Carte des pâturages du Sud-Ouest de la MAURITANIE 1982

Rangeland and Pasture Map of Southwestern MAURITANIE 1982

Une enquête de reconnaissance sur l'image de Landsat et des Studes sur le terrain.

Préparé pour

LE GOUVERNEMENT DE LA REPUBLIQUE ISLAMIQUE DE MAURITANIE

Par le projet de

GESTION DES RESSOURCES RENOUVELABLES

Une collaboration entre

GOUVERNEMENT DE LA REPUBLIQUE ISLAMIQUE DE MAURITANIE,
L'AGENCE ETATSUNIENNE POUR LE DEVELOPPEMENT INTERNATIONAL
et
L'INSTITUT DE LANDSBERG
de la
UNIVERSITE D'ETAT DU DAKOTA DU SUD

Par

Christopher W. Stowell, spécialiste en pâturage
Andrew Sayre, Ex Stowell, Bruce Thomson, Terry Jennings

A Reconnaissance Survey
Based on Landsat Imagery and Field Studies
Prepared for
THE GOVERNMENT OF THE ISLAMIC REPUBLIC OF MAURITANIA
by the
RENEWABLE RESOURCES MANAGEMENT PROJECT
A joint enterprise of the
GOVERNMENT OF THE ISLAMIC REPUBLIC OF MAURITANIA,
THE UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT,
and the
HUNTER BERRING INSTITUTE
of the
SOUTH DAKOTA STATE UNIVERSITY

By

Christopher W. Stowell, Range Scientist
Andrew Sayre, Ex Stowell, Bruce Thomson, Terry Jennings

LEGENDE
LEGEND

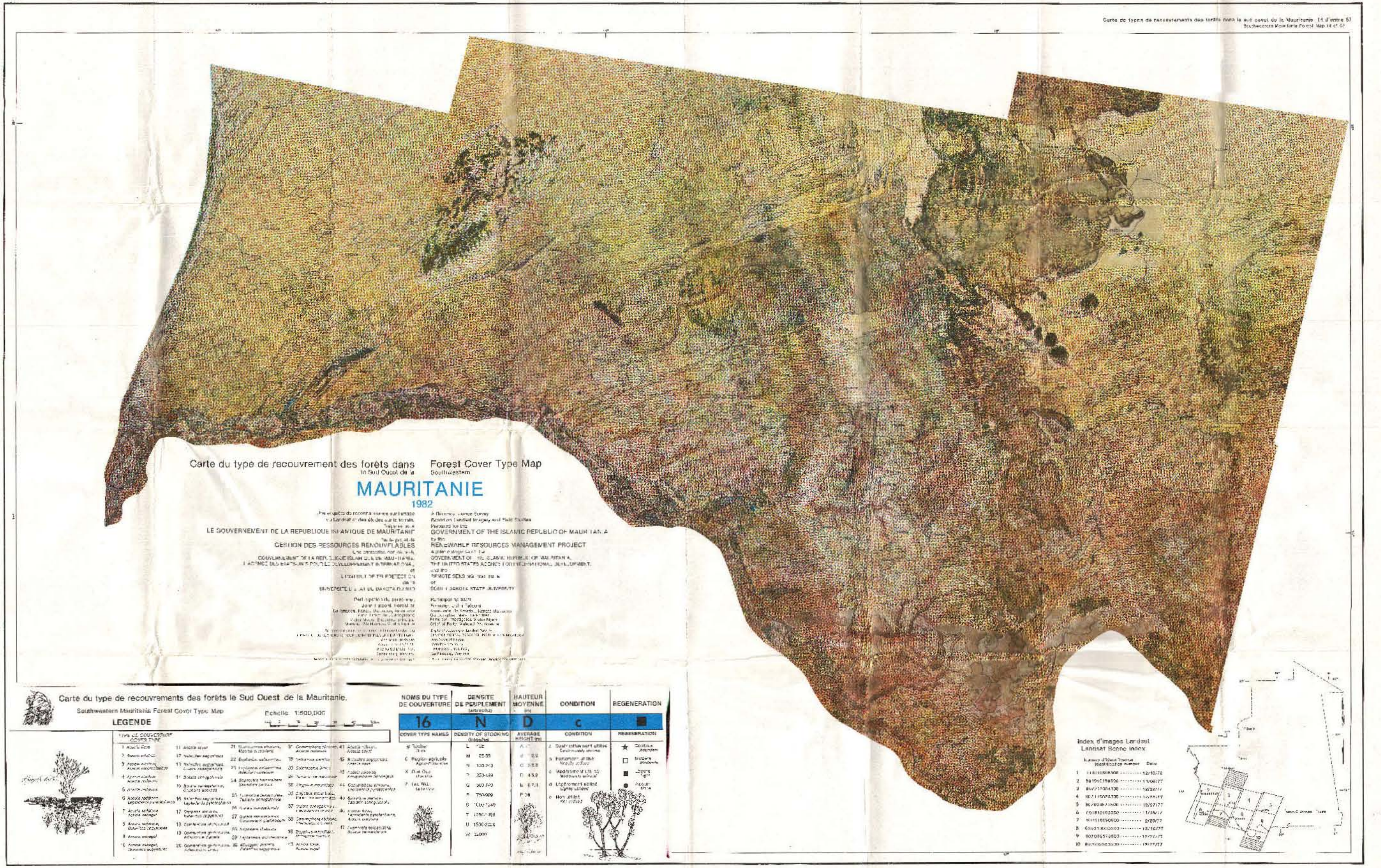
Carte des pâturages du Sud-Ouest de la Mauritanie
Southwestern Mauritania Rangeland and Pasture Map

Echelle 1:500,000

Description

Index d'images Landsat
Landsat Scene Index

	Identification	Date
1	1149-10008GO	10/18/77
2	62-1121-10000	11/06/77
3	60-2101-09100	12/29/77
4	60-1-1-09100	12/28/77
5	60-2-0-0-21500	12/27/77
6	60-1-1-0-21500	1/06/77
7	60-2-1-2-0-21500	12/28/77
8	1-2-0-1-2-0-21500	12/15/77
9	60-2-0-0-2-0-21500	12/27/77
10	60-2-0-1-0-21500	12/27/77


Carte du type de recouvrement des forêts dans le Sud Ouest de la
Forest Cover Type Map Southwestern
MAURITANIE
1982
LE GOUVERNEMENT DE LA REPUBLIQUE ISLAMIQUE DE MAURITANIE
GESTION DES RESSOURCES RENOUVELABLES
Based on Landsat Imagery and Field Studies
GOVERNMENT OF THE ISLAMIC REPUBLIC OF MAURITANIA
RENEWABLE RESOURCES MANAGEMENT PROJECT
SOUTH DAKOTA STATE UNIVERSITY
Carte du type de recouvrements des forêts le Sud Ouest de la Mauritanie.
Southwestern Mauritania Forest Cover Type Map
Echelle 1:500,000
LEGENDE
NOMS DU TYPE DE COUVERTURE
DENSITE DE PEUPLEMENT
HAUTEUR MOYENNE
CONDITION
REGENERATION
16
N
D
c
COVER TYPE NAMES
DENSITY OF STOCKING
AVERAGE HEIGHT
CONDITION
REGENERATION
Index d'images Landsat
Landsat Scene Index

C2 C1

C2
B

C1
B

Carte d'association des sols du S.-O. de la MAURITANIE

Soil Association Map of Southwestern MAURITANIE

1982

Une enquête en microwaves basée sur l'image de Landsat et sur des données sur le terrain
Réalisée par

LE GOUVERNEMENT DE LA REPUBLIQUE ISLAMIQUE DE MAURITANIE
par le
PROJET DE GESTION DES RESSOURCES RENOUVELABLES

Une enquête sur carte du
GOUVERNEMENT DE LA REPUBLIQUE ISLAMIQUE DE MAURITANIE
L'AGENCE DES ETATS-UNIS POUR LE DEVELOPPEMENT INTERNATIONAL

L'INSTITUT DE TELEDETECTION
UNIVERSITE D'ETAT DU DAKOTA DU SUD

Par: Gérard Tilquin
Dr. Soils et Remote Sensing
Mary Bullerdiek, Cartographe
Victor Tinney, Photo Interprète
Michael Hanson, Chef d'équipe

A Reconnaissance Survey
Based on Landsat Imagery and Ground Data
Prepared by
THE GOVERNMENT OF THE ISLAMIC REPUBLIC OF MAURITANIA
by the
RENEWABLE RESOURCES MANAGEMENT PROJECT

A GRANT REPORTING TO THE
GOVERNMENT OF THE ISLAMIC REPUBLIC OF MAURITANIA
THE UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT

REMOTE SENSING INSTITUTE
SOUTH DAKOTA STATE UNIVERSITY

Part-time Staff:
Dr. Soils and Remote Sensing
Mary Bullerdiek, Cartographer
Victor Tinney, Photo Interpreter
Michael Hanson, Chief of Party

LEGENDE
LEGEND

REGION DE SOL A
SOIL REGION A

REGION DE SOL B
SOIL REGION B
230-500 mm annual precipitation (Arabic, Zenaga)
84°C (Temperature annuelle moyenne maximale)
(24°C average annual temperature maximum)

REGION DE SOL C1
SOIL REGION C1
50-115 mm annual precipitation (Arabic, Arabic)
40°C (Temperature annuelle moyenne maximale)
(28°C average annual temperature maximum)

REGION DE SOL C2
SOIL REGION C2
125 mm annual precipitation (Arabic, Zenaga)
40°C (Temperature annuelle moyenne maximale)
(28°C average annual temperature maximum)

AA
SOLS ALLUVIAUX
ALLUVIAL SOILS

AB
SOLS SOLIDES
RECENT SOILS

AC
SOLS LITHIQUES
LITHIC SOILS

AD
SOLS DOTES DE SELS MINERAUX
SALT AFFECTED SOILS

AE
SOLS BRUNS
ALGOLIN SOILS

BA
SOLS ALLUVIAUX
ALLUVIAL SOILS

BB
SOLS SOLIDES
RECENT SOILS

BC
SOLS LITHIQUES
LITHIC SOILS

BD
SOLS DOTES DE SELS MINERAUX
SALT AFFECTED SOILS

BE
SOLS BRUNS
ALGOLIN SOILS

BU
SOLS DES HAUTES TERRES
UPLAND SOILS

C1A
SOLS ALLUVIAUX
ALLUVIAL SOILS

C1B
SOLS SOLIDES
ARIDSOLIC SOILS

C1C
SOLS LITHIQUES
LITHIC SOILS

C2A
SOLS ALLUVIAUX
ALLUVIAL SOILS

C2B
SOLS SOLIDES
ARIDSOLIC SOILS

C2C
SOLS LITHIQUES
LITHIC SOILS

LEGENDE

Zones Pedo-climatiques
Soil Climate Zones

Index d'images Landsat
Landsat Scene Index

Numéro d'identification Identification number	Date
1	12/10/77
2	11/06/77
3	12/07/77
4	12/06/77
5	12/07/77
6	11/06/77
7	2/05/77
8	12/10/77
9	12/07/77
10	12/07/77

Echelle(Scale) 1:500,000

Carte basée sur interprétation satellite du Sud-Ouest de la

Landsat-based map of Southwestern

MAURITANIE

1982

Préparée par le GOUVERNEMENT DE LA REPUBLIQUE ISLAMIQUE DE MAURITANIE par le PROJET DE GESTION DES RESSOURCES RENOUVELABLES du GOUVERNEMENT DE LA REPUBLIQUE ISLAMIQUE DE MAURITANIE, l'AGENCE DES NATIONS UNIES POUR LE DEVELOPPEMENT INTERNATIONAL, et l'INSTITUT DE TELEDETECTION de l'UNIVERSITE DU DAKOTA DU SUD

Prepared by THE GOVERNMENT OF THE ISLAMIC REPUBLIC OF MAURITANIA by the RENEWABLE RESOURCES MANAGEMENT PROJECT, the GOVERNMENT OF THE ISLAMIC REPUBLIC OF MAURITANIA, the UNITED NATIONS AGENCY FOR INTERNATIONAL DEVELOPMENT, and the REMOTE SENSING INSTITUTE of the SOUTH DAKOTA STATE UNIVERSITY

INVENTAIRE DES RESSOURCES DU SUD-OUEST MAURITANIEN

Géologie•Sols•Forêt•Pâturages

RESOURCE INVENTORY OF SOUTHWESTERN MAURITANIA

Geology•Soils•Forestry•Pastures

LEGENDE
LEGEND

Echelle (Scale) 1:500,000

BRAKNA

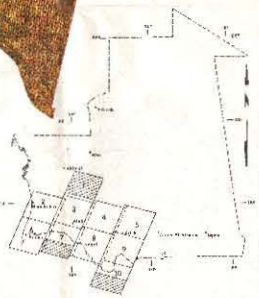
KOUMACHOTT

SENEGAL

ASSABA

Index d'images Landsat
Landsat Scene Index

	Référence d'un cliché (Landsat scene number)	Date
1	1142-1060500	12/13/75
2	1511-1101000	11/08/77
3	1572-1004500	12/09/77
4	0071-1002500	12/25/77
5	0070-0971000	12/24/77
6	0170-1010000	11/20/77
7	0071-0996000	12/26/77
8	0069-0958000	12/27/77
9	0070-0947000	12/27/77
10	0070-0910000	12/27/77



OCEAN ATLANTIQUE

Carte Géologique du Sud-Ouest de la

GEOLOGIC MAP Southwestern

MAURITANIE

1982

Préparée pour le
LE GOUVERNEMENT DE LA REPUBLIQUE ISLAMIQUE DE MAURITANIE
par le
PROJET DE GESTION DES RESSOURCES RENOUVELABLES
Une entreprise du Gouvernement
GOUVERNEMENT DE LA REPUBLIQUE ISLAMIQUE DE MAURITANIE,
L'AGENCE DES ETATS-UNIS POUR LE DEVELOPPEMENT INTERNATIONAL,
et
L'INSTITUT DE TELEDETECTION
de
UNIVERSITE D'ETAT DU DAKOTA DU SUD
Participant de la Personnel
A Harris Hornard Andrews, Spécialiste en Géologie
Alan Eric Anderson
Mary Buckelew, Cartographe
Victor Myers, Photographe
Steve Wilson, Géologue

Prepared for the
GOVERNMENT OF THE ISLAMIC REPUBLIC OF MAURITANIA
by the
RENEWABLE RESOURCES MANAGEMENT PROJECT
A joint undertaking of the
GOVERNMENT OF THE ISLAMIC REPUBLIC OF MAURITANIA,
THE UNITED STATES AGENCY FOR INTERNATIONAL DEVELOPMENT,
and the
REMOTE SENSING INSTITUTE
of
SOUTH DAKOTA STATE UNIVERSITY
Participating Staff
Harris Hornard Andrews, Geologist
Alan Eric Anderson
Mary Buckelew, Cartographer
Victor Myers, Photographer
Steve Wilson, Geologist

LEGENDE

Carte Géologique de Sud-Ouest de la Mauritanie

Geologic Map of Southwestern Mauritania

Echelle 1:500,000

Km 0 5 10 15 20 25 30

1. Sols à couleurs claires et filet vegétal alluvions
Light colored soils and alluvial streams
2. Dunes de sable actuelles
Active sand dunes
3. Sols en terrains argileux avec des dépressions et des cours d'eau
Clay soil (clay) sands in depressions and river courses
4. Argiles et sables de marine
Marine clays and silts
5. Plateau bosses sables poudreux
Low sandy plateau
6. Plateau Nombreux sables volcans et sol rouge
Volcanic sands and soil
7. Dépôts de sable et de sol sur des grès et des schistes
Thin sands covering gravel and clayey soils
8. Dépôts sont certains vallées, ruisseaux et sables poudreux, les sables vallées
Accepted marine and continental deposits covered by aeolian sands
9. Sables rouges, quartzites, grès de la série de la Mauritanie
Sands red, quartzites, sandstones of the Mauritanian series
10. Grès et de quartzites moins poudreux - Rocher
Sandstones and quartzites - Rocks
11. Grès quartzites sur conglomérat
Sandstones and quartzites, conglomerates
12. Plateaux de grès argileux
Plateaus and sandstones, mudstones
13. Grès et de Bas
Sandstones and clays
14. T Blow
Lattice
15. Centres volcaniques, lits de scoriacés
Volcanic centers, beds of scoria
16. Quartzites, de grès et sol sans végétation
Quartzites, sandstones and bare soil
17. Roches, granodiorite et gneiss
Granites, granodiorites and gneisses

Limite du aquifère
Aquifer limit
Limite sûre du fond du lac
Reliable limit of the lake
Mare dans fossile du Phase
Old beach line stations
Lac de sol et sel
Salt lake
Terre Semaoil
Semaoil River
Plateau Tobi
Tobi Plateau
Lits verticaux
Vertical beds
Lac sur sol
Lake on soil
Dune
Dune
Lineaments et les lignes fracture, non tient en déplacement
Lineaments or lines of fracture, not tied to displacement
Fractures and faults without showing horizontal displacement or one side of the other
Lignes et contactes
Contact lines
Limite géologique
Geologic boundary

Index d'images Landsat
Landsat Scene Index

Number	Date
1	12/13/73
2	11/06/77
3	12/20/77
4	12/26/77
5	12/27/77
6	11/06/77
7	12/20/77
8	12/10/77
9	12/27/77
10	12/21/77

SDSU-RSI-82-03

ISLAMIC REPUBLIC of MAURITANIA

RESOURCE INVENTORY of SOUTHWESTERN MAURITANIA

Geology-Soils-Forestry-Pasture

Renewable Resource Management

Prepared by

REMOTE SENSING INSTITUTE
SOUTH DAKOTA STATE UNIVERSITY

Under contract to

U.S. AGENCY
for
INTERNATIONAL DEVELOPMENT
Contract AID/afr-C-1619

1982

SDSU-RSI-82-03

RESOURCE INVENTORY OF SOUTHWESTERN MAURITANIA

Sponsored Jointly By

The Islamic Republic of Mauritania
Nouakchott, Mauritania

and

US Agency for International Development
Renewable Resources Management Project
Contract No. AID/afr-C-1619

In Cooperation With

Remote Sensing Institute
South Dakota State University
Brookings, South Dakota 57007 USA

Chief of Party - Dr. M. Wa Nsanga

Authors

Kevin Dalsted - Editor
A. Samuel Andrawis
John Falconi
Stephen Seefeldt
Christopher Stewart
Frederick Westin

Mauritanian Participants

Aly Sy
Ba Amadou
Abderrahmane Gaye
Ely O/Isselmou
Cheik Moussa

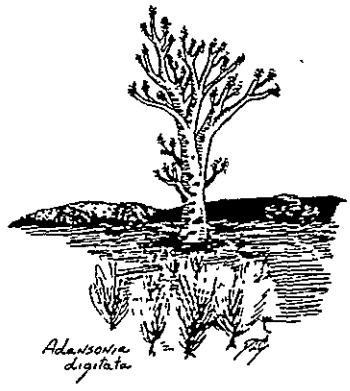
Principal Investigators - Victor Myers
Donald Moore

1982

PREFACE

This report contains the results of a 1980-81 survey of renewable resources in southwestern Mauritania. This report fulfills phase 2 of the 3-phase, 5-year USAID Mauritania Renewable Resources Management project, Contract no. AID/afr-C-1619, Project no. AID/682-0205. Phase 1 consisted of training six Mauritanians from the Ministry of Rural Development in remote sensing and resource systems. Phase 3, which is in progress, comprises site-specific programs of dune stabilization, forestry management, range management, and extension.

The reconnaissance resource survey (phase 2) commenced in September 1980 with the pasture inventory; the soil, geologic, and forestry surveys began in January 1981. Field work was completed in June 1981 and mapping unit boundaries were finalized in early July 1981.



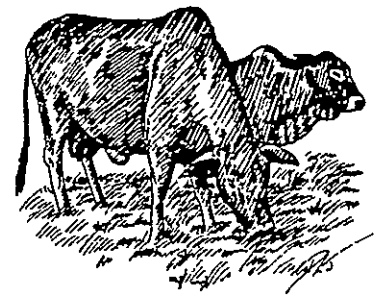
ACKNOWLEDGEMENTS

This report represents the culmination of numerous efforts by many industrious people from both Mauritania and the USA. The Government of the Islamic Republic of Mauritania (GIRM) and the U.S. Agency for International Development are commended for co-funding of this worthwhile project.

Special recognition is extended to the Mauritanian governmental agencies that effectively assisted and provided guidance to the resource survey team. The Ministry of Rural Development provided much support, especially Mr. Kane Hadya, Director of the Service de la Protection de la Nature. Other agencies that provided valuable assistance by opening their document files to the team include Direction de Topographie, Direction du Génie Rurale, Direction de Géologie, Direction du Service de l'Hydraulique, Direction de l'Agriculture and the United Nations FAO in Nouakchott. The Société Nationale de Développement Rural was especially helpful to the soil survey by providing valuable reports and by processing several soil samples for correlation purposes. The Centre de Recherches Vétérinaires was invaluable in the analysis of vegetative samples for the pasture survey.

Special recognition is given to the Mauritanian military and administrative institutions for all their attention to the many needs of the resource survey team, especially in the prompt approval of requests for field missions. In this context, many thanks are extended to Governors, Prefects, and their respective administrations in the Trarza, Brakna, Tagant, Gorgol, Assaba, Guidimaka, and Hodh Regions for the generous hospitality and assistance to the field survey teams. Much appreciation is extended to those Mauritanians, throughout the country, who graciously provided food, shelter, and guides for the field survey teams and who asked for nothing in return. The efforts in collection of field data would have been severely limited without the magnanimity of so many people. The regional and/or departmental Chefs de Services de l'Agriculture, des Eaux et Forêts, de l'Elevage, and the Direction de l'Ecole Nationale de Formation et Vulgarisation Agricole at Kaédi are also recognized for their participation in this project.

Finally, it is the desire of the Renewable Resources Management team to dedicate this report to the memory of Mr. Christopher William Ralph Stewart, who died on 1 November 1981. Chris provided the spark that kept the project moving and he inspired everyone through his diligence and untiring resolve in completing the pasture survey. The pastures of western Africa were a continual source of fascination to Chris both as a vocation and an avocation and their study has lost ground with Chris' death.



SUMMARY OF CONCLUSIONS and RECOMMENDATIONS

A reconnaissance survey (1:500,000 scale) of the natural resources of southwestern Mauritania was completed in 1981. The resources inventoried were geology, soils, forestry, and pastures. These data were delineated on a Landsat base map, field-checked and characterized, and are presented in this report and its accompanying maps.

This general-purpose survey was undertaken to locate and delineate the natural resources and their potentials and conditions in an intensively used portion of Mauritania (150,400 km^2 area). This report provides, among other possible uses, data for the determination of guidelines for planning and for development programs. In the following sections, a synopsis is presented for each resource chapter--geology, soils, forestry, and pasture; survey objectives, conclusions, and recommendations are highlighted.

GEOLOGY RESOURCES

Surficial geology and geologic structures were delineated upon a base of Landsat image interpretation and other map and data sources. The hydrogeology was completed using groundwater and well data combined with surficial geology and structural interpretations.

A broad range of surficial geology is represented in the project area--Pre-Cambrian to recent. The Pre-Cambrian and Cambrian formations constitute the "L'Arc des Mauritanides"; the dominant rocks are granites, granodiorites, and diorites in the Pre-Cambrian and chlorites, sericite schists, and mica schists in the Cambrian. The Cambro-Ordovician Period is represented by sedimentary formations that form the base of Tagant and Assaba Plateaus and that exist as outliers and plateaus in the eastern area. Rock types from this period are mainly mudstones, sandstones, and tillites. The western part of the area is a depositional depression (Senegalo-Mauritanian basin) of the Tertiary Period. Sandstones, marls, limestones, and dolomites are the dominant rocks in this period. Quaternary deposits include the terraces of the Senegal River, marine deposits near

the coast, alluvial deposits in seasonal stream beds, and aeolian sands, viz., dunes and gently undulating sand sheets.

Four tectonic movements have greatly shaped the structures of this region. The relatively young formations (i.e., plateaus, tillites, Eocene sandstones and dolomites) were, however, affected only by the last tectonic movement and thus retained their original horizontal bedding. The major effect of the tectonic movement on these younger formations has been the high intensity of faults and fractures. Two relatively large domes were identified on the imagery and are located east of Aleg. Numerous faults and fractures were mapped in the Assaba, Tagant, and Brakna Regions; the linears trends are generally northeast to southwest.

The project area was divided into three hydrogeologic zones: the Senegal River Valley, the Western Zone, and the Eastern Zone. The Western Zone has had most of the groundwater development, and nearly all the wells are hand-dug and don't penetrate beyond the upper horizons of the aquifer. A buried channel of the Senegal River was also located in the Western Zone; this old channel extends from a point west of Kaédi north toward Lake Aleg and then begins a southwesterly arc through Lake R'Kiz and into Senegal (Lake Guier). The Eastern Zone has a paucity of groundwater, although stream beds and some fault and fracture zones may be good sources. As a result of the hydrogeological and geological study, recommendations were made for the following surveys or studies:

1) a geophysical survey for the northwestern part of the project area thus revealing the configuration of the deposition basin and location of any structures

2) a detailed study of the dome structures for possible hydrologic or mineral locations

3) a field study of the plotted faults, their displacements, and their relationships to the adjoining rocks as related to groundwater occurrence

4) an investigation of the Trarza basin using deep bore holes to tap lower level aquifers and determine their characteristics

5) an investigation of recharging, through floodwaters, an old Senegal River channel

6) general studies (mainly geophysical) of buried river channels and tributaries, the Trarza basin and its aquifers, and the water-bearing zones in the weathered and fractured zones.

SOIL RESOURCES

Little was known about the soils of southwestern Mauritania except in the Senegal River Valley. The objectives of the general-purpose, reconnaissance soil survey were 1) to delineate soil associations (with climate-landform indices), 2) to determine soil suitabilities for agri-

culture, and 3) to inventory current land conditions, namely vegetative cover and erosion. A 3-level hierarchy--first, soil-climate zones; second, landforms; and third, soil associations--was used to partition the project area into soil mapping units.

Four soil-climate zones, based on soil temperature and moisture regimes, were defined across the project area. Soil Zone A, which has the most potential for rainfed agriculture, is classified as Ustic (>500 mm average annual rainfall) and Isohyperthermic (>24°C annual soil temperature with <5°C variation in a year). This zone included most of the Guidimaka Region. Soil Zone B, which has the most potential for flood-recessional agriculture, is classified as Aridic, Torric (225-500 mm average annual rainfall) and Isohyperthermic. This zone is located through the middle of the project area. Soil Zone C1 and C2 are low rainfall zones (<225 mm rainfall and Aridic, Torric) and differ only by soil temperature regimes, Hyperthermic (>24°C average annual temperature with >5°C variation in a year) and Isohyperthermic, respectively. The last two zones are located in the northern parts of the project area.

Landforms were the second level of the hierarchy. The dominant landforms were aeolian sands lithisols,ls (S), alluvial soils (A), uplands (U), desert pavement (P), and minor landforms, which were included with various members of the preceding five groupings. viz., marine terraces, sebkhas, coastal dunes, deltaic deposits, and various divisions of uplands.

Soil associations formed the third and lowest level of map divisions. Consequently, the 84 unique mapping units were described by soil zone, landform and the soil association criteria: soil slope, soil depth, drainage, texture, and composition of major soils. Most mapping units also were characterized by chemical and physical data from soil-profile and nonprofile descriptions and soil samples. Further definition of mapping units was compiled from field observations, Landsat interpretations, air-photo interpretations and published reports. These data included descriptions of minor soils, ranges of characteristics of the major components, major limitations for agriculture, suitability for rainfed or recessional cropland, and potential for development of alluvial lands.

Several mapping-unit interpretations were especially pertinent in the project area. The interpretations were erosion hazard, erosion, and suitability for agriculture.

Erosion hazard is defined as the susceptibility of land to wind or water erosion, and it takes into account the degree of existing erosion, soil texture, surface cover, soil slope, and soil drainage and permeability. Soil Zone A has, in general, both a moderate water- and wind-erosion hazard. The sands of Soil Zone B have a moderate to severe wind erosion hazard, and the other soil units have very slight or slight erosion hazard. Soil Zone C is characterized by a severe wind erosion hazard for most mapping units.

Mapping units that corresponded to large zones of actively moving sands were located in Soil Zones B and C. The units, in general, are

highly visible on the Landsat base map, having a northeast to southwest orientation. Numerous mapping units had areas of severe erosion interspersed among areas of slight and moderate erosion.

The UN FAO Suitability Classification was used to categorize agricultural potentials (sorghum and millet) for all mapping units. Three suitable ratings and two nonsuitable ratings were used. The moderately suitable category (S2) encompassed all or parts of seven mapping units for flood-recessional agriculture (4020 km^2) and two mapping units for rainfed agriculture (580 km^2). The S3 soils have severe limitations and can be expected to produce only marginal benefits from the necessary inputs. Ten mapping units were classified as being conditionally suitable for dryland agriculture (2870 km^2). The SC soils must receive more than 350 mm of precipitation before any benefits are produced. The long term 350 mm isohyet was adopted as the threshold value based upon previous agro-hydrologic studies (see soil chapter for further definition). The remaining majority of mapping units were categorized as currently or permanently nonsuitable (N1 and N2, respectively).

Management practices and land improvement possibilities were briefly described for soils with agricultural potential. Further research is required to insure that agronomic practices and crop varieties are optimal. Rainfall deficiency is the major limitation for agriculture throughout the project area; it is therefore imperative that variables that can be controlled by the farmer should be optimized to the greatest possible degree. Fertilization, crop rotation, animal tillage, proper weeding and thinning, good seed stock, and proper plant populations are part of a complete management plan. Selection of management alternatives for the agronomic variables should be tailored to soil-climatic conditions.

Control of soil erosion, conservation of moisture, and maintenance of soil fertility and tilth are the major soil problems in the project area. Integrated management programs can be used to address these soil problems. Residue management, tillage, strip cropping, and field windbreaks are among proven techniques to combat one or more of the above soil problems.

Land improvement options include contour dikes, terraces, and the inclusion of spillways for traditional dams. Careful site investigation and economic analyses are needed before any of these improvements should be implemented. Eight mapping units with good potential for development of alluvial lands were described. Most alluvial soils of Soil Zone A have considerable agricultural potential with or without development. Six mapping units with fair potential for development of alluvial lands were also noted.

More agro-climatological research is needed to determine the likelihood of receiving minimally required soil moisture for various crop varieties. Location of small dams for recession agriculture could be based on surface runoff indices and statistically derived precipitation distributions and amounts.

Further development of flood-recessional agriculture appears to offer the best means of improving crop production in southwestern Mauritania. Fair potential for rainfed agriculture exists in only a small portion of the project area; however, crop production in these areas could be improved through increased inputs and better management programs. Potentials for irrigation were not included in this survey, but some areas appear to have adequate groundwater, as indicated by temporary lakes, and should be investigated. Long-term range and forestry management offer the best means of slowing land degradation and maintaining soil productivity.

FORESTRY RESOURCES

The nature of vegetative changes and current status of the plant communities can be traced, and represented best, by maps of the cover types. The objectives of the forestry survey were as follows: 1) to map forest cover types by principal woody species, 2) to count stems per hectare (stocking rate), 3) to describe the general condition of the vegetation within mapping units, 4) to detail the species composition including dominant and associated species, as well as variants, and 5) to estimate the successional position of species by mapping unit.

A total of 47 cover types were identified along with three additional miscellaneous, nonvegetated mapping units. Ground data were comprised of 295 sample plots, each of which was 0.10 ha in extent.

Forest stands that were readily visible on the imagery were limited to classified forests along the Senegal River, large oases, and scattered dense stands that occupied drainages and depressions. While woody plant communities exist almost everywhere in southwestern Mauritania, very light stocking densities and feathery crowns of many tree species result in Landsat signatures that corresponded more closely to soils than to vegetation. To a certain degree, vegetation also changes with soil type, but the correlation is not always consistent or predictable. It is necessary, therefore, to have abundant ground truth data to differentiate the map units. Several forest cover types were very similiar to each other and they need further close observation and study to verify if separation is justifiable. This is particularly true for the types of the northern regions characterized by *Acacia raddiana, Leptadenia pyrotechnica, Commiphora africana,* and *Maerua crassifolia.* It may also extend to the cover types of the Aftout es Saheli and those along the Senegal River to Leqceiba.

In general, it is possible to delineate several patterns in the vegetative cover of the study area. The northwest is characterized by psammophiles such as *Leptadenia pyrotechnica, Commiphora africana* and *Acacia raddiana.* The southwest is a transition zone from purely sand species to those that colonize heavier soils, which have better soil-water conditions. *Acacia senegal* formerly occupied vast regions of the southwest, but is now centered around the southern Trarza in the department of Mederdra. Surrounding this department are small scattered remnants of *Acacia senegal* stands within much larger regions of devastation in which one finds very few *Acacia senegal,* scattered *Balanites aegyptiaca, Maeura crassifolia* and *Acacia raddiana.* These regions of devastation are evident to the north and east of Mederdra itself and to the east of Lake R'Kiz.

Between Lake Aleg and the Senegal River one finds extensive stands of *Boscia senegalensis* that yield to stands of acacias and finally to forests of *Acacia nilotica* along the river.

The Assaba and Tagant plateaus offer a curious admixture of plant communities that are undergoing transition. This is the result of sand deposition from the eastern dune zone, to the southern Brakna and western Assaba, deposition that continues to the west of the plateaus and is strikingly evident at Moudjeria.

East of the plateaus is a large area of sand dunes followed to the extreme east by rocky terrain and plateaus. The dune system varies from heavily vegetated in the southern portions to moving sand with little to no vegetation in the north. The latter situation is strikingly evident between Kiffa to Boumdeit.

The Guidimaka remains the most heavily vegetated zone of southwestern Mauritania and the only region, aside from the remnants of classified forests, in which forestry might be feasible as an industry. Heavy mortality of *Sterculia setigera* and over-exploitation of *Combretum glutinosum* are reducing the numbers of these trees in the region; nevertheless, they still form important components of many woody plant communities.

With only localized exceptions, the classified forests of *Acacia nilotica* are under seige and are threatened with elimination by uncontrolled exploitation of the tree for charcoal production. There is essentially no reproduction of the tree either naturally or through forest management practices, and no attempts have been made to replace it with another species that might serve the needs of the populace. This is an area of study that must be undertaken if Mauritania is to avoid becoming an importer of fuel wood.

Throughout the study area, over-exploitation of woody plants was the rule. Mortality of certain species was more pronounced in the northern area where drought, combined with uncontrolled use of trees, has reduced vegetation stocking densities to very low levels. The large-scale removal of vegetation is easily noted on Landsat imagery. Villages and large communities are often visible as yellow, or light colored, spots caused by bare soil rather than vegetation, which has been removed by a sedentary population unaware of conservation techniques and unable to control exploitation by passing herders and others.

There is a great need for immediate investigations and experimentations to restore or, at the very least, stop the over-exploitation of forest trees. Several areas of study present themselves immediately. These include a search for a tree that can replace *Acacia nilotica* as the principal source of firewood and charcoal. Its characteristics should include fast growth, dense wood, and the ability to withstand limited periods of drought. The only appropriate zones in which production on large scales can be contemplated are those adjacent to the Senegal River and other permanent bodies of water. Two tree species introduced into Mauritania show promise as replacements or substitutes for *Acacia nilotica*. These are *Eucalyptus camaldulensis* and *Leucaena leucocephala (L. glauca*

or mistakenly *peltophorum)*. Another research problem is the selection of methods that can insure wide-scale regeneration of *Acacia senegal* and/or other vegetation in order to increase the value of lands for year-round pasture and to guarantee a source of gum for at least local needs.

Another area of research centers around the production in nurseries of indigenous species that are locally important for items such as tooth sticks, medicines, edible fruits and poles. Species that could be emphasized include *Maerua crassifolia, Adansonia digitata, Zizyphus mauritiaca, Acacia raddiana,* and *Balanites aegyptiaca.*

The use of *Euphorbia balsamifera* for dune stabilization has proven highly successful around Nouakchott, but a variety of species should be studied and tried for appropriateness. Indigenous and exotic species must be included.

The research needs of Mauritania in the field of forestry are vast, but there is equally a vast potential for success, provided research is begun soon, species are intelligently and carefully selected, and the trained foresters of Mauritania are provided with the support and encouragement to help carry out these studies.

The present forestry map represents only the initial step in what should be a continuing process of refinement, correction and modification. It would be highly desirable to repeat the mapping at regular intervals of 5 to 10 years in order to trace shifts in stocking density and composition of the woody plant communities. Landsat imagery is indispensable to such an undertaking and should in the near future become more accessible and offer improved spatial and spectral resolution.

PASTURE RESOURCES

The pastures of southwest Mauritania are botanically heterogeneous with wide-ranging degrees of utilization, from untouched to devastated. Before proper management of pasture lands can be implemented, floral inventories, definitions and descriptions of pasture cover types, and carrying capacity data are required as management inputs. The objective of this survey was to gather these data at a reconnaissance level for input into the development of a region-wide pasture management plan.

The pasture survey was completed through the delineation of pasture cover types on the Landsat base mosaic. Verification and definition of cover types was accomplished by means of phytosociological sampling between September 1980 to March 1981. Actual data collection for estimation of dominant plant species was based on the point frequency method (Daget and Poissonet, 1971) within 0.25 ha sample sites (303 sites in total). Four to ten plots of 1 m^2 were harvested within a sample site in order to estimate potential productivity. Other field data included classes of species abundance (as percentage of vegetative cover), brief soil descriptions, plant height and palatibility indices. Jaccard's index of similarity was used to pool similar sample data for mapping unit definition and description.

An estimated 1000 vegetative species constitute the flora of the project area. Out of this number, 356 were collected and identified during the course of the field investigation. Descriptive data are presented in detail in Section III of Chapter 5.

Six major strata were used to organize pasture cover types: landscapes of 1) dunes (D), 2) non-dune sands (S), 3) loams (L--loamy sands to loams), 4) regs or lithosols (RG), 5) rocky or stoney (R), and 6) alluvium (O and A). Thirty-nine pure pasture types were defined; the remaining 40 pasture types were composites. Several subtypes were also noted. Each mapping unit was described by areal extent, potential productivity (dry matter in kg/ha), estimated carrying capacity (Tropical Bovine Units, TBU's), productivity class and recommended seasonal grazing capacities.

The extent of cover types by major strata is listed as follows: 1) D--62,860 km^2, 2) S--21,200 km^2, 3) L--11,180 km^2, 4) RG--37,110 km^2, 5) R--8,510 km^2, and 6) O and A--9,540 km^2. A further characterization by productivity class provides the following data: Class 0 (<450 kg dry matter/ha, should not be grazed)--460 km^2, Class 1 (<450 kg/ha)--80,680 km^2, Class 2 (450 to 910 kg/ha)--49,550 km^2, Class 3 (910 to 1525 kg/ha)--12,250 km^2, and Class 4 (1525 to 4560)--7460 km^2. The total estimated carrying for the project area is 1,895,430 TBU's/year; this calculation is based only upon vegetative resources as characterized by the field data and their interpretations and the adjustments for seasonal carrying capacities. Livestock numbers and distributions are inexactly known for Mauritania. The interaction between stocking rates and rangeland wells is discussed in Section V. The case is made for controlled grazing in conjunction with making proper utilization of permanent water sources (or adding to those sources).

The dynamic forage values of the many and varied pasture plants are well known in the literature. Consequently, these data were used to estimate pasture forage values. In addition to forage value, palatibility factors must also be considered; these plant features change by season with plant growth stage. Thus, forage value assessment, conditioned by palatibility, can be estimated by the ability of plants to satisfy two nutritional needs of the ruminant: energy needs and protein needs. Fodder (or Forage) Units (F.U.) were related to caloric intake (one F.U. being equal to 1650 calories). A categorization by four classes of fodder (Boudet, 1975) was given according to F.U. and protein values. Important annual and perennial grasses, herbaceous species, and wood species were valued across growth stage by the Boudet categories, F.U.'s, and protein quantity. These approximate valuations were further assigned to the 79 pasture cover types.

Range managers in the Sahel are faced with numerous problems. These difficulties include: 1) lack of knowledge of numbers and distributions of the 'sedentary' livestock, 2) land tenure problems, 3) uncertain climate, and 4) the "July crisis", i.e., shortage of nitrogen-rich plants at the end of the hot season and beginning of the rainy season, leading

to reduction in animal vigor and productivity. A number of interventions addressed toward the solving of the latter two problems are presented in Section VII. In this context, five major topics are examined: 1) improvement of natural pasture lands, 2) improvement of livestock feeding, 3) protection of pasture lands against bush fires and abusive exploitation, 4) limitation of animal stocking rates, and 5) limitation of nomadism and transhumance. The five major areas of improvement are discussed in detail, including advantages and disadvantages.

TABLE OF CONTENTS

	PAGE
TITLE PAGE	i
PREFACE	ii
ACKNOWLEDGEMENTS	iii
SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS	iv
TABLE OF CONTENTS	xiii
LIST OF FIGURES	xvii
LIST OF TABLES	xxiii
CHAPTER 1. AN OVERVIEW OF THE RESOURCE SURVEY OF SOUTHWESTERN MAURITANIA	1
I. Introduction	1
II. Application of Remote Sensing to the Mauritanian Survey	2
III. Utilization of the Resource Maps and Data	7
IV. Description of the Project Area	9
V. References	20
CHAPTER 2. GEOLOGY, STRUCTURES AND HYDROGEOLOGY	21
I. Introduction	21
II. Geology	21
Pre-Cambrian	22
Cambrian	22
Cambro-Ordovician	22
Tertiary	23
Quaternary	23

TABLE OF CONTENTS (cont'd)

	PAGE
III. Structures	23
Domes	24
Faults and Fractures	24
IV. Hydrogeology	25
The Senegal River Valley Zone	25
The Western Zone	25
The Eastern Zone	29
V. Recommendations and Conclusions	31
VI. References	32
CHAPTER 3. SOIL SURVEY	33
I. Introduction	33
II. General Description of the Project Area	33
Physiography	34
Climate	34
Land Use	36
III. Materials and Methods	38
IV. Utilization of the Soil Map	40
V. Brief Mapping Unit Descriptions	41
Soil Region A	41
Soil Region B	56
Soil Region C	85
VI. Soil Properties, Potentials, and Other Land Characteristics	95
Tables	96
Erosion and Erosion Hazard	113

TABLE OF CONTENTS (cont'd)

PAGE

Suitability for Agriculture 116

VII. Land Management for Agriculture 119

Agronomic Considerations 119

Soil Considerations 120

Agroclimatological Considerations 121

VIII. Summary and Conclusions 121

IX. References 126

CHAPTER 4. FOREST COVER TYPES 129

I. Introduction 129

II. Mapping Procedures 130

III. Results and Discussion 132

Cover-Type Descriptions 134

IV. Summary and Conclusions 163

V. References 167

CHAPTER 5. PASTURE COVER TYPES 168

I. Introduction 168

II. Methods 168

Mapping Pasture Cover Types 168

Field Survey 169

Herbaceous Stratum 169

Woody Stratum 170

Tally Sheet 170

Data Analysis 170

III. Floral Inventory 177

TABLE OF CONTENTS (cont'd)

PAGE

IV. Pastures of Southwestern Mauritania 201

Foreword 201

Pastureland Types 203

Summary 264

V. Animal Stocking Rates 267

VI. Assessment of Forage Value 273

VII. Range Management Problems and Recommendations 284

VIII. References 288

Appendixes 290

Appendix A - Soil Laboratory Procedures 291

Appendix B - Terms and Criteria Used for Rating Selected Soil Properties and Soil Interpretations 293

Appendix C - Profile and Site Descriptions with Chemical Analysis 296

Appendix D - Soil Taxonomy 329

LIST OF FIGURES

Figure		Page
1-1	Location of the Renewable Resources Management Project Area	3
1-2	Landsat coverage of the project area by path and row indices	4
1-3	The three areas of aerial photographic coverage (1980-81) are shown in the project area	6
1-4a	Isohyetal map shows mean rainfall amounts (in mm) within the project area, 1941-70	13
1-4b	Isohyetal map shows mean rainfall amounts (in mm) within the project area, 1970-80	13
1-5	Isohyetal map shows mean rainfall amounts (in mm) received in 1977	14
1-6	Isohyetal map shows mean rainfall amounts (in mm) received in 1979	14
1-7	Isohyetal map shows mean rainfall amounts (in mm) received in 1980	15
1-8	The distribution of annual rainfall is shown over a number of years for seven recording stations	16
1-9a	Mean January temperature data (^{o}C) is shown over the project area	19
1-9b	Mean April temperature data (^{o}C) is shown over the project area	19
2-1	Static water level and salinity contours over western Mauritania	26
2-2	A Landsat mosaic of band 7 images shows a buried river channel from east of Bababé to Lake Aleg to Lake R'Kiz to Lake Guier (in Senegal)	28
2-3	Locations of high probability for ground water occurrence	30
3-1	Major landforms and climatic zones are shown for the project area on a band 5 Landsat mosaic	35

LIST OF FIGURES (cont'd)

Figure		Page
3-2	Locations of sample sites for the soil investigation . . .	39
3-3	Alluvial zones of Soil Region A are illustrated near Selibaby	43
3-4	Lithic zones of Soil Region A are illustrated	46
3-5	Aeolian sands of Soil Region A are illustrated near Selibaby and Harr	49
3-6	Return Beam Vidicon (RBV) image shows the southern Guidimaka Region in October 1978	50
3-7	Uplands soils of Soil Region A are illustrated	52
3-8	Aeolian sands of Soil Region B are contrasted by comparison of the western and eastern parts of the project area	57
3-9	Lithic soils in Soil Region B are illustrated northwest of M'Bout and at the southern tip of the Assaba Plateau	68
3-10	Pediments or reg are illustrated southwest of Magta Lahjar and at the Letfata airport	72
3-11	Uplands in Soil Region B, dominated by heavy textured soils with little ground cover, are illustrated	75
3-12	Alluvial soils in Soil Region B are shown in the Oued Ketchi and at Lake R'Kiz	80
3-13	A band 7 Landsat scene (near-infrared) shows the extent of flooding in the southern Gorgol Region (September 1978)	82
3-14	Aeolian sands, the majority of land area in Soil Region C, are illustrated near Nouakchott, Boutilimit and Boumdeit	87
3-15	Lithic zones in Soil Region C are illustrated near and on the Tagant Plateau	92
3-16	An alluvial zone of Soil Region C is represented by an area 30 km northwest of Boumdeit	94

LIST OF FIGURES (cont'd)

Figure		Page
3-17	Proportions of major landforms are contrasted among Soil-Climate Zones A, B, and C	114
3-18	The erosion hazard is shown for the project area	115
3-19	Suitability for rainfed and flood-recessional agriculture is shown for the project area	117
4-1	City and village location map for geographic references in the forest cover type chapter	135
4-2	A mature Acacia flava stand illustrates a typical setting for cover type 2	136
4-3	Acacia raddiana and Acacia senegal dominate the woody vegetation in an interdune of cover type 7	139
4-4	A typical setting for cover type 22 consists of Euphorbia balsamifera in association with Acacia raddiana, Acacia senegal, Boscia senegalensis, and Panicum turgidum	148
4-5	Adenium obaesum, a principal species of cover type 23, is shown on a rocky slope between Kaëdi and Maghama. .	149
4-6	A Piliostigma reticulatum is shown in a small walo (i.e., floodplain lowland) east of Rosso toward Keur Maur	154
4-7	Euphorbia balsamifera, Dichrostachys glomerata, Boscia senegalensis, Guiera senegalensis, Acacia senegal, and Pterocarpus lucens are among the species that occupy a rocky site on the eastern face of the Assaba plateau (cover type 38)	157
4-8	An Anogeissus leiocarpus is associated with the smaller Zizyphus mauritiaca and Boscia senegalensis in cover Type 43	160
5-1	Sample locations and subsample plots are shown within the project area (pasture survey).	172
5-2	Various herbaceous species are characterized	178
5-3	Various legumes (Legumineuses) are characterized	179

LIST OF FIGURES (cont'd)

Figure		Page
5-4	Several grasses of the Aristideae family are characterized	180
5-5	Several grasses of the Eragrosteae family are characterized	181
5-6	Several grasses of the Paniceae family are characterized	182
5-7	Potential productivities for the pastures of the project area are shown	204
5-8	Stratification Diagrams, Type D1	205
5-9	Stratification Diagrams, Type D2	211
5-10	Stratification Diagrams, Type D3	212
5-11	Stratification Diagrams, Type D4	213
5-12	Stratification Diagrams, Type D5	214
5-13	A coastal dune with Salvadora persica, Euphorbia balsamifera, and Nitraria retusa typifies cover types DC1 and DC2	215
5-14	Stratification Diagrams, Type S1	216
5-15	A typical setting of type S2 is shown	222
5-16	Stratification Diagrams, Type S2	221
5-17	Stratification Diagrams, Type S3	223
5-18	Stratification Diagrams, Type S4	224
5-19	Stratification Diagrams, Type S5	225
5-20	Stratification Diagrams, Type S6	226
5-21	Stratification Diagrams, Type S7	227
5-22	Stratification Diagrams, Type L1	228
5-23	A typical setting for subtype L1a is shown	232
5-24	Stratification Diagrams, Type L2	233

LIST OF FIGURES (cont'd)

Figure		Page
5-25	Stratification Diagrams, Type L3	234
5-26	Stratification Diagrams, Type RG1	239
5-27	Stratification Diagrams, Type RG2	239
5-28	Stratification Diagrams, Type RG3	240
5-29	Stratification Diagrams, Type RG4	241
5-30	Stratification Diagrams, Type RG5	241
5-31	Stratification Diagrams, Type RG6	242
5-32	Stratification Diagrams, Type R1	247
5-33	Stratification Diagrams, Type R2	247
5-34	Subtype R2c is illustrated by a pasture in excellent condition	248
5-35	Stratification Diagrams, Type O1	254
5-36	Type O2 is typified by *Acacia nilotica* and *Acacia seyal* in primary floodplains	255
5-37	Stratification Diagrams, Type O2	256
5-38a	Stratification Diagrams, Type AW1c	257
5-38b	Stratification Diagrams, Type AW1d	257
5-39a	Stratification Diagrams, Type AW2a	259
5-39b	Stratification Diagrams, Type AW2d	259
5-40	Stratification Diagrams, Type AL	260
5-41	Stratification Diagrams, Type AM	261
5-42	Stratification Diagrams, Type AT	261
5-43	Stratification Diagrams, Type AS	262
5-44	The setting for Pasture Type A reveals a dense cover of *Acacia seyal* with patches of *Andropogon gayanus*	263

LIST OF FIGURES (cont'd)

Figure		Page
5-45	Stratification Diagrams, Type RK	264
5-46	The distribution of cemented wells is shown across the project area	271
5-47	A rangeland well located to the north of Boghē is shown	272
5-48	A contrast of utilization of pasture lands is shown . . .	274

LIST OF TABLES

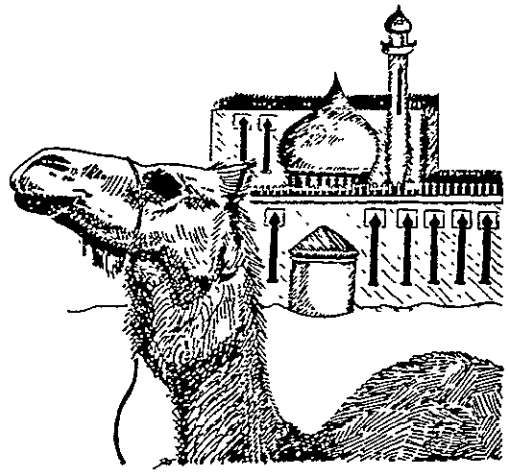
Table		Page
1-1	Precipitation received in the project area in 1980	12
3-1	Selected properties of the soil mapping units	97
3-2	Potentials and other soil mapping unit characteristics . .	104
3-3	Soil requirements for crops adapted to parts of the project area (after Young, 1976)	112
3-4	Categorization of the mapping units with agricultural potential	124
4-1	Forest cover types of southwestern Mauritanian and percentage of study area occupied by each cover type . . .	133
5-1	Example of a provisional phytosociologic table for pasture cover type RG3	173
5-2	Listing and interpretation of a possible phytosociologic table (RG3) using Jaccard Indices of Similarity	176
5-3	Important delineations of the flora found in the project area	184
5-4	Species abundance for 'D' cover types	206
5-5	Significant properties for the pasture cover types of dunes, 'D'	209
5-6	Species abundance for 'S' cover types	217
5-7	Significant properties for the pasture cover types of the sandy landscapes, 'S'	220
5-8	Species abundance for 'L' cover types	229
5-9	Significant properties for the pasture cover types of loamy landscapes, 'L'	231
5-10	Species abundance for 'RG' cover types	235
5-11	Significant properties for the pasture cover types of reg landscape, 'RG'	238
5-12	Species abundance for 'R' cover types and cover type 'A' .	243

LIST OF TABLES (cont'd)

Table		Page
5-13	Significant properties for the pasture cover types of rocky landscapes, 'R'	245
5-14	Species abundance for cover types 'O' and 'A'. Pasture type RK is also included	249
5-15	Significant properties for the pasture cover types of alluvial landscape, 'O' and 'A'	253
5-16	Distribution and number of livestock in the project area (1979 estimates in thousands of head and TBU's)	268
5-17	Estimation (1980-81) of the livestock population and TBU's in the Guidimaka Region	269
5-18	Fodder values for important annual grasses	277
5-19	Fodder values for important perennial grasses	279
5-20	Fodder values for various herbaceous species	280
5-21	Fodder values for important woody species	281
5-22	Fodder categories (after Boudet, 1975) by season for the pasture cover types	282

CHAPTER 1

AN OVERVIEW OF THE THE RESOURCE SURVEY OF SOUTHWESTERN MAURITANIA



I. INTRODUCTION

Serious environmental problems face the government and people of Mauritania. In the past decade (1968-77), a severe drought, sedentarization, and population requirements have put extreme demands upon natural resources. These demands have resulted in environmental degradation through wind and water erosion, regressive trends in range species and range condition, and reduction of forested land area. Among the agents of these detrimental processes are the multifaceted interactions among agricultural and livestock practices, societal demands for food, fiber, and space, and the climatic diversity associated with arid and semi-arid zones. In order to fully comprehend the magnitude of environmental problems in southwestern Mauritania, to realize the resource potentials, and to initiate ameliorative and positive programs, a complete body of information concerning renewable land resources was required. The environmental needs, potentials, and problems for the whole of Mauritania are further addressed in a recent U.N. Sahelian office report (UNSO, 1981).

Numerous site-specific and special-purpose studies have been completed in Mauritania. These investigations are, however, restrictive by design, age, and specific purpose. While these studies can be used to corroborate other smaller scale surveys, they cannot be easily incorporated into region-wide resource data bases. Synchronous collection of resource data is needed to assure uniformity in the establishment of baseline conditions. The extent and condition of various resource parameters is needed to furnish a foundation upon which national planning, implementation of remedial actions, and future updating of dynamic resource characteristics can be built. Region-wide natural resource data provide such a foundation.

In large-area surveys, small scales provide the best compromise between the level of detail and the expense and time needed to complete the survey. Landsat satellite data have been used successfully in several

small-scale, country- or region-wide resource surveys. Generally, multistage approaches are employed in Landsat-based surveys; the stages include Landsat Multispectral Scanners (MSS) and Return Beam Vidicon (RBV), aerial photography, and ground observation and sampling. Landsat base images, though limited by a small scale, offer synoptic, near-orthographic and multispectral coverage. The multidate coverage by Landsat further affords a potential for updating changes in resource variables, such as rangeland trends, land use, and erosion.

Regional inventories of Mauritanian renewable resources were virtually nonexistant. It was the aim of Phase 2 of the Mauritania Renewable Resources Management project to establish baseline data for a national, renewable resources plan. This was achieved through the utilization of a Landsat-based, multistage resource survey. The renewable resources inventoried in the 150,400 km^2 project area in southwestern Mauritania (Fig. 1-1) included pasture lands, forest lands, soils, and geology; additional correspondent interpretations and land conditions were also included. Reversal of environmental degradation and development of positive approaches to resource utilization through management and intervention plans requires an accurate indication of the location, extent, and condition of the current resource situation.

II. APPLICATION OF REMOTE SENSING TO THE MAURITANIAN SURVEY

Remote sensing is defined by the American Society of Photogrammetry as follows:

> imagery...acquired with a *sensor* other than (or in addition to) a conventional camera through which a scene is recorded, such as by electronic scanning, using radiations outside the normal visual range of the film and camera--microwave radar, thermal infrared, ultraviolet, as well as multispectral. Special techniques are applied to process and interpret remote-sensing imagery for the purpose of producing conventional maps, thematic maps, resources, surveys, etc., in the fields of agriculture, archaeology, forestry, geography, geology and others.

The Renewable Resources Management (RRM) project employed near-infrared and visible spectrum imagery, as well as digitally enhanced Landsat imagery, in completing the resource survey.

The Landsat satellite imagery consisted of MSS and RBV data. The MSS data are collected in four spectral "bands": band 4, 0.5 to 0.6 μm (green); band 5, 0.6 to 0.7 μm (red); band 6, 0.7 to 0.8 μm (near-infrared); and band 7, 0.8 to 1.1 μm (near-infrared). The RBV imagery (Landsat 3) is collected by a two-camera system that records data in the 0.505 to 0.750 μm spectral region. Scene coverage for a Landsat MSS scene is 185 by 185 km, whereas RBV coverage is 98 by 98 km (4 RBV scenes per MSS scene). The instantaneous ground resolution (i.e., the ground spot viewed at any instant by the optical system) is 0.45 ha for Landsat MSS and 0.10 ha for RBV. The Landsat satellite completely covers the earth every 18 days from an altitude of 917 km (coverage for Mauritania is shown in Fig. 1-2); however, recording and data handling facilities are limited and as a result MSS and RBV data are not transmitted continously over the land surface of the earth.

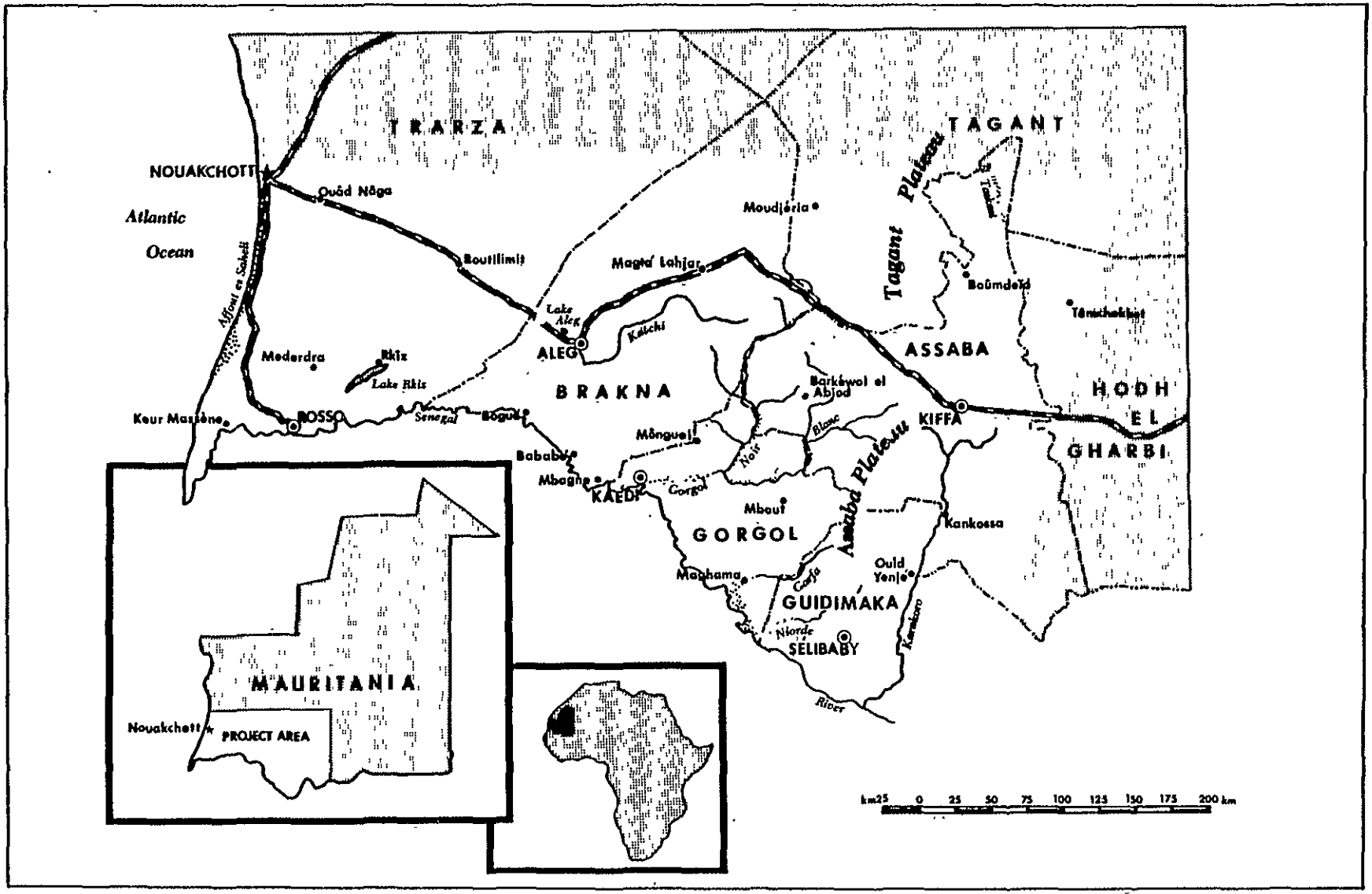


Fig. 1-1. Location of the Renewable Resources Management Project Area.

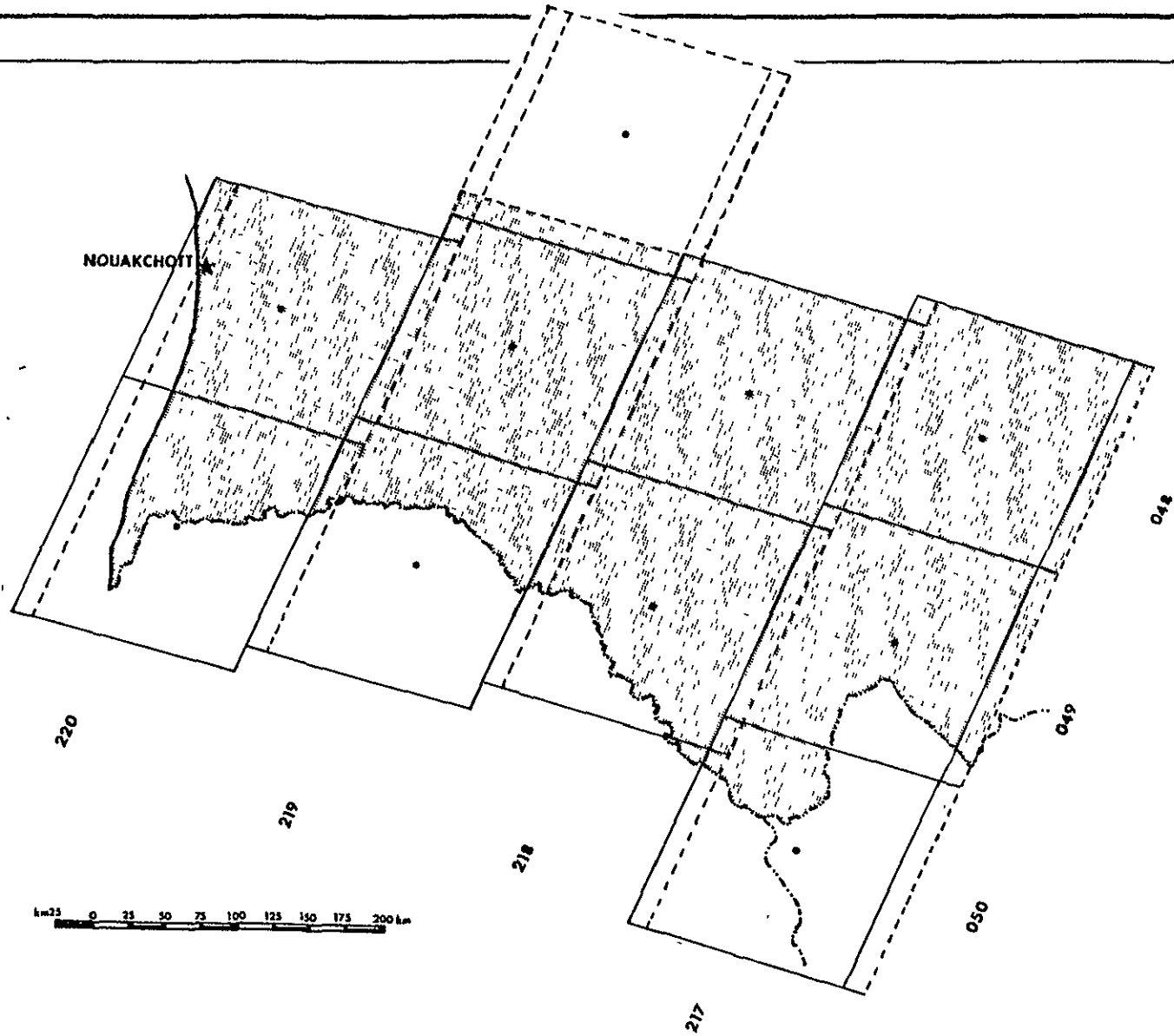


Fig. 1-2. Landsat coverage of the project area is shown by path and row indices. The center of each Landsat scene is indicated by a dot.

Color infrared (CIR) film is sensitive to radiation in the visible and near-infrared portions of the electromagnetic spectrum. Since growing vegetation absorbs radiation in the blue and red portions of the spectrum and reflects radiation in the green and near-infrared bands, CIR photography (and a composite of MSS bands 4, 5, and 7) offers the capacity to differentiate between actively growing and dormant vegetation. Landscape positions favorable for vegetative growth, some productive soils, and some management practices (e.g., irrigation) may often be identified on CIR photography due to increased vegetative production. The differentiation of actively growing vegetation from other terrain features provides valuable information in land resource surveys and resultant interpretations. The limited coverage of the project area by Organisation pour la Mise en Valeur du fleure Sénégal (OMVS) CIR photography (1980 at 1:50,000 scale) was used by the resource survey staff (Fig. 1-3).

The base map used for all resource mapping-unit delineations was a digitally enhanced (4 MSS bands) Landsat MSS mosaic (Wilson, no date). Selection of the Landsat scenes for this mosaic was limited by availability of coverage, cloud masking, and image quality problems. All scenes used in the mosaic except one were 1977 images ranging from 6 September to 27 December overpasses; the other scene (219, 47 northeast of the Nouakchott scene) was from a 1972 overpass. Two scenes from other years had slightly better quality of imagery, years, but selection of data in the same time frame (i.e., 1977) outweighed the slight improvement in cloud cover or image quality from the other dates. All available Landsat and RBV scenes were acquired and used in determining placement of mapping unit boundaries, i.e., photo-interpretations.

A hierarchical, or multistage, approach was utilized by each resource scientist in completing his respective map. This approach was based on photo-interpretation and analyses of multi-date (seasonal and different years) Landsat imagery and aerial photography. Preliminary photo-interpretative delineations were completed on the Landsat MSS mosaic before field work was started. Background materials, including site-specific studies and small scale maps together with the experience of the Mauritanian counterparts, were consulted during the preparation of the preliminary map.

Ground-verification trips were one to two weeks in length, and the resource teams generally worked separately due to the disparity of sampling techniques, i.e., type and number of ground observations. Plant samples of mounting quality, quantification of species per unit area, rock samples, soil-profile descriptions and soil sampling, slope mapping and qualitative estimation of ground cover were some of the methods of verifying mappingunit boundaries and descriptions. Specifics of the various resource sampling schemes are detailed in the appropriate chapters. After collection of the field data and samples, further analyses and collation took place in the RRM Nouakchott office.

The finalization of mapping unit boundaries took place after studying the results of the field observations, re-analyzing the Landsat and

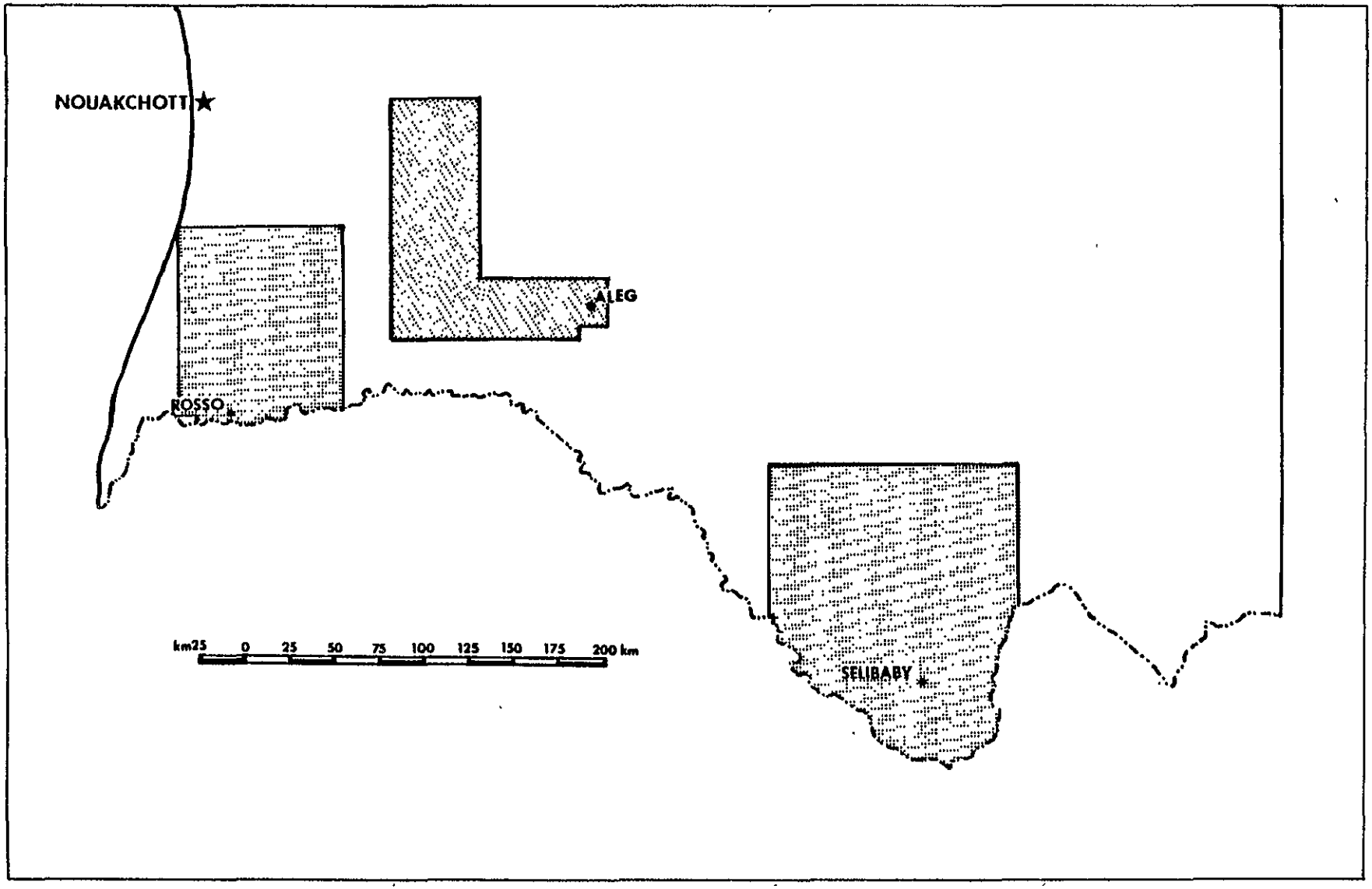


Fig. 1-3. Three areas of aerial photographic coverage (1980-81) are shown in the project area.

aerial imagery, and describing the mapping units such that significant differences excluded any further grouping or separating of delineations. The actual placement of boundaries was an objective task and depended upon the indices of each resource specialist and the representation of the ground area(s) on Landsat imageries. In the following section, the interaction of the various resources that were investigated will be analyzed in light of differences among the mapping unit demarcations.

Remote-sensing technology was used in this project to provide a basis for locating and describing the natural resources of southwestern Mauritania. This baseline resource information was collected and analyzed for immediate and future utilization by resource managers, planning personnel, and appropriate government officials. Remote sensing technology should also be considered in designing future activities that result from these survey data, as well as further use (i.e., larger scale surveys) to examine in detail some of the more promising land areas.

The 1980's will see rapid improvement in most aspects of satellite remote sensing capability: new satellites will have smaller instantaneous fields of view and better spectral differentiation, cartographic utilization, and "turn-around" time (Welch and Marko, 1981; Chevrel et. al., 1981). As satellite sensors are improved and the types of available spectral information expanded, remote-sensing applications to resource monitoring will provide the potential for more precision and better accuracy.

III. UTILIZATION OF THE RESOURCE MAPS AND DATA

Before the data in this report can be fully applied, an understanding of the term 'reconnaissance survey' is required together with an awareness of the relationships among the soil, pasture, and forestry mapping units. The inherent strengths and shortcomings of a reconnaissance survey predate the types of uses and decisions that can be based upon it. Likewise, similarities and disparities among the mapping units of the different resources should be understood if integrated programs are to be undertaken. (Since the geology map is general in nature and compiled in part from other sources, it is not discussed in this section.)

The level of detail in a resource survey is usually dictated by the scale of the base map and concomitantly by the density of ground observations. A scale of 1:500,000 was chosen for this survey because it provided the optimum amalgamation of detail, extent of project area, and time required from project beginning to report completion. At the 1:500,000 scale, mapping units consist of associations and have a minimum, prescribed size of 1000 ha. As an example of the scale limitations for mapping units, a line with a width of 1 mm on the base map corresponds to an on-ground width of 0.5 km. As a consequence, the survey results should be used only for general activities, such as broad planning and management uses, or in determining the locales for more detailed surveys.

In Mauritania, the interactions among geology, soils, and vegetation show a strong correlation to mapable features. Ideally this situation would dictate the use of land mapping units, i.e., composite units, each having the reasonably similar attributes of climate, geology, hydrology,

soil, flora, and fauna (Young, 1979). However, the differences in dynamics, or resistance to change, among the various resources and in the climate-land use interplay in Mauritania lead to the use of individualized resource surveys. Consequently, there are four resource maps for the project area instead of just one, and a general understanding of the similarities and differences among these maps will lead to a more complete utilization of the survey results.

Two variables should be recognized before working with the various resource maps: 1) the relationship of mapping-unit boundaries to the appearance of the specific resource on Landsat imagery and aerial photographs, and 2) the methods or levels of partitioning the project area into associations, or mapping units. Soils and geology are the major features that influence the Landsat-recorded spectral reflectance in southwestern Mauritania. In many places herbaceous ground cover influences spectral signatures, especially sandy areas in the more favorable rainfall zones. Woody species are rarely seen as distinct communities on the Landsat imagery; exceptions are some of the classified forests in the Senegal River Valley and large oases. Woody plant communities exist almost everywhere in southwestern Mauritania, but are generally too sparse to be distinctly recorded on Landsat imagery (aerial photography at a scale of 1:50,000 is useful, but a larger scale is needed for the individual identification of woody species by air-photo interpretation).

The soil and pasture maps were better correlated to spectral reflectance (as recorded on Landsat imagery) than was the forestry map, which relied more heavily on ground observations for mapping unit boundary placement. Several exceptions are noteable; for example, the Landsat-recorded tonal and textural patterns of the southwestern Trarza were associated with intensity of use and the intermix of *Acacia senegal*, *Acacia raddiana*, and *Balanites aegyptiaca* communities and resulted in several forestry mapping units, but only two or three pasture or soil mapping units.

A similar approach was used by each resource survey team in arriving at the final delineation of mapping units, but individual criteria for mapping unit definition differ substantially. Similarities among survey approaches includes 1) elimination of those cover types or soil units not likely to occur in a given locale and 2) a listing of expected associations in a given locale, based on imagery representations and known ecologic interactions. The various hierarchical criteria are listed as follows by the resource and in order, from highest to lowest levels:

1) soils--soil-climate zones, landform groupings, and soil associations, which are based soil slope and other measurable soil properties and including composition of differing, but nonseparable, soil groups

2) pasture--soil and landform groupings and dominance of major plant associations and occurrence of minor plant associations

3) forestry--dominant plant association, minor associations, and density of stocking (trees per hectare), average height, level of exploitation, and regeneration.

Each resource chapter discusses mapping unit definitions and interpretations. Utilization of a single resource map by itself requires little explanation, short of the previously mentioned limitations associated with reconnaissance maps. If an integrated approach is taken in which all the mapped natural resources are considered, some care must be taken in order to fully utilize, and to not discount, map differences. It would seem that the manner in which the various resource maps are combined would be related to the specific purpose of a project. For example, approximation of general levels of animal-carrying capacities could involve mapping-unit interpretations from the soil map (erosion and erosion hazard), the forestry map (level of exploitation and regeneration), and lastly, the most important source, the pasture map (pasture productivity). First the project area must be defined; second, the necessary mapping units are extracted; third, the pertinent or contributing interpretations are selected; fourth, the ordering of the important mapping-unit interpretations are determined; fifth, the various resource mapping-unit boundaries (via overlays) over the project area are compared and the appropriate boundaries are selected; and lastly, the hectares per defined unit are tallied.

Each cartographic unit represents a unique, natural landscape defined according to criteria established for mapping the four features: soils, resources. A broad perspective of the geology, soil, pasture, and forestry is presented for the defined project area. Areas with suitable potentials for certain activities can be located on the appropriate resource map. Conversely, areas that are not suitable for certain activities can also be located. Other possible uses of the resource data are numerous and include the following, incomplete listing: environmental monitoring of any of the measured dynamic variables, selection of areas that appear promising for development (detailed or intensive surveys or further specialized ground characterization), use in other on-going projects, use in the development of management objectives and applications, extension activities and student education. The resource data represented on the various maps and described in the following chapters provide a generalized, synoptic representation of the current state (1981) of the selected renewable resources of southwestern Mauritania.

IV. DESCRIPTION OF THE PROJECT AREA

General

Mauritania is the third largest country of West Africa with an area of 1,030,700 sq. km and approximately 1.5 million people (Fig. 1-1). It is bounded on the west by the Atlantic Ocean and on its south, east, and north lie the countries of Senegal, Mali and Algeria. Much of Mauritania (70-80%) is located in arid regions that normally receive less than 250 mm of annual precipitation. The remaining semi-arid regions in the south receives, on the average, between 250-700 mm of rainfall; although, in the past 10 to 12 years annual rainfall has generally been substantially less than average. The project area is located within the western extension of the 250-700 mm zone.

The project area encompasses 150,400 sq. km, including all or parts of seven administrative regions: the Trarza, Brakna, Gorgol, Assaba, Tagant, Guidimaka, and Western Hodh Regions (Fig. 1-1). A majority of the population

of Mauritania lives in this area, which also includes the Senegal River floodplain. The largest concentration of people in Mauritania is in Nouakchott, the capital city. The population density, otherwise, decreases with distance from the Senegal River.

The majority of people in this area are involved in livestock production. In recent years the livestock industry has shown a shift from nomadic to sedentary operations. Flood-recessional and dryland agriculture are also significant contributors to agricultural production. The major crops are sorghum and millet. Irrigated lands are minor in extent, but will increase as development plans are implemented. Most irrigated lands are located on the Senegal River floodplain; rice and maize are the major crops. Oases (dates) and garden plots (vegetables) are the least extensive forms of agriculture. Gum arabic production in the Trarza and charcoal production in the Senegal River Valley or near temporary lakes are or have been significant for at least domestic use. In many places, the exploitation of *Acacia senegal* and *Acacia nilotica* has resulted in the local annihilation of these important forestry species.

There are two paved highways in southwestern Mauritania--Nouakchott to Rosso and Nouakchott to Nema via Kiffa (Fig. 1-1). The other secondary routes are numerous, but rarely in improved condition. The regional capitals are generally accessible by paved or improved secondary roads and, in most cases, by the national airline.

The Physical Environment (See Fig. 3-1 in Chapter 3)

Most of the land area in the project area has elevations less than 150 to 200 m above sea level. The exceptions are the Tagant and Assaba Plateaus and the Affolé, which range in elevation from 200 m to greater than 500 m. Another notable escarpment is the north-south Oua Oua ridge in the central part of the study area. These topographic highs are generally windswept and the soils are shallow to bedrock. The southern Assaba contains the greatest variety and amount of vegetation.

The lowest topographic areas, which have elevations less than 50 m, are located along the Atlantic coastline. This area is generally narrow and is dominated by saline lands. Littoral dunes are also located in this zone, known as the Aftout es Saheli. Vegetation is generally localized in areas with optimal watertable levels and tolerable amounts of salinity.

A huge expanse of high sand dunes is situated immediately to the east of the coastal area. Elevations range from less than 50 to 100 m. These sands dominate the Trarza and Brakna regions. the interdunes are generally distinct and range from calcareous marine deposits to light-colored sands. Drainageways are very rare; however, an ancient course of the Senegal River loops through the southern and eastern parts of this zone (see Geology chapter, Fig. 2-2). Vegetation density increases with distance to the south, closely correlated with the long-term rainfall isohyets.

The area between the dune zone and the Tagant and Assaba plateaus consists of nearly level plains, desert pavements, and miscellaneous lithic buttes and small plateaus or mesas. Elevations are generally between 50 and 100 m. The soils are largely fine-textured; exceptions are a wind-blown

sandy cover and residual sandy loams and loamy sands. An integrated drainage system is associated with the area of fine-textured areas of the western Assaba, northern Gorgol and all of the Guidimaka except in the northwest and an area in the southwest. Major oueds include the Gorgol Noir, Gorgol Blanc, Niordé, Ketchi southern Karakoro, and Garfa. The vegetation is sparse on desert pavements and through the central part of this area. Drainageways generally have more favorable soil-water situations than the uplands, and an increase of vegetative density usually marks current alluvial boundaries. Further to the south in this zone, the density of vegetation increases with increasing average rainfall and/or permeable soils, i.e., the sandy soils of the southern Gorgol and Guidimaka Regions.

To the east of the Tagant and Assaba Plateaus, sand dunes dominate the land area. Elevations range from 100 to 200 m. These dunes are generally stable in the south and often covered with a wide diversity of vegetation. Drainageways are rare in this sandy environment. An ancient drainage system extends from north of Boumdeit to Kiffa and joins the Karakora Oued.

The extreme eastern part of the project area is dominated by sandstone plateaus. Elevations increase with distance to the east, ranging from 100 to 350 m. These areas (the eastern Assaba and western Hodh) are virtually inaccessible by vehicle. Drainageways are common and several temporary lakes are located east of Kiffa.

The Climate

The project area falls within the Sahelo-Saharan climatic zone in the north, the Sahelian and the Sahelo-Sudano zones in the south. The climate within the project area is characterized by four seasons: a rainy season from mid-July to September in the northern areas and from June to early October in the south; a short, hot season after the rains (October and November); a cold season from December to February, and an April to May hot season.

Seasonal extremes and the persistent northeasterly harmattan winds are the salient features of the climate. The winds of Mauritania blow almost year-round. The hot, dusty winds from the northeast dominate; however, winds shift to the south and east during the rainy months when moist air is brought into the interior. THe coastal area of Mauritania additionally receives cool, moist winds from the Atlantic Ocean.

Rainfall Characteristics

The commonly erratic nature of amounts and distributions of annual rainfall associated with semiarid and arid regions also applies to southwestern Mauritania. Since moisture deficiency is the major limiting factor that affects the productivity of Mauritanian lands, precipitation patterns are very important. The majority of rainfall is received between June and September, the rainy season, while the other months constitute the dry season.

A surprising amount of rainfall data is available for the study area. Cities in the project area with records covering periods of 33 to 59 years are: Aleg, Boghe, Boutilimit, Kaedi, Kankossa, Kiffa, M'bout, Mederdra, Moudjeria, Nouakchott, Rosso, and Selibabi. Other cities just outside the region, but with rainfall data, include Tamchekket and Matam, Podor, and St. Louis of Senegal. There are several sources of weather data and they do not always agree with each other. As a consequence, a composite table supplied by Robert Manly (1981) was used for all data calculations.

Average annual precipitation is greater in the south than in the north of the study area, as shown in Fig. 1-4a. These isohyets, based on 30 years (1941-1970) of data, do not show, however, the amount of variation among years or averages of other years. Long-term records reveal substantially higher average rainfall amounts than that received in the past 10-12 years. Fig. 1-4b shows the isohyets of the average annual rainfall for the 11 year period from 1970-1980. A general east-west orientation of rainfall isohyets marks the 1941-1970 period. Conversely, a marked deviation of isohyetal orientation is noted for below normal years (Fig. 1-5, 1-6).

Since the data for this project were gathered in the months following the 1980 rainy season, the isohyets for that year are included separately (Fig. 1-7). Table 1-1 gives precipitation totals for selected cities in the region. This table clearly shows a range of variations, Nouakchott receiving only 44.1% of its norm while Aleg, only about 350 km to the east, received over 100% of its norm. These differences in rainfall were reflected, in general in the biomass production and the condition of the pastures. In 1980 the 10 stations of Table 1-1 received an average 76.4% of normal rainfall with a standard deviation of 15.7% which would seem to be a somewhat moderate variation.

Table 1-1. Precipitation in 1980.

City	Rainfall	Average	% of Average
Aleg	258.5 mm	245.6 mm	105.3
Boghe	264.3 mm	323.6 mm	81.7
Boutilimit	155.4 mm	183.2 mm	84.8
Kaedi	282.7 mm	359.9 mm	78.5
Kiffa	266.0 mm	343.4 mm	77.5
M'bout	265.0 mm	323.6 mm	81.9
Nouakchott	51.1 mm	115.8 mm	44.1
Rosso	216.1 mm	286.0 mm	75.6
Selibaby	381.0 mm	609.0 mm	62.6
Tidjikja	107.0 mm	149.0 mm	71.8

Receiving average or above average rainfall does not necessarily result in an increase in area-wide biomass production. The effectiveness of rainfall (i.e., infiltration) is a key factor, and it is often reduced because of high intensity, short duration rainstorms. Rainfall intensities of over 100mm/hr. are not uncommon. The infiltration rates of soils vary according to soil texture, slope, and surface cover. Where sloping, bare, fine-textured soils occur, most rainfall runs off. In rocky regions, runoff percentages are also extremely high, and flooding is a possibility, especially if heavy rains last for more than 30 minutes. Throughout the central part of the study area, the fine density of drainage and the paucity of upland vegetation indicates high runoff rates. The sandy zones, however, can be expected to have low runoff rates and consequently, more infiltration.

Frequencies of annual precipitation rates are given in Figure 1-8 for Nouakchott, Tidjikja, Boutilimit, Rosso, Kiffa, Kaedi, and Selibaby as examples of yearly variations. The southerly stations (higher average precipitation) have notably wider ranges of rainfall amounts, e.g., Nouakchott vs. Selibaby.

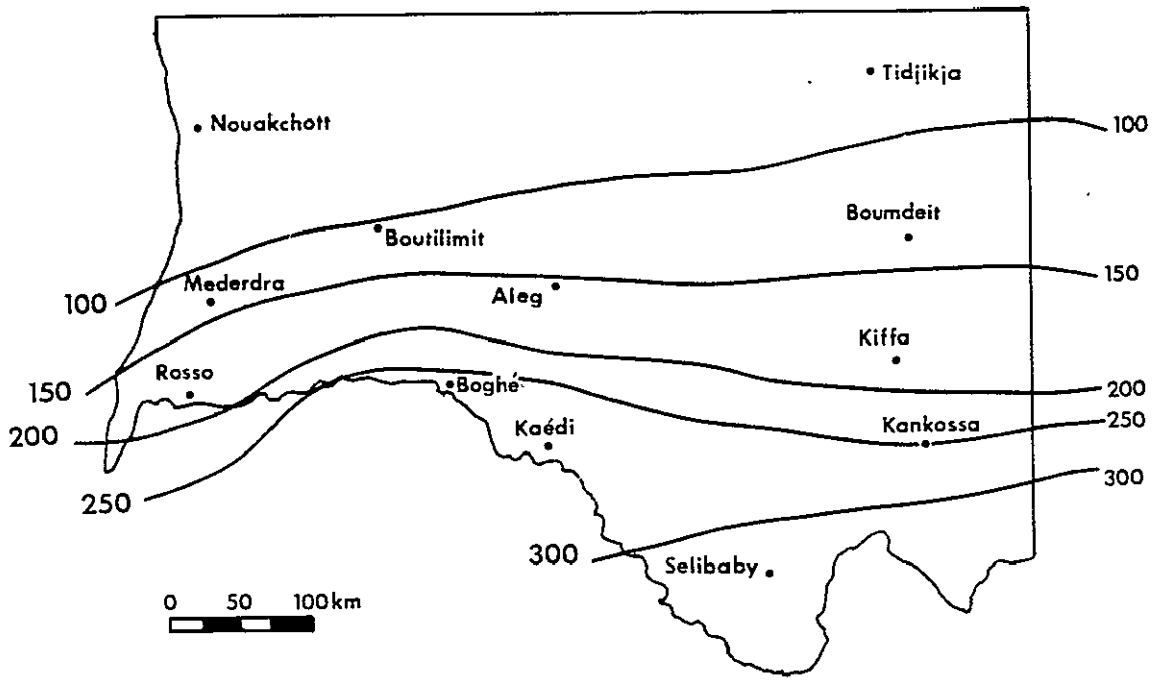


Fig. 1-4b. Isohyetal map shows mean rainfall amounts (in mm) within the project area, 1970-80.

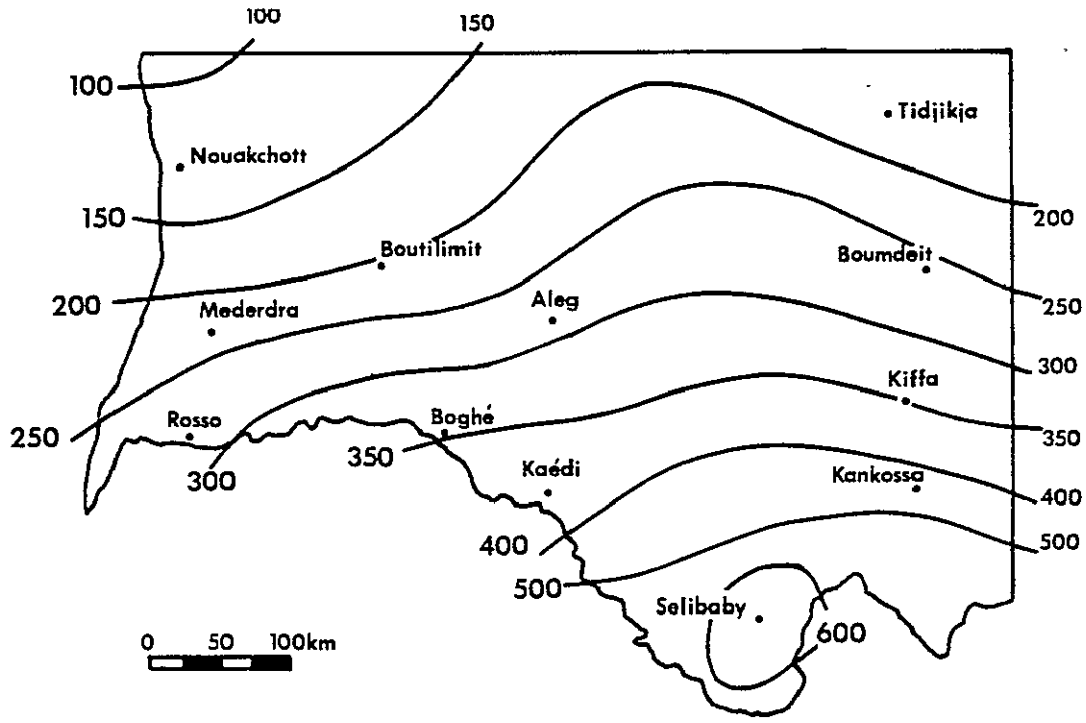


Fig. 1-4a. Isohyetal map shows mean rainfall amounts (in mm) within the project area, 1941-70.

