense rainfall episodes during the intervening period when the anti-cyclones dominate.

Normally, precipitation amounts build rapidly through July to a peak in August, during which 40 percent or more of the annual total may occur, and then rapidly decline through September to the start of the dry season in late October. Annual amounts are approximately 900 mm in the extreme north and in the eastern portions of the country. Annual precipitation gradually increases south and southwestward to 1200 mm near the coast, where, in a matter of a few kilometers, it increases to over 1400 mm on the southern coastal areas.

Minimum daily temperatures range from about 15° C during December and January to about 25° C in May and June. Maximum daily temperatures of 40° C and above occur inland during March, April and May. Coastal regions are cooler by 5° C or more. Mean daily temperatures in January range from 23° C on the coast to 24° C inland and in May range from 27° C on the coast to 32° C inland. Temperature and humidity are less influenced by the moderating effects of the Atlantic as one moves eastward, where weather fluctuations are more marked. With the exception of the rainy months, potential evaporation exceeds precipitation on an annual basis, particularly inland.

Characteristic of the precipitation pattern is that it is highly variable in amount, periodicity, and intensity and in the initiation and termination of the wet season. Such variation can and often does have a profound and disasterous effect on any or all phases of agricultural activity. It causes at least partial crop failure in one out of five years.

2.3 GEOMORPHOLOGY

Most of the land surface of The Gambia is derived from a sandstone formation of the late Tertiary period known as the "Continental Terminal." Structurally, it contains layers of sandstone mixed with beds of quartz gravels, sand and clay, and iron pan layers. The central feature of the Gambian landscape is the river, which has cut its way through the upper layers of sandstone, and its associated alluvial flats. In the east, the "Continental Terminal" formation is dissected by the river and its tributaries, forming rather narrow drainages and scarp slopes capped with ironpan. To the west, the "Continental Terminal" becomes progressively more dissected with fewer plateau remnants remaining. In the Western and North Bank Divisions, most of the landscape is characterized by low, rolling sandhills.

2.4 POPULATION AND SETTLEMENT

The Gambia is a densely populated country with approximately 650,000 inhabitants and an annual population growth rate of 2.7 percent. More than 70 percent of the population lives in rural areas, but there is a clear pattern of rural migration to Banjul, the capital.

Although The Gambia is a small country, it is inhabited by people of various ethnic groups; the majority of whom adheres to Islam. Most numerous are the Mandingo who are settled in locations throughout the country (Udo, 1978). The Fulanis, who are found in most of the countries of West Africa, are also represented here. They are a pastoral people, living mainly in the middle and upper river districts. The Wolof (Jolof), the dominant group in Senegal, are found mainly in Banjul and surrounding areas. The area south of Banjul is the home of the Jolas (Diola), who are more numerous in the neighboring Casamance region of Senegal.

2.5 THE GAMBIAN ECONOMY

The economy of The Gambia is based on agriculture (58 percent of the Gross Domestic Product (GDP)) with groundnuts the major product, comprising 30 to 40 percent of the GDP, and 90 percent of the country's export earnings (Donatelli, F. J., 1985). Food crops consist primarily of millet, sorghum, rice and maize. Local

food production provides about 70 percent of the population's food requirements. The country imports about 30 to 35,000 tons of rice each each year.

Although The Gambia is infested with the tsetse fly, which is fatal to cattle, the cattle population is nevertheless large. In 1977 it was estimated at 290,000 head of cattle, largely under control of the local Fulanis (Dunsmore et al., 1976). Sheep (estimated 95,000 in 1977) are also common livestock, and are in great demand during Muslim festivals.

CHAPTER 3

PLANIMETRIC BASEMAPS

3.1 INTRODUCTION

The planimetric update for the project was primarily from the 1982 (MarkHurd) 1:50,000 photography. Investigation was made for new roads and inter-village tracks, village expansion, new villages and abandoned villages. The planimetric update required some local field trips in the Banjul area to expedite photo interpretation and location of detail the bulk of the planimetric update was plotted on the DOS basemaps by means of a zoom transfer scope.

3.2 PLANIMETRIC UPDATE

With the exception of the larger population areas, little village expansion was discernible. Several new roads were plotted and road realignment projects plotted. The major planimetric changes were on the Banjul sheet #10. This sheet had been updated in 1980. New updates included reclassification of roads and new roads, notably in the stadium area and the Fajara tourist hotel district. Other notable civil projects included the kota power station, the stadium, the sanitary waste lagoons, and the runway expansion and airport improvements of Yundum International Airport.

A major aspect of the planimetric update was checking and verifying village and place names on the base maps. This work was done in concert with the Department of Survey. The initial investigation utilized the MarkHurd 1:25,000 photomaps prepared for the Gambia River Basin Development Project. Those maps were presumed to be current and correct. The Department of Survey then requested that those names changes be checked against the Gambian census maps of 1983. Significant discrepancies were noted, including names that were different, names that were interchanged, and missing names. The Department of Survey recommended that the census maps be the final authority for names update. The names changes were accordingly finalized. The names changes did not include minor spelling discrepancies as is expected from transliteration, e.g., Madina and Medina.

The international boundary was plotted from the Gambia-German Forestry Project's forestry maps, upon recommendation from the Department of Survey. The only exception was the extreme eastern portion of the Gambia which was the object of a recent treaty. A map showing that altered boundary was obtained from the Department of Survey and was used to update that boundary segment.

A list of wells was obtained from the Department of Water Resources. The list included the wells from the Rural Water System, the Saudi Sahelian Program, and the United Nation's Development Program well programs and was presented as being summary and complete. These lists are currently being used to identify those villages with wells. Three cartographic symbols are used on the updated maps to identify the well programs and the villages in which they are found.

The planimetric legend shows the roads and classifications, place names, communications lines, survey monuments, and governmental boundaries including divisional, district and international. Users needing information concerning governmental buildings, health care facilities, religious buildings or schools should be advised to consult the DOS maps.

CHAPTER 4

LANDSCAPE AND SOILS MAPS

4.1 INTRODUCTION

Mapping of the soils of The Gambia was implemented using the widely accepted physiographic approach. The resulting map is a combined landscape and soil map. Aerial photo interpretation was the major component in the mapping task. Auxiliary data provided the information necessary for designing the legend and characterizing the mapping units.

A summary of the mapping procedures is presented in Section 4.2. The description of the legend and mapping units is contained in Section 4.3.

4.2 MAPPING PROCEDURE

The procedures for developing the landscape and soil maps were similar to those used to produce the project's other maps. Differences were due primarily to the specificity of the various map themes and the availability of equipment and materials. Major limiting factors affecting product quality were the time contraints and related technical problems. As specified by the contract, the landscape and soils overlay was based primarily upon the existing 1:125,000 scale Soil Associations map accompanying J.R. Dunsmore, A.R. Rains, et al., 1976, Land Resource Study 22: The Agricultural Development of The Gambia, An Agricultural, Environmental and Socioeconomic Analysis (LRS22). A provisional legend was developed using the LRS22 study as well as knowledge from previous field experiences in Senegal and The Gambia. Because field work was limited to a few short multidisciplinary reconnaissance trips and an aerial overflight, the new mapping units were primarily delineated on the basis of the large-scale (nominally 1:50,000) aerial photographs. The legend was revised after studying numerous photo pairs or triplets selected over representative areas of the country. These representative areas were selected in order to get a good understanding of the mapping units shown on the LRS22 Soil Associations map and to evaluate the possibilities of locating precisely and/or dividing some of the units on the basis of a physiographic approach. The Teledyne 1:25,000 color infrared aerial photographs collected for the Gambia Mixed Farming and Resource Management Project were also consulted.

The provisional legend was used in completing the photo-interpretation exercise for the whole country. Three very short field trips and one overflight were organized during the same period, but no detailed soil survey observations (augerings,

mini-pits, profile pits) were actually made. The lack of field work necessitated a simplification of the interpretation lines in such a way that the map unit descriptions could be satisfactorily achieved by using available ancillary data. Interpretation work is uniform in quality because the project used recent (1982) and complete photo coverage of the country. The interpretation was finalized and transferred onto worksheets at the final scale of 1:50,000 in a single operation using a zoom transfer scope.

Photographically reduced negatives of the 1:50,000 soils sheets were then assembled to produce a mosaic which was used as a base for drafting the small-scale map sheets. The artwork and printing procedure is common to all project maps (see section 1.5).

4.3 LEGEND AND MAPPING UNITS

4.3.1 Introduction

The physiographic approach used for mapping the soils of The Gambia is widely used by many soil scientists involved in soil surveying and mapping. This approach excels in the representation of data gathered under the form of a structured legend. The legend displays much more information on landscape evolution and related soils distribution than would a classical taxonomical legend. The structure of the legend and mapping units are briefly described in Sections 4.3.2 and 4.3.3.

4.3.2 Legend

The only limitation placed on the design of the legend was that cartographic symbols should not exceed three digits. The legend was also tailored to both publishing scales (1:50,000 and 125,000). Structure was established at the highest level on the basis of predominant erosional and depositional processes, and at the two lower levels on the basis of physiography. The corresponding soil characteristics were identified by compiling the data presented by LRS22. Hence, the country was subdivided into five land types defined by the predominant erosional and depositional processes, with the first type subdivided into two formations on the basis of the intensity of dissection. These six formations were designated by a capital letter (the first symbol element used to identify the mapping units). This letter is used to identify the nature of the major process represented, such as A for alluvial or C for colluvial deposits.

The following formations were identified:

1. The soils developed on weathered material deriving from the Continental Terminal deposits, subdivided on the basis of

dissection: 1) the higher dissected plateaus of the eastern regions, D, and 2) the low hills and broad valleys of the western regions, S.

Lower level subdivisions were further made mainly on the basis of physiography, producing a total of six and seven mapping units for formations D and S, respectively.

2. The soils developed on colluvio-alluvial deposits. They occupy most of the lower slopes of the valleys, in which case they were subdivided according to their relationship with the surrounding land type, or they constitute the transition with the Gambia River floodplain. This C formation is made up of three mapping units.

3. The soils developed on predominantly alluvial deposits. They occupy most valley bottoms and the meander floodplain of the Gambia River, with the exception of the areas of marine influence. They may be rarely or never flooded or seasonally flooded. However, this concept was not used as a criterion to create a subdivision at the highest level since this formation is essentially dynamic as compared to formations D and S. A common symbol A is used, although subtitles do appear in the legend showing which mapping units are most likely to fall under one or the other category, with five and four mapping units, respectively. These mapping units were distinguished on the basis of physiography and location in the Gambia River basin.

4. The soils developed on predominantly fluvio-marine deposits, showing the extent of the influence of saline waters. These soils may be subject to total inundation or to wet-season inundation, but again the dynamics of the region does not favor a clear cut differentiation at the higher level. Thus, all mapping units fall under formation M with subtitles suggesting the split between tidal and wet-season inundation. Further subdivisions are made on the basis of physiography and vegetation cover. The total number of mapping units in this formation is four. It should be kept in mind that the boundary between formations A and M is also not clear cut, as the influence of saline waters upriver is strongly dependant on highly variable climatic conditions.

5. The soils developed on littoral deposits. These soils correspond to dunes and beaches constituting the two mapping units of formation E shown on the 1:50,000 scale map. These two mapping units are, however, combined into a single unit on the small-scale map.

The first cartographic symbol is thus one of the following capital letters: D, S, C, A, M, or E. The second code is a number ranging from 1 to 6 indicating a change in physiographic

unit. The third element is a number ranging from 1 to 3 showing, when applicable, a change in physiographic position within the preceding level of classification or a different location or vegetation cover. Hence, any mapping unit is identified by a two or three digit symbol such as S3 or A41. Additional information appears in the legend through the various headings which complete its structure. In Section 4.3.3, Mapping Unit Descriptions, direct reference is made to LRS22 and to the Gambian soil series. The mapping unit descriptions often refer to the classification of those soils in the French system as used by ORSTOM in neighboring Senegal, and in the Soil Taxonomy System (STS) in use in the United States.

4.3.3 Mapping Unit Descriptions

4.3.3.1 Soils developed on weathered material derived from the "Continental Terminal", D, S

Most of the Gambian landscape is developed over a highly weathered detailed sedimentary deposit (clayey sandstone of variegated color with interelated beds of gravel, sand, and clay) dating from the late Tertiary era. This is known as the "Continental Terminal". The typical "Continental Terminal" landform is a dissected plateau with rather narrow valleys, scarp slopes capped with an outcropping iron pan, and with gentle lower colluvial slopes. In the western part of the country, however, the plateau dips gently westward and merges into low gently sloping interfluves and fairly broad depressions and valleys. The transition from the higher plateaus of the dissected landscape D in the east to the low hills of the subdued landscape S in the west occurs towards Nokunda, west of the Bao Bolon on the north bank, and at the level of a line joining Bwiam to Maotah Point on the south bank.

A common set of characteristics applies to all the soils developed on the "Continental Terminal" within The Gambia. They all offer a low chemical fertility. The cation exchange capacity and the organic matter of these soils are low. The base saturation is usually fairly high. The pH tends to decrease slightly with depth from an average value of about 6 in the topsoil to an average value of 5.5 in the subsoil. These soils are usually poorly structured and of hard or very hard consistency when dry. The soil textures of surface horizons are usually sands or loamy sands, and less commonly sandy loams. The soil textures of subsoil horizons are most frequently sandy clay loams or sandy clays, though the range is from loamy sands to clays. The soils on the colluvial slopes and on the interfluves of the subdued landscape usually are coarser textured than the soils of the plateaus of the dissected landscape.

A. Dissected relief (higher dissected plateaus of the eastern regions), D

The Senegambian Plateau possibly reached an elevation of 40 or 50 m. above sea level. Three physiographic units are recognized on this plateau: the "uplands", the "plateau edges and upper slopes", the "lower slopes". In the "uplands", an "inner zone" (D11) with generally deeper soils, is distinguished from the "outer zone" (D12), with its shallower soils. The distinction between these two mapping units is based more on the frequency of "bowé", than on the proportion of agricultural land and woodland or on the physiographic position.

On reading the description of two mapping units D11 and D12, it should be kept in mind that it is not the purpose of this study to discuss whether the upland iron pans are relicts from older truncated ferralitic soils or have concurrently developed within the present soil.

Plateau edges and upper slopes include "scarps and detrital slopes" (D21) some "dissected talweg heads" (D22) and the more extruded "dipslopes and upland valleys" (D23). The differences are physiographic in nature, although the D21 and D22 units are largely in woodlands, while D23 is often under cultivation. The "lower slopes" are often very gentle "colluvial lower slopes" (D3), associated with scarp retreat and merging with the lower alluvial areas. These slopes are usually cultivated.

UPLANDS, D1

Symbols: D11, D22

Description

D11: Inner zones, generally flat areas, often cultivated with few or no "bowé"

This mapping unit covers the interior of the more extensive uplands. These uplands are generally flat, with deep soils, and often cultivated. The frequency of "bowé", small depressions flooded during the wet season and surrounded by a locally outcropping iron pan, is relatively low as compared to mapping unit D12. Within a short distance from the "bowe" or from the plateau edge, soils deepen and the iron pan is most commonly replaced by a plinthite layer at depth. This soil association is similar to Soil Association 11 of LRS22. This interpretation, however, tends to delineate units with a higher proportion of

deeper soils; although the boundary between units D11 and D12 is not really clear cut.

Soils of D11 are often deep. They have a pale colored matrix and show mottling and concretionary development usually related to inperfect drainage conditions. The texture may be coarse in the topsoil, but often becomes finer than sandy clay loam at depth, with sandy clay or clay being common. The base saturation may be quite low. The major dominant soil series present are expected to be the Bowé, Jar Kunda, Nyamanari and N'Joren Series. Minor dominant series are Kalem Poll, N'Geyen Sanjal and Faba Series. Dominant soils are depleted ferrugonous tropical soils with pseudogley mottling and concretions, associated soils are various shallow, undurated or lithic weakly developed soils and ferruginous tropical soils. These soils would be classified a Haplustox or also Eutrustox as dominants and Lithic, Petroferric or Plinthic Haplustox or also as Eutrustox as associated soils.

D12: Outer zones, bordering areas of dissection, seldom cultivated with frequent "bowé"

This mapping unit includes the border area of the more extensive uplands. On more dissected plateaus, it also may occur as larger areas extending towards the inner part of the plateau. It commonly constitutes the transition between units D11 and D21. These areas are seldom cultivated, and generally left as woodlands. Small wet season ponds related to iron pan outcrops (bowé) are more common in D12 in comparison to unit D11. The soil association represented here is similar to Soil Association 10 of LRS22. Better delineation than in the previous mapping of this soil association, especially at its boundary with with unit D21, was made, because, the good quality of available aerial photography.

Soils may be deep, but most are rather shallow on an iron pan or gravel at variable depths, with or without an overlying soft concretionary layer. The average texture, usually a sandy clay loam, seems to be lighter than in the D11. The base saturation of the soil is generally low. The major dominant soil series present are expected to be Bulgurk, Kalem Poll and Faba Series with Niji, Jar Kunda and N'Joren Series as minor dominant soil series. Dominant soils are lithosolic and indurated, eroded, weakly developed soils or truncated indurated ferruginous tropical soils; minor dominant soils are depleted ferruginous tropical soils with mottles and concretions. In the STS, dominant soils would be classified as Lithic Ustorthents and Plinthic Haplustox, for example, and minor dominant soils as Ultic Haplustox or Eutrustox.

PLATEAU EDGES AND UPPER SLOPES, D2

Symbols: D21, D22, D23

Description

D21: Scarps and detrital slopes

A more or less pronounced escarpment reaching an elevation of 40 to 60 m and capped by outcropping iron pan borders most of the "uplands". This forms unit D21 together with the edge of the plateaus and the detrital materials accumulating below the scarp slope. Small buttes and iron capped outliers and hills are also included in this mapping unit. The soil association is similar to Soil Association 8 of LRS22, but also locally contains Soil Association 9.

Soils are mostly shallow, stony, and bouldery especially on the slopes and with frequent outcrops at the plateau edge. The boundary between the scarp slope and the colluvial lower slope, unit D3, usually is strongly marked by a break in slope often corresponding to the edge of the cultivated zone. The woodland cover of the mapping unit is in a fairly undisturbed state.

Major dominant soil series to be expected are the Scarp and Bulgurk series with Kalem Poll, N'Geyen Sanjal and Kerewan Series as minor dominants. Major dominant soils are eroded, raw mineral soils and weakly developed soils (lithosolic) with indurated, depleted ferruginous tropical soils, often with gravel and cuirasse. In the STS, dominant soils would be classified as Lithic Usthorthents and Petroferric Haplustox, minor soils would be classified as Ultic Haplustox with again some Lithic Usthorthents and Petroferric Haplustox.

The woodlands constituting the vegetation cover of mapping unit are in a fairly undisturbed state.

D22: Dissected talweg heads

This unit is represented in a few locations where some drainage ways show talwegs eroding headwards into the scarp slopes and the plateaus. Soils are predominantly shallow and stony or bouldery. The soils association is similar to Soil Association 9 of LRS22 which is actually included in Soil Association 8. The distinction between Soil Association 8 and 9 seems arguable, since numerous small talweg heads actually are found along the scarp. These are very similar to those mapped under Soil Association 9. Therefore, only a few cases of talweg heads cutting through parts of a plateau were mapped under unit D22, while most of Soil Association 9 actually falls under unit D21. The vegetation cover

is the same as for D21. It is fairly undisturbed woodlands.

Dominant soil series are the Scarp, Kalem Poll and Kerewan Series. This is an association of eroded, lithosolic, raw mineral soils and weakly developed soils, and depleted ferruginous tropical soils over gravel and cuirasse. These are mainly Lithic Ustorthents, Petroferric and Ultic Haplustox in the STS.

D23: Dipslopes and upland valleys

Dipslopes and upland valleys are intermediate surfaces mostly located between the uplands and the lower colluvial slopes. Dipslopes are observed when the plateau grades to the colluvial slope through a long gentle slope. Upland valleys are at a somewhat higher level than the main valleys and a noticeable break in slope often marks the boundary with the lower colluvial slope. Scarp slopes may border upland valleys, but the scarp will be normally much less pronounced. This mapping unit is not well defined in terms of physiography. The same thing is true of Soil Association 12 of LRS22. The soils in this unit are more subject to erosion than those on the lower colluvial slopes. They are similar to the soils of the plateaus, often being rather fine textured (sandy clay) close to the surface. Agricultural cultivation is often associated with these soils. Ferradi, Bowe and Jar Kunda Series are the major dominant soils series. The minor dominants being Kalem Poll, Charmen and Fitu Series.

Major dominant soils are depleted, weakly unsaturated, ferralitic soils and depleted ferruginous tropical soils with pseudogley mottling and concretion. Minor soils are eroded weakly developed soils, various ferralitic-ferruginous tropical intergrades and modal depleted ferruginous tropical soils. This would be classified in the STS as .dominant Ultic Haplustox or Eutrustox with minor Lithic Ustorthents, Petroferric and Typic Haplustox, among others.

LOWER SLOPES, D3

Symbol: D3

Description

D3: Colluvial lower slopes

The colluvial lower slopes border the Gambia River floodplain and majority of Gambia River tributaries. These slopes cover a relatively large area resulting from an important period of scarp retreat and colluvial deposition concurrent with the Ogolian marine regression. This mapping unit includes both Soil Association 6 and 7 of LRS22, as their differentiation seems

questionable. The soils show a wide range of drainage conditions; the soil color varies from red to mottled pale yellow. Topsoils are deep and coarse textured. Pronounced textural breaks within the profile do show evidence of colluvial transportation, but an alluvial contribution also is locally possible. These slopes are very gentle (1 percent) and largely cultivated.

Major dominant soil series are Misera, Charmen and Bafuloto Series with Sutoma, Dandugu, and Fass Series as minor soil series. Dominant soils are the non-depleted or reworked depleted, ferruginous tropical soils with intergrades to depleted, weakly unsaturated, ferralitic soils upslope. Minor dominant soils are non-depleted or depleted reworked ferruginous tropical soils, sometimes with pseudogley mottling and concretions, on reworked fine textured material. Dominant soils would be classified as Ultic Eutrustox or Quartzipsammentic Eutrustox and minor dominant soils as Ultic Haplustox with Oxic Quartzipsamments.

B. Subdued relief (low hills and broad valleys of the western regions), S

The subdued landscape of the western regions shows variations in morphology due to the complex erosional/ depositional history, which affected this part of the country together with western Senegal during the Quaternary.

Three groups of residual uplands and upper slopes are identified for a total of five mapping units. Lower slopes and depressions have been divided into two mapping units.

1. Residual uplands and upper slopes, S1, S2, S3

TYPICAL RESIDUAL UPLANDS AND UPPER SLOPES, S1

Symbols: S11, S12

Three types of uplands are identified, corresponding to Soil Association 1, 2 and 3 of LRS22, although there are some differences in how these are interpreted and mapped. The first grouping of uplands shows no striking particularity. These are recognized as being composed of typical residual uplands and upper slopes. They are represented in two mapping units, that distinguish the "crests and interfluves" (S11) from the "middle to upper slopes" (S12). A second group of uplands, most extensive in the North Bank Division shows clues of ancient eolian influence related to the development of the Quaternary ergs of Senegal. Here, "slightly elevated ridges" (S21) and "middle to upper slopes" (S22) were mapped separately. Active erosional processes affect the third group of uplands. These constitute a series of "eroded promontories" (S3) pointing towards the Gambia River and

the Bintang Bolon and mostly located on the southern bank.

Symbols: S11, S12

Description

S11: Crests and interfluves

The most prominant "crests and interfluves" of Soil Association 1 of LRS22 are represented by this mapping unit. Soils are dry, well drained, red ferralitic soils. They have deep, coarse textured horizons over sandy clay. The soils were probably formed under earlier, wetter climatic conditions. The unit covers small areas within unit S12. It bares parkland savanna that is now largely under cultivation.