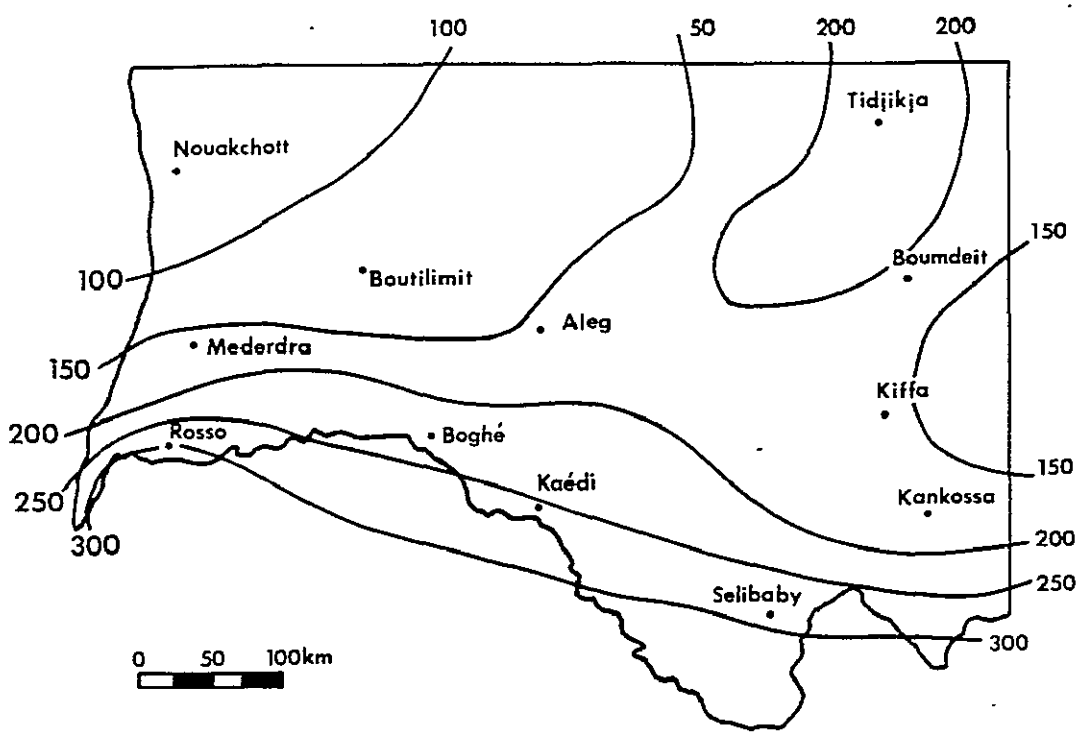


Fig. 1-5. Isohyetal map shows mean rainfall amounts (in mm) received in 1977.

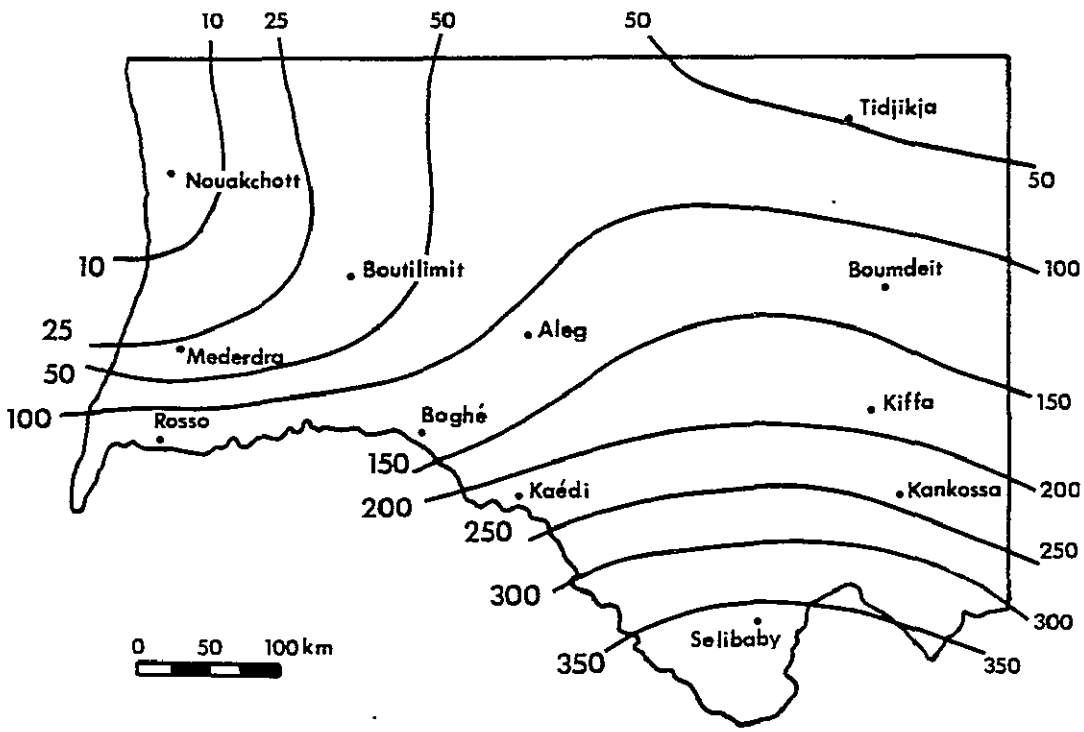


Fig. 1-6. Isohyetal map shows mean rainfall amounts (in mm) received in 1979.

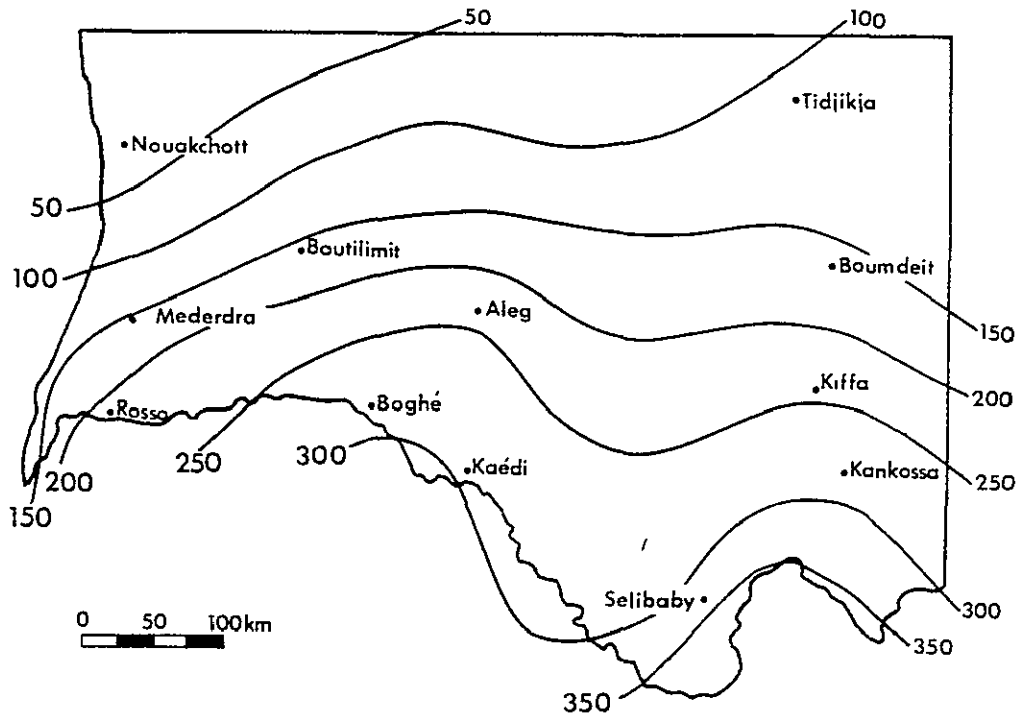


Fig. 1-7. Isohyetal map shows mean rainfall amounts (in mm) received in 1980.

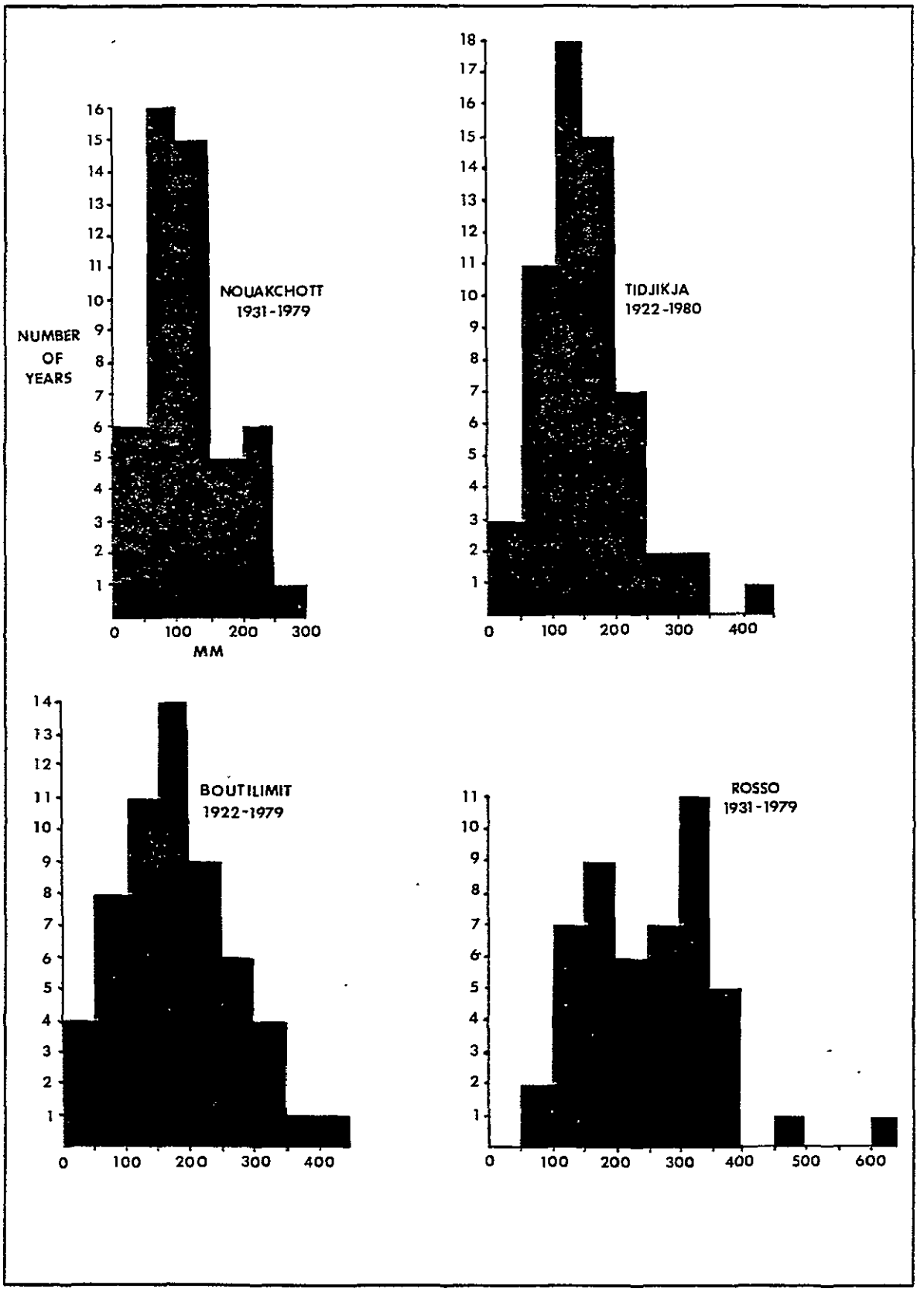


Fig. 1-8. The distribution of annual rainfall is shown over a number of years for seven recording stations.

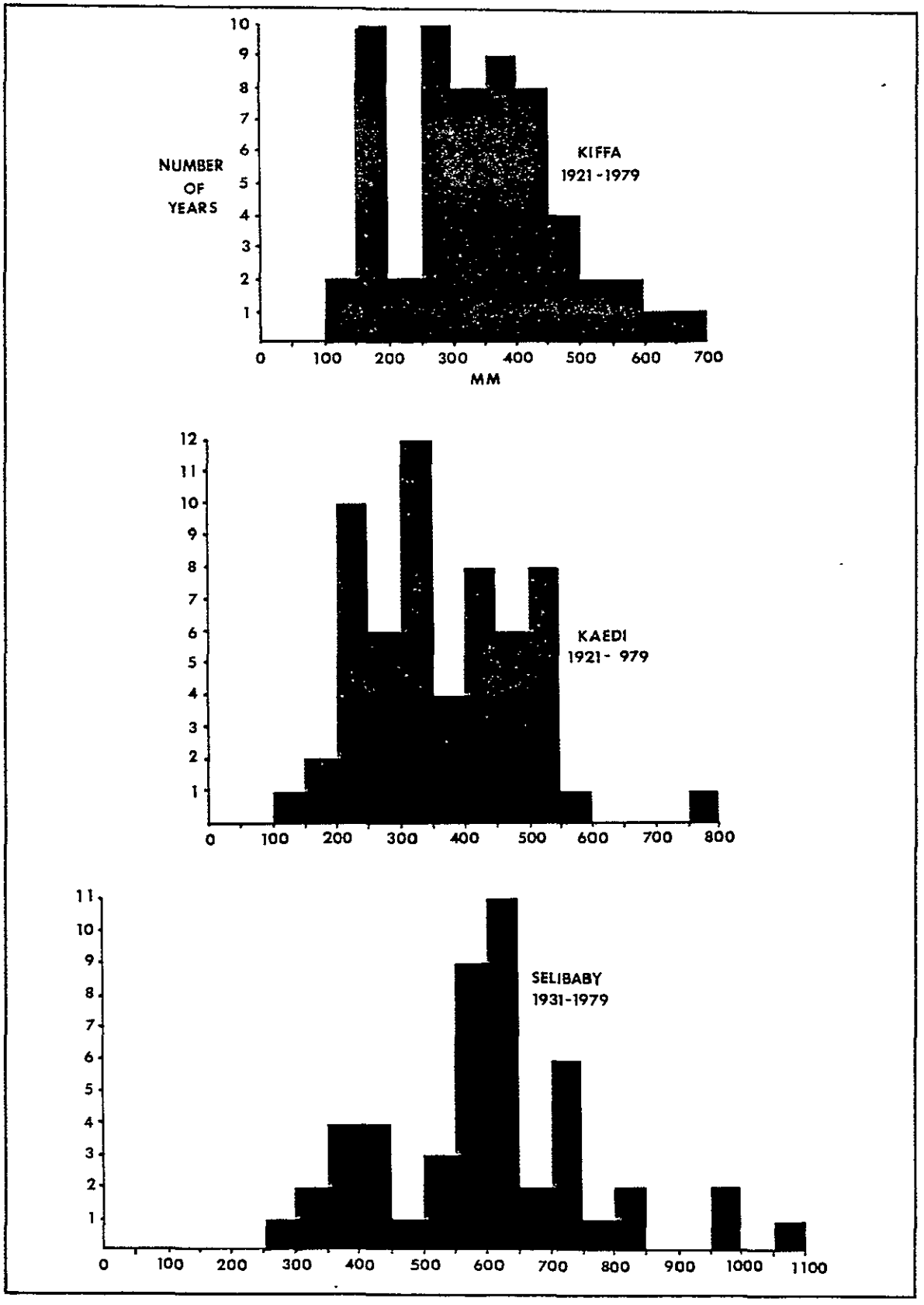


Fig. 1-8 continued.

Within each rainy season there is much irregularity in the timing and quantity of the rains. It follows logically that this increases the risks of failure in rain-dependent agriculture.

Temperature and Evaporation Potentials

The average annual temperature on the coast is greater than 26°C while in the interior it is greater than 28°C. As with rainfall, there is both seasonal and geographic variation. The average monthly temperatures range from a high of 36°C in the Guidimaka during May to a low of 20°C in the western Trarza during January (Leroux, 1977). In the RRM area of activities, the average January temperature is about 22°C (Fig. 1-9a), while the monthly average for April is 30°C (Fig. 1-9b).

Maximum daily temperatures near 45°C are common in the interior during the April-June period. Minimum daily temperatures approach 10°C throughout much of the project area in January, and low monthly averages for January hover around 13°C. Seasonal and daily extremes are greatest in the interior, whereas the maritime currents tend to minimize seasonal temperature differences in the western Trarza.

Estimated evaporation potentials fall in the range of 4500mm/yr. with 400 to 500mm in the months of May and June. Steady winds, low humidities (yearly average of 33%) and high temperatures contribute to this extremely high potential.

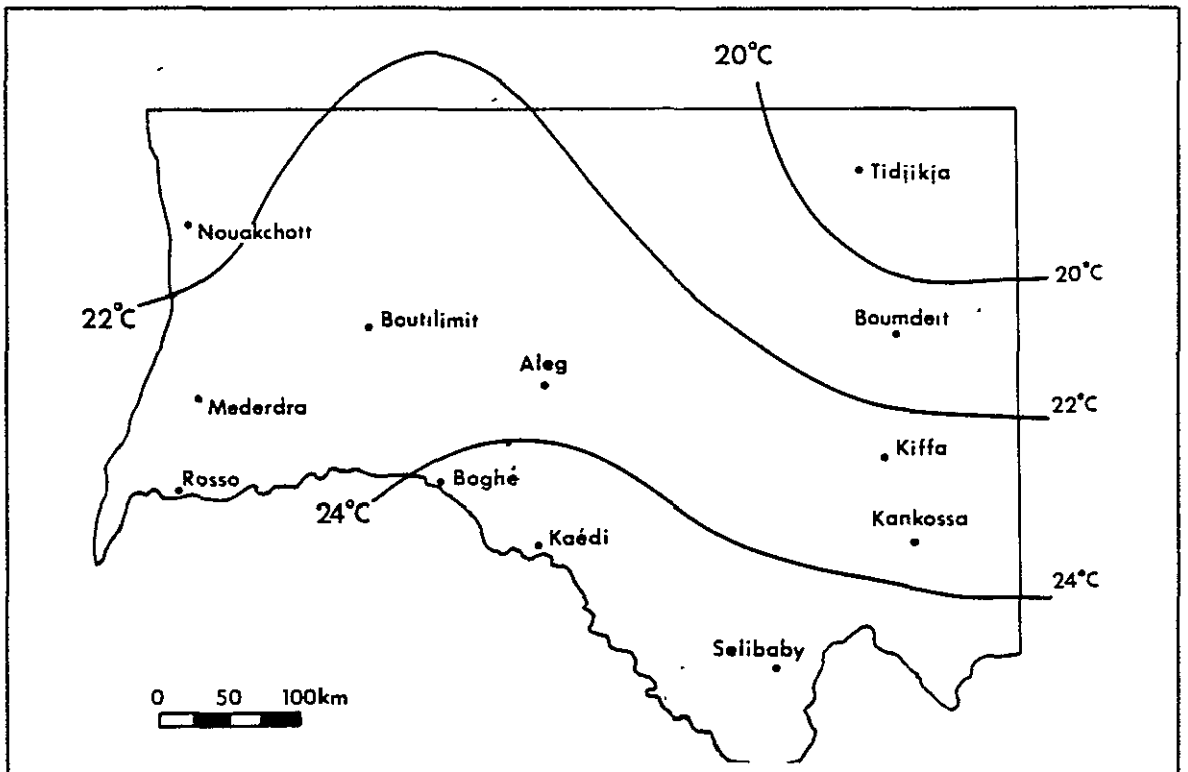


Fig. 1-9a. Mean January temperature data (°C) is shown over the project area.

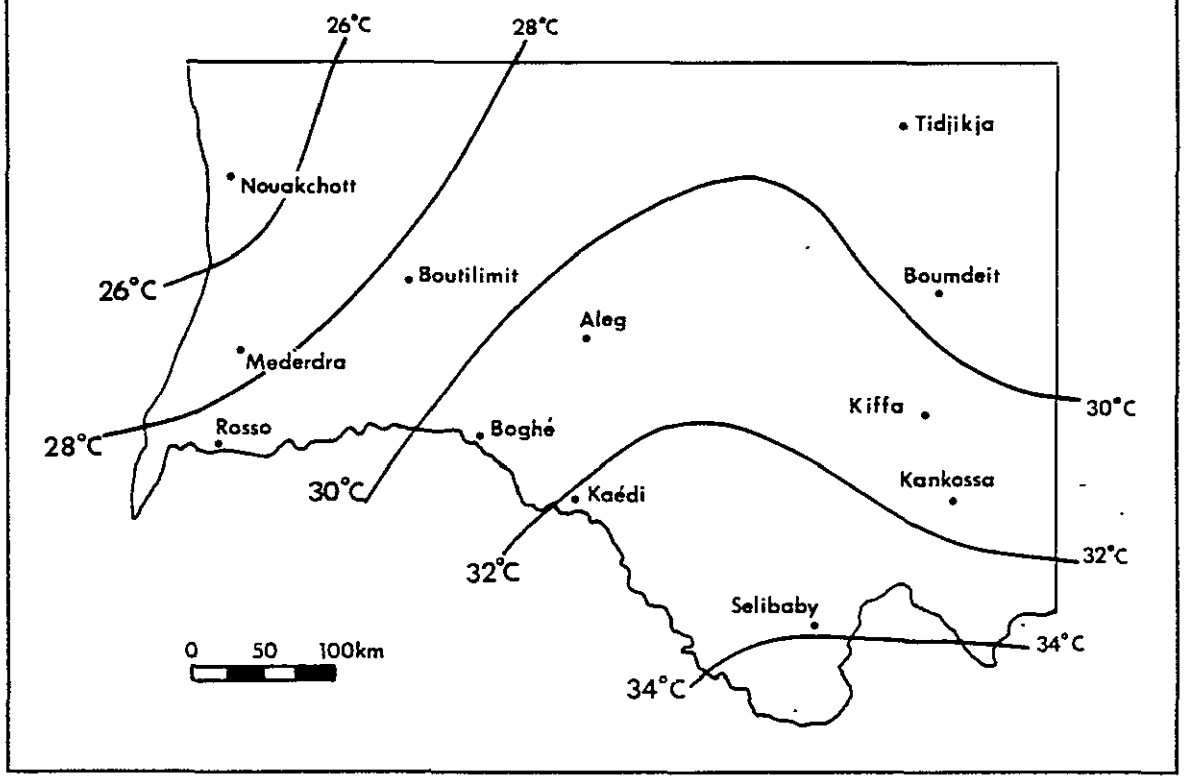


Fig. 1-9b. Mean April temperature data (°C) is shown over the project area.

V. REFERENCES

Chevrel, Michèle, Michel Courtois, and Gilbert Weill. 1981. The SPOT satellite remote sensing mission. Photogram. Eng. and Remote Sensing. Vol. 47(8):1163-1171.

Leroux, Marcel. 1977. Climate. p. 16-21. In Charles Toupet, Georges Laclaré, and Theodore Monod (eds). Atlas de la Rèpublique Islamique de Mauritanie. 64 p; éditions j.a. 51 avenue des Ternes-75017 Paris;

Manly, Robert. 1981. Personal communication. RAMS project data analyst, Nouakchott.

UNSO. 1981. Medium- and long-term program for sand fixation in Mauritania: Phase 1--analysis of nature and extent of sand movement and development of an approach for stabilization. SDSU-RSI-VISP-81-01 Under Contract to Office for Projects Execution, UNDP. MAU/80/503. New York.

Welch, R., and Wayne Marko. 1981. Cartographic potential of a spacecraft line-array camera system: Stereosat. Photogram. Eng. and Remote Sensing. Vol. 47(8):1173-1185.

Wilson, Charles L. No Date. Image mapping software at ERIM. Environmental Research Institute of Michigan, Ann Arbor, Michigan. USA. 30 p. (mimeo)

CHAPTER 2

GEOLOGY, STRUCTURES and HYDROGEOLOGY

I. INTRODUCTION

The study area, located in the southwestern corner of The Islamic Republic of Mauritania, is an area of moderate relief. The eastern part is hilly and higher than the western extent, with solid rocks mostly exposed on the surface. It has a well-developed drainage system. The western part, known as the "Trarza", lies within the Senegalo-Mauritanian basin, has low relief, and is mostly covered by aeolian sands in the form of sand dunes and sand sheets. Depressions, locally known as "Aftout", as well as inter-dunal flats, are common in this area.

The region has been studied by several researchers and institutions. However, this study, the first utilizing Landsat data, has revealed a considerable number of structures and features that have not been reported. These new findings should prove to be of great importance in groundwater and mineral explorations. The Landsat imagery was also helpful in making significant corrections for boundaries of several geologic units.

The main objectives of this survey are listed as follows:

1. the production of a surface geologic map showing the different geologic units and their relationships
2. the identification and mapping of all geologic structures in the area
3. the generation of a hydrogeologic map based on the geology and structures of the area combined with the data for the existing ground water conditions.

II. GEOLOGY

The geologic formations represented in the area cover a broad range of the geologic column, ranging from Pre-Cambrian to recent. The different

formations are well-exposed in the central and eastern parts of the area; they are obscured beneath a mantle of aeolian sand deposits of variable thickness in the west and northwest. The following section is a description of the different geologic formations found in the project area, beginning with the oldest.

Pre-Cambrian

These Pre-Cambrian rocks occur at the western end of the African Continental Shield. They outcrop north of Selibaby and east of Magta Lahjar where they form a discontinuous ridge trending north-south. There also are a few small isolated outcrops west of the main ridge.

The main rock types are granites, granodiorites and diorites. The granites are mostly alkali and monzonitic with muscovite and biotite. The diorites contain a small percentage of quartz. These rocks have been shown to be 1300 million years old (Afia, 1978).

Cambrian

The Cambrian rocks include a variety of metamorphic rocks, mainly chlorite and sericite schists, together with mica schists. Within the schists are bands of hard quartzites that form high ridges, known as the Oua Oua hills, trending north-south. The schists overlie the granites and occupy a wide zone, trending in a north-south direction.

The western boundary of the schists marks the eastern periphery of the Senegalo-Mauritanian basin in which the Eocene sandstones and limestones were deposited. To the east, the schists are overlain by metamorphosed volcanic and sedimentary rocks that belong to the Upper Cambrian. The metamorphosed volcanic rocks are mainly acidic.

All of the above mentioned Pre-Cambrian and Cambrian formations constitute what is known as "L'Arc Des Mauritanides" because of the arc shape they form. This arc separates the Taoudini sedimentary basin to the east, and the Senegalo-Mauritanian basin to the west. It extends from Senegal in the south to near the Moroccan boundary in the north. The rocks of the "Arc of Mauritanides" were exposed to intense tectonic movements, the effect of which is clearly noticeable in the schists, which are highly deformed, folded and faulted.

Cambro-Ordovician

These are the sedimentary formations that lie unconformably over the meta volcanics and meta sediments and to the east of them. They form the base of the Assaba and Tagant plateaux. They also outcrop on the surface forming the plain east of the Assaba plateau. These sedimentary formations are mainly mudstones with some horizons of argillaceous sandstones and tillites. The beds dip gently towards the west.

At the northwestern side of the Assaba, a band of tillites of the same age outcrops, showing distorted irregular bands. It is cut and displaced by a northwest-southeast fault.

The unconformity between the Cambro-Ordovician mudstones and the underlying meta volcanics and meta sediments was caused by a Hercynian horizontal sheet movement (Afia, 1978). The thick succession of the hard, quartizitic sandstones were then deposited, forming the Assaba and Tagant plateaux. They are either horizontally bedded or dip slightly towards the west. They are highly fractured and faulted.

Further eastwards there are Cambro-Ordovician outcrops of finer sandstones and tillites that form nearly horizontal beds.

Tertiary

The western part of the area, between the schists to the east and the ocean to the west, is a depositional depression, known as the Senegalo-Mauritanian basin. There the Cretaceous sediments were deposited, and then covered by the Eocene sandstones, marls, limestones and dolomites, which outcrop west of the schists of the "Arc des Mauritanides", from south of Maghama to Kaedi to Aleg. They dip gently towards the west and disappear under the deposits of the "Continental Terminal", which appear on the surface in a relatively small triangle west of the Eocene sandstones and north of the Senegal River (north of Bababé and Boghé).

Quaternary

The Quaternary deposits include the terraces of the Senegal River and the marine deposits in the western part of the Senegalo-Mauritanian basin. These can be seen in the Rkiz lake depression, and the surrounding area, and the area along the existing coast line in the salty flats known locally as "Sebkha".

The most extensive deposits are the aeolian sands that form different types of sand dunes and undulating sand sheets. They range in color from reddish to yellowish to grey-white, depending on the degree of oxidation of the iron content of the sand.

The alluvial sands, silts and clays in the seasonal stream beds of the drainage systems vary in thickness and lithology depending on several local factors, such as the parent rock, the slope gradient and the quantity of water running through the stream.

The results described in this section are displayed in the accompanying geologic and structural map at a scale of 1:500,000.

III. STRUCTURES

The region has been subjected to four tectonic movements, from the Archean movement to the Hercynian movement. The effect of these movements has resulted in variable degrees of metamorphism shattering of rocks, deformation and tilting of the old beds, and a considerable number of folds, faults and fractures.

The relatively younger formations, which were affected only by the last tectonic movement, still retain their original horizontal bedding.

These include the sandstones of the Assaba and Tagant plateaux, the sandstones and tillites east of Kiffa, and the Eocene sandstones and dolomites between Maghama and Aleg. The only effect of the last tectonic movement on these formations was the large extent of faulting and fracturing, which is clearly visible in the Landsat images.

A thick layer of aeolian sands covers the northwestern part of the area. For this reason a geophysical survey is recommended for that area to reveal the configuration of the depositional basin and any structures that might exist.

A previous investigation (Afia, 1978) mentioned that the log study of several wells in the basin showed that a north-south trending ridge of crystalline rocks in the bottom of the basin divides it into eastern and western sub-basins.

Domes

Two dome structures east of the village of Aleg were identified on the imagery. The eastern dome trends in a northwest-wouthease direction and is 33 kilometers long and 17 kilometers wide. It is plotted on the geologic map of Mauritania (Bureau de Recherches Géologiques et Minières, 1968) as a serpentine mass within the quartzite and schist formation.

The western dome trends in a north-south direction and is 45 kilometers long and 30 kilometers wide. This dome was not mentioned in previous studies and maps. It lies mostly within the Eocene sandstones and dolomites, with schists in its northeastern edge. The dome is gently dipping in all directions. It is recommended that these features be studied in detail as they might reveal valuable information for hydrogeologic or mineral investigations.

Faults and Fractures

One well-publicized advantage of the regional view offered by Landsat images and mosaics is that they reveal linear features indicating faults and fractures that might not otherwise be identifiable. This is the case with our study area, particularly the eastern part where the solid rocks are exposed on the surface. Numerous faults were located that were not shown by previous studies.

The Assaba and Tagant sandstones, as well as the schists and quartzites west of the Assaba, show considerable faulting and fracturing. The general trend of the fractures range from northeast-southwest to east northeast-west southwest. A few others trend north-south and northwest-southeast. The most prominent fault in the region extends northwest of Kiffa (passing just east of Kamor village) until it disappears under the sand dunes in the northwest. This fault shows considerable displacement and trends northwest-southeast for a distance of about 160 km. The faulting effect and displacement is clearly visible in the Assaba sandstone escarpment, as well as in the tillite rocks west of it. The northeastern block is displaced towards the northwest for about seven kilometers.

Another prominent fault extends in a northeast-southwest direction, west of the village of Matam on the Senegal River. The fault extends for

about 150 kilometers, cutting through the Eocene sandstones and the schists. The northwestern block was uplifted, bringing the Pre-Cambrian granites to the surface.

It is recommended that a field study be made of the plotted faults, to indicate their displacement and their relationship with one another and the adjoining rocks. Such a study may reveal valuable information about ground water occurrences.

IV. HYDROGEOLOGY

The study area can be divided into three different hydrogeologic zones. They are as follows:

1. The Senegal River Valley Zone
2. The Western Zone
3. The Eastern Zone.

The Senegal River Valley Zone

The Senegal River Valley is the most productive and the most populated part of the country. (The boundary with Senegal follows the main river channel.) Water is drawn by pumps from the river to irrigate the small farms along the valley. Shallow wells are dug through the valley alluvium and give a good supply of water. The water of these wells and the river water are connected so that the static water level in these wells follows the fluctuation of the river's water level. However, during the dry season when the flow of the river drops, the water from the ocean advances up the river to Podor, affecting the surrounding alluvial banks by raising its salinity. A dam is planned to be built at the mouth of the river to solve this problem. This dam will save the river's flood water now lost to the ocean. It also will protect the agricultural lands from the transgression of sea water during the dry season.

The Western Zone

This zone is located in the Trarza basin and it is part of the Senegalo-Mauritanian basin. Ground water is found in most of this zone at several depths and with variable quality. Figure 2-1 shows the static water level contours and the salinity contours based on the existing wells in the area (Bureau de Recherche Géologiques et Minières, 1962). A boundary was drawn showing the western limits of fresh ground water. Beyond this line the water is saline. Another boundary marks the eastern limit of the aquiferous zone of the basin.

Many of the wells of the region are hand-dug and do not penetrate beyond the upper horizons of the aquifer. The aquifer is recharged by the runoff from the eastern highlands and by the modest contribution from the low precipitation received in the region.

A buried channel of the Senegal River was located on the imagery (Fig. 2-2); no mention of this has been made in published works. This old channel is exposed from a point west of the city of Kaedi on the river northward to Aleg Lake. From here it can be seen through the overlying sand sheet as it turns westward and then southward in a large arc going through Lake Rkiz, and then crossing the existing river channel to

WATER LEVEL CONTOURS

Static water level contours with values in meters below mean sea level

Western limit of the Trarza Aquifer

Eastern limit of the Trarza Aquifer

Seasonal streams, dotted where buried

Coastline

Senegal River

Seasonal lakes

SALINITY CONTOURS

Water salinity contours with values in grams per liter

Old buried river boundary

River valley limits

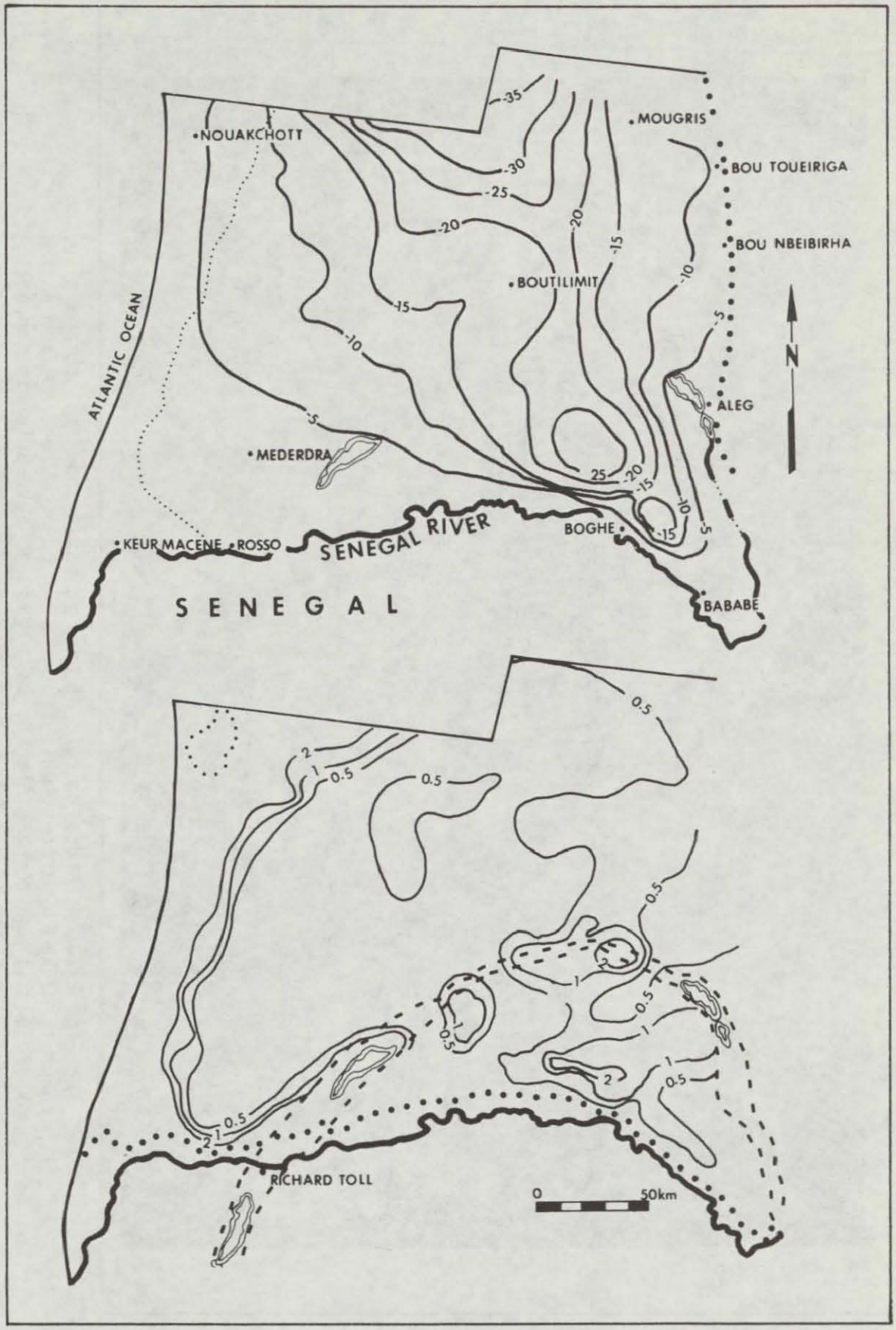
Local aquifer basin

Coastline

River boundary

Seasonal lakes

Fig. 2-1. Static water level and salinity contours.


NOUAKCHOTT
MOUGRIS
BOU TOUEIRIGA
BOU NBEIBIRHA
BOUTILIMIT
ALEG
MEDERDRA
ATLANTIC OCEAN
KEUR MACENE
ROSSO
SENEGAL RIVER
BOGHE
BABABE
SENEGAL
N
-35
-30
-25
-20
-15
-10
-5
25
0.5
1
2
RICHARD TOLL
0
50km

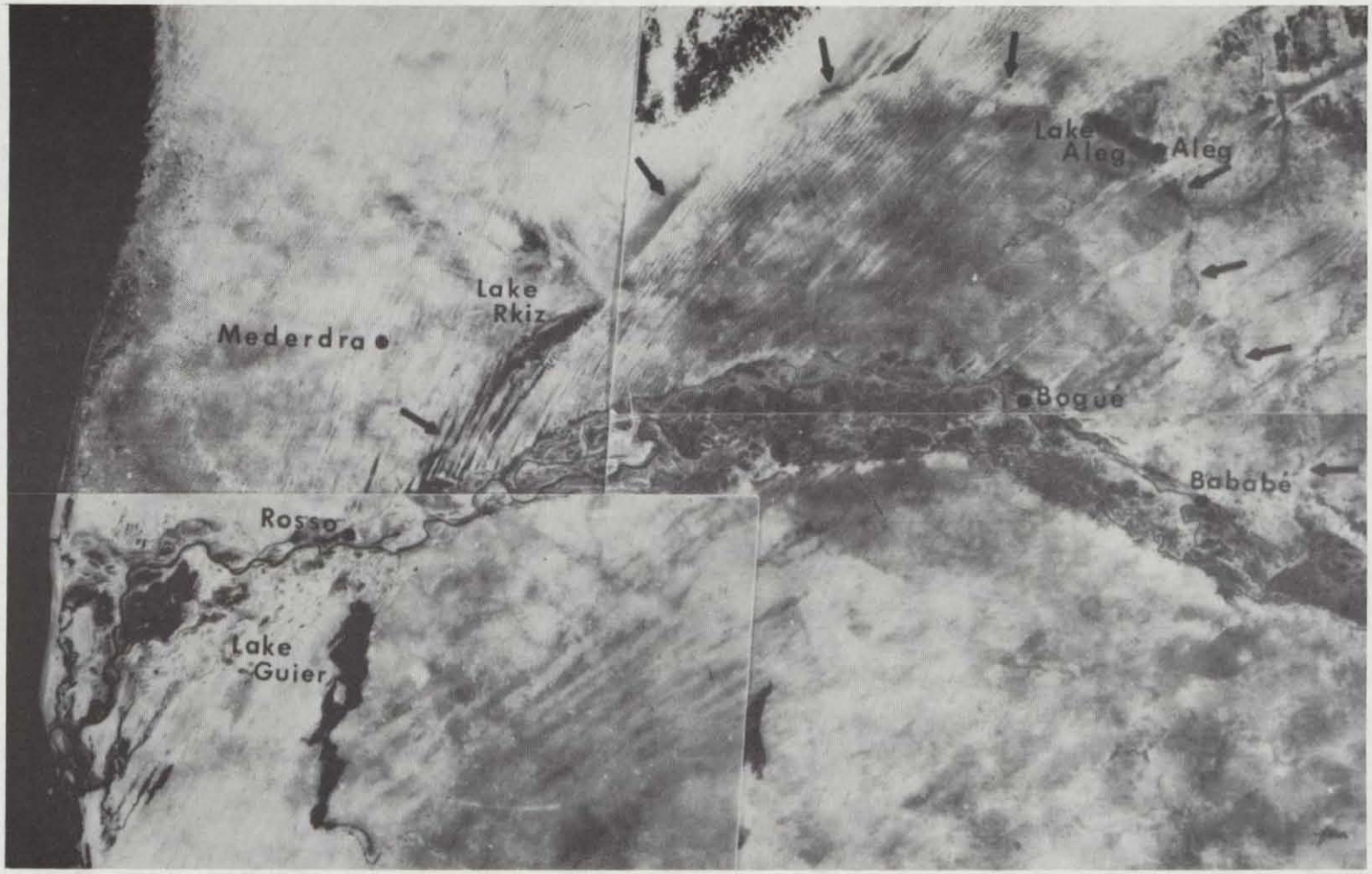


Fig. 2-2. A Landsat mosaic of band 7 images shows the buried river channel, marked by arrows, which forms a big curve extending from east of Bababé village to Lake Aleg to Lake R'kiz to Lake Guier in Senegal. Approximate scale is 1:1,600,000.

Lake Guier in Senegal. The part of the old channel from Lake R'Kiz to Lake Guier is probably controlled by a fault system trending northeast-southwest parallel to the general trend of faulting in the region.

The change of the river channel may have been caused by one or more of the following factors:

1. Tectonic movement resulting in a change of topography
2. Periods of droughts when the weak flow of the river silted up its original channel, and during a subsequent rainy period the river cut a new channel
3. Periods of alternating transgression and regression of the ocean adding a thickness of deposits in the area through which the river opened its new course
4. The transgression of wind-blown sand from the northeast buried the river channel and caused it to be diverted towards the south.

This old river channel is not recharged by the existing river since the level of the buried channel is higher than the existing river waters. A suggestion to utilize this old channel is made in the recommendations.

The Eastern Zone

This zone comprises the hilly part of the study area with solid rock formations exposed on the surface. The area of quartzitic sandstones forming the Assaba and Tagant plateaux are dry, except for the water stored in the fissures, fractures and faults, which are issued as perennial springs around the edges of the escarpments.

Other formations such as the gneisses, granites and schists are devoid of water except in the zones of weathered and fractured rock, which give poor yields of water. Depending on the composition of the host rock, this water may be high in salts.

Subsurface water in alluvial stream beds is a major source of ground water in the area. The quantity and quality of the available water depends on the thickness and porosity of the alluvial deposit and on the amount of recharge.

The occurrence of water in most of this area is difficult to predict. Therefore, it is appropriate to study, in the field, each location in need of water, to find the best solution to water problems,

Locations that are believed to have the best probability for ground water occurrence are marked in Figure 2-3. The basis for this assessment is the occurrence of faulted and fractured zones that appear more likely to carry water.

In areas where no ground water can be found, the only alternative is surface water storage behind dams or in dugouts in locations suitable for collecting and storing water.

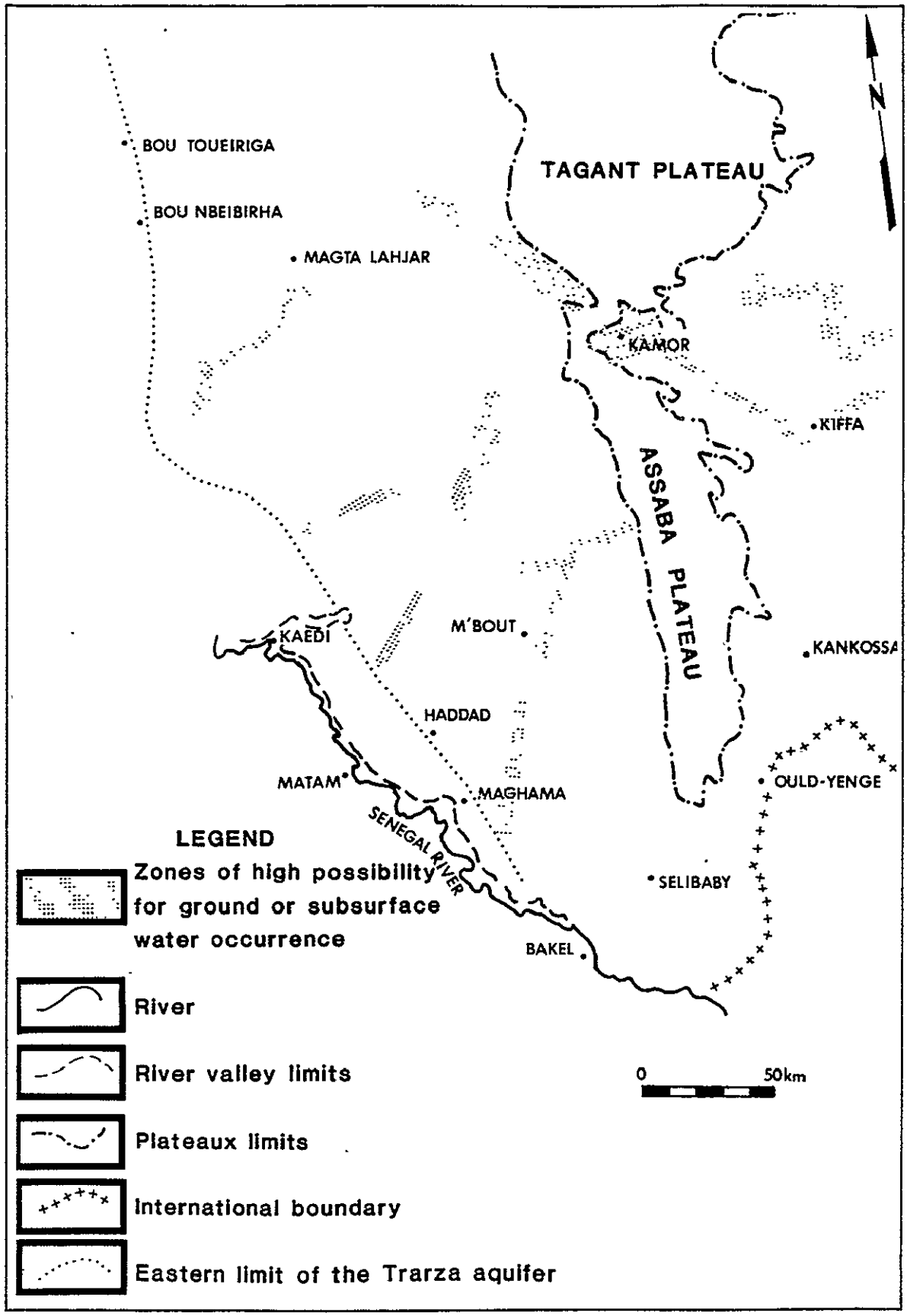


Fig. 2-3. Locations of high probability for ground water occurence.

V. RECOMMENDATIONS AND CONCLUSIONS

It is evident that the area has high water supply potential that is not fully or properly utilized. Following are the proposed procedures for developing the water resources of the area:

1. Conduct a detailed geophysical survey to investigate the following:
   a. Buried river channels and tributaries
   b. The Trarza basin and its aquifers
   c. Geologic structures and aquiferous zones under the sand cover in the northwestern area
   d. Water-bearing zones in the weathered and fractured rock areas.
2. Drill deep bore holes in the western basin to tap the lower levels of the aquifers.
3. Divert part of the flood water of the Senegal River by building a barrage near Kaedi, thus forcing the water through the old channel up to Aleg. This would require the removal of the sand barriers across the channel. This should recharge the old river bed through which numerous wells can be dug and give a good supply of high quality water. This project should also improve the quality of soil around Lake R'Kiz by the flushing out of salts
4. A number of sizeable streams cross the quartzite ridge (the Oua Oua Hills) which act as a natural barrier. Reservoirs can be constructed in these locations which would hold a supply of water.

VI. REFERENCES

Afia, Mohamed Samih. 1978. Geology & Hydrology. p. 91-152. In Islamic Republic of Mauritania, A Comprehensive Survey. The Arab Organization for Education, Culture and Sciences, Institute of Arabic Research and Studies. Cairo, Egypt. 875 p. (in Arabic).

Archambault, Jean. 1966. Synthèse Hydrogéologique et Aménagement Hydraulique du Sud-Est Mauritanien. BUR.GE.AP., 45, rue Perronet, Neuilly sur Seine, Malliot 40-55, Paris.

Bradley, Phillip, Claude Raynant, and Jorge Torrealba. 1977. The Guidimaka Region of Mauritania A Critical Analysis Leading to a Development Project. War on Want, Caledonian Road, London. 172 p.

Bureau de Recherches Géologiques et Minières, 1968. Carte Géologique. Ministère de l'Artisanat et des Mines, Direction des Mines et de l'Industrie, Nouakchott, Mauritanie. (Echelle 1:1,000.000).

Bureau de Recherches Géologiques et Minières. 1962. Carte Hydrogéologique du Bassin Sud-Ouest Mauritanien au 500.000e et Notice Explicative. Ministère de la Planification, Direction du Plan, Nouakchott, Mauritanie.

INSTRUPA. 1979. Développement Rural de la Région du Tagant. Rapport de Synthèse (39 p) et Annexes 1-6 avec cartes. SONADER, Nouakchott Mauritanie.

Operational Navigation Chart (ONC). 1965. Maps of Mauritania and Northern Senegal. Defense Mapping Agency Aerospace Center, St. Louis Air Force Station, Missouri. USA.

CHAPTER 3

SOIL SURVEY

I. INTRODUCTION

Proper utilization of land resources is necessary for the mainenance of the environment. In little known areas, regional surveys provide information about the distribution and characteristics of the land resources. This information is required before effective regional strategies can be implemented, e.g. land use planning, conservation management, agricultural development. Soil survey is an important component within a land resource survey.

Reconnaissance surveys offer a realistic compromise between the intensity of field investigation and the extent of the survey area. Reconnaissance soil survey is defined by scale, normally from 1:100,000 to 1:1,000,000, and by the fact that original field investigation takes place. However, only a part of the soil boundaries are actually located in the field (Soil Survey Staff, 1952).

In southwest Mauritania, excluding the Senegal River Valley, little was known about the extent and distribution of soils. The objectives of this general purpose survey were to delineate the major soil associations, to determine the soil suitabilities and soil limitations, and to record current land conditions, namely, relative vegetative cover and the degree of erosion of the surface soil.

II. GENERAL DESCRIPTION OF THE PROJECT AREA

This section is intended to briefly illustrate those factors that relate to soil formation and the use of the soil resources within the project area. All descriptions and information presented in this section should be assumed to be wihtin the limits of the project area, unless otherwise noted. More complete discussions of geography, geology, climate, and vegetation are found elsewhere in this report.

Physiography

Elevations are generally low with a majority of the land area lower than 150m. The range of elevations is from near sea level in the southwest to over 500m in the northwest on the Tagant Plateau. The regional slope is southerly and southwesterly. All interior drainageways are intermittent and most eventually flow into the Senegal River, the only perennial water course. Nearly the entire area is in the Senegal River Basin; exceptions are the discontinuous drainageways in the extreme north and northwest, among the numerous dune fields. Several ancient drainage courses are evident, notably to the north and northwest of Kiffa. The major drainageways, or oueds, are the Gorgol Noir, Gorgol Blanc, Garfa, Niordë, Ketchi, and Karakoro. Numerous drainageways exist throughout the middle and southeast areas; runoff in this area is intensified by a bare, dense soil surface.

The land surface is an old erosional surface with the exception of Quaternary Period sand dunes and recent alluvial deposits. Several major geologic processes have been active in producing the present land surface. Deflation, including the pediplanation process (Thornbury, 1969), aeolian sand deposition, and fluvial deposition are the major factors in the formation and/or alteration of the landforms. The intensity of the above geomorphic processes has been conditioned by the climate and the nature of the parent rocks. The types of parent rock are the major factor in determining inherent fertility of soils. Slow weathering and infrequent wetting of the regolith leads to a preponderance of shallow and sandy soils in the dry tropics (Young, 1976); this is the case throughout much of the project area.

Several geologic provinces exist in the area and are more thoroughly described in the geology section. Within these provinces, six dominant landforms were recognized as follows:

1) alluvial deposits
2) sand dunes and aeolian sands
3) pediments or reg
4) coastal dunes, sebhkas, marine terraces
5) rocky plateaus and outcrops
6) undifferentiated uplands.

Landforms and climatic regimes were used as an initial means of partitioning the project area (Fig. 3-1). More complete landform descriptions are included in the Brief Mapping Unit Description Section.

Climate

Climate has contributed and continues to contribute greatly to the character of the present-day land surface of southwestern Mauritania. The distribution and variability of the rainfall together with high evaporative demands, hot temperatures, and high wind velocities influence the stability and utility of the land. Moisture deficiency is the major factor which affects the productivity of agricultural crops and rangeland plants.

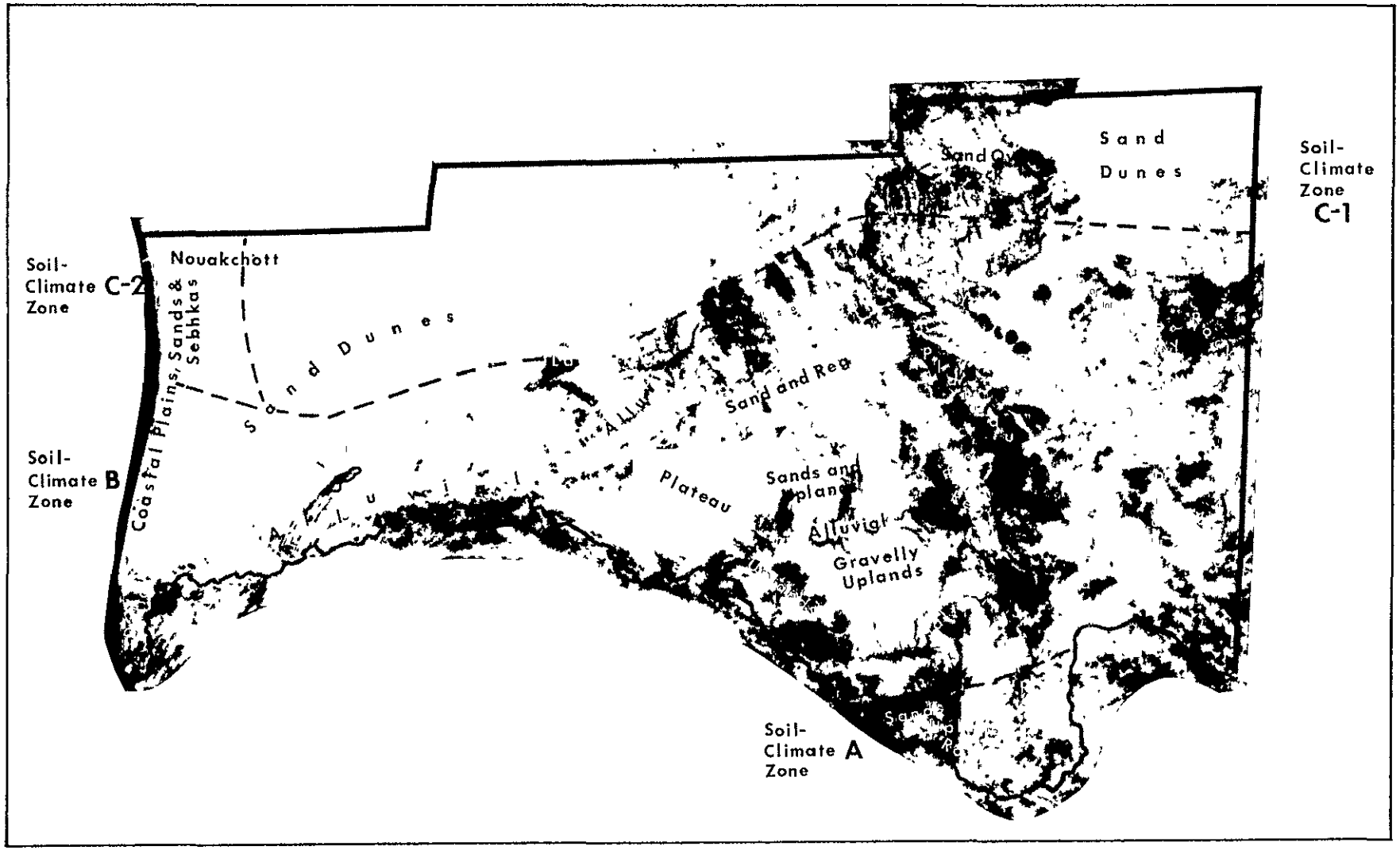


Fig. 3-1 Major landforms and climatic zones in the project area are shown on a Landsat band 5 mosaic. Soil-climate zones (after Boyadgiev, 1978) are described in the climate section. (Scale 1:3.5 million)

The majority of the project area is in the Sahelian climate zone; the southern two-thirds of the Guidimaka Region is in the northern Sudanian zone. The "wet" season is characterized by a three- to four-month period of rainfall during the summer and the dry season encompasses the remainder of the time. The range of average annual precipitation is from less than 150 mm to more than 600 mm (the characteristic variability of rainfall makes it imperative that a statistic of variance be considered when viewing isohyetal maps). Annual rainfall in the last 10 years has been considerably below "normal". Temperatures are hot; seasonal contrasts are more pronounced in the interior.

Soil moisture and temperature regimes are important features in soil survey. These climatic indices are basic, high-level criteria in soil taxonomic classification (Soil Survey Staff, 1975). The project area is divided into four moisture and temperature regimes (Fig. 3-1); they are Soil Zone A of limited moisture where the soil moisture control section (soil depth of 10 to 30cm) is moist in most years for 90 consecutive days ("ustic") and Soil Zones B, C1, and C2, which are three divisions of "aridic" and "torric" regimes, i.e. hot and dry areas with fewer than 90 consecutive days when the control section is moist. Limited areas of "aquic" moisture regimes exist in low-lying or run-in positions where the ground is saturated for lengthy periods. The "ustic" zone forms a transition between the dry savanna zone and the semiarid zone, and it is coincidental with fundamental changes in soil-forming processes, e.g., leaching of soluble products of weathering (Young, 1976).

In past geologic time significantly different climatic regimes have existed in the project area; this is evidenced by the advanced development of several soils in Soil Zone B. Since the most useful application of soil-climatic regimes is potential for crop production, only the present-day climatic regimes are considered. Another important factor that affects the moisture control section is position on the landscape and the slope shape (viz., rectilinear, convex, or concave). Lower slope positions and concave slopes often receive additional moisture through runoff. Conversely, steep slopes may be droughty even in zones of adequate rainfall. Runoff is an important feature in both the development and utility of soils in Mauritania.

Strong winds are a feature that has been influential in the on-going erosional processes in Mauritania. The susceptibility of land to wind erosion increases with coarse soil textures and sparse vegetative cover. The loss of surface soil through erosion is almost always significant to land productivity. The addition of wind-borne dust to Mauritanian soils is an unknown, but apparently a substantial, quantity.

Land Use

The major use of land is for livestock production. Pasture or rangeland types, typical herbaceous and woody species, and pasture potentials are discussed in detail elsewhere in this document. Cattle, goats and sheep are the major types of livestock along with significant numbers of camels and donkeys. Several aspects of livestock production in Mauritania, namely overgrazing and high stocking rates, have created environmental problems. In areas that are highly susceptible to erosion, proper range management is a necessary long-term practice for soil conservation.

Agriculture is the other important use of land in Mauritania. Climatic and soil factors are the main determinants in the type, yield, and extent of crop production. Several zones and types of agricultural production are identified in the following paragraphs; the data presented are based in part on two RAMS documents (Kraiem, 1980; RAMS, 1981).

The first zone is the Senegal River Valley. The valley is a major area of recessional, irrigated, and dryland agriculture. Sorghum is the major crop produced on the flood-recession lands; other crops are maize and cowpeas. The annual production is tied to the extent of flooding. The confluences of the Gorgol and Garfa Oueds with the Senegal River Valley have the largest concentration of cropped area, the annual extent being over 20,000 ha. Irrigation is limited in extent; paddy rice is the major irrigated crop. Two areas, one near Rosso and other near Kaëdi, constitute the largest areas under irrigation; they have a combined area of over 1300 ha. Small village irrigation sites (<25 ha) are numerous and total over 100 with an area of more than 2000 ha. Two crops are normally harvested each year. Paddy rice is grown during the rainy season and vegetables are the second crop grown during the cool, dry season in the Trarza, while rice and maize are the main crops outside the Trarza. Dryland agriculture is practiced at the boundaries of the Senegal Valley with millet being the dominant crop. Corn in the Guidimaka Region and bêrêf are other major dryland crops. This type of agriculture relies entirely on rainfall and thus the areal extent varies with annual precipitation.

The second zone is the rainfed agricultural region. The area encompassed by this zone varies according to annual precipitation, but it generally includes the area of land that receives more than an average of 350 mm/yr. The major crops are sorghum and millet; they occupy approximately 80 percent of the cropped areas. Other crops are bêrêf, corn, cowpeas, rice, and peanuts. The varieties of millet and sorghum are often mixed within fields.

Recessional agriculture occupies the third zone. It is practiced throughout the middle of the project area and this land use is especially prevalent where runoff is enhanced by the character of the land surface. Sorghum is the major crop in this zone. Traditional dams or dikes are more prevalent than modern dams. Several large areas behind modern dams are noteworthy because of their areal extent, namely, the areas at Guimi, Chogar, Mal, Sangarafa, Magta Lahjar, Aleg, and Djonâba.

The remaining types of agricultural production are located in palm groves and vegetable farms (i.e., outside of the Senegal River Valley). The areal extent of these two types of agriculture is limited but nevertheless very important locally. Dates and vegetable crops are the major produce of the palm groves, which occur where high water tables exist. The majority of palm groves are found in the Assaba and Tagant regions. Vegetable farm products include most common types of produce, e.g. potatoes, tomatoes, onions, etc. This type of production is generally located near larger cities, (viz., Nouakchott, Rosso, and Kiffa.)

III. MATERIALS AND METHODS

During the course of the soils investigation several levels or stages of observation were utilized. The stages were Landsat satellite false color imagery (1:500,000 and 1:250,000), 1980 color infrared photography (1:50,000), low altitude aircraft observation, and ground observation and sampling.

The initial soil mapping units were delineated on Landsat imagery and based on photo interpretation together with other sources of information, i.e., world soil maps (FAO and U.S. Soil Conservation Service), geologic and topographic maps, and other site specific studies. The preliminary delineations provided the basis for planning and implementing field investigations.

Aircraft flights over the project area preceded field observation, and they provided the survey team with a brief overview of terrain. Field observation and sampling began January 15 and ended May 19. The following field observations were recorded throughout the project area:

1) slope
2) surface texture
3) ground cover (vegetation and coarse fragments)
4) land use and condition
5) degree of erosion
6) type and density of alluvial lands

Soil sampling and site description were divided into "detailed" soil profile description and "nonprofile" soil samples (Fig. 3-2). Soil pits were located in areas representative of mapping units. Profile and site description forms were used at each soil pit (Worcester and Dalsted, 1980). Samples were taken from each soil horizon for physical and chemical characterization. Depth of soil profiles was variable but, in general, it was less than 1 meter. Nonprofile samples were taken to describe properties of minor soils and several major soils in the drier zones.

Chemical and physical characteristics of soil samples were determined by the members of the survey teams using portable soil testing kits. Electrical conductivity (EC), pH, cation exchange capacity (CEC), and base saturation (BS) were the major analyses. The methods and kits are described in Appendix A.

The final landform-soil delineations were completed after the field observation phase and the soil laboratory characterizations. Mapping unit names were completed according to landform-soil features and climatic regimes. Each mapping unit was composed of one to three major components. Estimation of the composition of each mapping unit was determined according to one or more of the following terms of references:

1) field observation
2) site description (profile and/or nonprofile)
3) aircraft reconnaissance
4) air photo- or Landsat-based interpretation
5) published information.

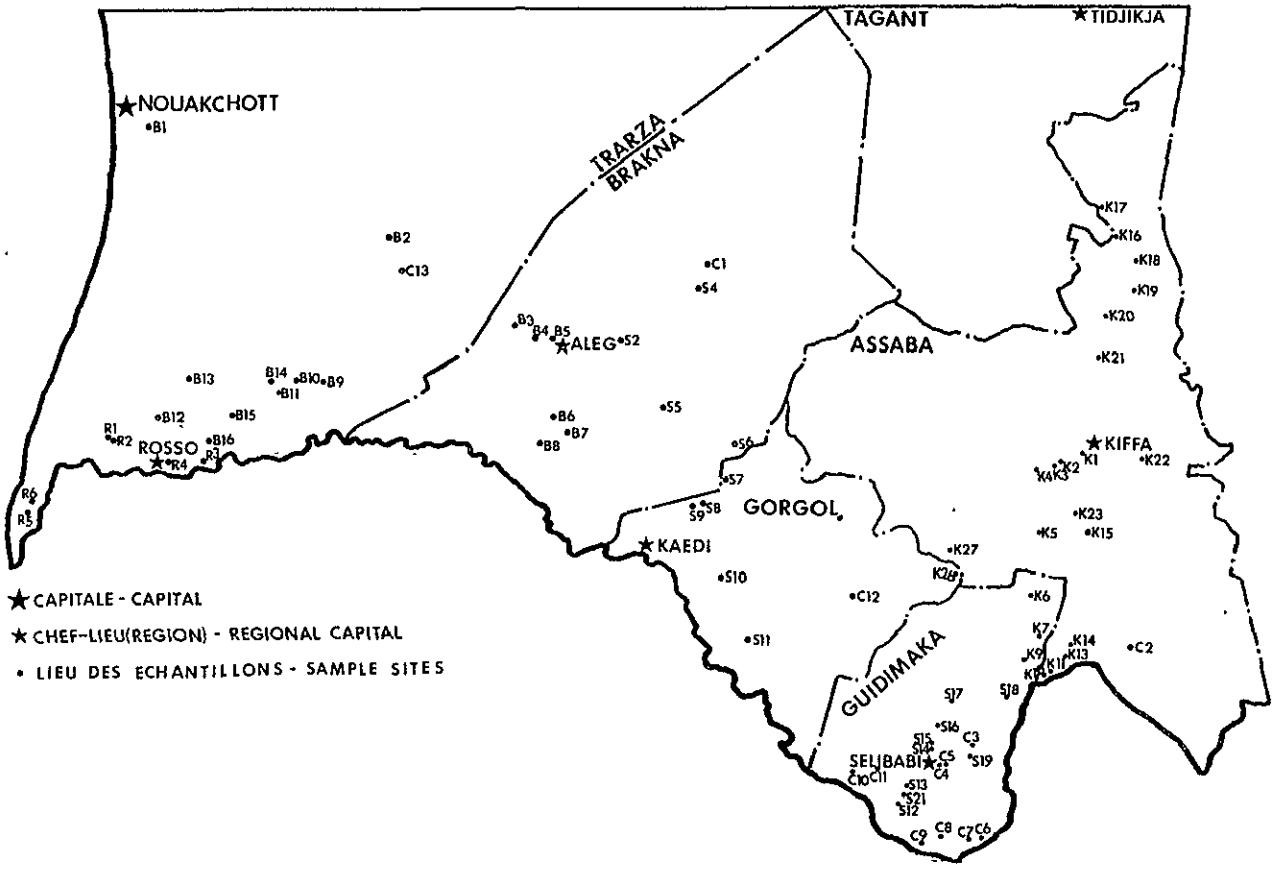


Fig. 3-2. Location of sample sites for soil investigation (scale 1:4 million). Sample notations may be referred to in Appendix C for profile and lab descriptions.

Soil properties, potentials, and interpretations were assigned to each major mapping-unit component; the criteria and classes are defined in Section VI and Appendix B.

IV. UTILIZATION OF THE SOIL MAP

Each mapping unit represents a unique soil-lanscape within its respective climatic zone. The mapping units have one or more major soils and a variable number of minor soils--each of which composed less than 15 percent of a unit. Throughout the survey, ground observations were used to assist in the definition of major and minor soils within most mapping units. Soil profile descriptions and nonprofile soil samples were used to typify the major soils and, in some cases, important minor soils within most mapping units. Each soil mapping unit was defined by soil-landscape characteristics that set them apart from all other mapping units.

The soil-landform map in the attached map folder shows the distribution of the mapping units, and together with the appropriate interpretations it displays general land-use potentials. Only general land-use considerations should be undertaken because of the small scale of the soil map. Most mapping units are represented by a soil profile or nonprofile description(s) that, in the best judgment of the survey team, is typical. Nevertheless, a range of soil characteristics that affect management exists for each mapping-unit component, and this factor along with the small scale precludes detailed planning efforts. The survey results should be used as a first step in the land-use planning sequence, that is, collecting and analyzing the appropriate data (Hudson, 1971).

In the following sections (V and VI), the soil mapping units are described, and interpretations for various uses are presented. These interpretations have been compiled for the major soils within mapping units unless otherwise noted. Tabulations of various soil properties and soil interpretations (e.g., erosion hazard) are listed by mapping unit and areal extent (km^2). It is often useful to graphically display a particular interpretation (e.g., soil texture or soil slope). This may be accomplished by placing an overlay on the soil-landscape map, grouping like interpretive classes, and drafting those lines which separate different classes.

A brief guide for best management procedures is presented in section VII. This chapter briefly outlines soil problems and the management tools to overcome these problems. Sociological and economic feasibility associated with various management or land improvement plans were not considered, e.g., distance from roads and/or markets, land tenure practices, costs associated with good management. Only soil and climatic variables were considered in completing the soil potentials.

V. BRIEF MAPPING UNIT DESCRIPTIONS

This section provides a brief description of the important characteristics and potentials for the major soils in each mapping unit. The range of accuracy for composition (major soils in mapping units) was estimated between 65 and 85 percent. Minor soils were given a compositional percentage only in cases when significant deviations occurred in land use potentials and/or composition exceeds 5 percent. An undifferentiated mapping unit was sometimes employed to characterize a range of compositions for major soils; in these cases a median estimation was used for the calculation of the areal extent of the major soils (Section VI, table 3-1).

Soil features that were important to the management for pasture and/or agricultural land were emphasized in this section. The range of soil properties for the major soils and some minor soils was described along with land use, vegetative cover, and erosion. Suitability for agriculture and limitations for use were included in each mapping unit description unless otherwise noted. A description of alluvial lands and drainage density was included for applicable soil-landform units. Typifying soil profiles and/or site descriptions (nonprofile) are named and can be referred to along with corresponding physical and chemical properties in Appendix C. Soil taxonomic considerations were not included in this section; this information is found in Appendix D.

This section is arranged by soil-climate zones (3), dominant landforms within soil-climate zones (3-5), and finally the lowest defined level, the soil association (84). Locations and shapes of mapping units in the accompanying soil-landform map (1:500,000) will enhance the use of this report. The terms used in describing or defining characteristics of mapping units are explained in Appendix B and Section VI, e.g., the meaning of Suitability Ratings, or the definition of shallow soils.

Soil Region A (greater than 500 mm precipitation, >24° C average annual temperature)

This region, which is the northern limit of the dry savanna, is transitional to the semi-arid zone (Soil Regions B and C). It makes up 3.8% of the project area. This zone encompasses most of the Guidimaka Region.

The northern boundary of this zone (after Boyadgiev, 1978) is somewhat arbitrary because of fluctuations in annual rainfall. The range of precipitation cited for this zone is based on long-term averages; although in recent years the average precipitation has been considerably less. The ability of soils to store moisture for any length of time is a critical factor in rating their potential for cropland and determining the taxonomic classification. This soil-climate zone offers the best potential for rainfed agriculture in the project area; however, since this zone is subject to the vagaries of rainfall, sustained production on suitable soils will be depressed by below-normal rainfall.

Within this zone several interesting soil features occur. The pH and soil development of sands vary with geographic location, i.e., sands in the north part of this zone are less developed and have a higher pH than the sands of the southern areas. Alluvial zones (mapped and nonmapped) are generally very productive soils in this unit. Recessional agriculture in alluvial soils is not as extensive as in Soil Region B.

The upland and lithic soils have a wide range of parent rocks and the more acid rocks have weathered to yield strongly to moderately acid soils. Parent materials are very important factors in determining potentials for cropland in the upland soils of this zone. (Additional reference: Bradley et al., 1977).

Alluvial Soils (A)

These soils occur throughout Soil Region A (Fig. 3-3). The soils can be divided into two major zones: the Senegal River Valley and interior drainageways. In this soil-climate zone alluvial soils occupy 10.4% of the land area. Only those alluvial soils which are 0.5 km wide or wider and occupy a minimum of 1000 hectares are mapped; these criteria are also applied to other soil-climate zones. Drainage density is described in other soil-landform units to typify smaller alluvial areas.

The majority of these soils are nearly level, but some gently sloping soils, primarily in the Senegal Valley, are included. Reaction varies from strongly acid to neutral. Soil drainage ranges from very poorly drained in basins and intermittent lakes to excessively drained in sandy levees. Annual flooding occurs to a variable extent each year in the Senegal Valley, and, to some extent waters are backed up in primary drainageways at their confluence with the Senegal Valley. Soil textures are generally medium and moderately fine, but, to a variable extent, all soil textures exist within these units. Sandy alluvial deposits are notable in the Senegal Valley.

These soils are used for agriculture and pasture land. Soil fertility is generally high.

AA1— Nearly level, deep, very poorly to somewhat poorly drained, moderately fine- and fine-textured soils (50%) and nearly level and gently sloping, deep, excessively and somewhat excessively drained, coarse- and moderately coarse-textured soils (50%).

The dominant soils are dark-colored, poorly drained clays in basins. Component 2 contains sandy and somewhat excessively drained soils of levees and sandy areas. Component 1 varies from very poorly to somewhat poorly drained and has fine to moderately fine textures. Soil reaction is generally strongly acid. Flooding occurs in most years and several lower topographic sites are waterlogged the year around (10%). Local names for these soils are waalo, low fondé, and hollalde blanc. Component 2 occurs on the higher, better drained sites. Soil textures range from coarse to medium. Soil reaction is moderately acid to neutral. Local names are fondé (high) and dieri.

These lands are used for pasture and cropland. Vegetative cover is poor to fair for Component 1 and good for Component 2. Some wind erosion has occurred in Component 2.

Fig. 3-3. Alluvial zones of Soil Region A are illustrated by a primary flood-plain of a large drainageway 18 km south of Selibaby (above) and a low terrace of a medium-sized oued 20 km north of Selibaby (below). Sorghum stubble is visible in the lower photo.

Component 1 has an S2 Suitability Rating[1] for cropland and Component 2 has an S3 rating. Soils of Compoennt 1 are best suited for sorghum production when flooding can be controlled or in those sites which are not susceptible to long periods of waterlogging. Maintenance of organic matter is a recommended management practice to improve structural stability and fertility. Tillage programs are needed to improve infiltration of rainfall on the higher sites and on all sites to break up soil crusts when soil workability is optimum, i.e., moisture slightly below field capacity.

Surface drainage and nitrogen, phosphorus, and potassium fertilization are also needed. Some of the more poorly drained sites have potential for rice production. Regulation of flooding, leveling, and proper preparation for rice culture are needed.

Under rainfed farming and good management, soils of Component 2 are best suited to dryland millet and sorghum. Other minor crops may also be utilized, e.g., peanuts in moderately coarse- and medium-textured minor soils of this unit. Fertilization programs and protection against wind erosion are needed for optimum production. Tillage programs are needed for improvement of infiltration rates in those soils finer in texture than loamy fine sand (10%).

These soils have been previously characterized and/or mapped at 1:50,000 and larger scales (PNUD, 1977; Boyadgiev 1978).

AA2- Nearly level, deep, somewhat poorly drained, moderately fine-textured soils.

The dominant soil in this unit is dark-colored, slightly acid, and generally very fertile. Narrow to moderately wide flood plains of intermittent drainageways constitute the setting for these the soils.

Soil textures are predominantly moderately fine with a range of fine to moderately coarse. A thin cover of aeolian sands occurs in a few places. Soil drainage varies from very poorly drained to well-drained. Most of these soils are not flooded for extended periods; however, a flooding hazard exists for the primary drainage ways, especially near the Senegal River Valley.

These soils are used extensively for agricultural production. Sorghum is the major crop with some areas of maize in the southern part of the Guidimaka Region. Native vegetation is a moderately dense cover of trees, shrubs, and grasses. Runoff from sparsely vegetated or nearly bare upland soils and flood waters that back up from the Senegal River Valley provide supplemental moisture.

These soils have an S2 Suitability Rating for agriculture. Tillage programs are needed to enhance infiltration and storage of soil moisture. Fertilization and protection from erosion are also required to ensure

---

[1] Based on FAO Suitability Classification, see Section VI for definitions.

sustained productivity. In some places surface drainage is needed to reduce wetness hazards. Maize can be grown in the well-drained soils of the southern areas.

Soils of primary flood zones are characterized by brief site description S21.[2]

Lithic Soils (L)

These soils occur throughout Soil Region A (Fig. 3-4) and occupy 20.3% of this soil-climate zone. Scattered buttes and steep, rocky ridges compose the majority of lithic soils in this landform group. The parent rocks of these soils vary widely in mineral types, but sandstones and quartzites are the dominant types. The dominant soils are very shallow to bedrock and excessively drained.

Several non-lithic soils are included in this category. These soils are generally sandy in texture, deep, and somewhat excessively to excessively drained. The soils of this landform group are commonly used for pasture. Soil fertility is generally medium to low.

AL1- Steep, very shallow, excessively drained, lithic soils (70%), and moderately sloping, deep, excessively drained, coarse-textured soils (30%).

The dominant soils are very shallow, well-fractured quartzites. Component 2 is a coarse-textured wind-deposited soil. Some soils included in Component 2 have formed in place and been reworked by winds. The range of soil slopes for Component 2 is gently sloping to moderately steep. Component 2 is similar to Component 1 of Unit AE1.

These soils are used almost exclusively for pasture. The vegetative cover is good and the erosion hazard is moderate for Component 2. In a few places overgrazing has led to severe wind erosion. Use of Component 1 for pasture is difficult because of steep and rocky terrain.

AL2-Component 1 has an N2 Suitability Rating for agricultural crops. Component 2 has an SC Suitability Rating. Soils of Component 2 are limited by coarse texture, low fertility, and a severe erosion hazard.

Moderately steep and steep, very shallow, excessively drained, lithic soils.

The dominant soils of this unit are composed of quartzitic rocks. A few areas of moderately sloping soils are included with this unit. These soils can be used only for pasture and then with some difficulty due to steep and rocky terrain. These rocky soils are not as consistently well-vegetated as the rocky soils of AL1. The Suitability Rating for agricultural production is N2.

---

[2] See Appendix C for Soil descriptions and chemical properties.

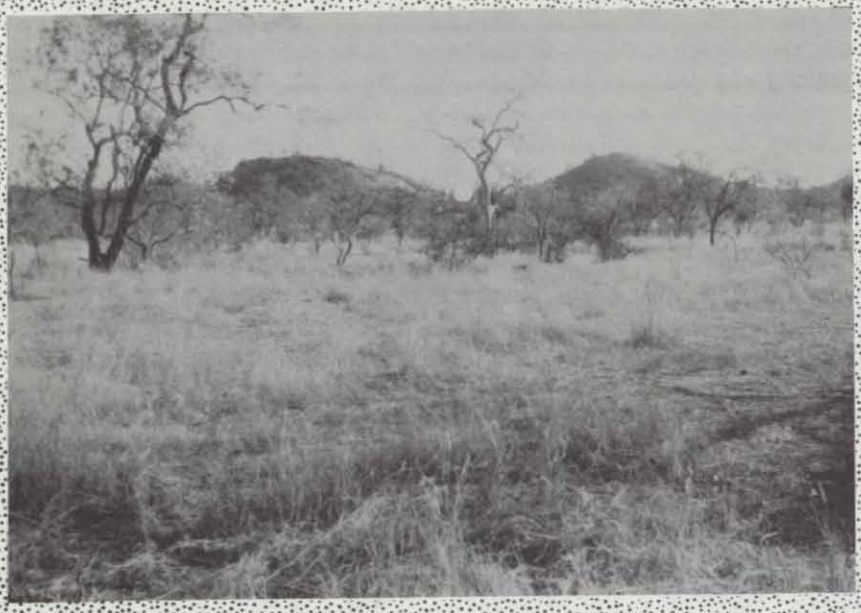


Fig. 3-4 Lithic zones of Soil Region A consist primarily of buttes (above) and low ridges (below). These ground photos were taken north and northeast of Selibaby, respectively. Lithic soils in this soil region often support fair to good stands of trees and grasses.

AL3- Steep, very shallow, excessively drained, lithic soils (30-50%); gently sloping, deep, well-drained to somewhat excessively drained, moderately coarse-textured soils with gravel (20-40%); and gently sloping, deep, moderately well-drained, moderately fine-textured soils with gravel (10-30%).

The dominant soils are steep sedimentary and volcanic buttes and ridges. Soil textures of Component 2 are moderately coarse and gravelly and have formed in upland colluvium. Soils of Component 3 are moderately fine-textured with gravel and have formed in upland colluvium. Soils of Component 1 are composed of variable rock types (Selibaby Series of undifferentiated geology). Soils of Component 1 and 2 include a few areas with nearly level slopes. These soils have variable amounts of surface and subsurface gravels; it was estimated that gravelly soils make up 40% of each of these components. Soil textures for Component 2 also include some coarse textures. Component 3 has some medium-textured soils.

Vegetative cover consists of trees and sparse grasses with Component 2 having slightly more ground cover than Component 1. Pasture land is the major use of this unit. Soils of Component 1 are limited by steep slopes, very shallow depths, and excessive runoff. They have an N2 Suitability Rating from Cropland. Vegetative cover is good, but use as range is difficult due to steep, rocky slopes. Soils of Component 2 are limited by gravelly and coarse textures, severe erosion hazard, and low fertility. They have an N1 Suitability Rating for cropland. When these soils are deep to gravel some potential exists for rainfed sorghum and millet; however, irregular shapes of these tracts of deep soils are a severe problem. Surface crusting occurs in most of these soils. Erosion control, tillage, and maintenance of soil moisture and fertility are recommended for cropped areas. These soils are best-suited to pasture lands. Soils of Component 3 are limited by gravelly textures, severe erosion hazard, and structural instability. The Suitability Rating is N1 for cropland. When these soils are deep to gravel some potential exists for rainfed sorghum; however, irregular shapes present a severe problem. Surface consistence is hard or very hard, resulting in a severe water erosion problem due to slow infiltration. Erosion control, maintenance of fertility and tilth, and tillage are recommended for cropped areas. These soils are best-suited for pasture lands.

Alluvial lands in this unit are generally narrow and gullied. Drainage density is coarse to medium. These lands are best suited for pasture. Soil Component 2 is similar to the soil of brief description C11. Soil Component 3 is represented by site description C5.

AL4- Moderately steep and steep, very shallow, excessively drained, coarse-textured and lithic soils (60%) and gently and moderately sloping, shallow to deep, excessively drained, coarse-textured soils (40%).

The dominant soils are very shallow, rocky soils. Component 2 consists of coarse-textured, shallow to deep soils formed in aeolian sands. Component 1 has some gently sloping and moderately sloping areas included in its range. Component 2 consists of deep sand dunes near the Karakoro Oued, while the sands are of variable depth (<25 cm) to bedrock elsewhere. Minor soils are gravelly or cobbly and medium-textured lands.

These soils are used for pasture. Vegetative cover is poor to medium. Near the Karakoro Oued deep sands are often cropped. Sorghum and millet are common crops. Severe wind erosion has occurred frequently in Component 2. Component 1 has an N2 Suitability Rating for cropland. Component 2 has a N1 Suitability Rating for cropland. These soils are best-suited for rangeland under proper management. Overgrazing will lead to severe wind erosion.

Aeolian Soils (E)

These soils occur throughout Soil Region A (Fig. 3-5). An October 1978 Return Beam Vidicon satellite image shows the distribution and appearance of these soils (Fig. 3-6). The soils in this landform unit occupy 14.3% of Region A. Other landforms included with this dominant landform type are lithic soils and undifferentiated upland soils. Some coarse-textured soils, which have formed in place, are also included with this unit. Slopes are gently to moderately sloping.

These soils are used primarily for pasture. They are limited for use by coarse textures, low fertility, and erosion hazard; these limitations should be assumed for each mapping unit. These soils are generally well-vegetated and protected from wind erosion by good surface cover.

AE1– Gently and moderately sloping, deep, excessively drained, coarse-textured soils (60%) and steep, very shallow, excessively drained, lithic soils (40%).

Minor soils make up 10% of the unit, and consist mostly of gravelly lands. The dominant soils are wind reworked while the second component consists of fractured quartzite. Component 1 is the same as Component 2 of Unit AL1 except that the dominant slopes are gentler. Component 2 is the same as Component 1 of Unit AL1. Utilization, vegetative cover, suitabilities (SC and N2) and limitations are the same as those data listed with Unit AL2 for the respective soils. The minor soils in this unit are best-suited for pasture lands; they occur in irregular patterns and most often are nearly devoid of vegetation. Soil profile S13 represents the central concept of Component 1.

AE2– Gently sloping, deep, excessively drained, coarse-textured soils (50-80%) and nearly level and gently sloping, deep, somewhat excessively drained, moderately coarse- to moderately fine-textured soils with gravel (20-40%).

Component 1 soils are deep, strongly acid, fine sands with well-developed soil profiles. Component 2 has a varying surface texture (sandy loam to clay loam), and it contains significant gravelly zones within 120 cm of the soils surface. Soil slope for Component 1 range from nearly level to gently sloping. Component 1 occurs in two geographic settings, i.e., a large area near the Niordé Oued and in the east central part of the Guidimaka Region. Near the Niordé Oued, the compositional percentage of Component 1 approaches 80% with some areas of thin sands over gravels. In this area some soils have formed in soft sandstone of Tertiary age. The other mapped area of Component 1 is lesser in extent and has some soils that consist of a thin covering of sands (25-100 cm) over heavier textures. A

Fig. 3-5 Aeolian sands of Soil Region A are generally well-vegetated. Grass and tree cover are similar 15 km south of Selibaby (above) and 2 km west of Harr (below).

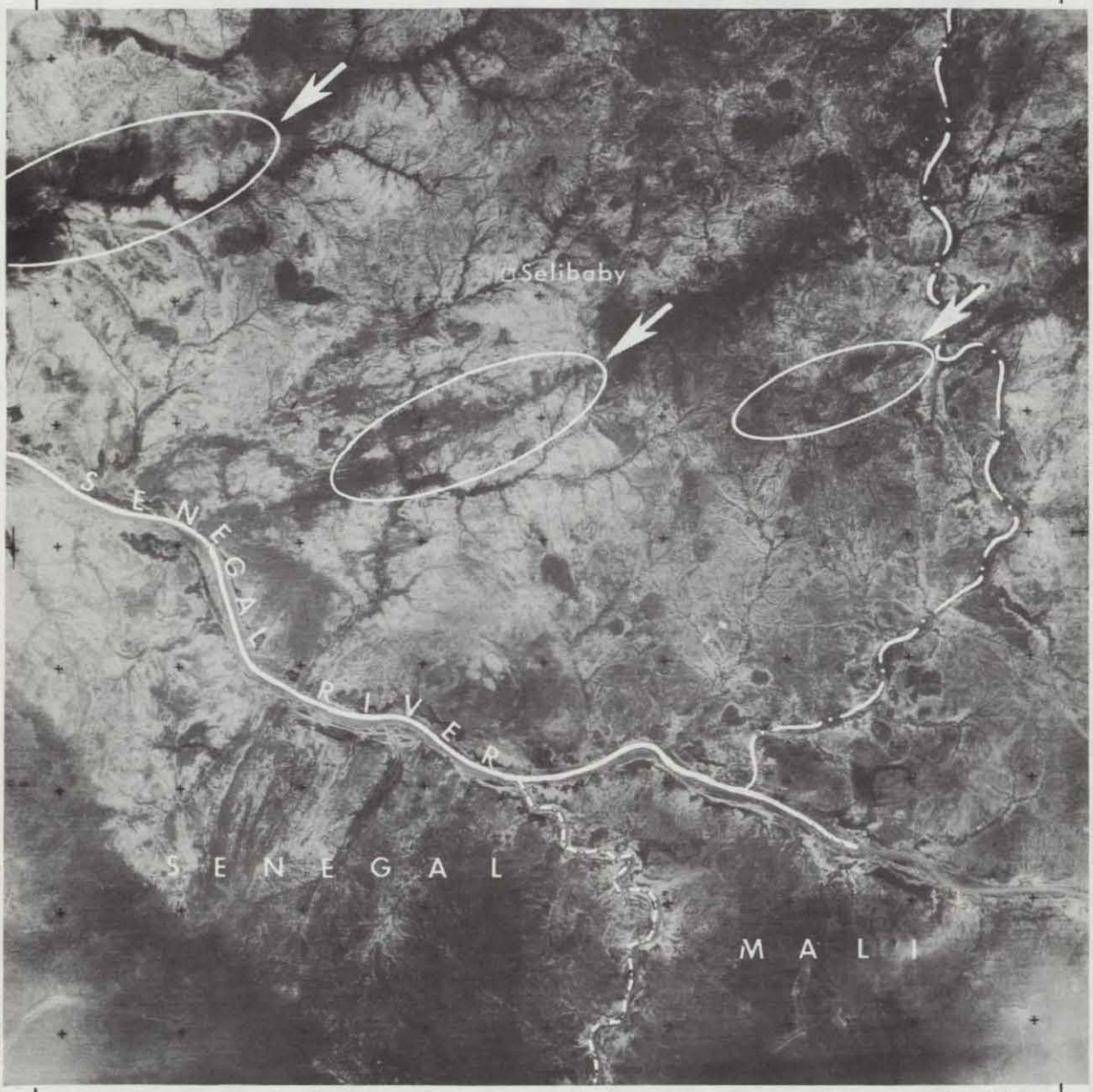


Fig. 3-6 Return Beam Vidicon (RBV) image showing the southern Guidimaka Region in October 1978. Arrows and ovals indicate linear patterns of aeolian sand deposition and the related spectral signatures.

minor soil is deep, moderately-coarse textured and occurs on nearly level and gentle slopes. Component 2 varies from coarse- to moderately fine-textured and has varying amounts of gravels. Minor soils associated with Component 2 are moderately coarse- to moderately fine-textured lands without appreciable gravel.