The dominant soil series is the Misera Series. The soils are modal, depleted, weakly unsaturated ferralitic soils which would be classified as an Ultic Eutrustox in the STS. Intergrades with ferruginous tropical soils may also be present.

S12: Middle to upper slopes

This mapping unit largely corresponds to Soil Association 1 of LRS22. Most summits, however, were mapped under unit S11. The dominant soils are deep, well drained, red ferralitic soils with a deep, coarse textured topsoil over sandy clay or sandy clay loam. They conceivably formed during an earlier more humid climatic period. This unit is most frequent in the western regions, mainly in the Western Division and west of the Bao Bolon in the North Bank Division. The vegetation cover is parkland savanna that is now largely under cultivation.

The soil series represented are Misera, Charmen and Timpa Series. They are depleted ferralitic soils and depleted ferruginous tropical soils with various intergrades. These soils are commonly classified as Ultic Eutrustox in the STS.

UPLANDS SHOWING ANCIENT EOLIAN INFLUENCE, S2

Symbols: S21, S22

Description

S21: Slightly elevated ridges

The most salient ridges of Soil Association 2 of LRS22 are represented by this mapping unit. They are often north-south oriented and possibly related to the ancient complex of the Sine Saloum area of Senegal. The soils are deep and well drained,

reworked ferruginous tropical soils. These are the reddest soils of Soil Association 2. They are lighter textured than the soils of unit S11 with a deep, coarse textured topsoil over sandy loam or sandy clay loam. The major constituent of this unit is the Bafuloto Series, reworked, depleted ferruginous tropical soils which are likely to be classified as Eutrustox in the STS. The unit covers small areas within unit S22. The vegetation is a parkland savanna which may be commonly cultivated.

S22: Middle to upper slopes

This mapping unit largely corresponds to Soil Association 2 of LRS22, though most of the ridges come under unit S21. It bares a relationship to the ancient dune complex present in the Sine Saloum area of Senegal.

Soils are deep and well drained, and somewhat lighter textured than those in unit S12, having a deep, coarse topsoil over clay loam to sandy (clay) loam or loamy sand. Soil hues are redder upslope and paler down slope. The major soil series in this association are Charmen, Bafuloto, Fass and Timpa series, e.g., depleted ferruginous tropical soils and modal depleted, weakly unsaturated ferralitic soils with various intergrades and commonly reworked soils. In the STS, Ultic Eutrustox occur with Quartzipsammentic Eutrustox, and reworked soils may even classify as Oxic Quartzipsammentic.

This mapping unit is mainly confined to North Bank Division, west of the Bao Bolon. It bares a parkland savanna vegetation type which may commonly be cultivated.

UPLANDS SHOWING ACTIVE EROSIONAL PROCESSES: S3

S3: Eroded promontories

This mapping unit contains eroded promontories projecting in the Gambia River and Bintang Bolon floodplains. It corresponds to Soil Association 3 of LRS22, merging gradually, to the east, into Soil Association 8 of LRS22 or mapping unit D21 of this study. It is, however, an arbitrary decision that locates the transition near the divisional boundary between Western and Lower River Divisions. The soil association includes both shallow and deep soils; all of which are freely drained and often reworked or having massive iron pan. This iron pan seems to be related to the lower iron pan level described by geomorphologists as outcropping below 15 meters in elevation (Michel, 1973). These soils are normally not cultivated. Forest parks commonly have been established in these areas.

The soil association is composed of the Kalem Poll and

Kerewan Series, which become increasingly dominant eastwards, and with the Misera, Charmen and Bafuloto Series as other major components. Thus lithosolic, eroded, weakly developed soils and shallow depleted ferruginous tropical soils over gravel or cuirasse are increasingly replacing moderately depleted, weakly unsaturated, ferralitic soils and depleted ferruginous tropical soils. In the STS, Eutrustox are losing ground to Haplustox and Lithic Ustorthents.

2. Lower slopes and depressions, S4, S5

The lower physiographic units are not subdivided to the same degree as the uplands. The two mapping units represented are the "lower colluvial slopes" (S4) and the "imperfectly drained depressions" (S5).

LOWER SLOPES, S4

Symbol: S4

Description

S4: Colluvial lower slopes

The colluvial lower slopes represented in this mapping unit may have been affected by several phases of localized colluvial action and reworking. The unit closely corresponds to Soil Association 4 of LRS22 and is confined to the western divisions. Textural discontinuities are common. The upper horizons are coarse textured often to about a depth of one meter with sandy loam or sandy clay loam textures in the lower horizons. The color gradually varies along the slope with a dominant, somewhat mottled pale yellow associated with slow or impeded drainage. This soil association is often cultivated in the higher reaches. In the lower reaches where shallow soil may occur overlying recemented iron pan gravel, the vegetation cover is often woodlands.

The major dominant soil series is Berending Series with associated Sutoma, Badari, Kurau Bakari and Kulari Series. These are young, or reworked, depleted ferruginous tropical soils which would be classified as Ultic Eutrustox in the STS. The major dominant series likely would be Quartzipsammentic Eutrustox.

DEPRESSIONS, S5

Symbol: S5

Description

S5: Imperfectly drained depressions

Many, often large, depressions are represented in the western regions of The Gambia. They are frequently elongated in shape and seem to be related to ancient drainage areas in the late Quaternary, since they are associated with drainage lines or seasonally, waterlogged headwater sites. The unit corresponds to Soil Association 5 of LRS22.

The soils are normally imperfectly drained and often shallow. They are seldom cultivated, but instead remain in woodlands, sometimes in reserved forest parks. This unit is related to the elongated clayey depressions of the Saloum area of Senegal where hydromorphic soils are largely dominant and even show a vertic tendency.

The most representative series is Nyambai Series, which is associated with the Faba and Koina Series. These soils are hydromorphic or indurated with pseudogley, depleted ferruginous tropical soils. In the STS the soils would be classified as Ultic, Plinthic or Aquic Eutrustox and Haplustox.

4.3.3.2 Soils developed on colluvio-alluvial deposits, C

Two types of coluvio-alluvial deposits are identified: 1) those covering the lower valley slopes and 2) those constituting the transition with the major floodplains. The "valleys" are subdivided into "narrow valleys of the dissected landscape" (C11) and "broad valleys of the subdued landscape" (C12).

The colluvio-alluvial transition is a complex mapping unit which often includes the narrow mapping units between the colluvial lower slopes (D3 or S4) and the Gambia River floodplain. The three mapping units, the C11 and C12 "valleys" and the "complex colluvio-alluvial transition to the Gambia River floodplain" (C2), correspond to Soil Association 13 of LRS22.

VALLEYS, C1

Symbols: C1, C2

Description

C11: Narrow valleys of the dissected landscape D

This mapping unit appears as a narrow strip corresponding to the valley bottom of minor, seasonally active tributaries of the Gambia River. They are generally located in the dissected landscape (D). It is most often represented within unit D3. The

valleys in unit D23 do not usually show a colluvio-alluvial strip, since the minimum mapping size standards are seldom met. The valley floors represented commonly have a width of about 200 m. Riparian thickets and woodlands are typical of this mapping unit.

The dominant soil series is the Banalcuda Series. The wide distribution of the mapping unit throughout the country suggests possible variability, which only can be assessed by fieldwork. Soils are hydromorphic with little organic matter, but showing various degrees of gleyification. A number of the soils would be classified as Tropaquepts in the STS.

C12: Broad valleys of the subdued landscape S

This subdued landscape is characterized by broad valleys, which are almost completely occupied by extensive colluvio-alluvial strips. This unit often reaches a width of more than one kilometer. A larger variety of soils series are expected, with hydromorphic conditions increasing from the edge of the unit downslope to the drainage channel. Soils range from somewhat hydromorphic, depleted ferruginous tropical to hydromorphic soils with little organic matter and showing a variable degree of gleyification. Classification in the STS would range from Ultic and Aquic Eutrostox to Tropaquepts.

Riparian thickets and woodlands are typical in this mapping unit, but agricultural activity has considerably modified the vegetation cover.

COLLUVIO-ALLUVIAL TRANSITION, C2

Symbol: C2

Description

C2: Complex colluvio-alluvial transition to the Gambia River floodplain

The transition between the lower colluvial slopes and the Gambia River floodplain is often marked by a narrow strip showing a complex of somewhat hydromorphic, ferruginous, tropical soils, or weakly developed soils and various types of hydromorphic soils. These soils would be classified as Eutrostox and Tropaquepts in STS.

A saline component is likely to appear along the border with the fluvio-marine deposits of units M11 or M12, Overlying hydromorphic soils can occur near the bolons. Riparian thickets and woodlands are typical in this mapping unit.

4.3.3.3 Soils developed on predominantly alluvial deposits, A

Alluvial deposits are predominantly those in the Gambia River floodplain. Minor tributaries also may show true alluvial features, such as levees or terraces. Two groups of alluvial deposits are recognized according to the expected frequency of flooding. "Levees and terraces" are rarely or never flooded, while "basins or lower lying floodplains" are seasonally flooded. In the vicinity of Walli Kunda, mapping units share a number of common characteristics and distinct trends in compositions, which are the result of the presence of a calcareous sandstone formation.

Soils series with high base saturation and alkaline reaction are dominant in this area, whereas soils with lower base saturation and acid reaction may occur elsewhere in the same mapping unit. This is especially the case for units A12, A22 and A42.

Nearly all alluvial soils are hydromorphic soils. They are grey colored and often have a high proportion of silt and clay. The structure is often well developed and related to soil wetness. The organic water content is usually high.

1. Rarely or never flooded, A1, A2, A3

The Gambia River has built a series of major levees, which are represented by the following mapping units: the "major levees in the Upper River Division" (A11) and the "major levees in the MacCarthy Island Division" (A12).

Minor levees are found adjacent to the major levees. A complex with small terraces, splays and spillways also is located around the basins. This complex is represented in the mapping units by the "minor levees, terraces and spillways in the Upper River Division" (A21) and the "minor levees terraces and spillways in the MacCarthy Island Division" (A22). "Ancient meander fills and terraces" are identified in the Upper River Division and given the mapping unit label A3.

MAJOR LEVEES OF THE GAMBIA RIVER, A1

Symbols: A11, A22

Description

A11: Major levees in the Upper River Division

These levees border the Gambia River mainly in the Upper River divisions of The Gambia. Typical vegetation is open woodland. The levees are normally not flooded for long periods of time. This unit does corresponds to some extent to Soil Association 23 in LRS22.

The soils are young and weakly developed with marked morphological variations showing a complex depositional history. These soils would be classified as Tropepts in the STS.

A12: Major levees in the MacCarthy Island Division

Narrow levees border the course of the Gambia River in the MacCarthy Island Division. The levees normally are not flooded and have an open woodland vegetation. This unit comprises only the levees of Soil Association 19 in LRS22. The terraces in this soil association are included in unit A22.

The major constituent soils are the Bambo Tumang and Walli Kunda Series. The Bambo Tumang series is most dominant and represented throughout the unit's extent. The Walli Kunda Series is locally dominant near the Kai Hai Islands. Various associated soil series may also be represented. These seem to proportionally increase eastwards. Of these soils, the Jakhaly and Kudang Series are the most common. In the STS, the dominant soils would be classified as Aeric to Tropaqualfs or Tropaquepts. Associated soils would be typic Tropaqualfs and Tropaquepts. The soils are hydromorphic soils with little organic matter, but often with pseudogley throughout the profile. They are neutral to strongly acid, usually fine textured soils with a high base saturation. However, alkaline horizons are present in the soils of the Walli Kunda and Jakhaly Series.