Component 1 is used mainly for pasture. Vegetative cover is good in Component 1; the area near the Niordé Oued has somewhat better cover than the eastern unit. Component 2 is an undifferentiated unit and has soil properties similar to Components 2 and 3 of Unit AL3. It is used for pasture and has irregular shapes with gravelly outcrops occurring mainly on convex slopes and near the edges of alluvial areas. An irregular, patchy surface cover of sands is common.

Component 1 has an SC Suitability Rating for agriculture. It is recommended that, when cropped, millet varieties be given precedence over sorghum due to millet's ability to endure drought and low fertility conditions. These soils are well-suited to pasture. Component 2 has an N1 Suitability Rating for agriculture. It is limited by gravelly zones, irregular shapes, erosion hazard, and poor physical condition. These soils are suitable to pasture.

Uplands, Undifferentiated (U)

These soils occur throughout Soil Region A (Fig. 3-7). They occupy 55% of Soil Region A. This landform unit is composed of a wide range of surficial geology. The Selibaby series and M'Bout-Bakel series of geology encompass most of this unit; these geologic series are composed of sedimentary, metamorphic, and volcanic rocks of indeterminate age. Parent material is the major factor in soil development in these units. A wide range of soil properties exists for the soil units in this zone. Slopes are commonly nearly level to gently sloping; moderately sloping soils also occur, but to a lesser extent. Soil textures range from coarse to fine. Gravelly deposits are common and usually found on convex, higher slopes and at the border between drainageways and uplands. Soil reaction varies from strongly acid to moderately alkaline.

Land use is generally pasture. Some areas are used extensively for agricultural production, especially in the south and southeast part of the Guidimaka Region. Alluvial soils within this zone often provide excellent soils for crop production. Common crops are sorghum and maize (in the extreme southern areas). Limitations for crop production include severe erosion, low fertility, poor physical condition, coarse and fine textures, and gravelly deposits. Some soils are subject to self-sealing. Soil crusts are common and vegetation cover in these areas is sparse.

AU1– Nearly level and gently sloping, deep, well-drained, medium- and moderately fine-textured soils with gravel (30-70%) and nearly level, deep, somewhat excessively drained, moderately coarse-textured soils (30-70%).

The dominant soils are deep and gravelly. Component 2 is a deep, moderately coarse-textured soil. Minor soils (15%) are nongravelly, moderately fine-textured soils associated with Component 1. Component 1 is essentially a complex of soils that occur on the landscape in intricate patterns. The range in characteristics is wide with no one soil dominating.

Fig. 3-7 Uplands soils of Soil Region A vary considerably in productivity and land use. Large areas of soils devoid of grasses are common (above) while the productive soils (Katamagne clays) are minor (below). The barren site is 13 km west of Selibaby and the clay soils are located in a DRIG (Integrated Rural Development in the Guidimaka) site 9 km north of Selibaby.

Component 2 includes some coarse- and moderately-coarse soils that are underlain by heavier soils at depths greater than 100 cm. The normal profile sequence for Component 2 is a coarse-textured surface soil underlain by a moderately coarse- to moderately fine-textured horizon of clay illuviation. A few buttes are scattered throughout this unit.

Component 1 is used for pasture and vegetative cover is generally poor. It has irregular shapes and is very nearly the same as Component 2 and 3 of Unit AL3 (a more detailed description is available in Unit AL3). Component 2 is used for pasture and some brush-fallow agriculture. The vegetative cover is fair and erosion is moderate to severe. Soil crusts are a problem in many places. Component 1 has an overall N1 Suitability Rating. The minor soils associated with Component 1 (i.e., nongravelly) are limited for cropland use by a severe erosion hazard, poor physical condition, and irregular shapes. Component 2 has an S3 Suitability Rating. It is limited for crop use by a coarse-textured surface horizon that very susceptible to wind erosion. Sorghum and millet can be grown in these soils. Low fertility is another limitation for crop production. Good management includes fertility and erosion control. Tillage is recommended when soil crusting occurs.

Alluvial zones in this unit offer some potential for agriculture. These soils are generally medium and moderately fine-textured and represent the best agricultural potential in this unit. Drainage density is medium. Some gullying and narrow drainageways are limiting factors for cropland.

Component 1 is described by Profile S12 and by site description C11. Component 2 is represented by Profile C4 and is site description C8.

AU2– Gently sloping, deep, well-drained, moderately coarse- to medium-textured soils (50%) and gently sloping, deep, excessively drained, coarse-textured soils (50%).

The dominant soils are moderately coarse and medium (fine sandy loams and very fine sandy loams), strongly acid, and prone to self-sealing or crusting. Component 2 is coarse-textured and moderately acid with a well-developed soil profile. Minor soils (15%) are gravelly lands that occur in scattered, discontinuous patterns throughout this unit. Component 1 generally occurs on long, gentle slopes, but some nearly level areas are included. Component 2 has been partially formed in aeolian sands as evidenced by scattered discontinuous islands of sands, which are also found overlying Component 1.

Component 1 is used primarily for pasture. It has a very poor vegetative cover. Component 2 is also used for pasture with somewhat better vegetative cover than Component 1.

Component 1 has an N1 Suitability Rating for cropland. It is prone to surface crusting by the process of microlamination of silt-sized mica flakes (Young, 1976). These soils are also infertile, have a severe erosion hazard, and provide little vegetation for pasture use. Component 2 has an N1 Suitability Rating for cropland. It is limited by coarse texture, severe erosion hazard, and low fertility.

Alluvial lands in this unit are rare. Drainage density is coarse. Alluvial soils are most often medium-textured to moderately coarse. Crop production on the wider bottomlands is possible and often used as such. These soils have moderate fertility.

Component 1 is represented by Profile C10.

AU3– Nearly level to moderately sloping, deep, well and somewhat excessively drained, medium- and moderately fine-textured soils with gravel.

The dominant soil in this unit is deep, moderately fine-textured and gravelly (90%). Range of characteristics include medium textures and thin lenses of coarse textures over finer materials with gravel. Several minor soils (10%) are notable in this unit; they are fine-textured, dark-colored, deep soils (local name is Katamagne) and moderately wide alluvial areas with medium and moderately fine textures. Buttes and rocky ridges and a moderately deep cover of coarse-textured materials over fine materials are included in this unit.

The dominant soil, which is used as pasture, has poor vegetative cover and severe wind and water erosion. Suitability for cropland is N2. Limitations are gravels, severe erosion hazard, and poor physical condition. The fine-textured and alluvial soils included in this unit (minor soils) provide excellent agricultural lands. Difficulty in tillage is the major problem for minor fine-textured soil, while alluvial soils require tillage and fertilization. Sorghum is the recommended crop for these soils.

Drainage density is medium to fine. Alluvial areas which are too narrow for cropland provide excellent vegetation for pasture use.

The major soil is represented by soil Profile S14. The minor soils are represented by site descriptions S15 for heavy soils and S16 and S17 for alluvial soils.

AU4– Nearly level, deep, moderately well-drained, moderately fine-textured soils (70%), and gently and moderately sloping, very shallow, somewhat excessively drained, medium-textured and lithic (shaly) soils (30%).

The dominant soil is moderately fine-textured with some profile gravel. It is neutral in reaction at the surface to moderately alkaline with depth. Component 2 is very shallow to well-fractured shale and neutral (moderately acid with depth) in reaction. Minor soils are coarse-textured and deep (10%) and gravelly lands (10%). The major soils in this unit have formed in basic parent materials. Component 1 is gravelly in some places (i.e., more than 17% gravel in the soil profile). Component 2 occurs on nearly level to moderately sloping lands; on level and gentle slopes, a thin dark-colored, fertile topsoil has formed.

The major soils of this unit are well-vegetated with trees and grasses (baobab trees are numerous). The unit is used extensively for pasture. Component 1 has an S2 Suitability Rating for cropland. It is limited by heavy textures, profile gravel, alkalinity in the substrata, and tillage difficulties. There may also be a sodium problem in some places. It is

well-suited to sorghum and when "average" rainfall is received; it is suited to maize. This soil provides good pasture. Component 2 has an N2 Suitability Rating for cropland. It provides excellent pasture land where a thin topsoil has developed; otherwise the grass stand is thinner. The minor soils have been described as Components 2 and 3 of Unit AL3.

Alluvial lands are common in this unit. Drainage density is medium. The wider alluvial areas offer good potential for maize and sorghum. Drainageways are normally too narrow for cropland use.

AU5-Component 1 is represented by profile C7 and Component 2 is represented by site description C6.

Nearly level to gently sloping, deep, moderately well- and somewhat poorly-drained, medium- and moderately fine-textured soils with gravel.

This is an undifferentiated unit in which gravelly and dense soils occur in intricate patterns. A minor soil (10%) is a thin to deep covering of sands over fine materials. This unit is similar to Unit AU3, but differs by having gentler slopes, less gravel at the soil surface, and different minor soil inclusions.

The major soils are used as pasture. Vegetative cover is generally poor with a few areas of fair cover. Water erosion is severe throughout this unit.

The dominant soils have an N1 Suitability Rating for cropland. Limitations for agriculture are gravelly areas, a dense soil surface, heavy textures, and an erosion hazard. Slow infiltration and irregular shapes are characteristics of the gravel-free, major soil areas.

Alluvial lands are common in this zone. Drainage density is medium to fine. Most alluvial zones are too narrow for agriculture, but provide excellent pasture. Some moderately wide alluvial areas are cropped, and these zones provide good potential for sustained crop production. Since many alluvial areas are shallow-sided and not well-incised, potentials for water-spreading are promising.

Soil profile S19 and site description C3 typify the major soils of this unit.

AU6- Nearly level, deep, moderately well-drained, fine-textured soils (65%) and nearly level, deep, well-drained, medium-textured soils (35%).

The dominant soils are deep, fine, moderately alkaline silty clays. Component 2 includes deep, medium textured, slightly acid to neutral soils. Minor soils are severely eroded, coarse-textured lands (15%) at the fringes of this unit. Component 1 has vertisolic tendencies and vertic soils exist in shallow, small basins.

Component 1 is used for both grazing and cropland. Brush fallow in various stages of regrowth is scattered throughout this unit. Heavy stands of Acacia seyal dominate the vegetative composition. Sorghum and maize are the common crops. No noticeable erosion was seen in this unit.

Component 2 has good vegetative cover and is commonly used for grazing. Minor areas of cropland probably exist. Component 1 has an S2 Suitability Rating for cropland and is well-suited for sorghum and suited for maize. It is limited by heavy textures and alkaline reaction. Tillage and fertilization programs are recommended. Component 2 has an S2 Suitability Rating for cropland. It is limited by a moderate erosion hazard and low to moderately low fertility. Peanuts and sorghum should do well on this soil.

Alluvial lands are concentrated in the southern end of this unit. They are suited to agricultural production when moderately wide.

Component 1 is represented by Profile C9.

Soil Region B(includes zones which receive 225-500 mm precipitation, >24°C average annual soil temperature)

This zone constitutes 60.5% of the project area and encompasses the southern Trarza and large parts of the Brakna, Gorgol, and Assaba Regions. Rainfall is quite variable. Temperatures are generally very hot in the interior with marked seasonal extremes. Along the coast temperatures are cooler with lesser seasonal extremes.

All of the major landforms occur in this soil-climate zone. In order of dominance the landforms are sand dunes or other aeolian sands, rock lands, desert pavement or pediments, undifferentiated uplands, alluvial lands, and coastal dunes, sebhkas, and miscellaneous. Soils of this zone differ considerably in profile development because of varying landform types and rainfall distributions. Most soils have minimal profile development, although many soils of the desert pavement zone have developed moderately deep soil profiles under past, more favorable climates. Soils formed in sands show a wide range in pH and depth of profile from north to south.

Pasture is the major land use in this zone. Agriculture is also an important land use. It consists of recessional agriculture (away from the Senegal Valley) and rainfed and recessional agriculture and irrigation in and near the Senegal River Valley. Soil and climatic limitations for agriculture are very severe in this zone.

Aeolian Sands (E)

These soils occur throughout this soil-climate zone (Fig. 3-8). The soils of this landform unit occupy 39.6% of Soil Zone B. The sands were deposited and/or reworked during the Quaternary Period. They can be divided into five major types: longitudinal dunes, slightly undulating sand sheets, transverse dunes, littoral dunes, and miscellaneous dune types. Two major areas of longitudinal dunes occur in the western part of the project area (Trarza and Brakna Regions) and a lesser area along the eastern side of the Assaba and Tagant Plateaus (Assaba Region). Gently sloping, sandy areas occur mainly in the Assaba Region, but other notable areas are located north of Boghé and in the Lake R'Kiz area. Transverse dunes are not extensive and they are located northwest of Rosso and Kiffa and near Moudjéria. Littoral dunes are found from the mouth of the

Fig.3-8 Aeolian sands of Soil Region B are contrasted by comparison of the western and eastern parts of the project area. In general, western sandy zones have been subjected to heavy use as illustrated by the dead Acacia trees and low grass located 16 km northeast of Mederdra (above). Sands east of the Assaba Plateau are generally well-vegetated. The diversity of trees, shrubs, and grasses is illustrated by an area 40 km northwest of Kankossa near the eastern face of the Assaba Plateau (below).

Senegal River along the coastline to and into Soil Region C. Miscellaneous dune types are constituted primarily of zones of actively moving sands, and they are located through the middle of the project zone.

The major means of differentiating soils formed in aeolian sands are slope and degree of soil development. Other important factors are the character of the interdunes, inclusions of other landform types, and soil catena forms (i.e., succession of soils on a slope).

Land use in this landform group is usually pasture. The majority of agricultural fields (rainfed) are found at the border of the Senegal River Valley. Vegetative cover ranges from a full cover of trees and grasses to nearly barren. These soils are extremely susceptible to wind erosion and the combined effects of overgrazing and drought have led to severe erosion in numerous places. Several of the southern areas, which have SC Suitability, can be expected to produce moderate yields with normal or above normal rainfall. These soils are fragile and soil conservation and management are necessary for agricultural and pasture use. Low rainfall and coarse textures are the major limitations for agricultural use.

BE1- Nearly level and gently sloping, deep, excessively drained, coarse-textured soils (40%); nearly level and gently sloping, deep, excessively drained pediments (30%); and steep, very shallow, excessively drained, lithic soils (30%).

The dominant soil is formed in nearly level and gently sloping aeolian sands. Component 2 is nearly level and gently sloping, gravelly and stony land. Component 3 consists of steep, rocky ridges and buttes. Component 1 includes some soils formed in place and reworked by winds. In places the sands are shallow to moderately deep to pediments. A few areas of steep, bare sands are included; these areas abut on the lee side of the Assaba Plateau. Component 2 includes some areas that have less than a full cover of gravel and cobbles. Component 3 includes some moderately sloping and moderately steep rocky ridges.

These soils are used for pasture. Component 1 normally has a fair cover of grasses with few trees, and it is moderately to severely eroded. Soils of Components 2 and 3 are virtually bare.

Soils of Component 1 have an N1 Suitability Rating for cropland. Limitations for agriculture are low rainfall, coarse textures, low fertility, and severe erosion hazard. Soils of Component 2 and 3 have an N2 Suitability Rating and provide little or no farage.

Alluvial lands are numerous in this unit. Drainage density is medium. These soils are generally moderately fine, and the wider areas are used for sorghum production. This unit forms the headwaters for several large oueds, namely, Garfa and Gorgol Noir Oueds. Drainageways are well-vegetated and provide good pasture. Potential for water-spreading exists in this region since drainageways are not well-incised and slopes at alluvial boundaries are often nearly level. Agricultural production is limited by fine textures, moderate water erosion hazard, and slow infiltration rates. Tillage and fertilization are needed for sustained production of crops. Alluvial soils are represented by site descriptions K26 and K27.

BE2- Gently and moderately sloping, deep, excessively drained, coarse-textured soils.

The dominant soils in this unit are moderately well-developed, fine and loamy fine sands on a gently rolling topography. A few areas of nearly level and moderately steep slopes are included in this unit. Minor soils are desert pavement and/or a deep, fine-textured soil located at some border areas.

This unit is used primarily for pasture and is well-vegetated. There are probably some minor cropped areas near villages. Erosion tends to be slight and localized areas of moderate or severe erosion are minor in extent.

This unit has an overall SC Suitability Rating for agriculture. The soils located on nearly level and gentle slopes should be given preference for agricultural fields. Millet is recommended over sorghum for these areas because of its ability to withstand droughty conditions. Limitations for agriculture are low rainfall, coarse textures, erosion hazard, and low fertility. Management should include fertilization and protection against wind erosion. Tillage may be required if soil crusting occurs.

Alluvial lands are fairly common, but they are narrow and usually gullied. Drainage density is coarse. The dominant soils are represented by Soil Profiles K14 and K7.

BE3- Gently sloping, deep, excessively drained, coarse-textured soils (70%) and gently sloping, deep, well-drained, moderately fine-textured soils with gravel (30%).

The dominant soils are coarse-textured, aeolian deposits with well- and moderately developed soil profiles. Soils of Component 2 are moderately fine-textured and have well-developed soil profiles. Component 1 includes moderately sloping areas. In a few places Component 1 exceeds the 70% composition. Component 2 includes some desert pavement and rocky ridges with gravel- to cobble-sized fragments. A shallow and very shallow cover of sands over soils of Component 2 is also included within its range. This unit differs from BU1 in order of dominant soils. These soils are used for pasture. Vegetation cover is poor to fair for Component 1 and poor for Component 2. Erosion is severe for the soils of Component 1.

These soils have an N1 Suitability Rating for cropland. Soils of Component 1 are limited by severe erosion hazard, coarse textures and low fertility. Soils of Component 2 are limited by slow permeability, coarse fragments, and irregular shapes (i.e., for soils without gravel).

Alluvial lands are rare. Two fairly large areas of moderately fine soil texture enter the Karakoro Oued from the east and the west just south of Kankossa. These soils have some potential for agriculture. Soils of Component 2 are represented by site description K6 and Profiles K9 and S18.

BE4- Moderately steep, deep, excessively drained, coarse-textured soils (65%) and gently sloping, deep, excessively drained, coarse-textured soils (35%).

The dominant soils are fine sands with little soil profile development and are formed in high transverse dunes. Soils of Component 2 are fine sands with moderate soil development found in gently sloping, well-pronounced interdunes. Component 1 includes some steep and moderately sloping sands. Component 2 includes some nearly level soils. A minor soil associated with Component 2 has fine textures and it is found in thalwegs (lowest points of a stream course).

Land use for both soils is pasture. A few areas of Component 2 are probably cropped. Component 1 has fair to poor vegetation cover, while Component 2 has good cover. Soils of Component 1 have been severely overgrazed and eroded, presumably because of their location near the Karakoro Oued and the easily accessible water. Component 2 has slight and moderate erosion.

Soils of Component 1 have an N1 Suitability Rating for cropland. They are limited for agriculture by slope, coarse texture, low fertility, and erosion hazard. Component 2 has an N1 Suitability Rating for cropland. It is limited for agriculture by coarse texture, low fertility, and erosion hazard. Soils of Component 2 appear to have a high seasonal watertable and they may have some potential for palm groves. Both components in this unit are limited by low rainfall.

Soils of Component 2 are represented by Soil Profile K15.

BE5– Steep, deep, excessively drained, coarse-textured soils (50-80%); and nearly level and gently sloping, deep, excessively drained, medium-textured and stony soils (20-50%) and steep, very shallow, excessively drained, lithic soils (0-20%).

The dominant soils are steep, fine sands found in zones of actively moving sands on the lee side of the Assaba. Component 2 consists of nearly level and gently sloping pediments. Component 3 is composed of steep rock outcrops. Component 2 includes some gentle slopes and in a few areas soils without an appreciable amount of coarse fragments. These lands are used for pasture, although vegetation is almost nonexistent. Limitations are steep, moving sands, gravelly or cobbly surface, and steep, rocky lands, respectively. This unit encompasses the active channels of moving sands as they descend off the Tagant and Assaba Plateaus.

The Suitability Rating for cropland is N1 for Component 1 and N2 for Components 2 and 3.

A few small springs are included in the unit. Alluvial lands are rare and consist of gravelly and cobbly soils.

BE6–Moderately sloping and moderately steep, deep, excessively drained, coarse-textured soils.

The dominant soils are fine sands formed in high, fixed longitudinal dunes. The typical soil catena consists of a steep crest with short, deep gullies in the shoulder slope position followed by moderately developed soils from the side slope to the slope bottom. A typical slope sequence from top to bottom has the following break-down: steep (10%),

moderately steep (60%), and moderately and gently sloping (30%), respectively. Most dune tops are moderately wide and moderately sloping. In the northern part of this unit, i.e., west and northwest of Kiffa, soils are somewhat less developed, but otherwise similar. Minor soils have moderately coarse or medium to fine textures found in some interdunal thalwegs (e.g., at Sani). This unit differs from unit BE2 by having steeper slopes and lesser soil development. Unit BE7 is found in association with this unit and it differs by being steep, having little or no soil development and sparse vegetative cover. BE18 differs by being somewhat less developed with shorter slopes, and by having well-defined interdunal areas. Unit BE10 is similar to this unit but has less soil development, more erosion, and a greater area of gentle slopes.

This unit is used for pasture land. Vegetative cover is good. Erosion is slight for the most part; however, some areas near villages are severely eroded. This soil unit has an overall N1 Suitability Rating for cropland. However, on gentle slopes where average rainfall exceeds 350 mm per year (2% of this unit) a CS Suitability Rating applies. The CS rating is solely dependent upon receiving the "normal" rainfall. Limitations for these zones are coarse textures, erosion hazard, and low fertility. Erosion protection and fertilization are recommended when these areas are farmed. Soil Profile K5 represents the moderately sloping component of this unit.

BE7-Moderately steep and steep, deep, excessively drained, coarse-textured soils.

The dominant soils are fine sands with no soil development and are located on erosional surfaces. These soils are found where winds converge upon higher rock outcrops and/or on the eastern face of the Assaba Plateau. Some lower slopes located in wind-protected positions have minimal soil development and are stable (20%).

These soils are used as pasture, but sparse vegetative cover and difficulties in accessibility are severe limitations. These soils have an N2 Suitability Rating for cropland.

Nearly level and gently sloping, deep, excessively drained, coarse-textured soils.

BE8-The dominant soils are fine sands with moderate to minimal soil development. These soils generally receive less than 350 mm of rainfall per year. Some moderately sloping soils are included, as well as, minor areas of rock outcrops and desert pavement, which includes a few areas of deep, fine-textured residual soils.

This unit is used for pasture. Vegetative cover is good and erosion is slight. This unit has an N1 Suitability Rating for cropland. Low annual precipitation is the major limiting factor; other limitations are coarse textures, erosion hazard, and low fertility. Alluvial lands are rare and drainage density is very coarse. This unit includes an ancient drainage channel east of the Tagant Plateau. The minor desert-pavement soil is represented by site description K20.

BE9—Moderately steep, deep, excessively drained, coarse-textured soils (70%) and gently sloping to steep, deep to very shallow, excessively drained, cobbly soils (30%).

The dominant soils are fine sands with little or no soil development formed in longitudinal dunes. Component 2 is a cobbly soil located in interdune positions. Component 1 is moderately sloping in places. Minor soils associated with Component 2 are nearly level, lithic soils; some areas of moderately steep, rocky ridges are also included.

These soils are used for pasture. Component 1 is poorly vegetated and severely eroded. Component 2 has a nearly bare surface. These soils have an N2 Suitability Rating for cropland. Steep slopes and cobbly surfaces are major limitations for Components 1 and 2, respectively. Component 1 has many areas of hard-crusted surfaces. Soils of Component 1 are represented by site description K2.

BE10-Moderately sloping, deep, excessively drained, coarse-textured soils (70%) and gently sloping, deep, excessively drained, coarse-textured soils (30%).

The dominant soils are fine sand with minimal soil-profile development located in broad, gently sloping areas. Component 1 has a catena similar to Unit BE6. This unit has neither the deep, short gullies, nor the moderately wide dune tops as described for Unit BE6, and it also has lesser soil-profile development. Moderately steep and steep slopes are included with Component 1. Component 2 includes some nearly level slopes. Component 2 is found for the most part in the northwest part of this unit, i.e., east of Boumdeit. A minor soil, which has formed in playas, is located east of Boumdeit.

This unit is used for pasture. Vegetation cover is fair for Component 1 and good for Component 2. Erosion is generally moderate for soils of Component 1; however, some significant areas of severe erosion exist to the south of Boumdeit. Component 2 has slight erosion.

These soils have an N1 Suitability Rating for cropland. Component 1 is limited by low annual rainfall, moderately steep slopes, coarse textures, severe erosion hazard, and low fertility. The major limitation for Component 2 is low annual rainfall. Alluvial lands are rare and drainage density is very coarse. An ancient waterway is included in this unit. Some small areas at the base of the Tagant Plateau have high water tables and/or receive additional runoff. Minor playa soils are represented by site description K18.

BE11-Nearly level and gently sloping, deep, excessively drained, coarse-textured soils (70%) and moderately steep, deep, excessively drained, coarse-textured soils (30%).

The dominant soils are fine sands with minimal soil-profile development found in broad, nearly level and gently sloping areas. Component

2 consists of fine sands with minimal soil-profile development located in moderately steep, isolated transverse dunes; some steep slopes are also included in the range of characteristics.

Land use is pasture with good vegetative cover for Component 1 and fair to good cover for Component 2. Erosion is slight and slight to moderate for the two components, respectively. These soils have an N1 Suitability Rating for cropland. Limitations are the same as those listed for unit BE10. Soils of Component 1 are represented by Soil Profile K19.

BE12– Moderately steep and steep, deep, excessively drained, coarse-textured soils (40%); moderately sloping, deep, excessively drained, coarse-textured soils (35%); and gently sloping, very shallow, excessively drained, stoney soils (25%).

The dominant soils are light-colored, fine sands with little or no soil-profile development located in alee positions near rock outcrops. These soils are located in a zone of actively moving sands. Component 2 consists of fine sands with minimal soil-profile development located adjacent to Component 1 in lee positions in stabilized zones. Component 3 is composed of cobbly soils formed in the lowest areas in this unit. Component 2 has a slope ranging from gently sloping to moderately steep. Component 3 includes some steeper rocky lands. These lands are used for pasture. Components 1 and 3 have nearly bare surfaces. Component 2 has a fair vegetative cover. Component 3 has moderate erosion. Components 1 and 3 have an N2 Suitability Rating for cropland. Component 2 has an N1 Suitability Rating, and its major limitation is low annual rainfall. A few zones of high water tables are located in this unit; these areas are generally used for palm groves. Encroachment of sand dunes in palm groves is a severe problem in several areas.

BE13– Moderately sloping and moderately steep, deep, excessively drained, coarse-textured soils (50%) and nearly level and gently sloping, deep, well-drained, medium textured soils (50%).

The dominant soils are fine sand with little or no soil-profile development and are located in sand dune stringers. Component 2 is a deep soil and it has a moderately well-developed soil profile. Component 1 includes nearly level and gently sloping areas of moderately deep sands over finer materials. Component 1 includes a shallow cover of sands. Soils of Component 2 are the same as the major soils of Unit BU5. Minor soils are desert pavement and moderately sloping rocky lands.

This unit is used for pasture. Soils are generally poorly vegetated; however, Component 1 has some areas of fair vegetative cover. These soils are found in a corridor of actively moving sands. The Suitability Rating for these soils is N1. The major limitation is its location in a zone of moving sands. Alluvial lands are common but narrow. Drainage density is medium. Some limited potential exists for water-spreading.

BE14– Moderately sloping and moderately steep, deep, excessively drained, coarse-textured soils.

The dominant soils in this unit are fine sands with little or no soil-profile development found in zones of moving sands. Some gently sloping soils and moderately deep sands over a medium-textured soil are included in this unit. Minor soils have a shallow cover of sands over medium-textured soils.

These lands are used for pasture. Vegetative cover is generally poor. Several flood-recession agricultural areas are found adjacent to this unit (i.e., Unit BA8). The dominant soils have an N1 Suitability Rating for cropland. The major limitation is low rainfall and severe erosion hazard. Alluvial lands are rare to common and generally narrow. Drainage density is coarse to medium.

BE15– Moderately sloping, deep, excessively drained, coarse-textured soils (60-90%) and nearly level and gently sloping, very shallow to gravel, well- and somewhat excessively drained, medium-textured soils with gravel (10-40%).

The dominant soils are coarse-textured with minimal to moderate soil-profile development; they have formed in longitudinal dunes. Component 2 is a gravelly and cobbly soil formed in Continental Terminal sediments. Component 1 includes some gently sloping soils. Soil-profile development of Component 1 decreases with distance to the north. Component 2 is the same as the major soils of unit BU6.

These lands are used for pasture. Some cropland is located in Component 1 near the Senegal River Valley. Vegetative cover is generally fair for Component 1. Component 2 has a poor vegetative cover. Soils of Component 1 are moderately to severely eroded with a hard soil crust (weak silica cementation) being common. Components 1 and 2 have an N1 and N2 Suitability Rating for cropland, respectively. Component 1 is limited by low rainfall, coarse textures, wind erosion hazard, low fertility, and soil crusting. The moderately well-developed soil of Component 1 is represented by Profile B8.

BE16– Gently sloping and moderately sloping, deep, excessively drained, coarse-textured soils (70%) and moderately sloping and moderately steep, deep, excessively drained, coarse-textured soils (30%).

The dominant soils are coarse-textured with minimal soil-profile development located in broad areas below steep dunes. Component 2 consists of fine sands with minimal soil-profile development located in longitudinal dunes. Component 1 includes a few areas of moderately sloping, interdunal soils. Soil-profile development is more advanced in the southern part of this unit. Minor soils include dark-colored, medium-textured, deep soils that are high in carbonates and moderately fine-textured soils similar to Component 2 in Unit C1E6. In the east-central part of this unit, microdepressions occur and these areas are similar to Unit BE21. The density of longitudinal dunes increases with distance to the west and south in this unit.

These soils are used predominantly for pasture. Vegetative cover is generally fair. On the southern end of this unit the cropland area varies from year-to-year depending on rainfall. Erosion is moderate and severe for these soils. Numerous wells are found in interdunal positions in the northern part of this unit.

These soils have an N1 Suitability Rating for cropland. Limitations are low rainfall, severe erosion hazard, coarse textures, and low fertility.

Component 1 is represented by Soil Profile B3--this profile has lesser development than the soils in the southern part of this unit. A minor calcareous soil is represented by site B9.

BE17- Gently sloping, deep, excessively drained, coarse-textured soils.

The dominant soils are deep, strongly acid, fine sands. These soils have a well-developed soil profile. Some nearly level slopes also occur in this unit. Minor soils are shallow sands over finer materials with gravel. These soils are similar to Component 1 of Unit AE2, but they differ by being in another soil-climate zone and by not including any residual soils.

This unit is used for pasture; although some minor areas of cropland probably exist near villages. Vegetative cover is good and erosion is generally slight with a few areas of moderate to severe erosion occurring near villages.

These soils have an SC Suitability Rating for cropland. Low rainfall and coarse textures are major limiting factors for agriculture. Millet varieties are recommended over sorghum for this unit. These soils are well-suited to pasture.

BE18- Moderately sloping and moderately steep, deep, excessively drained, coarse-textured soils (75%) and nearly level and gently sloping, deep, somewhat excessively and excessively drained, coarse- and moderately coarse-textured soils (25%).

The dominant soils, which have formed in longitudinal dunes, are fine sands with minimal soil-profile development. Component 2 is coarse- to moderately coarse-textured and it is found in well defined, moderately narrow interdunes. Component 1 includes some dune tops which are gently sloping. Minor soils are medium-textured lands (fine sandy loams) and fine-textured, saline lands; both are found in interdunal positions.

Pasture is the usual land use but minor cropped areas exist near some villages. Vegetative cover is generally fair to good. Light-colored tones on the Landsat mosaic indicate zones of active erosion. Erosion is slight to moderate for nearly all of this unit.

The Suitability Rating is N1 for the major soils of this unit. Low rainfall is the major limitation. Component 2 is represented by Soil Profile B13 and the medium-textured, minor soil is represented by Profile B12.

BE19-Moderately sloping, deep, excessively drained, coarse-textured soils (50-70%) and nearly level, deep, somewhat poorly and poorly drained, moderately fine- and fine-textured soils (30-50%).

The dominant soils, which have formed in longitudinal dunes, are fine sands with minimal soil-profile development. Component 2 is a moderately fine- and fine-textured soil located in interdunal positions (deltaic deposits) that are flooded in most years. Component 1 includes some moderately sloping areas. Soil drainage for Component 2 ranges from moderately well to very poorly drained. Salinity increases with distance to the north toward Lake R'Kiz. Minor soils associated with Component 2 are moderately well-drained, coarse and moderately coarse-textured soils over finer materials.

Component 1 is primarily used for pasture with some minor areas being used for dryland agriculture. Component 2 is used for flood-recessional agriculture and pasture. Vegetative cover is poor and fair for Component 1, and erosion is moderate to severe. Component 2 has fair vegetative cover and erosion consists of gullying in some thalwegs. Component 1 has an N1 Suitability Rating for cropland. The major limitation for these soils is low rainfall. Component 2 has an S2 Suitability Rating for recessional cropland. These soils are limited by fine textures (vertisolic tendencies), slow permeability, and flooding hazard after crops are planted. Recommended management should include fertilization and tillage. Sorghum is the major crop on these lands. Utilization of draft animals may be suitable to increase the efficiency of labor and therefore, in good years, the hectarage planted. Soil bunds (contour dikes) may provide a means of extending flood waters onto higher sites. Component 2 is represented by site description B16. Minor soils are described by site descriptions B11 and B15.

BE20- Moderately sloping and moderately steep, deep, excessively drained, coarse-textured soils (75%) and nearly level and gently sloping, deep, somewhat poorly and poorly drained, moderately fine- and fine-textured soils (25%).

The dominant soils are fine sands with minimal soil-profile development located in transverse dunes. Component 2 consists of moderately fine- and fine-textured, saline soils located in interdunal positions. Component 1 includes some gently sloping areas and a few areas of moderately deep sands over fine-textured materials. Component 2 includes a shallow covering of sands. Minor soils consist of sebhkas.

These lands are used for pasture. Component 1 has a fair to good vegetative cover. Component 2 has an overall poor vegetative cover; although the cover is fair in areas where a thin mantle of sand occurs. Erosion is moderate for Component 1. Severe erosion has taken place near villages and wells and in a corridor paralleling the Nouakchatt-Rosso highway. These soils have an N1 Suitability Rating for cropland. The major limitation is low annual rainfall. Component 2 is also limited by having slow permeability. The major soils are represented by site description R1 and R2, respectively.

BE21- Gently and moderately sloping, deep, excessively drained, coarse-textured soils.

The dominant soils are deep and moderately acid to slightly acid, and they have a minimally to moderately developed soil profile. This unit is composed of wind-blown sands underlain by soils formed in soft sandstones and/or conglomerates of the Teritary age. Narrow, sinuous, slightly concave areas are included with the dominant soils (10%). Minor soils consist of residual soils formed in sandstones with or without a very shallow or shallow cover of aeolian sands. Some areas of gravel and deposits of the Continental Terminal occur at the southern and eastern edges of this unit.

The land use is pasture and erosion is moderate to severe. Some cropland exists along the Senegal River Valley. Vegetative cover is fair to poor with the slightly concave sites having good cover. Soil crusting occurs in eroded areas. This soil has an N1 Suitability Rating for cropland. The major limitation is low rainfall. Alluvial areas are rare and drainage density is very coarse. An ancient waterway is located in the northwest part of this unit; ferruginous rocks, which have been exposed through the down-cutting of a river, mark the edges of this water course.

BE22-Moderately sloping, deep, excessively drained, coarse-textured soils.

The dominant soils in this minor unit are coastal dunes and other dunes located in the Senegal River delta. Minor soils are saline, fine-textured materials occurring in a few interdunal positions. This unit is used for pasture. Erosion is slight to moderate. Vegetative cover is fair to good. These soils have an N1 Suitability Rating for cropland. The major limitation is low rainfall. Brief site description R6 represents this unit.

Lithic Soils (L)

These soils occur in the eastern one-half of Soil Region B and occupy 22.8% of this area (Figure 3-9). This grouping includes a wide variety of rock types and geologic ages. Common rocks are quartzites, micaschists, granites, and sandstones. The range of geologic age is from the Pre-Cambrian to the Devonian period; a number of the geologic series have indeterminate age. The Assaba and Tagant Plateaus and the rocky lands of the Affole constitute the majority of this landform grouping. Lithic soils are generally very shallow to bedrock and excessively drained. Minor landforms included within this grouping are aeolian sands, desert pavement, and alluvial lands. Soils formed in place or in colluvium are rare in this landform group since most areas are subject to deflation. Drainage density in this group is generally very coarse. Pasture is the predominant use of these lands. Inaccessibility is often a problem for utilization of pasture lands.

Fig. 3-9. Lithic soils in Soil Region B are illustrated by a gently sloping area 14 km northwest of M'Bout (above) and outliers at the southern tip of the Assaba Plateau (below).

BL1- Moderately sloping, very shallow, excessively drained, lithic soils (50%) and gently sloping, deep, well-drained, medium- and moderately fine-textured soils with gravel (50%).

The dominant soils are stony and very shallow to rock. Component 2 consists of deep, well-developed soils with gravel. Component 1 includes some gently sloping areas. Micaschists are the dominant parent rocks associated with Component 1. Component 2 includes some gently sloping areas. Component 2 includes some nearly level areas. Gravelly zones are estimated to constitute 40% of Component 2. Minor soils (10%) are aeolian sands which have been deposited on the lee side of the Oua Oua ridges.

These lands are used for pasture. Vegetative cover is poor. Wind erosion is a severe problem for the above-listed minor soils. Component 2 has undergone severe water erosion near alluvial courses.

Component 1 has an N2 Suitability Rating for agriculture. Component 2 has an N1 Suitability Rating. Soils of Component 2 are limited by gravelly zones, slow permeability, and erosion hazard.

Alluvial lands are common and drainage density is medium to fine. Secondary drainageways generally have moderately sloping banks, while primary alluvial zones are sufficiently wide to be mapped (Unit BA4). Component 1 is represented by site description C12.

BL2- Steep, very shallow, excessively drained, lithic soils.

The dominant soils are very shallow to bedrock and they have formed in short, steep ridges. Quartzitic rocks are the principal parent material. Some less sloping ridges and interridges are also included. Minor soils consist of stony pediments.

These lands are used for pasture, but vegetative cover is poor. The Suitability Rating for cropland is N2.

BL3- Gently sloping to steep, very shallow, excessively drained lithic soils.

The dominant soils in this large unit are very shallow or shallow to bedrock (sandstones and quartzites). This unit includes all of the Assaba Plateau and the southern one-half of the Tagant Plateau. Stony areas are included in the range of characteristics of this unit. Minor soils include very shallow to deep aeolian sands and soils formed in colluvial slopes (more common in the Assaba Plateau).

The dominant use of these lands is pasture--accessibility is often a problem. Some minor areas of cropland probably exist near alluvial zones and on a few gentle slopes. This unit is generally windswept, i.e., a zone of deflation. Erosion is slight for the dominant soils and slight to severe for the minor soils, depending upon the landscape position and protection from winds. Vegetative cover is poor to fair. The dominant soils have an N2 Suitability Rating for cropland. Minor soils in the

southern part of the Assaba have an N1 rating although there may be some SC areas where slopes are gentle and rainfall exceeds 350 mm.

Alluvial lands are rare. Drainage density is coarse for the unit as a whole, but some zones have a medium density. Numerous faults and fractures exist in this unit and soil moisture and/or water is often available in these zones. The soils of the Tagant Plateau have been previously characterized (INSTRUPA, 1979).

BL4- Gently sloping to steep, very shallow, excessively drained, lithic soils (85%) and gently sloping, deep, somewhat excessively drained, moderately coarse- and coarse-textured soils (15%).

The dominant soils are very shallow, excessively drained, hard sandstones of the Follé geologic series. Component 2 consists of deep soils formed in colluvium; soil development in this component diminishes from south to north. Minor soils are coarse-textured and shallow to moderately deep to bedrock.

Pasture is the major use of the land. Some agriculture occurs in the southern part of this unit. Vegetative cover is poor to fair for Component 1 and fair for Component 2, which has slight to severe erosion. The Suitability for cropland is N2 for Component 1 and N1 for Component 2. Some soils of the southern one-fourth of the area have an SC rating (0.5% of the area). Limitations are coarse textures, erosion hazard, and low fertility. Management should include fertilization and protection against wind erosion. Millet is the recommended crop for the SC-rated soils.

Alluvial lands exist throughout this unit. Secondary drainageways are generally narrow and rocky. The larger alluvial zones are usually associated with Component 2, and they have fair to good agricultural potential.

Component 2 is represented by Profile C2 and is located in the southern area of this component.

BL5- Nearly level to steep, very shallow, excessively drained, lithic soils (60-80%) and gently and moderately sloping, deep, excessively drained, coarse-textured soils (20-40%).

The dominant soils occur on sandstone plateaus of varying slopes. Component 2 is coarse-textured with minimal soil-profile development; it consists of both aeolian sands and sandy residual soils. Component 1 includes some areas with a shallow cover of aeolian sands. Component 2 includes some areas of moderately deep sands over rock.

This unit is used for pasture. Vegetative cover for Component 1 is poor and for Component 2 is poor to fair. Erosion is moderate and severe for Component 2. Suitability Ratings are N2 for Component 1 and N1 for Component 2. Major limitations are low annual precipitation and rocky lands.

A few drainageways begin at the base of escarpments where there is additional runoff; these areas have some potential for recessional and/or dryland agriculture.

Desert Pavement or Pediments (P)

These soils occur throughout the eastern two-thirds of Soil Region B (Fig. 3-10). This landform group makes up 10.9% of this region. The majority of the soils included in this unit are located in the central part of the project area. Several prominent geologic provinces make up this group, namely, the M'Bout Series, Selibaby Series, and Letfata Series. Rock types are generally micaschists and granites. Soil profiles range from minimally to moderately developed. Surface coarse fragments are generally abundant and range in size from gravelly to cobbly and bouldery. Surface slopes are nearly level with minor areas of gentle slopes. Soil textures are medium- and moderately-fine. Other landforms included with this grouping are uplands, aeolian sands, and alluvial lands.

These soils are commonly used for pasture, although, vegetative cover is usually poor. This landform group includes or is associated with the majority of the "upland" flood-recessional areas (i.e., away from the confluences of major oueds with the Senegal River Valley). Sorghum is the dominant crop in these zones.

BP1- Nearly level and gently sloping, deep, excessively drained, stony soils (50%) and gently sloping, deep, somewhat excessively and excessively drained, coarse- and moderately coarse-textured soils (50%).

The dominant soils have a nearly continuous surface of cobbles and boulders. The soil fraction less than 2 mm in diameter is moderately fine. Component 2 is coarse-textured with minimal soil-profile development. A slaty cover is included within the range of Component 1. Component 2 consists of aeolian sands and moderately coarse- or coarse-textured soils that have formed in place. Moderately sloping areas are included within the range of Component 2.

Pasture is the dominant land use. At least one area of palm trees exists in this unit. Erosion is severe for Component 2. Vegetative cover is poor for Component 1 and poor to fair for Component 2. Component 1 has an N2 Suitability Rating for cropland. Component 2 has an N1 Suitability Rating; limitations are severe erosion, surface crusting, erosion hazard, coarse textures, and low fertility.

Alluvial lands are common and drainage density is medium. In the southern-most mapped unit, drainageways are often stony. In the unit that is mapped farther to the north a zone of fine-textured, heavily wooded (Acacia seyal) soils occur in association with alluvial lands (site description K4).

BP2- Nearly level and gently sloping, deep, well-drained, medium-textured soils with gravel or stones.

The dominant soil in this large unit has moderate profile development and a covering of desert pavement. Moderately fine-textured soils are included in this unit, as well as soils without gravel or stones. Some areas are covered with thin sands. A few rocky ridges are located south of Sangarafa.

Figure 3-10. Pediments or reg are illustrated by photos 20 km southwest of Magta Lahjar (above) and at the Letfata airport (below). Acacia flava is the dominant species in the above illustration; light and dark colors are differing gravel types. The illustration below is less gravelly; however, gravelly fragments are emphasized by their impediment to sand movement. The large ridge on the horizon is the beginning of a vast stretch of sand dunes (note: the object in left side of this ground photo is a wind sock).

The major use is pasture, but numerous small areas of traditional, recessional agriculture are located here. Vegetative cover is very poor to poor. This is a windswept zone.

The land suitability for cropland is N1. Alluvial lands are common and the drainage density is medium. These soils are fertile and the potential, in general, for recessional agriculture is fair to good.

A moderately fine-textured soil variant is represented by Soil Profile C1. Three soil investigations of this zone have been completed (SONADER, 1981; Gavaud, 1960; INSTRUPA, 1979).

BP3– Nearly level and gently sloping, deep, excessively drained, gravelly and stony soils (35%); gently sloping, deep, somewhat excessively and excessively drained, moderately coarse- and coarse-textured soils (35%); and moderately steep, very shallow, excessively drained, lithic soils (30%).

The dominant soils are dark-colored desert pavements. Component 2 consists of aeolian sands with minimal soil-profile development. Component 3 consists of rocky and stony lands. Component 1 commonly has a surface covering of very coarse sand or gravel; cobbly, nearly level soils are included within the range of properties. Component 2 includes moderately sloping lands and some moderately coarse-textured soils formed in colluvium. In a few places Component 2 is the dominant unit. Minor soils associated with Component 1 are gravel- and stone-free lands.

The major use of these lands is pasture. Erosion is moderate to severe for Component 2. Vegetative cover is poor for Component 1 and 3 and poor to fair for Component 2. Suitability Ratings for cropland are N1 for the dominant soils and for Component 2 and N2 for Component 3. The major limitation for cropland is low rainfall for the nonlithic and nongravelly soils of this unit.

Alluvial lands are rare in this unit, but there are several temporary lakes. These areas offer some agricultured potential for recessional agriculture and good potential for palm groves. Detailed ground water surveys should be undertaken in these areas to assess the potentials.

Component 1 is represented by K20, K21, and K22. Minor soils associated with Component 1 are represented by site description K1.

BP4– Moderately sloping, deep, excessively drained, stony and gravelly soils (50%) and nearly level and gently sloping, deep, well-drained, medium- and moderately fine-textured soils (50%).

The dominant soils are dark-colored, gravelly and stony lands. Component 2 is similar to the Component 2 in Unit BE13. Nearly level and gently sloping gravelly lands are included with Component 1. Most areas of Component 2 have a shallow cover of sand. Minor soils are moderately deep and deep aeolian sands.

This unit is used for pasture. Vegetative cover is very poor for Component 1 and poor for Component 2. This area is windswept and it is in a zone where sands are moving. Suitabilities for cropland are N2

and N1 for Components 1 and 2, respectively. Alluvial lands are coarsely spaced and they provide fair to good vegetation for pasture. Some potential exists for flood-recessional agriculture in these areas.

Several soil profiles have been previously described for this unit (SONADER, 1981).

BP5– Nearly level and gently sloping, deep, well-drained, medium- and moderately fine-textured soils with gravel.

The major soils are deep, gravelly lands. This unit is similar to Component 1 of Unit AU1, but it differs by being in a different soil climate zone and having lesser areas of coarse or moderately coarse textures. The major soils have significant gravelly zones at the surface or within 50 cm of depth. Minor soils are gravel-free zones and a very shallow to moderately deep cover of aeolian sands. The former minor soil occurs at the boundary between this unit and Unit BE17.

Land use is pasture and vegetative cover is poor. Erosion is moderate and soil crusts are common. These soils have an N1 Suitability Rating for cropland. Major limitations are low rainfall, gravel, and slow permeability.

Alluvial zones are common and drainage density is medium to fine. Alluvial areas are usually narrow and have gently or moderately sloping banks. Gullying is common and the channels are generally well-incised.

Uplands, Undifferentiated (U)

These landforms occur throughout the eastern two-thirds of this Soil Region B and make up 18.5% of this zone (Fig. 3-11). The landforms included in this generalized grouping are nearly level to sloping plains, stony plateaus, dissected and nondissected plains, and plains with micro-depressions. Geology includes the M'Bout Series, Selibaby Series, Continental Terminal, and several formations of Tertiary age. Sandstones, ferruginous rocks, clayey sandstones, conglomerates, schists and micaschists are some of the common parent rocks. Slopes are generally nearly level to gently sloping. Soil textures range from sands to clay loams (i.e., coarse to moderately fine). The coarse-textured soils generally have deeper soil profiles than the fine-textured areas. Soil development has been limited in some areas by dense zones of gravels and cobbles. Lithic soils and desert pavements are sometimes included with or associated with these landforms.

Land use is generally pasture. Cropland exists near the Senegal River Valley in the coarser sediments and in narrow alluvial zones where recessional agriculture is practiced.

BU1– Nearly level and gently sloping, deep, well-drained, medium- and moderately coarse-textured soils (60-80%) and gently sloping, very shallow, excessively drained, lithic soils (20-40%).

The dominant soils are severely eroded and moderately acid. Component 2 consists of rock outcrops and stony lands. Component 1, which is similar

Fig. 3-11. Uplands in Soil Region B are dominated by heavy textured soils with little ground cover (above). Other minor areas are more productive and have coarser soil textures (below). The above illustration is a ground photo of an area located approximately 20 km south of Aleg. Patches of gravel are common and a dune stringer is visible on the horizon. The illustration below is located about 20 km northwest of Maghama in area of excellent grass and tree cover.

to Component 1 of Unit BU10, includes a shallow cover of sands in most places. Minor soils associated with Component 2 are gravelly and cobbly lands. This unit is similar to Unit BE3,but it contains less aeolian sand cover.

These soils are used for pasture. Vegetative cover is poor to fair and very poor, respectively, for Components 1 and 2. Component 1 is severely eroded in most places. Component 1 has an N1 Suitability Rating for cropland, and Component 2 has an N2 rating. Component 1 is limited by severe erosion, surface crusting (poor soil physical condition) and severe erosion hazard. Alluvial lands are rare to common, and they are generally severely gullied and easily eroded.

BU2– Nearly level, deep, well-drained, medium-textured soils with gravel.

The dominant soils are medium-textured with moderate soil profile development. Gently sloping areas and moderately fine textures are included within the range of the dominant soils. Minor areas of gravel or a shallow cover of sand are scattered throughout this unit.

The dominant land use is pasture. Vegetative cover is poor and severe gullying has taken place throughout this unit. The Suitability Rating for cropland is N1. Limitations are erosion hazard, slow permeability, and a tendency toward surface crusting. Runoff is high in this unit.

Alluvial lands are very common and drainage density is medium to fine. Alluvial areas are generally moderately wide (25-50m). A good potential exists for small dams and recessional agriculture. However, these lands are susceptible to water erosion and careful planning must be involved in site selection and in eventual management of recession-agricultural use.

BU3– Gently sloping, deep, excessively and somewhat excessively drained, coarse- and moderately coarse-textured soils.

The dominant soils in this unit are coarse- or moderately coarse-textured with minimal to moderate soil-profile development. In places these soils are covered by shallow aeolian sands or have a wind-reworked surface. Minor areas of rock outcrops exist in this unit. These soils are very similar to unit BE8, but they differ by having greater soil development and by being in a different major landform group.

Land use is generally pasture. Vegetative cover is good and erosion is slight. These soils have an N1 Suitability Rating for agriculture. The major limitation is lack of rainfall.

Alluvial lands are fairly common. Drainage density is low to medium. Alluvial zones offer fair potential for agriculture and good potential for palm groves. There are several temporary lakes in this unit, which indicates that groundwater may be close to the surface. Potential for irrigation should be investigated in this unit.

BU4– Nearly level and gently sloping, deep, excessively and somewhat excessively drained, coarse- and moderately coarse-textured soils (80%) and gently sloping to steep, very shallow, excessively drained, lithic soils (20%).

The dominant soils are strongly acid and have a well-developed soil profile. These soils have formed in soft sandstone and coarse-textured conglomerates of the Tertiary period. Component 2 consists of rocky ferruginous plateaus and buttes. Some aeolian sands are included with Component 1.

The major land use is pasture. Some agriculture use (millet) occurs in area of Hadad and along the Senegal River Valley. Component 1 has a good vegetative cover and Component 2 has poor to fair cover. Erosion is slight for Component 1; however, some minor areas of moderate and severe erosion occur in overgrazed zones. The suitability for cropland is SC for Component 1 and N2 for Component 2. Limitations for Component 1 are low annual rainfall, coarse textures, strongly acid reaction and low fertility. Management should include fertilization and protection from erosion. Millet is the recommended crop (these soils are probably too acidic for sorghum production). Component 1 is represented by soil profile S11.

BU5– Gently sloping, deep, well-drained, medium-textured soils with gravel (50%) and gently and moderately sloping, deep, excessively drained, coarse-textured over medium-textured soil (50%).

The dominant soils of this unit are the same as those of Unit BU2; the unit differs by having a second soil. Component 2 consists of shallow and moderately deep aeolian sands over finer materials. Component 1 includes some gravelly areas, moderate slopes and a thin cover of sands. Component 2 includes some deep sands over an underlying, heavier soil.

The major use of this area is pasture. Some cropland exists in the wider oueds. Erosion is moderate to severe for Component 2. Vegetative cover is poor for Component 1 and poor to fair for Component 2. Suitability for cropland is N1 for these soils. Low rainfall is the major limitation for cropland for both components, as well as slow permeability for Component 1. Alluvial lands are common and they are similar to these alluvial lands described in Unit BU2.

BU6– Gently and moderately sloping, deep, excessively and somewhat excessively drained, moderately coarse- and coarse-textured soils (70%) and and gently sloping to steep, very shallow, excessively drained, lithic soils (30%).

The dominant soils are strongly acid and have well-developed soil profiles. Component 2 consists of rocky plateaus and buttes. Some nearly level and medium-textured areas (sandy loams) are included within the range of Component 1. A few gravelly and cobbly areas are included with Component 2. The geology for these soils is the same as that for Unit BU4. This unit differs from Unit BU4 in slope, composition, and erosion. The topography consists of gently rolling lands with short slopes. Alluvial lands are considered as minor soils (10%) in this unit.

These soils are used for pasture. Some cropland is located along the Senegal River Valley. Vegetative cover is fair. Erosion ranges from slight to severe for Component 1. In the northern part of this unit severe wind erosion has taken place, and through the middle of the unit moderate to severe wind and water erosion has occurred.

Component 1 has an N1 Suitability rating for cropland, and Component 2 has an N2 rating. Some nearly level and gently sloping areas in the southern part of this unit have an SC rating for cropland (5% of Component 1). Erosion protection and fertility programs are recommended for the SC soil. Component 1 is limited by erosion, erosion hazard, textures, low fertility and strongly acid reaction. These soils are best-suited for pasture.

Alluvial lands are common to plentiful in this unit. The drainage density is medium. The alluvial zones are generally narrow and gullied; however, these areas provide good pasture. Component 1 is represented by profile S10.

BU7– Nearly level, very shallow to gravel, somewhat excessively and well-drained, moderately coarse- and medium-textured soils (75%) and steep, very shallow, excessively drained, lithic soils (25%).

The dominant soils are shallow or very shallow to a dense zone of ferruginous gravels. Component 2 consists of bare, ferruginous rock located at the perimeters of this unit. The soils of Component 1 have formed in sediments of the Continental Terminal. Rectilinear slopes with scattered areas of circular, concave areas (10%) constitute the setting for Component 1. The small concave sites are shallow to gravel.

The dominant land use is pasture. Vegetative cover varies from poor to fair from north to south. Numerous areas of dead trees exist in this unit. The concave sites have good vegetative cover. The land Suitability Rating for these soils is N2; the major limitation is depth to gravel and bare rock. Component 1 is represented by site descriptions S5 in the north (near Mal) and S9 in the south (near Monguel).

BU8– Gently and moderately sloping, deep, somewhat excessively and excessively drained, moderately coarse- and coarse-textured soils.

The dominant soils in this unit are slightly acid to neutral and have moderately well-developed soil profiles. These soils are similar to units BU4 and BU6 in geology. Aeolian sands are common along the eastern edges of this unit. Minor soils are the steep, ferruginous outliers described in Unit BU7. The dominant soils have formed on long, simple slopes. Soil textures range from fine sand to fine sandy loam. Soil profile development decreases with distance to the north.

The land use is pasture. Vegetative cover is poor to fair. Erosion is severe to moderate. Numerous crusted areas exist in eroded zones (weak silica cementation of wind-deposited sands). Suitability Rating for cropland is N1. These soils are limited by low rainfall and erosion hazard. Alluvial zones are rare and the drainage density is coarse. Several associated alluvial zones, which are mapped, are described in Unit BA7.

BU9– Nearly level to gently sloping, very shallow and shallow to gravel, well- and somewhat excessively drained, medium-textured soils.

The dominant soil in this unit has a dense surface and it is shallow to gravel. The major soil of this unit is similar to Component 1 of

Unit BU7. Included with the dominant soil are slightly concave sites, which are shallow to gravel; these areas comprise approximately 15% of this unit. Minor soils (15%) include surficial gravels and thin to moderately deep, eroded sands over fine materials.

These lands are used for pasture, and they have a poor cover of vegetation when very shallow to gravel and a fair to good cover when shallow to gravel, i.e., in concave sites. Aeolian sands have accumulated where vegetative cover is fair or good. The Suitability Rating for cropland is N2 for these soils. The major limitation is depth to gravel and low annual rainfall. The concave sites in this unit are represented by soil profile B6.

BU10– Gently and moderately sloping, deep, well-drained, coarse- and moderately coarse-textured soils (60%) and gently and moderately sloping, very shallow, excessively drained, gravelly and stony soils (40%).

The dominant soils are severely eroded, moderately-coarse and coarse-textured lands with moderately to slightly acid reaction. Component 2 consists of gravelly zones and rocky ridges. Minor soils associated with Component 1 are well-vegetated, deep, coarse-textured aeolian deposits (10%). Associated with the gravelly component of soil 2 are minor, desert pavement soils (10%) that contain little gravel but have a dense soil surface and little vegetative cover.

Component 1 is used predominantly for pasture; although some limited areas of cropland exist on nearly level slopes near villages. The soils are poorly vegetated, but some zones of good vegetation exist near the plateaus on the eastern end of the unit. Soils of Component 2 are used for pasture. They generally produce little vegetation. There are some well-fractured rocks near the Karakora Oued; these areas have good stands of trees and grasses. Component 1 has an overall N1 suitability rating for cropland. Soils on gentle slopes have an SC Suitability Rating for agriculture (10% of this component). The SC areas are limited by low rainfall, coarse textures, severe erosion hazard, and low fertility. Erosion protection and fertility programs are recommended for SC-rated soils.

Component 2 has an N2 Suitability Rating for cropland; it is limited by soil depth. Alluvial lands are common through the center of this unit. These lands are limited by susceptibility to gullying and by a very hard surface consistence. These soils have moderate potential for agriculture. Utilization of these lands would require erosion stabilization programs. Other alluvial lands, which are located in the eastern part of this unit, occur less frequently; but they have a good potential for agriculture. Component 1 is represented by Soil Profile K11 while Component 2 is typified by site descriptions K10 and K13.

Alluvial Lands (A)

These soils occur throughout the Soil Zone B; however, they are mapped primarily through the middle of this area (Fig. 3-12). The lands make-up 8.2% of this climatic zone. Almost all the major oueds are included in this landform grouping; the Niordé Oued and part of the

Fig. 3-12. Alluvial soils in Soil Region B are generally heavy textured as noted by the vertisolic nature of the Oued Ketchi (above). The annual floodwaters of the Senegal River supply soil moisture for the crops of Lake R'Kiz (below). Soil cracking and microrelief are illustrated in the above photo, which was taken 30 km southwest of Magta Lahjar. The photo below is a low-altitude picture taken on the northeast edge of Lake R'Kiz in early January; the sorghum crop forms a distinct boundary with the nonvegetated, surrounding plain.

Karakoro Oued are in Soil-Climate Zone A. Most of these soils have formed in recent alluvial deposits. Other minor areas are older alluvium, marine deposits, and deltaic deposits. These minor soils are located along the coast, north of Lake R'Kiz, and west of Lake d'Aleg. Some alluvial zones were formed under wetter climates and these areas are not normally flooded. Soil textures range from coarse to fine, and soil drainage varies from very poorly to excessively drained. Other landforms included with this unit are nearly level uplands and aeolian sands. Land use is divided among pasture, flood-recessional and dryland agriculture. Annual flooding occurs in many alluvial units and its extent is critical to yearly crop production (Fig. 3-13). Several zones behind modern dams are included within this grouping. These areas are utilized almost totally for recessional agriculture. These lands are very fertile and their fertility is replenished annually by alluvially deposited sediment.

BA1,2,3– Nearly level, deep, very poorly to well-drained, moderately coarse- to fine-textured soils.

These units encompass the Senegal River Valley. The separation into three units is based on floodplain elevations (i.e., likelihood of annual flooding) and salinity (Unit BA3). Soils of BA1 are dominated by lands that receive annual flooding (60%); the secondary soils (40%) are levees, point bars, splays, and the higher floodbasin deposits of an earlier pluvial period.

Soils of Unit BA2 are similar to Unit BA1, but the dominant and secondary soils are reversed. Some areas of high soil salinity occur at the western edge of this unit.

Soils of Unit BA3 are deposits of a deltaic plain. Soil salinity is high in these soils. These three units are more thoroughly characterized in a 1:50,000 map (PNUD, 1977), in another Landsat-based investigation (Boyadgiev, 1978), and in numerous site-specific studies (e.g., Durand, 1974). Unit AA1 (Soil-Climate Zone A) also contains applicable soil descriptions.

Suitability Ratings for cropland are as follows by major and secondary soils: Unit BA1, S2 and N1; Unit BA2, N1 and S2; and Unit BA3, N1. The likelihood of flooding and high watertables are the most important features of these soils. Dryland agriculture is severely limited by the progressively lower rainfall from southeast to northwest. Irrigation and other potentials are detailed in several of the above reports. Brief sites descriptions R3 and R4 typify Unit BA2, while R5 represents Unit BA3.

BA4– Nearly level, deep, somewhat poorly and moderately well-drained, moderately fine- and fine-textured soils.

The dominant soils (60%) in this unit are flooded for variable time-periods in most years. However, the soils of secondary drainageways (40%), which are also included in this unit, are rarely flooded. This unit includes the Gorgol Noir, Gorgol Blanc, and the Oued Garfa. Minor soils include nearly level, deep, medium- and moderately fine-textured uplands. A thin cover of aeolian sands occurs where these soils extend into the northern part of the project area.

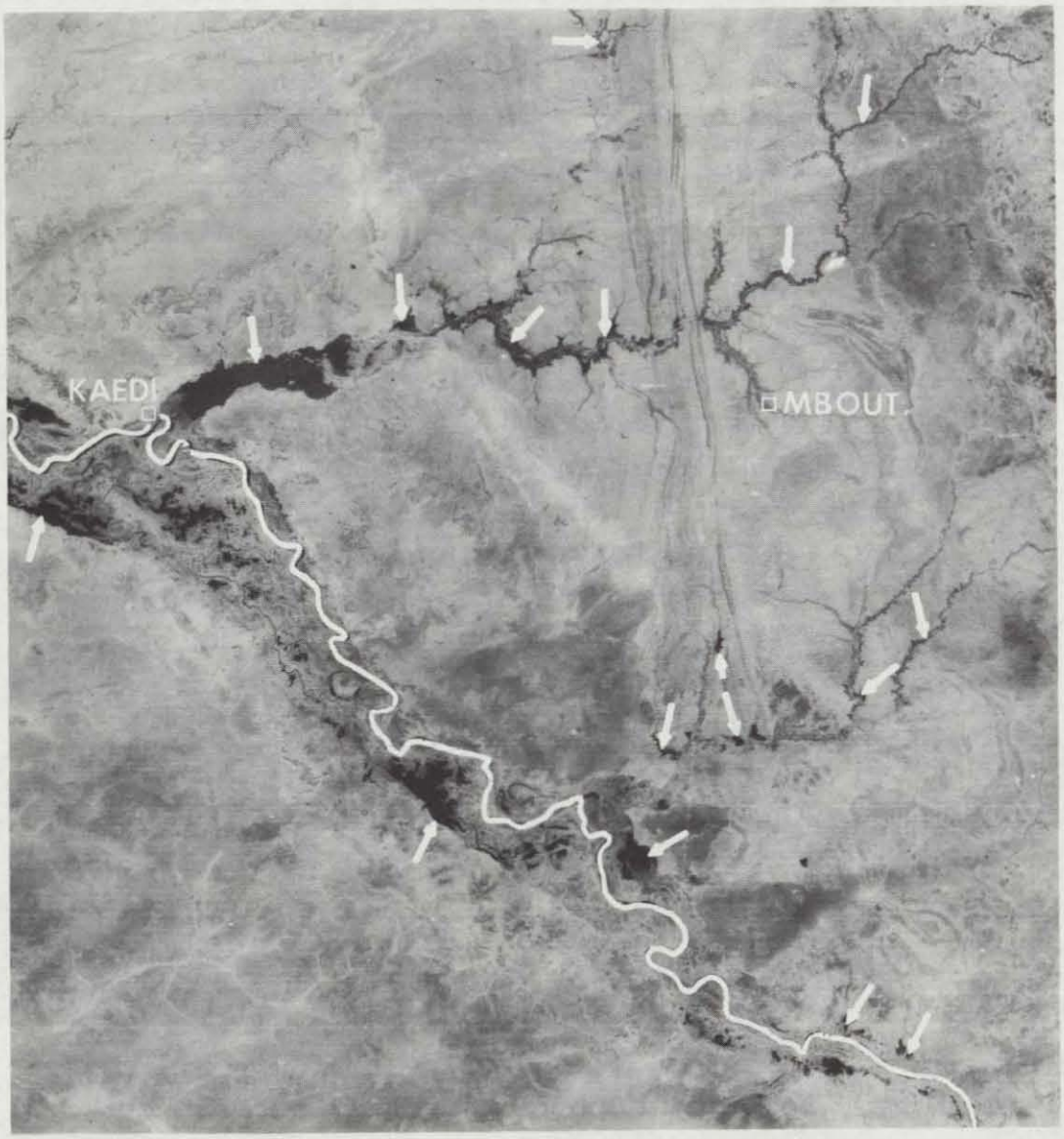


Fig. 3-13. Near-infrared Landsat image (band 7) shows the variable extent of flooding in the southern area of the Gorgol Region. Arrows indicate some of the many areas of standing water. (September 1978)

These soils are used predominately for pasture. However, noteworthy areas of both dryland and recessional agriculture are also located in this unit. Completion of construction of a dam at Foum Gleita will substantially increase the cropland in this unit. Vegetative cover is good and annual floodwaters provide temporary watering holes for livestock. These soils have an S2 Suitability Rating for recessional agriculture. Low rainfall precludes consistent production from dryland agriculture. Several sites in this unit have been characterized in a recent study (SONADER, 1981).

BA5- Nearly level and gently sloping, deep, somewhat excessively drained, coarse- and moderately coarse-textured soils.

The dominant soils in this unit are sands with minimal to moderate soil-profile development. This unit is mapped within the drainage channel of the Karakoro Oued. Minor soils are moderately fine-textured and located near thalwegs. These soils have been water- and wind-deposited. In a few places watertables are close enough to the surface to support palm trees. A minor area of rock outcrops is located just north of Kankossa.

This unit is used for pasture. Erosion is moderate and vegetative cover is fair to good. Overgrazing is a severe problem. This unit has an N1 Suitability Rating for cropland. Coarse textures and low annual rainfall are the major limitations. Potential for palm groves is good in a small part of this unit. The dominant soils are represented by site description K3 and the minor soils by site description K23.

BA6- Nearly level, deep, somewhat poorly to moderately well-drained moderately fine-textured soils (50-80%) and nearly level, deep, well-drained, moderately fine-textured soils (20-50%).

The dominant soils benefit from a seasonally high watertable and/or additional runoff from adjacent slopes. Component 2 is well-drained and it has formed in either alluvial and/or colluvial materials. Component 2 is more extensive in the units mapped southwest of Kiffa at the base of the Assaba Plateau. Minor soils have shallow to deep aeolian sands over fine materials. Component 1 is similar to unit C1A1 in the Aridic-Very Dry Zone (Soil-Climate Zone C).

Component 1 is used for palm groves and associated agriculture and Component 2 is used for pasture and some cropland. Vegetative cover is good and fair to good, respectively. Component 1 has an S2 Suitability Rating for palm grove agriculture. Sand dune encroachment is causing severe problems in several palm groves. Component 2 has an N1 rating and it is limited by moderately fine textures, slow permeability, and low rainfall. Some potential exists for irrigation in Component 2, if ground waters could be located.

BA7- Nearly level and gently sloping, deep, somewhat excessively and well-drained, moderately coarse- and medium-textured soils.

The dominant soils in this minor unit are deep and have a moderately well-developed soil profile. These soils are found in association with Unit BU8. Some areas of thin sands are included within this unit.

Minor soils are moderately deep and deep aeolian sands over fine materials. These soils are rarely flooded, but they do receive runoff in most years. This unit is used primarily for pasture, and areas of small fields are scattered throughout this unit. Vegetative cover is good and erosion is slight. This unit has an SC Suitability Rating for cropland. Low seasonal rainfall is the major limitation for these soils. These lands provide good pasture. The dominant soils is represented by Soil Profile S6.

BA8– Nearly level, deep, well- to poorly drained, moderately fine- and fine-textured soils.

The dominant soils in this unit are deep and they receive some flooding in most years. Several recessional areas behind modern dams and Lake R'Kiz and Lake d'Aleg are included in this unit. Microtopography, or gilgai, and wide cracks (associated with vertisols) are common throughout this unit, notably, in the Oued Ketchi. Other soils have deep, wide cracks, but lack gilgai. Minor soils are located in areas which are rarely flooded (i.e., secondary drainageways). Some areas have a thin cover of sands. This unit differs from Unit BA4 by having vertisols.

Recessional agriculture and pasture are the major land uses in this unit. Vegetative cover is good. These soils have an S2 Suitability Rating for recessional agriculture. Limitations are fine textures and the poor workability of the soil. Draft animals and tillage practices are recommended to speed seeding operations and improve infiltration of rainfall. Fertilization programs should be investigated to ensure that adequate amounts of plant nutrients, namely, nitrogen, phosphorous, and potassium, are supplied for sustained production. It appears that parts of the Oued Ketchi have good potential for recessional agriculture; vertisolic soils are the major limitation. The major soils are represented by Soil Profile S4 and site descriptions S2 and B7.

BA9– Nearly level, shallow and moderately deep to gravel, well-drained, medium-textured soils.

The dominant soils in this minor unit have formed in old alluvium over sediments of the Continental Terminal. This unit is located adjacent to Lake d'Aleg. A very shallow cover of sand is included as described in the dominant soil profile. Depth to gravelly materials is shallow to moderately deep. These soils have above-average organic matter compared to surrounding upland soils. Minor soils include surface gravels.

These soils are used for pasture. Vegetative cover is good on soils that are moderately deep to gravel and poor to fair on soils that are very shallow to shallow to gravel. These soils have an N1 Suitability Rating when moderately deep to gravel and N2 Rating elsewhere. The dominant soils are represented by Soil Profile B4.

BA10– Nearly level, deep, moderately well-drained, moderately fine- and fine-textured soils (60%) and nearly level and gently sloping, deep, excessively drained, coarse-textured soils (40%).

The dominant soils are formed in old marine beds. Component 2 consists of moderately deep and deep aeolian sands over finer materials.

Soils of Component 1 are generally high in sodium and/or salts. The range of characteristics also includes a shallow or very shallow cover of aeolian sands. Some gently sloping areas are included within the range of characteristics for Component 1. Component 2 includes a few areas with moderate slopes.

These soils are used for pasture. Vegetative cover is poor for Component 1 although a few areas near Lake R'Kiz receive enough additional moisture through flooding to sustain a fair cover. Component 2 has a poor to fair cover of vegetation and it is moderately to severely eroded.

This unit has an N1 Suitability Rating for cropland. Component 1 is limited by the soil physical characteristics associated with high sodium, i.e., very hard consistence and a nearly impenetrable subsurface horizon. Component 2 is limited by coarse textures, severe erosion hazard, and low fertility. Both components are limited by low annual precipitation.

Alluvial lands are rare. A moderately wide drainageway runs along the eastern edge of this unit. This area of alluvium appears to have some potential for recessional agriculture. Component 1 is represented by Soil Profile B14, and the minor drainageway is represented by Soil Profile B10.

BA11- Nearly level and gently sloping, deep, well- and moderately well-drained, medium-textured soils (60%) and gently sloping to moderately steep, deep, excessively drained, coarse-textured soils (40%).

The dominant soils are developed in saline, marine deposits. Component 2 consists of fine and medium sands with little or no soil-profile development. Component 1 has a saline watertable and lenses of compacted sea shells (Arca senilis). Sebhkas are included with this component. Component 2 includes coastal dunes and some sands which are similar to Component 1 of Unit C2E2 and Unit C2E1. Minor soils are moderately fine- and fine-textured and occur in slight depressions.

The land use is pasture and the vegetative cover is generally poor to fair for Component 1 and poor for Component 2, which is severely eroded. These soils have an N1 Suitability Rating for cropland. Low rainfall is the major limitation for these soils and Component 1 is also limited by high salinity. This region, which is known as the Aftout es Sahēli, has been previously investigated for irrigation potentials (SOGREAH, 1974).

Soil Region C (Includes Region C1, <225 mm precipitation, >24° C soil temperature; and Region C2, <100 mm precipitation, >24° C soil tempterature)

These zones include approximately the upper one-fourth to one-half of the project area, or 35.7% of the project area. The average rainfall is generally below 225 mm for the majority of lands included in this zone. Temperatures are generally very hot in the interior with marked seasonal extremes. Along the coast temperatures are cooler with

lesser seasonal extremes (C2 Zone). Three major landform groupings are noted in this soil-climate zone. The most extensive group is sand dunes, followed by rocklands (which include part of Tagant Plateau and the Affole), and finally the desert pavement or pediments, the least extensive. Agricultural production in this area is restricted to very limited areas with high water tables and/or collections of runoff water. Soils generally do not exhibit any extensive indications of profile development.

Aeolian Sands (E)

These soils, which occur throughout Soil Zone C (fig. 3-14), occupy 85.2% of the Region. The dunes were deposited during the Quaternary Period, and they can be divided into the following major groups: longitudinal, transverse, and littoral dunes and miscellaneous dune forms. The logitudinal dunes in this climatic zone cover most of the project area west of the Tagant Plateau. Transverse dunes are dominant east of the Tagant Plateau and they also are concentrated in a large area west of Moudjéria. The littoral dune grouping includes sebkhas and coastal soils in a narrow band along the coast. The miscellaneous dune grouping includes, among other types, barchans and parabolic dunes; this unit occurs north of Magta Lahjar and occupies a moderately large area.

A prime differentiating factor in separating soils formed in dune fields was the type, extent, and character of the interdunes. Coastal deposits (which are high in carbonates), sebkhas, nearly level sands, and moderately steep sands were the major interdunal types. Soil slope and the inclusion of rocklands were other important differentiating factors among mapping units.

The land use in this group of soils is pasture and it should be assumed unless otherwise noted within each brief mapping unit description. Browse species are more common than grasses, although substantial areas of grassland exist in the Trarza Region. The recent drought throughout these regions is evidenced by dead trees and severely wind-eroded soils. Moving sands are common, and vary from moving dune fields to drifting sand. Agriculture without supplemental water is not possible and the suitability of soils for cropland is not included in most brief descriptions. Ground water potential appears to be good throughout the Trarza Region as evidenced by the number of wells. (Additional references: Daveau,1970 and 1965; Ambroggi, 1966).

C1E1—Moderately steep and steep, deep, excessively drained, coarse-textured soils.

The dominant soils in this unit are fine sands with little or no soil-profile development, occurring on steep and moderately steep slopes. This unit is composed primarily of transverse dunes. Minor soils are the less sloping, sandy interdunes. A prominent, wide interdune (ancient waterway) is located in this unit to the northwest of Tâmchakket. Some minor areas of rock outcrops and fine-textured interdunes are also included in this unit. Small areas having high water tables and/or springs are located on the east edge of the Tagant Plateau.

Fig. 3-14. Aeolian sands cover the majority of land area in Soil Region C. Carbonate interdunes are common in the western part of the project area (above). The above photo was taken 15 km east of Nouakchott; a reddish sand dune is visible on the horizon. Balanites trees are common in many sandy sites (below). This ground photo was taken just west of Boutilimit. The last photo (next page) was taken 40 km northwest of Boumdeit. The height of sand dunes is contrasted to the Tagant Plateau (dust in the area caused the dim appearance of the Tagant Plateau).

Fig. 3-14 (continued)

Vegetative cover is generally poor and in most places erosion is severe. A large area of moving sands was noted on the east side of the Tagant Plateau; this is a source of the sands that are crossing the Tagant Plateau and encroaching on Moudjéria.

C1E2–Gently sloping to steep, deep, excessively drained, coarse-textured soils.

The dominant soils are fine sands with no soil-profile development. This zone of moving sands occurs west of Moudjéria. Some minor areas of desert pavement are included, although sands are covering these areas at a moderate rate as noted in a report that used multidate Landsat imagery (Worcester et al., 1978). Vegetative cover is poor and it is primarily woody. Some areas of high water tables and/or springs are located on the western edge of the Assaba Plateau.

C1E3– Moderately sloping to steep, deep, excessively drained, coarse-textured soils.

The dominant soils are fine sands with little or no soil-profile development. This large unit is found throughout the central part of Soil Region C. It is composed primarily of longitudinal dunes, but other dune types are included. Interdunal areas are generally less sloping than dune ridges, and often contain moving dunes. Minor soils are calcareous, nearly level interdunes, which are described in Unit C1E8. Other small areas of desert pavement, or pediments, are also included.

The vegetative cover is generally poor. Woody species are dominant with small areas of grasses and forbs. Erosion is severe and moving sands are common. Sangarafa, Maghta-Lahjar, and Guimi are villages where encroaching sands pose a serious problem.

C1E4– Gently sloping, deep, excessively drained, coarse-textured soils.

The dominant soils in this minor unit, which is located north of Chogar, are fine sands with minimal soil-profile development. Some nearly level slopes are included within the range of the major soils. Minor soils have formed in steep, transverse dunes and moderately fine-textured interdunal areas.

Vegetative cover is fair on the dominant soils. Minor soils have a less dense vegetative cover. This is a stable unit and it probably provides fair seasonal pasture.

C1E5– Moderately steep, deep, excessively drained, coarse-textured soils (60%) and gently sloping, deep, excessively drained, coarse-textured soils (40%).

The dominant soils are fine sands with little or no soil-profile development on transverse dunes. Component 2 is a gently sloping, fine sand with little soil-profile development. Component 1 includes steep slopes. Component 2 (the dominant soil in Unit C1E4) includes some nearly level slopes. Minor soils are sebkhas in the northwest part of this unit.

Vegetative cover is fair for this unit as a whole. Component 1 has a less dense cover than Component 2. This is a stable area and provides fair pasture.

C1E6– Gently sloping to moderately steep, deep, excessively drained, coarse-textured soils (55%) and nearly level, deep, well-drained, moderately fine-textured soils (30%).

The dominant soils in this small unit are fine sands with minimum soil-profile development. Component 2 has a moderately developed soil profile and moderately fine textures with a surface covering of pebbles. Minor soils (15%) are those areas where Component 2 is covered with a shallow to moderately deep mantle of sands.

Vegetative cover for Component 1 and the minor soil is fair; grasses and woody species are common. Component 2 has little cover. This unit is stable for the most part and it provides fair forage. Component 2 is represented by Soil Profile C13.

C1E7– Moderately sloping to steep, deep, excessively drained, coarse-textured soils (75%) and nearly level, deep, well-drained, medium-textured soils (25%).

The dominant soils are fine sands with little or no soil-profile development formed in longitudinal dunes. Component 2 consists of nearly level, calcareous soils formed in interdunes (marine sediments). Component 1 includes some fine sands found in interdunal positions and some areas with gentle slopes.

Vegetative cover varies from poor to fair for Component 1. In places grasses, trees and shrubs provide a nearly continuous cover; however, the majority of the unit has a poor cover. (Landsat imagery [see map folder] records the better vegetative cover in slightly darker tones.) Component 2 is nearly barren and only a few, widely spaced woody species exist. Locally, melons are cultivated in the more level, sandy interdune positions.

Component 1 is represented by Soil Profile B2.

C1E8– Moderately sloping and moderately steep, deep, excessively drained, coarse-textured soils (80%) and nearly level, deep, somewhat poorly drained, fine-textured soils (20%).

The dominant soils are fine sands with little or no soil-profile development formed in longitudinal dunes. Component 2, which has formed in marine deposits, consists of fine-textured and saline soils, and it is located in interdunal positions. Component 1 includes some steep and gently sloping sands. Minor soils are calcareous and are the same as Component 2 in Unit C1E7. This unit forms a transition between Soil-Climate Zones B and C. The soils of this unit are somewhat similar to Unit BE18, but generally have less vegetation cover.

Vegetative cover is fair to good in the southern part of the unit for Component 1 and erosion is moderate to severe. Some narrow bands of interdunal soils support very good stands of vegetation where the sands form a thin cover over finer-textured soils. Component 2 has little vegetative cover and it is limited by slow permeability and high salinity.

C2E1– Moderately sloping to steep, deep, excessively drained, coarse-textured soils (55%) and nearly level, deep, well-drained, fine-textured soils (45%).

This mapping unit is located in the extreme northwestern part of the study area (including Nouakchott). The dominant soils are fine sands with little or no soil-profile development formed in longitudinal dunes. Component 2 consists of calcareous soils of nearly level sebkhas. Component 1 also includes moving sands found in interdunal positions. This unit differs from unit C1E8 by having a greater percentage of calcareous interdune soils.

Vegetative cover is poor for the soils of this unit. For the most part, Component 1 is an area of eroded sands. Shrubs are the dominant vegetation. Component 2 is generally devoid of vegetation, and it is limited by high salinity and calcium carbonates. Component 2 is represented by profile B1.

C2E2– Moderately sloping and moderately steep, deep, excessively drained, coarse-textured soil.

The major soils are fine sands with little or no soil-profile development located in longitudinal dunes. Minor soils are fine-textured and saline and they are located in interdunal positions. This unit is similar to Unit C1E8, but it differs by being in a cooler temperature regime and by having a lesser area of fine-textured, interdunal soils.

Vegetative cover is poor to fair and erosion is moderate to severe.

Lithic Soils (L)

This landform grouping, which is located in the eastern one-half of Soil-Climate Zone C (Fig. 3-15), occupies 13.8% of this soil-climate zone. Its dominant members are the Tagant Plateau and the Affolé. Soil-profile development in the lithic parts (deflation zones) of these units is virtually nonexistent. Other landforms included with this landform grouping are aeolian sands, alluvial zones, and cobbly pediments. A single unit of desert pavement (C1L1) is included with the grouping for the sake of convenience. Slopes range from nearly level to steep.

C1L1– Nearly level, deep, excessively to well-drained, gravelly and medium-textured soils.

The dominant soils in this unit are desert pavements. Coarse fragments provide a nearly continuous surface cover. Vegetative cover is almost nonexistent.

C1L2– Nearly level to steep, very shallow, excessively drained, lithic soils.

Fig. 3-15. Lithic zones in Soil Region C are represented by a rock outcrop rising out of the Tagant Plateau (above). Sand accumulation is noticeable at the base of the outcrop. The illustration below shows an outlier of the Tagant Plateau just north of Boumdeit.

The dominant soils, which includes those found on the Tagant Plateau, are very shallow over bare rock, or more commonly, a bare rock surface. Minor soils include shallow to moderately deep aeolian sands, alluvial areas, cobbly or bouldery pediments, and a few small areas with high watertables due to springs. Vegetative cover is very poor; although localized areas of fair vegetation occur in faults, fractures, or alluvial lands. More extensive information concerning this unit is found in the geology section and elsewhere (INSTRUPA, 1979).

C1L3- Gently sloping to moderately steep, very shallow to moderately deep, excessively drained, coarse-textured soils over rock.

The dominant soils are fine sands that are shallow to bedrock. This unit occurs in a region where sands are moving across the Tagant Plateau. Minor inclusions consist of bare rock. This unit is included in the lithic landform because the majority of the soil control section (50-100 cm) is rock.

Vegetation cover is very poor. In a few places, i.e., where sand movement is broken by a barrier, sparse vegetation exists.

C1L4- Steep, very shallow, excessively drained, lithic soils (40-80%) and moderately steep and steep, deep, excessively drained, coarse-textured soils (20-60%).

Component 1 consists of bare rock. Component 2 includes fine sands that abut against rocky ridges or low mountains. Minor soils consist of desert pavements. Vegetative cover is very poor.

Alluvial Lands (A)

Three mapping units of alluvial soils are located in Soil-Climate Zone C (Fig. 3-16). These soils occupy 1% of this soil-climate zone with Unit C2A1 making up the majority. The mapping units in this grouping consist of moderately fine-textured soils, coarse- and moderately coarse-textured soils, and a marine terrace. Two major factors used in determining mappable alluvial zones were areal extent and vegetative cover. Numerous small, well-vegetated zones exist near and on the Tagant Plateau, and palm groves are often found in these nonmapped areas. Some large, coarse-textured interdunes located in Unit C1E1 are alluvial in nature, but these zones were generally less well-vegetated than the coarse- and moderately coarse-textured alluvial unit. The marine terrace soils, which are located along the coast line, are included in this group for the sake of convenience.

C1A1- Nearly level and gently sloping, deep, somewhat poorly to well-drained, moderately fine-textured soils.

The dominant soils in this small unit include the Tamourt en Naaj and a zone to the north-northeast of Boumdeit. These soils benefit from high watertables and/or additional runoff from adjacent rocky slopes. Minor soils include aeolian sands over the finer-textured substrata.

Vegetative cover is good. Dense trees form a nearly continuous surface

Fig. 3-16. An alluvial zone of Soil Region C is represented by this ground photo of an area 30 km northwest of Boumdeit. A brush fence is located in the forground while elsewhere numerous trees have been severely pruned.

cover. These areas offer good potential for palm groves and related agriculture. The Tamourt in Naaj has been included in a more detailed study (Gavaud, 1960). This unit has an S2 Suitability Rating for palm groves. Site description K17 represents this unit on the east side of the Tagant Plateau.

C1A2– Nearly level and gently sloping, deep, somewhat excessively and excessively drained, coarse- and moderately coarse-textured soils.

The dominant soils, which are located on the east edge of the Tagant Plateau, have been reworked by winds or are covered by surficial aeolian deposits. In some areas a moderately fine-textured soil is found within 120 cm of the surface. This unit is benefited by additional runoff.

Vegetative cover is good and consists of trees, shrubs and grasses. These areas make excellent pasture, but the erosion hazard is high. Site description K16 represents the unit located to the northeast of Boumdeit.

C2A1– Nearly level and gently sloping, deep, well- and moderately well-drained, medium-textured soils (60%) and gently sloping to moderately steep, deep, excessively drained, coarse-textured soils (40%).

The dominant soils have formed in saline marine deposits. Component 2 consists of fine and medium sands with little or no soil-profile development. Component 1 has a saline watertable and lenses of compacted sea shells (Arca senilis); sebkhas are included with this component. Component 2 includes coastal dunes and some sandy soils which are similar to Component 1 of Units C2E2 and C2E1. Minor soils are medium-textured with moderate soil-profile development--these soils commonly contain lenses of sands and sea shells.

The land use is pasture and vegetative cover is generally poor to fair for Component 1 and poor for Component 2, which is severely eroded. These soils have an N1 Suitability Rating for cropland. Low rainfall is the major limitation for these soils, and Component 1 is additionally limited by high salinity. This region, which is known as the Aftout es Sahéli, has been previously investigated for irrigation potentials (SOGREAH, 1974).

VI. SOIL PROPERTIES, POTENTIALS, AND OTHER CHARACTERISTICS

In this section various soil properties and interpretations are identified with or related to observed or measured soil features. Suitability for cropland, limitation for use, and other agriculturally-based characterizations are defined and related to physical and/or climatic criteria.

Physical characteristics that could be observed in the field formed the core of the site observations. Some soil characteristics, such as permeability and available water capacity, were inferred from the nature of other defined soil characteristics. Chemical and other laboratory analyses provided basic soil measurements (pH and electrical conductivity), as well as criteria used in taxonomic considerations (cation exchange

capacity, base saturation). The following discussion reflects the importance of these soil properties and interpretations for the general appraisal of the soil environment in southwest Mauritania.

Tables

Selected soil properties are presented in Table 3-1. This table consists of soil properties that were judged to be of importance in the project area. The preceding section (Brief Mapping Unit Descriptions) has included a discussion of several of these properties in the context of mapping-unit definition. All of the table headings, except "Term of Reference", are based on established guidelines (Soil Survey Staff, 1952, and 1975; FAO, 1977).

Present land condition, land potentials and suitabilities are given in Table 3-2. Vegetative cover of the land and erosion of the surface soil are subjective interpretations based on field observations (January through May 1981) and Landsat spectral signatures. Wind erodibility group (WEG) reflects the relative ease with which a bare soil surface can be eroded by wind. Erosion hazard is an expression of the susceptibility of land to wind and water erosion. It is determined by type and percentage of surface cover (coarse fragments and/or vegetation), WEG, slope, and soil drainage and permeability. This interpretation indicates the degree of an erosion limitation for land use.

The potential for agriculture categories are based on the FAO system of land suitability classification. The categories of this system are related to current land conditions. Land suitability orders divide lands into suitable and non-suitable categories for a particular use.

Suitable lands (S) can be expected to produce sustained yields that justify inputs. A conditionally suitable class (SC) is employed for those areas that may be suitable under specific conditions.

S1 - Highly suitable. Lands having no significant limitation for the defined use. These are highly productive lands. Crop production is not limited by soil factors and it can be expected to fully justify the necessary inputs and/or conservation practices.

S2 - Moderately suitable. Lands having limitations for the defined use. These are moderately productive lands. Crop yields are depressed by soil limitations. Crop production can be expected to yield moderate benefits from the necessary inputs.

S3 - Marginally suitable. Lands having severe limitations for the defined use. Crop yields are severely depressed by soil limitations to the extent that inputs produce only marginally profitable yields.

(Text continues on page 111)

Table 3-1. Selected soil properties of the mapping units.