MINOR LEVEES, TERRACES, AND SPILLWAYS OF THE GAMBIA RIVER, A2

Symbols: A21, A22

Description

A21: Minor levees, terraces and spillways in the Upper River Division

This unit contains the lower levees, low lying terraces and the splays and spillways of the Gambia River in the Upper River Division. These levees and associated features are not as well drained as the major levees of unit A11 and bares a grassland vegetation with scattered shrubs. The unit corresponds to some extent to Soil Association 22 in LRS22. The soils association

represented also are similar to those characterizing the adjacent basins, unit A41, although drainage conditions are expected to be better. Soils are hydromorphic soils with little organic matter, but with pseudogley throughout the profile. They have a neutral to strongly acid reaction, a high base saturation and a variable texture. Various soil series (i.e., Banatenda Series) may be represented. These soils would be classified as Typic and Aeric Tropaqualfs or Tropaquepts in the STS. A disturbed woodland vegetation characteristic of this mapping unit.

A22: Minor levee, terraces and spillways in the MacCarthy Island Division

This unit includes the lower levees, the low lying terraces and the splays and spillways of the Gambia River in MacCarthy Island Division. It groups the lower lying features of Soil Association 19 with Soil Association 20 of LRS22. These riverine features are normally not flooded. Disturbed woodlands are the major vegetation type.

The major soils of the association are the Walli Kunda and Bambo Tumang Series. The Walli Kunda Series is largely dominant near Deer Islands and Kai Hai Islands. Bambo Tumang series dominates eastwards. Jakhaly and Kudang Series are the major associates These soils are hydromorphic soils with little organic matter, but generally with pseudogley throughout the profile. They have a neutral to strongly acid reaction and a high base saturation. However, alkaline horizons are found in the soils of Walli Kunda and Jakhaly series. The texture is commonly fine. Dominant soil series would be classified as Aeric Tropaqualfs and Tropaquepts in the STS. Associated soils would be Typic Tropaqualfs and Tropaquepts.

MEANDER FILLS OF THE UPPER GAMBIA RIVER, A3

Symbol: A3

Description

A3: Ancient meander fills and terraces

These features are not identified in the soil associations of LRS22, but are included in either colluvial or alluvial associations. These features are quite visible on the aerial photography used for this survey. Therefore, they have been tentatively mapped as "ancient meander fills and terraces", although this has not been substantiated by field work. Unit A3 is represented east of Brifu, around Garowal, south of the Faraba swamp and south of Kai Hai Islands. This unit is seldom cultivated, and often in in a more dense forest than that on the

nearby terraces of unit A21. The features are similar in some respects to the depressions of mapping unit S5. Soils normally are imperfectly drained and rather fine textured. Hydromorphic, ferruginous tropical soils or hydromorphic soils with possible vertic tendencies are characteristic. These would be classified from Aquic Eutrustox to Vertic Tropaquepts in the STS.

B. Seasonally flooded, A4, A5, A6

The lower reaches behind the levees are seasonally flooded. Sloughs and basins are represented by mapping units: "basins in the Upper River Division" (A41) and the "basins in the MacCarthy Island Division" (A42). "The low lying floodplain of the Upper Gambia River" is characterized as a complex of "drainageways and depressions" (A5), forming a single mapping unit.

Small tributaries of the Gambia River show local depressional features, which are seasonally inundated by runoff waters. These "valley bottom" soils (A6) are represented by a single mapping unit.

BASINS OF THE UPPER GAMBIA RIVER, A4

Symbols: A41, A42

Description

A41: Basins in the Upper River Division

These broad, slightly concave sloughs bare a natural grass vegetation and are subject to wet season inundation, which is the result of river floods and rainfall runoff. This mapping unit is mainly represented in Upper River Division. It largely corresponds to Soil Association 21 of LRS22.

The major component of the Soil Association is Jonkoto Series with the Kudang Series as the secondary dominant. The Prufu and Banatenda Series also are associates. These soils are very poorly drained. They are fine textured in the dominant soil components, and have variable textures in the associated soils. A few of these ponded depressions remain flooded throughout the dry season. They are hydromorphic soils with little organic matter and usually with pseudogley or even gley throughout the profile. They have a neutral to strongly acid reaction. Most of these soils would be classified as Tropaquepts in the STS.

A42: Basins in the MacCarthy Island Division

This mapping unit occupies a very flat grassland area, partially or completely enclosed by a complex of higher lying

terraces and levees. These basins are often higher lying than the low lying floodplain of A5. This unit corresponds to a large extent to Soil Association 18 of LRS22.

The major constituents of the soil association are Kudang and Jakhaly Series. The Kudang Series is most dominant and is represented throughout the unit's extent, whereas the Jakhaly Series locally dominates between Deer Islands and Kai Hai Islands. Various associated soil series increase in proportion eastwards. The most common are the Bambo Tumang and Walli Kunda Series. In the STS, the dominant soils would be classified as Typic Tropaquepts or Tropaqualfs. The associated soils would be Aeric Tropaquepts and Tropaqualfs. These soils are hydromorphic soils with little organic matter but with pseudogley throughout the profile. They are usually fine textured soils and they often have a rather low base saturation and a neutral to strongly acid reaction with the exception of Jakhaly Series, which has an alkaline reaction and a high base saturation. Alkaline horizons are found in the soils of Walli Kunda Series.

LOW LYING FLOODPLAIN OF THE UPPER GAMBIA RIVER, A5

Symbol: A5

Description

A5: Drainageways and depressions

A low lying floodplain forms the transition between nonsaline soils from Pasal Island to Brikana Island. A high density of interconnecting temporary and permanent drainage depressions are characteristic of this unit. The flooding is seasonal. This mapping unit closely corresponds to Soil Association 17 of LRS22. The extent of the influence by salt water varies with time. The delineation of this mapping unit to the west is an arbitrary boundary. The vegetation cover is characterized as a medium height grassland with some incursions of riparian thicket.

The major component of the soil association is the Kudang Series The Jakhaly Series is a second component, which overrules Kudang Series in the vicinity of Walli Kunda. The soils are hydromorphic with little organic matter. They would be classified as Typic Tropaquepts in the STS. They are fine textured, and have a high base saturation. They have neutral to strongly acid reaction in the Kudang Series and alkaline reaction in the Jakhaly Series. The Jonkoto Series appears to be dominant west of Deer Islands.

VALLEY BOTTOM OF TRIBUTARIES, A6

Symbol: A6

Description

A6: Valley Bottom

Depressional areas of the valley bottom of some minor tributaries of the Gambia River were locally mapped as a separate unit showing the sites where runoff waters stagnate for some time at the end of the rainy season. This unit does not show on the soil association Map of LRS22. The soils should be hydromorphic with little organic matter and having pseudogley throughout the profile. They would be classified as Tropaquepts in the STS.

4.3.3.4 Soils developed on predominantly fluvio-marine deposits, M

The fluvio-marine deposits are somewhat arbitrarily separated into two types according to the frequency of inundation.

The tidal flats are subject to inundations. The "mangroves" (M11) are distinguished from the "barren flats" (M12). The "low lying floodplains and terraces" of the Lower Gambia River, (e.g., the "low lying river floodplain" (M2) and the "low lying river terrace" (M3)), are subject to wet season inundation. Differentiation between units M2 and M3 is fully justified in terms of physiography, though very difficult to do through aerial photographic interpretation.

All fluvio-marine soils are hydromorphic. They have a gray color and often a very high proportion of silt and clay. Because of soil wetness, structure is often much less developed than in the alluvial soils. The organic matter content is usually high and may be very high in some mangrove soils.

1. Subject to tidal inundation, M1, M2

TIDAL FLATS, M1

Symbol: M11, M12

Description

M11: Mangroves

This mapping unit corresponds to Soil Association 14 of LRS22. It is in mangrove vegetation and occurs along the Gambia River upstream as far as Kau-ur. The dominant soil is the

Mangrove Soils Series, which group somewhat organic, peaty soils on clayey and usually highly pyrite muds. They are hydromorphic, weakly developed soils. They may have a high organic matter content and a high sulphide content. The PH is usually neutral in situ, but can drop to values lower than 4 after oxidation. Sandier muds are likely to be found near the coast. These soils are commonly classified as Typic Sulfaquents in the STS.

M12: Barren flats

This mapping unit corresponds to the barren flats of Soil Association 14 in LRS22. The Mandori Series represents the dominant soil. It occurs upstream along the Gambia River as far as Kau-ur, constituting a fringe around larger areas of unit M11. The soils are very saline, extremely acid, and fine textured throughout the profile. The base saturation is high and the exchangeable sodium percentage (ESP) normally exceeds 20.

The soils range from acid saline sodic soils to saline hydromorphic soils. They would be classified as Typic Sulfaquents with intergrades to Typic Sulfaquepts in the STS.

2. Subject to wet season inundation, M2, M3

LOW LYING FLOODPLAIN OF THE LOWER GAMBIA RIVER, M2

Symbol: M2

Description

M2: Low lying river floodplain

This mapping unit includes, the lower reaches of the lower Gambia River floodplain up to Pasal Island. Minor areas of denuded mangrove soils also have been included in this mapping unit. Saline waters affect these soils for part of the year, but much of the salt is flushed out by the rains. The physiography of the unit is that of flat low lying extensions of the valley floor, possessing a complex network of temporary and permanent drainageways and depressions. It has a slightly lower elevation than unit M3. The vegetation type normally is a medium tall grass savanna subject to periodic flooding. The soil unit corresponds to some extent to Soil Association 16 in LRS22. The Salikene Series is the major constituent and the very strongly acid mandori Series the associated constituent.

A high watertable prevents the soils from becoming very acid. The watertable occurs within 30 cm of the surface. The PH ranges from 5.0 to 6.5, increasing in value with depth. The texture is

fine, and the base saturation high. The ESP normally exceeds 20. The soils are predominantly saline, hydromorphic soils with associated saline, sodic soils. They would be classified as Typic Sulfaquents with possible intergrades to Typic Sulfaquents in the STS.

LOW LYING TERRACE OF THE LOWER GAMBIA RIVER, M3

Symbol: M3

Description

M3: Low lying river terrace

This mapping unit consists of flat, low lying terraces, which are mainly extensions of the valley floor. It is characterized by a complex network of temporary and permanent drainageways and depressions. This unit is slightly higher in elevation than unit M2. It corresponds to some extent to Soil Association 15 in LRS22. Mandori Series is the major constituent and Salikene Series is the major associated series. It occurs along the Gambia River and upstream to Pasal Island. The soils are saline, fine textured, and very strongly or extremely acid. The depth to a watertable is often deep and can even occur below two meters depth. The soil has a high base saturation. The ESP in the soil normally exceeds 20. These acid, saline sodic soils and saline hydromorphic soils would be classified as Typic Sulfaquepts and Typic Sulfaquents, with intergrades present in the STS.

The vegetation is mainly herbaceous with the possible presence of woody species.

4.3.3.5 Soils developed on littoral deposits, E

The littoral deposits group the "coastal sand dunes" (E1) and the "coastal sand beaches" (E2). Both mapping units are included in Soil Association 24 of LRS22, which actually does not mention much about the sand beaches. The two are merged into a single mapping unit E on the small scale map.

DUNES, E1

Symbol: E1

Description

E1: Coastal sand dunes

Two types of dunes are present along the Gambian coastline, but they were not separated by the aerial photo interpretation.

The older red pre-Nouakchottian sand dunes show little profile development. The topsoil is somewhat stained by humic components, but there is virtually no structure throughout the profile. The soils are weakly developed, coarse textured soils of accumulation. The dominant soil series on the pre-Nouakchottian dunes is the Sanyang Series. The recent sand dunes show paler soils with a slight humic staining in the surface horizon. These are coarse textured, structureless raw mineral soils of accumulation. The dominant soil series is the Solifor Series.

The dunes have a variable vegetation cover often damaged by man and by browsing animals.

Soils would be classified as Quartzipsamments on most recent deposits and may show some incipient evolution on the older dunes with Eutric Ustropepts.

BEACHES, E2

Symbol: E2

Description

E2: Coastal Sand Beaches

Little information was available about the beaches of the Gambian coast. Most of them are likely to be sandy with raw mineral soils of accumulation, although some may locally be clayey with more developed sodic or hydromorphic soils.