Soil Mapping Unit	Component of Unit	%	Area Km^2	Soil Slope†	Soil Depth	Soil Texture	Coarse Fragments	Permeability	Internal Soil Drainage	Soil Reaction	Available Water Capacity	Term of Reference
						SOIL REGION A						
Alluvial												
AA1	1	50	330	NL	D	MF,F	0	VS,S	VP,P	SA,MA	M	PI,F
	2	50		NL,GS	D	C,MC	0	SE,W	SE,W	SA/N	VL,L	PI,F
AA2		100	260	NL	D	MF	0	S,MS	SP	MA,SA/N	M,H	F,S
Aeolian												
AE1	1	60	120	GS,MS	D	C	3	R	ED	MA,SA	L	F,S,
	2	40		ST	VS	R	5	-	ED	SA/N	VL	F
AE2	1	50-80(65)††	690	GS	D	C	0	R	ED	SA,MA	L	F
	2	20-40(35)		NL-GS	D	MC-MF	4	M-MR	W	SA	L,M	F
Lithic												
AL1	1	70	330	ST	VS	R	5	-	ED	SA/N	VL	F
	2	30		MS	D	C	0	R	ED	MA	L	F
AL2		100	60	MST-ST	VS	R	5	-	ED	SA/N	VL	F
AL3	1	30-50(45)	400	ST	VS	R	5	-	ED	SA/N	VL	F
	2	20-40(30)		GS	D	MC-G	4	MR	SE	SA	L	S,F
	3	10-30(25)		GS	D	MF	4	MS	MW	SA	M	S,F
AL4	1	60	360	MST-ST	VS	R	4	-	ED	SA/N	VL	F
	2	40		GS-MS	S-D	C	3	R	ED	MA	L	F
Upland												
AU1	1	30-70(60)	1030	NL,GS	D	M-MF	4	M	W	SA	M	F,S
	2	30-70(40)		NL	D	MC	2	MR	SE-W	SA,MA	L-M	F,S
AU2	1	50	470	GS	D	MC-M	3	MS	W	SA	L	F,S
	2	50		GS	D	C	2	R	ED	MA	L	F
AU3		100	540	NL-MS	D	M,MF	4	MS-M	W	SA-MA	M	F,S
AU4	1	70	610	NL	D	MF	2	M	W	SA/N	M	F,S
	2	30		GS-MS	VS	R,M	4	R	SE	SA/N	L	F,S
AU5		100	370	NL-GS	D	MF	4	MS-M	SP-W	MA	M	F,S
AU6	1	65	100	NL	D	F	0	MS	MW	MALK	M	F,S
	2	35		NL	D	M	0	MR	W	SA/N	M	F

†Terms and criteria are listed at the end of the table

††Based on total area

Table 3-1. Selected soil properties of the mapping units (cont'd)

Soil Mapping Unit	Component of Unit	%	Area Km^2	Soil Slope†	Soil Depth	Soil Texture	Coarse Fragmerts	Permeability	Internal Soil Drainage	Soil Reaction	Available Water Capacity	Term of Reference
						SOIL REGION B						
Alluvial												
BA1	1	60	1140	NL	D	MF-F	0	VS-MS	VP-SP	MA	M,H	PI-F
	2	40		NL	D	MC-MF	0	MS-R	SP-SE	MA,SA/N	L,M	PI-F
BA2	1	60	1680	NL	D	MC-MF	0	MS-R	SP-SE	MA,SA/N	L,M	PI,F,S
		40		NL	D	MF-F	0	VS-MS	VP-SP	MA	M,H	PI,F,S
BA3		100	950	NL	D	M-F	0	VS-MS	VP-SP	MA	M,H	PI,F,S
BA4		100	1420	NL	D	MF,F	2	S-M	SP-MW	SA/N,MA	M,H	PI,F
BA5		100	310	NL,GS	D	C,ME	2	R	SE	SA/N	L	F,S
BA6	1	50-80(50)	170	NL	D	MF	0	M	SP-MW	SA/N	M,H	F
	2	20-50(50)		NL	D	MF	0	M	W	MALK	M,H	F
BA7		100	100	NL,GS	D	MC,M	2	MR	SE,W	SA/N	L,M	F,S
BA8		100	540	NL	D	F,MF	0	VS-MS	P-W	SA/N	M	F,S
BA9		100	80	NL	D	M	3	M	W	SA/N,MALK	M	F,S
BA10	1	60	500	NL	D	MF,F	0	S	MW	MALK	L,M	F,S
	2	40		NL,GS	D	C	0	R	ED	SA/N	VL,L	F
BA11	1	60	590	NL,GS	D	M	0	M	W,MW	SA/N,MALK	L,N	F
	2	40		GS,MS	D	C	0	R	ED	SA/N	VL,L	F
Aeolian												
BE1	1	40	2350	NL,GS	D	C	0	R	ED	SA/N	VL,L	F
	2	30		NL,GS	D	G	5	R	ED	SA/N	VL	F
	3	30		ST	VS	R	4	-	ED	SA/N	VL	F
BE2		100	800	GS-MS	D	C	1	R	ED	SA/N	L	F,S
BE3	1	70	950	GS	D	C	0	R	ED	SA/N	VL,L	F,S
	2	30		GS	D	MF	4	MS	W	SA/N	M	F,S
BE4	1	65	310	MST	D	C	0	R	ED	SA/N	VL,L	F
	2	35		GS	D	C	0	R	ED	SA/N	L	F,S

Table 3-1. Selected soil properties of the mapping units (cont'd)

Soil Mapping Unit	Component of Unit	%	Area Km^2	Soil Slope†	Soil Depth	Soil Texture	Coarse Fragments	Permeability	Internal Soil Drainage	Soil Reaction	Available Water Capacity	Term of Reference
						SOIL REGION B						
BE5	1	50-80(65)	460	ST	D	C	0	R	ED	SA/N	VL	F
	2	20-50(20)		NL,GS	D	M-S	4	R-W	W-ED	SA/N	M	F
	3	0-20(15)		ST	VS	R	5	-	ED	SA/N	VL	F
BE6		100	2520	MS,MST	D	C	0	R	ED	SA/N	L	F,S
BE7		100	150	MST,ST	D	C	0	R	ED	SA/N	L,VL	F
BE8		100	4930	NL,GS	D	C	0	R	ED	SA/N	L	F
BE9	1	70	580	MS	D	C	0	R	ED	SA/N	L,VL	F,S
	2	30		GS,ST,	D-VS	S,R	4	R	ED	SA/N	VL	F
BE10	1	70	2670	MS	D	C	0	R	ED	SA/N	VL,L	F
	2	30		GS	D	C	0	R	ED	SA/N	VL,L	F
BE11	1	70	920	NL,GS	D	C	0	R	ED	SA/N	VL,L	F,S
	2	30		MST	D	C	0	R	ED	SA/N	VL,L	F
BE12	1	40	1030	MST,ST	D	C	0	R	ED	SA/N	VL	F
	2	35		MS	D	C	0	R	ED	SA/N	VL,L	F
	3	25		GS	VS	S	5	R	ED	SA/N	VL	F
BE13	1	50	1740	MS,MST	D	C	0	R	ED	SA/N	VL,L	F
	2	50		NL,GS	D	M	4	M	W	SA/N	M	F
BE14		100	1290	MS,MST	D	C	2	R	ED	SA/N	VL,L	F
BE15	1	60-90(80)	1120	MS	D	C	0	R	ED	MA-SA/N	VL,L	F,S
	2	10-40(20)		NL,GS	D	M G	4	M	W,SE	SA/N	L,M	F
BE16	1	70	4550	GS,MS	D	C	0	R	ED	SA/N	VL,L	F,S
	2	30		MST	D	C	0	R	ED	SA/N	VL,L	F
BE17		100	150	GS	D	C	2	R	ED	SA	L	-
BE18	1	75	4940	MS,MST	D	C	0	R	ED	SA/N	VL,L	API
	2	25		NL,GS	D	C,MC	0	R,MR	ED,SE	SA/N	L	API,F,S
BE19	1	50-70(60)	710	MS	D	C	0	R	ED	SA/N	VL,L	F
	2	30-50(40)		NL	D	MF,F	0	S,MS	SP,P	MA	M	F,S

Table 3-1. Selected soil properties of the mapping units (cont'd)

Soil Mapping Unit	Component of Unit	%	Area Km^2	Soil Slope†	Soil Depth	Soil Texture	Coarse Fragments	Permeability	Internal Soil Drainage	Soil Reaction	Available Water Capacity	Term of Reference
						SOIL REGION B						
BE20	1	75	2030	MS,MST	D	C	0	R	ED	SA/N	VL,L	F,S
	2	25		NL,GS	D	MF,F	0	S,MS	SP,P	MA	M	F,S
BE21		100	1520	GS,MS	D	C	1	MR,R	ED	MA-SA/N	VL,L	F,API
BE22		100	300	MS	D	C	0	R	ED	MA-SA/N	VL,L	F,S
Lithic												
BL1	1	50	3060	MS	VS	S,R	5	-	ED	MA	VL	F,S
	2	50		GS	D	M,MF,G	4	MS	W	SA/N	M	F
BL2		100	630	ST	VS	R	4	-	ED	MA	VL	F,A
BL3		100	10,050	GS,ST	VS	R,S	4	-	ED	SA/N	VL	F,A,PI
BL4	1	85	5070	GS-ST	VS	R	3	-	ED	SA/N	VL	F
	2	15		GS	D	MC,C	3	MR	SE,ED	SA/N	L	F,S
BL5	1	60-80(70)	1940	NL-ST	VS	R	3	-	ED	SA/N	VL	-
	2	20-40(30)		GS,MS	D	C	0	R	ED	SA/N	VL,L	-
Desert Pavement												
BP1	1	50	260	NL,GS	D	S	4	MR	ED	SA/N	VL	F
	2	50		GS	D	C,MC	4	R	SE,ED	SA/N	L,VL	F
BP2		100	5410	NL,GS	D	M,G,S	4	M	W	MALK	M	F,S,PI
BP3	1	35	180	NL,GS	D	G,S	5	VR	ED	SA/N	VL	F,S
	2	35		GS	D	C,MC	3	R	ED,SE	SA/N	VL,L	F
	3	30		MST	VS	R	5	-	ED	SA/N	VL	F
BP4	1	50	3720	MS	D	G	5	VR	ED	SA/N	VL	F
	2	50		NL,GS	D	M,MF	3	MS,M	W	MALK	M	F,PI
BP5		100	340	NL,GS	D	M,MF,G	4	M	W	SA	M	F

Table 3-1. Selected soil properties of the mapping units (cont'd)

Soil Mapping Unit	Component of Unit	%	Area Km^2	Soil Slope†	Soil Depth	Soil Texture	Coarse Fragments	Permeability	Internal Soil Drainage	Soil Reaction	Available Water Capacity	Term of Reference
						SOIL REGION B						
Uplands												
BU1	1	60-80(70)	580	NL,GS	D	M,MC	3	MS,M	W	MA	L,M	F
	2	20-40(30)		GS	VS	S,R	5	-	ED	SA/N	VL	F
BU2		100	3100	NL	D	M	3	MS	W	MALK-SA/N	M	F
BU3		100	1200	GS	D	C,MC	3	R	SE-ED	SA/N	VL,L	F
BU4	1	80	1310	NL,GS	D	C,MC	2	R	ED-SE	VSA,SA	VL,L	F,S
	2	20		GS,ST	VS	R,S	5	-	ED	SA/N	VL	F
BU5	1	50	2440	GS	D	M	3	MS	W	SA/N,MALK	M	F
	2	50		L,MS	D	C	0	R	ED	SA/N	VL,L	F
BU6	1	70	1360	GS,MS	D	C,MC	2	R	ED,SE	SA	VL,L	F,S
	2	30		GS-ST	VS	R,S	5	-	ED	SA/N	VL	F
BU7	1	75	1750	NL	VS	MC,M	3	M	W,SE	MA	VL,L	F,S
	2	25		ST	VS	R,S	5	-	ED	SA/N	VL	F
BU8		100	3010	GS,MS	D	MC,C	2	R	SE,ED	SA/N	L,VL	F,S
BU9		100	1550	NL,GS	VS,S	M	3	M	W,SE	MA	VL,L	F,S
BU10	1	60	580	GS,MS	D	C,MC	3	M	W	MA-SA/N	L	F,S
	2	40		GS,MS	VS	G,S	5	-	ED	SA/N	VL	F,S

Table 3-1. Selected soil properties of the mapping units (cont'd)

Soil Mapping Unit	Component of Unit	%	Area Km^2	Soil Slope†	Soil Depth	Soil Texture	Coarse Fragments	Permeability	Internal Soil Drainage	Soil Reaction	Available Water Capacity	Term of Reference
						SOIL REGION C						
Alluvial												
C1A1		100	60	NL,GS	D	MF	0	M	SP	SA/N	M	PI,F,S
C1A2		100	50	NL,GS	D	C,ME	0	R	ED,SE	SA/N	L	F,S
C2A1	1	60	430	NL,GS	D	M	0	M,MR	W,MW	MALK	L,M	PI,F
	2	40		GS,MST	D	C	0	R	ED	SA/N	VL	PI,F
Aeolian												
C1E1		100	7940	MS,ST	D	C	0	R	ED	SA/N	VL	A,PI
C1E2		100	920	GS,ST	D	C	2	R	ED	SA/N	VL	F
C1E3		100	17,420	MS,ST	D	C	2	R	ED	SA/N	VL	F
C1E4		100	270	GS	D	C	2	R	ED	SA/N	VL	OF
C1E5	1	60	2080	MST	D	C	0	R	ED	SA/N	VL	OF
	2	40		GS	D	C	2	R	ED	SA/N	VL	OF
C1E6	1	55	940	GS-MST	D	C	0	R	ED	SA/N	VL	F
	2	45		NL	D	MF	4	M	W	MALK	M	F,S
C1E7	1	75	11,220	MS-ST	D	C	0	R	ED	SA/N	VL	F,S,P
	2	25		NL	D	M	0	M	W	MALK	M	F
C1E8	1	80	1480	MS,ST	D	C	0	R	ED	SA/N	VL,L	F
	2	20		NL	D	F	0	S	SP	SA/N	M	F
C2E1	1	55	1550	MS-ST	D	C	0	R	ED	SA/N	VL	F
	2	45		NL	D	M	0	M	W	MALK	M	S,F
C2E2		100	1900	MS-MST	D	C	0	R	ED	SA/N	VL,L	F
Lithic												
C1L1		100	510	NL	D	G	5	R	ED	MALK	L	OF
C1L2		100	4830	NL-ST	VS	P	4	-	ED	SA/N	VL	F,PI
C1L3		100	920	GS	VS,MD	C,R	3	R	ED	SA/N	L	OF,PI
C1L4	1	40-80(55)	1170	ST	VS	R	3	-	ED	SA/N	VL	A
	2	20-60(45)		MST,ST	D	C	3	R	ED	SA/N	VL	A

Table 3-1. (Continued)

TERMS AND CRITERIA

Soil Slope: NL - nearly level (0-3%); GS - gently sloping (3-6%); MS - moderately sloping (6-10%); MST - moderately steep (10-20%); ST - steep (>20%).

Soil Depth: D - deep (>120 cm); MD - moderately deep (50-100 cm); S - shallow (25-50 cm); VS - very shallow (<25 cm).

Texture: S - stony; R- rocky; G - gravelly; C - coarse: sand and loamy sand; MC - moderately coarse: sandy loam and fine sandy loam; M - medium: very fine sandy loam, loam, silt loam, silt; MF - moderately fine: clay loam, sandy clay loam, silty clay loam; F - fine: sandy clay, silty clay, and clay.

Coarse Fragments: 0 - 0% ground cover; 1 - 0.1%; 2 - 0.1 to 3%; 3 - 3 to 15%; 4 - 15 to 90%; 5 - >90%.

Permeability (cm/hr): VS - very slow, <0.1; S - slow, 0.1 to 0.5; MS - moderately slow, 0.5 to 1.5; M - moderate, 1.5 to 5.1; MR - moderately rapid, 5.1 to 15.2; R - rapid, 15.2 to 50.8; VR - very rapid, >50.8.

Internal Soil Drainage: VP - very poorly drained; P - poorly drained; SP - somewhat poorly drained; MW - moderately well-drained; W - well-drained; SE - somewhat excessively drained; ED - excessively drained.

Soil Reaction (pH): VSA - very strongly acid, <4.2; SA - strongly acid, 4.3 to 5.0; MA - moderately acid 5.1 to 6.0; SA/N - slightly acid to neutral, 6.1 to 7.3; MALK - moderately alkaline, 7.4 to 8.2; SALK - strongly and very strongly alkaline >8.2.

Available Water Capacity: (Depth of 140 cm or to restricting layer) VL - very low, 0 to 8 cm; L - low, 8 to 15 cm; M - moderate, 15 to 23 cm; H - high, >23 cm.

Term of Reference: (In addition to Landsat interpretation) F - field observation; OF - field observation from other field survey team (pasture or forestry); A - aircraft reconnaissance; API - air photo interpretation; PI - published information.

Table 3-2. Soil potentials and other mapping unit characteristics.

Soil Mapping Unit	Component of Unit	%	Area Km^2	Percent Vegetative Cover†	Erosion	Wind Erodibility Group	Erosion Hazard	Major Limitations	FAO Class	Rainfed Sorghum - Millet	Rainfed Sorghum	Recessional Sorghum
						SOIL REGION A						
Alluvial												
AA1	1	50	330	3,2	NS	4	1	W,V,I	S2(90%)††	XX*		XX
	2	50		1	NS,M	1,2	3 Wi	M,F	S3	X**	XX	
AA2		100	260	1	NS	4,6,7	2 W	I	S2(80%)	XX	XX	XX
Aeolian												
AE1	1	60	120	1	NS,M	1	3 Wi	M,E,F	SC(80%)	X		
	2	40		1,2	NS	8	1	D				
AE2	1	50-80(65)†††	690	1	NS	1	3 Wi	M,E,F	SC	X		
	2	20-40(35)		3	SE	2,3,4	4 W, 3 Wi		N1			
Lithic												
AL1	1	70	330	1,2	NS	8	1		N2			
	2	30		1	M	1	3 Wi	M,E,F	SC(75%)	X		
AL2		100	60	1-3	NS	8	1		N2			
AL3	1	30-50(45)	400	1,2	NS	8	1		N2			
	2	20-40(30)		2	S	3	4 Wi,3 W		N1			
	3	10-30(25)		3	SE	4	4 W, 2 Wi		N1			
AL4	1	60	360	3	NS	8	1		N2			
	2	40		2,3	SE	1	4 Wi		N1			
Upland												
AU1	1	30-70(60)	1030	3	SE	4,5	4 W, 3 Wi		N1			
	2	30-70(40)		2	M,SE	3	4 Wi	E,M	S3	X	X	
AU2	1	50	470	3	SE	3	3 Wi,3 W		N1			
	2	50		2,3	SE	1,2	4 Wi		N1			
AU3		100	540	3	SE	4	4 W, 2 Wi		N2			
AU4	1	70	610	1,2	NS	4L	2 W	G,V,A	S2(70%)	XX	X	
	2	30		1	NS	6,8	1		N2			
AU5		100	370	3,2	SE	4	3 W		N1			
AU6	1	65	100	1	NS	4L	1	V,A	S2(70%)	XX	X	
	2	35		1	NS	5	2-3 Wi	M,F	S2(8%)	XX	XX	

†Terms and criteria are listed at the end of the table

††Percentage of component which has S rating, no value indicates 100% of component

†††Based on total area

*well suited

**suited

Table 3-2. Soil potentials and other mapping unit characteristics (cont'd)

Soil Mapping Unit	Component of Unit	%	Area Km^2	Percent Vegetative Cover†	Erosion	Wind Erodibility Group	Erosion Hazard	Major Limitations	FAO Class	Rainfed Sorghum - Millet	Rainfed Sorghum - Millet	Recessional Sorghum
						SOIL REGION B						
Alluvial												
BA1	1	60	1140	2,3	NS	4	1	V,I	S2(90%)			XX
	2	40		2	NS	2-4	2 Wi		N1			
BA2	1	60	1680	2	NS	2-4	2 Wi		N1			XX
	2	40		2,3	NS	4	1	V,I	S2(90%)			XX
BA3		100	950	1,2	NS	4	1		N1			
BA4		100	1420	1,2	NS	4	2 W	V,I	S2(60%)			XX
BA5		100	310	2,1	M	1,2,3	3 Wi		N1			
BA6	1	50-80(50)	170	1	NS	4	1		S2 Palm Grove			
	2	20-50(50)		2,3	NS	4	2		N1			
BA7		100	100	1,2	M	3,5	2,3 Wi	C,M,F	SC	X	X	
BA8		100	540	1,2	NS	4	1	V,I	S2(80%)			XX
BA9		100	80	1,2	NS	5	2 Wi		N1			
BA10	1	60	500	3	NS	4	1		N1			
	2	40		3,2	SE	1	4 Wi		N1			
BA11	1	60	590	2,3	NS	6	1		N1			
	2	40		3	SE	1	4 Wi		N1			
Aeolian												
BE1	1	40	2350	2	M,SE	1,2	4 Wi		N1			
	2	30		3	NS	8	1		N2			
	3	30		3	NS	8	1		N2			
BE2		100	800	1	NS	1,2	3 Wi	C,M,F	SC(90%)		X	

Table 3-2. Soil potentials and other mapping unit characteristics. (cont'd)

Soil Mapping Unit	Component of Unit	%	Area Km^2	Percent Vegetative Cover†	Erosion	Wind Erodibility Group	Erosion Hazard	Major Limitations	FAO Class	Rainfed Sorghum - Millet	Recessional Sorghum
						SOIL REGION B					
BE3	1	70	950	2,3	SE	1,2	4 Wi		N1		
	2	30		3	NS	4	2 W		N1		
BE4	1	65	310	2,3	M,SE	1	4 Wi		N1		
	2	35		1,2	NS,M	1	3 Wi		N1		
BE5	1	50-80(65)	460	3	SE	1	4 Wi		N1		
	2	20-50(20)		3	NS	8	1		N2		
	3	0-20(15)		3	NS	8	1		N2		
BE6		100	2520	1,2	NS,M	1	3 Wi	C,M,F	N1(SC 2.0% of area)	X	
BE7		100	150	3	SE	1	4 Wi		N2		
BE8		100	4930	1,2	NS,M	1	3 Wi		N1		
BE9	1	70	580	3	SE	1	4 Wi		N2		
	2	30		3	NS	8	1		N2		
BE10	1	70	2670	2,3	M,SE	1	4 Wi		N1		
	2	30		1,2	M,NS	1	3 Wi		N1		
BE11	1	70	920	1	NS	1	3 Wi		N1		
	2	30		2	M,SE	1	4 Wi		N1		
BE12	1	40	1030	3	SE	1	4 Wi		N2		
	2	35		2,3	M,SE	1	4 Wi		N1		
	3	25		3	NS	8	1		N2		
BE13	1	50	1740	3	SE	1	4 Wi		N1		
	2	50		3	NS	6	1		N1		
BE14		100	1290	3	SE	1	4 Wi		N1		
BE15	1	60-90(80)	1120	2,3	M,SE	1	3 Wi		N1		
	2	10-40(20)		3	NS	6	1		N2		

Table 3-2. Soil potentials and other mapping unit characteristics (cont'd)

Soil Mapping Unit	Component of Unit	%	Area Km^2	Percent Vegetative Cover†	Erosion	Wind Erodibility Group	Erosion Hazard	Major Limitations	FAO Class	Rainfed Sorghum - Millet	Recessional Sorghum
						SOIL REGION B					
BE16	1	70	4550	1,2	M	1	3 Wi		N1		
	2	30		2,3	M,SE	1	4 Wi		N1		
BE17		100	150	1	NS	1,2	3 Wi	C,M,F	SC(90%)	X	
BE18	1	75	4940	2	M	1	3,4 Wi		N1		
	2	25		2,1	M,NS	1,2,3	3 Wi		N1		
BE19	1	50-70(60)	710	2,3	M,SE	1	4 Wi		N1		
	2	30-50(40)		1,2	NS	4	1	V,I	S2(90%)		XX
BE20	1	75	2030	2	M,SE	1	4 Wi		N1		
	2	25		3	NS	4	1		N1		
BE21		100	1520	2,3	M,SE	1,2	4 Wi		N1		
BE22		100	300	1,2	NS	1	3 Wi		N1		
Lithic											
BL1	1	50	3060	3	NS	8	1		N2		
	2	50		3	NS	6	3W		N1		
BL2		100	630	3	NS	8	1		N2		
BL3		100	10,050	3,2	NS	8	1		N2		
BL4	1	85	5070	3,2	NS	8	1		N2		
	2	15		2	M	2,3	3 Wi	C,M,F	N1 (SC 5.0%)	X	
BL5	1	60-80(70)	1940	3	NS	8	1		N2		
	2	20-40(30)		2,3	M,SE	1	4 Wi		N1		
Desert Pavement											
BP1	1	50	260	3	NS	8	1		N2		
	2	50		2,3	SE	1,2	4 Wi		N1		
BP2		100	5410	3	NS	6,8	1		N1		

Table 3-2. Soil potentials and other mapping unit characteristics (cont'd)

Soil Mapping Unit	Component of Unit	%	Area Km^2	Percent Vegetative Cover†	Erosion	Wind Erodibility Group	Erosion Hazard	Major Limitations	FAO Class	Rainfed Sorghum - Millet	Recessional Sorghum
						SOIL REGION B					
BP3	1	35	180	3	NS	8	1		N2		
	2	35		2	M,SE	1,2	4 Wi		N1		
	3	30		3	NS	8	1		N2		
BP4	1	50	3720	3	NS	8	1		N2		
	2	50		3	NS	4,6	2		N1		
BP5		100	340	3	M	4,6	3 Wi		N1		
Uplands											
BU1	1	60-80(70)	580	3,2	SE	2,3	4 Wi		N1		
	2	20-40(30)		3	NS	8	1		N2		
BU2		100	3100	3	NS	6	3 Wi		N1		
BU3		100	1200	1	NS	1,2	3 Wi		N1		
BU4	1	80	1310	1	NS	1,2	3 Wi	C,M,F	SC		X
	2	20		3	NS	8	1		N2		
BU5	1	50	2440	3	NS	6	3 W		N1		
	2	50		2,3	SE	1	4 Wi		N1		
BU6	1	70	1360	1,2	M	1,2,3	3 W, 3 Wi	C,M,F	N1 (SC 5% of area)		X
	2	30		3	NS	8	1		N2		
BU7	1	75	1750	2,3	NS	3,5	2 Wi		N2		
	2	25		3	NS	8	1		N2		
BU8		100	3010	2,3	M,SE	1,2,3	4 Wi		N1		
BU9		100	1550	3	NS	6	1		N2		
BU10	1	60	580	3,2	SE,M	1,2,3	4,3 Wi	C,M,F,E	N1 (SC 10% of area)		X

Table 3-2. Soil potentials and other mapping unit characteristics (cont'd)

Soil Mapping Unit	Component of Unit	%	Area Km^2	Percent Vegetative Cover†	Erosion	Wind Erodibility Group	Erosion Hazard	Major Limitations	FAO Class	Rainfed Sorghum - Millet	Recessional Sorghum
						SOIL REGION C					
Alluvial											
C1A1		100	60	1	NS	4	2 W	C	S2 Palm groves		
C1A2		100	50	2	M	1-2	3 Wi		N1		
C2A1	1	60	430	2	M	4 L	3 Wi		N1		
	2	40		3,2	SE	1	4 Wi		N1		
Aeolian											
C1E1		100	7940	3	SE	1	4 Wi		N1		
C1E2		100	920	3	SE	1	4 Wi		N1		
C1E3		100	17,420	3	SE	1	4 Wi		N1		
C1E4		100	270	2	M	1	3,4 Wi		N1		
C1E5	1	60	2080	3	M	1	4 Wi		N1		
	2	40		2	M	1	3,4 Wi		N1		
C1E6	1	55	940	2	M	1	3,4 Wi		N1		
	2	45		3	NS	4	1		N1		
C1E7	1	75	11,220	3,2	SE	1	4 Wi		N1		
	2	25		3	NS	4 L	3 Wi		N1		
C1E8	1	80	1480	2,3	M,SE	1	4 Wi		N1		
	2	20		3	NS	4	1		N1		
C2E1	1	55	1550	3	SE	1	4 Wi		N1		
	2	45		3	NS	4 L	3 Wi		N1		
C2E2		100	1900	3,2	SE	1	4 Wi		N1		
Lithic											
C1L1		100	510	3	NS	8	1		N2		
C1L2		100	4 830	3	NS	8	1		N2		
C1L3		100	920	3	SE	1	4 Wi		N2		
C1L4	1	40-80(55)	1170	3	NS	8	1		N2		
	2	20-60(45)		3	SE	1	4 Wi		N1		

Table 3-2. (Continued)
TERMS AND CRITERIA

Vegetative Cover: 1 - good >75%; 2 - fair 50 to 75%; 3 - poor <50%.

Erosion (of surface soil): NS - none to slight <25%; M - moderate 25 to 75%; SE - severe >75%.

Wind Erodibility Group: 1 - sands; 2 - loamy sands; 3 - sandy loams; 4L - calcareous loams; 4 - clay loams or finer (silty clay loam with >35% clay); 5 - coarse loams (<18% clay); 6 - fine loams; 7 silty clay loams (35% clay); 8 - not subject to blowing.

Erosion Hazard: 1 - very slight; 2 - slight; 3 - moderate; 4 - severe. Wi - wind is major agent; W - water is major agent.

Major Limitations: See text.

FAO Class (Suitability Rating for agriculture): S1 - highly suitable; S2 - moderately suitable; S3 - marginally suitable; SC - conditionally suitable; N1 - currently nonsuitable; N2 - permanently nonsuitable.

Rainfed and/or Recessional Agriculture: XX - well suited; X - suited.

Nonsuitable lands (N) have soil properties and/or characteristics that preclude sustained use for agriculture.

N1 - Currently nonsuitable. Land having limitations that presently cannot be economically corrected. These limitations preclude utilization in the defined manner.

N2 - Permanently nonsuitable. Land having limitations so severe as to be permanently unchangeable.

Subclasses are also used to further distinguish the types of limitations for agriculture. If more than one limitation occurs, the symbols are arranged from left to right in order of importance. These subclasses indicate the types of soil problems that should be provided for in land management. The following limitations are used:

a - alkalinity; alkaline soil reaction and high exchangeable sodium percentage.

c - climate; adverse climatic conditions, extremes in precipitation or temperature.

d - depth and stoniness; shallowness and/or stoniness restrict rooting.

e - erosion; previous damage by erosion or high erosion hazard.

f - fertility; low inherent fertility status or limited response to fertilization.

g - surface gravel or stones; gravel or stone surface pavement impeding cultivation or seedling emergence.

i - inundation; susceptible to frequent flooding.

m - moisture deficiency; drought susceptible soil.

p - physical soil condition; adverse soil conditions other than v.

t - topography; relief (macro or micro), elevation or slope.

v - vertisolic; vertisol soils with a high content of swelling clay minerals.

w - wetness; waterlogging caused by a high water table, slow permeability, slow surface runoff or a combination of these.

Crop preferences for various soil properties were used in assigning suitabilities. Table 3-3 lists the major crops and other possible crop varieties and their characteristic preferences for varying soil properties. Since sorghum and millet are the major crops in southwest Mauritania, these were the only crops categorized by the suitability in Table 3-2. The other crops, including different varieties of millet, listed in Table 3-3, appear to have potential application in various parts of the project area.

Table 3-3. Soil requirements for crops adapted to parts of the project area (after Young, 1976).

	Texture				Depth		Drainage			Moisture			Reaction (pH)		Nutrients			
	Preferred		Tolerated		Pre-ferred	Tol-erated	Req.	Tolerated			Req.	Well Tolerated			Required			
Crop	Mod. Fine	Med.	Mod. Coarse	Coarse	Deep	Mod. Deep Shallow	Well	Imperfect	Poor	Drought Resist.	High AWC†	Low AWC†	Optimum Range	Max. Range	High	Med.	Low	Special Requirement
Maize (*Zea mays*)	X				X		X	X		Low	X		5.5-7.0	5.0-8.0	X			High Nitrogen
Sorghum (*Sorghum sep.*)	X		X						X	Medium		X	5.5-6.5	5.0-8.5		X		High Nitrogen
Finger millet (*Eleusine coracana*)			X			X	X			Medium		X				X		
Bulrush millet (*Pennisetum typhoides*)		X	X	X			X			High		X				X		
Panicum millet (*Panicum miliaceum*)			X							High		X				X		
Hungry Rice (*Digitania exilis*)			X			X				Medium		X					X	
Ground Nuts (*Arachis hypogaea*)		X sandy	X	X			X			Medium		X	5.3-6.6	5.0-7.0		X		Balanced
Cow Peas (*Vigna sinensis*)			X							Medium		X		5.0-7.0			X	

†AWC - Available Water Capacity

Erosion and Erosion Hazard

Soil loss through erosion is a serious problem throughout the project area. The type of erosion is strongly influenced by landform, and a clear relationship between landforms and erosion-type is evidenced by the distribution of landforms by soil-climate zones (Fig. 3-17). Soil Zone C has the greatest extent of wind erosion and Soil Zone A has experienced the most severe water erosion. Aeolian landforms are very susceptible to wind erosion under conditions of sparse ground cover, dry surface, and winds. Conditions that favor water erosion are steep slopes, slow infiltration rates, sparse ground cover, and high intensity rainfalls. Uplands are the landform category with the greatest potential for water-erosion damage.

Soil crusting is sometimes associated with erosion damage. In Soil Zones B and C compacted areas of sands appear in some areas where severe erosion has taken place. In these cases the hardened sand surface is the result of weak silica cementation caused by the solubility of silica at high pH. Deposition of high pH sands over weathered sands will often produce the same results.

In the Guidimaka Region bare, hardened surfaces are common. Here the erosion of the topsoil, which is a zone of accumulation of organic matter, has exposed substrata horizons that are low in organic matter. Soils with low organic matter and high contents of silt generally have low structural (aggregate) stabilities that are associated with soil crusting (Cary and Evans, 1974). A third type of soil crusting was also noted to the south of Harr and this type is caused by alignment of silt-sized mica flakes, or microlamination (Young, 1976).

Encroachment by sands is a major problem in the northern and central parts of the project area. Soil Zone C is generally the driest zone in the project area, and, consequently, it is the most susceptible to wind erosion of sands. Mapping units C1E1, C1E2, C1E3, and C1L3 form a major zone of sand movement in the Tagant and Brakna Regions. Other aeolian mapping units are also affected to varying degrees.

Soil Zone B contains numerous areas where sand encroachment poses a severe problem. The most serious problem areas are located west of the Tagant and Assaba Plateaus. Active zones of sand movement are included in mapping units BE5, BE7, BE12, BE13, and BE14. Desert pavement landforms and a few upland units are affected by sand movement, but accumulation of significant amounts of sands was not visible on Landsat imagery. These units are generally windswept and few barriers exist to impede sand movement.

The moderate- and severe-erosion-hazard interpretation indicates those mapping units that are extremely susceptible to or have already sustained severe wind erosion. The mapping units which are included in the severe wind-erosion-hazard category (4 Wi) are generally coarse-textured, have a poor surface cover of vegetation or coarse fragments, and have sustained previous, severe erosion of the surface soil. The "3 Wi" category (moderate-wind-erosion hazard) includes mapping units with characteristics similar to those mentioned above, but the vegetative cover is fair to good with annual precipitation that is generally greater than those units with a "4 Wi" rating (Fig. 3-18).

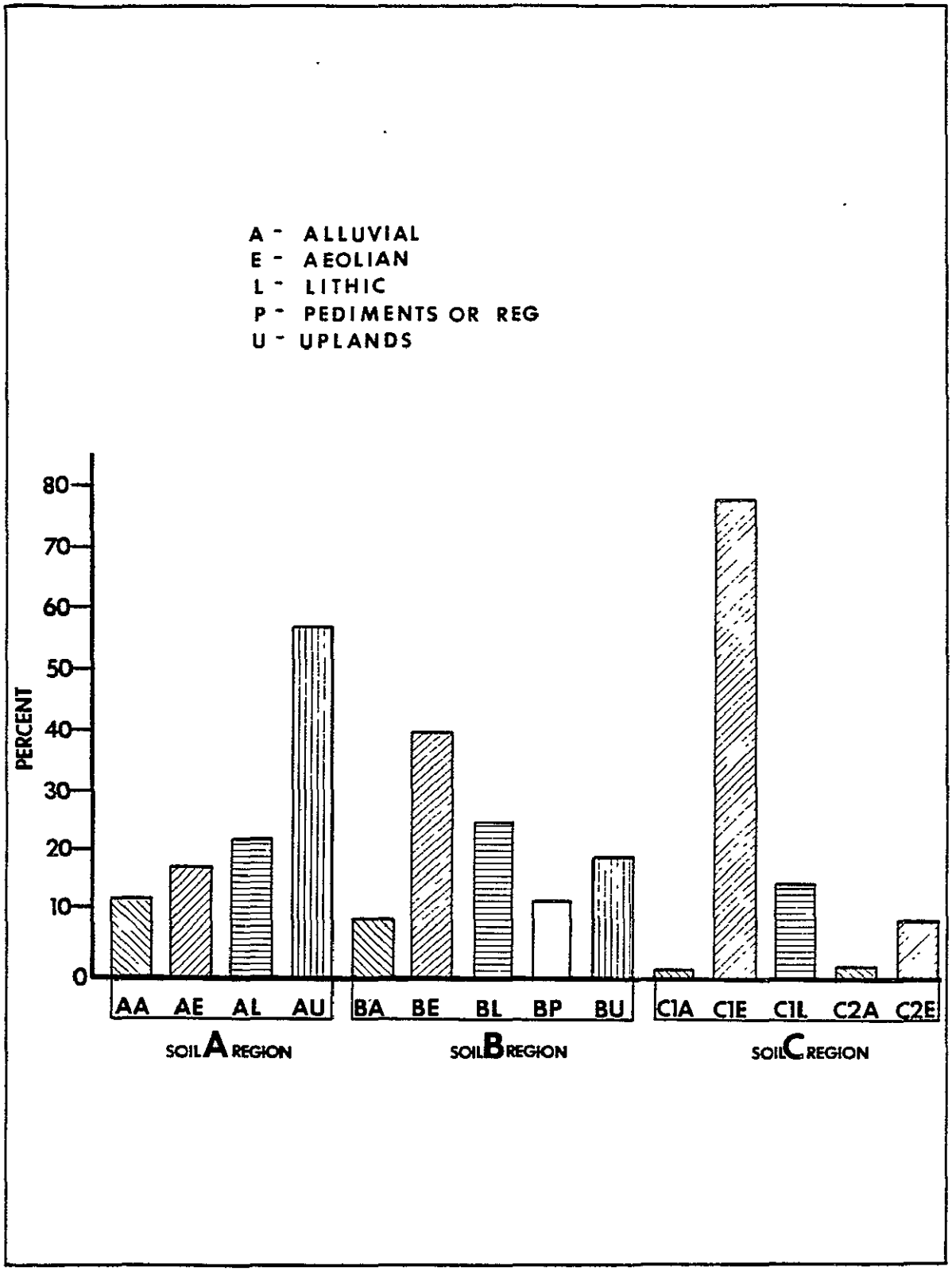


Fig. 3-17. Proportions of major landforms are contrasted among Soil-Climate Zones A, B, and C. Alluvial groupings (i.e., AA, BA, C1A, C2A) decrease dramatically among Soil Zones (left to right) while the opposite occurs for aeolian groupings.

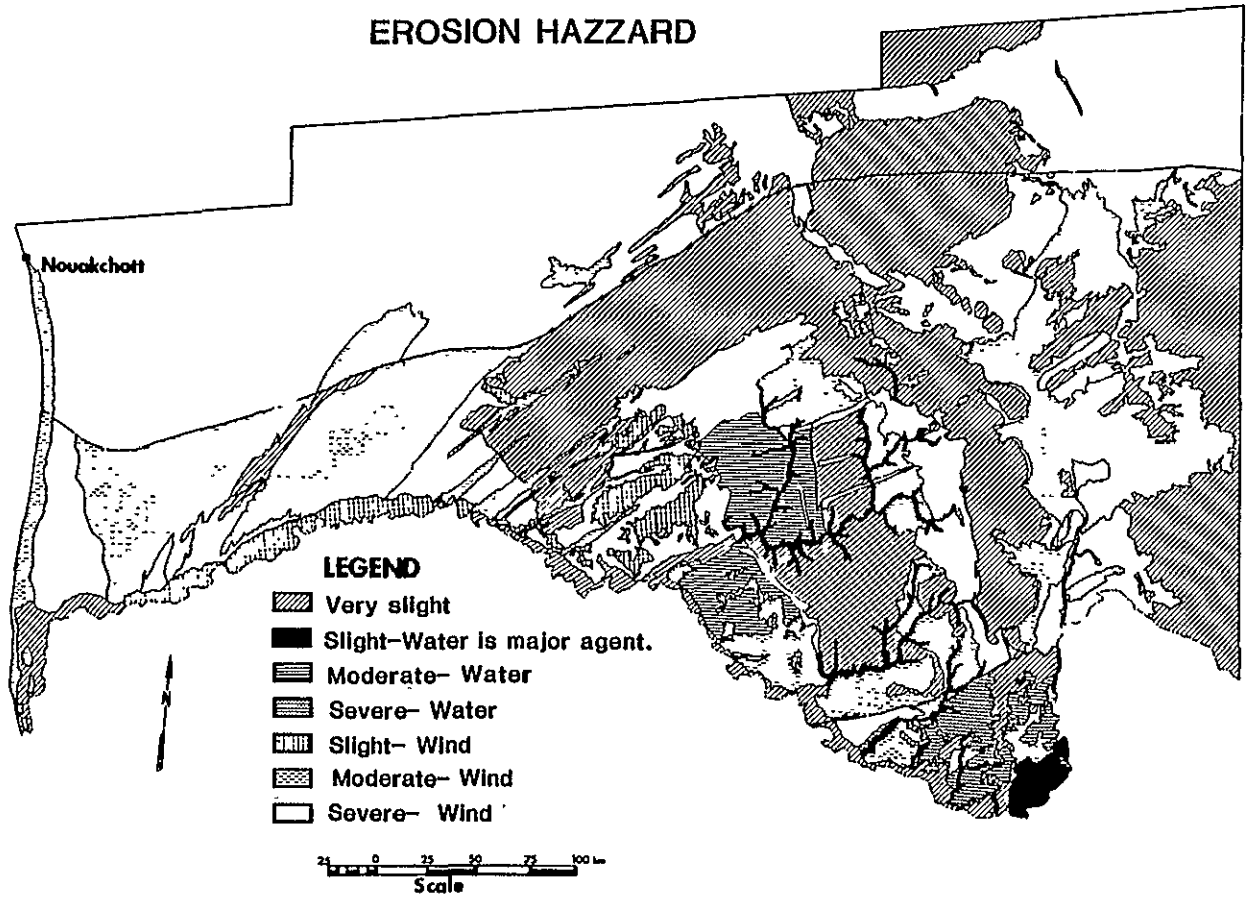


Fig. 3-18. Erosion hazard is shown for the project area. The hazards are based on the dominant soils within each mapping unit (i.e., Component 1).

Suitability for Agriculture

The FAO system of suitability classification is based on current land conditions; although, as used in this report, lands which are suitable for recessional agriculture will require installation of structures. Three of the four suitability ratings (i.e., S2, S3, SC) were employed to categorize lands with potential for growing climatically adapted crops (Fig. 3-19). The S1 category (highly suitable) was not used because of the extremes and variabilities associated with climatic patterns. Sorghum and millet were rated as well-suited or suited for particular mapping units. Some alternative crops are identified in Table 3-3; limited data on other local crops prevented their inclusion.

The scale of this survey precluded the delineation of narrow alluvial lands that are suitable for agriculture. The areas are discussed in applicable mapping descriptions and in a brief section following the suitability for agriculture section. Semi-detailed or larger scale mapping is needed for accurate spatial and areal determinations of these important agricultural areas.

Moderately Suitable (S2). Mapping units included in this category are divided among soils that are suited to flood-recessional agriculture, rainfed agriculture, or both. Lands suited for recessional agriculture have often been utilized for some time in this fashion; other areas which have potential lack only for development. These lands compose 2.5% of the project area; when the Senegal River Valley units are excluded, the figure is 1.6%. These figures for suitable lands are deceiving in that runoff would probably be insufficient in most years for the development of all possible lands. The mapping units included are AA1 (Component 1), AA2, BA1 (Component 1), BA2 (Component 2), BA4, BA8, and BE19 (Component 2). Sorghum is the recommended crop for this type of agriculture. Common limitations are fine textures, flooding hazard, and high watertables. Fertility is generally high for these soils and soil nutrients are replenished by annual deposits of sediments. Recommended management should include tillage, disease-resistant varieties, and good weeding programs. Further research and extension should be undertaken to dictate the optimum length of flooding for varying soil textures. The soils of the Senegal River Valley are more thoroughly described and evaluated in a previous report (PNUD, 1977).

The remaining mapping units are moderately suitable for rainfed agriculture. These lands occur in the extreme south of the Guidimaka Region and they occupy 0.3% of the lands in the project area. Mapping Units AU4 (Component 1) and AU6 make up this grouping. These soils are fine- or moderately fine-textured lands and they are suitable for maize and sorghum. Limitations are fine textures, alkalinity, and profile gravel (only AU4). Fertility is moderately high for these soils and when this land is farmed bush fallow is used for replenishment of fertility. These lands could be used more intensively than at present. Recommended management for sustained productivity includes fertilization, tillage, and crop rotation.

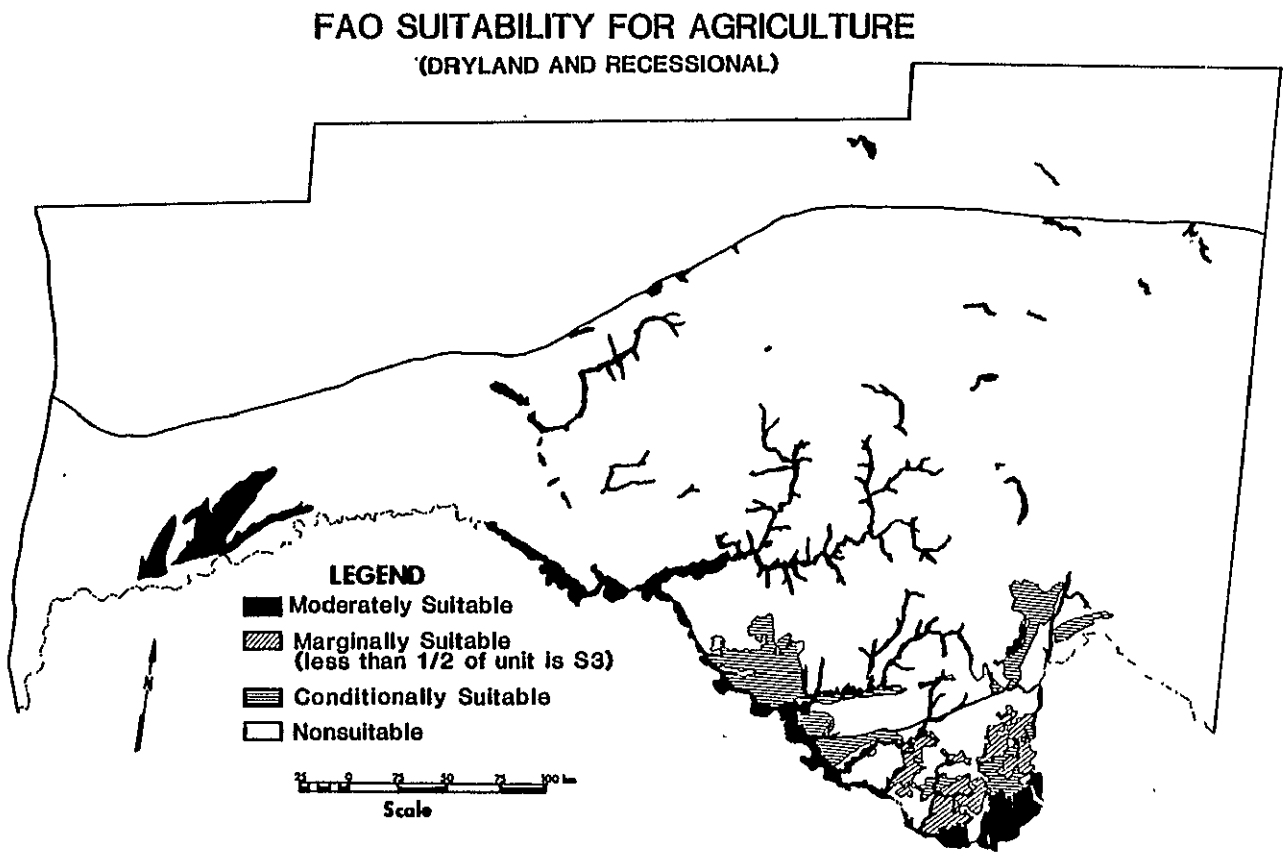


Fig. 3-19. Suitability for rainfed and flood recessional agriculture is shown for the project area. Mapping units that have more than 15% of the total area with a 'suitable' rating are also included. (Refer to the accompanying soils map and table 3-2).

Marginally Suitable (S3). Mapping units in this category occupy 0.3% of project area and they include AU1 (Component 2) and AA1 (Component 2). These mapping units are composed of moderately coarse-textured soils and they are used predominantly for pasture. Only a few scattered areas of bush fallow-cropland exist on these soils. Millet, sorghum, cowpeas, and possibly groundnuts are suitable crops. Limitations are erosion, erosion hazard, droughtiness, and low fertility. Management should include programs of fertilization, protection against erosion, and crop rotation. Intercropping is possible in most places, and tillage should be used when soil crusting is a problem.

Conditionally Suitable (SC). Mapping units in this category occupy 1.7% of the project area, and they include AE1 (Component 1), AE2 (Component 1), AL1 (Component 2), BA7, BE2, BE6 (2% of mapping unit), BE17, BL4 (5% of Component 2), BU4 (Component 1), BU6 (5% of Component 1), and BU10 (10% of Component 1). Millet is the recommended crop for these soils. Common limitations are droughtiness, erosion hazard, and low fertility. Management should include programs of fertilization, protection from erosion, and disease- and insect-resistant crop varieties. The soils of SC differ from the soils of S3 by being coarser in texture (sands or loamy sands vs. sandy loams), and one unit (BA7) that is not coarser in texture is located in an alluvial zone.

The conditionally suitable category is based on marginal crop production in most years. The 350 mm isohyet forms a line of minimally required precipitation for soils with an SC rating. The minimal, necessary precipitation was determined from an agrohydrologic budget in which 80% of the plant moisture requirements (75-day varieties) are met 8 or more years in 10 years (based on work by Dancette discussed in Dancette and Hall, 1979). Short-maturing crops are necessary for these soils; however, in recent years the 350 isohyet has retreated a considerable distance to the south and many of these soils have received less than 350 mm.

Development Potential for Alluvial and Other Lands. Numerous zones in the project area have a drainage density of medium to fine. The density of drainage is an expression of the geologic materials and the character of the land surface. Efficient utilization of runoff waters together with small dams and/or contour dikes could add substantially to the area of cropped lands in the project area. This section describes those alluvial lands that have fair or good potentials for agricultural development, but are too small to be mapped at the survey-scale (1:500,000).

Characteristics that indicate potential for agricultural development of alluvial lands are: 1) nearly level slopes, 2) potential flood zones of adequate width (minimum of 30 m), 3) presence of fair to good vegetative cover, and 4) no or shallow gullying. The criteria listed above were subjectively applied during the field-observation phase of this survey. The mapping units whose alluvial zones meet these criteria (good potential) are BE3, BU2, BU5, AU1, AU2, AU3, AU4, and AU6. Soil Zone A includes alluvial lands that are also moderately suitable for rainfed agriculture. Mapping units that offer lesser, but nevertheless notable, potentials are BE1, BE13, BE16, BL4, BL5, BU10, AU5, and AU6. The alluvial soils with fair and good potentials are generally moderately fine- or fine-textured and have good fertility. Common limitations are hard consistence and

moderate water erosion hazard.

Other lands which appear to have good potential for irrigation are the mapping units that encompass upland, temporary lakes, i.e., BP3, BU3, and BA6 (Component 2). Other mapping units may have irrigation potentials, but easily observable features were not noted during the field- or Landsat-interpretation phases.

VII. LAND MANAGEMENT FOR AGRICULTURE

Best management programs include those techniques and practices that produce optimum, sustained yields while concurrently making provisions for appropriate methods of soil conservation. Many variables are involved in developing specific management plans. While climate is outside the farmers' control, numerous other variables can be managed to produce improved crop yields. This section provides a brief, generalized guideline for managing the soil resource in southwestern Mauritania for crop production. Only rainfed and recessional agriculture are considered. Land improvement that requires minor inputs are emphasized.

Agronomic Considerations

Many areas of crop production research are needed for Mauritanian crops and soils. Currently, this type of research is being carried out on a small scale in the project area (CNRADA, 1980; DRIG, 1981). Seeding rates, time of seeding, row spacing and plant populations, varietal suitabilities, and tillage operations are some of the considerations that need further research and extension. Many of these considerations are involved in ongoing research programs in similar climatic regions (e.g., ICRISAT) and it remains only to integrate proven techniques and improved crop varieties as they are developed.

The major crops suitable to the Mauritanian climate and soils are sorghum and millet. Cowpeas are a suitable crop in mixed or intercropping practices. Groundnuts and maize may be grown in the extreme southern part of the study area, but rainfall under 600 mm/year will depress yields. Other minor crops are of local importance, but the scope of this survey excludes them from consideration in this report. All crops grown in Mauritania have differing requirements for water, soil fertility, drainage, etc. (Table 3-3). Land suitabilities and soil limitations should be considered in selecting the appropriate crop(s); these interpretations also provide an indication of the soil problems and likelihood of producing optimal yields.

All of the crops adapted to Mauritanian conditions will respond to fertilization, expecially to the addition of nitrogen. Animal manure provides the best alternative of adding nutrients to the soil in the project area. Manure also provides organic material that is important in improving the soil's physical character, or tilth (Kipps, 1971). Investigation is needed to determine optimum amounts of manure to apply, the best time of application, and the economics of this practice. Ley farming also improves the condition of the soil and adds to soil fertility, but the economics of this practice need more research (McCown et al., 1979). Shifting cultivation provides a supplementary, but labor-intensive, means of allowing the soil fertility to renew itself.

The use of manual labor for all aspects of crop production is dominant throughout the project zone. Utilization of draft animals is recommended to increase the efficiency of labor and to provide improved tillage practices for soils finer in texture than loamy fine sand. Weeding and thinning programs are practiced in the project zone, but extension programs should be instigated to teach farmers to recognize and remove undesirable wild cultivars during weeding. Adjusting plant populations according to the extent of rainfall may be an additional tool in crop management; for example, in a dry year it is advisable to have no more than two sorghum plants per 30 centimeters in a row where the row spacing is 91 to 107 cm (Ismom and Worker, 1979). Crop rotation should be practiced where plant diseases, insects, and other soil-pest problems occur. While this is not possible everywhere, it does provide a good management option in the higher rainfall zones. Improved varieties and purity of seed stock can also improve resistance to some plant diseases and pest problems.

Soil Considerations

Control of soil erosion, conservation of moisture, and maintenance of soil fertility and tilth are the major soil problems in the project area. These factors are interrelated and can be managed in an integrated program. Other lesser soil problems are soil salinity and flooding hazard and/or soil drainage.

Wind erosion of croplands is prevalent throughout Mauritania. Coarse-textured soils are especially susceptible to wind erosion. Effective means of controlling wind erosion are listed as follows: 1) producing stable soil aggregates, 2) roughening the soil surface, and 3) using barriers or crop strips to reduce wind velocities (Cannell and Weeks, 1979). Another effective technique is stripcropping, which consists of designing field width and orientation according to soil textures and prevailing winds, respectively. The narrowest fields are needed for coarse-textured soils since these soils are the most prone to wind erosion (see wind erodibility groups, Table 3-2). Crop residue management and field windbreaks are also proven methods of reducing wind erosion.

Water erosion is a severe problem in many areas of the study area, especially for soil textures that are finer than moderately-coarse and are located on steeper slopes. The character of rainstorms, i.e., high amounts in short time periods, enhances the likelihood of erosion on all soils. Runoff-control structures can be employed to curtail the overland flow of rainwaters; these structures include bunds or ridges on the slope contours and terraces (Cannell and Weeks, 1979). Design should be site-specific and yearly maintenance programs are essential. These structures are recommended for those agricultural areas where water erosion is severe and inputs are available. Another effective means of controlling overland flow is tillage, and in some cases (i.e., gentle slopes) it is more important in improving infiltration rates and reducing water erosion than control structures (Frenkel and Hadas, 1981). Tillage is recommended for areas with textures finer than loamy fine sand, and tillage probably should be considered before the more expensive control structures are implemented. Residue management, surface roughness, and stable aggregates are important in increasing infiltration rates and breaking the velocity and momentum of impacting raindrops. Fields should not be situated on slopes steeper than

10%. Nearly level and gently sloping areas (0-6%) are more desirable than moderately sloping areas (6-9%) as a preventive measure against water erosion. In rangeland areas shallow pitting may be an effective and economical means of preventing water erosion.

Management for flood-recessional agriculture relies on holding runoff waters on a given tract of land until the soil profile is thoroughly wetted. Utilization of traditional dams is much more common throughout the project area than the modern, larger dams. The major improvement needed in this type of agriculture is spillways to funnel away excess waters. The development and extension of inexpensive, simply designed traditional dams, which have a life of several years, is needed.

The optimal length of flooding should be tied to soil textural profiles and managed as such. Additionally, waterspreading programs should be investigated as a means of increasing the flooded area and introducing other suitable crops.

Soils that are prone to surface sealing or have an unstable structure are dominant throughout the Senegal River Valley. Programs of adding organic matter to these soils can improve soil tilth. Where additional inputs are available, soil conditioners offer an alternative, more rapid means of improving soil structure. An example of a suitable soil conditioner is IBMA, or polyisobutylmaleic amide (Focht and Martin, 1979).

Agroclimatological Considerations

Evaporative demands of various crops during the rainy season are important features in selecting crop varieties in rainfed agriculture. More and improved climatic-gathering stations are needed throughout southwestern Mauritania to supply this essential information. Agroclimatological data can be used to predict the likelihood of reaching minimal plant requirements for moisture during the growing season. These data can be extended to varietal recommendations for various areas. For crops that are often sown in dry ground (e.g., millet) the chances of success for various planting dates can be made based on past rainfall records (Dancette and Hall, 1979). Irrigation scheduling is also a very important factor that is based on climatic, soil, and crop indices. Together with soil hydrologic groups (categories of surface runoff), rainfall prediction can be used to determine volumes of runoff within a drainage basin under given circumstances. Location of small dams for recessional agriculture can be based on the likelihood of receiving minimal waters for agriculture production.

VIII. SUMMARY AND CONCLUSIONS

Little was known about the soils of southwestern Mauritania except for those of the Senegal River Valley. The objectives of this general-purpose, reconnaissance soil survey were to delineate soil associations by climate-landform indices, to determine the soil suitabilities for agriculture, and to inventory current land conditions, namely vegetative cover and erosion. Computer-enhanced Landsat imagery (1977) at a scale of 1:500,000 was used as the base map for this project. The Landsat imagery provided valuable spatial and spectral information that was utilized in locating mapping unit boundaries and in defining mapping-unit composition.

Four soil-climate zones (A,B,C1, and C2) divide the project area into areas of "ustic" and "aridic and torric" moisture regimes. Soil-climate Zone A (ustic) occurs in the southern Guidimaka Region in the zone with the most favorable soil-moisture regime within the project area. The other soil-climate zones are large in comparison to Soil Zone A, but they occur in areas of low precipitation and have little or no agricultural potential (rainfed). Soil Zone A has the most potential for rainfed agriculture while Soil Zone B has the largest area with potential for flood-recessional agriculture.

Landforms were the second level of partitioning the project area. The dominant landforms were aeolian sands (E), lithic soils (L), alluvial soils (A), uplands (U), desert pavement (P), and minor landforms, which were included with various members of the preceding five groupings, i.e. marine terraces, sebkhas, coastal dunes, deltaic deposits, and various divisions of uplands.

Soil associations formed the third and lowest level of map division; 84 unique mapping units were described by soil slope, soil depth, drainage, texture, and composition of major soils. Most mapping units also were characterized by chemical and physical data from soil-profile and non-profile descriptions and their respective soil samples. Further definition of mapping units was compiled from field observations, Landsat interpretations, air-photo interpretations and published reports. These data included descriptions of minor soils, range of characteristics of the major components, major limitations for agriculture, suitability for rainfed or recessional cropland, and potential for development of alluvial lands.

Each mapping unit has a brief written description of its properties and potentials; the properties and potentials data are also listed in tabular form and include areal extents (Km^2). Erosion hazard and suitability for rainfed and recessional agriculture are emphasized throughout the soil survey report. Erosion hazard is defined as the susceptibility of land to wind or water erosion, and it takes into account the existing erosion, soil texture, surface cover, soil slope, and soil drainage and permeability. Soil Zone A has, in general, both a moderate water- and wind-erosion hazard. The sands of Soil Zone B have a moderate to severe wind erosion hazard and the other soil units have very slight or slight erosion hazard. Soil Zone C is characterized by a severe wind erosion hazard for most mapping units.

Mapping units that corresponded to large zones of actively moving sands were located in Soil Zones B and C. The units included, but were not restricted to, BE5, BE7, BE12, BE13, BE14, C1E1, C1E2, C1E3, and C1L3. Numerous other mapping units have had severe erosion but these units also contain areas of slight and moderate erosion. Corridors of sand movement were easily visible on the Landsat imagery.

The FAO Suitability Classification is used to categorize the agricultural potentials for mapping units. Three Suitability Ratings-- S2 moderately suitable, S3 marginally suitable, and SC conditionally suitable--were found to represent soils with potential for rainfed or flood-recessional agriculture. Nonsuitable Ratings--N1 currently nonsuitable and N2 permanently nonsuitable--described the majority of mapping units.

Mapping units with an S2 Suitability Rating were as follows: for recessional agriculture--AA1 (Component 1), AA2, BA1(1), BA2(2), BA4, BA8, and BE19(12) and for rainfed agriculture--AU4(1) and AU6--(Table 3-4). These mapping units have some limitations for use and they can be expected to yield moderate benefits from the necessary inputs. Common limitations for recessional units are churning clay (vertisolic), wetness, and inundation. The common limitations for rainfed agriculture are vertisolic clays, alkalinity, and profile gravel (for AU4). Proper management for the S2 mapping units should include fertilization, tillage, and crop rotation.

Mapping units with an S3 Suitability Rating were AU1(2) and AA1(2). These units are suitable only for rainfed agriculture. The soils of this category have severe limitations for the defined use and can be expected to produce only marginal benefits from the necessary inputs. The mapping units included in the Marginally Suitable class are sandy (moderately coarse-textured) and they are limited by droughtiness, low fertility, erosion, and erosion hazard. Fertilization, protection from wind erosion, and crop rotation and/or intercropping are the recommended management for these soils.

Mapping units with a Conditionally Suitable rating (SC) include AE1(1), AE2(1), AL1(2), BA7, BE2, BE6(2%), BE17, BL4(5% of 2), BU4(1), BU6(5% of 1) and BU10(10% of 1). The soils of these mapping units are sands and, rarely, sandy loams. The long-term 350 mm isohyet was determined to be the minimum precipitation required in order to be rated SC; BA7 receives less annual precipitation but benefits from runoff and by having sandy loam textures. The 350 mm isohyet was adopted on the basis of previous agro-hydrologic work, i.e., 80% of plant moisture requirement is received 8 of 10 years for 75-day varieties (Dancette and Hall, 1979). Common limitations for these soils are droughtiness, erosion hazard, and low fertility. In the past several years annual precipitation has been below the minimum for almost all these mapping units. These units are generally used for pasture and they produce high amounts of forage. Fertilization, protection from erosion, and disease- and insect-resistant varieties should be included in management plans when these soils are cropped.

Management practices and land improvement possibilities were briefly described for soils with agricultural potentials. Further research is required to insure that agronomic practices and crop varieties are optimal. Rainfall deficiency is the major limitation for agriculture throughout the project area; it is therefore imperative that variables that can be controlled by the farmer should be optimized to the greatest possible degree. Fertilization, crop rotation, animal tillage, proper weeding and thinning, good seed stock, and proper plant populations may be part of a complete management plan. Selection of management alternatives for the agronomic variables should be tailored to soil-climatic conditions.

Control of soil erosion, conservation of moisture, and maintenance of soil fertility and tilth are the major soil problems in the project area. Integrated management programs can be used to attack these soil problems. Residue management, tillage, strip cropping, and field windbreaks are among proven techniques to combat one or more of the above soil problems.

Land improvement options include contour dikes, terraces, and the inclusion of spillways for traditional dams. Careful site investigation and economic analyses are needed before any of these improvements should be implemented.

Table 3-4. Break-down of the mapping units with agricultural potential.

S2 Moderately Suitable For Cropping				S3 Marginally Suitable For Cropping		SC Conditionally Suitable For Cropping	
Recessional Agriculture		Rainfed Agriculture		Rainfed Agriculture		Rainfed Agriculture	
M.U.	Km^2	M.U.	Km^2	M.U.	Km^2	M.U.	Km^2
AA1(1)†	165	AU4(1)	427	AU1(2)	412	AE1(1)	72
AA2	260	AU6	100	AA1(2)	165	AE2(1)	448
BA1(1)	684					AL1(2)	99
BA2(2)	672					BA7	100
BA4	1,420					BE2	800
BA8	540					BE6(2%)	50
BE19(2)	284					BE17	135
						BL4(5% of 2)	38
						BU4(1)	1,048
						BU6(5% of 1)	48
						BU10(10% of 1)	35
TOTALS	4,025		527		577		2,873

TOTAL S2, S3, SC = 8,002 Km^2

TOTAL Project Area 150,400 Km^2

5.3% in S2, S3 and SC
2.6% in S2 Recessional
.35% in S2 Rainfed
.38% in S3
1.9% in SC

† Number in parenthesis refers to the component of a mapping unit (MU).

Mapping units with good potential for development of alluvial lands are BE3, BU2, BU5, AU1, AU2, AU3, AU4, and AU6; the alluvial soils of Soil-Climate Zone A have considerable agricultural potential without development. Mapping units with fair potential for development of alluvial lands are BE1, BE13, BE16, BL4, BL5, BU10, AU5, and AU6.

More agro-climatological research is needed to determine the likelihood of receiving minimally required soil moisture for various crop varieties. Location of small dams can be based on surface-runoff indices and statistically-derived precipitation distributions and amounts.

The soils and the climate of southwestern Mauritania co-exist in a fragile balance. The interaction between increased grazing pressure and low precipitation often leads to serious degradation of the environment. Protection of topsoil from wind and water erosion is best accomplished by maintenance of a good surface cover of vegetation. Throughout the project area severe erosion was observed. Soil Zone A has numerous crusted areas as a result of water and wind erosion while wind erosion was the major agent in the other soil-climate zones. Long-term range and forestry management appears to offer the best means of slowing land degradation.

Further development of flood-recessional agriculture appears to offer the best means of improving crop production in southwestern Mauritania. Fair potential for rainfed agriculture exists in only a small portion of the project area; crop production in these areas could be improved through increased inputs and better management programs. Potentials for irrigation were not included in this survey, but some areas appear to have groundwater close to the surface and these areas should be investigated further.

IX. REFERENCES

Ambroggi, Robert P. 1966. Water under the Sahara. Scient. Amer. 214(5):21-29.

Boyadgiev, T.G. 1978. Projet de recherche agronomique et de developpement agricole pour la mise en valeur du bassin du Sénégal. AG:DP/RAF/73/060. Rapport technique 1. PNUD, FAO, Rome. 158p.

Bradley, Phillip, Claude Raynaut, and Jorge Torrealba. 1977. The Guidimaka Region of Mauritania a critical analysis leading to a development project. War on Want, Caledonian Road, London. 172p.

Cannell, G.H., and L. V. Weeks. 1979. Erosion and its control in semi-arid environments. p224-237. In Hall, A.E., G. H. Cannell, and H. W. Lawton (ed.). 1979. Agriculture in semi-arid environments. Springler-Verlag New York. 340p.

Cary, John W., and Daniel D. Evans (eds.). 1974. Soil crusts. Tech. Bull. no. 214. University of Arizona Ag. Experiment Sta., Tucson. 58p. (mimeo).

Centre National de Recherche Agronomique et de Developpement Agricole (CNRADA). 1980. Perspectives de developpement agricole en RIM. Series of seminars. CNRADA, Kaédi. 39p.

Dancette, C., and A.E. Hall. 1979. Agroclimatology applied to water management in Sudanian and Sahelian Zones of Agrica. p. 98-118. In Hall, A.E., G.H. Cannell, and H. W. Lawton (ed.). 1979. Agriculture in semi-arid environments. Springler-Verlag New York. 340p.

Daveau, Suzanne. 1965. Dune ravinees et dépots du Quaternaire Recent dans le Sahel Mauritanien. Revue de Géographie de l'Afrique Occidentale (Dakar) No. 1-2:7-47.

Daveau, Suzanne. 1970. L'évolution géomorphologique guaternaire au aud-ouest du Sahara (Mauritanie). Annales de Géographie 79(431):20-38.

DRIG. 1981. Agronomic division action program rainy season 1981-82. Project Document. Developpement Rurale Integré, Guidimaka. Nouckchott. 16p. (translation).

Durand, J.H. 1974. Etude pedologique de la plaine de Boghé. L'Agronomic Tropicale: 1284-1316.

FAO. 1977. Guidelines for soil profile description. 2nd Ed. Food and Agriculture Organization, Rome. 66p.

Focht, D.D., and J.P. Martin. 1979. Microbiological and biochemical aspects of semi-arid agricultural soils. p.119-147. In Hall, A.E., G.H. Cannell, and H. W. Lawton (ed.). 1979. Agriculture in semi-arid environments. Springler-Verlay New York. 340p.

Frenkel, H., and A. Hadas. 1981. Effects of tillage and gypsum incorporation on rain runoff and crust strength in field soils irrigated with saline-sodic water. Soil Sci. Soc. Am. J. 45:156-158.

Gavaud, M. 1960. Etudes pedologiques des cuvettes argileuseo dans le cercle du Brakna. Centre de Pedologie de Hann - Dakar, Sénégal. 73p.

Hudson, Norman. 1971. Soil conservation. BT Batsford Limited, London. 320p.

INSTRUPA. 1979. Developpement rurale de la Région du Tagant. Rapport de Synthese (39p) and Annexes 1-6 with maps. SONADER, Nouakchott, Mauritania.

Ismom, W.H., and G. F. Worker. 1979. Crop management in semi-arid environments. p.200-223. In Hall, A.E., G.H. Cannell, and H. W. Lawton (ed.). 1979. Agriculture in semi-arid environments. Springler-Verlag New York. 340p.

Kipps, M.S. 1971. Production of field crops. 6th Edition. Tata McGraw Publishing Company Limited New Delhi. 790p.

Kraiem, Habib. 1980. Etude du sous-secteur de l'agriculture "en sec." Rapport preliminaire RAMS. USAID and Directorate of Studies and Programming, Ministry of Economy and Finance, Government of Mauritania, Nouakchott. 197p.

McCown, R.L., G. Haaland, and C. DeHaan. 1979. The interaction between cultivation and livestock production in semi-arid Africa. p.297-332. In Hall, A.E., G.H. Cannell, and H. W. Lawton (ed.). 1979. Agriculture in semi-arid environments. Springler-Verlag New York. 340p.

PNUD. 1977. Etude hydroagricole du bassin du Fleuve Sénégal. Rapport de synthese des etudes et travaux. AG:DP/RAF/65/061 Rapport Technique 1 PNUD, FAO, Rome. 310p. and maps.

RAMS. 1981. Agro-ecological zones of Mauritania. USAID and Directorate of Studies and Programming, Ministry of Economy and Finance, Government of Mauritania, Nouakchott. 197p.

SOGREAH. 1974. Aménagement de l'Aftout es Sahéli. Preliminary studies and master plan. Annex 3 - Pedalogical Report (Interim Report). IRM, SOGREAH, Nouakchott, Mauritania.

Soil Survey Staff. 1952. Soil survey manual. USDA Handbook No. 18. U.S. Gov. Printing Office, Washington 25, D.C. 503p.

Soil Survey Staff. 1975. Soil taxonomy a basic system of soil classification for making and interpreting soil surveys. Ag. Handbook No. 436, U.S. Gov. Printing Office, Washington. 754p.

SONADER. 1981. Etude pedologique de 15 curvettes des Régions du Brakna et du Gorgol. USAID, Nouakchott, Mauritania (mimeo).

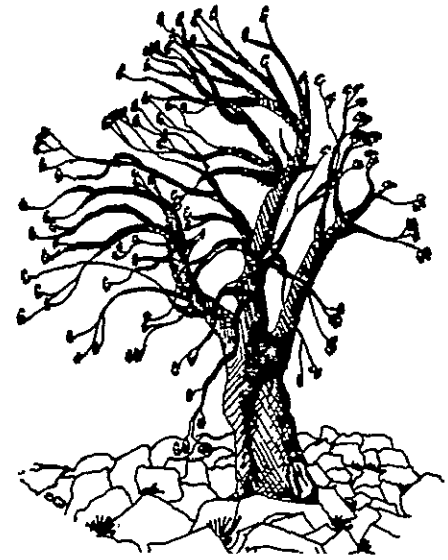
Thornbury, William B. 1969. Principles of geomorphology. 2nd Edition. John Wiley & Sons, Inc. New York. 594p.

Worcester, B.K., K.J. Dalsted, and D.G. Moore. 1978. Sahel-Sudano desertification study. Final report for USAID PIO/T No. 625-907-3-6786453. Remote Sensing Institute, South Dakota State University, Brookings, SD, USA 57007.

Worcester, B.K., and K.J. Dalsted. 1980. Soil manual for Mauritania. SDSU-RSI-80-11. Remote Sensing Institute, South Dakota State University, Brookings, SD, USA 57007.

Young, Anthony. 1976. Tropical soils and soil survey. Cambridge University Press, New York. 468p.

CHAPTER 4



FOREST COVER TYPES

I. INTRODUCTION

The southwestern corner of Mauritania, between the Atlantic coast and the 11th longitude (W.) and between the 15th and 18th latitudes (N.), comprises a highly diverse vegetative cover. Great differences are found from north to south, and the coastal zone supports a vegetative cover unlike any other in the country. These differences correspond closely to rainfall variations, groundwater conditions, topographic positions, and soils. In addition, the current condition and the composition of the plant communities reflect the influences of an extended drought during the late 1960's and 1970's, human exploitation, and grazing patterns.

Regions in which a severe mortality of one or several indigenous plant species has occurred are evident throughout southwestern Mauritania. The present plant communities reflect the mortality, but simultaneously help us learn which of the woody plants can persist through years of adverse growing conditions.

A forest cover type, as defined by the Society of American Foresters (1954), is "a descriptive term used to group stands of similar character as regards composition and development due to given ecological factors, by which they may be differentiated from other groups of stands." The nature of vegetation changes and the current status of the communities can be traced and represented best by maps of the cover types. To date, only one region of Mauritania, the Tagant, has been mapped in any detail for vegetative cover. The map and its accompanying report (INSTRUPA, 1979) are useful, but provide only general information on species composition within the mapping units. Institute Geographique National (IGN) maps at a scale of 1:200,000 show limits of of various vegetation units without providing any information on species composition, stocking density, or condition. The Atlas de la Republique Islamique de Mauritanie (1979) provides a very small scale map (1:6,500,000) of the whole of Mauritania. It is particularly interesting and useful as a comparative document. At such a small scale, however, one is severely limited by lack of detail.

The vegetation study conducted by Adam (1966) in the Aftout es Saheli provides invaluable information on the species composition of this diverse zone and outlines in great detail the effects that water, topography and soils have on the plant communities. Adam's purpose was to schematize vegetation changes along a single transect in the Aftout, approximately midway between the northern and southern limits of the zone. He felt sufficiently confident in the work to permit extrapolation of the data to other similar sites north and south of the transect. Therefore, we can use his data as baseline information; however, we must make modifications for the vegetation variations, especially with distance from the transect location.

The maps and reports discussed above furnish valuable, though limited, information on the vegetation of Mauritania. The accompanying forestry map provides data that until now have not been documented. It, therefore, complements these prior works. Specifically, this vegetation map and the accompanying text provide the following information on southwestern Mauritania:

(1) the forest cover types named after the principal species of the woody plant communities
(2) the approximate stocking density of the woody vegetation in number of stems per hectare
(3) the general condition of the vegetation within each mapping unit
(4) a detailed description of each major woody plant community with all associates cited
(5) when possible, a successional position either as climax, transitional or pioneer
(6) variants of the principal cover types.

(The forestry map and its descriptive legend are based on the statistical tendencies of the complete set of ground data. These ground data were deemed too extensive for inclusion in this report and are available to interested individuals through USAID, Nouakchott.)

II. MAPPING PROCEDURES

The forestry-cover-type map was based on interpretations from Landsat imagery (1972-1980), 1980-81 aerial photography, and ground-truth missions conducted between January and July of 1981. The final 1:500,000 map product was comprised of several distinct, yet continuous, processes and procedures: establishment of spectral signatures on the Landsat imagery, characterization and refinement of preliminary mapping units through ground data collection, compilation of ground data for descriptive purposes, and finalization of mapping unit boundaries and descriptions.

Spectral responses recorded by Landsat imagery indicated a very limited vegetative cover; however, the vegetation is actually extensive but lacking sufficient density. Soils and geology are often the major factors that influence spectral signatures on Landsat imagery. It became necessary to base initial mapping units in part, upon the spectral signatures of soils and geology. Ground data collection in these initial mapping units provided a means of adjusting boundaries to reflect plant communities.

Photographic coverage (1:50,000) enabled more detailed examination of spectral signatures in three parts of the study area (Fig. 1-3).

Circular plots (1/10 hectare) were placed within each unit. Plot data included counting and identifying woody species, estimating average height, counting woody plant regeneration, recording mortality, and assessing the condition of the vegetation. Plots (a total of 295) were placed where noticeable changes in vegetation occurred and when the new vegetation type was sufficiently extensive to warrant a separate unit. Otherwise, a differing type of vegetation was treated as a small inclusion in a larger unit, but was inventoried just the same and reported as less common associates of the principal plant components. The sampling was not random, nor was an attempt made to obtain enough samples per unit to perform statistical analysis of stocking density. Rather, the sample plots were selected upon qualitative criteria, namely representativeness.

The plot data were analyzed to determine, on a percentage basis, which species predominated in each cover type. Data from plots that belonged to the same cover type were pooled by principal species to present a comprehensive list of associates for each description, as well as the range of the other ground variables.

From the ground data, the aerial photography, and the computer-enhanced Landsat imagery, final forestry-cover-type units were established (a total of 47). These units are modeled after the Society of American Foresters (SAF) system of forest classification for North America (1954). Modifications of the SAF system were required to meet local conditions. These modifications are discussed below. Since this is a first attempt to classify Mauritanian forestry-cover types in this way, there are undoubtedly shortcomings. Some of these will be discussed in the results section.

Cover-type nomenclature was based strictly on the woody vegetation present at the time of sampling. Names were assigned on the basis of the species or combination of species that together accounted for at least 50% of the woody cover. Generally one or two names were sufficient to describe the principal components. Type names were given in the order of numerical importance within the association and only scientific nomenclature was used in order to avoid the often confusing common names.

Indicator species existed for several plant communities and helped primarily to designate geographic location of the cover type. Usually they did not dominate in the association.

No attempt has been made to avoid mixed cover types composed of species for which there were already pure cover types. For example, Type 12 is dominated by Balanites aegyptiaca, but this same tree is also found as a co-dominant in eight other cover types.

Variants of the cover types may, in some areas, become new cover types when additional field observation is carried out. For the purposes of this initial classification, when a cover type was observed only one time, it was treated as a variant of another type unless its extent on the ground justified separate classification.

The successional position of each community was determined on the basis of trends in the vegetation composition that were apparent in the field. The assessment took into account the condition of the living vegetation and the level of exploitation of the species constituting each community.

Variants of the cover types are woody communities whose principal components are generally the same, but whose associates differ because of topography, rainfall, exploitation or deaphic conditions. In the case of this study, more field observation may show that some of the 47 cover types should be treated as variants of the remaining types.

III. RESULTS AND DISCUSSION

The forest cover of the study area has been classified into 47 different types on the basis of species composition. The cover type descriptions are included in this section. Table 4-1 lists the names of each cover type and the composite percentage and area (km^2) occupied by each type within the study area. The study area encompassed 150,400 square kilometers.

The forest cover type map represents the first attempt to categorize the woody plant communities of southwestern Mauritania and undoubtedly contains delineations that need more field verification. A prominent limitation in the preparation of this map was the large amount and unequal distribution of ground truth data (295 sample plots). This limitation was due to inaccessibility, particularly the plateau regions of the Affolé and eastward.

The lack of easily identifiable landmarks throughout much of the study area made accurate location of all sampling plots on maps difficult. Roads currently in use do not always correspond to those indicated on the IGN maps of Mauritania, and some villages shown on these road maps no longer exist or have been moved to new locations. Nevertheless, the plot locations were deemed sufficiently accurate for the purposes of this study.

Another of the difficulties encountered during the preparation of the forest cover type descriptions was the determination of each community's successional position. In addition to natural factors that affect succession, all of Mauritania's plant communities suffer from varying degrees of exploitation by human and animal populations. Many plant communities, if not most, appear transitional as a result. Given the current patterns of exploitation, the existing cover types would appear to be yielding to types composed of the least desirable or least exploited species, or to types composed of the most persistent woody plant. In some areas the cover types are already at such a point. A list of important exploited species is as follows: Acacia senegal, Acacia nilotica, Acacia seyal, Acacia raddiana, Combretum glutinosum, Commiphora africana, Maerua crassifolia, Balanites aegyptiaca, Combretum aculeatum, and Borassus aethiopum. These species may be reduced in importance in southwestern Mauritania, with the exception of Balanites aegyptiaca, as exploitation continues to eliminate them from marginal areas and as environmental degradation continues to make more lands marginal.

Table 4-1. Forest cover types of southwestern Mauritania and percentage of study area occupied by each cover type

Cover Type	Name	Percentage	Square Kilometers
1	Acacia flava	7.41	11,140
2	Acacia nilotica	0.23	350
3	Acacia nilotica, Acacia macrostachya	0.08	120
4	Acacia nilotica, Acacia raddiana	0.08	120
5	Acacia raddiana	5.10	7,670
6	Acacia raddiana, Leptadenia pyrotechnica	7.70	11,580
7	Acacia raddiana, Acacia senegal	3.61	5,430
8	Acacia raddiana, Balanites aegyptiaca	4.42	6,650
9	Acacia senegal	3.44	5,170
10	Acacia senegal, Balanites aegyptiaca	4.13	6,210
11	Acacia seyal	0.53	800
12	Balanites aegyptiaca	9.06	13,630
13	Balanites aegyptiaca, Guiera senegalensis	0.87	1,310
14	Boscia senegalensis	4.06	6,110
15	Balanites senegalensis, Capparis decidua	3.52	5,290
16	Balanites aegyptiaca, Leptadenia pyrotechnica	0.48	720
17	Capparis decidua, Balanites aegyptiaca	0.72	1,080
18	Combretum glutinosum	2.15	3,230
19	Combretum glutinosum, Adansonia digitata	0.54	810
20	Combretum glutinosum, Sclerocarya birrea	0.60	900
21	Commiphora africana, Maerua crassifolia	3.50	5,260
22	Euphorbia balsamifera	1.48	2,230
23	Euphorbia balsamifera, Adenium obaesum	1.71	2,570
24	Euphorbia balsamifera, Salvadora persica	0.48	720
25	Euphorbia balsamifera, Tamarix senegalensis	0.30	450
26	Guiera senegalensis	0.61	920
27	Guiera senegalensis, Combretum glutinosum	0.98	1,470
28	Hyphaene thebaica	0.05	80
29	Leptadenia pyrotechnica	1.69	2,540
30	Mitragyna inermis, Balanites aegyptiaca	0.28	420
31	Commiphora africana, Acacia raddiana	9.61	14,450
32	Salvadora persica	0.41	620
33	Sclerocarya birrea	0.20	300
34	Tamarix senegalensis	0.81	1,220
35	Zizyphus mauritiaca	0.53	800
36	Zizyphus mauritiaca, Balanites aegyptiaca	2.08	3,130
37	Guiera senegalensis, Pterocarpus lucens	0.26	390
38	Commiphora africana, Pterocarpus lucens	2.83	4,260
39	Zizyphus mauritiaca, Mitragyna inermis	0.28	420
40	Acacia flava, Acacia seyal	0.06	90
41	Acacia nilotica, Acacia seyal	0.12	180
42	Balanites aegyptiaca, Acacia flava	3.00	4,510
43	Acacia nilotica, Anogeissus leiocarpus	0.15	230
44	Commiphora africana, Leptadenia pyrotechnica	2.57	3,870
45	Salvadora persica, Tamarix senegalensis	1.12	1,680
46	Acacia flava, Leptadenia pyrotechnica	2.16	3,250
47	Euphorbia balsamifera, Boscia senegalensis	3.35	5,040
+	Rock	0.35	530
x	Oua Oua	0.08	120
z	Lake R'Kiz	0.08	120
o	Agricultural Area	0.14	210

In the following section, descriptions of the 47 forest-cover types are identified and described for southwestern Mauritania. Consistent with the Society of American Foresters methodology, the principal components of the cover types are first defined along with all their woody associates and then a discussion of habitat and geographic location, successional position, and finally the description of variants of the cover type.

COVER-TYPE DESCRIPTIONS

Type 1: *Acacia flava*

Acacia flava predominates over any single associate. The most frequently observed associates are Balanites aegyptiaca, Zizyphus mauritiaca, and Capparis decidua. Other common associates are Acacia senegal, Calotropis procera, Combretum glutinosum, Combretum aculeatum, Maerua crassifolia, Acacia seyal, Boscia senegalensis, and Bauhinia rufescens.

Acacia flava usually grows in small groups, widely scattered on regs or hard-packed sandy soils, particularly in the Gorgol, southern Brakna, and in the Assaba to either side of the plateau systems. Extensive stands are found south of the paved road between Magta Lahjar and Chogar. The type occurs almost exclusively on level, hard surfaces at either low elevations. Such as in the Gorgol, or on plateaus. Soil characteristics dominate over elevations as a determining factor of type occurrence. Small patches also occur widely on zones of the Tagant plateau where reg soils are found.

This type is probably a climax community and may form when heavy grazing and cutting reduce the principal associate, Balanites aegyptiaca. It appears to be highly tolerant of very compacted soil conditions and limited water availability.

Variations in the type occur primarily near drainages where Zizyphus mauritiaca often becomes an important associate. Several zones include Boscia senegalensis as a dominant associate. These include sites between Guimi and Aleg and sites south of El Mechra on the Tagant Plateau. (See Fig. 4-1 for locations of these and ensuing geographical references).

Type 2: *Acacia nilotica*

Acacia nilotica grows in nearly pure stands. Associates include Capparis carymbosa, Acacia macrostachya, Mitragyna inermis, Zizyphus mauritiaca, Acacia albida, and Piliostigma reticulatum.

Acacia nilotica grows in pure stands on clay soils that are subject to inundation (Fig. 4-2). Extensive stands commonly occur in classified forests along the Senegal River and farther south along the river course in the western Guidimaka. Dense stands also occur in the Tamourt en Naaj on the west central Tagant plateau and in scattered large clay depressions north of Kiffa. Less extensive stands occur in drainages of the Gorgol region and along the Karokoro basin from Kankossa southward. The type depends heavily on yearly inundation.

Acacia nilotica is a climax community. When stands are mature and crown cover is essentially complete, little regeneration occurs. Heavy

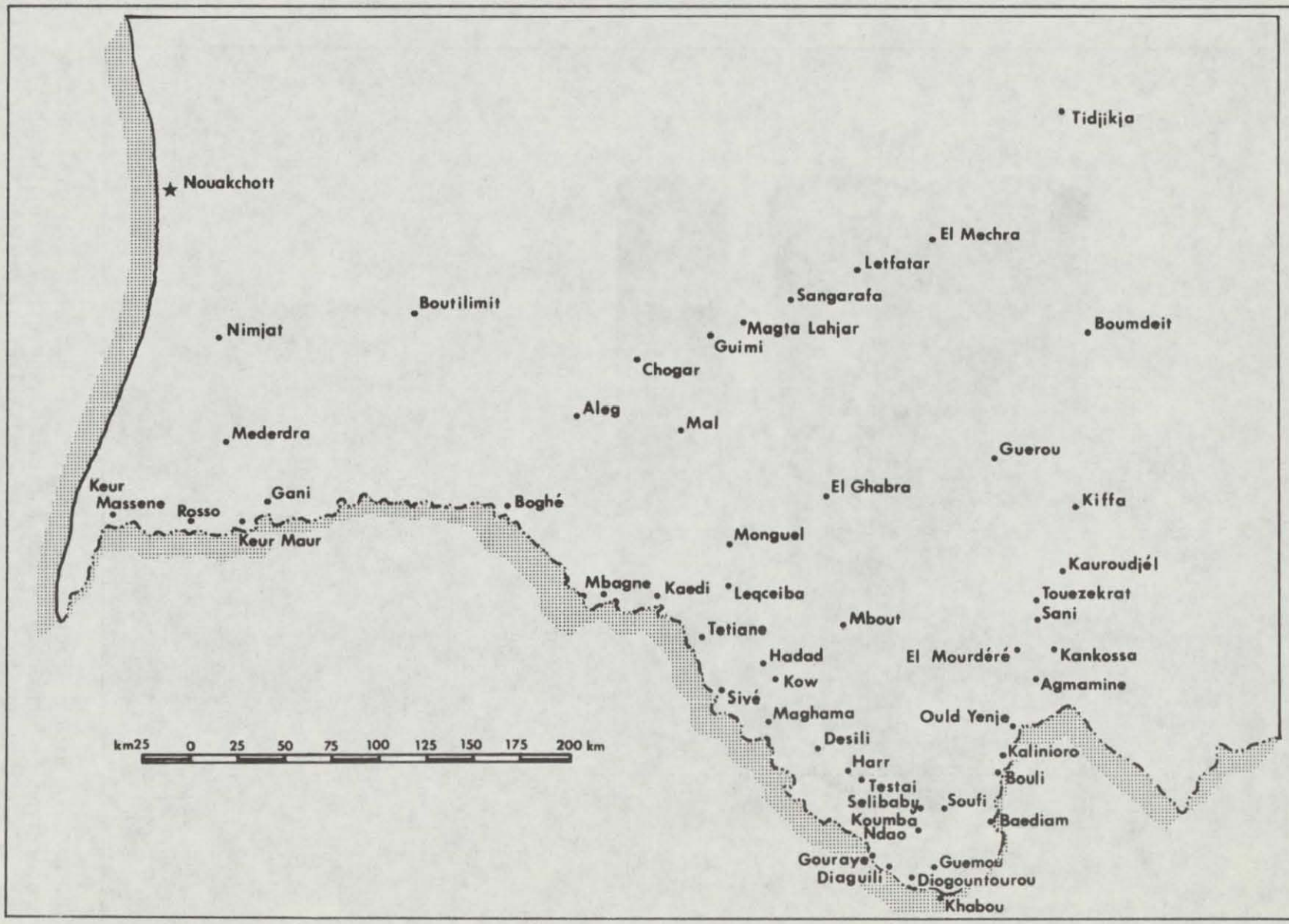


Fig. 4-1. City and village location map for the forest cover type chapter.

Fig. 4-2. A mature Acacia nilotica stand illustrates a typical setting for cover type 2. Understory tree and brush vegetation are noticeably absent. The photo was taken in the Senegal Valley at the forest near Silbé, west of Boghé.

exploitation for charcoal production and uncontrolled grazing threaten this cover type's existence.

The type is occasionally associated with Acacia seyal especially in the Guidimaka region near Harr.

Type 3. *Acacia nilotica, Acacia macrostachya*

Acacia nilotica predominates in this association. Acacia macrostachya occurs in heavy patches throughout, but serves mainly as an indicator species of geographic location. Common associates include Mitragyna inermis and Zizyphus mauritiaca. Other associates are Dichrostachys glomerata, Balanites aegyptiaca, Acacia flava, Capparis decidua, Acacia seyal and the herbaceous plant Indigofera oblongifolia.

The type commonly occupies drainages in the northwestern Assaba near El Ghabra but may also be found in small stands where drainages occur south of this location and in the Guidimaka. Soils are clayey and compacted in drainages and more sandy adjacent to them.

The type is probably climax although some associates, most notably Acacia seyal and Dichrostachys glomerata, are under heavy exploitation pressures.

Type 4. *Acacia nilotica, Acacia raddiana*

The type is composed primarily of Acacia nilotica and Acacia raddiana which together account for approximately 70% of the forest cover. The numerous associates include Zizyphus mauritiaca, Boscia senegalensis, Balanites aegyptiaca, Bauhinia rufescens, and Capparis decidua.

This type occurs in the Tamourt en Naaj on the west central Tagant plateau and extends throughout most of the oued north of El Mechra. Soils are clayey and subject to yearly flooding. Sand is gradually moving into the oued and supports an association of Acacia nilotica with Leptodenia pyrotechnica. Dense patches of Indigofera oblongifolia may occur around some of the forest stands.

With sand encroachment the type is transitional and yields to psammophilic species such as Leptodenia pyrotechnica. Acacia nilotica may eventually become a secondary species to Acacia raddiana and Balanites aegyptiaca as exploitation and edaphic conditions reduce its numbers.

Where exploitation has reduced the vegetation concentration, Balanites aegyptiaca or Boscia senegalensis become dominant species or dominant associates of Acacia raddiana.

Type 5. *Acacia raddiana*

Acacia raddiana dominates but rarely forms a pure stand. Principal associates include Balanites aegyptiaca, Leptadenia pyrotechnica, Acacia senegal, Capparis decidua, and Commiphora africana. The type is also associated occasionally with Boscia senegalensis and Maerua crassifolia, especially in southern parts of its range near Boghe and in several limited zones south of Boumdeit.

Acacia raddiana forms extensive moderately dense stands, particularly in sandy soils north of the east-west paved road. It is also common in the south where very sandy soils predominate, such as in the southern Trarza and Brakna regions. On the Tagant plateau it grows extensively but generally in thin stands where sands overlie regs or where sands have blown in from the east. Sandy soils and annual rainfall below 350 mm appear to be principal factors in range determination of the type.

Under completely natural conditions this is a climax forest type. It appears more drought hardy than Acacia senegal, one of its principal associates, and regenerates well by coppicing. Both principal associates, Acacia senegal and Balanites aegyptiaca, are more heavily exploited, one for its sap and the other for its browse desirability. This may also explain why the type forms a climax community.

Type 6. *Acacia raddiana, Leptadenia pyrotechnica*

Acacia raddiana and Leptadenia pyrotechnica predominate in the association which has as principal associates Commiphora africana, Maerua crassifolia, and Acacia senegal. Minor associates include Balanites aegyptiaca, Capparis decidua and Combretum aculeatum.

The type occurs extensively on sandy dune soils with sandy or sandy clay interdunes throughout the northern extent of the study area. The principal components and the principal associates colonize the dunes. The interdunes are characterized especially by the minor associates. Vegetation density is very light and varies from 25 trees per hectare in the most northern zones to about 150 trees per hectare in the south.

The type is climax, but the three principal associates tend to be overexploited and in poor condition.

Type 7. *Acacia raddiana, Acacia senegal*

Acacia raddiana and Acacia senegal are co-dominant in the type. Together they account for up to 90% of the woody plants that form the community. The principal associates are Balanites aegyptiaca and Leptadenia pyrotechnica. Other associates including Maerua crassifolia, Acacia seyal, Zizyphus mauritiaca, Bauhinia rufescens, and Combretum glutinosum appear only from Mederdra southwards (Fig. 4-3). Correspondingly, Leptadenia pyrotechnica and especially Maerua crassifolia become rarer members in these southern zones.

Heavy exploitation of Acacia senegal and Acacia raddiana is causing this type to yield to one whose principal component is Balanites aegyptiaca, Type 12. Evidence of this transition is common throughout the range of this type.

Type 8. *Acacia raddiana, Balanites aegyptiaca*

Acacia raddiana and Balanites aegyptiaca predominate. Associates are numerous but the most common ones include Capparis decidua, Zizyphus mauritiaca, Bauhinia rufescens, Acacia seyal, Leptadenia pyrotechnica, Commiphora africana, and Acacia senegal. Other associates include Calotropis procera, Combretum aculeatum and Acacia flava.

Fig. 4-3. Acacia raddiana (taller trees) and Acacia senegal dominate the woody vegetation in this interdune portion of cover type 7. Balanites aegyptiaca trees, the center-right of the photo (where sand dune begins), are a principal associate. The photo was taken near Mederdra.

The cover type is found south of Boumdeit, approximately 10 to 15 km northwest of Kiffa along the paved road toward Kamour, and west of Maghta Lahjar. It occupies soils that are either very sandy and support Leptadenia pyrotechnica, Commiphora africana and Acacia senegal, or soils that have a higher clay content and form parts of drainage systems.

The type occurs in fairly extensive stands at the locations cited and is probably the remnant of a community that formed from an association of Acacia raddiana, Balanites aegyptiaca and Acacia senegal. Due to exploitation and decline of the latter species, the type has taken its present form.

Where soils are very heavy, Acacia flava and Boscia senegalensis become predominant associates.

Type 9. *Acacia senegal*

Acacia senegal is strongly predominant and forms up to 90% of the tree species. Most common associates are Balanites aegyptiaca, Combretum glutinosum, Leptadenia pyrotechnica, and Combretum aculeatum. Other species that are commonly found in the northern extent of its range are Commiphora africana, Acacia raddiana, and Maerua crassifolia. In moister drainage systems it may occur with Acacia seyal, Guiera senegalensis, and Piliostigma reticulatum. Many other less common associates are found throughout the range of this type. These include Capparis decidua, Maerua angolensis, Calotropis procera, Leptadenia pyrotechnica, Acacia flava, Dalbergia melanoxylon, Adenium obaesum, Sterculia setigera, Grewia bicolor, Mitragyna inermis, Acacia nilotica, and Acacia dudgeoni.

The type occurs in sandy soils east of the Assaba Plateau, north of the paved road between Sangarafa and Aleg, the southern Brakna from Mal south to El Ghabra and west of Monguel. It is also common between Kaédi and Boghé, very common throughout the southern Trarza, and scattered in the Guidimaka, viz., south of Maghama, north of Baediam, Bouli and south of Kankossa. The most common habitat is on sandy dune soils, although the type occasionally occupies compact sandy soils near drainages. It tolerates drought conditions if not severely exploited for gum or cut for browse. Severe mortality results when drought combined with excessive exploitation weakens the trees.

Acacia senegal forms a climax community under natural conditions. However, due to the desirability of its products for humans and animals alike, it rarely escapes exploitation. Under these circumstances the type may be transitional to one dominated by Balanites aegyptiaca.

In the southern Trarza Acacia senegal yields to Acacia raddiana, Type 5, due to mortality of the former. North of the paved road in the Trarza it forms an association with Leptadenia pyrotechnica or Commiphora africana. Between Aleg and Chogar and south of Mal it forms an association with Boscia senegalensis.

Type 10. *Acacia senegal, Balanites aegyptiaca*

Acacia senegal and Balanites aegyptiaca form at least 50% of the association and have numerous associates. Among these are Acacia raddiana,

Combretum glutinosum, Zizyphus mauritiaca, Capparis decidua, Calotropis procera, Acacia seyal, Commiphora africana, Guiera senegalensis, Maytenus senegalensis, Bauhinia rufescens, Mitragyna inermis, and Leptadenia hastata. Combretum glutinosum and Zizyphus mauritiaca appear to be particularly characteristic.

The type is found in limited stands in the southern Brakna between Kaédi and Boghé, north of Lekseiba toward Monguel, and in several locations in the Guidimaka, particularly east of Selibaby. Soils are generally hard-packed sands overlying clay subhorizons. The type often occurs near drainages.

Natural regeneration of Acacia senegal tends to assure the permanence of the type, but, as with other stands of Acacia senegal, the species is susceptible to drought-provoked loss and heavy exploitation. Balanites aegyptiaca is often severely browsed but persists well in the association.

Under conditions of exploitation or drought loss, particularly of Acacia senegal, the type may be transitional to a community dominated by Balanites aegyptiaca. Otherwise it appears to be a climax community able to reproduce under itself and to maintain the dominant species.

Three principal variants exist. On shallow sandy soils, Boscia senegalensis may replace Balanites aegyptiaca as an associate. This is found northeast of Aleg and southeast of Mal in the southern Brakna. A second variant occurs on sand-covered regs in the vicinity of El Moudéré, where Commiphora africana replaces Balanites aegyptiaca as the principal associate. On the very sandy dune soils east of Boutilimit, Leptadenia pyrotechnica replaces Balanites aegyptiaca as an associate.

Type 11. *Acacia seyal*

Acacia seyal is heavily dominant in the type. The principal associate is Balanites aegyptiaca. Other common associates are Zizyphus mauritiaca, Combretum glutinosum, Mitragyna inermis, Acacia macrostachya, Combretum aculeatum, Piliostigma reticulatum, Grewia bicolor, Sclerocarya birrea, Sterculia setigera, Dichrostachys glomerata, Acacia nilotica, Acacia flava, Capparis dicidua, Boscia senegalensis, Pterocarpus lucens, Dalbergia melanoxylon, Maerua angolensis, Leptadenia hastata, and Acacia dudgeoni.

The type is found predominantly in the Guidimaka south of Selibaby in the vicinity of Koumba Ndao and Guemou, east of Selibaby near Soufi, between Selibaby and Harr to the northwest, and west of Diaguili. It also occurs southeast of Kaédi and north of Lekseiba toward Monguel. Between Tarf Tintara and Tarf Mzeimat (southwest of Kiffa) is a very extensive, dense stand. The type appears to proliferate only in flat lowland zones where soils tend to be hard-packed sands, sandy clays, or occasionally regs. Generally the type grows near drainages or where moisture conditions are among the most favorable.

Acacia seyal forms a climax community in the Guidimaka region where it is found largely as even-aged stands. On heavy soils or regs it may be transitional to a community of Balanites aegyptiaca or to one of Acacia flava. Acacia seyal is exploited for its bark, which is used for medicinal benefits. Southeast of Testai, Acacia seyal is in association with Balanites aegytiaca; both are in approximately equal numbers. Acacia seyal commonly grows in association with Zizyphus mauritiaca and Mitragyna inermis.

instance are Acacia nilotica, Piliostigma reticulatum, and Acacia macrostachya.

Type 12. *Balanites aegyptiaca*

Balanites aegyptiaca predominates over its associates and occasionally forms almost pure stands, especially when associates are severely exploited. This cover type is found in more varied conditions than any other in Mauritania. As such, it has very many associates; the most common of which are Zizyphus mauritiaca, Acacia senegal, Bauhinia rufescens, Combretum glutinosum, Acacia flava, Piliostigma reticulatum, Capparis decidua, Acacia nilotica, Acacia seyal, Guiera senegalensis, Acacia raddiana, Acacia sieberiana, Maytenus senegalensis, Mitragyna inermis, Leptadenia pyrotechnica, Boscia senegalensis, Combretum aculeatum, Leptadenia hastata, Sclerocarya birrea, and Commiphora africana.

The type occurs on all soils except those that are saline. Altitude or topographic position do not seem to affect the occurrence of the type, nor does limited rainfall. In spite of heavy browse damage by camels, Balanites aegyptiaca persists and regenerates. Pure, dense stands are found at the base of the Assaba from Tarf Bou Effra to south of Touezekrat. From the vicinity of Sani to Kiffa, extensive stands dominated by Balanites aegyptiaca proliferate. Other essentially pure stands are found along the Senegal River from Kaedi westward beyond Mbagne. Typical associates in this habitat include Bauhinia rufescens and Zizyphus mauritiaca. In the Guidimaka the type is found commonly between Harr and Selibaby, especially on regs or very-heavy soils. Between Selibabi and Guemou, north of Gouraye, near Baediam, and north of Ould Yenje the type also occurs extensively. Between Soufa and Mbout, Balanites aegyptiaca alone or in association with Acacia raddiana, forms the principal cover type on the reg soils. Along the paved road from Sangaraffa to Chogar the type is also found, although in this region it usually grows in association with a wide variety of other trees.

In interdune areas north of the east-west paved road, Balanites aegyptiaca often forms an association with Capparis decidua. Soils are characteristically heavy and the stands which form on them are generally dense.

Type 13. *Balanites aegyptiaca, Guiera senegalensis*

Balanites aegyptiaca and Guiera senegalensis form at least 60% of the type. Common associates include Combretum glutinosum, Sclerocarya birrea, and Zizyphus mauritiaca. Other associates that are often found are Piliostigma reticulatum, Sterculia setigera, and Dichrostachys glomerata. The remaining associates are numerous and include Combretum nigricans, Acacia senegal, Grewia tenax, Commiphora africana, Grewia bicolor, Combretum aculeatum, Acacia dudgeoni, Adansonia digitata, Acacia seyal, Pterocarpus lucens, Maytenus senegalensis, Borassus aethiopum, and Leptadenia hastata.

The type is found on sandy soils or loose sands overlying clays about 20 km northeast of Gouraye, slightly east of Selibabi and north of Kalinioro. The association occurs where a water source appears to be reliable, such as in a lowland situation.

The type is transitional to an association dominated by Balanites

aegyptiaca when lack of water or exploitation reduces the number of the associated species, or to an association dominated by Guiera senegalensis when water is rarely limiting, as is the case north of Kalinioro.

The type yields to an association in which Combretum glutinosum forms an important component. This occurs especially in slightly elevated locations.

Type 14. *Boscia senegalensis*

Boscia senegalensis forms at least 40% of the association, but usually accounts for approximately 70%. The most common associates are Zizyphus mauritiaca, Acacia flava, Capparis decidua, and Commiphora africana. Other associates include Balanites aegyptiaca, Acacia senegal, Guiera senegalensis, Calotropis procera, Maerua crassifolia, Grewia bicolor, Combretum aculeatum, Acacia raddiana, and occasionally Euphorbia balsamifera, Mitragyna inermis, Bauhinia rufescens, Combretum glutinosum, Pterocarpus lucens, Dichrostachys glomerata, Acacia seyal, and Acacia albida.

In the north on regs, Boscia senegalensis forms dense but patchy communities with Acacia flava, Capparis decidua, and Balanites aegyptiaca. Zizyphus mauritiaca is also a common associate. Near drainages the associates become more diverse and include Guiera senegalensis, Grewia bicolor, Mitragyna inermis, Bauhinia rufescens, Dichrostachys glomerata, and Acacia seyal. On sand-covered clays or on compact sands Acacia raddiana and Commiphora africana are often associated with Boscia senegalensis. West of Monguel on clay soils the principal associates become Pterocarpus lucens and Commiphora africana. Approximately 15 km southeast of Boghé the principal associate is Zizyphus mauritiaca. Soils are sandy clays over compacted sands.

The type is climax because most associates are desirable browse species or are otherwise severely exploited. These then contribute less to the composition of the type.

North of Boumdeit and west of Sangarafa on sand-covered regs, Boscia senegalensis forms associations with Capparis decidua, the two being in almost equal numbers and together forming almost 80% of the total woody vegetation.

Type 15. *Boscia senegalensis, Capparis decidua*

Boscia senegalensis and Capparis decidua generally represent between 55% and 90% of the woody vegetation. Within this cover type are numerous small inclusions dominated by Acacia flava. Associates of the cover type are numerous and reflect the changing nature of the soils as well as exploitation. The principal associates include Zizyphus mauritiaca, Commiphora africana, Calotropis procera, and Maerua crassifolia. Secondary associates are Grewia tenax, Grewia bicolor, Combretum aculeatum, Adansonia digitata, Leptadenia pyrotechnica, Acacia senegal, Acacia raddiana, and Balanites aegyptiaca. In several limited zones one also finds Mitragyna inermis, Bauhinia rufescens and Euphorbia balsamifera.

This type is found most commonly between Aleg and Guerou both north and south of the paved road. North of the road the type occupies very compact, flat, clay soils amidst large dunes. Stocking densities tend

to be very slight. South of the road soils vary from compacted clays to sandy clays with large inclusions of barren reg. Where sand accumulations occur, one finds Leptadenia pyrotechnica, Acacia senegal and Commiphora africana. Boscia senegalensis may be found in dense patches with abundant regeneration. It is rarely browsed or otherwise exploited. Capparis decidua and all other associates are exploited and generally heavily browsed with the exceptions of Adansonia digitata and Euphorbia balsamifera.

The type is transitional to one dominated by Boscia senegalensis since browse pressure is reducing the codominant species, Capparis decidua.

Type 16. *Balanites aegyptiaca, Leptadenia pyrotechnica*

The two principal components of this type account for up to 100% of the living woody vegetation. Associates include Acacia senegal, Acacia raddiana, Calotropis procera and rarely Acacia seyal and Combretum glutinosum in the south.

The type is found southeast of Lake Rkiz on very sandy soils in a zone of gently undulating dunes. This zone was formerly dominated by Acacia senegal; however, one now sees only vast expanses of dead Acacia senegal with an occasional living specimen. South in the zone Acacia raddiana is more common and one sees there the other associates as well. Stocking densities are generally low, especially at the northern limits of this type.

This cover type is tentatively placed as climax, given the unlikely chance that Acacia senegal will regenerate naturally in the southern Trarza and once again gain dominance. Current exploitation of all remaining species of the type will result in diminishing stocking densities.

Type 17. *Capparis decidua, Balanites aegyptiaca*

The principal components of this type account for approximately 80% of the woody vegetation. Boscia senegalensis and Acacia raddiana count among the relatively small number of associates. Others include Combretum aculeatum, rarely Combretum glutinosum, Zizyphus mauritiaca and Acacia flava.

This type is found in the ancient channel of the Senegal River which extends from Kaedi northward toward Aleg, west and southwest toward Rosso. Soils are compacted clays with some sand deposits. Surrounding Lake Aleg itself is a zone, several kilometers wide, of this cover type. Stocking densities are moderately high and vegetation, though regularly browsed, is vigorous.

Throughout its range this type forms a climax community although, browse pressure may act to reduce the importance of Capparis decidua in the future.

Type 18. *Combretum glutinosum*

Combretum glutinosum predominates over all associates and generally

forms between 50% and 90% of the community. The most common associates are Balanites aegyptiaca, Guiera senegalensis, Zizyphus mauritiaca, Leptadenia hastata, Acacia senegal, C. nigricans, Sclerocarya birrea, and Sterculia setigera. Other common associates include Commiphora africana and Piliostigma reticulatum. Numerous other woody associates of the species can be found. Among these are Acacia flava, Mitragyna inermis, Acacia seyal, Maytenus senegalensis, Bauhinia rufescens, Grewia tenax and Grewia bicolor. Adansonia digitata is also frequently seen as an associate.

Extensive stands of this type occur in the area roughly bounded by Kaedi, Lekseiba, Hadad and Sive. Soils are very sandy, but soil moisture conditions appear favorable to the development of somewhat dense stands dominated by Combretum glutinosum. Associates include Balanites aegyptiaca, Sclerocarya birrea, Guiera senegalensis, Pterocarpus lucens, and C. nigricans.

Southeast of Maghama the soils contain slightly more clay. The principal associate is Sterculia setigera. Others include Zizyphus mauritiaca and Balanites aegyptiaca.

On sandy loam soils in the vicinity of Koumba Ndao, south of Selibaby the principal associate is Guiera senegalensis. The remaining associates are diverse and include Mitragyna inermis, Dichrostachys glomerata, Acacia seyal, Grewia tenax, and Pterocarpus lucens.

Between Kalinioro and Agmamine westward toward the Assaba plateau, Combretum glutinosum dominates on loose sands. Principal associates include Combretum nigricans, Sclerocarya birrea and Balanites aegyptiaca.

Combretum glutinosum is often heavily exploited for charcoal production. As such it forms a transitional community. Climax communities may include Guiera senegalensis, Sclerocarya birrea or Balanites aegyptiaca.

Type 19. *Combretum glutinosum, Adansonia digitata*

Combretum glutinosum is the principal component of the cover type. Adansonia digitata is an indicator species for the southeastern Guidimaka. Common associates include Combretum aculeatum, Guiera senegalensis, Acacia seyal, Balanites aegyptiaca, Leptadenia hastata, Combretum nigricans, Sclerocarya birrea, and Sterculia setigera.

This type is found in the southeastern Guidimaka between Baediam and Khabou near and along the Karakoro basin. Adjacent to the basin the numbers of Adansonia digitata increase greatly to where it becomes a principal component along with Combretum glutinosum.

This type is climax in spite of traditional exploitation of Combretum glutinosum.

Type 20. *Combretum glutinosum, Sclerocarya birrea*

Combretum glutinosum forms approximately 70% of the woody plant community. Sclerocarya birrea is an indicator species of this type in the Gorgol near Maghama. In this cover type there are numerous inclu-

sions ranging from Acacia senegal to Guiera senegalensis. Additionally, the type has many associates. The principal ones are Guiera senegalensis, Combretum aculeatum, Zizyphus mauritiaca, Acacia macrostachya, Adansonia digitata, and Balanites aegyptiaca. Secondary associates include Sterculia setigera, Acacia albida, Bauhinia rufescens, Acacia seyal, Dichrostachys glomerata, Mitragyna inermis, and occasionally Maytenus senegalensis and Piliostigma reticulatum. Leptadenia hastata, Calotropis procera, and M. angolensis are rare associates.

This type is found in the vicinity of Maghama on sands to clayey sands. Numerous small drainages intersect the zone and account for the variety of associates. The larger drainages are typically inhabited by Acacia nilotica, Mitragyna inermis, Bauhinia rufescens, and other species. Soils tend to be clayey and vertic. Throughout the zone, trees are heavily exploited and overbrowsed. In spite of this abuse, vegetation densities are fairly heavy. Most of the secondary associates are found in more low land positions than the primary associates. Soil and water differences are responsible for the divergence, the secondary associates preferring clays and better water relations than the primary ones.

Under normal conditions this type would be climax, but exploitation and grazing threaten it at present. In addition, Sclerocarya birrea shows signs of decline in this region, probably due to former drought conditions. The transition of this cover type will probably tend towards one dominated by Guiera senegalensis, which seems able to reproduce prolifically. This species will be limited in its ability to spread because of its water dependence. Uphill sites may yield to a cover type dominated by Balanites aegyptiaca and Acacia senegal if this latter is not overexploited.

Type 21. *Commiphora africana, Maerua crassifolia*

The two principal components of this type account for approximately 80% of the woody vegetation. Associates are few and include Acacia raddiana, Balanites aegyptiaca, Leptadenia pyrotechnica, occasionally Acacia senegal, and rarely Capparis decidua.

The type occurs extensively north of the paved road between Nouakchott and Aleg. Soils are dominated by dune sands with an occasional clayey interdune. Vegetation density is usually slight with 25 to 125 trees per hectare. Both principal species of this association are heavily exploited, and Commiphora africana has, in addition, suffered heavy mortality during the years of drought.

This cover type is transitional to one dominated by Acacia raddiana or Maerua crassifolia. A regular decrease in the density of stocking of this type occurs as one passes from the western-most to the eastern-most extent of its range.

Type 22. *Euphorbia balsamifera*

Euphorbia balsamifera dominates in the cover type and forms between 50% and 75% of the plant community. The principal associates include Maerua crassifolia, Commiphora africana, Acacia raddiana, Balanites aegyptiaca,

Boscia senegalensis, Combretum aculeatum and the grass Panicum turgidum. Other species that occasionally occur in the type are Acacia flava, Jatropha chevalieri and Chrozophora brocchiana, a herbaceous plant.

Extensive stands of the type run parallel to the coast of Mauritania and form a band as wide as 25 km in parts. Soils are sandy throughout. Close to the coast Euphorbia balsamifera and its associates usually occupy dune crest positions. A small stand is found several kilometers east of Aleg on loose shallow sands over compacted sands and clays.

Other stands of this type are frequently found near and on the Tagant plateau system. Northwest of Lefta, a village north of Boumdeit, the type occurs on soft sand in a protected valley. On the eastern plateau the type occurs sporadically, especially where sand has been deposited on the reg surface. On the western Tagant the sand cover is far greater than on the east and the type is found here much more extensively (Fig. 4-4).

Where Euphorbia balsamifera grows it tends to form a climax community. The species itself is rarely browsed and unexploited by humans because of the irritating white latex it exudes when cut.

Type 23. *Euphorbia balsamifera, Adenium obaesum*

Euphorbia balsamifera dominates an association that includes numerous other woody species. Adenium obaesum is an indicator species for the eastern Tagant where reg soils predominate. The most common associates include Boscia senegalensis, Acacia raddiana, Balanites aegyptiaca, Maerua crassifolia and Commiphora africana. Less common associates are Acacia senegal, Capparis decidua, Acacia flava, Combretum glutinosum, Combretum aculeatum, Calotropis procera, Bauhinia rufescens, and occasionally Leptadenia pyrotechnica.

The type occurs only on the eastern Tagant where regs or rocks are surrounded by sand deposits (Fig. 4-5). Stands are scattered and may attain a stocking density of up to 200 plants per hectare. Growth of the vegetation is often stunted and exploitation is heavy. Where water collects in sufficient quantities, there are date palms (Phoenix dactylifera) and an occasional baobab (Adansonia digitata).

This type is transitional in those zones lacking heavy sand deposits to a community dominated by Balanites aegyptiaca and Boscia senegalensis. Where sand is collecting, Euphorbia balsamifera will continue to dominate the association and Leptadenia pyrotechnica will begin to increase in numbers.

Type 24. *Euphorbia balsamifera, Salvadora persica*

Euphorbia balsamifera forms up to 90% of the cover type. Associates include Acacia raddiana, Bauhinia rufescens, Commiphora africana, Tamarix senegalensis, and Maytenus senegalensis. Less common associates include Acacia senegal, Leptadenia pyrotechnica, Piliostigma reticulatum and Combretum glutinosum. Rarely, one finds Adenium obaesum in the association. Salvadora persica is an indicator species that appears principally in

Fig. 4-4. A typical setting for cover type 22 consists of Euphorbia balsamifera in association with Acacia raddiana, Acacia senegal, Boscia senegalensis, and Panicum turgidum. The rocky outlier in the photo center is part of cover type 23. The photo was taken northwest of Boumdeit near the base of the Tagant Plateau.

Fig. 4-5. Adenium obaesum (the flowering tree), a principal species of cover type 23, is shown on a rocky slope between Kaédi and Maghama. In this general area (cover type 13) the sandy plain (upper right of the photo) is dominated by a sparse stand of Piliostigma reticulatum and Combretum glutinosum

the most southwestern corner of Mauritania where high salinity characterizes the soils and water.

Stands are extensive with Euphorbia balsamifera almost always occupying dune crests and small hummocks. Salvadora persica is found in hollows with Tamarix senegalensis. Soils are sandy on dunes and hummocks, and clayey in hollows and depressions. The type occurs in southwestern Mauritania adjacent to the coastal zone. Several stands between Rosso and Keur Massene also include heavy concentrations of Maytenus senegalensis on upland, sandy sites.

This type appears to be a stable climax community that suffers little from human or animal exploitation. On the western edge of the type Tamarix senegalensis comes into the association, whereas Acacia raddiana is more common in the eastern part of the zone. Soil salinity seems to be an important factor in this regard.

Type 25. *Euphorbia balsamifera, Tamarix senegalensis*

Tamarix senegalensis dominates depressions and Euphorbia balsamifera dominates hummocks and small dunes. Associates in the depressions include Zizyphus mauritiaca and Arthrocnemum idicum, whereas those on hummocks and dunes include Commiphora africana, Acacia raddiana and very occasionally, Leptadenia pyrotechnica.

The type occurs extensively in the Aftout es Saheli in those zones characterized by numerous small dunes and depressions. The associates are clearly defined along lines of topography as are the major components of the cover type. On a larger mapping scale, this type would logically be separated into two pure types dominated by either Tamarix senegalensis or Euphorbia balsamifera.

This is a climax community whose principal species suffer little at present from grazing or human exploitation.

Type 26. *Guiera senegalensis*

The type is dominated by Guiera senegalensis, which accounts for an average of 75% of the woody vegetation. The primary associates include Combretum glutinosum, Acacia senegal, Commiphora africana, Grewia bicolor, Piliostigma reticulatum, Acacia seyal, Sterculia setigera, Balanites aegyptiaca, and Zizyphus mauritiaca. The many secondary, non-indicator associates include Pterocarpus lucens, Sclerocarya birrea, Dichrostachys glomerata, Boscia senegalensis, Mitragyna inermis, Anogoeissus leiocarpus, Acacia dudgeoni, and Adansonia digitata.

This cover type occurs mostly south of the line connecting Kaedi, Mbout, and Kankossa. Extensive stands grow between Tetiane, Maghama, Hadad and Kow. Other extensive stands are found southwest of Selibaby in the vicinity of Guemou, Diogountourou and Gouraye, and east of Selibaby near Soufi.

Drainages or basins near wadis characterize the habitat of the type. Soils are generally sandy, occasionally clayey or rarely with sand deposits on regs.

The successional position of the type is not clear, but without

over-exploitation either as browse or for human needs, the type seems to form dense climax communities. Its associates, however, are often heavily exploited and thereby reduced in importance as community members.

Type 27. *Guiera senegalensis, Combretum glutinosum*

Guiera senegalensis forms between 30 and 60% of the woody plants, and Combretum glutinosum accounts for 25 to 35%. The principal associates include Balanites aegyptiaca, Zizyphus mauritiaca, Mitragyna inermis, and Piliostigma reticulatum. Other common associates are Acacia senegal, Bauhinia rufescens, Dichrostachys glomerata, Sterculia setigera, Sclerocarya birrea and Combretum nigricans. There are numerous other associates, most of which are characterized by their apparent occupation of sites with dependable water resources. These include Acacia nilotica, Dalbergia melanoxylon, Terminalia avicennioides, Pterocarpus lucens, Acacia seyal, Acacia sieberiana, Acacia dudgeoni, Borassus aethiopum, Hyphaene thebaica and Adansonia digitata.

The type occurs primarily in the Guidimaka with one additional large stand near the village of Dolol, northwest of Maghama. Other stands are found near Gouraye, east of Selibaby and north of Baediam. Soils tend to be sands or sandy clays near drainages.

As Combretum glutinosum is removed for charcoal production, the type will become dominated by Guiera senegalensis and one or several of its associates. The type is, therefore, transitional under present circumstances.

Between Desili and Harr in the Guidimaka, the principal associate of Guiera senegalensis is frequently Dichrostachys glomerata. Secondary associates in this community are Combretum aculeatum, Combretum glutinosum, Acacia seyal, Sclerocarya birrea, Sterculia setigera, and Acacia dudgeoni.

Type 28. *Hyphaene thebaica*

Hyphaene thebaica accounts for at least 50% of the tree vegetation. Common associates may include Phoenix dactylifera, Combretum glutinosum, Zizyphus mauritiaca, Guiera senegalensis, Mitragyna inermis, and Piliostigma reticulatum. Less commonly one finds Acacia senegal, Maytenus senegalensis, Leptadenia hastata, Dichrostachys glomerata and Commiphora africana.

The type is found in or near the Karakoro basin from Kouroudjel to Baediam and in the southwestern Trarza near Rosso. It usually occupies clayey depressions, but where the water table seems to be high, it may occupy higher positions in sandy soils. This is frequently the case along the Karakoro. The doum palm (Hyphaene thebaica) grows in clusters or singly and has stocking densities between 50 and 120 per hectare. The total stocking density can be considerably greater where doum occupies depressions.

Type 29. *Leptadenia pyrotechnica*

Leptadenia pyrotechnica represents between 50 and 85% of the vegetative cover. Associates are limited in types to Balanites aegyptiaca, Acacia raddiana, Acacia senegal, Maerua crassifolia, Commiphora africana,

the grass Panicum turgidum, and less commonly to Calotropis procera, Acacia flava, Capparis decidua, and Combretum aculeatum. Woody vegetative cover is usually sparse, the number of stems varying between 25 and 220 per hectare. However, when the tuft grass, Panicum turgidum, is present, the total plant cover may reach approximately 1000 per hectare.

The type occurs primarily on loose dune soils; although, it sometimes is found on compacted sands and rarely on sand covered regs. It is most commonly seen from slightly west of Boutilimit almost to Aleg, north of Chogar, slightly north of Kouroudjel, and on dunes between Sangarafa and Letfatar. On the western Tagant small patches exist alone or, curiously, with Acacia nilotica where sands have been deposited.

The successional position of the type is not certain, but occasionally it is browsed and/or exploited for roofing materials or mats, thereby reducing its numbers.

Type 30. *Mitragyna inermis, Balanites aegyptiaca*

Balanites aegyptiaca accounts for 30 to 60% of the woody vegetation. Mitragyna inermis is an indicator species whose stocking density often makes it a prominent member of the plant community. The most common associates are Guiera senegalensis, Combretum glutinosum, Zizyphus mauritiaca, Combretum aculeatum, Acacia nilotica, Acacia senegal and Acacia seyal. Secondary associates include Sterculia setigera, Acacia dudgeoni, Acacia sieberiana, Adansonia digitata, Anogoeissus leiocarpus, Ficus dicranistyla, Ficus gnaphalocarpa, Grewia bicolor, Leptadenia hastata, Sclerocarya birrea, Bauhinia rufescens, Piliostigma reticulatum, Capparis tomentosa, Tamarindus indica, and Maytenus senegalensis.

The type occupies principally the Guidimaka in or near drainages or in large depressions. It is also common along the Senegal River between Diogontourou and Gouraye. Soils vary from loose sandy clays to heavy compacted clays that receive abundant water during rainy periods. Mitragyna inermis is the most common hydrophilic tree where the type is found and serves as the best indicator.

Many of the principal and secondary associates along with the principal components of the type are heavily browsed. In spite of this, the the type is climax community. The associates vary widely from site to site where the type occurs, probably due to differing exploitation pressures.

Type 31. *Commiphora africana, Acacia raddiana*

The two principal species of this type account for up to 85% of the woody vegetation. The associates are limited to Acacia senegal, Leptadenia pyrotechnica, Maerua crassifolia, Balanites aegyptiaca, Capparis deciduaand rarely Combretum aculeatum. Found within the principal cover type to the north of its range are inclusions of plant communities dominated by Boscia senegalensis.

This type covers extensive territory in the northwestern section of the study area. Soils are predominantly sandy with occasional limited zones of clayey interdunes. Sand dunes cover most of the extent of

this type.

Vegetation stocking densities are low and generally fall within the range of 15 to 125 trees per hectare. Inclusions, where Boscia senegalensis predominates, have slightly higher stocking densities with a maximum of 175 plants per hectare.

This type is transitional to a type dominated by Acacia raddiana. Heavy mortality and exploitation have reduced Commiphora africana throughout the zone.

Type 32. *Salvadora persica*

Salvadora persica is the principal component of this type and accounts for up to 80% of the woody vegetation. Associates are numerous and include most commonly Tamarix senegalensis, Balanites aegyptiaca, and Acacia nilotica. Other common associates are Maytenus senegalensis, Mitragyna inermis, Piliostigma reticulatum, and Bauhinia rufescens. Less common associates are Acacia albida, Acacia seyal, Acacia senegal, Acacia sieberiana and the herbaceous plant Indigofera oblongifolia.

This type is found along the Senegal River between Gani and Rosso, with the heaviest concentrations in the region between Gani and Keur Maur (Fig. 4-6). It occupies flat, compacted clays to sandy clay soils of the river floodplain. The presence of Tamarix senegalensis and the gradual shifting to a community dominated by this species in the extreme southwest also indicate the limit of saltwater penetration up the Senegal River.

Salvadora persica grows in dense patches that give heavy crown cover and largely exclude colonization by other plants. In some sites Salvadora persica forms almost pure, dense stands.

This type appears to form a climax community given current patterns of exploitation and browsing.

Type 33. *Sclerocarya birrea*

Sclerocarya birrea generally represents between 35 and 50% of the woody plant community. It is almost always associated with Combretum glutinosum, frequently with Guiera senegalensis and Pterocarpus lucens, and variably with Sterculia setigera, Commiphora africana, Leptadenia hastata, Acacia senegal, Grewia tenax, Maerua angolensis, Dichrostachys glomerata, Combretum aculeatum and occasionally with Adansonia digitata, Combretum nigricans, Balanites aegyptiaca, and Grewia bicolor. A rare associate is Acacia macrostachya.

Sclerocarya birrea and its numerous associates prefer upland sandy soils with good drainage characteristics. The type is found in limited zones near or in the Guidimaka and between Hadad and Tétiane. The terrain is undulating and broken up by rocky outcrops, especially as one approaches Tétiane.

Sclerocarya forests are among the least exploited of Mauritania. Nevertheless, the tree has suffered some mortality due to drought conditions.

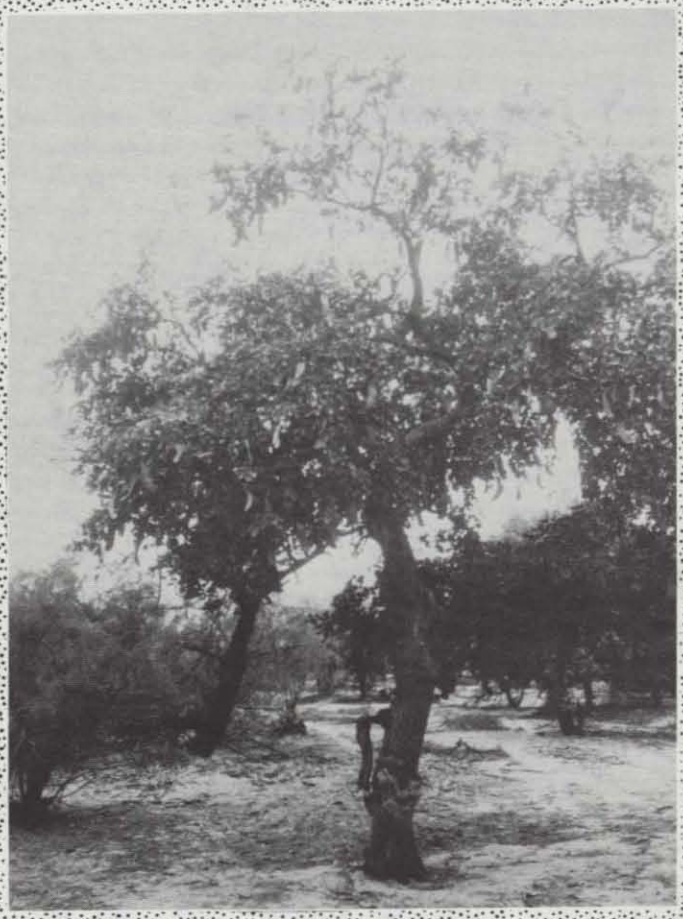


Fig. 4-6. A Piliostigma reticulatum (tree in foreground) is shown in a small walo (i.e., floodplain lowland) east of Rosso toward Keur Maur. Tamarix senegalensis (background) indicates soil salinity in this unit (cover type 32).

These forests are also characterized by large trees and light stocking densities. Crown closure of the forests is often heavy due to the large size of individual crowns.

The type appears transitional to forests dominated either by Combretum glutinosum or by Pterocarpus lucens.

Type 34. *Tamarix senegalensis*

Tamarix senegalensis dominates over all associates and forms up to 90% of the community. Associates include Salvadora persica on hummocks and other salt-tolerant species in hollows and depressions. These associates include Arthrocnemum indicum, Nitraria retusa, rarely Acacia raddiana and Indigofera oblongifolia.

The type is found in the Aftout es Saheli and in the Senegal River basin west of Gani. It generally occupies heavier soils that appear to have a shallow aquifer of saline or brackish water. Communities tend to be very dense throughout the range of the type but great differences in height of plants exist. In the southern extent of its range, the trees attain approximately 3 meters in height, whereas in the northern limits, the plant forms extensive stands barely one-half meter in height.

Because of its salt-tolerance, the type forms a climax community, but one that is nevertheless often heavily browsed by camels and other domestic animals.

Type 35. *Zizyphus mauritiaca*

Zizyphus mauritiaca represents between 50 and 70% of the woody vegetation. Its most common associates are Balanites aegyptiaca, Bauhinia rufescens, Acacia seyal, and Acacia flava. Other associates include those commonly found along drainage channels such as Anogoeissus leiocarpus, Piliostigma reticulatum, Acacia nilotica, Dalbergia melanoxylon, and Grewia bicolor. The remaining associates include Acacia senegal, Combretum aculeatum, Combretum glutinosum, Leptadenia hastata, Capparis decidua, Maerua crassifolia, and Boscia senegalensis.

The type is generally found near sandy drainages in areas dominated by regs. The occurence is most common between Kiffa and Leqceiba, an area characterized by extensive reg soils and numerous narrow drainages. Both the principal component and many of its associates are often heavily browsed or exploited for wood, bark or fruit. Nevertheless, the type reproduces prolifically under itself, and this appears to guarantee its continuance as a type. The successional position of the type is not certain.

Type 36. *Zizyphus mauritiaca, Balanites aegyptiaca*

The two principal species of this type account for up to 80% of the woody vegetation. The principal associates are Acacia senegal, Acacia flava, and Acacia seyal. Secondary associates are Combretum glutinosum, Combretum aculeatum, Calotropis procera, Adansonia digitata and Bauhinia rufescens. Rarely, one finds Piliostigma reticulatum and Capparis decidua in the association.

The type is found most frequently and extensively in the region between Mekessm and Selibaby to the south. The two main components of the type are found in approximately equal numbers. Soils vary from sandy clays to compacted clays and are generally dissected with drainages. Occasionally regs may be found near the type, particularly when Acacia flava is one of the primary associates. Stocking densities vary greatly, but generally fall in the range of 300 to 450 plants per hectare.

The type is climax and its persistence is guaranteed by the ability of the principal components to withstand browse pressure and exploitation for fruit. Only several of the main associates are threatened with reduction in numbers by overexploitation.

Type 37. *Guiera senegalensis, Pterocarpus lucens*

Guiera senegalensis predominates in this type as the principal woody plant, but Pterocarpus lucens is the most important large tree found in the association. Other woody plants of the type include Commiphora africana, Combretum glutinosum, Boscia senegalensis, Maerua crassifolia, and less commonly Grewia tenax, Sterculia setigera, and Adansonia digitata.

The type is found in the region east and southeast of Kaédi between Hadad, Tétiane and Sivé on the river. It occupies very sandy soils with interspersed outcroppings of rock on undulating terrain. The stocking density can be very high, with 1250 plants or slightly more per hectare, most of which are Guiera senegalensis. Pasture grasses are also abundant since this type is found in one of the least utilized areas of southwestern Mauritania.

Browse pressure appears very slight as does human exploitation of the available wood. Unless this changes, the type will remain identifiable; although, Pterocarpus lucens may be reduced to a role as an indicator species rather than an important member of the community.

Type 38. *Commiphora africana, Pterocarpus lucens*

The two principal species of this cover type account for 40% to 65% of the woody plant vegetation. This community is one of the most diverse and includes many associates. Principal ones are Combretum glutinosum, Grewia bicolor, Zizyphus mauritiaca, Bauhinia rufescens, and Boscia senegalensis. The secondary associates include Acacia seyal, Combretum nigricans, Sterculia setigera, Adansonia digitata, Mitragyna inermis, Combretum micranthum, Balanites aegyptiaca, Sclerocarya birrea, Dalbergia melanoxylon, Capparis tomentosa, Acacia dudgeoni, Anogoeissus leiocarpus, Adenium obaesum, and Acacia senegal.

This type occurs on the southern Assaba plateau and in the very rocky terrain of the southeastern corner of the study area (Fig. 4-7). Soils on which one finds the abundant vegetation tend to be sandy to sandy clay with frequent rock outcroppings. The topography varies from flat to gently sloping, but the type never occupies the steep slopes immediately adjacent to large rock outcroppings. Exploitation by animal herds is slight because of the light plant population. Shallow

Fig. 4-7. Euphorbia balsamifera, Dichrostachys glomerata, Boscia senegalensis, Guiera senegalensis, Acacia senegal, and Pterocarpus lucens are among the species that occupy a rocky site on the eastern face of the Assaba Plateau (cover Type 38). In the center of the photo, a lower, nearly level area is dominated by Balanites aegyptiaca with some Combretum glutinosum (cover Type 12), while nearby, high sand dunes are part of cover Type 8. The photo was taken northwest of Kankossa (near Samoga).

groundwater or available soil moisture for plant growth appears to be favorable, especially on the southern Assaba. This permits a surprisingly dense stocking of woody plants amidst the rocks.

This type is climax under current conditions of exploitation.

Type 39. *Zizyphus mauritiaca, Mitragyna inermis*

The two principal species of the type usually dominate the plant community, but Balanites aegyptiaca or Acacia seyal may predominate locally. The many associates include most commonly Combretum aculeatum, Leptadenia hastata, Grewia bicolor, Balanites aegyptiaca, and Acacia seyal. Secondary associates are Guiera senegalensis, Combretum glutinosum, Acacia senegal, Acacia nilotica, Anogeissus leiocarpus, Pterocarpus erinaceus, Bauhinia rufescens, Piliostigma reticulatum, Acacia macrostachya, and Adansonia digitata. Dichrostachys glomerata is also occasionally found, as is Pterocarpus lucens.

This type is found throughout the drainage systems of the Guidimaka and southern Gorgol. Soils are invariably sandy clays or compacted clays. Within the drainage systems themselves are found the typical hydrophilic species of the type. These are Zizyphus mauritiaca, Mitragyna inermis, Acacia nilotica, Anogoeissus leiocarpus, Bauhinia rufescens, Piliostigma reticulatum, and Acacia seyal. Bordering the drainages are the remaining species of the association.

Mitragyna inermis is often severely browsed by camels and other animals. Zizyphus mauritiaca is the source of a highly desirable fruit and is often abused during fruit gathering. In spite of browse pressure and abuse, these two trees remain as a climax community because they persist well in the association.

Type 40. *Acacia flava, Acacia seyal*

Acacia seyal and Acacia flava form up to 95% of the woody plants in this type. The associates are limited to Balanites aegyptiaca, Capparis decidua, Acacia senegal, Zizyphus mauritiaca and an occasional doum palm (Hyphaene thebaica).

The type occupies an extensive region between the Tarf Tintara and the Tarf Mzeimat (southwest of Kiffa). Acacia flava occupies the southern end of this valley and Acacia seyal occupies the greater part of the basin itself, with some intermixing throughout. Soils vary from sandy loams in the south to rocky terrain in the central parts of the valley.

The type is climax in spite of exploitation patterns. Both species reproduce prolifically to form extensive dense stands. Stocking densities may be very heavy with as many as 1250 stems per hectare.

Type 41. *Acacia nilotica, Acacia seyal*

Acacia nilotica and Acacia seyal form the large percentage of woody plants in this type. Together they account for approximately 70% of the

members. The principal associates are Acacia albida, Balanites aegyptiaca, Zizyphus mauritiaca, and Bauhinia rufescens. Other associates include Guiera senegalensis and Mitragyna inermis.

This is another drainage channel type of the Guidimaka region. It also is found in several forests that lie along the Senegal River southeast of Kaedi. Soils are clayey and usually compacted. All members of this type are severely exploited by grazing or for wood products.

The type is transitional to one dominated by Acacia seyal, since the Acacia nilotica will eventually be eliminated in the search for suitable firewood.

Type 42. *Balanites aegyptiaca, Acacia flava*

Balanites aegyptiaca and Acacia flava form up to 80% of the woody plants in this type. There are numerous associates, but the principal ones are Boscia senegalensis, Capparis decidua, Maerua crassifolia, and Zizyphus mauritiaca. Less common associates include Combretum glutinosum, Bauhinia rufescens, Acacia senegal, and Acacia seyal. Rarely, one finds Dalbergia melanoxylon and Acacia raddiana.

This type occupies extensive regions of predominantly reg soils in the Gorgol, western Assaba, and southern Brakna regions. In addition to regs, one commonly finds compacted sands and clays. The stocking density varies greatly from no plants on pure regs to maximum densities of 850 plants per hectare. Such concentrations are local and, in general, the regions must be described as very sparsely vegetated with virtually all the vegetation concentrated in scattered dense patches. The drainages of these regions are characterized by somewhat different woody plants, but occasionally it is only the concentrations of the species mentioned above that change.

This cover type is climax and appears stable under current conditions. All plants of the association are exploited to a certain extent, but they seem capable of remaining firmly fixed in the region.

Type 43. *Acacia nilotica, Anogoeissus leiocarpus*

Anogoeissus leiocarpus is an indicator species of this type and is located in the region of the Oued Ketchi in the central Brakna. Acacia nilotica is the characteristic species in this very large drainage channel. The principal associates include Boscia senegalensis, Balanites aegyptiaca, Zizyphus mauritiaca, Capparis decidua, and Grewia bicolor. Secondary associates are Combretum aculeatum, Acacia seyal, Maerua crassifolia, and Boscia angustifolia.

The type is characteristic of the very large drainage called the Oued Ketchi of the central Brakna (Fig. 4-8). This appears to be a transition zone from slightly more moist conditions to the south to the very arid and sandy conditions to the north where only Acacia raddiana and Commiphora africana plus several associates are found. Stocking densities are moderately high due to the high concentration of Acacia nilotica, which is typically found in such drainages. Maximum concentra-

Fig. 4-8. An Anogeissus leiocarpus (tree in photo center) is associated with the smaller Zizyphus mauritiaca (foreground left) and Boscia senegalensis (foreground right) in cover Type 43. The photo was taken in the Oued Katchi, south of Chogar.

tions reach 480 plants per hectare only in the drainage channel itself. With the sole exception of Boscia senegalensis all other species are exploited either for wood products or as browse by animals.

This type is climax and only increased pressure on the trees for their products will greatly alter the composition of the community.

Type 44. *Commiphora africana, Leptadenia pyrotechnica*

This cover type includes few plants other than the two principal components. Occasionally, one finds Acacia raddiana, Calotropis procera, and Maerua crassifolia in the association.

The type occupies dune soils that are generally unstable. Vegetation stocking densities are slight due to the inability of plants to colonize the moving sands. As elsewhere, Commiphora africana has suffered moderately high mortality during the drought years. Leptadenia pyrotechnica is often heavily grazed and in poor condition.

It appears that this type is climax but may be gradually declining as reproduction of the components becomes less and less assured.

Type 45. *Salvadora persica, Tamarix senegalensis*

Both principal components, Salvadora persica and Tamarix senegalensis, occur in approximately equal numbers in the community. Associates include Acacia senegal, Balanites aegyptiaca, Maytenus senegalensis, occasionally Commiphora africana and Acacia raddiana, and Euphorbia balsamifera. Interspersed in the community are patches of essentially pure Acacia nilotica.

Stands are dense and extensive between Gani and Rosso in the southern Trarza. Soils occupied are generally clayey and may have watertables that become saline during the last months of the dry season. The type occupies very compacted soils on level terrain.

Although Salvadora persica is often heavily browsed, the type seems to be a stable climax community.

Type 46. *Acacia flava, Leptadenia pyrotechnica, Acacia raddiana*

The three components in the type account for about 65% of the woody plants. Associates vary according to the soil type, and include Boscia senegalensis, Commiphora africana, Acacia senegal, Balanites aegyptiaca, Capparis decidua, rarely Acacia seyal and in drainage areas Zizyphus mauritiaca and Guiera senegalensis.

This type occupies a variety of soils from regs to regs covered by deposits of aeolian sand, to clays and sandy clays. Rock outcroppings throughout the regions characterize the type. Species that normally occupy reg soils include Acacia flava and Boscia senegalensis, although the latter species also colonizes more compacted sandy soils. Leptadenia pyrotechnica and Acacia raddiana occupy principally sandy soils that

overlie more compacted soils that are either sandy or clayey and occasionally are reg. Where temporary drainages exist one finds Acacia seyal, Guiera senegalensis, and Zizyphus mauritiaca, with Acacia seyal occuring rarely in the association.

The type is climax and appears stable. Stocking densities vary greatly due to the characteristic way in which Acacia flava forms small, but very dense stands; and Léptadenia pyrotechnica and Acacia raddiana form very sparse, extensive stands.

Type 47. *Euphorbia balsamifera, Boscia senegalensis*

The type is characterized by few woody plants other than the two principal components (Euphorbia balsamifera and Boscia senegalensis). Associates include Adansonia digitata, Maerua crassifolia, Grewia bicolor, occasionally Commiphora africana and Capparis decidua plus Balanites aegyptiaca. Other associates include Combretum glutinosum, Combretum aculeatum and Acacia raddiana.

This type occupies compacted clays to sandy clays. Small stands are east of Aleg, while more extensive stands can be found east of the plateau systems. Currently in this community, Grewia bicolor is on the decline as it has suffered heavy losses during the drought period. Adansonia digitata is not abundant in the association, but is, as always, very visible, especially near temporary drainages.

The stocking densities are moderately high due primarily to the prolific reproduction of Boscia senegalensis and the dense nature of Euphorbia balsamifera stands.

Since neither principal species of this type is browsed or otherwise exploited, the type is climax and stable.

Type +. *Bare Rock*

Throughout the plateau region of south central Mauritania are numerous barren rock formations resembling buttes. Although they generally fail to meet the minimum surface area for mapping purposes, they do serve as valuable markers for site identification and, therefore, are encircled and given a separate designation. They support only the most sparse herbaceous cover and rarely any woody vegetation on their precipitous slopes. The summits are inaccessible, but we can assume there would be some scrubby, very sparse woody plants occupying these sites. In spite of this, the designation as bare rock is reasonably accurate.

Type 0. *Agricultural Areas*

Kaëdi, Mbagne, Rosso, and Keur Massene are sites of large-scale cultivated or flooded areas. During and after the rainy season, these areas are covered either by corn, millet or rice or by aquatic herbaceous vegetation. Tree cover is essentially absent in these areas with only an occasional Acacia albida, Piliostigma reticulatum, Tamarindus indica, or Mitragyna inermis between fields. This Type and Type + do not constitute forest cover types, but are sufficiently prominent and important to merit designation.

Type X. *OuaOua - Gorgol*

The ridge formations known as the OuaOua run north-south in the Gorgol region of southern Mauritania. On and between these ridges is found a special plant community that is strikingly different from those immediately surrounding the OuaOua.

The rocky slopes of the crests support a woody plant community composed of Acacia flava, Zizyphus mauritiaca, Balanites aegyptiaca, Boscia senegalensis, Commiphora africana, Adenium obaesum, Grewia bicolor, Dichrostachys glomerata and Dalbergia melanoxylon. Between the parallel ridges are small valleys containing Combretum glutinosum, Combretum aculeatum, Calotropis procera, Leptadenia pyrotechnica, Acacia senegal and Balanites aegyptiaca.

The vegetation stocking density is moderately light with occasionally heavy patches of Grewia bicolor on the rocky crests. Exploitation appears light and the community is stable. Soil-water relationships seem to be favorable for abundant pasture in the valleys between parallel ridges.

Type Z. *Lake R'Kiz*

Surrounding Lake R'Kiz in the southern Trarza is a woody plant community under severe exploitation pressure. The community is diverse and includes among its principal species Balanites aegyptiaca, Leptadenia pyrotechnica, Capparis decidua, Acacia raddiana and Calotropis procera. Secondary species include Maerua crassifolia, Zizyphus mauritiaca, Combretum glutinosum, Acacia senegal and Bauhinia rufescens. The stocking densities vary from approximately 300 to 500 plants per hectare. The numerous Acacia raddiana surrounding the lake are at maturity and stand about 10 to 12 meters high. Other vegetation is stunted by severe overbrowsing.

The community is transitional to one composed almost exclusively of Balanites aegyptiaca, Leptadenia pyrotechnica, and Calotropis procera.

IV. SUMMARY AND CONCLUSIONS

In general, several patterns of the vegetative cover can be described across the study area. The sandy northwest is characterized by psammophiles such as Leptadenia pyrotechnica, Commiphora africana and Acacia raddiana. The southwest is a transition zone from purely sand species to those that colonize heavier soils with better soil-water conditions. Acacia senegal formerly occupied vast regions of the southwest, but is now centered around the southern Trarza in the department of Mederdra. Surrounding this department are small, scattered remnants of Acacia senegal stands within much larger regions of devastation in which one finds very few Acacia senegal, scattered Balanites aegyptiaca, Maerua crassifolia and Acacia raddiana. These larger zones are evident to the north and east of Mederdra itself and to the east of Lake Rkiz. Between Lake Aleg and the Senegal River one finds extensive stands of Boscia senegalensis that yield to stands of acacias and finally to forests

of Acacia nilotica along the river.

The plateaus (i.e., Tagant and Assaba) offer a curious admixture of species and plant communities that are undergoing transition. This is the result of on-going sand movement from the eastern dune zone to west of the plateaus; deposition to the west of the plateaus is strikingly evident at Moudjeria, in the southern Brakna, and in the western Assaba. One of the more interesting plant communities occupies the flanks of the plateaus, and it often resembles neither the vegetation on the plateau nor at its base.

East of the plateaus is a large area of sand dunes followed by more rocky terrain and plateaus again to the extreme east. The dune system varies from heavily vegetated in the southern portions (south of Kankossa) to essentially moving sand with little or no vegetation in the north. One sees evidence of this latter situation in traveling from Kiffa to Boumdeit.

The Guidimaka remains the most heavily vegetated zone of southwestern Mauritania, and the only region, aside from the remnants of classified forests, in which forestry might be feasible as an industry. Heavy mortality of Sterculia setigera and overexploitation of Combretum glutinosum are reducing the numbers of these trees in the region; nevertheless, they still form important components of many woody plant communities.

The Mauritanian forests of the study area have been classified into 47 types based on the Society of American Foresters (SAF) classification. Since any classification is artificial, there are inevitable weaknesses and, perhaps, errors due to insufficient field verification and ignorance of true successional positions of the cover types. These problems may be alleviated gradually with more field observation and study. It appeared to the forestry survey team that fewer cover types might be adequate to describe the same forests in the future. Several different types are so similar to each other as to warrant close observation and study to verify if, in fact, separation is justifiable. This is particularly true for the types of the northern regions characterized by Acacia raddiana, Leptadenia pyrotechnica, Commiphora africana, and Maerua crassifolia. It may also extend to the types of the Aftout es Saheli and to those along the Senegal River to Leqceiba.

In general, the 1977 Landsat imagery provided a sufficient base for forestry mapping; however, extensive ground data were needed for corroboration and description of mapping units. Vegetative cover was not always well-represented on Landsat imagery due to sparseness of the plant communities and the dates of the imagery (early winter) and the rainfall patterns. The best time for imagery collection (for vegetation mapping) is during the rainy season or shortly thereafter; however, these data are generally inexistent or cloud-covered.

Classified forests along the Senegal River, large oases, and scattered, dense woody stands in drainages and depressions were easily visible on most Landsat imagery. While woody plant communities exist almost everywhere in southwestern Mauritania, very light stocking densities

and feathery crowns of many tree species result in spectral responses that correspond more closely to soil conditions than to vegetation. To a certain degree, vegetation also changes with soil type, but the overlap is not always consistent or predictable. It is necessary, therefore, to have abundant ground truth data on which to base the map units.

Necessary modifications have been made in the SAF classification in order to accommodate the special characteristics of Mauritanian forests. The principles of the SAF system of classification are appropriate for Mauritania, but the present document represents only the initial step in what should be a continuing process of refinement, correction and modification as circumstances dictate. It would be highly desirable to repeat the mapping at regular intervals of 5 to 10 years in order to trace shifts in stocking density and composition of the woody plant communities. Landsat imagery is indispensable to such an undertaking and should in the near future become more accessible and provide improved spectral and spatial resolutions. In years of abundant rainfall, such as the 1981 rainy season, false color images should suffice, but during drought years, computer-enhanced imagery would greatly ease the task of mapping.

Throughout the study area overexploitation of woody plants is the rule. Mortality of certain species is more pronounced in the north, where drought, combined with uncontrolled use of trees, has reduced vegetation stocking densities to very low levels. Landsat imagery shows only too clearly that removal of vegetation is especially pronounced along the two main paved roads. Villages and large communities are often visible as yellow, or light-colored spots on Landsat imagery, indicating bare soils rather than vegetation, which has been removed by a sedentary population unaware of conservation techniques and unable to control exploitation by passing herders and others.

With only localized exceptions, the classified forests of Acacia nilotica are under seige and are threatened with elimination by uncontrolled exploitation of the tree for charcoal production. There is essentially no reproduction of the tree either naturally or through forest management practices, and no attempts have been made to replace it with another species that might serve the needs of the populace. This is an area of study that must be undertaken if Mauritania is to avoid becoming an importer of fuel wood.

Though this was intended to be only a mapping of the wood species of southwestern Mauritania, one cannot help but perceive the need for an immediate investigation and experimentation to restore or, at the very least, stop the overexploitation of forest trees. Several areas of study present themselves immediately. These include a search for a tree that can replace Acacia nilotica as the principal source of firewood and charcoal. Its characteristics should include fast growth, dense wood, and the ability to withstand limited periods of drought. In the study area the only appropriate zones in which production on large scales should be contemplated are those adjacent to the Senegal River and other permanent bodies of water. Two tree species introduced into Mauritania show promise as replacements or substitutes for Acacia nilotica. These

are Eucalyptus camaldulensis and Leucaena leucocephala (L. glauca or mistakenly Peltophorum).

Another area of investigation is the search for methods that can serve for widescale regeneration of Acacia senegal or other vegetation in order to increase the value of lands for year-round pasture and to guarantee a source of gum for at least local needs. At present only exclosures have been proposed and will be tried in this regard at several sites by staff of the USAID-funded Renewable Resources Project.

Another area of research centers around the production in nurseries of indigenous species that are important locally for items such as tooth sticks, medicines, edible fruits and poles. Species that could be emphasized include Maerua crassifolia, Adansonia digitata, Zizyphus mauritiaca, Acacia raddiana, and Balanites aegyptiaca.

The use of Euphorbia balsamifera for dune stabilization has proven highly successful around Nouakchott, but a variety of species should be studied and tried for appropriateness. Indigenous, as well as exotic species, must be included in these trials.

The research needs of Mauritania in the field of forestry are vast, but there is equally vast potential for success provided research is begun soon, species are intelligently and carefully selected, and the trained foresters of Mauritania are given the support and encouragement necessary to carry out these studies.

V. REFERENCES

Adam, J.G. 1966. La végétation de l'aftout es Saheli (Mauritanie occidentale). Institute Fordemental d'Afrique Noire Bulletin. Vol. 28(4):1292-1319. Sér. A

INSTRUPA. 1979. Developpement rurale de la Rëgion du Tagant. Reports 1-6 with maps. SONADER, Nouakchott, Mauritanie.

Society of American Foresters. 1954. Forest Cover Types of North America. SAF, Bethesda, Maryland. USA.

Toupet, C., and G. LaClavere (eds). 1979. Les atlas de la Republique Islamique de Mauritanie. Editions jeune Afrique, Paris.

CHAPTER 5

PASTURE COVER TYPES

I. INTRODUCTION

This report and the accompanying Pasture Map of Southwest Mauritania, at a scale of 1:500,000, represent the results of a vegetative survey of the project area. The pasture map displays the 79 cover types, while this report provides the detailed descriptions of those types. Additionally, the subjects presented in the following paragraph are also addressed.

The report describes the methods used in gathering field data and their analysis (Section II), a floral inventory of the plants identified during the survey (Section III), definitions and descriptions of the types of pasture lands including an estimation of their average carrying capacities (Section IV), a summary of the available data on the animal stocking rate of the zone (Section V), an introduction to the subject of forage value (Section V) and an assessment of the forage value evolution in the different pasture lands of the project area (Section VI), and finally a discussion of the types of interventions to be considered in order to improve the management of these pasture lands (Section VII).

II.METHODS

Mapping Pasture Cover Types

The delineation of pasture units was based on interpretation of Landsat imagery. For the most part, delineations corresponded to surficial variations, but other delineations, corresponding to climatic differences, could only be mapped by locating the botanical sampling sites on the imagery and extrapolating those results. Aerial photography at a scale of 1:50,000 was used to verify some delineations and to determine more exactly the woody cover of some vegetated zones. Once the units had been delineated and identified, their area was measured with a compensating polar planimeter. For a more complete discussion of the use of remote sensing materials and techniques, see Chapter 1, Section II: Application of Remote Sensing to the Mauritania Resource Survey.

Field Survey

The survey for the pasture land map was done by means of phytosociological sampling. The sampling was, in fact, a methodical collection of all necessary information for the characterization of the vegetation within a well-defined surface area, usually 0.25 hectares. Sometimes the heterogeneity of a landscape made it necessary to perform studies on a one hectare plot. The vegetation was divided into herbaceous and woody strata, which were studied separately.

Herbaceous Stratum

The data collection was based on the point frequency method of Daget and Poissonet (1971). This method produced a moderately precise estimation of the overall herbaceous cover as well as the relative dominance of the constituent species. Since this method tends to exclude a certain number of less abundant species, it was supplemented by visual observations to complete the floral inventory of the sample.

The sampled species were classified according to:

1) palatability
2) height (in cm)
3) state of development.

Harvesting the herbaceous cover of 4 to 10 plots per Pasture Type, 1 m^2 each, made it possible to evaluate the maximum potential productivity of the herbaceous stratum. Owing to a lack of appropriate equipment at the time this field study was being conducted, analysis of collected samples was performed at the Centre National d'Elevage et de Recherche Veterinaire. The following data and methods were used to speed the analysis of the samples:

1) wet weights of vegetation at the time of sampling
2) dry weights including dry-down moisture
3) standardization of samples to a common dry sample moisture percentage to yield kg of dry matter/ha.

The location and orientation of the sampling line for the point frequency method and the location of the harvested plots were determined by tossing metal stakes. After data collection by this method and additional observations, a within-sample coefficient representing abundance and dominance was given to each species present at a single site. They are as follows:

+ species present only rarely, or in isolation, and with little cover
1 species moderately abundant, but with less than 5% cover
2 species abundant, represents 5% of the vegetative cover
3 species represents 5 to 35% of the vegetative cover

4 species represents 35 to 65% of the vegetative cover
5 species represents over 65% of the vegetative cover

A symbol (!) accompanying the coefficient of abundance/dominance indicates a special distribution, i.e., species distributed in localized zones.

It did not seem necessary to follow the practice of some authors, such as Boudet and Duverger (1961), who counted the numbers of each species (easily done during hand-cutting operations), because the numerical abundance of a species has, in many cases, little relationship with its contribution to the herbaceous biomass. On the contrary, the dominance (extent of cover) of the species along with its average height gave a good indication of its true importance as a constituent of the total herbaceous cover. In this regard, the averages of the measured heights for the individuals of a given species were calculated. This made it possible to divide the herbaceous species into six strata as discussed in Section III.

Woody Stratum

Since an independent study of the forestry cover of the mapped area has been undertaken and is part of this report (see Chapter 4), examination of the woody stratum followed the procedure hereafter:

1) the number of shrubs was either counted on a quarter hectare or determined according to an estimation of the average space between stems
2) the average crown diameter was estimated in order to determine the extent of woody cover
3) the woody stands were subdivided into four height strata:

   1. < 2 meters
   2. 2 to 4 meters
   3. 4 to 8 meters
   4. > 8 meters.

   The contribution of each stratum to the woody cover was estimated and expressed as a percentage.
4) woody species were identified and an abundance/dominance coefficient assigned to each.

Tally Sheet

All collected data were recorded on a tally sheet, including the sample number, the date, the geographic coordinates, and a brief description of the soil type and the niche.

Data Analysis Derivation and Description of Pasture Types

Three hundred and three sites were sampled during eight field missions undertaken between 1 October 1980 and 5 April 1981. The sampling

points are shown in Fig. 5-1. The next stage consisted of classifying the samples as pasture types, each of which was more or less homogeneous. This was done by using Jaccard's index of similarity, a method of determining the degree of similarity between the flora of two sampling sites. Computation of this coefficient is listed in the following equation:

$$P = \frac{c}{A + B - c} (100)$$

where c = number of species common to the two sites
A = number of species present at the first site
B = number of species present at the second site

Unfortunately, with a large sample, only a computer could complete the calculations of indices of all possible sample pairs in a reasonable amount of time. For example, 460,560 different calculations would be required for 303 samples, and that at a rate of 30 per hour for a well-trained person. As no computer was available, it was necessary first to make an intuitive conditional division based on:

1) the similarity of edaphic types and niches
2) visual identification of the dominant species, and sometimes,
3) presence of indicator species.

For example, by beginning the separations from the pooled data, e.g., those data that were collected in dune habitats (including interdune depressions not mapped separately because of the scale) the sample size is still too large. To further facilitate the task, the next step was locating and pooling the samples characterized by species that are clearly Saharan (Stipagrostis pungens, Cyperus jeminicus, etc.) and those species of the sub-desertic steppe (Farsetia spp.). On the other end of the climatic range, the grouping begins with the samples that abound in Sudanian species, such as Combretum glutinosum, Andropogon spp., and then the samples predominated by mesophytic Sahelian species, such as Acacia senegal and Dactyloctenium aegyptium. The result is clearly a climatological stratification within which manageable numbers of samples were grouped.

The tentatively grouped samples were then pooled in a phytosociological table in order to facilitate the computation of the Jaccard indicies. These indices determined the position of the tentative groupings. The integrity of some were confirmed while others were divided among different groups and sub-groups. Several groupings were completely absorbed by one or several neighboring groups. Some samples were transferred to new groups when their superficial similarities, according to indicator species, were contradicted by their coefficients, which are based, of course, on the entire floral population and are therefore considered more reliable than one or several indicator species. Table 5-1 presents an example of a phytosociological table for a provisional grouping. The Jaccard indices are listed below, together with the conclusions (Table 5-2).

Once the grouping had been clearly defined, it was then referred to as a Pasture Type and an average abundance/dominance coefficient was

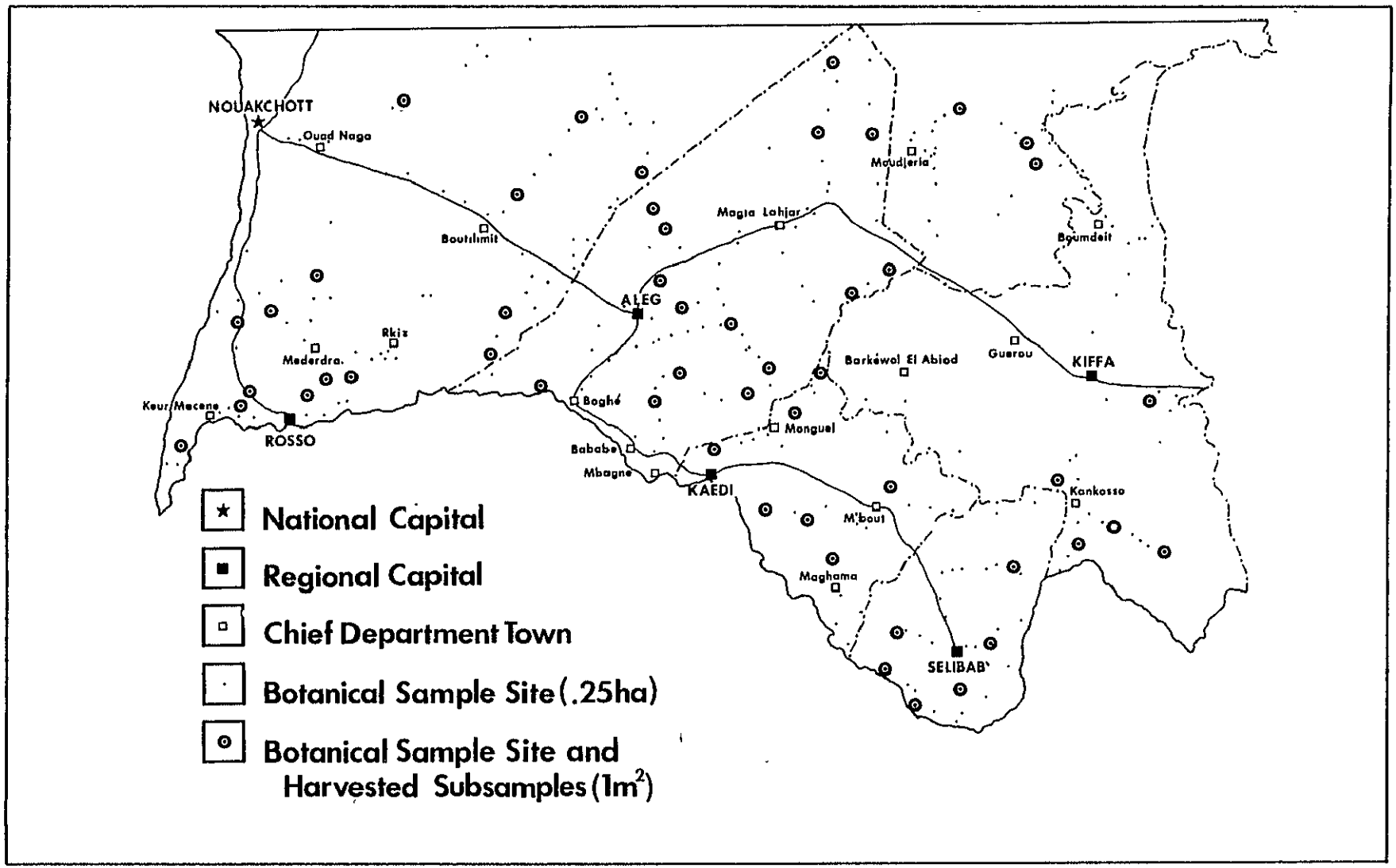


Fig. 5-1. Sample locations and subsample plots are shown within the project area. Sample locations mark the sites where the point frequency method was used; subsample sites indicate harvested plots.

Table 5-1. - Example of a provisional phytosociologic table for pasture cover type RG3.

(The numerical-symbol designations are listed in herbaceous stratum discussion).

Species / Sample Number	6	31	74	76	78	79	81	91	92	94	100
Aeschynomene indica	-	-	-	-	-	1	-	-	-	-	-
Alysicarpus oval	-	-	1	-	-	-	-	-	+	-	1
Borreria chaetocephala	-	+	-	-	-	1	-	-	-	-	-
Cassia tora	-	-	-	1	+	-	1	-	+	-	-
Citrullus colocyn	-	+	-	+	1	-	-	-	-	-	-
Cleome tenella	-	-	-	-	-	-	-	-	-	+	-
Corchorus tridens	-	2	-	1	1	-	-	-	-	-	-
Crotolaria podocarpa	-	1	-	-	-	-	-	-	-	-	-
Indigofera senegalensis	+	2	+	1	1	2	+	1	1	+	2
Ipomoea coptica	-	-	-	2	-	-	-	+	-	-	-
Mollugo nudicaulis	-	+	+	-	-	-	-	+	-	-	-
Tribulus terrestis	2	2	3	2	1	-	1	-	-	-	2
Urgines indica	-	-	-	1	-	-	-	-	-	-	-
Zaleya pentapra	-	+	-	-	-	-	-	-	-	-	-
Zornia glochidiata	-	-	-	2	1	1	+	-	-	-	-
Aristida adscensionis	-	-	-	-	-	-	+	1	2	1	-
Aristida funiculata	1	1	-	-	-	-	+	1	+	1	-
Aristida mutabilis	1	+	+	+	+	-	+	-	-	-	-
Cenchrus bifloris	-	+	+	+	-	-	+	-	+	-	-
Chloris pilosa	-	-	-	1	+	-	-	-	-	-	-
Chloris virgata	-	-	+	-	-	1	-	-	-	-	-
Cymbopogon schoenanthus	-	-	-	-	-	-	1	+	1	+	-

Table 5-1. (cont'd)

Species	Sample Number 6	31	74	76	78	79	81	91	92	94	100
Dactylotenium aegyptium	-	-	1	-	-	-	-	-	-	-	1
Digitaria sp.	+	+	-	+	-	-	-	-	-	-	-
Echinochloa colona	-	-	-	-	-	4	-	-	-	-	-
Eragrostis ciliaris	-	1	-	-	-	-	-	-	-	-	-
Eragrostis pilosa	3!	3!	1	3	2	2	2	+	1	1	2!
Eragrostis tremula	+	1	-	+	+	-	+	-	-	-	+
Panicum laetum	-	!	-	1	1	2	+	1	-	-	-
Pennisetum pedicellatum	-	-	-	-	-	+	-	-	-	-	-
Schoenfeldia gracilis	3	2	3	2	3	1	2	4	3	3	3
Sporobolus helvolus	-	-	-	-	-	1	-	-	-	-	-
Tetrapogon cenchrifomis	-	+	+	+	-	-	+	2	+	+	-
Tragus racemosus	+	1	2	-	-	-	-	-	-	-	-
Acacia antaxacantha	-	-	-	-	-	+	-	-	-	-	-
Acacia flava	1	+	+	+	+	-	1	-	-	-	-
Adansonia digitata	-	+	+	+	+	+	+	-	+	+	+
Balanites aegyptiaca	-	1	-	-	-	1	-	-	-	-	+
Boscia senegalensis	2	3	2	3	3	2	3	1	1	2	3
Calotropis procera	-	1	-	-	-	-	+	-	-	-	+
Combretum acculatum	-	-	-	-	-	1	-	-	-	-	-
Combretum micranthum	-	-	-	-	-	1	-	-	-	-	-
Commiphora africana	-	+	1	1	1	-	2	3	2	3	+
Dichrastachys glomerata	-	-	-	-	-	+	-	-	-	-	-
Euphorbia balsamifera	-	!	-	-	-	-	-	-	-	-	-
Grewia bicolor	-	-	-	-	-	3	-	+	+	+	-

Table 5-1. (cont'd)

Species	Sample Number	6	31	74	76	78	79	81	91	92	94	100
Guiera senegalensis		-	-	-	-	-	3	-	-	-	-	-
Maerua angolensis		-	-	-	-	-	1	-	-	-	-	-
Maerua crassifolia		-	-	-	-	-	-	-	1	+	+	-
Ziziphus mauritiaca		-	1	-	-	-	1	-	-	+	-	-
Total number of species represented		11	27	16	21	16	22	19	14	16	13	12

Table 5-2. - Listing and interpretation of a possible phytosociologic table (RG3) using Jaccard Indices of Similarity.

Listing

Sample Number	6	31	74	76	78	79	81	91	92	94	100
100	35	35	47	33	40	17	35	24	33	32	
94	26	25	32	26	26	21	45	69	71		
92	23	30	39	32	28	19	52	58			
91	25	28	30	30	25	20	44				
81	43	44	46	60	59	21					
79	27	20	19	19	23						
78	42	43	39	76							
76	39	50	42								
74	42	43									
31	41										
6											

Interpretation

1. Analysis of the coefficients indicates the existence of two clearly distinct groups. These are the subtypes:

   1) RG3a, grouping of samples 31, 74, 76, 78, & 81, and
   2) RG3b, grouping of samples 91, 92, & 94.

2. Samples 6 and 100 show only weak similarities with this type. In fact, sample 6 has been pooled in type S3Q and sample 100 in type L2.

3. Sample 79 represents a landscape associated with a woody depression (Loamy sand soils).

computed for each species. The coefficient represents the occurrence and importance of the species across all samples that belong to the pasture type. In this regard, samples collected on non-characteristic landscapes of the type (small depressions or non-mapped wadis, for example) are not taken into consideration. The across-samples coefficients (i.e., compilation of the within-sample coefficients per cover type) are given as follows:

- R - less than 30% representation, slight abundance and slight cover
- ! - less than 30% representation, good abundance and good cover
- X - about 50% representation, slight to moderate abundance and slight to moderate cover
- 1! to 5! - about 50% representation, good abundance, and cover percentages <5%, 5%, 5-35%, 35-65%, and >65% for the numerals 1, 2, 3, 4, and 5, respectively
- !1 to !5 - at least 75% representation, good abundance, and cover percentages corresponding to the above notation
- + to 5 - same as above, but with a more generalized distribution of species
- + to 5 followed by 2! to 5! - same as above with the second symbol representing a denser cover (in 50% of samples) than normally attributed to the above descriptions

These coefficients are assembled in synoptic tables (Section IV), which help to facilitate comparison between the types. To limit the extent of these tables, species which do not receive in any type, a coefficient greater than "!" are not shown, unless they carry special significance.

In order to measure the importance of a given species as a constituent of a pasture type, its average coefficient (shown in tables of Section IV) could be juxtaposed to its normal height (Dominance x height = biovolume) and to its palatability. These determinations are presented in tabular form in the floral listing (Section III).

III. FLORAL INVENTORY

The individual species constituting the pastural lands of the project area were estimated at about 1000. Out of this number, 356 were identified and are presented in this section. These constitute most of the species from the Mauritanian Sudanese and Sahelian zones; the species not listed from both of these zones are of minor importance in regard to their contribution to the overall biomass. Plant characters of a broad cross-section of the sampled species are displayed in Fig. 5-2, 5-3, 5-4, 5-5, and 5-6.

Lacking a catalogue of Mauritanian plants, the nomenclature results from several sources; the nomenclature of gramineae follows Naegélé (1977). Many of the identified species are synonymous, which complicates the utility of the floral listing. A list of synonymies most often found in the literature is presented after the floral listing. A similar problem exists with the family-related nomenclature. International convention states that

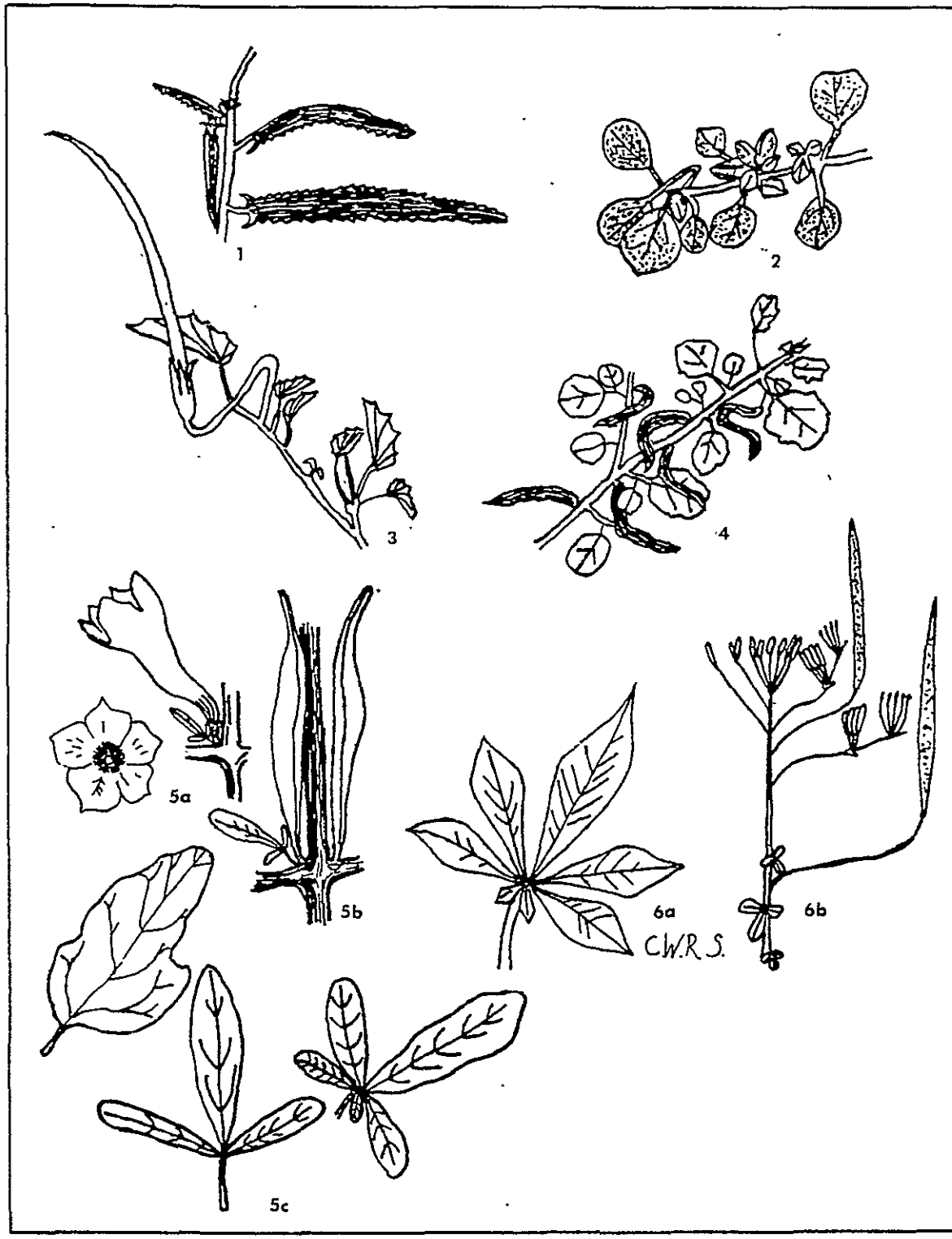


Fig. 5-2. Various herbaceous species are characterized.

1. Corchorus tridens L. 2. Glinus lotoides L. 3. Monsonia senegalensis G. and Perr. 4. Corchorus depressus (L.) Christens. 5. Sesamum alatum Thon.; a) flower (pale violet in color) b) opposing fruits c) leaves 6. Gynandropsis gynandra (L.) Briq.; a) leaf b) inflorescence

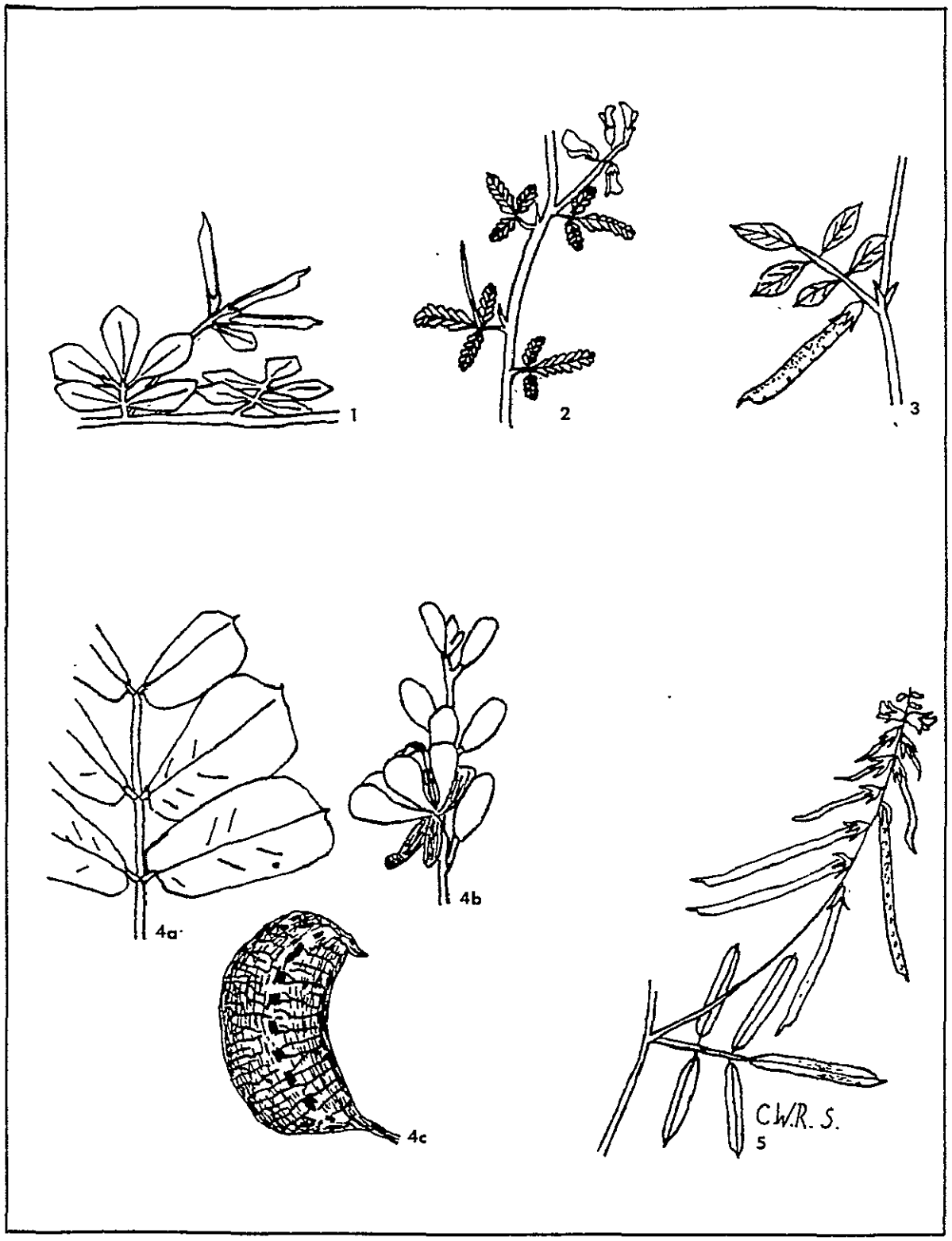


Fig. 5-3. Various legumes (Legumineuses) are characterized.

1. Lotus arabicus L. 2. Psoralea plicata Del. 3. Tephrosia uniflora Pers. 4. Cassia italica (Mill.) Lam.; a) obovate leaf b) inflorescence c) flattened fruit 5. Indigofera aspera Perr.

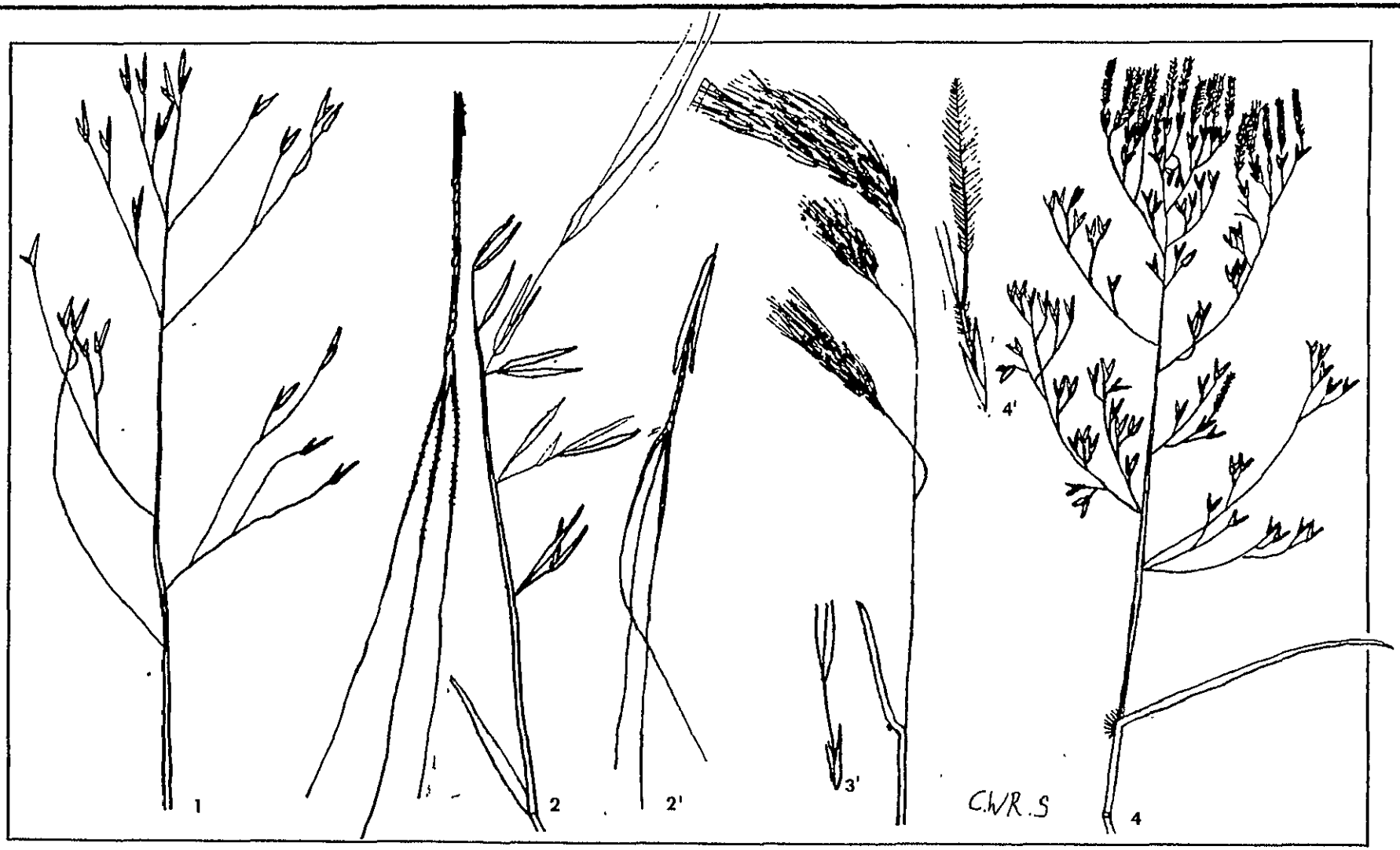


Fig. 5-4. Several grasses of the Aristideae family are characterized.