CHAPTER 5

LAND USE/LAND COVER MAPS

5.1 INTRODUCTION

This chapter presents the results of the land use and land cover mapping effort. Three sets of interrelated thematic maps were prepared: Forested Lands, Rangelands, and Agricultural Lands. These maps fall into the general heading of land use and land cover. The term land cover relates to the types of features present on the surface of the earth, e.g., lakes, savanna woodlands, mangroves, millet fields, etc. The term land use relates to the human activity associated with a specific land surface (Lillesand and Kiefer, 1979). Examples include agricultural use, rangeland use, forestry, etc. From a practical standpoint, it is common to mix the two systems when a map is based on an aerial survey. While the land cover was directly interpreted from the aerial photographs of The Gambia, information about human and livestock activity on the land (land use) relied heavily on our knowledge of the region, on existing field data and references in the published literature.

The maps of Forested Lands, Rangelands, and Agricultural Lands were prepared at two mapping scales: 1:50,000 (twenty sheets to cover The Gambia for each theme), and 1:125,000 scale (four sheets for each theme).

This chapter describes the legends of the three map themes, the approaches used in the various map unit classifications, and the similarities and differences between map themes. Also presented is a description of the various land use and land cover types that appear on the maps, giving additional information which could not be shown graphically on the maps.

5.2 THE FORESTED LANDS MAPS

The Forested Lands map is essentially a map of vegetation cover of The Gambia. Numerous systems of mapping vegetation are used around the world, including physiognomic, ecological, areal-geographical and floristic systems (Kuchler, 1967). The approach adopted for this effort is a combination physiognomic-floristic system. This system combines physiognomic (structural) descriptions of the vegetation cover with basic information on the floristic composition of a vegetation community. Thus, this approach has the advantage of extending the scope and usefulness of the map. It was originally planned that this project use the German forestry maps of The Gambia, 1:10,000 scale, published in 1983, as the basic data source for the Forested Lands map. Upon examination of the German maps, it

became apparent that these "forestry" maps were actually land use and land cover maps; a decision was made to produce an original set of forestry maps. In doing so, additional vegetation cover types could be shown as identified from the aerial photographs. A vegetation classification approach could be used that would be consistent with vegetation maps published in Senegal, and the interpretations would be based on the most recent aerial survey available. Any discrepancies between the two map sets can be attributed to different dates of aerial photography, subjective differences inherent in photo interpretation, and different approaches to vegetation classification. This should not diminish the validity or usefulness of either set.

The fundamental map units of the Forested lands map are based on the physiognomic part of the physiognomic-floristic system. Physiognomic classifications are particularly valuable in that the maps can be used and interpreted by a wide variety of people in various disciplines, as they do not presuppose a taxonomic knowledge of the vegetation. Furthermore, this approach lends itself to vegetation mapping using aerial photography, since the various physiognomic types (or vegetation formations) can usually be distinguished on remotely sensed data (particularly on aerial photographs). The floristic approach to mapping must rely heavily, if not totally, on field data collection.

There are numerous systems used for describing the physiognomy of vegetation. The specific system adopted here is the "Yangambi" one, since it is particularly tailored to Africa (Trochain, 1957). This approach is based on an inter-African accord on the nomenclature of the types (formations) of vegetation of tropical Africa. Furthermore, in using the Yangambi physiognomic system, the Forested Lands maps are consistent with and directly comparable to vegetation and rangeland maps published on Senegal (see Stancioff, Staljanssens, and Tappan, 1986; Boudet, 1970). This system is found throughout the literature on the vegetation of West Africa.

The various physiognomic types found in the legend of the Forested Lands maps, as defined in the Yangambi approach, are summarized as follows:

A. Herbaceous steppe: an open herbaceous formation where trees and shrubs are totally or practically absent. Perennial and annual grasses do not usually reach a height of 80 cm.

B. Savanna: a herbaceous formation composed of a cover of tall grasses measuring at least 80 cm at the end of the growing season. Forbs of lesser heights occur among the grasses. This cover is generally burned each year.

Trees and/or shrubs are often scattered among the grass cover.

C. Shrub savanna: a savanna with scattered shrubs.

D. Tree savanna: a savanna with scattered shrubs and trees.

E. Savanna woodland: a savanna where trees and shrubs form a generally open cover.

F. Woodland (dry): an open woodland with deciduous trees of small to medium size whose canopies are more or less contiguous.

G. Gallery forest: a dense woodland formation found along watercourses in savanna, steppe or prairie environments

H. Palm grove: a generally open formation dominated by species of palm trees.

I. Mangrove: a coastal evergreen forest formation colonized predominantly by species of mangroves.

In addition to the above vegetation formation definitions, the following physiognomic classes of percentage of cover based on the ICITV (1976) classification were used to further define some of the formations:

Shrub savanna Tree savanna	Woody cover between 2 and 20%
Savanna woodland	Woody cover between 20 and 50%
Woodland	Woody cover between 50 and 80%

Finally, a height of 5 m was adopted to distinguish between shrubs and trees.

The Forested Lands legend is arranged in a hierarchical fashion such that the mapping units are grouped first into two major groupings. The first grouping, natural vegetation formations, are those which are relatively undisturbed by man's

activities, although in reality all of the present-day formations have probably experienced man-related modifications to varying degrees. The second grouping, anthropogenic vegetation formations, are those areas where man has a clear impact on the vegetation through cultivation, deforestation, etc. The second order groupings relate to basic landscape types: uplands, slopes, valleys, and alluvial plains.

The last level within the legend is the individual map unit which is based on the physiognomic types described above. Following the physiognomic type area a series of scientific names of the dominant and/or component species which further characterize the floristic make-up of the general veg ation community. The species names are listed in three lines, the first being dominant species of the tree stratum, the second refers to the shrub and small tree stratum, and the third refers to the grasses within the herbaceous stratum. It is not possible to list all species that occur in the vegetation community on a map legend and the order in which the species are listed is not significant. The actual choice and number of species listed in the legend is somewhat arbitrary; the selection was based on species known to occur commonly in the various plant communities. The floristic information was compiled from the best available sources, including Dunsmore, et al. (1976), Stancioff, Staljanssens, and Tappan, (1986), Boudet, (1970), and Diallo, (1968).

Because climate, especially rainfall, plays a major role in determining vegetation distribution in The Gambia, a gradual transition of vegetation types occurs from the drier areas in the north and east, to the areas of higher rainfall in the southwest. While it is difficult to show gradual transitions in vegetation types by drawing a line on a map, such transitions are reflected on the maps of Forested Lands through physiognomic types that reflect a transition. For example, the upland natural vegetation type that predominates in the north and east regions of the country is a savanna woodland. The southwest is dominated by a true woodland, and the transition between the two is gradual and nearly imperceptible. The gradation has been shown cartographically by the transitional savanna woodland/woodland (map unit BF), containing characteristics of both types. Because of the close relationship between vegetation physiognomy and floristic composition, the floristic make-up of the zonal vegetation communities also changes gradually over distance. For this reason, the savanna woodland map unit, occuring both in the eastern and western parts of the country, is subdivided into eastern and western plant communities. While these subtypes are not shown on the maps as distinct units, the first is considered to occur generally in the eastern half of the country, and the second dominates the western half.

5.3 THE RANGELAND MAPS

The map of rangelands is one which emphasizes the land use rather than the land cover aspects of the Gambian vegetation resource. The legend is organized into two major range groupings: natural rangelands, and rangelands associated with agricultural areas. The natural rangelands are those which occur in vegetation formations that are relatively undisturbed by man (refer to the description of natural vegetation formations). Because considerable grazing occurs within agricultural areas, the second grouping of rangeland types in the legend presents some basic information on grazing within cultivated areas.

The basic rangeland types are defined by the vegetation types, since there is a direct relationship between the quality and carrying capacity of rangelands and the vegetation physiognomy and composition. Nearly all of the vegetation types found in The Gambia are grazed or browsed by livestock to varying degrees. Because the approach to mapping rangelands from aerial photographs was essentiallly the same as that of drawing the vegetation boundaries, the delineations on the two maps are identical. The major difference between the two is that the Forested Lands map emphasizes land cover (vegetation cover), and the rangeland map emphasizes land use (vegetation for livestock).

Associated with each rangeland type are dry season grazing values, wet season grazing values, and principal species of grasses. Because the nature of this project did not allow for extensive field work, grazing values were compiled from available documents and from preliminary field observations made by this team. In some areas, grazing value could be extrapolated from the excellent pasture maps published over parts of Senegal bordering on The Gambia (see Diallo, 1968; Boudet, 1970). The grazing value ratings range from poor to excellent. No attempt was made to relate these ratings to quantitative measurements of carrying capacity for two reasons. First, data on carrying capacity were not available on a nation-wide basis. Second, a given rangeland type as defined here can occur on a variety of landscape and soil types, and within a varying climatic environment that changes from northeast to the southwest. The grazing values will certainly be affected by these variations, making a generalized, qualitative rating system more appropriate than a quantitative one.

The "Rangeland Resource Mapping Legend of The Gambia," adopted by the Gambia Mixed Farming and Resource Management Project, was used in the development of the legends prepared under the present effort. Upon examination, the legend was found to contain very little information on rangelands per se, but provided a good classification of the general land use and land cover types

found in The Gambia.

5.4 THE AGRICULTURAL LANDS MAPS

The maps of Agricultural Lands are also ones which stress land use over land cover. The agricultural map units are grouped under two main headings:

a) Rainfed Agriculture: Upland and Colluvial Soils.

b) Swamp and Irrigated Agriculture: Alluvial Soils. Non-agricultural lands are also shown, grouped under two additional headings:

c) Non-Agricultural Areas: Upland and Colluvial Soils.

d) Non-Agricultural Areas: Alluvial Soils.

The individual map units are described under each heading. The major crop types associated with each map unit are listed in descending order of importance as a function of surface area. For example, in map unit Ai, groundnuts are listed first since they generally cover more surface area than millet, while maize generally occupies the least surface area. This ranking is based on long-term national averages which may change as farming policy and practices change. No attempt was made to determine crop type or surface area by crop from the aerial photographs. Crop information was derived mainly from preliminary field observations and previous studies (Dunsmore et al., 1976, U. of Michigan, 1985).

The non-agricultural map units are the vegetation cover types which are not associated directly with cultivation. These types are derived from the vegetation map.

5.5 GENERAL MAP CHARACTERISTICS

The maps of Landscape and Soils, Forested Lands, Rangelands, and Agricultural Lands were prepared as transparent overlays to the Planimetric Base maps. The thematic overlay maps and the base maps compliment each other and should be used together. For example, some of the vegetation map units appear on the overlays as open-ended areas rather than as closed polygons. When used in conjunction with the base maps, the open-ended units on the overlays always occur adjacent to towns and villages whose perimeters serve to close the units.

The map of Forested Lands, Rangelands, and Agricultural Lands all have identical map delineations as they were derived from a single air photo interpretation of land use and land cover. This

approach was taken because, by definition, the basic cover types (wooded areas and agricultural areas) interface with each other throughout the country, forming mutually exclusive classes that share a common line on the map. Thus, the same set of delineations serve both maps. Furthermore, since grazing occurs within nearly all vegetation and agricultural areas, and the rangeland types are closely tied to vegetation types, the same set of delineations serve to define the range types.

One of the main considerations in preparing the overlays was whether a given map theme (e.g., agricultural lands) should be shown independently of the other themes. If so, the agricultural lands overlay would show only areas of agriculture, leaving the other cover types (woodlands, mangroves, barren flats, etc.) entirely blank. In order to get a complete picture, the user would have to use all three overlays simultaneously. This approach was abandoned in favor of the present approach in which all cover types are identified on every overlay. We felt it important that a given theme (e.g., agricultural lands) be shown in the geographical context of the surrounding cover types.