1. Aristida stipoides Lam.; 1' awn. 2. Aristida funiculata Trin. and Rupr.; 2' awn and floret. 3. Aristida mutabilis Trin. and Rupr.; 3' awn and floret. 4. Stipagrostis uniplumis (Licht.) de Winter; 4' awn and floret.

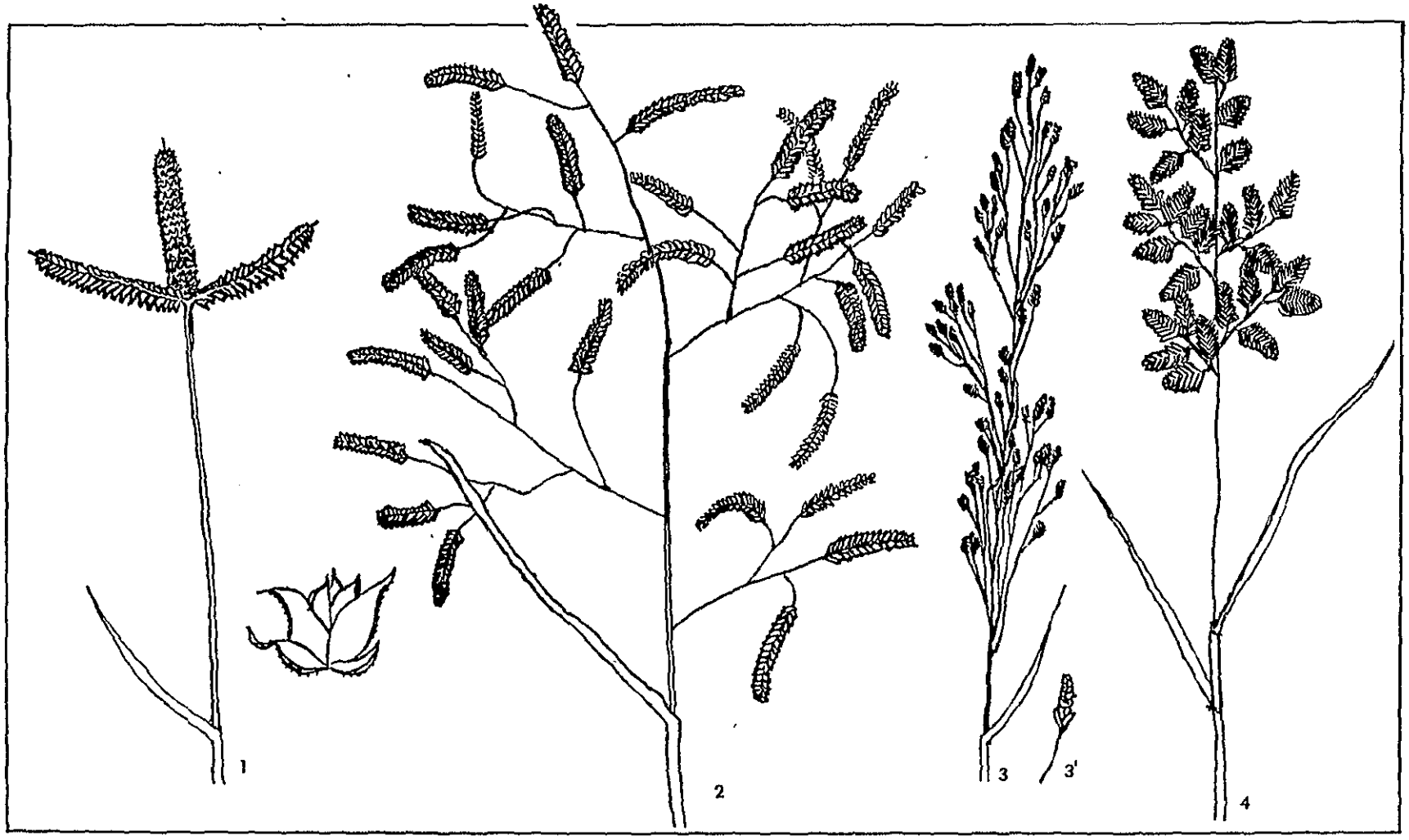


Fig. 5-5. Several grasses of the Eragrosteae family are characterized.

1. Dactyloctenium aegyptium (L.) P. Beauv.; 1' spikelet. 2. Eragrostis tremula Hochst. ex Steud. 3. Eragrostis pilosa (L.) P. Beauv.; 3' spikelet. 4. Eragrostis cilianensis (All.) Lut.

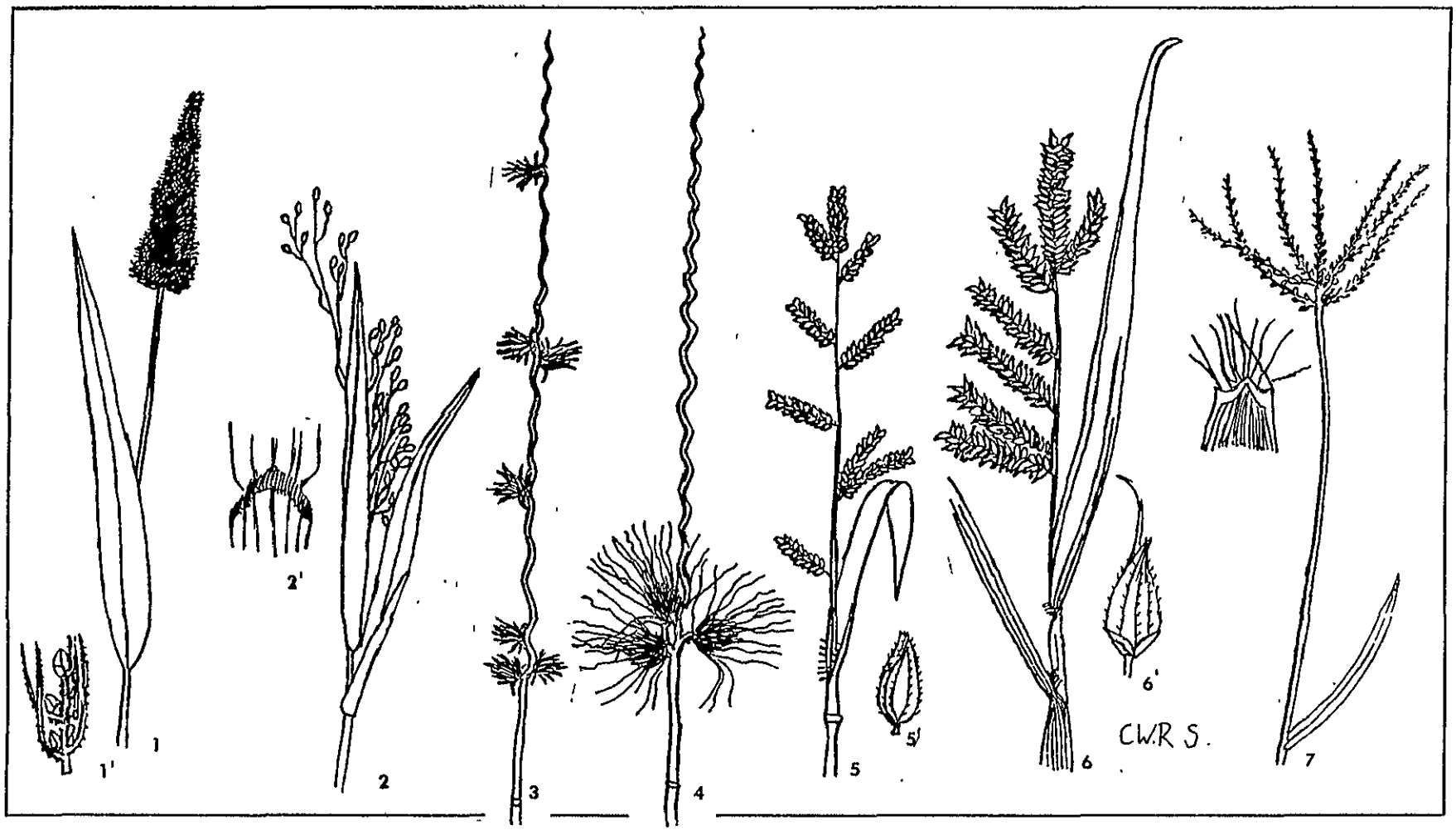


Fig. 5-6. Several grasses of the Paniceae family are characterized.

1. Setaria verticillata (L.) P. Beauv.; 1'. raceme (of the false spike). 2. Panicum laetum Kunth; 2'. ligule. 3. Cenchrus biflorus Roxb. 4. Cenchrus prieuri (Kunth) Maire. 5. Echinochloa colona (L.) Link.; 5' floret. 6. Echinochloa stagnina (Retz.) P. Beauv.; 6' floret. 7. Digitaria horizontalis Willd.; 7' ligule

every family name should be formed from a genus name, consequently, many family names were changed. Some of the most common changes are indicated as follows:

Aizoaceae	:	Mulluginaceae	: Ficoideae
Arecaceae	:	Palmae	
Asteraceae	:	Compositae	
Brassicaceae	:	Cruciferae	
Fabaceae	:	Papillionaceae	
Lamiaceae	:	Labiatae	
Poaceae	:	Gramineae	
Vitaceae	:	Ampelidaceae	

Table 5-3 lists the 356 species identified during the field study. Apart from the family and scientific names, table 5-3 includes five columns:

In column 3, Biologic Form (B.F.), plants are classified according to their morphology in the following categories:

- Ps - Trees whose mature individuals reach more than 9 m in height
- NP - Trees and arborescent shrubs of minor height
- PL - Arborescent liana (woody)
- CH - Perennial shrubby plants with the lower part remaining alive all year
- H - Perennial plants with the renewal point close to the soil
- G - Perennial plants with the renewal point under the soil
- GB - Geophytes with bulbs
- GA - Perennial gramineae, sod-forming with rhizomes
- T - Annual plants
- TG - Perennial climbing plants
- TR - Perennial prostrate plants

In column 4, Palatability, the categories are based on field observations or found in the literature. They are listed as follows:

- TA - Heavily grazed and actively sought out
- A - Preferred
- PA - Seldom and occassional grazed
- NA - Usually not grazed

In column 5, Habitat, the classes include (1) the soil or topographic situation and (2) the characteristic climatic zone preferred by the specie:

(1)	(2)
S - Sandy	SR - Saharian
L - Silty (loamy)	SL - Sahelian
R - Rocky and lithic soils	SD - Sudanian
A - Argiles : hydromorphic soils	U - Regionally present

(Listing continued on page 201)

Table 5-3. Important delineations of the flora found in the project area.

(1) Scientific Name	(2) Family	(3) B.F.	(4) Palat.	(5) Habitat	(6) Stratum	(7) Local Name
1. Abutilon fructosum G. and P.	Malvaceae	T	NA	L/SL	H3	-
2. Abutilon pannosum (Forsk.f.) Schlect.	Malvaceae	T	NA	I/SL	H3	-
3. Acacia albida Del.	Mimosaceae	P	A	S/SD	A1	Afrar
4. Acacia ataxacantha D.C.	Mimosaceae	NP	NA	I/SD	A3	Ashram
5. Acacia campylacantha Hochst. ex Rich.	Mimosaceae	NP	A	A/SD	A2	-
6. Acacia flava (Forsk.) Schweif.	Mimosaceae	NP	A	R/SL	A3	Tamat
7. Acacia laeta R.Br. ex Benth	Mimosaceae	NP	PA	S/SL	A3	Erwar
8. Acacia macrostachya Reichb.	Mimosaceae	NP	A	I/SD	A2	-
9. Acacia nilotica (L.) Willd.	Mimosaceae	-	-	-	-	-
-v. adansonii (G. and P.O. Ktze.)	Mimosaceae	P	TA	I/U	A2	Amour; Gaodi (P.)
-v. nilotica A.F. Hill	Mimosaceae	P	A	A/U	A1	Amour; Gaodi (P.)
-v. tomentosa (Benth.) A.F. Hill.	Mimosaceae	P	A	A/U	A1	Amour; Gaodi (P.)
10. Acacia raddiana Savi.	Mimosaceae	P	TA	S/SL	A2	Talhaya
11. Acacia senegal (L.) Willd.	Mimosaceae	NP	TA	S/SL	A2	Awourwar; Patuki (P.)
12. Acacia seyal Del.	Mimosaceae	NP	TA	A/SL	A3	Sdar Albeza; Bulbi (P.)
13. Acacia sieberiana D.C.	Mimosaceae	P	PA	A/SD	A1	Anluki (T.)
14. Achyranthes aspera L.	Amaranthaceae	T	NA	O/SL	H4	Beitilabde
15. Acrachne racemosa (Heyne) Ohwi	Poaceae/Eragrosteae	T	PA	A/SD	H4	-
16. Adansonia digitata L.	Bombaceae	P	PA	I/SD	A1	Teidum
17. Adenium obesum R. and Schum	Apocynaceae	NP	NA	-	-	Teidum-Teddib
18. Aerva tavenica (Brom R.) ex Schult	Amaranthaceae	Ch	PA	S/U	H3	Attamia Moghamlé
19. Aeschynomene afraspera J. Leon	Fabaceae	T	A	M/SD	H1	-
20. Aeschynomene elaphroxylon (G. and P.) Taub	Fabaceae	Ch	A	M/SL	H2	-

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
21. Aeschynomene indica L.	Fabaceae	T	TA	M/SL	H2	-
22. Aeschynomene nilotica Taub.	Fabaceae	T	A	M/SL	H1	-
23. Alternantera nodiflora R. Br.	Amaranthaceae	T	NA	M/SD	H5	Hammir; Ardeissak
24. Alysicarpus ovalifolius(Schum and Thonn) J. Leon.	Fabaceae	T	A	S/SL	H4	Son Khali
25. Alysicarpus rugosus L.	Fabaceae	T	A	I/SD	H4	Son Khali
26. Amaranthus graecizans L.	Amaranthaceae	T	PA	RU/SL	H4	Bodbada
27. Ammania senegalensis Lan.	Lythraceae	T	?	M/SL	H5	-
28. Andropogon amplectens Nees.	Poaceae/Andropogoneae	T	TA	S/SD	H3	-
29. Andropogon gayanus Kunth.	Poaceae/Andropogoneae	-	-	-	-	-
-var. gayanus Hack.	Poaceae/Andro.	H	TA	S/SD	H2	-
-var. bisquamulatus Hack.	Poaceae/Andro.	H	TA	S/SD	H2	-
30. Andropogon tectorum Schum	Poaceae/Andro.	T(?)	TA	S/SD	H3	-
31. Anogeissus leiocarpus (D.C.) G.and P.	Combretaceae	P	NA	A/SD	A1	Aglel; Aglayé
32. Anticharis linearis	Scrophulariaceae	T	?	A/SD	H4	-
33. Aristida adscensionis L.	Poaceae/Aristideae	T	A	I/SL	H3	L'Haiyet Lehmar
34. Aristida funiculata Trin. and Rupr.	Poaceae/Aristideae	T	A	L/SL	H4	Tizzit
35. Aristida mutabilis Trin. and Rupr.	Poaceae/Aristideae	T	TA	S/SL	H3	Ladhir; L'Haiyet; Lehmar
36. Aristida sieberana Trin.	Poaceae/Aristideae	H	A	S/U	H3	Agbadane; L'Haiyet, Lehmar
37. Aristida stipoides	Poaceae/Aristideae	T	NA	S/SL	H2	Oumar Lebga
38. Arthrocnemum glaucum (Del.) Ung. Steral.	Chenopodiaceae	CH	TA	H/SL	H3	Arjem; El Mulah
39. Balanites aegyptiaca (L.) Del.	Zygophyllaceae	NP	A	I/SL	A3	Teichott; Murtuki
40. Bauhinia reticulata D.C.	Caesalpinaceae	NP	A	L/SD	A3	Tazakraé
41. Bauhinia rufescens Lam.	Caesalpinaceae	NP	A	L/SL	A3	Ndern

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
42. Bergia ammanioides Heyne ex Roth.	Elatinaceae	CH	A	L/SL	H5	Nyipere (T.)
43. Bergia suffructicosa (Del.) Fenzl.	Elatinaceae	CH	TA	L/SL	H4	Zerk
44. Bidens pilosa L.	Asteraceae	T	?	L/SL	H4	-
45. Blainvillea gayana Cay.	Asteraceae	T	NA	L/SD	H2	-
46. Blepharis linariifolia Pers.	Acanthaceae	T	TA	S/SL	H5	Elfelch
47. Blumea aurita D.C.	Asteraceae	T	NA	L/SL	H4	-
48. Boerhavia erecta L.	Nyctagynaceae	T	A	I/SD	H4	-
49. Boerhavia repens L.	Nyctagynaceae	TR	TA	S/SL	H6	Altig; Imoshel; Ankan Lebel
50. Boerhavia vulvarifolia Don	Nyctacynaceae	TR	PA	I/SL	H6	Imoshel
51. Borassus aethiopum Mart.	Arecaceae	P	NA	A/SD	A1	Akof
52. Borreria chaetocephala	Rubiaceae	T	NA	A/SL	H5	-
53. Borreria radiata	Rubiaceae	T	NA	A/SD	H5	-
54. Borreria verticillata (L.) G.F.W. Mey	Rubiaceae	T	NA	A/SD	H5	-
55. Boscia augustifolia A. Rich.	Capparidaceae	NP	NA	R/SD	A2	Tirewi (T.)
56. Boscia salcifolia Oliv.	Capparidaceae	NP	PA	R/SD	A3	-
57. Boscia senegalensis Lam.	Capparidaceae	NP	NA	I/SL	A4	Eizzen
58. Brachiaria lata (Schum.) Hubb.	Poaceae/Paniceae	T	TA	S/SD	H3	Zereg
59. Brachiaria mutica Stapf.	Poaceae/Paniceae	H	TA	M/SD	H2	-
60. Brachiaria ramosa Stapf.	Poaceae/Paniceae	T	TA	S/SL	H3	Az Muldib
61. Brachiaria stipitata Hubb.	Poaceae/Paniceae	T	TA	L/SD	H3	Az
62. Brachiaria xantholeuca Stapf.	Poaceae/Paniceae	T	TA	S/SD	H3	Zereg
63. Cadaba farinosa Forssk.	Capparidaceae	NP	NA	I/SL	A4	Zrem

Table 5-3: (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
64. Calotropis procera Ait.	Asclepiadaceae	NP	NA	I/U	A3	Turze
65. Capparis corymbosa Lam.	Capparidaceae	NP	A	A/SL	A3	Lehleifoe
66. Capparis decidua Ait. F.	Capparidaceae	NP	A	A/SL	A3	Eignin; Agani
67. Capparis tomentosa Lam.	Capparidaceae	NP	A	I/SD	A3	Lelheifoe; Diamar
68. Cardiospermum halicacabum L.	Sapindaceae	TG	NA	L/SD	-	-
69. Cassia italica (Mill.) Lam.	Caesalpinaceae	CH	NA	S/SL	H3	Vellajit
70. Cassia nigricans Vahl.	Caesalpinaceae	T	PA	I/SD	H4	-
71. Cassia mimosoides L.	Caesalpinaceae	T	NA	I/SD	H4	Helb Hed
72. Cassia occidentalis L.	Caesalpinaceae	T	NA	RU/U	H4	Sersaré
73. Cassia tora L.	Caesalpinaceae	T	PA	I/U	H3	Vollekje; Afeljet
74. Celtis integrifolia Lam.	Ulmaceae	P	NA	L/SD	A1	-
75. Cenchrus biflorus Ronb.	Poaceae/Paniceae	T	A	S/SL	H3	Initi; Hébéré (T.) Cram Cram (Fr.)
76. Cenchrus ciliaris L.	Poaceae/Paniceae	H	TA	I/SL	H3	Tilimit
77. Cenchrus prisurii (Kunth.) Maire	Poaceae/Paniceae	T	A	S/SL	H3	Tilimit; Gasba
78. Cenchrus setigerus Vahl.	Poaceae/Paniceae	H	TA	S/SL	H3	Zmellig
79. Centaurea perrotettii D.C.	Asteraceae	CH	A	I/SL	H4	Hachalilah
80. Caeratotheca sesamoides Endl.	Pedaliaceae	T	A	S/SL	H4	Eragem
81. Chloris pilosa Schum. et Thonn.	Poaceae/Chlorideae	T	TA	S/SD	H3	-
82. Chloris prieurii Kunth.	Poaceae/Chlorideae	T	TA	S/SL	H4	Infi; Boussokif; Kraal Ghorah
83. Chloris virgata SW.	Poaceae/Chlorideae	T	TA	S/SL	H3	Infi
84. Chrozophora brochiana Vis.	Euphorbiaceae	CH	TA	S/SL	H3	Eremche; Tahmie

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
85. Chrozophora plicata Juss.	Euphorbiaceae	T	NA	I/SL	H4	Armache
86. Chrozophora senegalensis (Lam.) A. Juss.	Euphorbiaceae	T	NA	I/SL	H4	Armache
87. Cissus quadriangularia L.	Vitaceae	PL	NA	A/SL	-	Asfel Al Fil
88. Cistanche phelepaea (L.) P. Cout.	Orobanchaceae	T	TA	S/SL	H4	Damour; Dhanoun
89. Cistanche violaceae (Desf.) Beck.	Orobanchaceae	T	TA	S/SR	H4	Damour
90. Citrullus colocybthis L.	Cucurbitaceae	TR	A	S/SL	H6	Fundi; Lehdez; Afrikan
91. Citrullus lanatos Thumb.	Cucurbitaceae	TR	A	RU/SD	H6	Aferziz
92. Cleome arabica L.	Capparidaceae	T	A	S/SR	H4	Laona-Inza; Lembeinze
93. Cleome tenella L.F.	Capparidaceae	T	A	S/SL	H4	NNSE
94. Cleome viscosa L.	Capparidaceae	T	TA	RS/U	H3	Erraegem
95. Coccinea grandis (L.)	Cucurbitaceae	PL	A	A/SD	-	Tumbaha (T.)
96. Combretum acculeatum (D.C.) Vent.	Combretaceae	NP	TA	I/SL	A3	Ikik; Launyandé
97. Combretum glutinosum G. and P.	Combretaceae	NP	NA	I/SD	A2	Tikfit; Doaki (T.)
98. Combretum micranthum Den.	Combretaceae	NP	NA	L/SD	A3	Dafo; Bufumled; Kinkliba (T.)
99. Combretum nigricans Lepr.	Combretaceae	NP	NA	A/SD	A2	Duté (W)
100. Combretum paniculatum Vent.	Combretaceae	NP	NA	A/SD	A3	-
101. Commelina forskalaei Vahl.	Commelinaceae	TR	A	S/SL	H6	Agerf; Eain
102. Commiphora africana (A. Rich.) Engl.	Burseraceae	NP	A	I/SL	A3	Adress; Badi (T.)
103. Convovulus microphyllus Sieber ex Scheng.	Convolvulaceae	T	NA	L/SL	H4	Lyatig
104. Corchorus depressus (L.) Christens.	Tiliaceae	TR	NA	M/SR	H6	Takhikh
105. Corchorus olitorius L.	Tiliaceae	T	NA	M/SD	H3	Lalo
106. Corchorus tridens L.	Tiliaceae	T	PA	L/SL	H4	Lalo Trab; Elsen'Hore

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
107. Cordia rothii Roehm. Schult.	Boraginaceae	NP	PA	I/SL	A3	Agjul
108. Cordia sinensis Lam.	Boraginaceae	NP	PA	I/SL	A3	Nwazgor
109. Cornulaca monacantha Del.	Chenopodiaceae	CH	TA	S/SR	H4	HAD
110. Crataeva religiosa Firsk. f.	Capparidaceae	NP	PA	L/SD	A4	-
111. Cressa cretica L.	Convolvulaceae	T	A	H/SD	H4	Legbweire; Ihéné
112. Crotolaria arenaria Benth.	Fabaceae	T	A	S/SL	H3	Fule Ted Dra; Al Volé
113. Crotolaria ebenoides (G. and P. Walp.)	Fabaceae	T-CH	PA	S/SD	H3	-
114. Crotolaria podocarpa D.C.	Fabaceae	T	PA	S/SL	H3	Tertage
115. Crotolaria saharae Cosson	Fabaceae	CH	TA	S/SR	H3	Um L'kfweifat; Al Valu
116. Crotolaria SP.	Fabaceae	T	A	S/SL	H3	-
117. Cryspis schoenoides (L.) Lam.	Poaceae/Sporaboleae	T	TA	L/SR	H6	Mbidi (T.)
118. Ctenium elegans Kunth.	Poaceae/Chlorideae	T	A	S/SD	H3	Kra Al Ghorab
119. Cucumis ficfolius A. Rich.	Cucurbitaceae	TR	A	A/SR	H6	Agtastaf
120. Cucumis melo (L.) Naud.	Cucurbitaceae	TR	A	I/SL	H6	Bafreizat
121. Cucumis prophetarium L.	Cucurbitaceae	TR	PA	I/SL	H6	Tagesfarit
122. Cymbopogon giganteus	Poaceae/Andropogoneae	H	A	I/SD	H2	-
123. Cymbopogon schoenanthus (L.) Spreng.	Poaceae/Andropogoneae	H	A	R/SL	H3	Idzkhir; Umreize
124. Cynodon datylon Pers.	Poaceae/Chlorideae	GA	A	L/U	H4	Afar; Iverd; Nesem
125. Cyperus aristatus Rottb.	Cyperaceae	T	A	S/SD	H4	-
126. Cyperus articulatus Rottb.	Cyperaceae	T	A	M/SD	H4	-
127. Cyperus auricomus Sieber	Cyperaceae	T	PA	M/SD	H2	-
128. Cyperus bulbosus Vahl	Cyperaceae	GB	A	L/SL	H4	-
129. Cyperus divers Del.	Cyperaceae	T	A	A/SD	H3	-

Table 5-3: (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
130. Cyperus jeminicus Rotth.	Cyperaceae	H	TA	S/SR	H4	Serd; Télébut
131. Cyperus iria L.	Cyperaceae	T	TA	L/SL	H4	Sihit
132. Cyperus rotundus L.	Cyperaceae	T	TA	M/U	H4	Atsed
133. Cyperus Sp.	Cyperaceae	T	A	L/SL	H3	-
34. Dactyloctenium aegyptium (L.) P. Beauv.	Poaceae/Eragrosteae	T	TA	S/SD	H4	Kra Al Ghurab
35. Dalbergia melanoxylon G. and P.	Fabaceae	NP	A	R/U	A4	Sanghu; Djalambani
36. Datura stramonium L.	Solanaceae	CH	NA	RU/U	H1	Tfille
37. Desmodium Sp.	Fabaceae	T	?	M/SD	H3	-
38. Dichantium annulatum (Forsk.) Stapf.	Poaceae/Andropogoneae	HH	PA	L/SL	H3	L'hamra
.39. Dichrastachys glomerata (Forsk.) Stapf.	Mimosaceae	NP	PA	L/SD	A3	Burli (T.)
.40. Digitaria debilia Willd.	Poaceae/Paniceae	T	A	S/SD	H3	-
41. Digitaria gayana Stapf.	Poaceae/Paniceae	T	TA	S/SD	H3	-
42. Digitaria horizontalis Willd.	Poacese/Paniceae	T	A	S/SL	H4	-
43. Digitaria perrotettii Kunth.	Poacese/Paniceae	T	A	S/SD	H3	-
.44. Digitaria Sp.	Poaceae/Paniceae	T	A	S/SL	H4	-
.45. Dinebra retroflexa Panz.	Poaceae/Eragrosteae	T	PA	I/SD	H4	-
46. Diospyros mesipiliformis Huchat.	Ebenaceae	P	NA	A/SD	A1	-
47. Dipcadi longifolium Baker	Liliaceae	GB	?	S/SL	H4	Béjouge
.48. Diplachne fusca P. Beauv.	Poaceae/Eragrosteae	H	PA	M/SD	H3	-
.49. Echinochloa colona (L.) Link.	Poaceae/Paniceae	T	TA	M/SL	H3	Az; Az Buelbo; Sireg
.50. Echinochloa pyramidalis Hitch and Ch.	Poaceae/Paniceae	H	TA	M/SD	H2	-
.51. Echinochloa stagmina P. Beauv.	Poaceae/Paniceae	H	TA	M/SD	H3	Bourgou (Fr.)
52. Eleusine indica Gaerth.	Poaceae/Eragrosteae	T	PA	RU/SD	H3	-

Table 5-3.. (cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
153. Elionurus elegans Kunth.	Poaceae/Andropogoneae	T	NA	LR/SD	H4	-
154. Elytrophorus spicatus (Willd.) A; Cam.	Poaceae/Elytrophoreae	T	PA	M/SL	H5	-
155. Enneapogon desvauxii P. Beauv.	Poaceae/Pappophoreae	H	A	R/SR	H5	Tizzit; Hagboada
156. Enneapogon Sp.	Poaceae/Pappophoreae	H	A	R/SL	H5	Tizzit
157. Eragrostis barrelieri Daveau	Poaceae/Eragrosteae	T	A	L/SR	H3	Azmeil; Lehmeire
158. Eragrostis cilianensis (All.) Lut.	Poaceae/Eragrosteae	T	A	I/SL	H4	Tukurit; Tinesmert; Lehmeire
159. Eragrostis ciliaris R. Br.	Poaceae/Eragrosteae	T	A	S/SL	H4	Hamra
160. Eragrostis gangetica (Roxb.) Steud.	Poaceae/Eragrosteae	T	PA	A/SD	H4	-
161. Eragrostis perbella Benth.	Poaceae/Eragrosteae	T	NA	L/SD	H5	Hamra
162. Eragrostis pilosa (L.) P. Beauv.	Poaceae/Eragrosteae	T	TA	L/SL	H4	Hamra
163. Eragrostis tenalla Rochst.	Poaceae/Eragrosteae	T	PA	S/SD	H3	-
164. Eragrostis tremula Rochst.	Poaceae/Eragrosteae	-	--	S/SL	H3	Hamra; Tahamerit
165. Eragrostis Sp.	Poaceae/Eragrosteae	T	?	S/SL	H4	-
166. Euphorbia balsamifera Ait.	Euphorbiaceae	NP	NA	SR/U	A4	Ifernan; Afdir
167. Euphorbia hirta L.	Euphorbiaceae	TR	NA	RU/U	H6	-
168. Euphorbia scordifolia	Euphorbiaceae	T	NA	S/SL	H5	En Ould Ben; L'Embeteha
169. Fagonia arabica L.	Zygophyllaceae	CH	A	S/SR	H4	Tizirkan; Tleha
170. Fagonia cretica L.	Zygophyllaceae	CH	A	S/SR	H4	Tleha
171. Fagonia Sp.	Zygophyllaceae	CH	A	R/SR	H4	Tleha; Tleaj
172. Farsetia hamiltonii Royle	Brassicaceae	T	A	S/SR	H5	Sdert L'Ehnes
173. Farsetia ramosissima Hochst.	Brassicaceae	T	TA	S/SR	H4	Akshit
174. Ficus gnaphalocarpa A. Rich.	Moraceae	P	PA	I/SD	A1	-

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
175. Ficus lecardii Warb.	Moraceae	P	?	I/SD	A2	-
176. Fimbristilis exilis Roehm. et Schult.	Cyperaceae	T	PA	M/SD	H4	Said
177. Geigeria alata Benth. et Hook F.	Asteraceae	T	A	S/SR	H4	Nouatgig; Awziz
178. Goekia pharuacioides L.	Aizoaceae	TR	A	S/SL	H6	Amsrar
.79. Glinus lotoides L.	Aizoaceae	TR	NA	A/U	H6	Bed L'Ehmar
.80. Grewia betulifolia Juss.	Tiliaceae	NP	PA	A/SL	A3	Legleya
81. Grewia bicolor Juss.	Tiliaceae	NP	PA	L/SL	A3	Imijij; Kili (T.)
.82. Grewia villosa Willd.	Tiliaceae	NP	PA	I/SD	A3	Berchaga
.83. Guiera senegalensis J.F. Gmel.	Combretaceae	NP	A	L/SL	A4	Elyinie
84. Gynandropsis gynandra (L.) Briq.	Capparidaceae	T	A	S/SL	H3	Eregem; Asenked
85. Heliotropium bacciferum Forssk.	Boraginaceae	CH	NA	S/U	H3	Lehbalae
86. Heliotropium ovalifolium Forssk.	Boraginaceae	TR	NA	A/SD	H6	-
87. Heliotropium strigosum Willd.	Boraginaceae	T	PA	S/U	H4	Belerengel; Amadis
88. Heliotropium supinium L.	Boraginaceae	TR	NA	L/SD	H6	E'mer Reich
89. Heteroposon contortus R. et Sch.	Andropogoneae	H	?	L/SD	H4	-
90. Hibiscus asper Hook F.	Malvaceae	T	NA	I/SD	H3	-
.91. Hibiscus esculentus L.	Malvaceae	T	NA	RU/SD	H2	-
.92. Hibiscus panduriformis Burm. F.	Malvaceae	T	NA	L/SD	H2	-
93. Hibiscus Sp.	Malvaceae	T	NA	RU/SD	H3	-
94. Hygrophila auriculata (Sch.) Heine	Acanthaceae	T	NA	M/SD	H4	-
95. Hyparrhenia rufa Stapf	Poaceae/Andropogoneae	H	A	A/SD	H2	-
96. Hyphaene thebaica (Del.) Mart.	Arecaceae	NP	A	L/SL	A2	Zgellem; Doum (Fr.)
97. Indigofera argentea Burm. F.	Fabaceae	T	TA	S/SR	H4	Téjar; Tejeu
98. Indigofera aspera Perr.	Fabaceae	T	TA	S/SL	H5	-

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
199. Indigofera astragalina D.C.	Fabaceae	T	A	S/SD	H3	-
200. Indigofera colutea (Burm.) Merr.	Fabaceae	T	TA	S/SL	H4	-
201. Indigofera diphylla Vent.	Fabaceae	T	A	S/SD	H4	-
202. Indigofera hirsuta L.	Fabaceae	T	A	S/SD	H4	-
203. Indigofera oblongifolia Forssk.	Fabaceae	NP	A	A/U	A4	Antouf Al Henné
204. Indigofera secundiflora Poir.	Fabaceae	T	A	S/SD	H4	-
205. Indigofera senegalensis Lam.	Fabaceae	T	TA	L/SL	H5	Tigengelit
206. Indigofera Sp.	Fabaceae	T	A	S/SL	H4	Lakmilash
207. Indmoea aquatica Forssk.	Convolvulaceae	TR	A	M/SL	H6	Ababo (?) (.T.)
208. Ipomoea argentaurata Hallier	Convolvulaceae	TG	NA	I/SD	-	-
209. Ipomoea asarifolia (Desr.) R. and Sch.	Convolvulaceae	T	NA	A/U	H4	Bina'aman
210. Ipomoea coptica (L.) Roth.	Convolvulaceae	TR	A	S/SL	H6	-
211. Ipomoea cosceanosperma Hochst.	Convolvulaceae	T	?	L/SD	H4	-
212. Ipomoea dichroa Choisy.	Convolvulaceae	TG	NA	O/SL	-	-
213. Ipomoea eriocarpa R. Br.	Convolvulaceae	T	?	A/SL	H5	-
214. Ipomoea heterotricha F. Dior.	Convolvulaceae	TG	?	L/SL	-	-
215. Ipomoea kotschyana Hochst.	Convolvulaceae	TR	A	S/SL	H6	Lemcherka
216. Ipomoea nil (L.) Roth.	Convolvulaceae	TG	?	L/SD	-	-
217. Ipomoea pilosa Sweet	Convolvulaceae	TG	NA	O/SD	-	-
218. Ipomoea Sp.	Convolvulaceae	T	A	S/SL	H4	-
219. Jatropha chevalieri Beille.	Euphorbiaceae	NP	NA	S/SR	A4	Gendefer
220. Jussiaea decurrens (Walt.) D.C.	Onagraceae	T	NA	M/SD	H2	-
221. Jussiaea perrenis (L.) Bren.	Onagraceae	T	NA	L/SD	H2	-

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
222. Khaya senegalensis Juss.	Meliaceae	P	NA	RU/SD	A1	Kahi (T.); Caicedla (Fr.)
223. Kigelia africana (Lam.) Benth.	Bignoniaceae	P	NA	L/SD	A2	-
224. Kyllinga bleparinota Hochst.	Cyperaceae	T	A	L/SL	H4	Sehet, L'Chit
225. Lannea acida A. Rich.	Anacardiceae	NP	NA	I/SD	A2	Gereine
226. Latipes senegalensis Kunth.	Poaceae/Zoysieae	H	TA	S/SL	H4	Tigurit
227. Leptadenia lancifolia (Schum.) Deene.	Asclepiadaceae	NP	PA	L/SD	A4	Bu Zerga
228. Leptadenia spartium Night.	Asclepiadaceae	NP	A	S/SL	A3	Titarek
229. Leucas martinicensis R. Br.	Lamiaceae	T	NA	L/SD	H4	-
230. Limeum pterocarpum (Gay) Heimerl	Aizoaceae	TR	A	SR/SL	H5	-
231. Limeum linifolium Fenzl.	Aizoaceae	TR	A	S/SD	H6	Egninvol
232. Limeum viscosum (Gay) Fenzl.	Aizoaceae	TR	TA	S/SL	H6	L'Emdeisma
233. Lobelia senegalensis A. DC.	Lobeliaceae	T	A	S/SD	H4	-
234. Lotus arabicus L.	Fabaceae	T	A	L/U	H4	Atiq; Urbeia
235. Lotus arenarius Brut.	Fabaceae	T	A	L/SL	H5	-
236. Lotus glinoides Batt.	Fabaceae	TR	A	L/SR	H6	Ateg
237. Maerua angolensis D.C.	Capparidaceae	NP	?	I/SD	A2	Bagi (T.)
238. Maerua crassifolia	Capparidaceae	NP	A	I/SL	A3	Atil; Aneb
239. Malcomir africana	Brassicaceae	T	A	M/SD	H3	Tozbagit
240. Marisous ligularis (L.) Hutch.	Cyperaceae	T	A	M/SD	H5	-
41. Maytenus senegalensis (Lam.) Exell.	Celastraceae	NP	NA	I/U	A3	Aouseig; Buhlal; Gialgoti (T.)
42. Marremia aegyptiaca (L.) Urban	Convolvulaceae	TG	NA	SL/SD	-	-
43. Merremia pinnata Hall F.	Convolvulaceae	TG	A	S/SL	-	-
44. Mimosa pigra L.	Mimosaceae	NP	A	M/SD	A4	Ganyang (T.)

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
245. Mitracarpus scaber Zugg.	Rubiaceae	T	NA	S/SL	H5	Chamtardi (T.)
246. Mitragyna inermis (Willd.) O. Ktze.	Rubiaceae	NP	A	A/SD	A2	Agelal
247. Mollugo nudicaulis Lam.	Aizoaceae	T	PA	S/SL	H5	Atasa
248. Mollugo Sp.	Aizoaceae	T	?	S/SL	H4	-
249. Momordica balgamina L.	Cucurbitaceae	TG	A	S/SR	-	Tegetrarit; Burbut (T.)
250. Monsonia senegalensis G. and P.	Geraniaceae	T	A	S/SL	H5	Ragem
251. Morettia canescens Boiss.	Brassicaceae	T	?	I/SR	H4	Tozbagit
252. Neptunia oleracea Lour	Mimosaceae	T	PA	M/SD	H6	-
253. Nesaea aspera (G. et P.) Koehne	Lythraceae	T	NA	M/SD	H5	-
254. Nesaea Sp.	Lythraceae	T	NA	M/SL	H4	-
255. Nitraria retusa (Forssk.) Asch.	Zygophyllaceae	NP	A	H/SR	A4	Grzim
256. Nymphea lotus L.	Nympheaceae	T	NA	M/U	H5	Ndairi
257. Ocimum basilicum L.	Lamiaceae	T	TA	I/SL	H4	Azeftenni
258. Oryza barthii A. Chev.	Poaceae/Oryzeae	T	TA	M/SL	H3	Maro
259. Oryza longistaminata Chev. and Roehr.	Poaceae/Oryzeae	H	TA	M/SD	H2	Maro
260. Pancratium trianthum Herb.	Amaryllidaceae	GB	A	S/SL	H4	Amaziz; Teilum
261. Pandiaka heudelotii Hook. F.	Amaranthaceae	T	A	R/SD	H5	-
262. Panicum anabaptistim Steud.	Poaceae/Paniceae	H	A	M/SD	H2	-
263. Panicum fluvicola Steud.	Poaceae/Paniceae	T	TA	L/SD	H3	-
264. Panicum laetum Kunth	Poaceae/Paniceae	H	A	L/SL	H4	Az; Al Hamiré Pagri
265. Panicum maximum Jacq.	Poaceae/Paniceae	H	A	M/SD	H2	-
266. Panicum turgidum	Poaceae/Paniceae	CH	A	S/SL	H2	Morkba
267. Parkinsonia aculeata	Caesalpinaceae	NP	A	I/SD	A3	-

Table 5-3. (Cont'd)

	Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
268.	Paspalum orbiculara Forst.	Poaceae/Paniceae	H	PA	AO/SD	H4	Oqkundé (T.)
269.	Pennisetum pedicellatum Trin.	Poaceae/Paniceae	T	PA	S/SL	H3	Tilimit
270.	Pennisetum violaceum (Lam.) Rich.	Poaceae/Paniceae	T	PA	S/SR	H3	Intilimit
271.	Pergularia tomentosa L.	Asclepiadaceae	T	NA	L/SR	H3	-
272.	Phoenix dactylifera L.	Arecaceae	NP	NA	L/SR	A2	Nhal; Agezzuf
273.	Phragmites australis (Cav.) Trin. ex Steud.	Poaceae/Arundineae	H	A	M/U	H1	Tigert; Legsaiboc
274.	Phyllanthus pentandrus Schum. et Thonn.	Euphorbiaceae	T	A	S/SL	H5	Tenechmarit
75.	Phyllanthus rotundifolius Klein	Euphorbiaceae	T	NA	I/SL	H4	Bedrine
76.	Polycarpea linearifolia D.C.	Caryophyllaceae	T	NA	S/SL	H4	Lebeiss
77.	Polycarpea nivea (ait.) Webb.	Caryophyllaceae	CH	?	SLT/U	H4	L'Katerkta
78.	Polygala erioptera D.C.	Polygalaceae	T	NA	S/SL	H4	Sbé - Ya
79.	Polygala irregularia Boiss.	Polygalaceae	T	NA	S/SD	H4	-
80.	Polygala Sp.	Polygalaceae	T	NA	S/SL	H4	Bo'ole
81.	Polygonum plebeium R. Br.	Polygalaceae	T	NA	L/SD	H4	-
82.	Portulaca oleracea L.	Portulacaceae	TR	PA	RU/U	H6	Ershbat
83.	Prosopis africana Taub.	Mimosaceae	NP	A	L/SD	A2	-
84.	Psoralea plicata Del.	Fabaceae	CH	TA	L/SR	H4	Tetraret
85.	Pterocarpus lucens G. and P.	Fabaceae	NP	A	RS/SD	A2	Changi (T.)
86.	Pulicaria crispa Benth. et Hook F.	Asteraceae	T	PA	L/SR	H4	Ateitsa
87.	Pupalia lappacea Juss.	Amaranthaceae	T	PA	I/U	H4	Leseig
88.	Phynchospora corymbosa Britt.	Cyperaceae	T	NA	M/SD	H2	Sakin
89.	Rhynchosia minima (L.) D.C.	Fabaceae	T	TA	S/SL	H4	Mousrane L'Ehair

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
290. Rogeria adenophylla J. Gay	Pedaliaceae	T	NA	SL/SL	H3	Saw - Vab.
291. Rottboellia exaltata	Poaceae/Andropogonea	T	A	A/SD	H2	Hagbeda
292. Sacciolepis africana C.E. Hubbard and Snowden	Poaceae/Paniceae	GA	PA	M/SD	H3	-
293. Salicornia senegalensis D.C.	Chenopodiaceae	CH	A	H/SL	H3	Tasré; Arjem
294. Salsola barymosa (Schult.) Dandy	Chenopodiaceae	CH	A	H/SR	H4	Aghemal; ALghasala
295. Salvadora persica L.	Salvadoraceae	NP	NA	L/SL	A4	Irak; Afershir; Gudi (T.)
296. Schizachyrium exile Stapf	Poaceae/Andropogoneae	T	PA	SR/SD	H4	-
297. Schmidtia pappophoroides Steud.	Poppophoreae	H	A	SR/SR	H3	Tizzit; Irkheir
298. Schoenfeldia gracillis Kunth	Paniceae/Chlorideae	T	PA	SL/SL	H4	Hinvi; Tegouri; Thielbé (T.)
299. Scirpus praelongatus Poir.	Cyperaceae	T	A	M/SD	H5	Blajder
300. Sclerocarya birrea (A. Rich) Hochst.	Anacardiaceae	P	A	S/SD	A2	Dembo; Eri (T.)
301. Scoparia dulcis L.	Scrofulariaceae	T	NA	L/U	H4	-
302. Securinega virosa (Roxb.) Baill.	Euphorbiaceae	NP	?	L/SD	A4	-
303. Sesamum alatum Thonn.	Pedaliaceae	T	NA	S/SL	H2	Gabun; Selg Elmo'R
304. Sesbania rostrata Brem.	Caesalpinaceae	CH	A	A/SL	H2	-
305. Sesbania sesban (L.) Merill.	Caesalpinaceae	NP	A	L/SD	A3	-
306. Setaria palledefusca Stapf and Hubb.	Poaceae/Paniceae	T	PA	O/SD	H4	Initi
307. Setaria verticillata (L.) P. Beauv.	Poaceae/Paniceae	T	PA	O/SL	H3	Lesseg.
308. Sida alba L.	Malvaceae	T	NA	L/SD	H3	Uden An'nage
309. Sphenoclea zeylanica Gaertn.	Sphenocleaceae	T	NA	M/SD	H3	-
310. Sporobolus festivus Hochst. ex A. Rich	Poaceae/Sporoboleae	T	PA	A/SD	H3	-
311. Sporobolus helvolus Dur. et Schinz	Poaceae/Sporoboleae	H	TA	A/U	H2	Akrich

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
312. Sporobolus spicatus Kunth	Poaceae/Sporoboleae	H	A	SLI/U	H4	Azidi; Rasmir
313. Stachytarpheta angustifolia Vahl.	Verbana	T	NA	L/SD	H4	-
314. Sterculia setigera Del.	Sterculiaceae	NP	NA	SR/SD	A2	Dafréoula
315. Stereospermum Kunthianium Cham.	Bignoniaceae	NP	PA	L/SD	A3	Golombi (T.)
316. Stipagrostis plumosa (L.) Munro ex T. Anders	Poaceae/Aristideae	H	A	S/SR	H3	Nsil
317. Stipagrostis pungens (Desf) De Winter	Poaceae/Aristideae	H	A	S/SR	H2	Sbot
318. Stipagrostis uniplumis (Licht.) De Winter	Poaceae/Aristideae	H	TA	S/SR	H3	Azezig
319. Striga gesneroides (Willd.) Vatke	Scrofulariaceae	P	NA	D	H5	-
320. Striga Sp.	Scrofulariaceae	T	NA	S/SD	H4	-
321. Stylochiton hypogaeus Lepr.	Araceae	T	NA	M/SD	H4	-
322. Suaeda fruticosa (L.) Forssk. ex J.F. Gmel	Chenopodiaceae	CH	A	H/U	H4	Aorbeye
323. Suaeda maritima (L.)	Chenopodiaceae	CH	A	H/U	H4	-
324. Tamarindus indiga L.	Caesalpinaceae	P	PA	L/SD	A1	Aganat; Jemi (T.)
325. Tamarix senegalensis D.C.	Tamaricaceae	NP	A	H/SL	A4	Tarfa; Akawar
326. Tapinanthus globiferus (A. Rich.) van Tiegh	Loranthaceae	P	TA	SL	-	Enlaf
327. Tapinanthus Sp.	Loranthaceae	P	TA	SL	-	Enlaf
328. Tephrosia bracteolata G. and P.	Fabaceae	T	A	S/SD	H3	-
329. Tephrosia elegans Schum.	Fabaceae	T	PA	S/SR	H3	-
330. Tephrosia linearis Pers.	Fabaceae	T	A	S/U	H4	-
331. Tephrosia nubica (Bolos.) Baker	Fabaceae	T	A	R/SL	H3	-
332. Tephrosia obcordata (L.) Baker	Fabaceae	CH	TA	I/SR	H3	Desma

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
333. Tephrosia purpurea (L.) Pers.	Fabaceae	T	PA	I/SD	H3	Amasmaz
334. Tephrosia uniflora Pers.	Fabaceae	T	PA	I/SD	H3	Mulkheisat; Amasmaz
335. Terminalia avicennioides G. and P.	Combretaceae	NP	NA	SR/SD	A3	Pulemi (T.)
336. Terminalia macroptera G. and P.	Combretaceae	NP	NA	R/SD	H4	Uden Al Faras; Bode (T.)
337. Tetrapogon cenchriformis (A. Rich.) W.D. Clay	Poaceae/Chlorideae	T	A	RL/SL	H4	Takaraft; Afakri
338. Tragus racemosus (L.) All.	Poaceae/Zoysieae	T	TA	S/SL	H4	Tinesmert
339. Tribulus terrestris L.	Zygophylaceae	TR	TA	S/SL	H6	Tadresa
340. Trichodesma africana (L.) R. Br.	Boraginaceae	T	NA	R/SR	H4	Harish
341. Typha australis L.	Typhaceae	H	NA	M/SD	H1	Sekin; Tagada
342. Urginea indica Kunth.	Liliaceae	GB	NA	I/SL	H4	Amaziz
343. Urginea salmonea Berh.	Liliaceae	GB	NA	I/SD	H4	Amaziz
344. Urochloa trichopus (Hochst.) Stapf	Poaceae/Paniceae	T	TA	L/SL	H3	Bahra
345. Vahlia digyna (Retz.) O. Ktze.	Saxifraceae	TR	NA	A/SL	H6	Chengé
346. Vernonia kotschyana Sch. Bip.	Asteraceae	CH	A	S/SD	H4	-
347. Vetiveria nigritana Stapf	Poaceae/Andropogoneae	H	A	A/SD	H1	Semban (R.); Sekkeh
348. Waltheria americana L.	Sterculiaceae	CH	A	S/SL	H3	Oudel Nage
349. Waltheria indica L.	Sterculiaceae	CH	A	I/SL	H3	-
350. Zaleya pentapra L.	Aizoaceae	T	A	I/U	H4	Agertin
351. Ziziphus amphibia A. Chev.	Rhamnaceae	NP	A	A/SD	A3	Djabi Foru (T.)
352. Ziziphus mauritiaca Lam.	Rhamnaceae	NP	A	I/SL	A3	Sder; Baouia; Djabi Djeri (P.)
353. Ziziphus mucronata Willd.	Rhamnaceae	NP	NA	A/SD	A3	Sder; Gulumaui (T.)
354. Ziziphus spinacristi (L.) Willd.	Rhamnaceae	NP	A	L/SD	A3	Sder L'Abid; Djabi Walo (P.)

Table 5-3. (Cont'd)

Scientific Name	Family	B.F.	Palat.	Habitat	Stratum	Local Name
355. Zornia glochidiata Reichb. ex. D.C.	Fabaceae	T	TA	I/SL	H4	Leseice
356. Zygophyllum simplex L.	Zygophyllaceae	TR	A	L/SR	H6	L'Mellam

Common Synonyms

Acacia albida	=	Feldherbia albida	Enneapogon desvauxii	=	E. brachystachyrus
Acacia camphylacantha	=	A. polycantha = A. cafra	Grewia betulifolia	=	G. tenax
Acacia nilotica spp.	=	A. acorpioides spp.	Jussiaea spp.	=	Ludwigia spp.
Acacia raddiana	=	A. tortilis	Latipes senegalensis	=	Leptothrium senegalense
Acrachne ramosa	=	Eleusine ramosa	Leptadenia lancifolia	=	L. hastata
Aerva javanica	=	Ae. tomentosa	Leptadenia spartium	=	L. pyrotechnica
Aristida sieberana	=	A. longiflora = A. pallida	Maytenus senegalensis	=	Gymn osporia senegalensis
Bauhinia reticulata	=	Piliostigma reticulata = P. thonningii	Pennisetum violaceum	=	P. mollissimum
Cassia italica	=	C. obovata	Phragmites australis	=	P. communis = P. vulgaris = Arundo phragmites
Cenchrus ciliaris	=	Pennisetum ciliare	Sclerocary birrea	=	Poupartia birrea
Citrullus colocynthis	=	Colocynthis citrullus	Stipagrostis plumosa	=	Aristida plumosa
Citrullus lanatus	=	Colocynthis vulgaris	Stipagrostis pungens	=	Aristida pungens
Commiphora africana	=	Balsamodendron africanum	Stipagrostis uniplumis	=	Aristida papposa
Crypsis schoenoides	=	Heleochloa schoenoides	Tephrosia obcordata	=	Requienia obcardata
Cyperus jeminicus	=	C. conglomeratus	Tetrapogon cenchriformis	=	T. spathaceus
Digitaria horizontalis	=	D. velutina	Zaleya pentanda	=	Trianthema pentandra

M - Marshy
H - Saline
I - Undifferentiated
O - Shade

In column 6, Stratum (ST), the plants are divided into 10 strata, four woody and six herbaceous. The attribute of a stratum indicates the height of the mature individuals of the species in the project area, and not the maximum height of the species. The stratum designations are defined as follows:

Stratum A1 : Woody plants greater than 8 m in height
Stratum A2 : Woody plants of 4 to 8 m
Stratum A3 : Woody plants of 2 to 4 m
Stratum A4 : Woody plants of less than 2 m
Stratum H1 : Herbaceous plants greater than 2 m in height
Stratum H2 : Herbaceous plants 1 to 2 m
Stratum H3 : Herbaceous plants 0.50 to 1 m
Stratum H4 : Grasses 0.25 to 0.50 m
Stratum H5 : Grasses 0.1 cm to 0.25 m
Stratum H6 : Herbaceous prostrated plants

In column 7, local names, unless otherwise noted, are given in Hassaniya (Maure). Other local names are indicated by the following symbols:

(T) - Toucouleur
(P) - Poular
(W) - Wolof
(Fr) - French

IV. PASTURES OF SOUTHERN MAURITANIA

Foreword

The analysis of phytosociological samples in conjunction with the Landsat interpretation resulted in the definition of 39 pure Pasture Types. These are as follows:

Ten types on dune systems or on formations associated with them. They are D1, D2, D3, D4, D5, DL, DC1, DC2, DX, and IC.
Seven types on non-dune sandy landscapes. They are S1, S2, S3, S4, S5, S6, and S7.
Three types on landscapes ranging from loamy sands to loams. They are L1, L2, and L3.
Seven types on regs or lithosols. They are RG1, RG2, RG3, RG4, RG5, RG6, and RG7.
Two types on rocks or loose stoney soils. They are R1 and R2.
Ten types on alluvial tracts or landscapes associated with alluvial systems These include O1, O2, AW1, AW2, AL, AM, AT, AS, A and RK.

Some of these types of pasture land are divided into subtypes identified by lower case letters, e.g., D1b, AW2d, etc.

In addition to the pure pasture types, there are 40 composite types. They define zones in which two or more types co-exist and form a vegetative mosaic whose constituents cannot be mapped separately at a scale of 1:500,000. They are named after the predominant type or subtype followed by a capital letter, for instance, D4X, RG1Q, LIaX.

Descriptions of the pasture types, which constitute the principal subject of Section IV, include the following information:

1. A definition including climatic, edaphic and floristic data
2. A description of soils and topography, as well as important related formations (drainage systems, interdunes, etc.) present in the type, as mapped
3. The total area occupied by the type in km^2 (measured planimetrically)
4. The potential productivity of dry matter, in kilograms per hectare
5. The estimated annual carrying capacity in Tropical Bovine Units (T.B.U.) per hectare
6. The total annual carrying capacity, which is the product of the area and the carrying capacity given in T.B.U.
7. Productivity class of rangeland as defined elsewhere in this section
8. Recommendations for the optimal stocking rates by season, abbreviated as P1 (July to August, rainy season), P2 (September to October, post-rainy season), P3 (October to February, cold season) and P4 (February to June, hot season)
9. Comments on the suitability of the type
10. Current condition and apparent trends when available, comparable to a type's potential
11. The stratification diagrams of the herbaceous and woody strata

For composite types, the following descriptions are given:

a. the composition,
b. the area occupied and
c. their carrying capacity and class.

Floristic definitions of types and subtypes are generally limited to four species including two woody and two herbaceous plants. The woody or herbaceous species named first is always among the dominant species. The second may be less dominant and used instead to differentiate one type from other similar types (such is the case for Indigofera diahylla in S1b and Pandiaka heudelotti in RG5).

The synoptic tables, which are included in the section entitled Description of Pasture Cover Types, help to characterize more completely the floral composition of plant communities. Symbols used in the tables have been defined in Section II.

The number of samples and hand-cuttings with dry weight measures was not sufficient to permit a valid presentation of confidence intervals for

potential productivity. Only averages of sample weights are presented along with the ranges of weights. The latter item is an indication of the variability in herbaceous production of the pasture type. In general, the greater the sampling range, with reference to the average, the greater the confidence interval. Nevertheless, these results are valid indicators of the approximate abundance of the potential productivity as observed in 1980-81. They are presented with reservation as far as their applicability in the coming years is concerned, especially for northern sandy landscapes, where plentiful production may be followed by none because of fluctuations in rainfall.

Listed below are the carrying capacity classes as presented by Boudet (1975).

CLASS	CARRYING CAPACITY IN T.B.U./ha	POTENTIAL PRODUCTIVITY IN kg dry matter/ha
0	0	≤450
1	≤0.1	≤450
2	0.1 to 0.196	450 to 910
3	0.196 to 0.322	910 to 1525
4	0.322 to 0.909	1525 to 4560
5	≥0.909	≥4560

No rangeland types in Mauritania were included in class 5. The project area did have pasture lands within that class, but their size was such that they could not be mapped at a scale of 1:500,000. On the other extreme, some dune surfaces are so fragile that they must not be subjected to any grazing until they have been fully revegetated. The most important of these units can be seen on the map. They constitute Class 0 and are assigned a carrying capacity of zero. A simplified map (Fig. 5-7) allows a project-wide view of the distribution of the different classes. These classes are also included in the legend of the Pasture Cover Type Map.

Pastureland Cover Types

The 79 pasture cover types are characterized in this section by various descriptive criteria. The synoptic tables list 1) herbaceous and woody species abundance for the major cover types and 2) areal and carrying capacity data for all cover types. The figures included in this section present a graphic display of ground cover by woody and herbaceous groupings. The narrative provides further species, soil, topographic, compositional, and miscellaneous descriptions for each cover type.

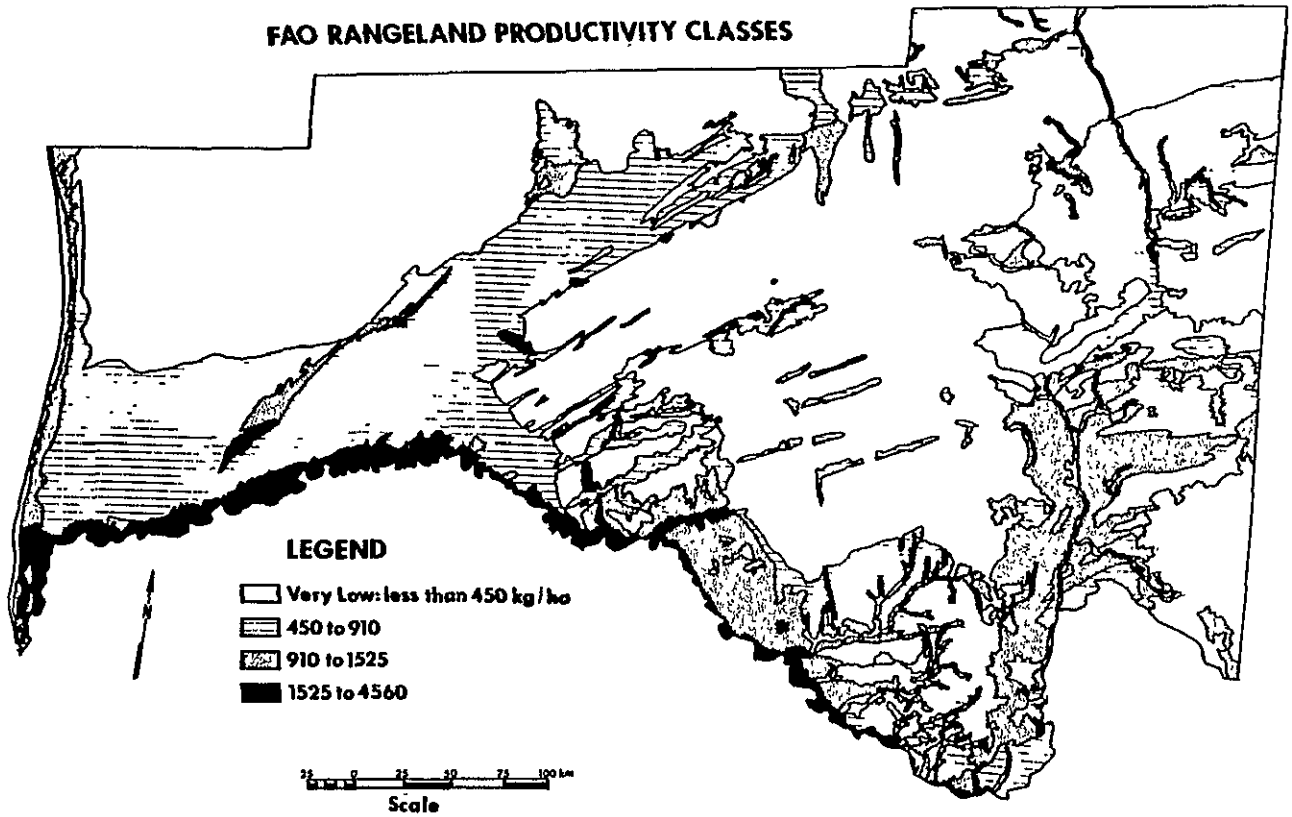


Fig. 5-7. Potential productivities for the pastures of the project area are shown.

D. Pasture Cover Types on Dunes

Table 5-4 lists species abundance for the major 'D' cover types (i.e., D1, D2, D3, etc.). The carrying capacity data for all the 'D' cover types are presented in Table 5-5. Tables 5-4 and 5-5 should be referred to for each pasture cover type description in the text.

(1) **D1**: Sudano-Sahelian Dune Pastures with Balanites aegyptiaca, Aristida mutabilis, Cenchrus biflorus, Dactyloctenium aegyptium and Sesamum alatum. It is found in coarse, aeolian soils, usually characterized by stable dunes with gentle slopes. Loamy sands and clayey soils dominate the interdune depressions.

It has two subtypes, D1a and D1b. D1a is located in the southwest of the study area and has Acacia albida, Euphorbia balsamifera and Brachiaria xantholeuca as dominant species. D1b, in the southeast, is dominated by Combretum glutinosum, Acacia senegal and Alysicarpus ovalifolius.

A typical composition for woody and herbaceous cover is shown in Fig. 5-8.

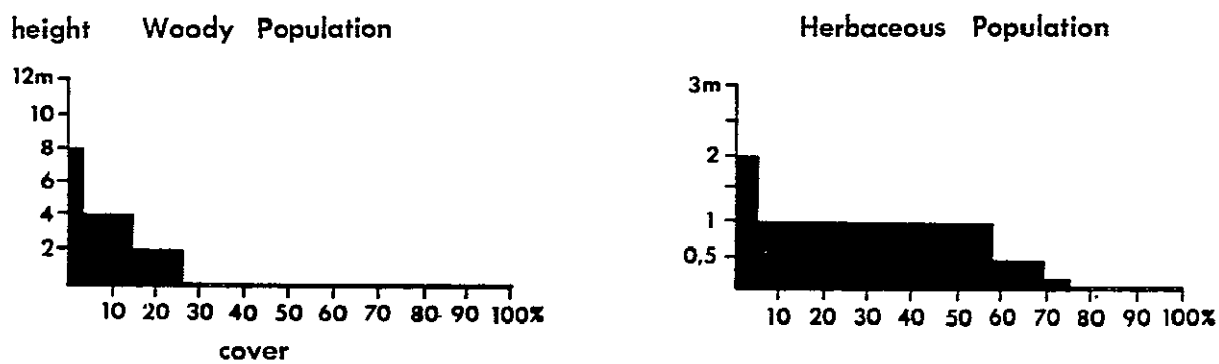


Fig. 5-8 Stratification Diagrams, Type D1

(2) **D1X**: Composed of types DIb (80%), RG1 (15%) and O2 (5%).

It has very reduced carrying capacity during the dry season. D1a is in mediocre condition, degrading due to overexploitation. D1b is in good condition, apparently stable.

Table 5-4. Species abundance for 'D' cover types.

	D1	D2	D3	D4	D5	DC1	DC2
Aristida funiculata		R		X		!	!
Aristida mutabilis	3	2,3!	X	1	R	3	2
Aristida sieberana	R	R	R	R	X	R	R
Aristida stipoides	!					R	
Bracharia xantholeuca	X	R					
Cenchrus bifloris	3	2,3!	2,3!	1,3!	1!	2,3!	1
Cenchrus prieurii	+,1!	1!	1	X	R	1!	+
Chloris prieurii	2!	!				2	2!
Dactyloctenium aegyptium	1,2!	1!	!			X	
Elionurus elegans	!						
Eragrostis cilianenis	X	R	R			R	
Eragrostis pilosa		!	!	R		!	R
Eragrostis tremala	1,2!	X				X	R
Latipes senegalensis	X	1!	R	R		X	R
Panicum turgidum		!	R	1	+	1!	1,2!
Pennisetum pedicellatum		R				R	
Schoenfeldia gracilis	!	R	!	R		!	
Tragus racemosus	1,2!	2	R	R	R	2!	X
Aerva javanica			R		R		R,+
Alysicarpus ovalifolius	X	!				X	
Cassia italica	R						R
Cassia mimosoides	R						
Cassia tora		!				R	

Table 5-4. (Cont'd)

	D1	D2	D3	D4	D5	DC1	DC2
Ceratotheca sesamoides						R	
Chrozophora brocehiana	X	R		R	R	R	X
Citrullus colocynthis	X	X	X	X	R	R	X
Citrullus lanatus		R				R	
Cornulaca monacantha					!		
Cyperus jeninicus					1,2!		3!
Euphorbia scordifolia	!	R	1	X	R	R	R
Fagonia cretica				!	R		R
Farsetia ramosissina			R	2,3!	1,2!		2
Gisekia pharnaciaides	R	X	!	!	R	R	X
Heliotropium bacciferum	R	X	R	+	!	R	R
Heliotropium strigosum	R	R	X	R	R		R
Indigofera argentea			R		R		
Indigofera aspera	1,2!	1,2!	1	1,2!	R	X	X
Indigofera diphylla	X						
Indigofera senegalensis	!	!	R	R		!	R
Limeum viscosum		!	X	X	R	R	R
Morremia pinnata	R						
Mollugo nudicaulis	X	R			R	R	R
Paneratium trianthum		R	X	R	R	R	
Polycarpea linearifolia	R					R	
Sesamum alatum	1	1!	R		R	R	
Tribulus terrestris	X	1,2!			1	1!	X

Table 5-4. (Cont'd)

	D1	D2	D3	D4	D5	DC1	DC2
Zornia glochidiata	!	!				R	
Acacia albida	!					R	
Acacia flava		R					
Acacia raddiana	!	!	2!	1!	1	3	2!
Acacia senegal	2!	1,2!	R	R		1,2!	R
Adansonia digitata	R						
Balanites aegyptiaca	2	1,2!	1,2!		1!		X
Bauhinia rufescens	!	R					
Boscia senegalensis	R	R	R	R		R	
Calotropis procera	!	!	R	R	R	X	X
Capparis decidua		R	R	R	R	R	X
Combretum acculeatum	R	R					
Combretum glutinosum	1,2!						
Commiphora africana	R		X	+,1!	1!	R	1
Euphorbia balsamifera	!	R		R	R	X	3
Guiera senegalensis	R						
Leptadenia lancifolia	R						
Leptadenia spartium	!	1!	1,2!	X	1!	X	1,2!
Maerua crassifolia		R	R	X	X	R	R
Maytenus senegalensis	R				R	R	
Sclerocarya birrea	R						
Ziziphus mauritiaca	!	R				R	

Table 5-5. Significant properties for the pasture cover types of dunes, 'D'.

Cover Type	Subtype	Area (km^2)	Harvested Yield of Herbaceous Layer (kg dry matter/ha) Average	Range	Estimated Carrying Capacity (TBU/ha)	Estimated Total Carrying Capacity (TBU/yr)	Carrying Capacity Class	Estimated Seasonal Carrying Capacity (TBU/ha)
D1	D1a, D1b	4700	1060	360	0.22	103,600	3	P1-2: 0.40 P3-4: 0.05
D1X		130			0.21	2,900	3	
D2		2330	620	300	0.13	30,300	2	P1-2: 0.23 P3-4: 0.033
D2X		80			0.11	900	2	
D2Y		7380			0.16	118,800	2	P1-2: 0.29 P3 : 0.09
D2Z		850			0.14	11,900	2	
D3		1800	690	490	0.15	27,000	2	P1-2: 0.26 P3 : 0.075
D3X		1330			0.15	20,000	2	
D3Y		2810			0.09	25,300	1	
D4		1200	630	360	0.13	15,700	2	P1-3: 0.17 P4 : 0.033
D4X		6800			0.14	95,300	2	
D4Y		420			0.14	6,000	2	
D4Z		60			0.09	600	1	
D4Q		14,530			0.08	116,300	1	
D4K		500			0.15	7,500	2	
D5		440	240	141	0.05	2,200	1	P2 : 0.10 P3 : 0.05
D5X		5350			0.07	37,500	1	
D5Y		9360			0.05	46,800	1	

Table 5-5. (Cont'd)

Cover Type	Subtype	Area (km^2)	Harvested Yield of Herbaceous Layer (kg dry matter/ha) Average	Range	Estimated Carrying Capacity (TBU/ha)	Estimated Total Carrying Capacity (TBU/yr)	Carrying Capacity Class	Estimated Seasonal Carrying Capacity (TBU/ha)
DX		460			---	---	---	
DL		640	220†	--	0.05	3,200	1	P3-4: 0.09
DC1		1120	540	380	0.11	12,400	2	P1-2: 0.15 P3 : 0.10 P4 : 0.05
DC2		570	480	430	0.10	5,700	2	P1-2: 0.18 P3 : 0.05

† Only one sample.

(3) **D2:** Southern Sahelian Dunes with Acacia senegal, Balanites aegyptiaca, Cenchrus biflorus and Alysicarpus ovalifolius. It is found on light yellow to reddish sands. It is characterized by steep slopes, and loamy sands and sometimes calcareous interdune depressions are of minor extent.

Ground cover composition is shown in Fig. 5-9.

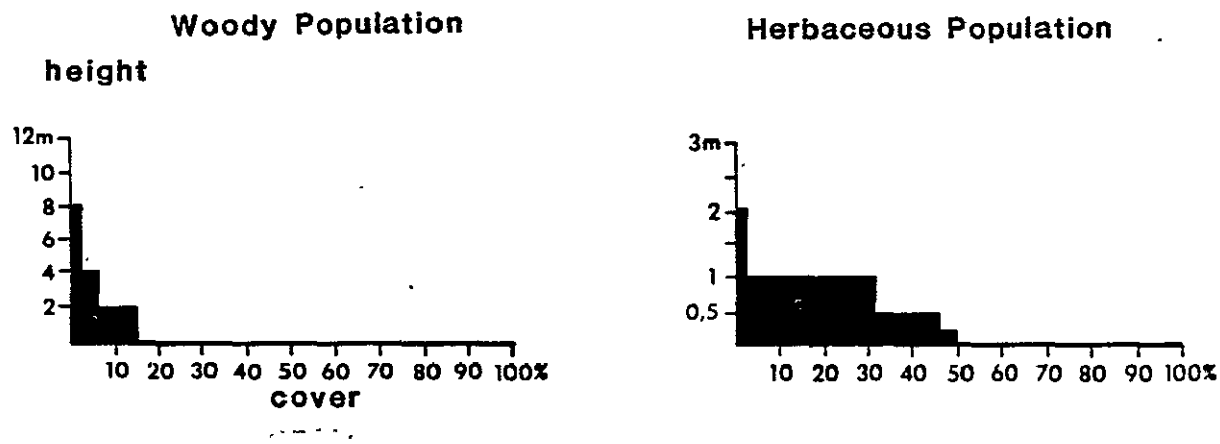


Fig. 5-9 Stratification Diagrams, Type D2

This unit provides excellent pasture during rainy seasons and early dry season; it becomes poor when herbaceous legumes disappear. The condition of the unit is good, and it is stable except in the vicinity of Boghé where wind erosion constitutes an important factor.

(4) **D2X:** Composed of types D2 (85%) and RG1 (15%).

(5) **D2Y:** Composed of types D2 (60%), L2 (25%) and S2a (15%).

Owing to the heavy tree mortality on this range, D2Y is less suitable than other D2 units to support grazing during dry season.

(6) **D2Z:** Composed of types D2 (40%), L3 (40%) and S2a (20%).

(7) **D3**: Sahelian Dunes with Balanites aegyptiaca, Leptadenia spartium, Cenchrus spp. and Indigofera aspera. It is found mainly in rolling dunes with minor sandy interdunes.

Ground cover composition is shown in Fig. 5-10.

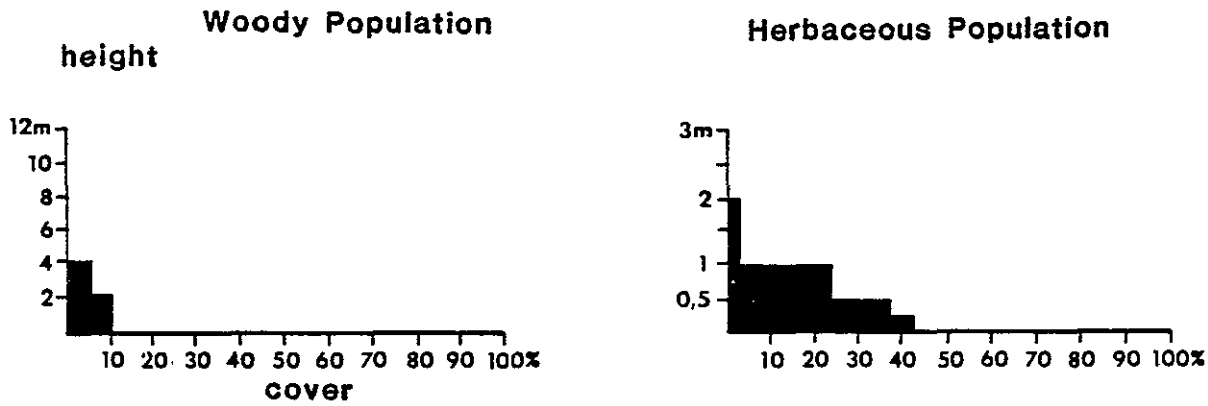


Fig. 5-10 Stratification Diagrams, Type D3

Note that the estimations in table 5-5 are based on 1980 herbaceous production, a good year compared to the many poor years of the last decade, especially in the heart of this rangeland type, in the vicinity of Aleg.

Lack of proteinaceous material in plants during the hot season grazing period (P4) is a limiting factor. There are areas of heavily degrading pastures near settlements along the main east-west road (Chogar, Guimi, etc.) where dunes are destabilized and vegetative cover extremely reduced. In other areas, conditions are fair to good.

(8) **D3X**: Composed of types D3 (90%) and L2 (10%).

(9) **D3Y**: Composed of types D3 (50%), S3 (45%) and IC (5%). This unit, located in the region of Nimjat in the Trarza, is among the most degraded rangelands in Mauritania. Its estimated carrying capacity is far below others of the S3 type, which this type resembles. The woody cover is very reduced (about 4%), and is predominated by the useless shrub Calotropis procera. Vegetative mortality has been very severe during the last decade, especially for Acacia senegal, Acacia raddiana and Commiphora africana. Soil compaction is sometimes advanced and is accompanied by the formation of microbuttes due to surface heaving. The drought is implicated in the degradation, as well as the ill-conceived increase of the watering sites. Near Nimjat, one finds a cemented well about every 2 Km.

(10) **D4**: Sahelian-Saharan Dunes with Balanites aegyptiaca, Commiphora africana, Farsetia ramosissima and Panicum turgidum. It is found in red dunes, often with active ridges. Sharp, abrupt slopes border upon significant areas of sandy interdunes (sometime calcareous) that are generally barren.

Ground cover composition is shown in Fig. 5-11.

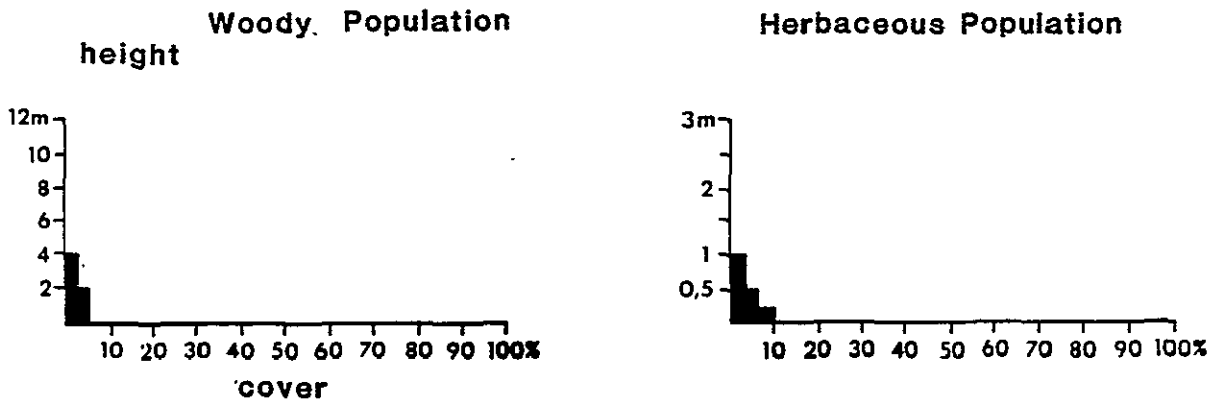


Fig. 5-11 Stratification Diagrams, Type D4

The predominance of Farsetia, a highly valued species by Moor breeders, as well as Citrullus colocynthis and Panicum turgidum all add to the value of this pasture type. These species generally remain green until February. As a consequence, this semi-desertic steppe can support significant grazing until the onset of the hot season.

Significant degradation has occurred near the settlements of Boutilimit, Magta Lahjar, etc.

(11) **D4X**: Composed of the rangeland types D4 (80%) and S5 (20%).

(12) **D4Y**: Composed of types D4 (70%) and S3 (30%).

(13) **D4Z**: Composed of types D4 (70%) and R1 (30%).

(14) **D4Q**: Composed of rangeland types D4 and DX (80%) and IC (20%).

Condition is mediocre to fairly good. Rapid degradation around communities along the main road has resulted in near denudation of the herbaceous

cover and in increasing sand mobility. Furthermore, mortality of the shrubby stratum is considerable.

(15)**D4K**: Composed of types D4 (60%) and L2 (40%).

(16)**D5**: Desert Dunes with Acacia raddiana, Stipagrostis spp, and Cyperus jeminicus. It is found on high red dunes with very prominent relief features and calcareous or sandy interdunes.

Ground cover composition is shown in Fig. 5-12.

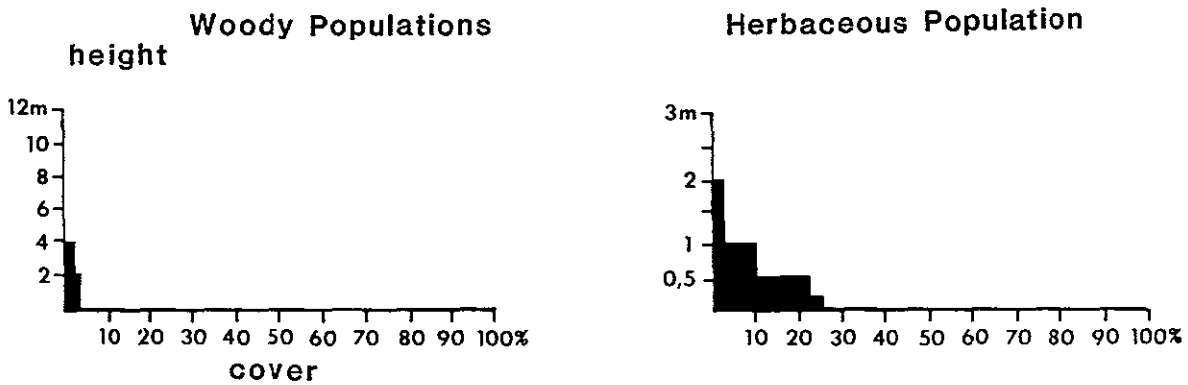


Fig. 5-12 Stratification Diagrams, Type D5

This pasture is used mainly for camels. The vegetation is rich in nitrogeneous materials; however, annual product is highly variable.

(17)**D5X**: Composed of D5 (80%) and S5 (15%). This is excellent rangeland for camels. The pastures are in good condition.

(18)**D5Y**: Composed of types D5 (85%) and IC (15%). As the case was in D4Q, highly pronounced destabilization of dunes occurs in the vicinity of communities located along the main road.

(19)**DX**: Destabilized and almost denuded dunes, undifferentiated. The sparce vegetation found on those landscapes is similar botanically to that of types 'D' or 'S', which surround it. Carrying capacity is estimated to be zero since no grazing should be allowed on those landscapes until vegetation is re-established.

(20) **DL**: Coastline and Coastal Dunes with Tamarix senegalensis, Nitraria retusa, Sporobolus spicatus, and Polygarpea nivea. It is found on white dunes in the saline zone and has gentle to well-pronounced relief.

This type has little importance as a rangeland resource. It could be considered as complementary to Type AS. The condition is fairly good; developmental tendencies are hardly noticeable.

(21) **DC1**: Coastal Dunes in the Sahelian Zone with Acacia raddiana, Salvadora persica, Chloris prieurii, and Aristida mutabilis. It is found in high red dunes with many deep, clayey depressions (sometimes with gypsum), sometimes wooded with Salvadora and Borassus aethiopum, and sometimes shrubless with only Cenchrus ciliaris, Schoenfeldia gracilis, and Aristida funiculata (Fig. 5-13).

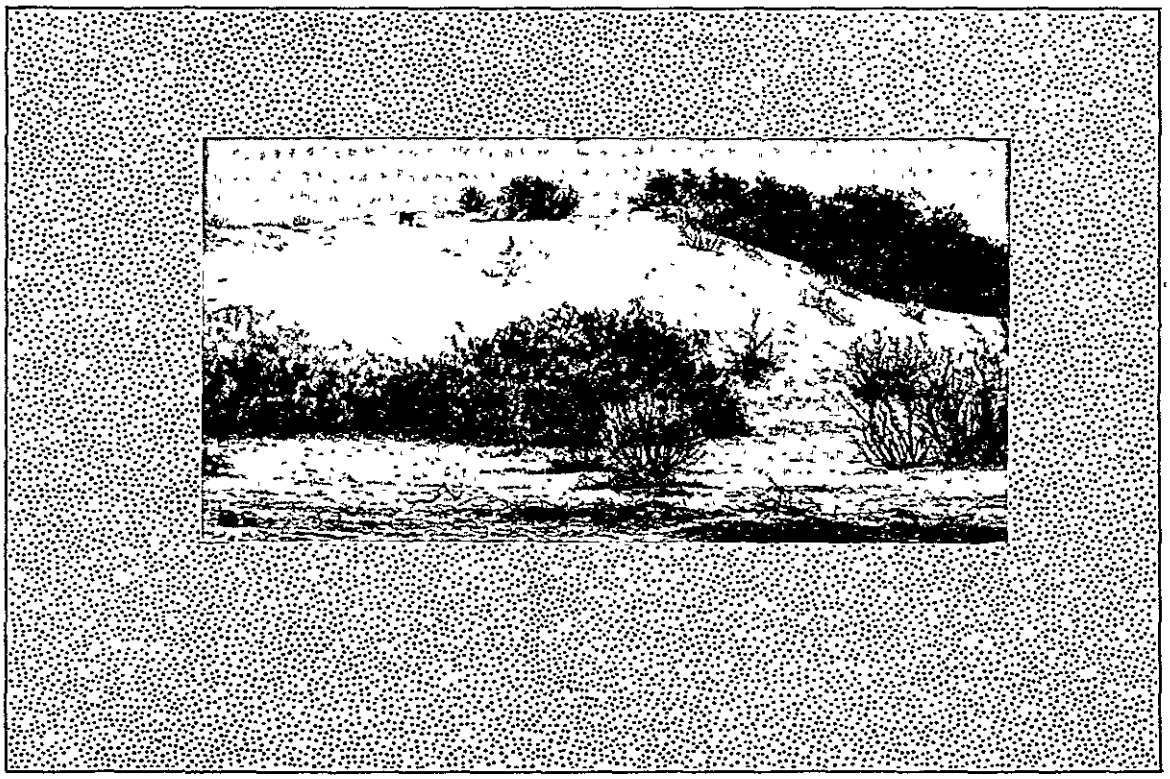


Fig. 5-13. A coast dune typifies cover types DC1 and DC2. Salvadora persica, Euphorbia balsamifera, and Nitraria retusa are common in this setting.

This forage production is conservative as the 1980-81 herbaceous production was poor in that region. Because of its significant woody cover (23%)this rangeland can be alternated with the AS type (year-round).

The condition is generally good, but some significant "circles of devastation" are developing around communities along the Nouakchott-Rosso asphalt road. Generally, this unit seems to have escaped the recent natural mortality characterizing the adjacent Type D2Y.

(22)**DC2**: Coastal Dunes in the Sahelian/Saharan Zone with Euphorbia balsamifera, Commiphora africana, Panicum turgidum, and Cenchrus biflorus. It is found on high red dunes with very pronounced relief and has sandy interdunes with Acacia laeta, Acacia raddiana, Farsetia ramosissima and Tribulus terrestris.

It is of little value during the dry season despite its relatively significant woody cover, owing to the predominance of Euphorbia, which is not used, and Commiphora which does not retain any green matter after December. It is in good condition; although, the successional trends are unknown.

S. Pasture Cover Types on Sands

Table 5-6 lists species abundance for the major 'S' cover types. The carrying capacity data for all 'S' cover types is presented in Table 5-7. Tables 5-6 and 5-7 should be referred to for each cover type description in the text.

(23) **S1**: Sudano-Sahelian Sandy Landscapes with Combretum glutinosum, Sclerocarya birrea, Cenchrus biflorus, and Aristida mutabilis. This unit is found on generally flat, sandy soils with small rocky outcrops. Gullied wadis are striking examples of erosion. Ground cover composition is displayed in Fig. 5-14.

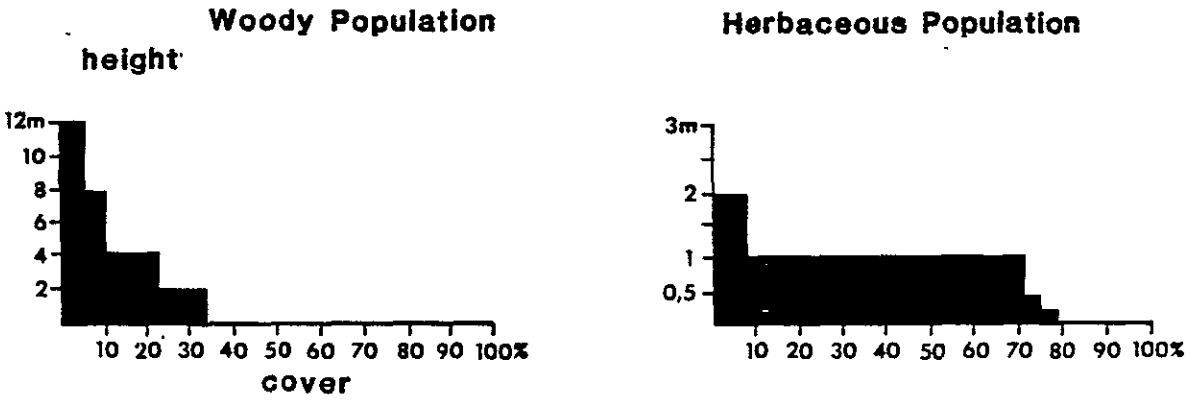


Fig. 5-14 Stratification Diagrams, Type S1

Table 5-6. Species abundance for 'S' cover types.

	S1	S2	S3	S4	S5	S6	S7
Andropogon amplectens	R			+			
Andropogon gayanus	X			X			
Aristida funiculata	R	R	R	R	R		
Aristida mutabilis	3,4!	1,3!	3	3	2	1	2
Aristida sieberana		!			R	1!	
Aristida stipoides	+,1!			R			
Bracharia lata	!	X		R			
Bracharia zantholeuca	R	R		1!			
Cenchrus biflorus	2,3!	3,4!	3	3	3	1!	3
Cenchrus prieurii	!	!	1		1,2!	!	1!
Chloris prieurii	R	R	R				R
Dactyloctenium aegyptium	2	1,2!	1!	1,2!	R		R
Dinebra retroflexa	!						
Elionurus elegans	X			R			
Eragrostis cilianenis	R	R	R				
Eragrostis perbella	!			R			
Eragrostis pilosa	X	!	R	1			
Eragrostis tremala	1,2!	!	1!	R			1!
Latipes senegalensis	R	X	X		R		
Panicum turgidum			!		1,2!	+	1,2!
Pennisetum pedicellatum	X	R		+			
Schoenfeldia gracilis	2!	1!	!	1	R		1,2!

Table 5-6. (Cont'd)

	S1	S2	S3	S4	S5	S6	S7
Indigofera diphylla	R	X	R	R			
Indigofera senegalensis	X	!	!	!	!		2!
Limeum viscosum		R	R	R	!	R	
Morremia pinnata	X		R	1!			
Mollugo nudicaulis	R			R			
Paneratium trianthum	R	R	R	R	R		
Polycarpea linearifolia	X	R	R	R			
Sesamum alatum	R	R	X				
Tephrosia bracteolata	R			X			
Tribulus terrestris		1,2!	1,2!	R	1!	1	2!
Zornia glochidiata	1!	1		3!			
Acacia albida	R	R					
Acacia flava			R	R	!		1!
Acacia raddiana		X			1	1	1,2!
Acacia senegal	1!	1	1,2!	R			X
Adansonia digitata	R						X
Balanites aegyptiaca	1	1,2!	2	1!	1		1,2!
Bauhinia rufescens	R	R		1,2!			
Boscia senegalensis	R	!	!	1,2!	R	R	2
Calotropis procera	X	X	X	R			R
Capparis decidua		R	X		R		
Combretum acculeatum	R	X	!				R
Combretum glutinosum	2	1,2!		R			

Table 5-6. (Cont'd)

	S1	S2	S3	S4	S5	S6	S7
Tragus racemosus	1!	X	1!		!		R
Aerva javanica	R	R	R		R		R
Alysicarpus ovalifolius	X	2!		2			
Blepharis linariifolia				X			
Cassia italica		R					X
Cassia mimosoides	X	R		!			
Cassia tora	X	R	R	R			R
Ceratotheca sesamoides	X		R				
Chrozophora brocehiana		R		R	R		
Citrullus colocynthis		R	1!				X
Citrullus lanatus	R	X					
Crotolaria ebenoides	R			X			
Cyperus jeninicus						1,2!	
Euphorbia scordifolia	R		R		R		
Fagonia cretica							X
Farsetia ramosissina					2!	2	2!
Gisekia pharnaciaides	R	!	X		!		1!
Heliotropium bacciferum	R	R	2!		1!	R	R
Heliotropium strigosum			R			X	R
Indigofera argentea				!			
Indigofera aspera		1,2!	1,2!	R	1		X
Indigofera astragalina	R			X			

Table 5-7. Significant properties for the pasture cover types of the sandy landscapes, 'S'.

Cover Type	Subtype	Area (km^2)	Harvested Yields of Herbaceous Layer (kg dry matter/ha) Average	Range	Estimated Carrying Capacities (TBU/ha)	Estimated Total Carrying Capacity (TBU/yr)	Carrying Capacity Class	Estimated Seasonal Carrying Capacity (TBU/ha)
S1	S1a, S1b	3460	1090	400	0.23	79,600	3	P1-2: 0.31 P3 : 0.23 P4 : 0.077
S1aP		480			0.20	9,600	3	P1-2: 0.41
S2	S2a, S2b	1440	1290	430	0.27	39,100	3	P1-2: 0.45 P3 : 0.20
S3		2230	800	520	0.18	40,300	2	P1-2: 0.3 P3 : 0.12
S3X		230			0.16	3,700	2	
S34		530			0.16	8,500	2	
S3Z		1010			0.07	7,100	1	
S3Q		2030			0.09	18,300	1	
S4		1290	1470	590	0.31	40,000	3	P1-4: 0.31
S5		1420	930	730	0.20	28,400	2	P1-2: 0.34 P3 : 0.12
S5X		420			0.15	6,400	2	
S5Y		180			0.17	3,200	2	
S5Z		260			0.13	3,400	2	
S6		900	480	440	0.10	9,000	2	P1 : 0.15 P2 : 0.22
S6X		1400			0.08	11,200	1	
S7		610	500	370	0.11	6,700	2	P1 : 0.18 P2 : 0.5
S7X		1250			0.08	10,000	1	
SRR		2060			0.10	20,600	1	

This unit is suited to year-round grazing, but has reduced carrying capacity in the hot season (P4). Condition is fairly good to mediocre in the west and central Guidimaka, where some soil crusting has occurred. In the Gorgol, the Assaba and east of the Guidimaka conditions are excellent.

Two subtypes are included wiht this cover type. S1a is the most important one with Andropogon guyanus, Cassia mimosoides, and Guiera senegalensis (Wadis). S1b is limited to near the Senegal River with Maytenus senegalensis, Leptadenia lancifolia, Eragrostis tremula, and Indigofera diphylia.

(24) **S1aP:** Composed of S1a (75%) and R2b (25%). This unit provides excellent grazing and is in very good condition.

(25) **S2:** Sudano-Sahelian Sandy Landscapes with Combretum glutinosum, Acacia senegal, Balanites aegyptiaca, Cenchrus biflorus, and Indigofera aspera (Fig. 5-15). It is found on sandy soils often located at the base of sandstone plateaus or of dune-ridges. The slopes are usually pronounced, and few wadis were noted. The ground cover composition is illustrated in Fig. 5-16.

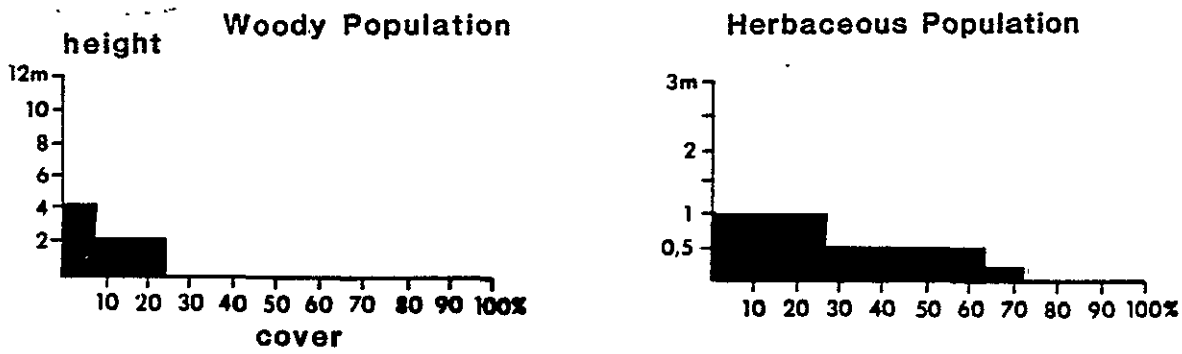


Fig. 5-16 Stratification Diagrams, Type S2

This unit has two subtypes. S2a is near Kaédi and has Guiera senegalensis, Eragrostis pilosa, Brachiaria xantholeuca (silty micro-depressions). S2b is in the Assaba with Acacia raddiana, Latipes senegalensis and Brachiaria lata. The S2b subtype contains several zones that are too small to be mapped where Leptadenia spartium forms dense, almost pure stands, along with the herbaceous species mentioned.

Figure 5-15. A typical setting of type S2 is shown (above). Combretum glutinosum, Acacia senegal, Cenchrus biflorus and Indofera aspera are the dominant species. Calitropis procera is the large-leaved species in the center of the photo. A baobab tree is on the horizon. Inclusions of subtype S2b are shown (below). Leptadenia spartium, Cenchrus bifloris and Indofera aspera constitute the species of this photo, taken about 25 km east of Kiffa.

The vegetation lacks proteinaceous matter during the hot season (P4), but is otherwise suitable for other season grazing (P1 to 3). Condition is generally good to excellent and apparently stable.

(26) **S3**: Sahelian, Sandy Landscapes with Acacia senegal, Balanites aegyptiaca, Cenchrus biflorus, Aristida mutabilis, and Heliotropium bacciferum. It is found in sandy soils, sometimes slightly silty, sometimes compacted, with nearly level to gentle slopes. Ground cover composition is shown in Fig. 5-17.

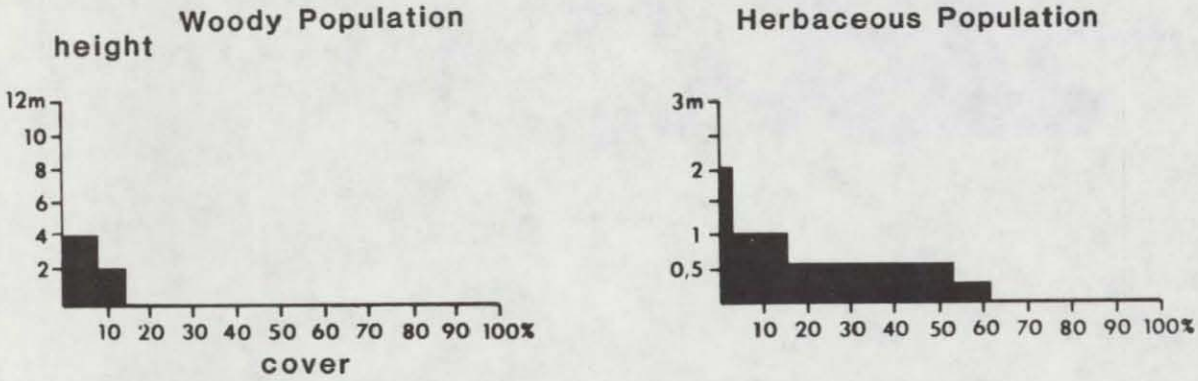


Fig. 5-17 Stratification Diagrams, Type S3

Grazing is suitable during the rainy to cold seasons (P1 to P3). A very pronounced lack of proteinaceous matter occurs during the dry season. The condition varies depending on the degree of exploitation. Degradation was noted in the Guérou-Diouck region.

(27) **S3X**: Composed of S3 types (55%) and D2 (45%).

(28) **S3Y**: Composed of S3 types (60%) and D4 (40%).

(29) **S3Z**: Composed of type S3 (50%), RG1 (20%), DX (20%), and R1 (10%).

(30) **S3Q**: Composed of type S3 (40%), RG1 (35%), and D3 (25%). This unit contains very fragile rangeland and has experienced severe wind erosion. It has very reduced carrying capacity compared to the best S3 units. Advanced degradation on sands and dunes in the Djonaba area (Brakna region) were observed.

(31) **S4**: Sandy to Sandy Loam Landscapes with Pterocarpus lucens, Aristida mutabilis, Andropogon spp, and Indigofera astragalina. It is found on sandy to sandy loam soils with many rocky outcroppings (15%). There are also many small silty clay depressions with Guiera senegalensis, and Eragrostis pilosa, and small wadis (10% alluvial deposits). The unit is generally in broken landscapes. The ground cover composition is illustrated in Fig. 5-18.

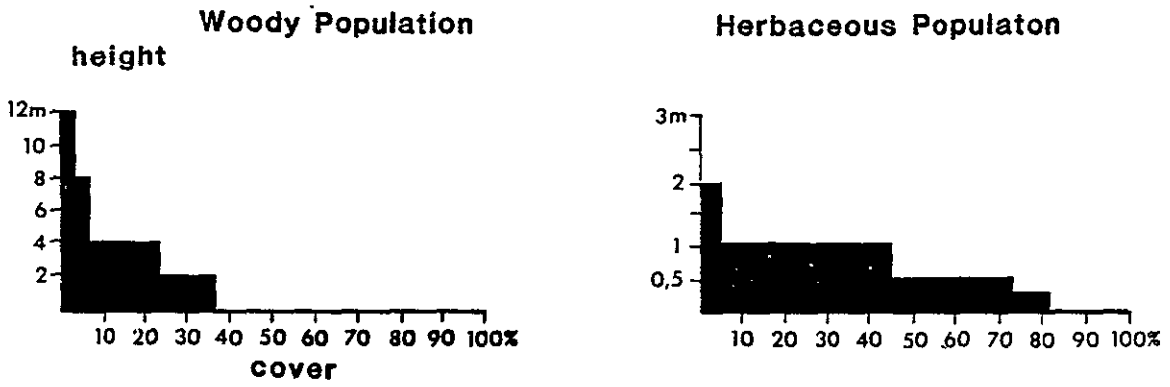


Fig. 5-18 Stratification Diagrams, Type S4

This unit is suitable for year-round rangeland as a result of the variety of its herbaceous vegetation as well as its abundant woody strata. Water availability, however, limits its utility during P3 and P4. The pasture is in excellent condition and is stable for the most part. Climax vegetation dominates the composition of this unit.

(32) **S5:** Sahelo-Saharan Sandy Landscapes with Commiphora africana, Leptadenia spartium, Cenchrus spp, and Panicum turgidum. It is found in habitats without considerable relief. Wadis are rare and covered with a mantle of sand (see type 01). The ground cover composition is shown in Fig. 5-19. The abundant dry matter and the wide sample range are due to the highly variable contribution of Panicum turgidum.

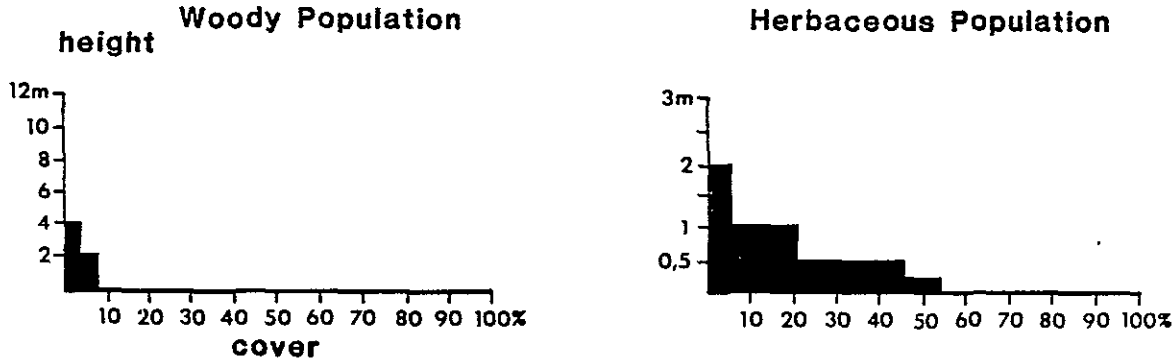


Fig. 5-19 Stratification Diagrams, Type S5

Lack of nitrogenous matter in P3 - 4 season are limiting factors for year-round suitability for pasture. The conditions are fair to very good depending on the animal stocking rate and the availability of water for the animals. This unit is somewhat degraded in the Trarza, but good in the Assaba.

(33) **S5X:** Composed of types S5 (70%), and RG1 (30%).

(34) **S5Y:** Composed of types S5 (70%) and D4 (30%).

(35) **S5Z:** Composed of types S5 (60%), R1 (20%), and D5 (20%).

(36) **S6:** Saharan Sands with Acacia raddiana, Commiphora africana, Farsetia ramosissima, and Cyperus jeminicus. It is found on fine sands, more or less compacted, with little relief. The ground cover composition is shown in Fig. 5-20.

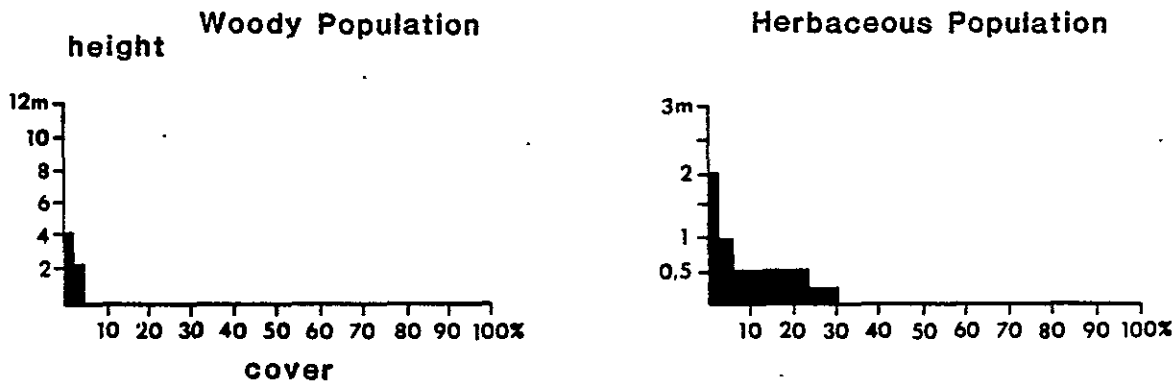


Fig. 5-20 Stratification Diagrams, Type S6

This unit is suitable rangeland for camels, especially in P1 and P2. The condition is highly variable depending on the stocking rate and the recent rainfall. Overall, the condition is fair.

(37) **S6X:** Composed of types S6 (70%), R1 (15%), and D5 (15%).

(38) **S7:** Sands On The Tagant with Boscia senegalensis, Maerua crassifolia, Panicum turgidum, and Cenchrus spp. It is found on coarse, shallow sands, on lithic soils, or on regs. The terrain is flat to undulating with several dune formations along the eastern edge of the plateau. The ground cover composition is displayed in Fig. 5-21.

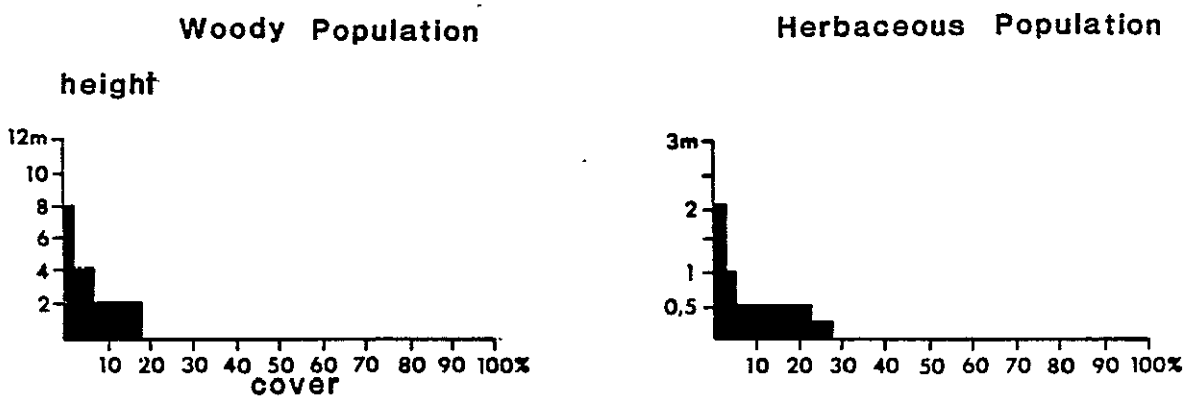


Fig. 5-21 Stratification Diagrams, Type S7

This pasture is not suitable for use in P3 - 4. This unit is subject to, and has experienced, rapid degradation from wind erosion. The herbaceous annuals were sparse in 1980-81 due to lack of rain.

(39)**S7X:** Composed of types S7 (60%), RG4 (25%), and R1 (15%).

(40)**SRR:** Composed of S3 (40%), R2b (30%), RG1 (25%), and RG2 (5%).

L. Pasture Cover Types of Loams

Table 5-8 lists species abundance for the major 'L' cover types. The carrying capacity data for all 'L' cover types is shown in Table 5-9. Table 5-8 and 5-9 should be referred to for each cover type description in the text.

(41) **L1**: Sudano-Sahelian Landscapes, Generally Loamy, with Balanites aegyptiaca, Adansonia digitata, Schoenfeldia gracilis, and Zornia glochidiata. It is found on loamy sand to dominantly sandy loam soils. The terrain is broken with numerous rocky outcroppings typical of those within types R2a or R2b (10%). A dense to very dense drainage system (small wadis of type 02, about 20%) is found throughout the area. The ground cover composition is shown in Fig. 5-22.

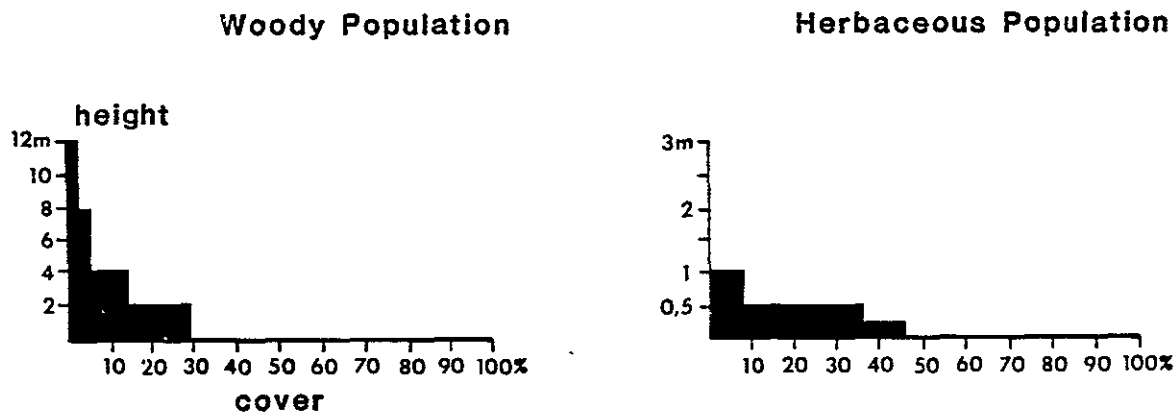


Fig. 5-22 Stratification Diagrams, Type L1

There are two subtypes. L1a is somewhat sandy with Combretum glutinosum, Aristida mutabilis, Eragrostis tremula, and Indigofera senegalensis (Fig. 5-23). While, L1b is somewhat loamy with Acacia flava, Aristida adscensionis, and Aristida funicalata.

This unit is suitable for year-round rangeland due to the abundance of the woody stratum, but it is subject to reduced capacity at the end of season. Owing to erosion and trampling, a slow deterioration is likely to occur. This will result in the eventual replacement of type L1a by L1b, and ultimately L1b will be replaced by type RG2.

(42) **L1aX**: Composed of L2a (70%), and D1b (30%).

Table 5-8. Species abundance for 'L' cover types.

	L1	L2	L3
Andropogon amplectens	R		
Andropogon gayanus	R		
Aristida adscensionis	X		
Aristida funiculata	!	X	1,2!
Aristida mutabilis	2	2	3
Cenchrus biflorus	1	2	2,3!
Cenchrus prieurii	R	X	1
Chloris prieurii	R		R
Chloris virgata		X	
Cymbopogon achoenanthus			!
Dactyloctenium aegyptium	X	1	R
Enneapogon desvauxii	R	!	1
Eragrostis cilianensis	R	X	
Eragrostis pilosa	!	1,2!	
Eragrostis tremula	1!	!	!
Latipes senegalensis		R	X
Panicum lactum	R	R	
Panicum turgidum			+
Pennisetum pedicellatum	!		
Schoenfeldia gracilia	3	2,3!	R
Tetrapogon cenchrifomis		+	
Tragus racemosus	!	1!	1
Aerva javanica			X
Alysicarpus ovafifolius	!	1!	R
Blepharis linariifolia	R		
Boerhavia repens			+
Cassia mimosoides	1		
Cassia tora	X	R	
Chrozophora bracchiana			R
Citrullus colocynthis			1!
Corchorus depressus			R

Table 5-8. (Cont'd)

	L1	L2	L3
Farsetia ramosissima			2
Heliotropium bacciferum		R	+
Indigofera astragalina	X		
Indigofera senegalensis	1!	1,2!	2
Limeum viscosum	R		1
Mollugo nudicaulis		X	+
Morettia canescens			R
Polycarpea linearifolia	R	+	
Tribulus terrestris	!	X	1!
Zornia glochidiata	2	X	
Acacia flava	!	X	!
Acacia raddiana		!	R
Acacia senegal	1	1	R
Acacia seyal	2!		
Adansonia digitata	+	R	
Adenium obesum	R		
Balanites aegyptiaca	2	1	+
Boscia senegalensis	R	3	1!
Calotropis procera	X	R	X
Capparis decidua			1!
Combretum acculeatum	R		
Combretum glutinosum	1		
Commiphora africana	!	R	R
Grewia bicolor	!	R	
Guiera senegalensis	!	R	
Leptadenia spartium			X
Maerua crassifolia			2
Pterocarpus lucens	R		
Sclerocarya birrea	X		
Sterculia setigera	X		
Ziziphus mauritiaca	+	R	
Ziziphus spinacristi	R		

Table 5-9. Significant properties for the pasture cover types of loamy landscapes, 'L'.

Cover Type	Subtype	Area (km^2)	Harvested Yields of Herbaceous Layer (kg dry matter/ha) Average	Range	Estimated Carrying Capacity (TBU/ha)	Estimated Total Carrying Capacity (TBU/yr)	Carrying Capacity Class	Estimated Seasonal Carrying Capacity (TBU/ha)
L1	L1a, L1b	6400	740	260	0.16	102,500	2	P1-2: 0.23 P3 : 0.16 P4 : 0.10
L1ax		230			0.18	4,100	2	
L2		3280	840	620	0.18	59,000	2	P1-2: 0.23 P3 : 0.15 P4 : 0.10
L2X		740			0.17	12,600	2	
L3		530	460	430	0.10	530	2	P1-2: 0.14 P3 : 0.08 P4 : 0.04

Figure 5-23. A typical setting for subtype L1a is shown. Combretum glutinosum, Aristida mutabilis, Eragrostis tremula and Indigofera aspera constitute this landscape southwest of Selibaby.

(43) **L2**: Sahelian Landscapes, Generally Loamy, with Boscia senegalensis, Acacia senegal, Schoenfeldia gracilis, and Cenchrus biflorus. This unit is found especially in valley sites situated near rocky or lateritic plateaus. Rocky outcroppings constitute about 15% of this unit. The drainage network is well developed; major wadis have been mapped separately. The ground cover composition is shown in Fig. 5-24.

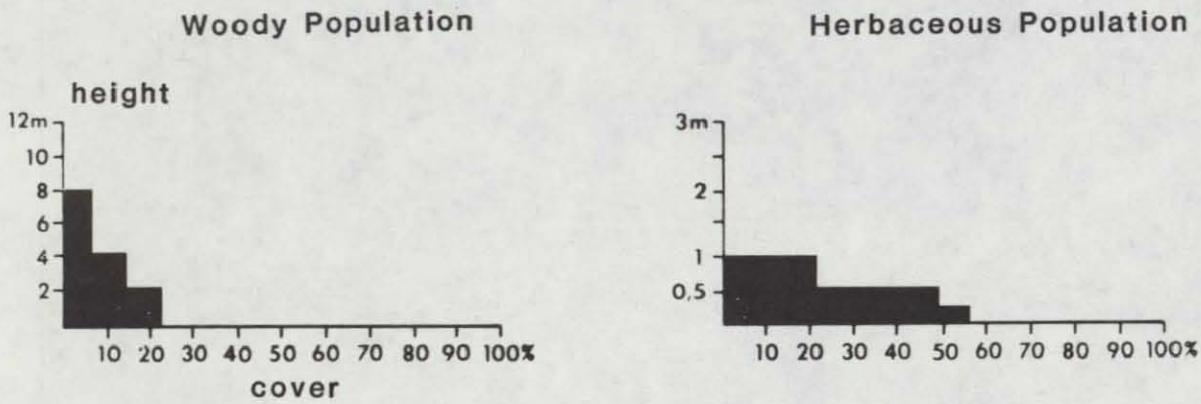


Fig. 5-24 Stratification Diagrams, Type L2

The pasture is suitable for year-round grazing, but capacity is considerably reduced in P3 - 4. The overall pasture condition is from fair to good.

(44)**L2X**: Composed of types L2 (85%) and D2 (15%).

(45) **L3**: Sahelian Loamy Landscapes with Maerua crassifolia, Balanites aegyptiaca, Aristida mutabilis, and Enneapogon desvauxii. It is found on sandy loams to loamy sands in moderately wide, nearly level interdunal depressions. The ground cover composition is shown in Fig. 5-25.

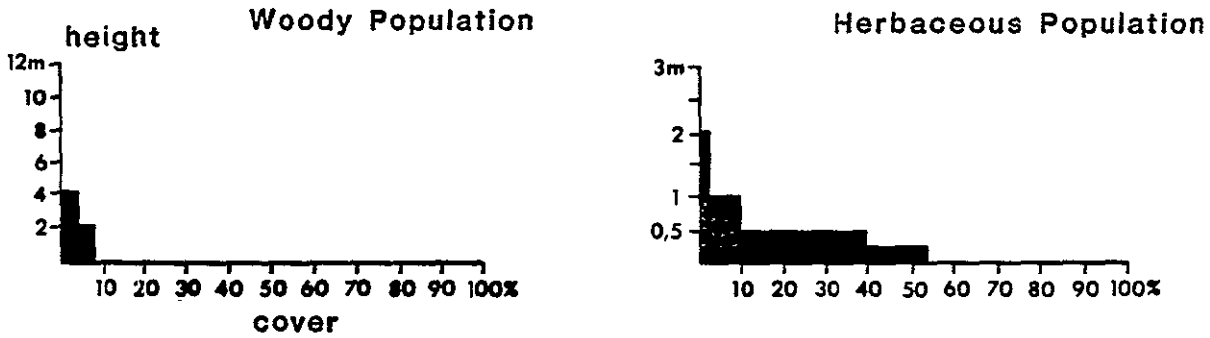


Fig. 5-25 Stratification Diagrams, Type L3

The pasture is reduced to little or no suitability for grazing by the end of the dry season. The pasture is in mediocre condition. The irregularity of rainfall in 1980 had produced a wide range of biomass production estimates (see Table 5-8).

RG. Pasture Cover Types of Regs

Table 5-10 lists species abundance for the major 'RG' cover types. The carrying capacity data for all 'RG' cover types are shown in Table 5-11. Tables 5-10 and 5-11 should be referred to for each cover type description in the text.

(46)**RG1**: Barren Sahelian reg with Acacia flava, Balanites aegyptiaca, and Schoenfeldia gracilis. This cover type is found in fine gravel landscapes, more or less impermeable, often rich in sodium. Shallow sands or loams make up about 25% of the type. A very dense drainage system with many wadis of different sizes provides the environment where the bulk of the vegetative biomass is produced. The ground cover composition is shown in Fig. 5-26.

Table 5-10. Species abundance for 'RG' cover types.

	RG1	RG2	RG3	RG4	RG5	RG6
Andropogon gayanus		!				
Aristida adscensionis	R	1,2!	X	1!	X	R
Aristida funiculata	1!	1!	X	X	X	
Aristida mutabilis	X	R	1!	X	3!	R
Cenchrus biflorus	!		X	1!	4!	X
Cenchrus prieurii				R	1!	X
Chloris prieurii		R			X	
Chloris virgata		R	R		R	
Cymbopogon achoenanthus	R		X	1		
Dactyloctenium aegyptium	R	X		R		
Echinochloa colona					2!	
Enneapogon desvauxii		X		R	X	
Eragrostis cilianensis	R	X		R		
Eragrostis pilosa	!	1!	2		2,3!	
Eragrostis tremula		R	1!		!	
Latipes senegalensis				R		
Panicum lactum	!		1!		3!	
Panicum turgidum				R		1
Pennisetum pedicellatum		!1	R			
Schoenfeldia gracilia	1,2!	3	2,3!	1	3	
Tetrapogon cenchrifomis	R	!	1!	X		
Tragus racemosus		R		R	!	
Aerva javanica	R			X		+

Table 5-10. (Cont'd)

	RG1	RG2	RG3	RG4	RG5	RG6
Alysicarpus ovafifolius	R		X			+
Blepharis linariifolia					R	R
Boerhavia repens	R					2!
Cassia mimosoides		!				
Cassia tora	R	1!	X	R	3!	
Chrozophora bracchiana						X
Citrullus colocynthis	R		R	R		!
Cleome viscosum	R	!		R		R
Corchorus depressus		R			X	
Corchorus tridens	R		X			
Crotolaria saharae				X		
Cyperus jeminicus						!
Farsetia ramosissima				R		2,3!
Heliotropium bacciferum	R			X		R
Indigofera argentea						X
Indigofera senegalensis	1!	!	1	X	X	
Limeum viscosum						X
Mollugo nudicaulis	R	R	R			R
Morettia canescens				R		X
Pandiaka heudelotii		!				
Polycarpea linearifolia	R	R				
Tribulus terrestris	1!	R	1	X		1
Zornia glochidiata		X	X			

Table 5-10. (Cont'd)

	RG1	RG2	RG3	RG4	RG5	RG6
Acacia flava	1,2!	R	1!	+	X	
Acacia raddiana				R	R	+
Acacia senegal		X		R	X	
Acacia seyal	R	2,3!			1!	
Adansonia digitata	R	1!	+	R	X	
Adenium obesum	R	X		X		
Balanites aegyptiaca	1	1,2!	X	X	2	X
Boscia senegalensis	X	R	2,3!	1	1!	1,2!
Calotropis procera	R		X	R		
Capparis decidua	X			R	R	X
Combretum acculeatum	R	X	R	X	1!	
Combretum glutinosum		1!		R	X	
Commiphora africana	R	R	1	1!		R
Euphorbia balsamifera			R	1,3!		
Grewia bicolor		1!	!		R	
Guiera senegalensis		R	!			
Leptadenia spartium	R					1
Maerua crassifolia	R		R	1!		1
Pterocarpus lucens		X				
Sclerocarya birrea		X				
Sterculia setigera		X				
Ziziphus mauritiaca	!	R	X	R	1!	
Ziziphus spinacristi		R				

Table 5-11. Significant properties for the pasture cover types of reg landscape, 'RG'.

Cover Type	Subtype	Area (km^2)	Harvested Yields of Herbaceous Layer (kg dry matter/ha) Average	Range	Estimated Carrying Capacity (TBU/ha)	Estimated Total Carrying Capacity (TBU/yr)	Carrying Capacity Class	Estimated Seasonal Carrying Capacity (TBU/ha)
RG1		14,160	120	110	0.025	35,400	1	P1 :0.08 P2 : 0.02
RG1X		80			0.06	500	1	
RG1Y		810			0.06	4,900	1	
RG1Z		1700			0.02	3,400	1	
RG1Q		610			0.08	4,900	1	
RG2		3850	560	330	0.12	46,200	2	P1-2: 0.17 P3 : 0.08 P4 : 0.05
RG3	RG3a, RG3b	4140	350	19	0.074	30,700	1	P1-2: 0.11 P3 : 0.05 P4 : 0.03
RG3X		50			0.09	500	1	
RG4		2220	170	120	0.036	8,000	1	P1 : 0.09 P2 : 0.04 P3 : 0.015
RG4X		2600			0.04	10,400	1	
RG4Y		690			0.055	3,800	1	
RG4Z		760			0.05	3,800	1	
RG4Q		280			0.025	700	1	
RG5		550	550	370	0.12	6,700	2	P1-2: 0.14 P3 : 0.10 P4 : 0.07
RG6		440	310	280	0.065	2,900	1	P2 : 0.15 P3 : 0.05
RG7		4170	430	--	0.09	37,600	1	P1-2: 0.16 P3 : 0.05

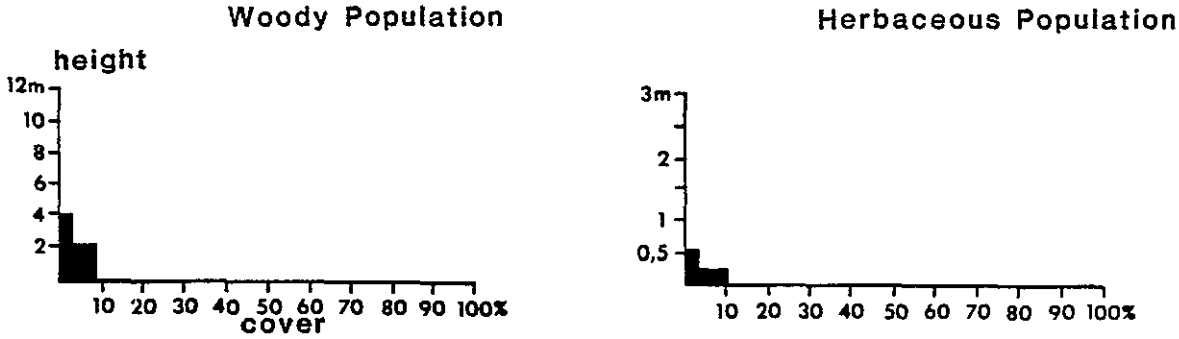


Fig. 5-26 Stratification Diagrams, Type RG1

The grazing on this pasture type is of limited suitability only after the rainy season. This unit is in mediocre condition with extremely variable conditions in the wadis. The successional tendencies are unknown.

(47)**RG1X:** Composed of types RG1 (80%), and D1b (20%).

(48)**RG1Y:** Composed of types RG1 (55%), S3 (25%), D4 (10%), and R1 (10%).

(49)**RG1Z:** Composed of types RG1 (75%), and R1 (25%).

(50)**RG1Q:** Composed of types RG1 (50%), S3 (30%), and D3 (20%).

(51)**RG2:** Sudano-Sahelian Reg with Acacia seyal, Adansonia digitata, Schoenfeldia gracilis, and Aristida adscensionis. Lithic and gravelly soils dominate the setting of this unit. Sandy loam to clay loam textures are found in microdepressions. The landscape is composed of a relatively broken terrain. The ground cover composition is illustrated in Fig. 5-27.

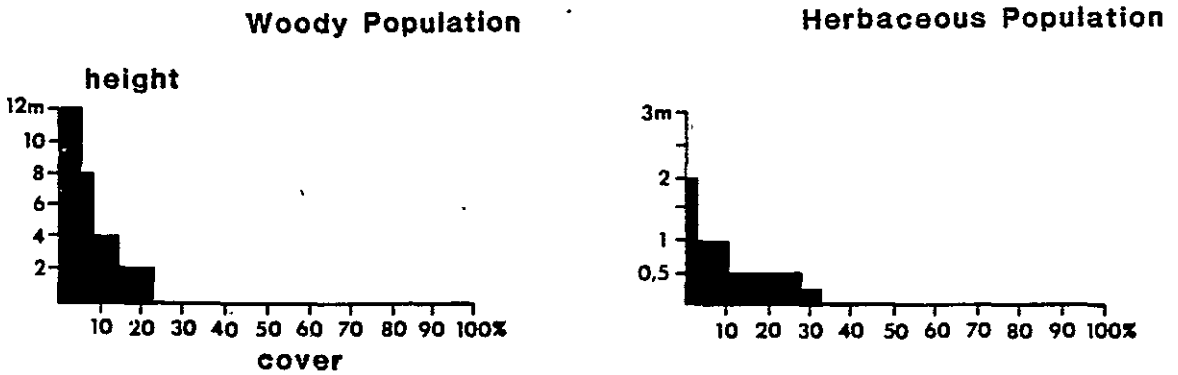


Fig. 5-27 Stratification Diagrams, Type RG2

Suitability for grazing is extremely reduced in the dry seasons (P3 - 4). The condition of this unit is fair to good; however, successional tendencies are unknown.

(52)**RG3:** Sahelian Reg with Boscia senegalensis, Adansonia digitata, and Schoenfeldia gracilis. This unit is characterized by two physiographic settings of the subtypes RG3a and RG3b. RG3a is a mosaic of cuirasses with numerous clayey to loamy depressions and nearly level, shallow sandy soils. RG3b also is found on cuirasses, with fewer depressions than RG3a on the sandstone plateaus, whose flanks more or less sheer. The plateau tops are nearly level. The ground cover composition is shown in Fig. 5-28.

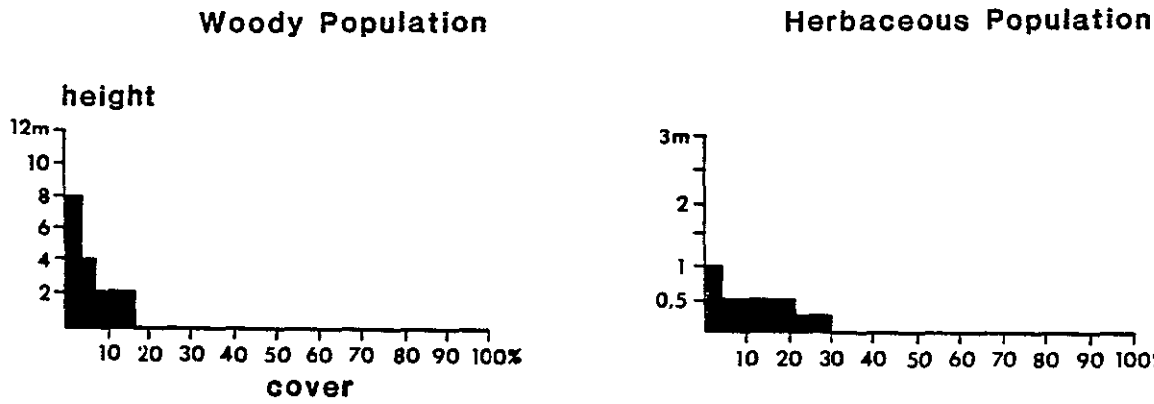


Fig. 5-28 Stratification Diagrams, Type RG3

This unit is suitable for rangeland principally in P1 and P2; critical lack of water occurs in type RG3b during the dry season.

The dominant species of RG3a are Acacia flava, Eragrostis tremula, and Tribulus terrestris; while RG3b is dominated by Grewia bicolor, Maerua crassifolia, Cymbopogon schoenanthus and Aristida adscensionis. Relatively advanced degradation of RG3a is characterized by barren, loamy sand plates and dominated by worthless ephemeral nitrogen-loving species. RG3b rangeland type is in good, stable condition.

(53) **RG3X:** Composed of types RG3a (75%), and D2 (25%).

(54) **RG4:** Reg on High Sandstone Plateau with Euphorbia balsamifera, Boscia senegalensis, and Cymbopogon schoenanthus. This cover type is found on more or less impermeable soils sometimes with a shallow aeolian cover. Numerous small wadis and ponds typical of types O1 and O2 are commonplace in this unit. Relief is level to undulating. The ground cover composition is shown in Fig. 5-29.

This pasture type is suitable for year-round grazing since it has a significant woody stratum. In effect, it is lack of water for animals that limits the animal load on these rangelands. This unit is in good condition and is apparently stable.

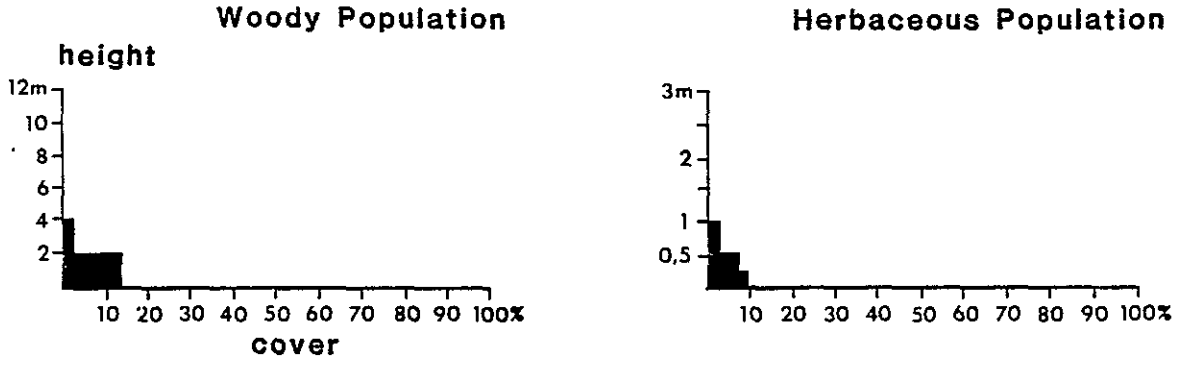


Fig. 5-29 Stratification Diagrams, Type RG4

This cover type is suitable for essentially the rainy season grazing. It is in relatively good condition. Its successional sequences are unknowr

(55) **RG4X:** Composed of types RG4 (50%), R1 (30%), and S7 (20%).

(56) **RG4Y:** Composed of types RG4 (40%), S7 (35%), and R1 (25%).

(57) **RG4Z:** Composed of types RG4 (70%), S7 (25%), and R1 (5%).

(58) **RG4Q:** Composed of types RG4 (60%), and R1 (40%).

(59) **RG5:** Sudano-Sahelian Highland Reg with Pterocarpus lucens, Acacia seyal, Schoenfeldia gracilis, and Pandiaka heudelotii. It is found on lithosols and rocky folds with small rocky wadis, strongly gullied. It has gentle to very pronounced slopes. The ground cover composition is shown in Fig. 5-30.

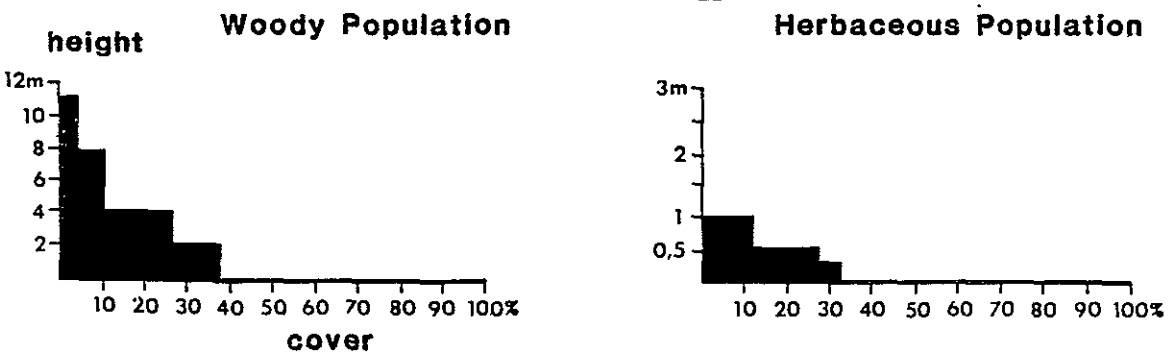


Fig. 5-30 Stratification Diagrams, Type RG5

(60)**RG6:** Sahelian-Saharan Reg with Boscia senegalensis, Capparis decidua, Panicum turgidum, and Farsetia ramosissima. It is found on undulating reg with shallow drainage channels where the majority of herbaceous production is found. A few treeless, cultivable clayey-argillaceous depressions (such as Oblat Boit, south of Tamoussoumit) are located within this unit. The ground cover composition is shown in Figure 5-31.

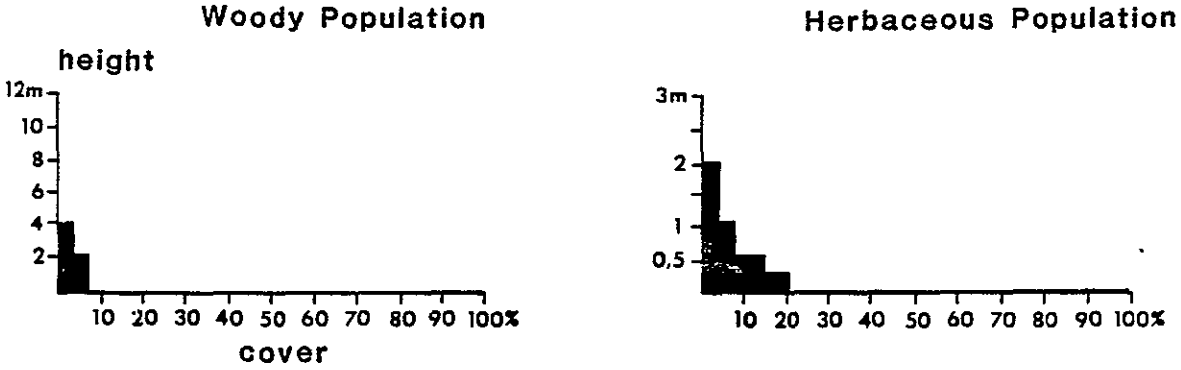


Fig. 5-31 Stratification Diagrams, Type RG6

It is suitable for camel grazing at the end of the rainy season and the beginning of dry season. Its condition is good; observed production on these lands during 1980-81 appears to be around their productive potential.

(61) **RG7:** Sahelian-Sudano Landscapes on Lithosols with Commiphora africana, Pterocarpus lucens, Schoenfeldia gracilis, and Aristida adscensionis. It is found on gravelly soils with shallow, clayey horizons. The lands consist of low tablelands. The sideslopes of the tablelands produce an excellent, but inaccessible, pasture with Andropogon gayanus and Blepharis linarüfolia.

It is suitable for limited grazing at the end of the annual pastoral cycle. Watering points for animals in dry season are nonexistent. It is in good condition.

The inaccessibility of this unit made field characterization impractical. Consequently, this cover type was not seen extensively in the field. The definition and description of this unit is based on only one sample located at the periphery of the delineated area.

R. Pasture Cover Types of Rocky Lands

Table 5-12 lists species abundance for the major 'R' cover types and a single alluvial cover type, A. The carrying capacity data for all 'R' cover types are shown in Table 5-13. Tables 5-12 and 5-13 should be referred to for each cover type description in the text.

Table 5-12. Species abundance for 'R' cover types and cover type 'A'.

	R1	R2	A
Andropogon amplectens		X	R
Andropogon gayanus		1	4
Aristida adscensionis	+	2,3!	X
Aristida funiculata	R	X	R
Aristida mutabilis	R	1!	
Cenchrus biflorus	R	X	
Chloris prieurii	R		
Cymbopogon achoenanthus	+		
Dactyloctenium adgyptium		X	X
Eragrostis cilianensis	R	R	
Eragrostis pilosa	R		3!
Eragrostis tremula		R	
Latipes senegalensis		R	
Panicum lactum		R	X
Pennisetum pedicellatum		X	3
Schoenfeldia gracilia	X	1,2!	2
Tetrapogon cenchrifomis		2	
Tragus racemosus		R	
Aerva javanica	!		
Blepharis linariifolia		!	
Blainvillea gayana			1!2
Cassia mimosoides		!	2
Cassia tora		R	X
Cleome viscosum	X	1!	
Corchorus depressus	R		
Indigofera astragalina		R	2
Indigofera senegalensis	R	R	X
Limeum viscosum	R		
Mollugo nudicaulis	R	R	
Morettia canescens	R		
Pandiaka heudelotii	R	2!	

Table 5-12. (Cont'd)

	R1	R2	A
Polycarpea linearifolia		R	X
Tribulus terrestris	R	R	
Zornia glochidiata		R	R
Acacia flava	R		
Acacia raddiana	R		
Acacia senegal		R	
Acacia seyal		R	4
Adansonia digitata	R	R	+
Adenium obesum	+!	X	
Balanites aegyptiaca	R	X	
Boscia senegalensis	1	R	
Calotropis procera	R		
Capparis decidua	R		
Combretum acculeatum		X	1
Combretum glutinosum	R	1,2!	X
Commiphora africana	R	1,2!	X
Euphorbia balsamifera	1,3!		
Grewia bicolor		X	
Guiera senegalensis	R	1!	
Leptadenia spartium	R		1
Maerua crassifolia	R		
Maytenus senegalensis			2
Pterocarpus lucens		!	R
Stericulia setigera		X	R
Ziziphus mauritiaca		R	
Ziziphus spinacristi			X

Table 5-13. Significant properties for the pasture cover types of rocky landscapes, 'R'.

Cover Type	Subtype	Area (km^2)	Harvested Yields of Herbaceous Layer (kg dry matter/ha) Average	Range	Estimated Carrying Capacity (TBU/ha)	Estimated Total Carrying Capacity (TBU/yr)	Carrying Capacity Class	Estimated Seasonal Carrying Capacity (TBU/ha)
R1		2800	90	120	0.01	2,800	1	
R2	R2a, R2b, R2c	1580	1100	750	0.12	19,000	2	P1-2: 0.16 P3-4: 0.07
RX		730			0.06	4,400	1	
R1X		1820			0.05	9,100	1	
R1Y		280			0.045	1,300	1	
R1D		800			0.015	1,200	1	
R1DD		500			0.01	500	1	

(62) **R1:** Sahelian-Saharan Rocky Landscapes with Euphorbia balsamifera, Boscia senegalensis, Aristida adscensionis, and Tetrapogon cenchriformis. This pasture cover type is found on shallow, aeolian sands over sandstone. The ground cover composition is shown in Fig. 5-32.

The inaccessibility to these rangelands is such that their real range value is estimated at half their theoretical value. The pasture can be used only by goats in vicinity of permanent settlements and nomadic encampments. It is in good condition and is stable.

(63) **R2:** Sahelo-Saharan Rocky Landscapes with Combretum glutinosum, Commiphora africana, Aristida ascensionis, Tetrapogon cenchriformis, and Andropogon gayanus var. Bisquamualatus. It is found on shallow aeolian sands over granitic rocks or sandstone. The ground cover composition is displayed in Fig. 5-33.

There are three subtypes. R2a is dominated by Pterocarpus lucens and Andropogon amplectens; R2b by Grewia bicolor, Adenium obesum, and Aristida mutabilis; and R2c by Guiera senegalensis, Pterocarpus lucens, Schoenfeldia gracilis, and Elionurus elegans (Fig. 5-34).

This unit is often inaccessible to large ruminants; its carrying capacity is, therefore, estimated at half of what the biomass sampling would indicate. It is suited for year-round rangelands, especially during P1 - 2. Its condition is good to very good.

(64) **RX:** Composed of types R1 (40%), S3 (40%) and RG1 (20%).

(65) **R1X:** Composed of R1 (70%), and S3 (30%).

(66) **R1Y:** Composed of R1 (75%), and S5 (25%).

(67) **R1D:** Composed of R1 (90%), D4 (5%), and DX (5%).

(68) **R1DD:** Composed of R1 (85%), DX (10%), and D5 (5%).

O and A. Pasture Cover Types of Alluvium

Table 5-14 lists species abundance for the major 'O' and 'A' cover types. (Pasture cover type A is listed in Table 5-12). The carrying capacity data for all 'O' and 'A' cover types are listed in Table 5-15. The above tables should be viewed as each cover type is described in

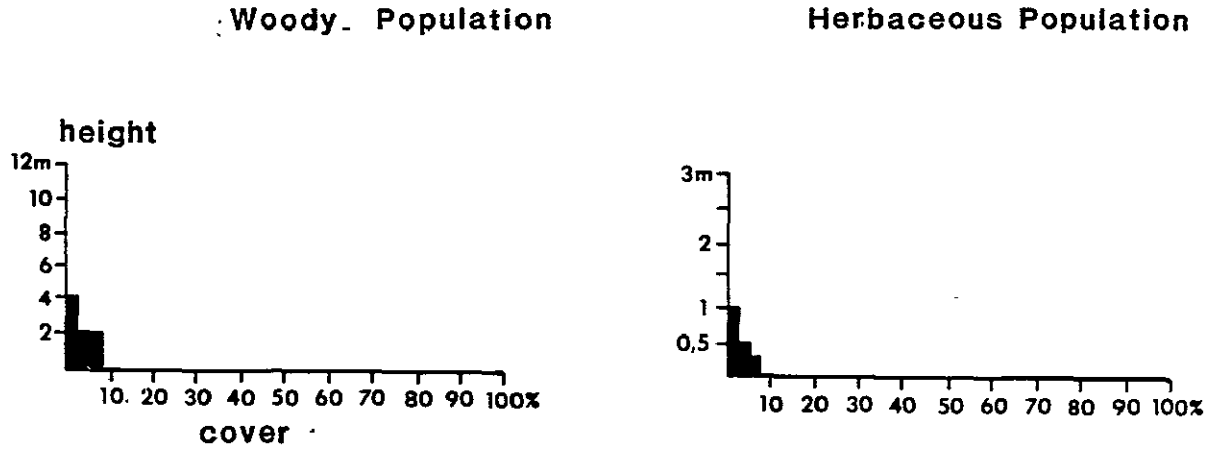


Fig. 5-32 Stratification Diagrams, Type R1

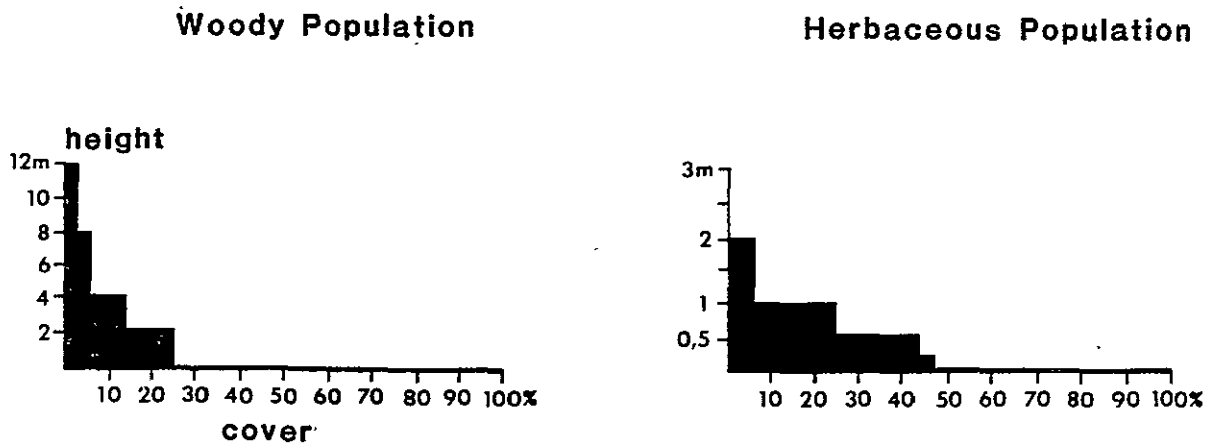


Fig. 5-33 Stratification Diagrams, Type R2

Figure 5-34. Subtype R2c is illustrated by a pasture in excellent condition. Guiera senegalensis, Acacia senegal and Acacia seyal make up the woody stratum at this site.

Table 5-14. Species abundance is presented for cover types 'O' and 'A'. Pasture Type RK is also included.

	01	02	AS	AM	AT	AW1	AW2	RK	AL
Aristida adscensionis		R		!			X	!	
Aristida funiculata		!		1!	X	!	!	!	
Aristida mutabilis		R			!	R		2,3!	
Brachiaria xantholeuca								X	
Cenchrus biflorus	R	R	R			R		2,3!	R
Chloris pilosa		R	1						
Crypsis schoenoides					2	X	R		
Cynadon dactylon					1,3!	!			!
Dactyloctenium aegyptium		X				!	X	1!	!
Dinebra retroflexa						X			
Echinochloa colona		3		3!		3!	X	R	2
Echinochloa pyramidalis									X
Echinochloa stagnina									3!
Eragrostis pilosa	X	3		4		2	2	3!	!
Eragrostis tremula		X				R	R	X	
Latipes senegalensis	R		2					!	
Panicum laetum		3		3		2	2	X	X
Panicum turgidum	1,2!		X		R	R			
Phragmites communis									X
Sacciolepis africana									1!
Schoenfeldia gracilia	R	X		2!		X	X	1,3!	!
Sporobolus helvolus		X		X		!	!		
Tragus racemosus						R		X	R
Urginea indica				X					

Table 5-14. (Cont'd)

	01	02	AS	AM	AT	AW1	AW2	RK	AL
Vetiveria nigritana		X							R
Indigofera senegalensis	1	X		X		!	R	X	!
Jussiaea perrenis									1!
Lotus arenarius			1						
Lotus glinoides		R			2				
Polycarpea nivea			1						
Psoralea plicata		R			3				
Salsola barymosa			1	2		!			
Sesbania rostratum									2!
Sphenoclea zeylanica		!		X		X	!		3!
Suaeda fruticosa			+						
Tribulus terrestris	X	R					R	1,2!	
Vahlia digyna		R						X	X
Zornia glochidiata								X	
Zygophyllum simplex			+						
Acacia flava	1!	1!		R			!		
Acacia nilotica var. adansonii						R	!	X	
Acacia nilotica var. nilotica		3		X	#	X	3!	!	
Acacia raddiana	1,2!							X	
Acacia senegal	!	!			R	R	!	2!	
Achyranthes aspera		X							
Aeschynomene elaphroxylon						!	R		X
Aeschynomene indica		2!		2!		R	R	R	X

Table 5-14. (Cont'd)

	01	02	AS	AM	AT	AW1	AW2	RK	AL
Aeschynomene nilotica									2
Arthrocnemum glaucum			4						
Bergia ammanioides		R			2!		X	!	R
Blumea aurita		X		R		R			
Borreria chaetocephala		2,3!		!	3!			!	
Borreria verticillata						X	R		3
Cassia italica	!	R							
Cassia tora	X	X					2		R
Cistanche purpurea			+						
Citrullus colocynthis	1								
Corchorus depressus	X	R	1						
Corchorus olitorius							X		
Cressa cretica			2						
Cyperus auricomus		R				1!	R		!
Cyperus divers									1!
Cyperus iria		!		X					
Cyperus rotundus				X			R		
Glimus lotoides	R	R		X	1!	!	X	R	X
Heliotropium bacciferum	!		+		R				
Heliotropium ovalifolium					1		R		
Heliotropium strigosum			+						
Acacia seyal		1,2!		R		X	2	R	
Adansonia digitata		+							

Table 5-14. (Cont'd)

	01	02	AS	AM	AT	AW1	AW2	RK	AL
Anogeissus leiocarpus		X					R		
Balanites aegyptiaca	1,2!	1		X	1!	2!	1!		
Bauhinia reticulata		!				X	2!		
Bauhinia refuscens	R	X			+		+	X	
Boscia senegalensis	2	X			1!		R		
Calotropis procera	R	!		X	+	R	R	R	X
Capparis decidua	2!	X		R	X		!		!
Commiphora africana			1!			R			
Euphorbia balsamifera			3!			R		1	
Grewia bicolor		X					R		
Guiera senegalensis		X					X	!	
Indigofera oblongifolia		R			X	1!	R	!	1
Leptadenia spartium	X				!			X	
Maerua crassifolia	X	R						R	
Maytenus senegalensis		R					X	!	
Mitragyna inermis		2!		R		R	X	!	
Nitraria retusa			1!						
Salvadora persica						1		X	
Tamarix senegalensis			3			2!		R	
Ziziphus mauritiaca	R	2		R	1	X		R	
Ziziphus mucronata		R			R	R	X	R	
Ziziphus spina-cristi		!		R		X	!	R	R

Table 5-15. Significant properties for the pasture cover types of alluvial landscape, 'O' and 'A'.

Cover Type	Subtype	Area (km^2)	Harvested Yields of Herbaceous Layer (kg dry matter/ha) Average	Range	Estimated Carrying Capacity (TBU/ha)	Estimated Total Carrying Capacity (TBU/yr)	Carrying Capacity Class	Estimated Seasonal Carrying Capacity (TBU/ha)
O1		210	520	340	0.11	2,300	2	
O2		3010	2980	990	0.63	190,200	4	P3-4: 1.31
AW1	AW1a, AW1b, AW1c, AW1d, AW1x	1630	1930	1380	0.41	67,200	4	P3-4: 0.80
AW2	AW2a, AW2b, AW2c, AW2d	2470	2160	1390	0.54	133,400	4	P3-4: 1.07
IC		100	130	110	0.03	300	1	P1-2: 0.055
AL		200	3470	620	0.73	14,600	4	P3-4: 1.44
AM		150	1610	1020	0.34	5,400	4	P3-4: 0.67
AT		150	780	670	0.16	2,500	2	P3-4: 0.32
AS		650	920	590	0.19	12,500	3	P2 : 0.15 P3-4: 0.31
A		100	1520	370	0.32	3,200	3	P3-4: 0.63
RK		870	630	370	0.13	11,400	2	P1-2: 0.17 P3 : 0.13 P4 : 0.07

the text. One complex pasture cover type, RK, is included with this general grouping; it consists of dunes and overflow channels, from Senegal River floodplain to Lake R'Kiz.

(69) **01**: Sandy-Saharan Wadis (Oueds) with Acacia raddiana, Boscia senegalensis, Panicum turgidum, Citrullus colocynthis, and Indigofera senegalensis. It is found on more or less deep aeolian sands over alluvium. Non-alluvial lowlands are reg or sandy soils. The ground cover composition is shown in Fig. 5-35.

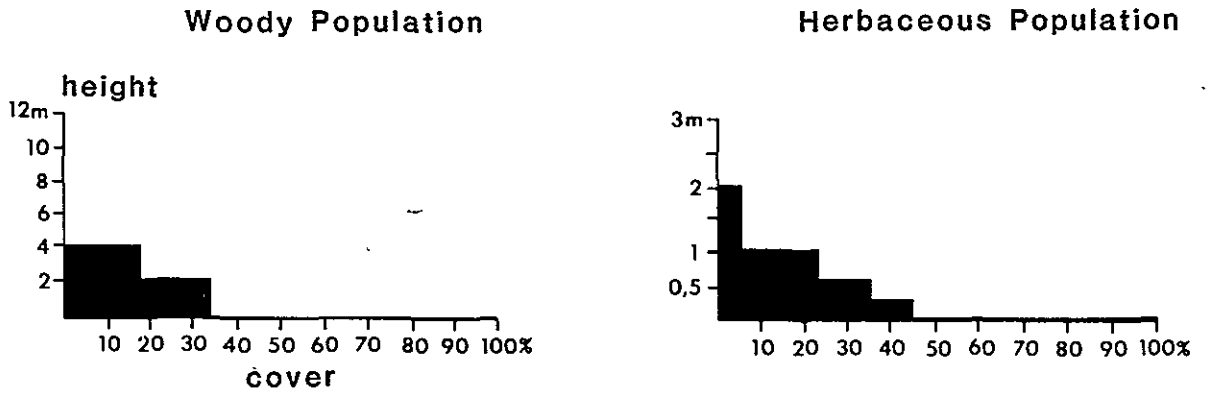


Fig. 5-35 Stratification Diagrams, Type 01

This cover type should be utilized as rangeland reserve for the end of the annual cycle (P3, P4). The condition of this type is mediocre to fairly good.

(70) **02**: Major Wadis (Oueds) with Acacia nilotica, Acacia seyal, Echinochloa colona, and Aeschynomene indica (Fig. 5-36). This cover type is found on clayey to sandy loam soils. The riverbed typically consists of coarse sand. Other soils types are irregularly distributed in bands according to overflow and deposition patterns. The ground cover types are shown in Fig. 5-37.

Figure 5-36. Type 02 is typified by Acacia nilotica and Acacia seyal in primary floodplains.

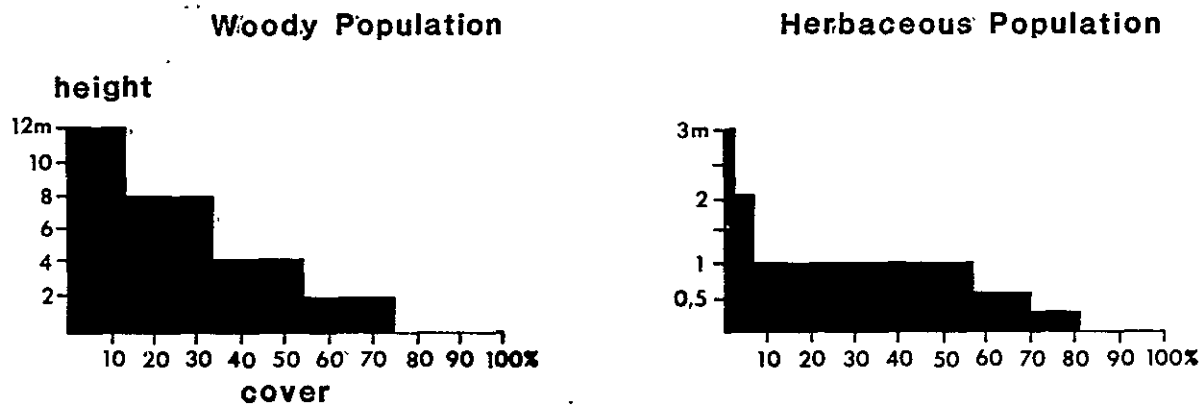


Fig. 5-37 Stratification Diagrams, Type 02

The relatively luxuriant vegetation of the wadis should be kept as a nutritive reserve for the end of pastoral cycle, i.e., end of hot season and beginning of rainy season. (See Section V for a discussion of this question). The condition of this type is generally mediocre. Often, wadis are denuded of palatable vegetation shortly after the end of rainy season. Due to intensive trampling during the rainy season, a surface crust is produced on fine-textured soils. In other respects, non-palatable or slightly palatable species (Cassia tora, and Borreria spp.) predominate and act as an index.

(71)**AW1**: Low Alluvial Plain (Estuary) with Acacia nilotica, Tamarix senegalensis, Indigofera oblongifolia, Eragrostis pilosa, and Panicum lactum. The unit is found on a variety of soils, especially compacted loams, annually flooded vertisols, and other hydromorphic soils. Major habitats include ridges of steep riverbanks, maritime lagoons, flooded settling basins, and silty areas, which are rarely or never flooded. The halomorphic soils that exist in this unit have gained profile salinity from the penetration of ocean water in the estuary. The ground cover composition for AW1c and AW1d is shown in Fig. 5-38a and 38b.

There are five subtypes. AW1a is found as dense forests on hydromorphic clay with Acacia nilotica v. nilotica, Mimosa digra, Echinochloa colona, and Aeschynomene spp. AW1b consists of cultivated vertisols and fallow lands with Indigofera oblongifolia, Bauhinia reticulata, Panicum laetum, and Ciperus auriconus. AW1c is the treeless acquatic plains

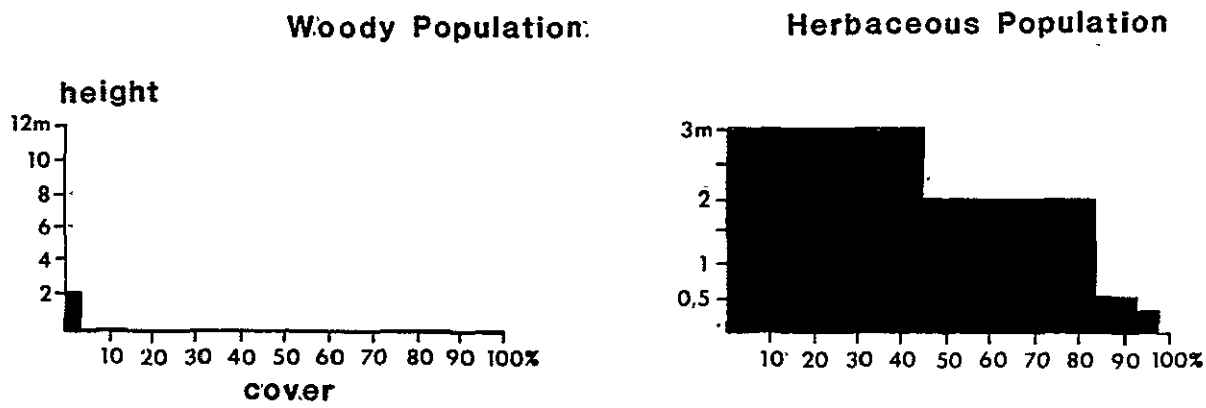


Fig. 5-38a Stratification Diagrams, Type AW1c

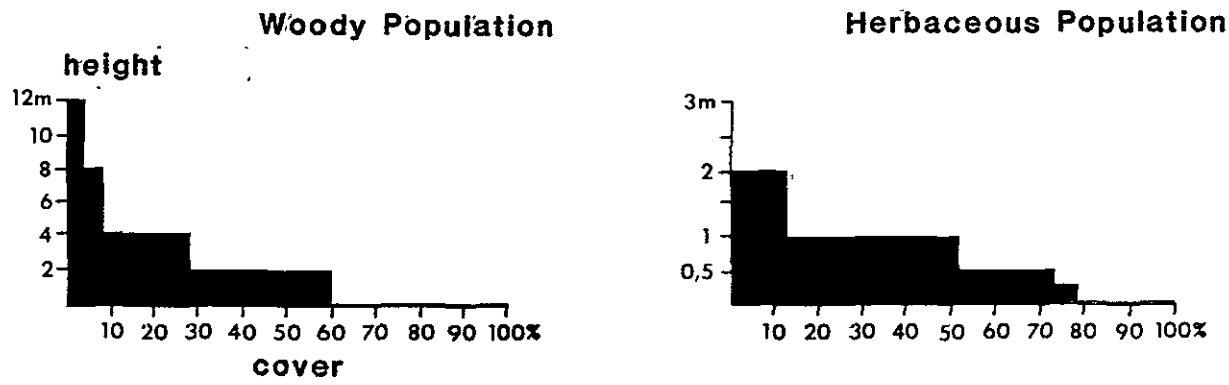


Fig. 5-38b Stratification Diagrams, Type AW1d

with Oryza longistamimata, Typha australis, Sporobolus helvolus, and Sphenoclea zeylanica. AW1d is composed of thin-forest on varied silts (loams) and other undifferenciated landscapes with Acacia nilotica v. adansonii, Balanites aegyptiaca, Salvadora persica, and Aristida funiculata. AW1x is the permanent littoral lagoons with no vegetation.

This pasture, especially at the end of the pastoral cycle. The general condition of this unit is fairly good to mediocre. As in pasture type O2, this rangeland often suffers from over-exploitation, and especially from ill-timed exploitation. Shifting cultivation and uncontrolled tree cutting result in devastation; the concentration of herds during the rainy season (during the period which these rangelands should be left unexploited) diminishes the basic productivity on the heavy soils.

(72) **AW2:** Alluvial Plain Upstream (from the estuary of the Senegal River) with Bauhinia spp., Acacia seyal, Eragrostis pilosa, and Panicum laetum. It is found on the same soils and habitats as the preceding type, but on non-halomorphic soils. The ground cover composition for AW2a and AW2d is illustrated in Fig. 5-39a and 5-39b.

Four subtypes constitute this cover type. AW2a is found on dense forest on hydromorphic soils with Acacia nilotica V. nilotica, Ziziphus mucronata, Cassia tora, and Sphenoclea zeylanica. AW2b consists of cultivated vertisols and fallow lands with Acacia albida, Schoenfeldia gracilis, Aristida funiculata, and Cassia tora. AW2c is found on the flooded silt-plain with Bergia suffructicosa, Indigofera oblongifolia, Eragrostis pilosa, and Ipomoea asarifolia. AW2d is described as a light-forest (savanna) on varying silts, and other undifferenciated habitats with Balanites aegyptiaca, Bauhinia spp., Schoenfeldia gracilis, and Dactyloctenium aegyptium. As described in other 'A' and 'O' types, this cover type is suited for dry season range. The condition is mediocre to fairly good. Remarks made for AW2 also apply for this case.

(73) **IC:** Calcareous Interdunal Landscapes with Leptadenia spartium, Fagonia cretica, Panicum turgidum, and Farsetia ramosissima. This type is found on loamy more or less barren sand to clayey soils often with a mantle of white sands. These are linear interdunal depressions which sometimes form troughs tens of km long.

The rangeland is suitable for grazing at the beginning of the rainy season. The range condition may be described as fairly good to mediocre. Successional tendencies are not apparent.

(74) **AL:** Lacustrine Landscapes with Mimosa pigra, Indigofera oblongifolia, Echinochloa pyramidalis, and Achynomene spp. This unit is found on the soils around temporary lakes; soil texture range from sandy loam to clay from the lake edges toward the inner depression. The shallow lakes of R'Kiz, Aleg, and Mâl constitute the make-up of this unit. Waters begin to recede during the month of October onwards; by June, only a very small portion of the mapped area remains flooded. The ground cover composition is shown in Fig. 5-40.

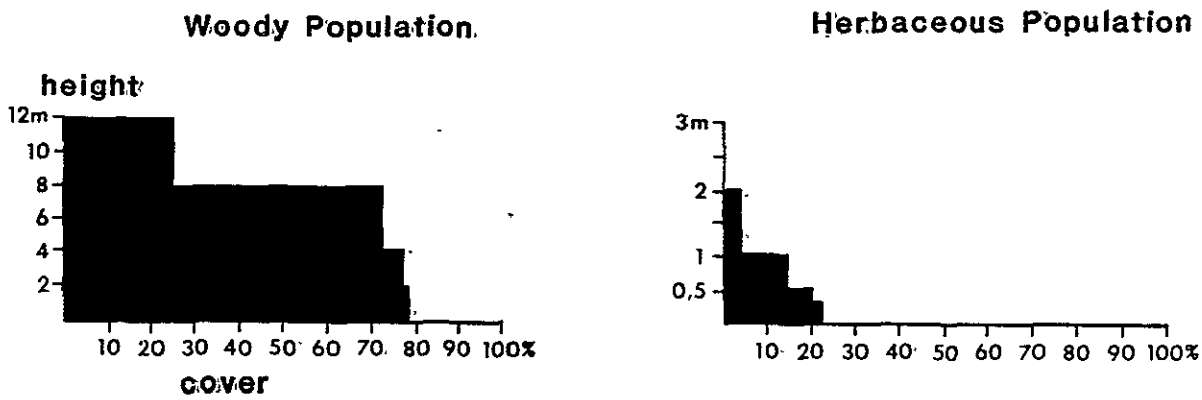


Fig. 5-39a Stratification Diagrams, Type AW2a

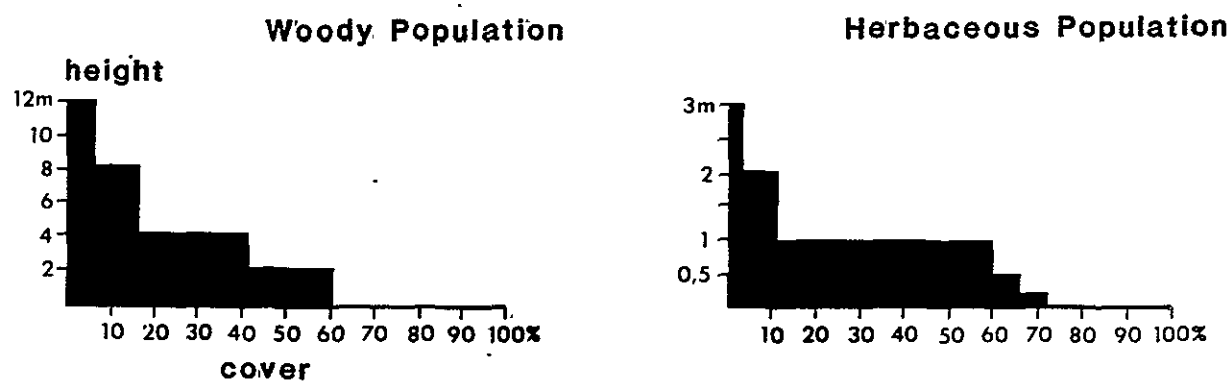


Fig. 5-39b Stratification Diagrams, Type AW2d

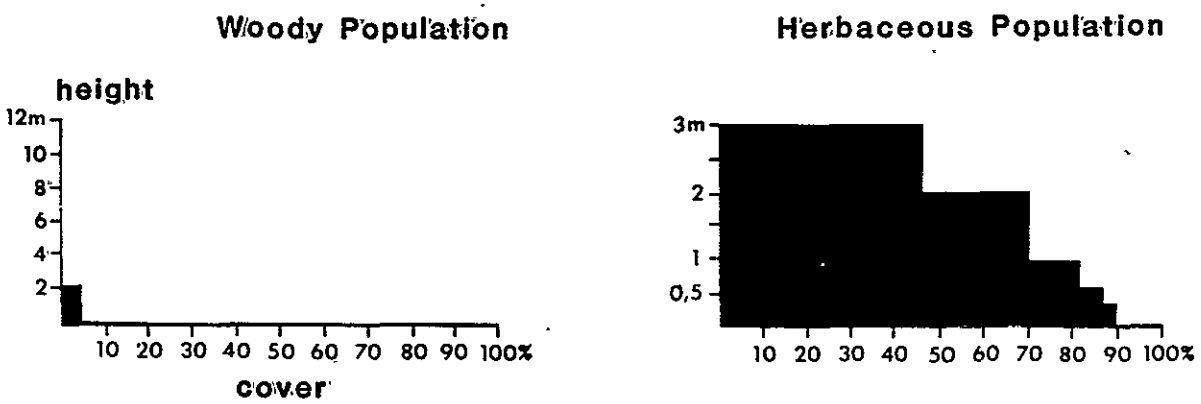


Fig. 5-40 Stratification Diagrams, Type AL

The principal use of these lands is unquestionably for the cultivation of sorghum. From the beginning of the withdrawal of waters, a band of cultivated fields appears and spreads towards the center. This cultivated band, continuing for kilometers, makes access difficult for the very rich recessional pasture, which it surrounds. The dual development of the range and agricultural potentials of the lakes are not in any way impossible. However, it requires a particular effort in extension activities to put an end to the current chaotic situation (see Section V).

The annual renewal of the soil fertility (as a result of flooding) is such that even the most heavily cultivated external strips of land produce luxurious herbaceous vegetation, annnual growth sometimes reaches three meters in height (Phragmites, Typha, etc.). There is little difference between these zones and those at the center untouched by cultivation. The range condition is excellent and a stable environment is prevalent.

(75)AM: Temporary Ponds with Acacia nilotica V. nilotica, Echinochloa colona, Eragrostis pilosa, and Acschynomene spp. This unit is found in rain water collection basins. The soils are sandy-clay soils to hydromorphic clays. The ground cover composition is shown in Fig. 5-41.

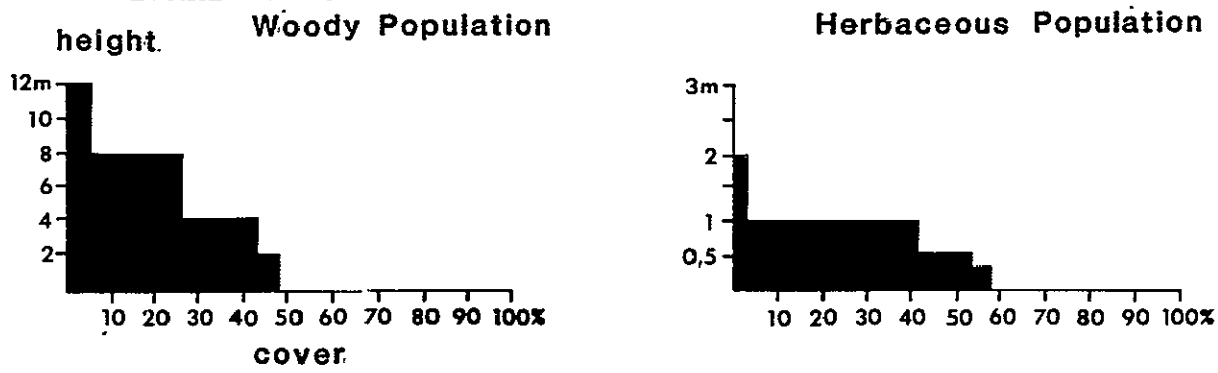


Fig. 5-41 Stratification Diagrams, Type AM

There are two types of wetland pastures which, because of the small scale, are undifferentiated on the map. They include a) wooded wetlands with Acacia nilotica V. nilotica, Echinochloa colona, Diplachne fusca, and Sphenoclea zeylanka, and b) treeless prairies subject to flooding with Eragrostis spp., Schoenfeldia gracilis, Calotropis procera, and Indigofera senegalensis.

(76) **AT**: Wetlands in the Saharan Zone with Acacia nilotica V. nilotica, Crypsis schoenoides, Cinodon dactylon, Psoralea plicata, and Lotus glinoides. This cover type is found in poorly drained basins or wadi of or adjacent to the Tagant plateau. The ground cover composition is shown in Fig. 5-42.

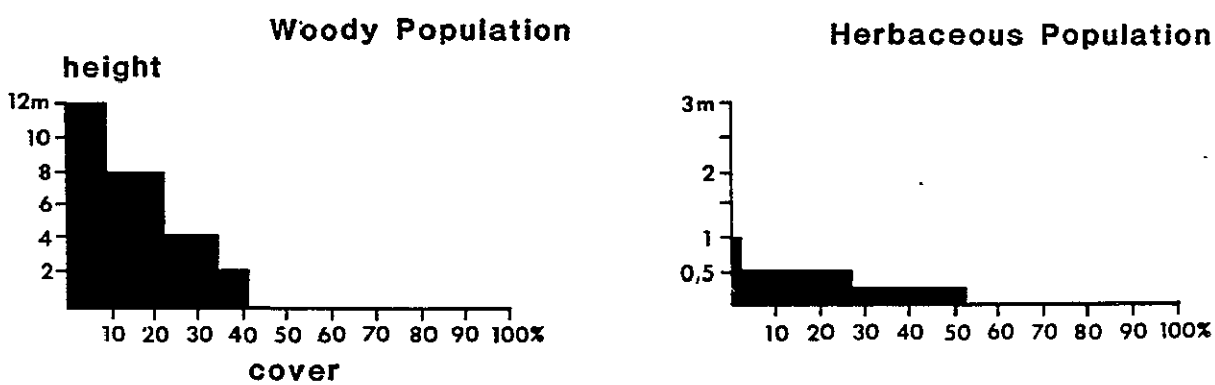


Fig. 5-42 Stratification Diagrams, Type AT

This pasture type is suitable for end of dry season rangeland. The predominance of high value forage species (Psoralea, Crypsis, etc.) indicates that the condition is fairly good.

(77) **AS**: Aftout es Saheli (salt swamps) with Tamarix senegalensis, Euphorbia balsamifera, Arthrocnemum glaucum, and Latipes senegalensis. This unit is found on moist, saline clay soils with small white dune formations over about 40% of the type. Frequently, flooded Sebkhas with no vegetation cover occupy about 15% of the type. The ground cover composition is shown in Fig. 5-43.

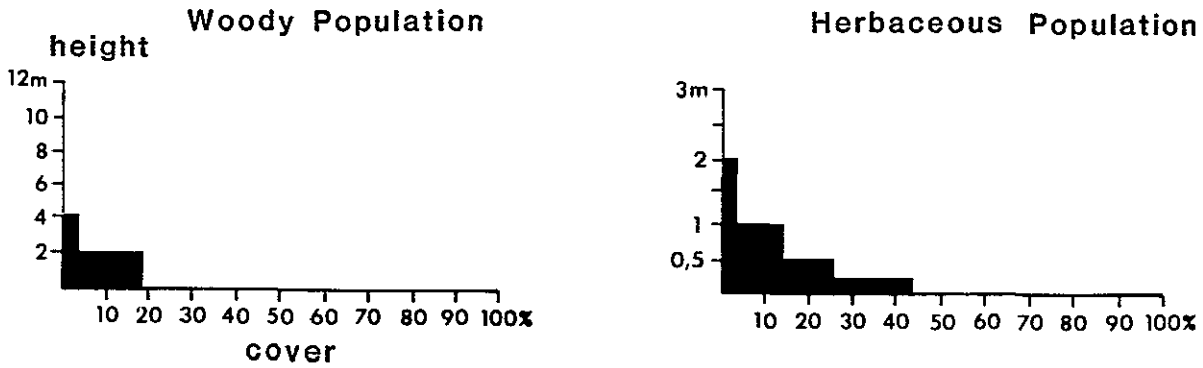


Fig. 5-43 Stratification Diagrams, Type AS

The pastures provide excellent dry season grazing; however, the vegetation can be tolerated by herds for only 20 successive days because of its salinity. The vegetative trend, according to several herders, is toward a slow reduction of the herbaceous cover on sandy habitats, especially with regard to the contribution by perennial graminaceae (Panicum turgidum, Latipes senegalensis).

(78) **A**: Sudano-Sahelian Forest with Acacia seyal, Maytenus senegalensis, Andropogon gayanus, Pennisetum pedicellatum, and Indigofera astragalina (Fig. 5-44). This unit is found on nearly level clays to black, friable silty clays. This unit provides excellent dry season pasture. The range condition is good. There is a danger of degradation as a result of excessive cutting of the woody cover for shifting cultivation. A plan for rotating cultivation with controlled pasture is needed in order to preserve this valuable unit.

(79) **RK**: Dunes and Interdunal Drainage Channels with Acacia senegal, Euphorbia balsamifera, Guiera senegalensis, Aristida mutabilis, and Eragrostis pilosa. This unit is found on a complex of red dunes (60%) with very sharp slopes and with drainage channels (40%) linking the low plain of the Senegal River Valley to Lake R'Kiz. The ground cover composition is shown in Fig. 5-45.

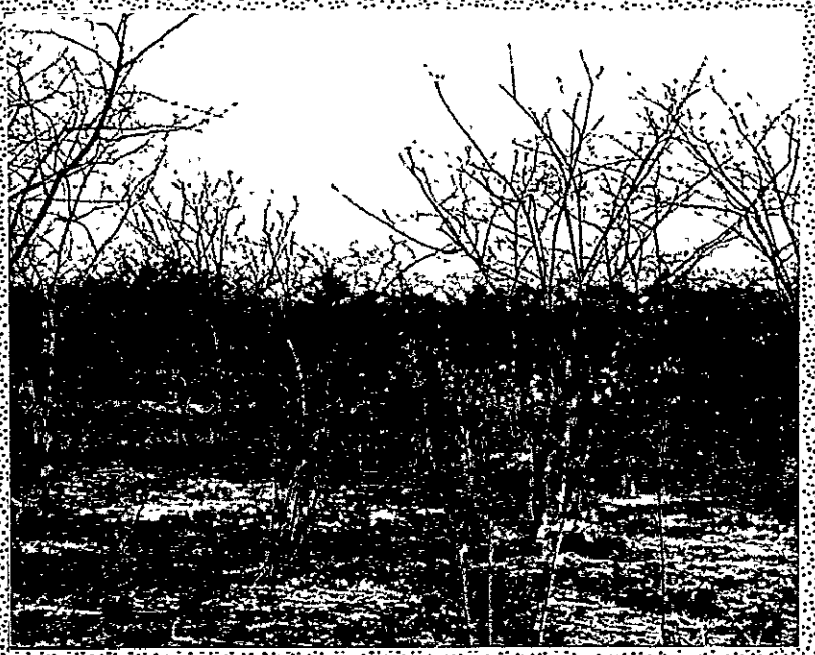


Figure 5-44. The setting for Pasture Type A reveals a dense cover of Acacia seyal with patches of Andropogon gayanus. This photo was taken just north of the intersection of the Senegal River and the Falemé River.

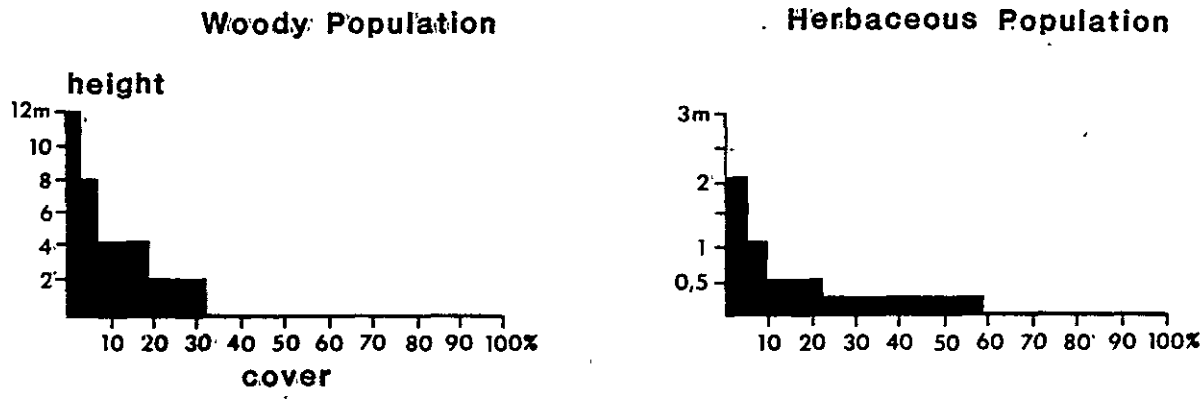


Fig. 5-45 Stratification Diagrams, Type RK

Summary

This unit is suitable for year-round pasture. Carrying capacity is somewhat reduced in P3-4 (excess animals are herded to the pastures of types AL and AW1). Some mortality of Acacias is found on the dunes; elsewhere, good range conditions prevail.

1. - Distribution by edaphic characteristics

a) Dune cover types ('D') and associated types (including the composit types whose principal component is a dune type) occupy 62,860 km^2 or 41.8% of the defined project area. They have an overall carrying capacity of 689,900 TBU/year, or 36.4% of the total.

b) Types on non-dune sands ('S') occupy 21,200 km^2 or 14.1% of the total project area. The annual carrying capacity amounts to 345,100 TBU, or 18.2% of the total.

c) Types on loams ('L') constitutes 11,180 km^2 or 7.4% of the total project area. The carrying capacity is 178,730 TBU/year, or 9.4% of the total.

d) Types on reg ('RG') occupy 37,110 km^2 or 24.7% of the total project area. The annual carrying capacity is 200,400 TBU/year or 10.5%.

e) Types on rocky (or stony) landscapes ('R') constitute 8,510 km^2 or 5.7% of the total project area. The annual carrying capacity is 38,300 TBU/year, or 2.0%.

f) Types on alluvium ('O' and 'A') have an areal extent of 9,540 km^2, representing 6.3% of the total project area. The annual carrying capacity is 443,000 TBU/year, or 23.4% of the total capacity.