The 1:125,000 scale maps (smaller scale), consisting of four sheets per map theme, represent a somewhat generalized version of the more detailed 1:50,000 scale maps. Since they were prepared from photographic reductions of the twenty 1:50,000 scale map sheets, many of the map units became too small to be included. The map delineations were redrawn according to the basic principles of cartographic generalization. These include the elimination, where necessary, of detail; the graphic summarizing of essential characteristics; the rescaling and grouping of geographic features; and application of the logical process of inference. This resulted in smaller-scale maps which present all of the major elements of the larger-scale versions, while eliminating all unnecessary detail. The only map units to be totally eliminated by the generalization process are the Ai (intensive cultivation) and Af (non-intensive cultivation with fallow fields) map units. These two units were generalized to a unit A (agricultural areas), containing both subtypes.

5.6 COVER TYPE DESCRIPTIONS

5.6.1 B - Savanna Woodlands

This unit is found on upland areas and on the gentle slopes leading into drainages. Extensive areas of this type have been cleared for agriculture, an ongoing process that appears to be accelerating. Crown cover is usually in the 20 to 40 percent range, forming an open woody type with considerable understory growth during the wet season. (see Figures 1 and 2). Much of this type is subjected to burning each year by intentional or

accidental fire or the occasional natural fire which has resulted in fire-tolerant species being favored, decreasing the diversity in most areas. Additional, more profound changes have been brought about by cutting trees for fuel (either as firewood or for charcoal production), lumber or branches for cattle feed during the dry season.

Grazing value potential of this type is normally high during the middle and late portions of the wet season after sufficient growth has taken place, but before grasses mature and lignify, given good soils and reasonable past utilization. Extensive portions of this type have been abused with desirable grasses such as Andropogon gayanus and A. amplectens being rare or absent, having been replaced by less desirable grasses, forbs and/or shrubs. Although the grasses are adapted to burning, the practice of moving animals into burned areas as soon as regrowth appears has resulted in over-exploitation of the better grasses causing a change in dominance to less desirable species.

5.6.2 BF - Savanna Woodlands/Woodlands

This unit is found on the uplands and gentle slopes. This type represents a transition type between the savanna woodlands and true upland woodlands. Crown cover is usually 40 to 60 percent, though local variations in cover may range from 20 to 80 percent. It is found integrated with savanna woodlands on the better soil in the dryer portions of its range and with dense uplands and woodlands in the wetter portion on poorer soils. In general, it has been subject to the same activities of man as the above type, with the same results.

Grazing value is generally good during the wet season until the grasses mature. Utilization by animals can be somewhat limited due to the higher density of woody plants.

5.6.3 F - Woodlands

This type is limited to the uplands and slopes in the southwestern portions of The Gambia. Crown cover generally ranges from 50 to 80 percent with large trees and a well developed shrub layer. Herbaceous composition varies with crown cover, those being characteristic of the more open woodland and savanna woodlands in the more open phase while in the closed phase more shade-tolerant species such as Paspalum ssp., Oplismenus ssp., and Schizachyrium ssp. may be found.

Man's actions have destroyed extensive areas of this type through the same activities carried out in other woodland types. Due to the density of woody vegetation, access by animals may

Figures 1 and 2. Aerial and ground views of the extensive but dwindling savanna woodlands (map units B and BF) which once blanketed nearly all of the uplands of The Gambia. These dry, deciduous savanna woodlands are quite heterogeneous in floristic composition, with no one species dominating. The patchy appearance from the air results from bare areas created by eroded remnants of old termite mounds. June 26, 1986; altitude 300 meters; Niamina West District.

somewhat limit utilization of what forage is available. In general, adequate supplies of excellent forage are present through the wet season and into the early dry season.

5.6.4 L - Palm Groves

This type is mapped as a separate unit only in the western portions of the country where it forms extensive enough areas to meet minimum map unit size. (Figure 12) However, it is found throughout much of the country in narrow bands, often at the junction of slope and flood plain and ground margins of swamps and poorly drained basins. Due to this distribution characteristic, this unit when not mapped separately was included most often in the BFv mapping unit complex. (Figures 3 and 4)

It is normally associated with non-saline, productive, medium- to fine-textured soils with favorable moisture conditions. Because of this, much of the area is the site of intensive agricultural activities including rainfed rice and garden plots.

Major tree species are Elaeis guineensis and Borassus aethiopium. Since it is an area of agriculture, its main value for grazing is after harvest on crop aftermath or for grazing on woody herbaceous and woody vegetation on fallow areas when rotation periods are sufficient for its development.

5.6.5 BFv - Riparian and Fringing Savanna Woodlands and Woodlands

This mapping unit occurs primarily on colluvial slopes between the upland and flood plain areas which almost never exceed an elevation change of more than a few tens of meters. It also extends up narrow drainages and blends with other flood plain types on its lower extents. (Figures 3, 4, and 13)

It is characterized by an open to fairly contiguous semi-evergreen tree cover with woodland understory. Due to the photo scale and narrow linear nature of palm stands, they were included in this mapping unit where they were not extensive enough to facilitate separation.

Grazing value is highly variable in this type. Slopes are utilized during the wet season until grasses become coarse, dry and lignified by the start of the dry season. More level adjacent areas are preferentially grazed, an increasingly important factor as slope increases. At some locations runoff water over the toe slope results in a more mesic habitat producing additional forage which often stays palatable later into the dry season.

Figures 3 and 4. Map unit BFv, the riparian and fringing savanna woodlands and woodlands, is illustrated by this high oblique aerial photo and accompanying ground photo. The vegetation is characterized by tall, semi-evergreen mesophytic and hydrophytic trees found along valleys, along the toe slopes of escarpments, and fringing the floodplain. Four distinct land cover types are visible from the air: mangroves (unit M) in the foreground, traditional swamp rice (Ar) in the valley floor, unit BFv fringing the valley, and the rainfed agricultural lands (units Ai and Af) at upper left. June 26, 1986, altitude: 300 meters; a tributary of Bulok Bolon.

5.6.6 G - Gallery Forests

The dense, tall, semi-evergreen forests occur along stream courses on rich, deep, non-saline soils. Canopy density is generally heavy enough to create a micro-climate and to obscure the streambed from vertical view. Understory is usually sparse, often more dominated by forbs than grasses. Due to this and their very limited extent, they are of little importance as a grazing resource in The Gambia, but are important in wildlife areas.

5.6.7 M - Mangroves

Mangroves characteristically occupy the tidal influenced zones along The Gambia River and its tributaries. (Figures 3, 5, and 12) This community normally forms a continuous, dense cover made up of tall mangrove (Rhizophora racemosa) found on the banks of streams and estuaries channeled to the limit of daily tidal surges. The short black mangrove (Avicennia africana) occurs up to the limit of the highest annual tide mark behind the tall mangrove with Rhizophora mangle occupying a zone between the tall and black mangrove.

Succession is due to the accumulation of litter and deposition of alluvium during which the short black mangrove eventually replaces the other species. With continued accumulation, these now raised areas become dried and more saline which in the extreme result in barren flats where the succulent Sesuvium portulacastrum may occur or in less extreme the grasses Sporobolus spicatus, Paspalum vaginatum and Diplachne fusca may occur.

Essentially the mangrove community proper has no grazing value but is quite important as habitat for a number of wildlife species.

5.6.8 T - Barren Flats

Barren flats are characterized by sparse or absence of vegetation. Several types of halophytes can occur on these strongly acid, saline soils or saline-alkali soils. These include Sesuvium portulacastrum (in extreme soil conditions), and Sporobolus spicatus, Paspalum vaginatum and Diplachne fusca on more favorable sites. The grazing value of the sparsely vegetated flats is generally poor.

5.6.9 Ps - Herbaceous Steppes

This unit occurs on the floodplains of The Gambia River and its tributaries in both brackish and freshwater situations. (Figures 5, 6, and 7). They are characterized by having high

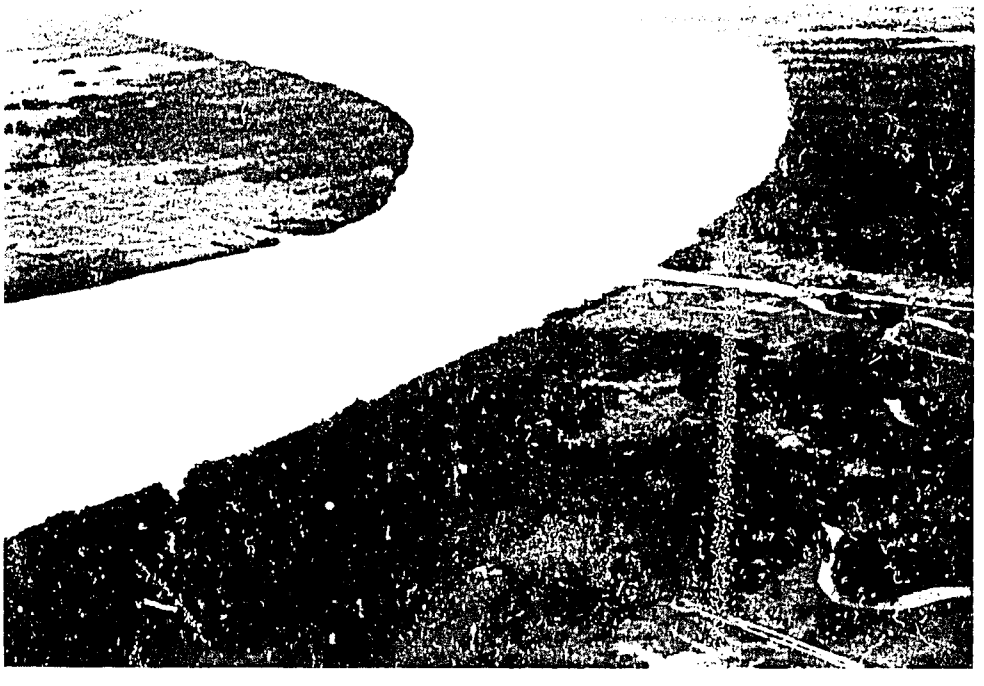

Figure 5. An aerial view of mangrove communities (map unit M) at the Farafenni crossing. The taller stands fringing the waterways are Rhizorphora racemosa; the lower stands are composed of Rhizophora mangle and Avicennia Africana. Herbaceous steppes (units Ps) occur on the open flats. They are used in this area for swamp rice cultivation. Date: September 17, 1984. Altitude: 400 meters.

water tables and by being inundated by water, at least during the wet season, or longer to varying depths. Certain of these are also affected by tidal, brackish water on a daily basis for some or all of the year depending on location. Soils are generally fine-textured with a wide range of pH and salinity values. With such a variation in habitat, there is a wide diversity of communities within this unit.

Portions of this unit have been used as rice paddies. However, a number of these have been allowed to revert back due to unfavorable soil changes. In some cases, changes have been severe enough that the result is not swamp prairie but barren areas.

Due to the diverse habitats available, many subtypes may be present, however: Paspalum vaginatum, Diplachne fusca, Phragmites karka, Echinochloa pyramidalis, Anadelphia afzeliana, Vetivera nigritana, Panicum ssp., Cyperus papyrus, C. articulatus, Heleocharis plantaginea, Oryza ssp., Brachiaria mutica and others have been reported as examples of major species.

5.6.10 Pd - Floodplain Grass Savannas

This type is found in drainages and poorly drained depressions and floodplains which at times are flooded or wet but are quite dry during portions of the years. (Figures 6 and 8) Soils are normally fine-textured and may contain clay pans, may be saline and can vary widely in pH. In short, a combination of the above factors discourage establishment of woody species. Therefore, ground cover is primarily grassy with varying amounts of forbs and/or succulents with little or no woody vegetation present. Species commonly reported to be present include Anadelphia afzeliana, Eragrostis atrovirens, Vetiveria nigritana, Phragmites karka, Panicum anabaptistum, and Vetivera nigritana. When adjacent to barren flats, the transition zone normally contains sedges and rushes while the transition with swampy areas may contain significant amounts of Schizachyrium brevifolium and Paspalum ssp.

Though highly variable, this type usually provides good grazing during most of the year and is an important resource particularly during the dry season for domestic and wildlife species.

5.6.11 Pvs - Floodplain Shrub and Tree Savannas

Structurally, the floodplain shrub and tree savannas differ somewhat from those of map unit VS in that they are basically natural formations occuring on alluvial soils which experience occasional flooding from the Gambia River. They also differ in that the herbaceous understory is low and discontinuous. (Figures

Figure 6. This oblique air photo shows a portion of Painor Swamp, Upper River Division, showing map units Pb (Floodplain savanna woodland, foreground), Pvs (Floodplain shrub and tree savanna, bordering swamp), Pd (grass savanna to the right of the swamp bottom), and Ps (discontinuous herbaceous steppe occupying the swamp bottom). The swamp was dry in this late dry season photo. In the distance is an irrigated rice field (unit Ari). June 25, 1986; altitude: 300 meters.

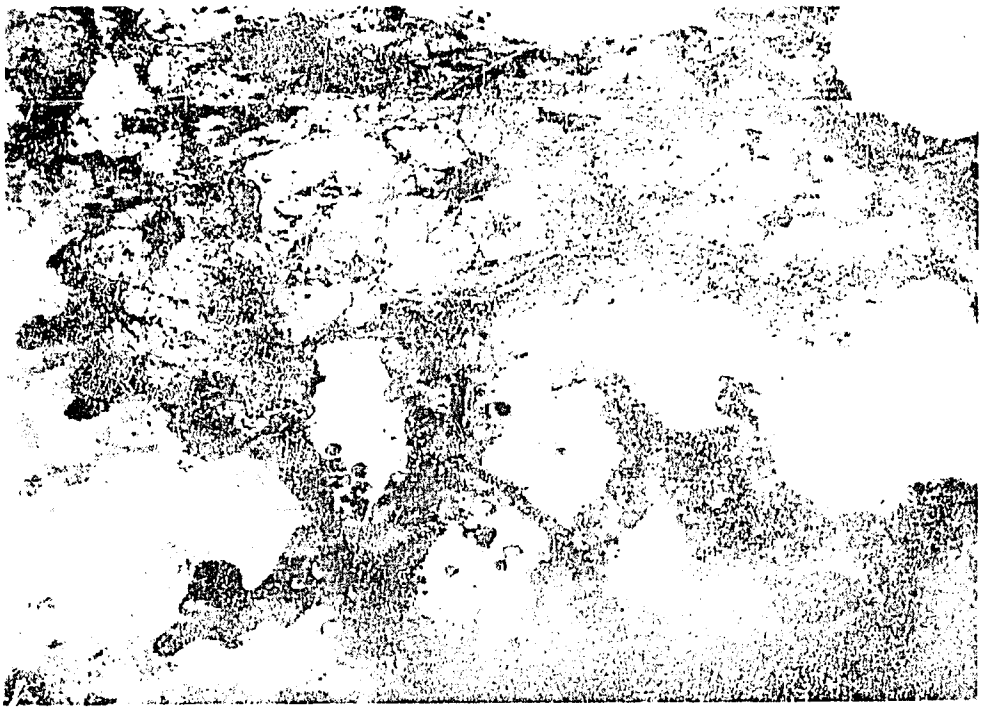

Figure 7. An aerial view of a wetland adjacent to the Gambia River near Jappeni. The herbaceous steppe (map unit Ps) provides good grazing, particularly in the dry season. A number of cattle can be discerned in this photo. June 25, 1986; altitude: 300 meters.

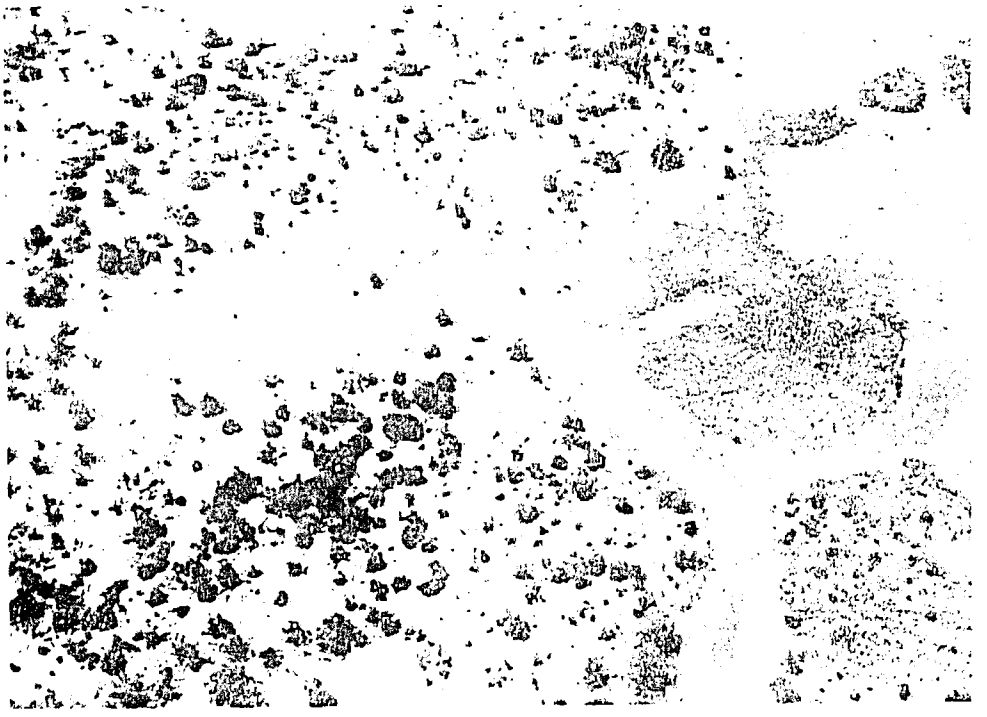

Figure 8. Map units Pd (right third) and Pvs (left two-thirds) are represented on this aerial photograph. The first unit consists of a grass savanna or grass steppe occuring on the floodplain of the Gambia River. These areas are flooded only during the highwater season and/or after heavy rain. They provide good dry season grazing. The second unit (Pvs) is a floodplain shrub and tree savanna, dominated by Mitragyna inermis and Acacia seyal. June 26, 1986; altitude 300 meters; South of Diabugu.

6 and 8). The woody stratum is floristically distinct dominated by low trees or shrubs of Mitragyna inermis and Acacia seyal. The grazing value is quite good in the wet season. The herbaceous grazing value deteriorates as the dry season progresses.

5.6.12 Pb - Savanna Woodlands on Floodplains

This type exists primarily in the upper reaches of The Gambia River where open woodland types of vegetation cover have developed on the floodplain. It is characterized by small scattered trees with shrub understories and herbaceous ground cover. (Figures 6 and 13). It is an important grazing area during both the wet and dry season, but is limited in extent.

5.6.13 Pf - Riparian Woodlands

This woodland type occupies the banks of streams and levees and is very similar to a gallery forest. It is found on the fine-texture, non-saline soils with a high water table and are considered to be semi-evergreen forests due to a mix of evergreens and deciduous species. These are very limited in extent and they have a high grazing and wildlife habitat value (Figure 13).

5.6.14 Ai - Current Agriculture and Af - Fallow Agriculture

Current agriculture is that which was interpreted to have been cropped during the year of the aerial photography. Usually it was readily identifiable because of the relatively high reflection from the bare soil surface after crop removal. In contrast, fallow land normally displayed darker tones due to the absorption by the initial year's growth of herbaceous ground cover and subsequent years, woody species. (Figures 3, 9, 10, 11, and 14). The reader is reminded at this point that a specific unit in either of these land categories is dynamic due to rotation practices. In general, those lands near villages are more intensively utilized, some being either continuously cropped or cropped on alternate years, while more distant parcels may be idle for 4 to 5 years before being cropped for a year or two.

Also, certain fallow land will not be returned to current status but will revert back to a shrub or tree savanna on the uplands or some other type depending on habitat. For purposes of interpretation, dry areas were considered fallow as long as individual fields or plots were visible, that is, not overgrown with herbaceous or woody species. In wet habitats, lands were considered fallow until overgrown by grassy and/or other herbaceous species even though field patterns were still visible well into later successional stages.

With all of the above in mind, current cropland and fallow

Figure 9. An example of map unit Ai, representing current, intensive cultivation of land surrounding a settlement. Unlike map unit Af, there is no evidence of fallowing. Taken during the late dry season (June 26, 1986), the regular dark spots in the fields represent the ash remains of burned stubble. The predominant crops in this area (near Basse) are millet, sorghum, groundnuts, and maize. Altitude: 300 meters. Village of Sare Fodigey.

Figure 10. A vertical aerial view of a village in an agricultural setting in the North Bank Division, showing intensive cultivation (map unit Ai, right two-thirds) and non-intensive cultivation with fallow lands dominating (map unit Af, left third of frame). Shrub-covered old fields are also visible (unit VS) at left. Source: Teledyne, October, 1980.

should be referenced as a unit on a spatial basis, the two categories being most meaningful for purposes of determining the ratio of fallow to current agricultural land. Fallow lands are an important grazing resource with the grasses Andropogon gayanus, Pennisetum subangustum, P. pedicellatum, Eragrostis tremula, and Cenchus biflorus being the most prevalent.

5.6.15 VS - Upland Shrub and Tree Savannas

This mapping unit represents those areas which have undergone severe disturbance by man, probably at least a decade or more ago. They are characterized by a uniform height and density of shrubs and trees. In old field areas, the outlines of individual fields and may or may not be present. However, boundaries between this and other woody types are usually quite apparent. (Figures 10 and 11). In addition, scattered large trees are sometimes present due to the clearing practice of retaining scattered individuals of primarily Cordyla pinnata, Pterocarpus erinacens, Arogeisus leiocarpus, Lannea acida, Terminalia ssp., and, where present, Acacia ssp. As would be expected, the understory species vary greatly due to the combination of soils, former agricultural practices and stand age. The following shrubs occur commonly: Combretum micranthum, C. glutinosum, C. nigricans, Terminalia albida, T. macroptera, Guiera senegalensis, Acacia macrostachya, Piliostigma reticulatum, Zizyphus mauritiana, Dicrostachys glomerata, Heeria insignis, Grewia ssp.., and numerous others. The herbaceous layer is equally diverse and includes Pennisetum ssp.., Eragrostis tremula, Andropogon ssp., Ctenium elegans, Schoenefeldia gracilis, Panicum ssp., Schizachyriun exile, Paspalum ssp., and numerous forbs.

Woody species crown cover in this type is variable, but generally ranges from 10 to 20 percent. Grazing value can range from fair to good during the wet season.

5.6.16 O - Plantations

Plantations are those areas which have been devoted to growing monocultures of trees often a rapid growing species such as Gmelina arborea, Terminalia superba, Azadirachta indica or Tectona grandis for pulp, firewood or construction material or for food crops such as cashew (Anacardium occidentalis) or limes (Citrus aurantifolia). At present these are limited in both number and extent in The Gambia.

5.6.17 Ari - Irrigated Rice

Irrigated rice is irrigated by pump from The Gambia river and is limited in westward extent by the intrusion of salt water upstream. Usually the water delivery system was readily visible,

Figure 11. Surrounding the open fields (unit Ai) is a shrub and tree savanna (unit VS) which represents the invasion of woody species onto abandoned agricultural fields. This vegetation type, dominated by species of Combretum, generally represents areas disturbed by man through cultivation, through overgrazing, or repeated burning. Old field boundaries are often visible under the shrub cover.

The settlement pictured here is a new one, established within the last four years. It was "discovered" (though its name has not been determined) as a result of this 1986 aerial survey. Additional field surveys are recommended for including such settlements into the maps and census records. Location: 1.5 Km. north-northeast of Sare Sofi. Altitude: 300 meters: June 25, 1986.

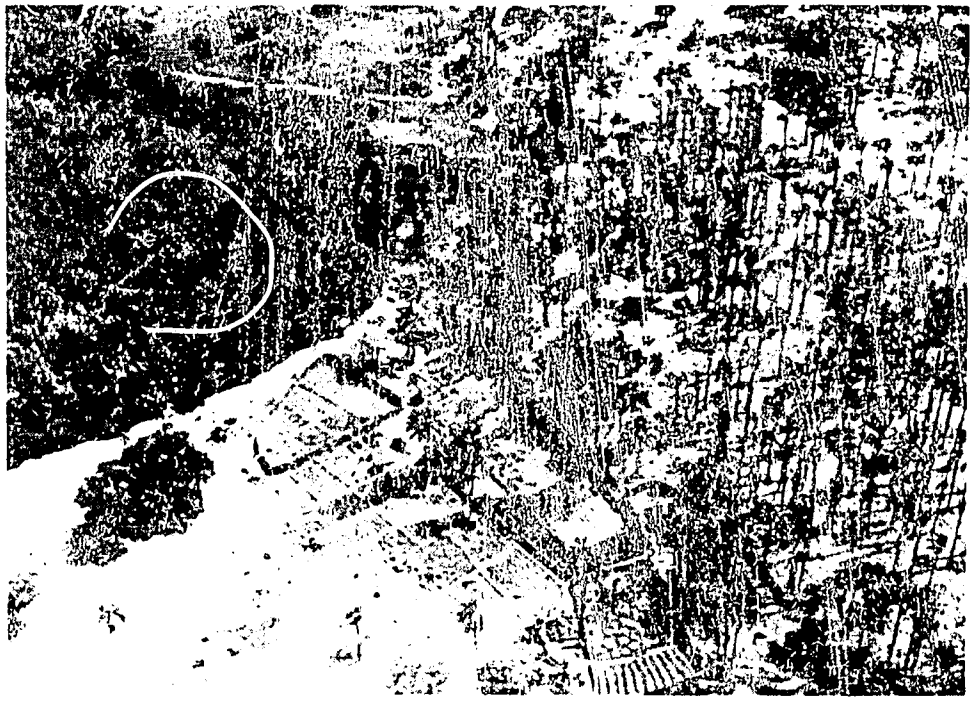

Figure 12. An example of swamp agriculture (unit Ar), in this case rice fields, prior to the growing season. Periodic flooding by rain and/or estuaries keeps the ground moist much of the year. On the right is a palm grove (unit L), under which are grown various crops (Western Division, near Yundum). May 23, 1986. altitude: 200 meters.

which in addition to rice plot size and shape augmented identification. (Figures 6 and 13). It is known that there has been abandonment of some areas due to salinity and other soil problems. Eventually these areas return to a grass cover, however, during the first year or two of abandonment they can normally not be delineated from active paddies.

5.6.18 Ar - Swamp Rice

Swamp rice is rice grown in naturally wet, sometimes brackish areas. In addition to plot size and shape, topography and associated vegetation were used to identify this land use category. Much of this type appears to have been abandoned due to increased salinity or for other reasons and reverts back to a wet grassland or barren flats. As with irrigated rice, extensive field verification would be needed to firmly establish exact number of hectares. (Figures 3, 4, 5, and 12).

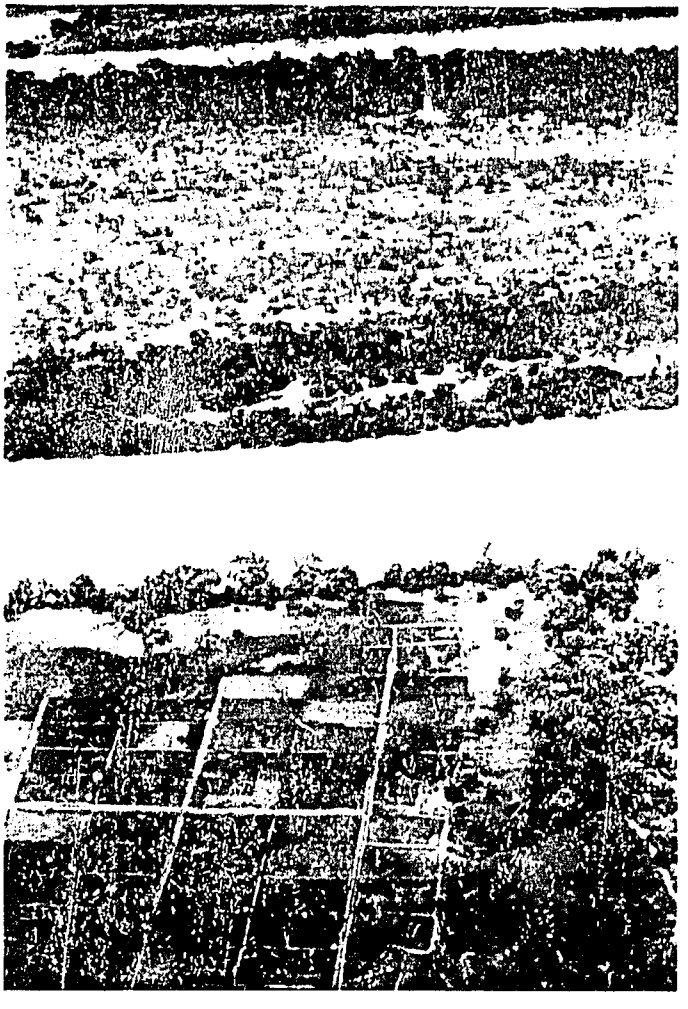

Figure 13. An aerial view of irrigated rice fields (map unit Ari) along the Gambia River adjacent to the Baboon Islands, MacCarthy Island Division. The island is fringed by riparian woodlands (unit Pf), with the more mesophytic savanna woodlands (Pb) occuring in the center of the island. June 26, 1986; altitude: 300 meters.

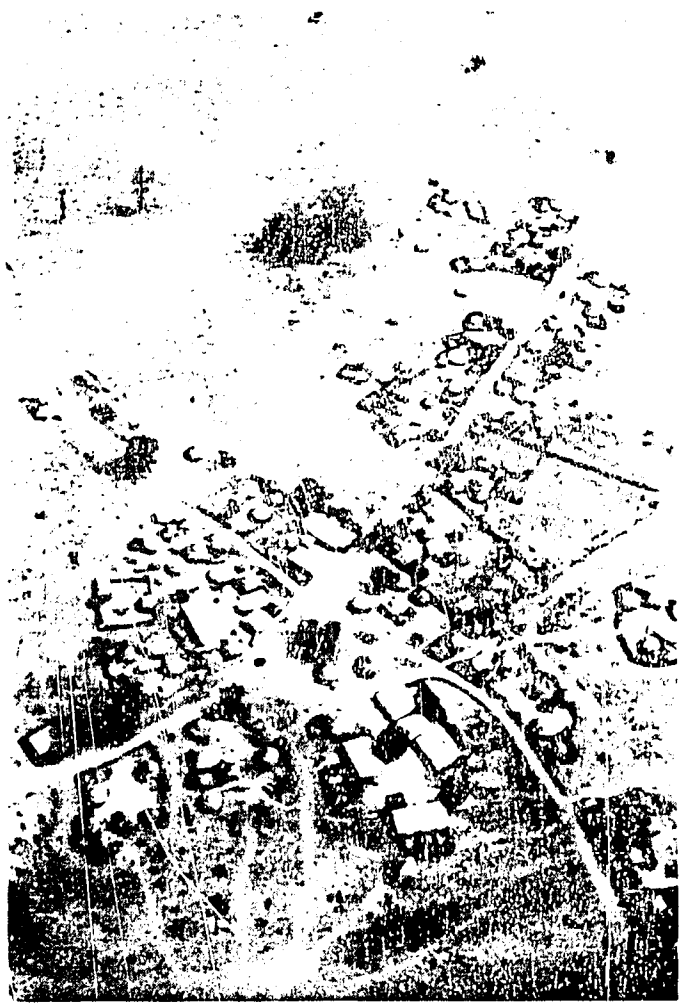

Figure 14. Low level oblique photograph of the village Jamali Ganiado Njie, north of Georgetown. Typical of agricultural villages in the MacCarthy Island Division, the village is characterized by low density of structures, few dwellings with metal roofs, and abundance of livestock housed in the village. The compound in the foreground exhibits signs of greater wealth and prosperity than others in the village, judging from the number and size of metal roofed concrete structures, the fresh repairs on the thatch roofed buildings, and the concentration of livestock around its perimeter.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

The principal contribution of the survey and mapping of The Gambia is the extensive set of maps which provide an updated, nation-wide inventory of the highly dynamic, fragile surface resources. Every attempt was made within the limited time available to exploit the information-rich, high quality aerial photography at our disposal, and to integrate existing sources of environmental data into our own original contributions to produce readable, useful maps.

The map products prepared by the present effort fit well within a development strategy which includes increasing agricultural production while taking steps to improve range management, and to conserve the soil, water and forest resources of The Gambia. The maps are essential tools for working within an environment whose dwindling resources are being severely and adversely affected by day-to-day human activities (Univ. of Michigan, 1985). The map user is encouraged to use these baseline resource maps as:

- an inventory of the soils, vegetation; land use and land cover of The Gambia, showing in detail the areal distributions and geographic contexts of the various surface resources.

- a tool for analyzing the natural environment and the relationships between it and the ways in which the land is being utilized.

- a means of assessing the development potential on a national, regional and local basis.

- a means of gaining insight to temporal changes caused by human and climatic pressures on the land. Of particular interest would be the comparison of these maps with older maps and aerial photographs in order to pinpoint areas of erosion, loss of vegetation cover, and land use changes.

- a means of planning future action with regard to an optimal, integrated land use plan.

6.2 RECOMMENDATIONS

Because of the short duration of the project, the majority of effort was spent on aerial photo interpretion and map production,

leaving little time for data analysis and integration and for the development of a comprehensive set of recommendations. The short list of suggested activities that follow are based on the team's experience in the development and use of resource maps.

- An more extensive ground survey could now be conducted to fully characterize the mapping units. This is particularly recommended with regard to the western three divisions of The Gambia not included in the rangeland studies completed by the Gambia Mixed Farming and Resource Management Project. Field data collection should include the soils, floristic composition of vegetation communities, and detailed crop inventories.

- The soils maps and additional field data should be analyzed in order to prepare land/soils suitability maps of The Gambia. Such maps would rate the soils for their suitabilities for supporting such basic land uses as forestry, agriculture, and rangelands. These would be particularly useful in any integrated plan to optimize the uses of the existing limited resources of The Gambia. The soil types could also be rated for their suitabilities for growing specific crops.

- Area estimations should be made of the various land classication categories for the purpose of providing statistical data for research, planning and management of agricultural and forested lands. Calculations of forested lands will provide the Department of Forestry with updated statistics (1983) on the amount of woodland cover remaining in The Gambia. Comparison of these statistics with those derived from the Gambia-German Forestry Maps would yield information on the rates of deforestation and location of most affected zones.

- Some of the map sets could be upgraded to color maps. The distinct advantage of the use of color is that the various map units can be readily distinguished by color. The geographic extent and distribution of any given map unit (e.g., savanna woodlands) becomes clear immediately, which is not the case with the present map format (use of codes on line-maps). Although publishing the full set in color is an expensive proposition, we recommend that the smaller-scale (1:125,000) soils and forested lands map sets be upgraded to color. This would be a total of eight color sheets.

- In order to analyze effectively and rapidly the considerable amount of geographical data presented on the maps, and to properly integrate these data with those

previously collected (and future data), it is recommended that a Geographic Information System (GIS) be developed. Such a system has been shown to be a rapid, efficient and comprehensive means of analyzing large amounts of illustrative, descriptive and statistical data in many parts of the world.

- More emphasis should be placed on periodic, repetitive monitoring of the dynamic surface resources of vegetation and land use, taking advantage of the repetitive Landsat-5 and SPOT satellite coverage of The Gambia. This new generation of satellites provides high resolution (up to ten meters) images, enabling resource specialists to closely monitor such problems as the locations and rates of deforestation, the effects and distribution of bush fires on rangelands, the extent and severity of mangrove dieback, and the monitoring of cultivated areas and crops on a seasonal basis.

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