2. - Distribution by Classes of Carrying Capacity

a) Class 0 types occupy 460 km^2, which is 0.3% of the total study area. Their carrying capacity is zero.

b) Class 1 types occupy 80,680 km^2, which is 53.6% of the total study area. Their carrying capacity equals 465,900 TBU/year, or 24.6% of the total.

c) Class 2 types occupy 49,550 km^2, which is 32.9% of the total study area. They have a carrying capacity of 727,930 TBU/year, or 38.4% of the total.

d) Class 3 types occupy 12,250 km^2, which is 8.1% of the total study area. Their carrying capacity equals 290,500 TBU/year, or 15.3% of the total.

e) Class 4 types occupy 7,460 km^2, which is 5.0% of the total study area. They have a carrying capacity of 410,800 TBU/year, or 21.7%.

3. - Distribution by administrative region

Administrative Region †	Area	Total Area %	Carrying capacity in TBU/year	% of total carrying capacity
a) TRARZA	44,750 km^2	29.7	443,530	23.4%
b) BRAKNA	25,560	17.0	312,750	16.5
c) GORGOL	13,180	8.8	274,840	14.5
d) GUIDIMAKA	11,600	7.7	242,610	12.8
e) ASSABA	34,490	22.9	456,800	24.1
f) TAGANT	10,110	6.7	70,130	3.7

(Cont'd)

Administrative Region †	Area	Total Area %	Carrying capacity in TBU/year	% of total carrying capacity
g) WESTERN HODH	10,710	7.1	94,770	5.0
Totals for the mapped zone	150,400 km^2		1,895,430 TBU/year	

† Only the Gorgol and Guidimaka regions fall entirely within the mapped zone; values given relate to mapped areas of the other regions.

4. - Average Carrying Capacity and potential production by administrative region

Administrative Region †	Average Class	Average Carrying Capacity TBU/year	Average Potential Production Kg. DM/Ha
a) GORGOL	3	0.21	994 Kg.
b) GUIDIMAKA	3	0.21	991
c) ASSABA	2	0.13	630
d) BRAKNA	2	0.12	581
e) TRARZA	2	0.10	472
f) WESTERN HODH	1	0.09	417
g) TAGANT	1	0.07	333
Overall classification for the mapped area	2	0.13 TBU/Ha	599 Kg. DM/Ha

† Only the Gorgol and Guidimaka regions fall entirely within the mapped zone; values given relate to mapped areas of the other regions.

V. ANIMAL STOCKING RATES

Relatively accurate information about current stocking rates and grazing practices is necessary if a rational grazing plan for Mauritania is to be developed. These data are, however, difficult to obtain throughout the Sahel, including Mauritania.

In Mauritania, regular, systematic surveys of livestock numbers are not conducted due to a lack of trained personnel and equipment. Consequently, at the time of this report (1980-1981) only the estimates of herd sizes from the Service de l'Elevage were available plus generalities about their distribution. These data were of very little use in evaluating animal stocking rates for the project area or in ascertaining livestock distributions.

Relative estimates of animal herd size were completed by region in 1978-1979 and were obtained from governmental sources. These official estimates were the basis for Table 5-16 which, in addition to the estimated herd sizes of the mapped regions, gives the estimates made by the pasture survey team for partially mapped regions, i.e., the Trarza and Western Hodh. Presentation of the equivalents in T.B.U. allows both the count of the entire livestock population as well as a comparision of the estimates of carrying capacity presented in section IV.

Assuming that the carrying capacities and estimates of herd sizes are correct, the entire study area would seem to be correctly stocked during years with normal weather. However, if regions are considered individually, a different picture emerges. For example, in the Trarza the numbers indicate an understocking of about 35%, yet by various experts, it is considered to be the most degraded in Mauritania attributable mainly to overgrazing, interacting with climatic and human activities factors. In contrast, the Brakna would be over 40% overstocked using these numbers, but it was observed in 1980 to be producing near to what is believed to be its potential based on soils.

Table 5-16 and Table 5-17 represent estimates of livestock and TBU made two years apart. A comparison between those two data sets reveals disparate results. For example, using the estimates for the Guidimaka Region, the former data report a total stocking rate of 172,500 TBU while the latter reports a stocking rate of 181,624 TBU for only the non-migrating herds, which (if the nomadic animal numbers stay the same or increased slightly) would indicate a phenominal, probably unattainable, increase in numbers. In addition, numbers by category are reported very differently in the two tables. It is obvious that available data are insufficient to permit a valid evaluation of the true stocking rate in the project area, even on a regional or larger scale. Finally, so broad a view of stocking rates do not consider variation in the productivity, and non-uniformity of grazing distribution as discussed below.

In the Sahel, the animal stocking rates are closely linked to the availability of water. In explaining the causes of overgrazing and the resultant environmental degradation, the policy of increasing the number

Table 5-16. Distribution and number of livestock in the project area (1979 Estimates in thousands of head and T.B.U.).[1]

REGIONS	Cattle		SHEEP AND GOATS		CAMELS		DONKEYS		TOTALS	
	Head	T.B.U.**	Head	T.B.U.	Head	T.B.U.	Head	T.B.U.	Head	T.B.U.
TRARZA	168	121	680	82	82.5	82.5	1.6	1.2	932.1	286.7
BRAKNA	294	212	1190	143	90	90	1.3	0.9	1575.3	445.9
GORGOL	231	166	595	71	7.5	7.5	0.7	0.5	834.2	245
TAGANT*	100	72	350	42	45	45	0.4	0.3	495.4	159.3
GUIDIMAKHA	168	121	425	51	-	-	0.7	0.5	593.7	172.5
ASSABA	336	242	850	102	45	45	1.4	1.0	1232.4	390
HODH*	112	81	380	46	43	43	0.4	0.3	535.4	170.3
TOTALS	1409	1015	4470	537	313	313	6.5	4.7	6198.5	1869.7

* ESTIMATES FOR THE MAPPED AREA BY THE RRM TEAM

** 1. T.B.U. = 250 Kg. WEIGHT OF A LIVING RUMINANT ANIMAL = 1 HORSE.
1 COW = 1 DONKEY = 0.72 T.B.U.
1 SHEEP = 1 GOAT = 0.12 T.B.U.

[1] SOURCE: DIRECTION DE L'ELEVAGE, NOUAKCHOTT, MAURITANIA.

Table 5-17. Estimation (1980-81) of the livestock population and TBU in Guidimaka Region.

	NON MIGRANT ANIMALS		NOMADIC ANIMALS		TOTALS	
	Numbers of head	Equivalent T.B.U.	Numbers of head	Equivalent T.B.U.*	Numbers of head	Equivalent T.B.U.
CATTLE	200,000	144,000	100,000	54,400	300,000	199,000
SHEEP/GOATS	300,000	36,000	300,000	27,000	600,000	63,000
CAMELS	660	660	450	338	1,110	998
DONKEYS	700	504	-	-	700	504
HORSES	460	460	-	-	460	460
TOTAL	501,820	181,624	400,450	81,338	902,270	263,962

* T.B.U. based on assumed 9 month grazing season for nomadic animals.

of rangeland wells and the alleged practice by breeders of stocking a grazing tract up to the limit of its water resources has been listed as the major cause. Based on survey team observations, the problem is slightly more subtle than that. It derives instead from systems of grazing, and in some very special cases, from the location of wells.

The cemented rangeland well, which ensures the required water during the dry seasons in most of the Sahelian zones, is admirably adapted to the needs of extensive livestock raising. From survey team observations in the Trarza, such a well, 70m deep and provided with four wooden pulley forks, each of which allow water to be drawn with the aid of harnessed animals, can yield about 12,000 liters of water per hour. If the well operates at this pace for a period of 10 hours, it could theoretically supply water for about 4000 TBU of livestock daily (assuming that the well is used during two sunlit hours to meet the needs of the human population).

According to Boudet (1975) a Sahelian rangeland tract could be considered as an imaginary circle with a radius of ten kilometers surrounding a permanent source of water. If we arbitrarily allocated to this area of 31,400 ha, a carrying capacity of 0.13 TBU/ha (average for the zone studied), we would estimate its overall carrying capacity at 4,082 TBU/year, a figure that is very near the water output referred to in the preceding paragraph. In fact, those wells rarely operate at capacity and are generally used only part of the year.

In conclusion, proper spacing of rangeland wells (about 20 km from each other) would make an animal overstocking on a rangeland impossible. Unfortunately, these norms are not always respected. For example, around the well called Janijei, northeast of Nimjat in the Trarza, are found not fewer than six other cemented wells within a radius of 10 km. Fig. 5-46 illustrates in a very approximate way, the distribution of those cemented wells in the zone of study. It is even more important to underline the following fact: avoiding animal overstocking will not necessarily avoid overgrazing.

Where the grazing system is anarchic, overgrazing and degradation of the vegetative cover are to be feared, even if animal stocking rates are very much below capacity. If, for example, the animal herds graze the central part of a tract intensively in the immediate vicinity of the well during the first three or four months of the dry season, and denude it completely (Fig. 5-47), they will have to go longer and longer distances to find range areas as the season progresses. This seems to be the case very often. The livestock are consequently weakened by the increasing heat and the growing inadequacy of feed and will begin to perish. After a certain length of time, the grazing tract will be abandoned and the herds will move southward. The denuded soil is therefore at the mercy of erosional forces while the peripheral areas of the tract remain underexploited and in some locations untouched. Also the denuded area is no longer productive, meaning less area for the same number of animals which in reality means the stocking rate has been increased without adding any animals.

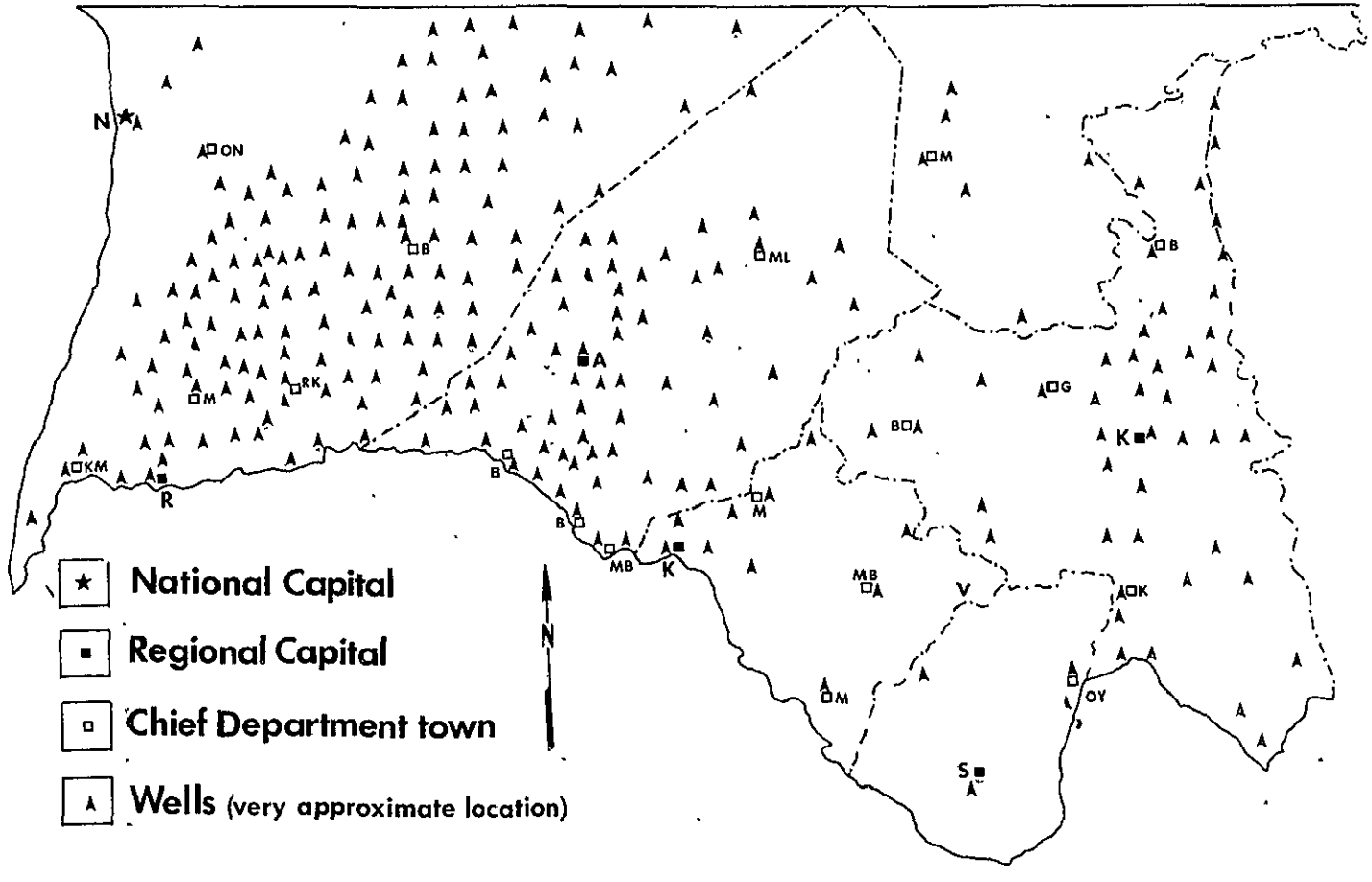


Fig. 5-46. The distribution of cemented wells is shown across the project area. (Refer to Fig. 1-1 for the names of abbreviated cities and towns).

Figure 5-47. Livestock are gathered around a rangeland well located to the north of Boghé.

In the past, the solution most often brought forward for this problem, was the following: increase the number of wells to make accessible those rangelands far from the original wells and to lighten the animal stocking rate in the immediate vicinity. At a certain time in the past, this was plausible, but since the last great drought it has been discredited. Unfortunately, its result has been to multiply the number of animals in order to take advantage of newly "opened" rangelands. In a very short time the animal stocking rates around the new wells became as heavy as those around the original wells. Consequently, devastation developed around several water sources instead of around only one.

The danger of increasing permanent water sources without the implementation of controlled grazing is now almost universally recognized. In spite of this, new wells are being dug everywhere in the Sahel without implementation of rational management systems (Fig. 5-48).

VI. ASSESSMENT OF FORAGE VALUE

The dynamic nature of fodder value in Sahelian pastures is well-known; it has been the subject of many studies in small areas. This section will, therefore, be restricted to a brief summary of concepts regarding the fodder value individually, for Mauritanian and Sahelian plants and, collectively, for pastures. These data have been collected from several sources, and to the extent possible, have been evaluated as to the implications of these notions on pasture types defined in Section IV. With a few exceptions, the analyses made on collected samples in the context of this study, did not include the fodder value for two reasons, beside the existence of much data on this subject, as discussed in the following paragraphs.

The fodder value of any Sahelian grazing ground is continually changing throughout the season. Analyses on a sample clipped in November do not provide information on the value of the same pasture in September, February or in March. Consequently, these analyses do not allow cross comparisons of values with those from other pastures sampled at different periods. For sampling to provide significant information, samples need be collected during all seasons, and in all pasture types. A work of such magnitude is envisionable only for areas smaller than those of interest in this report.

Since the RRM Project did not have appropriate lab equipment during the sampling period, analyses were conducted at the "Centre National d'Elevage et de Recherches Vétérinaires" (CNERV) at Nouakchott. Equipment breakdowns, however, restricted analyses to only biomass content, the main area of interest.

Palatibility of Plants

The flora listed in Section III were given a palatibility rating for plant species identified during the sampling periods. The rating is based on indications obtained from literature and also on our observations in

Figure 5-48. A contrast of utilization of pasture lands is shown. The fenced area is part of the DRIG project (USAID) located 10 km east of Selibaby.

Mauritania and elsewhere in the Sahel. To estimate the proportion of palatible fodder in the total biomass is a first step in the estimation of the quality of a given pasture. It is, however, necessary to understand that palatibility is a relative characteristic being dependent on species composition, stage of growth, soil moisture and chemical characteristics, species of grazer and others. Several illustrative examples are listed as follows:

(1) The perennial graminods are generally left during the rainy season in favor of the annual ones. Later on, when the latter grasses will dry up, the perennials, which stay photosynthetic much longer, become preferable (Boudet, 1975).

(2) Some species are not palatable during a certain period of their growing cycle because of particular characteristics, e.g., the Cymbopogon schoenanthus because of its smell when it is green (Boudet 1975) and the Cenchrus biflorus because of its wounding fruits; the first is readily eaten when dry and the second is taken before the fruits hardened and after they have fallen.

(3) Some species are left or ignored where other preferred species are predominant (such is the case of Schoenfeldia gracilis in L1, S4, etc., pasture types). However, where these species constitute the only (and pure) population (Schoenfeldia gracilis in RG2, RG7, etc.) it provides the main source of food for herds.

(4) Other plants that are disliked and not taken by most of the herbivores are used by only one species; such is the case of the Citrullus leaves used by donkies, the Calotropis procera used by Gazella rufifrona (Grants' gazelle), and the Cassia italica used by the ostrich (Newby 1974).

Fodder Value of Plants

Apart from mineral content, which is dependent mostly on soil composition at individual sites, the fodder value can be defined as the plant's ability to satisfy two needs of the ruminant, energy and protein. Energy values can be expressed in terms of Fodder Units (F.U.), one F.U. being equivalent to 1650 calories. The protein value or nitrogen value corresponds to the content of digestible nitrogenous matter which is given in grams per kilogram of dry matter (g.M.A.D./kg M.S.).

The amount of daily ingested fodder by T.B.U. is reflected in animal productivity by gain of weight or milk production, conditioned by the fodder quality (F.U. and M.A.D.). Maintenance of an animal requires at least 6.25 kg of dry matter/day.

Boudet (1975) defines the four following categories of fodder (not to be confused with pasture classes discussed in Section IV:

Category One: Poor Fodder

- less than 0.45 F.U./Kg M.S.
- less than 25g M.A.D./Kg M.S.
- does not insure the maintenance of the T.B.U.

Category Two: Fair Fodder

- from 0.45 to 0.50 F.U./Kg M.S.
- from 25 to 34 g M.A.D./Kg M.S.
- insure the maintenance of the T.B.U. and a production of less than 100g/day or less than 1 liter of milk/day.

Category Three: Good Fodder

- from 0.50 to 0.60 F.U./Kg M.S.
- from 34 to 53g M.A.D./Kg M.S.
- production able to reach from 100g to 300g/day or from 1 liter to 3 liters of milk/day.

Category Four: Excellent Fodder

- more than 0.60 F.U./Kg M.S.
- more than 53g M.A.D./Kg M.S.
- production of more than 300g of weight/day or 3 liters of milk/day.

The two contents in F.U. and in M.A.D. are not tied. Often it is seen that the two values correspond to two different categories for the same fodder. In that case, the fodder value is considered to be in the lower category. The evolution of fodder value for pasture plants found in the southwestern Mauritania provides some illustration (after Boudet, 1975 and Mosnier, 1961).

During the rainy season, the annual grasses constitute the main fodder used by livestock, even the most mediocre is used (i.e., Schoenfeldia gracilis and Eragrostis tremula). Most of the annual grasses have fodder value from good to excellent up to the floral stage. In general the energy value (F.U.) of annual grasses comes to its maximum at the floral stage, which is a period corresponding to the maximum yield in weight, wet and dry. From this stage on, the content of F.U. records a gradual decline; the standing, dead material through the hot season (March to June) contain no more than 60 percent of this maximum value (Table 5-18).

The nitrogen value (M.A.D.) comes to its maximum at about the end of the vegetative growth stage. During the full floral stage this value has been already reduced by as much as one half. The standing material (essentially non-green) is an important source of energy; however, it contains very little nitrogen and other important nutrients. In short, maintenance requirements of the animals are usually not met.

Table 5-18. The fodder values for important annual grasses are presented.

Species	Stage - Period	Fodder Value per Kg of Dry. Matter		Category
		F.U.†	M.A.d	
Aristida mutabilis	Early growth (July)	0.55	38	3
	Vegetative growth (Aug.-Sept.)	0.50	82	3
	Floral stage (Sept.)	0.56	36	3
	Seed production (Sept.)	0.46	10	1
	Straw (Oct.-Feb.)	0.44	1	1
	Straw (March-June)	0.36	TR††	1
Cenchrus biflorus	Vegetative growth (Aug.)	0.50	45	3
	Floral stage (Sept.)	0.64	113	4
	Straw (Oct.-Feb.)	0.42	TR	1
	Straw (March-June)	0.37	TR	1
Panicum laetum	Vegetative growth (Aug.)	0.68	49	3
	Straw (Oct.-Feb.)	0.62	0.1	1
Schoenfeldia gracilis	Vegetative growth (Aug.)	0.68	33	2
	Floral stage (Sept.)	0.43	21	1
	Straw (Oct.-Feb.)	0.42	TR	1
	Straw (March-June)	0.39	TR	1
Eragrostis tremula	Floral stage (Sept.)	0.64	29	2
	Straw (Dec.)	0.50	TR	1

† F.U. = Fodder Unit = 1650 Calories
gM.A.D. = digestible nitrogenous material in grams/kilograms of dry matter

†† TR = trace

The perennial grasses are used by livestock mainly during the dry season. They conserve green matter and some nitrogen value longer than the annuals, some species into December (Table 5-19). More importantly, perennial species can respond to non-seasonal rains (fairly common in parts of Mauritania) or to stimulation by fire (when sufficient soil moisture is present) providing nitrogen-rich regrowth when otherwise a deficiency is present.

The herbaceous vegetation provides the main source of nitrogen up to the end of cool season (February). Thus, these species complement the energy source available in the straw of the annual grasses (Table 5-20). Most of these species disappear in December - February through disintegration; Blepharis linariifolia is an exception (this persistent plant is particularly liked by herders; they contend that in a pasture where this species is abundant, animals can be maintained up to the beginning of the rainy season). Following are examples of fodder plants more or less persistent in this category: Tribulis terrestris, Heliotropium bacciferum, Chrozophora brocchiana, Indigofera astragalina, and Citrullus spp.

Table 5-21 illustrates the richness of the aerial pastures and especially its nitrogen content. These species provide the main source of nitrogen once the annuals stop growing.

The preceding tables provide important data concerning the dynamics of the fodder value for the pastures within the project area. During the rainy season, all pastures produce a quality fodder rating from good to excellent (3 or 4), thus insuring the maintenance of animals and good productivity.

During the dry season, however, the fodder quality depends on the presence of plants capable of satisfying animal needs for protein. These plant characteristics are:

- perennial grasses capable of having regrowth in dry season
- legumineous and other persistent herbaceous species, and mainly
- woody plants capable of producing palatible green matter during the critical hot season period.

Based on these data, the quality of fodder produced can be estimated for different types of pastures around the pastoral year. These estimations, summarized in Table 5-22, come only from the study of floristic data and are not the result of analyses made on samples collected and analyzed in different seasons. These data are, thus, presented with reserve.

Table 5-19. The fodder values for important perennial grasses are presented.

Species	Stage - Period	Fodder Value per Kg of Dry Matter		Category
		F.U.†	M.A.d	
Andropogon gayanus	Leaves (Aug.)	0.57	41	3
	Leaves (Oct.)	0.60	31	2
	Floral stage (Oct.)	0.59	4.7	1
	Leaves (Oct.)	0.46	TR††	1
	Regrowth (May)	0.57	47	3
Echinochloa stagnina	Floral stage (Oct.-Nov.)	0.46	51	2
	Stems (Nov.)	0.32	7.5	1
	Straw (May)	0.49	TR	1
	Regrowth (May)	0.64	99	4
Panicum turgidum	Floral stage (Oct.-May)	0.45	10	1
	Stems	0.44	5.7	1

† F.U. = Fodder Unit = 1650 Calories
gM.A.d = digestible nitrogenous material in grams/kilograms of dry matter

†† TR = trace

Table 5-20. The fodder values for various herbaceous species are presented.

Species	Stage - Period	Fodder Value per Kg of Dry Matter		Category
		F.U.†	M.A.d	
Alysicarpus ovalfalius (Legumineous)	Vegetative growth (Aug.-Sept.)	0.70	127	4
	Floral stage (Sept.)	0.75	134	
	Seed production (Oct.)	0.80	93	4
	Straw (Oct.-Feb.)	0.72	13	1
Zornia glochidiata (Legumineous)	Vegetative growth (Aug.)	0.55	110	3
	Seed production (Sept.)	0.75	113	4
	Straw (Oct.)	0.40	89	1
Tribulus terrestris (Zygophyllaceae)	Early growth (July)	0.77	97	4
	Floral stage (Sept.)	0.75	110	4
Blepharis linarüfolia (Acanthaceae)	Floral stage (Sept.)	0.83	43	3
	Seed production	0.73	41	3

† F.U. = Fodder Unit = 1650 Calories
M.A.d = digestible nitrogenous material in grams/kilograms of dry matter

Table 5-21. The fodder values for important woody species is presented.

Species	Stage - Period	Fodder Value per Kg of Dry Matter		Category
		F.U.†	M.A.d	
Acacia albida	Leaves (Feb.)	1.00	130	4
	Fruits (March)	1.05	64	
Acacia raddiana	Fruits (April)	0.90	104	
Acacia senegal	Fruits (Feb.)	0.88	106	4
Acacia seyal	Green fruits (Dec.)	1.00	124	4
Balanites aegyptiaca	Dry leaves (Feb.)	0.95	53	4
	Leaves and flowers (April)	0.90	150	4
Grewia bicolor	Leaves (Nov.)	0.90	120	4
	Dry leaves (Feb.)	0.90	34	3
Pterocarpus lucens	Leaves (Nov.)	0.83	145	4
	Dry leaves (Feb.)	0.88	103	4

† F.U. = Fodder Unit = 1650 Calories
M.A.d = digestible nitrogenous material in grams/kilograms of dry matter

Table 5-22. Fodder categories (after Boudet, 1975) are presented by season for the pasture cover types.

Types	July-Aug.	Sept.-Oct.	Oct.-Feb.	Feb.-June
D1	4	3	3	2
D2	4	3	2	1
D3	4	3	1	1
D4	3	2	1	1
D5	3	3	2	1
DL	3	3	3	2
DC1	4	3	2	2
DC2	4	2	1	1
S1	4	3	2	1
S2	4	3	2	1
S3	4	2	2	1
S4	4	3	2	2
S5	3	2	1	1
S6	3	2	2	1
S7	3	2	1	1
L1	3	3	2	2
L2	3	3	2	2
L3	3	3	2	1
RG1	3	2	1	1
RG2	3	2	2	1
RG3	3	2	1	1
RG4	3	2	1	1
RG5	3	3	2	2
RG6	3	2	2	1
RG7	3	2	2	1
R1	4	3	1	1
R2	4	3	2	2
O1	3	2	2	2
O2	4	4	3	3

Table 5-22. (Cont'd)

Types	July-Aug.	Sept.-Oct.	Oct.-Feb.	Feb.-June
AW1a	4	4	3	2
AW1b	4	3	2	2
AW1c	3	3	3	2
AW1d	4	3	2	2
AW2a	4	4	3	2
AW2c	3	3	3	2
AW2d	4	3	2	2
1C	3	2	1	1
AL	4	3	2	2
AM	3	4	2	2
AT	4	3	2	2
AS	4	3	3	3
A	4	4	3	2
RK	4	3	2	2

VII. RANGE MANAGEMENT PROBLEMS AND RECOMMENDATIONS

The main problems facing range managers in the Sahel can be defined as follows:

1) the difficulty of knowing, with the required precision, the true pastoral situation with regard to number and distribution of the sedentary livestock and the numbers and movements of nomadic livestock.
2) lack of land tenure legislation to protect rights of land users on grazing tracts and to encourage them to rationalize their exploitation.
3) the most uncertain climate which according to some, makes any animal stocking on a medium or long term basis, impossible.
4) the "July crisis" characterized by a shortage of nitrogen-rich plant material at the end of the hot season and the beginning of the rainy season, which is harmful to the vigor and productivity of animal herds even during the most favorable years.

The first two problems could be termed social problems and the last two as technical problems. In truth, social and technical aspects of pastoralism cannot be separated since it is the herders who, in the final analysis, must decide to accept or reject any proposed solution. One is, therefore, always compelled (except in special experimental contexts) to resort to educational efforts and dialogue.

These latter two problems have been expressed and analyzed in Sections V and VI. The rest of this section consists of a discussion of possible interventions aimed at solving those problems.

The following measures have been tried or proposed as solutions for environmental, social and feeding problems of extensive Sahelian livestock breeding:

1) improvement of natural pasture lands through:
   a. introduction of exotic herbaceous crops (especially perennial graminaceous or leguminous species) of high forage value
   b. promotion of valuable herbaceous crops by the multiplication of seeds, or a seed bed nursery
   c. scarification treatments on sand surfaces and hummocky sandy loam landscapes
   d. increase of the potential productivity by means of chemical fertilizers
   e) planting of woody browse species.

2) improvement of feeding through:
   a. distribution of industrial by-products such as salt, cotton or peanut oil cakes, etc.
   b. introduction of forage crops (both rainfed or irrigated)
   c. introduction of hay-cutting methods and silage.

3) protection of pasture lands against bush fires and abusive exploitation through:
   a. fire breaks
   b. control and restriction of cutting the woody stratum
   c. protection of overexploited and/or fragile soils.

4) limitation of animal stocking rates through:
   a. educational actions to encourage herders to eliminate the excess or useless animals
   b. legislative action to compel herders to eliminate such animals
   c. creation of new markets in order to facilitate the reduction of animal numbers
   d. the opening of new pastoral expanses through multiplication of pastoral and drilled wells
   e. introduction of a controlled grazing scheme in order to distribute the existing animal stock better. This measure should be taken jointly with
   f. the preparation of a land tenure code to define grazing rights (access to grazing tracts).

5) limitation of nomadism and transhumance.

The suitability of the interventions listed above to contribute usefully to the solution of pasture land problems and their applicability in the Sahelian context is assessed in the following paragraphs.

1. Any initiative leading practically to increase nitrogen-rich plant materials at the end of the dry season would be desirable. Among those initiatives listed earlier, the promotion of local crops that retain some nitrogen during the dry season, seems to be the most promising in general. Direct sowing of seeds produced in seed beds or collected in the bush, can be both efficient and economical. There should be seeds of leguminous species (such as Zornia glochidiata, Indigofera spp., etc.) and other nitrogen-rich herbaceous crops (such as Blephoris linariifolia). The promotion of perennial indigenous grasses (Cenchrus ciliaris, Aristida sieberana, etc.) is equally very useful, but even though the nutritional role of those plants is significant, it remains secondary compared to their ecological role of contributing to the ability of soils to resist erosion.

The introduction of exotic species is, of course, more risky since the adaptability of these plants to Sahelian conditions remains to be shown. Plants of very high forage and ecological value are known, however, (e.g., Opuntia spp., Atriplex spp., Stylosanthes spp., etc.) and this type of action should not be set aside, even if it is limited, at first, to experiments on a modest scale.

Attempts at the rehabilitation of degraded surfaces using superficial scarification have had considerable successes (Penning de Vries, 1978; Stewart and Dulieu, 1979), but the cost of these interventions seemed to make their application impractical in the context of nomadism (Greenwood 1980). It has been proven (Penning de Vries, 1978 and Penning de Vries and Heemst, 1975) that the sandy Sahelian landscapes could be made more productive by applying fertilizers since the availability of phosphorus and nitrogen in these soils is a limiting factor. The cost of applying this solution on a significant scale seems to be prohibitive. The promotion of leguminous species would probably be the best solution for this problem.

Planting shrubs or propagating them by direct seeding, where they are lacking, is indispensable to any action of improvement or rehabilitation. Shrubs are also the best nitrogen source in dry season, the best anti-erosional elements and, in the case of leguminous plants, such as the Acacias, Dichrostachys spp. and Pterocarpus spp., are the best nitrogen-fixers. The introduction of exotic woody species appears to be inappropriate owing to the number of local species of high quality.

2. The distribution and sale of feed supplements is very popular among herders, but obtaining them in sufficient quantity is not possible in most of the Sahel.

Concerning the cultivation of forage crops (Cajanus cajanas, Dolichos lablab, etc.), it could play a very significant role in agricultural systems of the Sahel by creating a source of good forage during the dry season, and in a crop rotation system, by ensuring the renewal of fertility in agricultural soils. Unfortunately, the idea of cultivating plants for animal consumption is not accepted by most inhabitants of the Sahel region. The effort required by the ancient labor techniques, which still prevail in this part of the world, is such that the farmer, perhaps with reason, feels restricted to devoting his work to satisfying only human food needs.

Introducing techniques of properly timed cutting of hay and silage would be more promising than cultivating plants for use in the dry season. Many people in the Sahel, including herders and others, cut dried hay in the dry season to feed their own animals or to sell. Harvesting those plants at the right plant stage (end of the boot stage for grasses) would increase greatly the forage value. Unfortunately, the ideal cutting time often coincides with that of other field work. Nevertheless, it is possible that this practice might become a profitable specialization for some segments of the society.

3. The need to protect the vegetative cover against bush fires and abusive cutting is obvious. These protective practices deserve very much to be continued and reinforced. Owing to a lack of means, active fencing protection is rarely carried out in the Sahel except within the context of a project. The value of this technique, especially in facilitating regeneration of the woody stratum, has been demonstrated only in a few instances.

4. Herders in the Sahel have often been reproached for keeping surplus animals in their herds. For some it is the "cause" of overgrazing. Recent documents tend either to deny this or to minimize its importance (Ketalaars, 1978). The argument in Section V of this report presents information to support the theory that environmental degradation in the Sahel is the result of anarchic grazing systems.

The introduction of a controlled grazing system should be the first priority for placing the exploitation of the Sahel pastoral resources

on a more rational basis. Controlling grazing and limiting access to grazing tracts are not only necessary, they are sine qua non for any attempts to improve natural pastures; however, the results of such efforts could easily be nullified or rendered superfluous in an anarchic grazing system.

The formation of herders' cooperatives for facilitating the sale of animals and animal products is highly desirable where herders themselves truly want them. Where herders are hostile or indifferent to the formation of such enterprises, these cooperatives are bound to fail. It is obvious that the need for new systems to organize a rapid reduction of animals in difficult years is being felt everywhere. Strategies for multiplying wells have been fully discussed in Section V.

5. Limiting traditional transhumance has often been considered desirable. To be sure, it would simplify enormously the work of the range manager. It must, however, be acknowledged that herders will never voluntarily abandon this system, which they see as the best long term guarantee of survival for their herds, unless another system is proposed which gives similar guarantees of year-round feed for animals in the restricted zone, and if possible, during drought years. Any proposed system should, therefore, allow optimal exploitation of existing resources. It must also be sufficiently flexible to permit the temporary departure of herds from grazing lands that suffer from lack of rain to those lands that are better vegetated. In such instances, the acceptance of a herd in a new area should be conditional and subject to 1) the approval of the landowners, and 2) the advice from a competent range management service as to the ability of the grazing tract in question to support the additional stock.

VII. SELECTED REFERENCES

Adam, J.G. 1962. Itinéraires Botaniques en Afrique Occidentale; In: Journal d'Agriculture Trop. et de Bot. Appl.; T. IX, N° 3-6; p. 84-200 et T. IX; N° 7-10. p. 297-425.

Berhaut, J. 1976. Flore du Sénégal; 2e édition, Dakar, Libr. Clairafrique.

Boudet, G. 1976. Mali (case study); In: H. Le Houerou and B. Lundholm (eds). Can desert encroachment be stopped? Ecol. Bull. 24:137-154.

Boudet, G. 1975. Manuel sur les pâturages tropicaux et les cultures fourragères; 2e édition; Rép. Francaise; Ministé'é de la Coopération, I.E.M.V.T.; Manuel N°4; 256 p.

Boudet, G. et E. Duverger. 1961. Etude des pâturages naturels sahéliens: le Hodh (Mauritanie); Inst. Féd; de Recherches Zoötechniques; Bamako/ I.E.M.V.T.; Paris. 157 p.

Clanet, J. 1977. Les Conséquences des années séches 1969-1973 sur la mobilité des éleveurs du Kanem; In: Gallais, J. (ed.) Stratégies pastorales et agricoles des Sahéliens devant la sécheresse 1969-1974. CEGET/CNRS. Travaux et documents de Géographie Tropicale; N° 30; p. 237-259.

Daget, P. et J. Poissonet. 1971. Méthode d'analyse de la végétation des pâturages. Ann. Agron, 22:5-41.

Draz, O. 1969. The "Hema" System of Range Reserves in the Arabian Peninsula; FAO/PL; PFC/13.

Gillet, H. 1967. Essai d'évaluation de la Biomasse végétale en zone sahélienne (végétation annuelle): In: Jour. Agric. trop. et de Bot. Appl. T. XIV; N° 4-5: p. 123-159.

Greenwood, G.B. 1980. Thesis: Pastoral Development in the Sahel Colorado State Univ., Fort Collins.

Ketalaars, S. 1978. Problémes concernant l'élevage au Sahel: implication pour la recherche faite par le Projet "Production Primaire au Sahel"; Mimeo; 73 p.

Mosnier, M. 1961. Pâturages naturels sahéliens; région de Kaédi (Mauritanie); Maisons Alfort, I.E.M.V.T; 169 (Etude agrostologique N° 3).

Naegélé, A.F.C. 1977. Les Graminées des pâturages de Mauritanie. Etude N° 5; Pâturages et cultures fourragéres; FAO; Rome.

Newby, J.E. 1974. An Ecological Inventory of the O; Rimé-O; Achim Faunal Reserve; WWF; Geneva, 278 p.

Ozenda, P. 1958. Flore du Sahara septentrional et central; Paris, CNRS.

Penning de Vries, F. 1978. Results and perspectives of the Project "PPS"- a sketch halfway; Mimeo. 41 p.

Penning de Vries, F., and H. Heemst. 1975. Potential primary production of unirrigated land in the Sahel; In: Evaluation and Mapping of Tropical African Rangeland. ILCA, Addis Ababa; p. 323-328.

Stewart, C.W.R. and D. Dulieu. 1979. Réhabilitation des parcours Sableux et sablo-limoneux au Secteur Serbeouel (Caméroun); CBLT/I.E.M.V.T.; Mimeo; 37 p.

Swift, J. 1979. West African pastoral production systems. Working paper N°3. Cen. for Research on Econ. Dev.; Univ. of Michigan; Ann Arbor; 102 p.

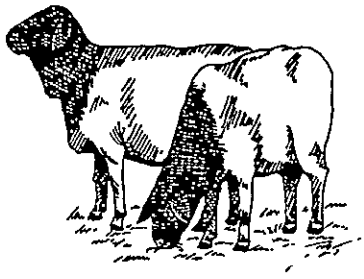
Valenza, J. et F. Fayolle. 1965. Notes sur les essais de charges de pâturages en République du Sénégal; Rev. Elev. Méd. Vét. Pays Trop.; 18(3):321-327.

Weber, F.R. 1977. Reforestation in Arid Lands; ACTION/Peace Corps, Program and Training Journal; Manual Series N°5.

Chapter 3

APPENDIXES

A – B – C – D



Appendix A

Soil Laboratory Procedures

Soil Chemical and Physical Analyses

The following characterizations were completed for each soil sample: 1) pH, 1:1 extract H_2O; 2) electrical conductivity, (EC),1:1 extract; 3) buffer extractable acidity; 4) calcium plus magnesium; and 5) calculation of cation exchange capacity and base saturation. Other soil analyses were completed when indicated by the preceding results. These tests included soluble salts 1:2 extract where EC was greater than 0.4 mmhos/cm, sodium (as gypsum requirement) where pH exceeded 7.8, and calcium carbonate equivalent when a response was observed with weak HCL. Aluminum (neutral salt extractable acidity) was completed for several soils with pH less than 5.0, but results were consistently low (sandy textures) and further tests were not completed.

Battery-driven, portable meters were used for pH and EC determinations, Chemtrix Type 40 pH meter and Hach Mini conductivity meter model 17250, respectively. The chemical analysis were completed with a Hach Soil Analysis Laboratory Kit SA-I Model A 12317.[1/]

The cation exchange properties were determined by extraction with a potassium chloride-triethanolamine buffer at pH 8.1. Results may be biased in strongly acid soils giving an underestimation of CEC (Young, 1976). Sodium was determined by leaching soil samples with saturated gypsum solution and noting the decrease. Calcium carbonate was determined by measuring the volume of carbon dioxide generated by reaction of a measured weight of soil with strong HCL. Corrections for temperature, elevation, and solubility were provided. Total soluble salts (1:2) were determined by first titrating the carbonate and bicarbonate, then passing the extract through a hydrogen-form resin. Titration of the released acidity gave a value equivalent to the total soluble salts (Hach Ag. Division, 1973).[2/]

Soil texture was determined by the "feel" method. In this method the ability of a wetted sample to be formed in a ribbon is used to estimate the sand, silt, and clay percentages. The textures of several samples were completed by the pipette method at the SONADER Laboratory, Nouakchott, and the correspondence between results was good. Hydrometer testing and sieving for textures of all the samples was planned, but due to shipping problems, not completed.

[1/] Brand names and model numbers are included only for informational purposes.

[2/] Hach Agricultural Division. 1973. Instruction manual Hach soil analysis laboratory SA-I. P.O. Box 907, Ames, Iowa, U.S.A.

Appendix B

Terms and Criteria for Rating Selected Soil Properties and Soil Interpretations

SLOPE
- NL - nearly level, 0 to 3%
- GS - gently sloping, 3 to 6%
- MS - moderately sloping, 6 to 10%
- MST - moderately steep, 10 to 20%
- ST - steep, >20%

DEPTH
- D - deep, 100-120 cm or more
- MD - moderately deep, 50 - 100 cm
- S - shallow, 25 - 50 cm
- VS - very shallow, <25 cm

TEXTURE
- S - stoney, rocky,
- G - gravelly
- C - coarse; sand and ls
- MC - moderately coarse; sl, fsl
- M - medium, vfsl, l, siL, si
- MF - moderately fine; cl, scl, sicl
- F - fine; sc, sic, c

FRAGMENTS (% ground cover)
- 0 - 0%
- 1 - 0.1%
- 2 - 0.1 to 3%
- 3 - 3 to 15%
- 4 - 15 to 90%
- 5 - over 90%

PERMEABILITY (cm/hr)
- VS - very slow, <0.1
- S - slow, 0.1 to 0.5
- MS - moderately slow, 0.5 to 1.5
- M - moderate, 1.5 to 5.1
- MR - moderately rapid, 5.1 to 15.2
- R - rapid, 15.2 to 50.8
- VR - very rapid, more than 50.8

INTERNAL SOIL DRAINAGE
- VP - very poorly drained
- P - poorly drained
- SP - somewhat poorly drained
- MW - moderately well-drained
- W - well-drained
- SE - somewhat excessively drained
- ED - excessively drained

SOIL REACTION (pH)
- VSA - very strongly acid <4.2
- SA - strongly acid, 4.3 to 5.0
- MA - moderately acid, 5.1 to 6.0
- SA/N - slightly acid/neutral, 6.1 to 7.3
- MALK - moderately alkaline, 7.4 to 8.2
- SALK - strongly/very strongly alkaline, >8.2

AVAILABLE WATER CAPACITY (Depth of 140 cm or to restricting layer)
- VL - very low, 0 to 8 cm
- L - low, 8 to 15 cm
- M - moderate, 15 to 23 cm
- H - high, >23

TERM OF REFERENCE
- F - field observation
- FO - field observation, other resource survey team members
- S - site description
- A - aircraft reconnaissance
- API - air photo interpretation
- PI - published information

VEGETATIVE COVER % (Canopy and ground)
1 - greater than 75
2 - 50 to 75
3 - less than 50

EROSION %
NS - none to slight, <25
M - moderate, 25 to 75%
SE - severe, >75

WIND ERODIBILITY GROUP
1 - sands
2 - loamy sands
3 - sandy loams
4L - calcareous loams and clays
4 - mf and f, sicl with >35% clay
5 - coarse loams (<18% clay)
6 - fine loams
7 - sicl (<35 clay)
8 - not subject to blowing

EROSION HAZARD
1 - very slight
2 - slight
3 - moderate
4 - severe
wi - wind is major agent
w - water is major agent

POTENTIAL FOR AGRICULTURE
S1 - highly suitable
S2 - moderately suitable
S3 - marginally suitable
SC - conditionally suitable
N1 - currently nonsuitable
N2 - permanently nonsuitable

Soil Component

Term used to designate contituent major soils within a mapping unit. Component 1 is the major soil within any mapping unit followed in order by Component 2 and Component 3 (if needed). Components are defined by slope, depth, drainage, and texture and are identified adjacent to the upper case mapping unit symbol in the Brief Mapping Unit Description (Section V).

Appendix C

Profile and Site Descriptions with Chemical Analyses

Brief Site Descriptions (Non-Profile)

The following descriptions present an abbreviated account of non-profile soil samples. Only the top soil is included in the brief description and Munsell colors are for dry soil. Taxonomic classification is taken as far as possible dependent upon depth of sampling and differentiating, taxonomic criteria. These sites range from very productive to devoid of vegetation. Several sites provide an indication of the range of characteristics within a mapping unit when compared to soil profile description and/or other site, e.g. S2 and S4.

C3. 15°12' N. Lat. and 11°59' W. Long. Barren gravelly uplands, 3% slope. Brown (7.5 yr 5/5) gravelly very fine sandy clay loam with dark brown (7.5 yr 4/4) clay skins. 0-25 cm sample. Notes: truncated B 2t horizon; B 3ca was observed but not sampled. Numerous surrounding areas of gravel and loose sand deposits. Argid.

C5. 15°7' N. Lat. and 11°56' W. Long. Dissected uplands, 3% slope. Yellowish red (5 yr 5/8) clay loam. 0-25 cm sample. Notes: sampled in gully. Severely water erosion. Ustalf.

C6. 14°49' N. Lat. and 11°58' W. Long. Rocky uplands, 2% slope. Grayish brown (10 yr 5/2) shaly loam, 0-8 cm and 8-25 cm samples. Notes: heavy vegetation, numerous Baobob trees. Very shaly at 8 cm, soil has formed in joints and cracks. High in organic matter. Mollic Ustorthent.

C8. 14°50'30" N. Lat. and 12° 10' W. Long. Uplands, 2% slope. Reddish brown (5 yr 5/3) very fine sandy loam. 0-5 cm and 5-20 cm samples. Notes: sampled in area of crusted, barren surface. Scattered areas of fixed sands are common on the surface. Ustalfs.

C11. 15°08' N. Lat. and 12°29' W. Long. Uplands (felsic rock). Brown (7.5 yr 5/3) loamy fine sand with mica flakes. 0-15 cm and 15-25 cm samples with a 0-10 cm sample of nearby fixed aeolian sand. Notes: sheet erosion is severe in this gently sloping area. Haplustalfs.

C12. 15°58' N. Lat. and 12°32' W. Long. Rocky uplands (micaschists), 7% slope. Yellowish red (5 yr 5. 5/6) very cobbly light clay loam. 0-15 cm sample. Notes: white rock surface in moderately sloping to moderately steep unit. No vegetation on the uplands, some in alluvial positions. Lithic Torriorthent.

C13. 17° 22' N. Lat. and 15° 40' W. Long. Old alluvium, 1% slope. Strong brown (7.5 yr 5/6) gravelly loam. 0-17 cm and 17-30 cm samples. Notes: barren surface. Typic Haplargid.

S2. 17° 02' N. Lat. and 13° 32' W. Long. Alluvial plain (Oued Ketchi), 1% slope. Brown (7.5 yr 5/4) clay loam. 0-17 cm sample. Notes: some carbonates were visible at 20 cm, overgrazed but good stand of trees including Acacia nilotica. Ustertic Torrifluvents.

S5. 16° 47' N. Lat. and 13° 21' W. Long. Plateau, 1% slope. Brown (7.5 yr 5.5/4) sandy loam. 0-13 cm and 13-25 cm samples. Notes: cobbles and gravel (ferruginous) were dominant in second sample. More vegetation is located where depth to stony horizon is greater than 25 cm. Orthents.

S9. 16° 19' N. Lat. and 13° 19' W. Long. Plateau, 1% slope. Reddish brown (5 yr 5/4) loam. 0-15 cm and 15-30 cm. Notes: very similar to S5 with

very gravelly zone at 15 cm. In slight depressions, where heavier vegetation exists, depth to gravelly zone at one site was 35 cm. Vegetation is thicker here than at S5 due to more rainfall. Numerous dead trees and dormant vegetation were noted (2/13/81). Orthents.

S15. 15° 18' N. Lat. and 12° 13' W. Long. Uplands. 1% slope. Dark brown (7.5 yr 4/2) clay with dark brown (7.5 yr 3/2) clay skins. 0-35 cm and 35-70 cm samples. Notes: samples taken in DRIG North Site. Slightly concave area. Some areas are shallow to shale. Excellent vegetation production. Katamagne is the local name for this soil (Bradley et al., 1977). Mollic Torrerts.

S16. 15° 21' N. Lat. 12° 14' W. Long. Floodplain, moderately wide, 1% slope. Dark brown (7.5 yr 4/4) silty clay loam. 0 - 40 cm sample. Remarks: sampled in cropland. Soil cracks were very coarsely spaced; this soil tends toward vertic. It appears to be very productive. Vertic Ustropepts.

S17. 15° 28' N. Lat. and 12° 15' W. Long. Floodplain, moderately wide, 1% slope. Dark brown (7.5 yr 4/4) silt loam. 0-20 cm, 20-40 cm, and 40-60 cm samples. Remarks: soil has moderate, medium, subangular blocky structure in B horizon. Fluventic Ustropepts.

S21. 12° 19' N. Lat. and 15° 02' W. Long. Primary floodplain of major, intermittent water course. Brown (7.5 yr 5/2) clay loam with common, fine, distinct yellowish red (5 yr 4/6) mottles. 0-23 cm and 23-40 cm samples. Remarks: good stand of trees but no grasses. Flooding appears to occur nearly every year. Mollic Ustifluvents.

B1. 18° 03' N. Lat. and 15° 50' W. Long. Marine terrace between sand dunes, 1% slope. Very pale brown (10yr 8/3) loam. 0-10 cm, 10-20 cm, and 20-30 cm samples. Notes: Barren. Some leaching has taken place. Scattered sea shells on surface; strong to violent effervescence in all samples. Calciorthids.

B5. 17° 05' N. Lat. and 13° 56' W. Long. Old lake bed (Lac d'Aleg), 1% slope. Dark gray (10 yr 4/1) clay. 0-12 cm and 12-47 cm samples. Notes: Some aeolian sands at surface. Sampled at edge of a flood-recessional sorghum field. Wide cracks through profile but some moistness was noted at 12 cm. Native vegetation (Casia spp) was tall. Annual flooding occurs. Somewhat poorly drained with some oxidized, yellowish red (5 yr 4/6) root casts to surface. Ustertic Torrifluvents.

B11. 16° 51' N. Lat. and 15° 15' W. Long. Alluvial sands (east of Lac R'Kiz). Very dark brown, mixed (10 yr 3.5/2) loamy fine sand. 0-17 cm, 17-30 cm, 30-49 cm, and 49-68 cm samples. Notes: excellent stand of trees and grasses. Aquipsamments.

B15. 16° 45' N. Lat. and 15" 28' W. Long. Alluvium. Very dark gray (10 yr 3.5/1) heavy clay loam. 0-14 cm, 14-22, and 22-42 cm samples. Notes: somewhat poorly drained site. Mottles in second sample. Aquic Torrifluvents.

B16. 16° 38' N. Lat. and 15° 31' W. Long. Alluvium. Dark grayish brown (10 yr 4/2) clay with few prominent, fine yellowish red (5 yr 5/6) mottles, 0-25 cm sample. Notes: sampled in sorghum field. Ustertic Torrifluvents.

K1. 16° 35' N. Lat. and 11° 30' W. Long. Reg. plain with thin aeolian sand cover. Brown (7.5 yr 5/4) heavy loamy sand. 0-4 cm, 4-22 cm, and 22-35 cm samples. Notes: Ustollic Haplargids.

K2. 16° 32' N. Lat. and 11° 36' W. Long. Lower midslope of a longitudinal dune, 8% slope. Brown (7 yr 5/4) fine sand. 0-15 cm sample. Notes: crusted, hard smooth surface with patches of loose, moving sand. Typic Torripsamment.

K3. 16° 31' N. Lat. and 11" 36' W. Long. Interdune, alluvial position, 1% slope. Brown (7 yr 4.5/2) fine sand. Notes: ground water is close enough to surface to support palm trees. Typic Torrifluvent.

K4. 16° 29' N. Lat. and 11° 42' W. Long. Alluvial position in reg plain. 1% slope. Dark grayish brown (10 yr 4/2) clay. 0-25, 25-50, 50-75 cm samples. Notes: heavy stand of Acacia seyal. Vertic Torrifluvents.

K6. 15° 54' N. Lat. and 11° 38' W. Long. Plain, 2% slope. Brown (7.5 yr 5/4) clay loam. 0-15 cm sample. Note: surface is barren. Aridisols.

K10. 15° 32' N. Lat. and 15° 32' W. Long. Rocky plain, 3% slope. Brown (7 yr 5/4) very cherty sandy loam. 0-5 cm sample. Notes: in places this soil supports fair stands of trees. The parent rocks are well fractured. Lithic Torriorthents.

K13. 15° 38' N. Lat. and 11° 36' W. Long. Reg plain, 1% slope. Yellowish red (5 yr 4/6) gravelly loam. 0-10 cm sample. Notes: barren surface. Orthids.

K17. 17° 35' N. Lat. and 11° 19' W. Long. Alluvial plain, 1% slope. Strong brown (7.5 yr 5/6) loamy, stratified soils. 0-10 cm and 10-25 cm samples. Notes: heavy stands of trees indicate runoff from surrounding slopes is good in most years. Typic Torrifluvents.

K18. 17° 23' N. Lat. and 11° 11' W. Long. Playa, 1% slope. Light brownish gray (10 yr 6/2) calcareous silty clay. 0-15 cm sample. Calciorthid.

K20. 17° 09' N. Lat. and 11° 21' W. Long. Reg plain with gravel- and coarse sand-covered surface, 1% slope. Yellowish red (5 yr 4/6) sandy clay loam. 0-15 cm sample. Notes: strongly developed structure with clay skins. Argid.

K21. 17° 03' N. Lat. and 11° 23' W. Long. Fixed, aeolian sands, 3% hummocky slope. Brown (7.5 yr 5/4) loamy fine sand. 0-15 cm sample. Notes: weakly crusted surface. Typic Torripsamment.

K22. 16° 30' N. Lat. and 11° 05' W. Long. Barren plain, 1% slope. Brown (7.5 yr 5/4) sandy loam. 0-7 cm and 7-15 cm samples. Notes: wind-blown, semi-fixed sands cover this soil in places. Aridisol.

K23. 16° 23' N. Lat. and 11° 31' W. Long. Gullied (1/2 m deep) alluvial plain, 2% slope. Dark brown (10 yr 4/3) clay loam. 0-13 cm and 13-18 cm samples. Notes: less than 50% cover of grass, hard surface. Fluvent.

K26. 16° 02' N. Lat. and 12° 03' W. Long. Narrow alluvial plain, 1% slope. Brown (10 yr 5/3) clay loam. 0-10 cm sample. Notes: extremely hard, dry consistence. Well vegetated. Torrifluvent.

K27. 16° 09' N. Lat. and 12° 03' W. Long. Wide alluvial plain, 1% slope. Brown (7.5 yr 5/3) silty clay loam. 0-15 cm sample Notes: cropped field (sorghum) and livestock-grazed residue. It had 2 m deep gully running through the center of the field. Torrifluvent.

R1. 16° 45' N. Lat. and 16° 15' W. Long. Fixed sand dune. Brown (7.5 yr 5/4) fine sand. 0-20 cm and 20-40 cm samples. Notes: heavily overgrazed, severely eroded site. Ustic Torripsamment.

R2. 16° 45' N. Lat. and 16° 15' W. Long. Marine terrace between dunes. Very dark grayish brown (10 yr 3/2) fine sandy clay loam. 0-25 cm sample. Notes: bare surface, salts visible at 20 cm. Argid.

R3. 16° 32' N. Lat. and 15° 36' W. Long. Senegal River Delta. Brown, mixed (10 yr 5/3) clay. 0-15 cm sample. Notes: very poorly drained, gleyed soil. Sampled in sorghum field. Vertisol.

R4. 16° 30' N. Lat. and 15° 46' W. Long. Senegal River Delta. Pinkish gray (7.5 yr 6/2) silty clay loam with few, fine, prominent yellowish red (5 yr 5/6) mottles. 0-25 cm sample. Notes: barren. Aquic Ustifluvent.

R5. 16° 29' N. Lat. and 15° 23' W. Long. Senegal River Delta. Yellowish brown (10 yr 5/4) heavy clay loam with common, medium, distinct yellowish red (5 yr 5/6) mottles. 0-25 cm sample. Notes: salts visible at 10 cm. Prismatic structure. Halaquept.

R6. 16° 20' N. Lat. and 16° 22' W. Long. Fixed littoral dune. Brown (7.5 yr 5.5/4) sand. 0-25 cm sample. Notes: good organic matter. Ustic Torripsamment.

Soil Profile C1

Classification: Typic Haplargids
Location: 17° 23' N. Lat. and 13° 12' W. Long.
Physiography: Old sedimentary plain
Topography: nearly level (1%) rectilinear slope with slight northerly aspect.
Vegetation: sparse cover, Acacia flava and Balanites aegyptiaca
Date: 5/12/81
Remarks: light desert pavement surface (class 2 gravel).

B1 0-15 cm. Reddish brown (5 yr 5/5) light clay loam with few pebbles, reddish brown (5 yr 4/5) moist; strong medium subangular blocky structure; slightly hard and sticky; few fine roots; pH 7.2 slightly effervescent; clear, smooth boundary.

$B2_{t}ca$ 15-34 cm. Brown (7.5 yr 5/5) clay loam with dark brown clay skins (7.5 yr 4/4) and few pebbles, dark brown (7.5 yr 4/4) moist; strong medium subangular blocky structure; hard and sticky; very few fine roots; pH 7.7 strongly effervescent; clear, smooth boundary.

C1ca 34-45 cm. Brown (7.5 yr 5.5/5) sandy clay loam with few pebbles, brown (7.5 yr 4.5/5) moist; massive; hard and sticky; very few roots; pH 7.9 violently effervescent.

Soil Profile C2

Classification: Typic Haplustalf
Location: 15° 34' 40" N. Lat. 11° 9' N. Long.
Physiography: Colluvial fan
Topography: Gently sloping (5%) rectilinear slope of medium length with north aspect. Sampled in midbackslope position.
Vegetation: Brush fallow. Fair regrowth, Combretum glutinosum, Cenchrus spp., a few small palms.

Date: 5/13/81
Remarks:

A11 0-13cm. Brown (7.5 yr 5/4) loamy fine sand, dark brown (7.5 4/4) moist; massive to single grain structure; slightly hard and nonsticky; very few fine roots; pH 6.4; clear, smooth boundary.

A12 13-29 cm. Reddish brown (5 yr 4/4) sandy loam, reddish brown (5 yr 4/4) moist; massive structure; hard and nonsticky; common fine roots; pH 6.5; clear smooth boundary.

B1 29-43 cm. Redish brown (5 yr 4/5) fine sandy loam, dark reddish brown (5 yr 3/5) moist; massive structure; hard and slightly sticky; common fine roots; pH 6.9; clear, smooth boundary.

B2t 43-65 cm. Yellowish red (5 yr 4.5/6) sandy clay loam, yellowish red (5 yr 3.5/6) moist; moderate medium subangular blocky structure; hard and sticky; very few fine roots; pH 6.9. Numerous $CaCO_3$ threads in lower part of this horizon.

Soil Profile C4

Classification: Typic Haplustalf
Location: 15° 9' N. Lat. 11° 59" W. Long.
Physiography: uplands
Topography: nearly level (1%) rectilinear slope with west aspect.
Vegetation: Brush fallow. Poor cover of grasses and trees, Combretum glutinosum, Gueira senegalensis, Balanites aegyptiaca.
Date: 5/15/81
Remarks: Location is near DRIG east site.

A1 0-19 cm. Reddish brown (5 yr 5/3) light fine sandy loam, reddish brown (5 yr 4/3) moist; massive structure; slightly hard and nonsticky; few fine and medium roots; pH 4.9; clear, smooth boundary.

B1 19-34 cm. Brown (7.5 yr 5/4) light fine sandy loam, dark brown (7.5 yr 5/3) moist; massive structure; slightly hard and nonsticky; few fine and medium roots; pH 4.5; clear, smooth boundary.

B21t 34-49 cm. Reddish brown (5 yr 5/5) fine sandy loam, with clay bridges visible, reddish brown (5 yr 4/5) moist; massive structure; slightly hard and nonsticky; few fine and medium roots; pH 4.7; clear, smooth boundary.

B22t 49-63 cm. Yellowish red (5 yr 5/6) fine sandy loam, yellowish red (5 yr 4/6) moist; massive structrue; slightly hard and nonsticky; very few fine roots; pH 4.9.

Soil Profile C7

Classification: Typic Hapustalf
Location: 14° 49' 20" N. Lat. 12° 2' 30" W. Long.
Physiography: Uplands (basic colluvial material)
Topography: Nearly level (2%) rectilinear slope with south aspect
Vegetation: Good cover of low grass and trees, numerous Baobob, Acacia senegal, A. seyal.

Date: 5/15/81
Remarks: Tends toward vertic

A1 0-10 cm. Dark brown (7.5 yr 4/4) light gravelly clay loam, dark brown 7.5 yr 3.3) moist; strong fine angular blocky structure; hard and slightly sticky; common fine roots; pH 6.7; clear, smooth boundary.

B21t 10-30 cm. Brown (7.5 yr 5/4) heavy gravelly clay loam, dark brown (7.5 yr 4/4) moist; strong medium prismatic parting to moderate medium subangular blocky structure; hard and sticky; common fine roots; pH 7.8; clear, smooth boundary.

B22tca 30-45 cm. Brown (7.5 yr 5.5/4) heavy gravelly clay loam with numerous dark brown (7.5 yr 4/4) clay skins, dark brown (7.5 yr 4/4) moist; strong medium prismatic parting to moderate medium subangular blocky structure; very hard and sticky; pH 8.3.

Soil Profile C9

Classification: Vertic Eutrocrept
Location: 14° 50' N. Lat. 12° 12' W. Long.
Physiography: Alluvial plain
Topography: Nearly level (1%) rectilinear slope with south aspect
Vegetation: Old brush fallow. Dense stand of Acacia seyal
Date: 5/16/81
Remarks: This area has various stages of regrowth of former fields. Some small slight depressions are vertisols. Medium-spaced, narrow cracks extend from base Ap to 60 cm. Tendency toward mollisol.

Ap 0-17 cm. Yellowish brown (10 yr 5/4) heavy silty clay loam, dark yellowish brown (10 yr 4/4) moist; moderate medium granular structure; slightly hard and sticky; common and many fine roots; pH 8.0 strongly effervescent; clear, smooth boundary.

B2 17-35 cm. Brown (10 yr 5/3) silty clay with few pebbles and brown (10 yr 4/3) clay skins, dark brown (10 yr 3/3) moist; strong medium angular blocky structure; very hard and sticky; common fine roots; pH 8.2 violent effervescent; gradual, smooth boundary.

C1ca 35-55 cm. Yellowish brown (10 yr 5/4) silty clay with pressure facets (10-30°) and dark brown (10 yr 4/3) slickensides, dark yellowish brown (10 yr 4/4) moist; strong medium and coarse plates; very few fine and coarse roots; pH 8.4 violent effervescent.

Soil Profile C10

Classification: Ustic Dystropepts
Location: 15° 9' N. Lat. 12° 26' W. Long.
Physiography: Uplands (felsic rocks)
Topography: Low midslope of long gentle slope (3%) with west aspect.
Vegetation: bare, few Balanites aegyptiaca
Date: 5/16/81
Remarks: Barren, crusted zone. Mica flakes appear to cause a self-sealing phenomenon. Fixed aeolian sand deposits are numerous, but are being removed by erosion.

A1 0-15 cm. Reddish brown (5 yr 5/3) fine sandy loam with mica flakes, dark reddish brown (5 yr 3/3) moist; massive structure; slightly hard and nonsticky; few fine roots; pH 4.6; clear smooth boundary.

B1 15-25 cm. Brown (7.5 yr 5/4) very fine sandy loam with mica flakes, dark brown (7.5 yr 4/4) moist; massive structure; slightly hard and hard and nonsticky; very few fine, medium, and coarse roots; pH 5.0; gradual, smooth boundary.

B2 25-36 cm. Brown (7.5 yr 5/5) fine sandy loam with mica flakes, dark brown (7.5 yr 5/4) moist; massive structure; hard and slightly sticky; no roots; pH 5.1; gradual, smooth boundary.

C1 36-60 cm. Strong brown (7.5 yr 5/6) fine sandy loam with mica flakes, dark brown (7.5 yr 5/4) moist; massive structure; slightly hard and slightly sticky; no roots; pH 4.9.

Soil Profile B2

Classification: Typic Torripsamment
Location: 17° 33' N. Lat. and 14° 43' W. Long.
Physiography: Sand dune
Topography: Toeslope of complex dune slope, slightly concave, 7% slope, northwest aspect.
Vegetation: Bare with few trees, Balanites aegyptiaca, Leptadenia spartium
Date: 3/9/81
Remarks: Moving sands. Moisture at 26 cm. Sampled in Boutilimit intervention site.

C1 0-26 cm. Yellowish red (5.5 yr 5/8) fine sand, yellowish red (5 yr 4/8) moist; single grain structure; soft and nonsticky; no roots; pH 7.6; clear, smooth boundary.

A1 26-57 cm. Yellowish red (5 yr 5/6) fine sand; yellowish red (5 yr 4/6) moist; single grain structure; soft and nonsticky; no roots; pH 7.4; gradual smooth boundary.

C2 57-80 cm. Yellowish red (5 yr 5/7) fine sand, yellowish red (5 yr 4/7) moist; single grain structure; soft and nonsticky; no roots; pH 7.4; gradual, smooth boundary.

C4 80-120 cm. Yellowish red (5 yr 5/8) fine sand, yellowish red (5 yr 4/8) moist; single grain structure; soft and nonsticky; no roots; pH 7.6.

Soil Profile B3

Classification: Typic Torripsamments
Location: 17°09' N. Lat. and 14° 8' W. Long.
Physiography: Fixed sand dune
Topography: Hummocky, 5% slope, broad, sandy area between steeper dunes with northwest aspect
Vegetation: Nearly full of grass with few trees, Balanites aegyptiaca, Commiphera africana, Leptadenia spartium, Cenchrus spp., Calotropis procera

Date: 3/9/81
Remarks: Heavily grazed, moderately eroded. 'A' horizons are weakly developed.

A1 0-45 cm. Yellowish red (5 yr 5/6) fine sand, yellowish red (5 yr 5/6) moist; weakly cemented, single grain structure, weakly cemented; soft and nonsticky; few and common fine roots; pH 7.4; gradual smooth boundary.

AC 45-73 cm. Colors, texture and consistence same as above, few fine roots; pH 7.4; gradual, smooth boundary.

C1 73-95 cm. Yellowish red (5 yr 5/8) fine sand, yellowish red (5 yr 4/8) moist; weakly cemented single grain structure; soft and nonsticky; few fine roots; pH 7.5.

Soil Profile B4

Classification: Ustollic Camborthids
Location: 17° 06' N. Lat. and 14° 03' W. Long.
Physiography: Old alluvial plain
Topography: Nearly level (1%), rectilinear slope (nondissected) with northeast aspect.
Vegetation: Nearly full cover of grasses and trees, Balanites aegyptiaca
Remarks: Heavily grazed in surrounding area, vegetation is denser or sparser depending upon depth to gravelly horizon. Very coarse, fine cracks noted to 50 cm from base of A1 horizon. Surface horizon is aeolian deposited and wind reworked.

A11 0-23 cm. Brown (7.5 yr 5.5/4) loamy fine sand, brown (7.5 yr 4.5/4) moist; single grain structure, weakly cemented; slightly hard and nonsticky; few medium and common fine roots; pH 7.0; abrupt, smooth boundary.

A12 23-45 cm. Brown (7.5 yr 4.5/4) fine sandy clay loam, dark brown (7.5 yr 3/3) moist; weak medium subangular blocky structure; slightly hard and slightly sticky; common fine roots; pH 7.4; clear, smooth boundary.

B2 45-75 cm. Dark brown (7.5 yr 4/4) light sandy clay loam, dark brown (7.5 yr 3/3) moist; weak medium prismatic parting to weak, medium subangular blocky structure; slightly hard and slightly sticky; common fine roots; pH 6.8; clear, smooth boundary.

C1 75-90 cm. Brown (7.5 yr 5/4) light gravelly sandy loam, dark brown (7.5 yr 4/4) moist; massive structure; slightly hard and slightly sticky; few fine roots; pH 7.8.

Soil Profile B6

Classification: Typic Camborthids
Location: 17° 01' N. Lat. and 13° 56' W. Long.
Physiography: Old plain, Continental Terminal
Topography: Slight depression, 1% concave slope with northeast aspect.
Date: 3/10/82
Vegetation: Nearly full cover of grasses and trees, Acacia flava, Boscia senegalensis, Balanites aegyptiaca, Commophora africana
Remarks: Some addition of aeolian sands to surface on ped faces. Soil tends toward vertic. Site is well vegetated.

A1 0-11 cm. Brown (7.5 yr 5.5/4) clay loam, dark brown (7.5 yr 4.5/4) moist; moderate medium subangular blocky structure; hard and sticky; few fine and medium roots; pH 6.0; abrupt, smooth boundary.

B2 11-18 cm. Yellowish brown (10 yr 5/4) silty clay loam, dark yellowish brown (10 yr 4/4) moist; strong medium angular blocky structure; hard and sticky; few fine roots; pH 6.5; clear, smooth boundary.

B3ca 18-45 cm. Yellowish brown (10yr 5.5/4) clay loam, dark yellowish brown (10 yr 4.5/4) moist; weak, medium subangular blocky structure; hard and sticky; few fine roots; pH 7.8 strongly effervescent; clear, smooth boundary.

C1ca 45-47 cm. Colors and consistence same as above, gravelly clay loam; massive structure, few fine roots, pH 8.0.

Soil Profile B7

Classification: Vertic Haplargid
Location: 16°58' N. Lat. and 13° 55' W. Long.
Physiography: Old alluvial plain
Topography: Slightly concave, nearly level (1%) slope with east aspect
Date: 3/10/81
Vegetation: Full cover of Cassia tora
Remarks: Sampled near sorghum field. Cracks present with 18 cm spacing, 40 cm deep and cracks at surface are 2 cm wide.

A1 0-19 cm. Brown (7.5 yr 5/4) clay loam, dark brown (7.5 yr 4/4) moist; moderate medium and fine subangular blocky parting to moderate medium granular structure; hard and sticky; few fine and medium roots; pH 6.9; clear, smooth boundary.

B21tca 19-33 cm. Dark brown (7.5 yr 4/4) heavy clay loam with dark brown (7.5 yr 4/3) clay films on ped surfaces, dark brown (7.5 yr 4/3) moist; moderate coarse prismatic parting to strong medium angular blocky structure; hard and sticky; few fine roots; pH 7.8 strongly effervescent; gradual, smooth boundary.

B22tca 33-40 cm. Colors, texture, and consistence same as above; strong coarse prismatic parting to strong medium subangular blocky structure; hard and sticky; few fine roots; pH 7.6 strongly effervescent.

Soil Profile B8

Classification: Ustic Torripsamment
Location: 16° 52' N. Lat. and 14° 2' W. Long.
Physiography: Fixed sand dune
Topography: Hummocky area. Site is slightly concave, gently sloping (3%) with west aspect.
Vegetation: Fair cover of grasses and few trees, Cenchrus spp. Balanites aegyptiaca
Remarks: Severely eroded area. Bare, weakly cemented crusts are common.

A11 0-10 cm. Brown (7.5 yr 5/4) fine sand, dark brown (7.5 yr 4/4) moist; weakly cemented to single grain structure; soft and nonsticky; common fine and few medium roots; pH 7.0; clear smooth boundary.

A12 10-40 cm. Yellowish red (5 yr 5/6) fine sand, yellowish red (5 yr 4/6) moist; weakly cemented, single grain structure; soft and nonsticky; few, fine roots; pH 5.6; gradual, smooth boundary.

AC 40-57 cm. Colors, texture, structure, and consistence same as above; few, fine roots; pH 6.2; clear, smooth boundary.

C1 57-97 cm. Yellowish red (5 yr 5/7) fine sand, yellowish red (5 yr 5/6) moist; weakly cemented to single grain structure; soft and nonsticky; few fine roots; pH 5.8.

Soil Profile B9

Classification: Ustollic Haplargid
Location: 16° 53' N. Lat. and 14° 56' W. Long.
Physiography: Old marine terrace between dunes
Topography: Nearly level (2%) rectilinear slope
Date: 3/11/81
Vegetation: Nearly bare cover with few trees, Balanites aegyptiaca, Calotrophis procera, Acacia raddianna
Remarks: Scattered sea shells on surface. All horizons are strongly effervescent, C1ca is violently effervescent. Barren surface.

A1 0-27 cm. Dark grayish brown (10 yr 4/2) loam, very dark grayish brown (10 yr 3/2) moist; structureless; slightly hard and slightly sticky; few fine roots; pH 7.8; clear, smooth boundary.

B2t 27-37 cm. Dark yellowish brown (10 yr 4/4) clay loam, dark brown (10 yr 3/3) moist; weak medium subangular blocky; slightly hard and sticky; few fine roots; pH 7.8; abrupt, smooth boundary.

B3ca 37-57 cm. Pale brown (10 yr 6/3) loam, dark brown (10 yr 4/3) moist; structureless; slightly hard and slightly sticky; no roots; pH 7.8.

Soil Profile B10

Classification: Ustertic Haplargids
Location: 16° 54' N. Lat. and 15° 10' W. Long.
Physiography: Old alluvial plain
Topography: Gently sloping (3%) rectilinear slope with south aspect
Date: 3/11/81
Vegetation: Fair cover of trees
Remarks: Thin scattering of aeolian sand on surface. Very coarsely spaced, narrow cracks to 45 cm. Poorly drained.

A1 0-13 cm. Dark gray (10 yr 4/1) sandy clay loam, very dark gray (10 yr 3/1) moist; strong, coarse subangular blocky structure; hard and sticky; few, fine roots; pH 5.8; clear, smooth boundary.

B1 13-24 cm. Matrix of soil colors: grayish brown (10 yr 5/2) and very dark gray (10 yr 3/1) heavy sandy loam; dark grayish brown (10 yr 4/2) and black (10 yr 2.5/1) moist; moderate medium prismatic blocky medium subangular parting to moderate structure; hard and sticky; few fine roots; pH 6.2; clear, smooth boundary.

B2t 24-45 cm. Matrix of soil colors: light grayish brown (10 yr 6/2) and very dark gray (10 yr 3/1) sandy clay loam, grayish brown (10 yr 5/2) and very dark gray (10 yr 3/1) moist; moderate, medium prismatic parting to strong medium subangular blocky; very hard and sticky; very few fine roots; pH 6.2; abrupt, smooth boundary.

C1 45-65 cm. Matrix of soil colors: light gray (10 yr 7/2) and very dark gray (10 yr 3/1) sandy loam, grayish brown (10 yr 5/2) and very dark gray (10 yr 3/1) moist; massive; hard and slightly sticky; very few fine roots; pH 6.7.

Soil Profile B12

Classification: Cumulic Hapustolls
Location: 16° 43' N. Lat. and 15° 48' W. Long.
Physiography: Interdune edge. Wind and water-deposited sands
Topography: Hummocky, gently sloping (3%) with east aspect
Date: 3/12/81
Vegetation: Fair cover of grasses and trees, Acacia senegal, Balanites aegyptiaca
Remarks: Krotovina were observed in AC horizon. AC and C1 horizons had few, fine, distinct yellowish red (5 yr 5/6) mottles.

A11 0-23 cm. Brown (7.5 yr 4.5/4) loamy fine sand, dark brown (7.5 yr 3/3) moist; single-grain structure; soft and nonsticky; few fine and medium roots; pH 6.2; abrupt, smooth boundary.

A12 23-37 cm. Dark reddish brown (5 yr 3.5/4) loamy fine sand, dark reddish brown (5 yr 3/2.5), moist; single grain structure; soft and nonsticky; few fine and medium roots; pH 6.5; gradual, smooth boundary.

AC 37-62 cm. Colors, consistence, and structure same as above, heavy loamy fine sand; few fine roots; pH 6.5; gradual smooth boundary.

C1 62-104 cm. Reddish brown (5 yr 4/4) heavy loamy fine sand, dark reddish brown (5 yr 3/3) moist; single grain structure; soft and nonsticky; very few roots; pH 6.7.

Soil Profile B13

Classification: Ustic Torripsamments
Location: 16° 56' N. Lat. and 15° 39' W. Long.
Physiography: Interdune
Topography: Hummocky, gently sloping (3%) site with a southeast aspect
Date: 3/12/81
Vegetation: Good cover of trees with some grasses, Acacia senegal, Balanites aegyptiaca
Remarks: Sampled in Mederdra Intervention Site

C1 0-8 cm. Brown (7.5 yr 5/4) fine sand, dark brown (7.5 yr 4/4) moist; weakly cemented single grain; soft and nonsticky; few fine and medium roots; pH 7.3; clear, smooth boundary.

C2 8-65 cm. Brown (7.5 yr 4.5/4) fine sand, dark brown (7.5 yr 4/4) moist; weakly cemented single grain; soft and nonsticky; common fine and few coarse and medium roots in upper part of horizon; pH 7.2; gradual smooth boundary.

C3 65-85 cm. Colors, texture, structure, and consistence same as above; few fine roots, pH 7.2.

Soil Profile B14

Classification: Typic Natrargid
Location: 16° 55' N. Lat. and 15° 12' W. Long.
Physiography: Marine Terrace
Topography: Nearly level (2%) rectilinear slope with east aspect
Date: 3/12/81
Vegetation: Little cover, Acacia raddianna, Balanites aegyptiaca
Remarks: Aeolian sands form variable-depth surface cover

A1 0-11 cm. Brown (7.5 yr 5.5/2) loamy sand, brown (7.5 yr 4.5/2) moist; massive to single grain structure; slightly hard and nonsticky; few, fine roots; pH 7.4; abrupt, wavy boundary.

B21t 11-22 cm. Brown (7.5 yr 4.5/2) clay loam, dark brown (7.5 yr 3.5/2) moist; strong medium columnar parting to strong, medium angular blocky structure; extremely hard and sticky; few fine roots on ped faces; pH 7.3; clear, smooth boundary.

B22tca 22-50 cm. Brown (7.5 yr 5/2) heavy sandy clay loam, dark brown (7.5 yr 4/2) moist; strong, medium prismatic parting to strong, medium angular blocky structure; extremely hard and sticky; few fine roots on ped faces; pH 8.5.

Soil Profile K5

Classification: Ustic Torripsamments
Location: 16° 18' N. Lat. and 11° 40' W. Long.
Physiography: Fixed sand dune
Topography: Moderately steep (6%) lower back slope of long rectilinear slope with west aspect
Date: 1/23/81
Vegetation: Full ground cover with short grasses and few trees, Balanites aegyptiaca and Cenchrus spp.
Remarks: Overgrazing is evident, but ground cover is still sufficient to prevent serious erosion.

A1 0-10 cm. Brown (7.5 yr 5/4) loamy fine sand, dark brown (7.5 yr 3/3) moist; weakly cemented to single grain structure; soft and nonsticky; few and common fine roots; pH 6.8; clear, smooth boundary.

AC 10-30 cm. Strong brown (7.5 yr 5/6) fine sand, brown (7.5 yr 4/4) moist; weakly cemented to single grain structure; soft and nonsticky, very fine roots; pH 7.0; clear, smooth boundary.

C1 30-50 cm. Yellowish red (5 yr 5/6) fine sand, yellow red (5 yr 4/6) moist; weakly cemented single grain structure; soft and nonsticky; few fine roots; pH 7.0.

Soil Profile K7

Classification: Ustic Torripsamments
Location: 15° 45' N. Lat. and 11° 41' W. Long.
Physiography: Fixed aeolian sands
Topography: Nearly level (2%) rectilinear slope with south aspect.
Vegetation: Full cover of grasses and few trees, Cenchrus spp. and Balanites aegyptiacea

Date: 1/23/81
Remarks: Sampled a cut in the upper end of gully. First horizon is recent wind-deposited sand.

A11 0-5 cm. Brown (7.5 yr 5/4) sand, dark brown (7.5 yr 4/4) moist; weakly cemented single grain structure; soft and nonsticky; few fine roots; pH 7.5; very abrupt, smooth boundary.

A12 5-28. Dark brown (10 yr 4/3) loamy sand, dark brown (10 yr 3/3) moist; weakly cemented to single grain structure, soft and nonsticky; few to common, fine roots; pH 6.5; gradual, smooth boundary.

AC 28-40. Brown (7.5 yr 4.5/4) loamy sand, dark brown (7.5 yr 3/3) moist; weakly cemented single grain, soft and nonsticky; few fine roots; pH 6.8; clear, smooth boundary.

C1 40-60. Brown (7.5 yr 4/4) loamy sand, dark brown (7.5 yr 3/3) moist; weakly cemented single grain structure; soft and nonsticky; few fine roots; pH 6.5

Soil Profile K9

Classification: Ustic Torripsamment
Location: 15° 36' N. Lat. and 11° 42' W. Long.
Physiography: Fixed aeolian sands.
Topography: Nearly level (2%) rectilinear slope with south aspect
Vegetation: Full cover of grasses and trees, Cenchrus spp. Combretum glutinosum, Balanites aegyptiaca
Date: 1/23/81
Remarks: Slightly eroded, some alga crusting. Little evidence of grazing. Gradation to alfisols.

A11 0-15 cm. Brown (7.5 yr 5/4) loamy fine sand, brown (7.5 yr 4/4) moist; weakly cemented to single grain structure; soft and nonsticky; few to common fine roots; pH 6.1; clear, smooth boundary.

A12 15-25 cm. Brown (7.5 yr 5/4) loamy fine sand, brown (7.5 yr 4/4) moist; weakly cemented to single grain; soft and nonsticky, few to common fine roots; pH 6.0; clear, smooth boundary.

C1 25-40 cm. Reddish brown (5 yr 5/4) loamy fine sand, reddish brown (5 yr 4/4) moist; weakly cemented single grain structure; slightly hard and nonsticky; few to common fine roots, pH 6.9.

Soil Profile K11

Classification: Aridic Haplustalf
Location: 11° 39' N. Lat. and 15° 33' W. Long.
Physiography: Sandy uplands (colluvium)
Topography: Gentle sloping (4%) mid-backslope of short, rectilinear slope with north aspects.
Vegetation: Few short grasses
Date: 1/24/81
Remarks: Severely eroded, patches of wind-blown sand, partially vegetated. Numerous areas of crusted surface.

A11 0-14 cm. Reddish brown (5 yr 5/4) loamy sand, reddish brown (5 yr 4/4) moist; single grain structure; soft and nonsticky; common, fine roots; pH 5.8; very abrupt, smooth boundary.

A12 14-26 cm. Brown (7.5 yr 5/3) loamy fine sand, brown (7.5 yr 4/4) moist; weakly cemented to single grain structure; slightly hard and nonsticky; common, fine roots; pH 4.9; clear, smooth boundary.

B2t 26-50 cm. Brown (7.5 yr 5/4) sandy loam with few fine laminae, brown (7.5 yr 4/4) moist; massive structure; slightly hard and nonsticky; few to common fine roots; pH 5.8; clear, smooth boundary.

C1 50-70 cm. Yellowish red (5 yr 5/6) sandy loam, reddish brown (5 yr 4/6) moist; massive structure; slightly hard and nonsticky; few fine roots; pH 6.0.

Soil Profile K14

Classification: Ustic Torripsamment
Location: 11° 30' N. Lat. and 15° 60' W. Long.
Physiography: Fixed sand dune
Topography: Gently sloping (2%) slightly convex slope with south aspect.
Vegetation: Full cover of grasses and trees, Combretum glutinosum, Cenchrus spp.
Date: 1/25/81
Remarks: Alga crust in places

A11 0-11 cm. Brown (7.5 yr 4.5/4) fine sand, dark brown (7.5 yr 4/4) moist; single grained structure; soft and nonsticky; common fine roots; pH 6.0; clear, smooth boundary.

A12 11-21 cm. Brown (7.5 yr 5/5) fine sand, dark brown (7.5 yr 5/4) moist; single grained structure; soft and nonsticky; common fine roots; pH 6.4; clear, smooth boundary.

A3 21-50 cm. Yellowish red (5 yr 4.5/6) fine sand, yellowish red (5 yr 4/6) moist; single grained structure; soft and nonsticky; few fine roots; pH 7.0.

Soil Profile K15

Classification: Typic Torrifluvent
Location: 16° 16' N. Lat. and 11° 11 W. Long.
Physiography: Interdune, fixed
Topography: Gentle sloping (4%) toeslope of long rectilinear slope with northeast aspect.
Vegetation: Nearly full cover of grasses and trees, Panicum turgidum, Cenchrus spp., Aristada spp., Acacia senegal, Balanites aegyptiaca.
Date: 1/25/81
Remarks: Severely overgrazed. The narrow thalweg (50m downslope) is a slightly heavier, more densely vegetated soil zone. Water table is sufficiently close to surface to support palm trees in many places.

A11 0-15 cm. Brown (7.5 yr 5/4) fine sand, dark brown (7.5 yr 4/4) moist; single grain structure; soft and nonsticky; few, fine roots; pH 7.3; gradual, smooth boundary.

A12 15-30 cm. Brown (7.5 yr 5/4) fine sand, dark brown (10 yr 3/3) moist; single grain structure; soft and nonsticky; few, fine roots; pH 7.4; gradual, smooth boundary.

C1 30-46 cm. Yellowish red (5 yr 4/6) fine sand, reddish brown (5 yr 4/4) moist; single grain structure; soft and nonsticky; few fine roots; pH 7.4.

Soil Profile K16

Classification: Typic Torrifluvent
Location: 17° 37' N. Lat. and 11° 20' W. Long.
Physiography: Water-deposited and wind-reworked alluvium
Topography: Hummocky, 2% average slope with west aspect
Vegetation: Moderate cover of grasses and trees, Panicum turgidum, Leptadenia spartium, Balanites aegyptiaca
Date: 1/26/81
Remarks: Surface horizon is wind-deposited

C1 0-5 cm. Strong brown (7.5 yr 5/6) sand, brown (7.5 yr 4/5) moist; single grain structure; soft and nonsticky; few fine and medium roots; pH 7.5; abrupt, smooth boundary.

C11 5-24 cm. Yellowish red (5 yr 5/6) sand, yellowish red (5 yr 4/6) moist; single grain structure; soft and nonsticky; few fine and medium roots; pH 7.5; clear, smooth boundary.

C111 24-50 cm. Brown (7.5 yr 5/5) sand, dark brown (7.5 yr 4/4) moist; single grain structure soft and nonsticky, few fine roots; pH 7.5.

Soil Profile K19

Classification: Typic Torripsamment
Location: 11° 10' N. Lat. and 17° 18' W. Long.
Physiography: Fixed aeolian sands
Topography: Broad nearly level (2%) flat with south aspect
Vegetation: Full cover of short grasses and very few trees. Cenchrus spp. and Balanites aegyptiaca
Date: 1/26/81
Remarks: Profile excavation was shallow because of uniformity of materials and that indicator species implied deep sands.

C1 0-15 cm. Strong brown (7.5 yr 5/6) fine sand, strong brown (7.5 yr 4/6) moist; weakly cemented parting to single grain structure; soft and nonsticky; common, fine roots; pH 7.5; clear, smooth boundary.

C11 15-30 cm. Strong brown (7.5 yr 5/7) fine sand, strong brown (7.5 yr 4/7) moist; weakly cemented to single grain structure; soft and nonsticky; common fine roots; pH 7.6.

Soil Profile S4

Classification: Mollic Torrert
Location: 17° 20' N. Lat. and 13° 20' W. Long.
Physiography: Alluvial deposits
Topography: Gilgai, general slope of 2%
Vegetation: Nearly full cover of grasses and trees
Date: 2/12/81

Remarks: Aeolian sands are in evidence at surface and in cracks. This soil flooded extensively in 1978 as seen on Landsat imagery.

A11 0-3 cm. Brown (7.5 yr 5/4) light clay, dark brown (7.5 yr 4/4) moist; weak, medium platy structure with coarsely spaced cracks; hard and very sticky; few, fine roots; pH 6.7; abrupt, smooth boundary.

A12 3-15 cm. Dark yellowish brown (10 yr 4.5/4) clay, dark brown (10 yr 3/3) moist; very coarse prismatic parting to moderate, medium, platy structure with coarsely spaced cracks; hard and very sticky; very few, fine roots; pH 7.6; gradual, wavy boundary.

AC 15-50 cm. Colors and texture same as above, medium structure with very coarse prismatic parting to moderate; coarsely spaced cracks ending at bottom of this horizon; extremely hard and very sticky, no roots; pH 7.3; gradual, wavy boundary.

C1 50-70 cm. Colors and texture same as above; strong medium platy structure with slickensides and pressures facets (20-50°); extremely hard and very sticky; no roots; pH 7.2.

Soil Profile S6

Classification: Fluventic Camborthids
Location: 16° 39' N. Lat. and 13° 04' W. Long.
Physiography: Alluvial interdune
Topography: Nearly level (2%), slightly concave, slope with southwest aspect.
Vegetation: Revegetated field, nearly full cover of grasses and trees, Ziziphus mauritiaca, Cassia tora, Balanites aegyptiaca, Calitropis procera.
Date: 2/13/81
Remarks: Very coarsely-spaced, narrow cracks (less than 5mm) were observed from the bottom of the Ap to 57 cm. Slightly eroded and overgrazed.

Ap 0-23 cm. Brown (7.5 yr 5/4) sandy loam, dark brown (7.5 yr 4/4) moist; weak, medium platy; slicky-hard and slightly sticky; few fine roots; pH 6.8; abrupt smooth boundary.

B21 23-57 cm. Reddish brown (5 yr 4/4) sandy loam, dark reddish brown (5 yr 3/4) moist; moderate, medium prismatic structure; slightly hard and slightly sticky; very few fine roots; pH 6.7; clear, smooth boundary.

B22 57-77 cm. Reddish brown (5 yr 4/4) light sandy clay loam with few pebbles, dark reddish brown (5 yr 3/4) moist; weak medium prismatic structure; slightly hard and slightly sticky; very few fine roots; pH 6.9.

Soil Profile S7

Classification: Ustalfic Haplargids
Location: 16° 23' N. Lat. and 13° 09' W. Long.
Physiography: Upland
Topography: Gently sloping (4%) rectilinear, mid-backslope position, long steeper upslope. Hummocky in places.
Vegetation: Sparse cover with few grassea and trees, Balanites aegyptiaca, Acacia flava, Cenchrus spp.

Date: 2/13/81
Remarks: Severely eroded, barren site, coarse sand grains scattered at surface. Other lesser eroded sites have cover of low grasses. Surface was hard-packed.

A1 0-15 cm. Brown (7.5 yr 5.5/4) loamy sand, dark brown (7.5 yr 4/4) moist; massive structure; slightly hard and nonsticky; very few fine roots; pH 5.5; abrupt, smooth boundary.

B21t 15-40 cm. Yellowish red (5 yr 4.5/6) sandy loam, yellowish red (5 yr 4/6) moist; massive structure; slightly hard and slightly sticky; no roots; pH 7.2; clear, smooth boundary.

B22tca 40-55 cm. Yellowish red (5 yr 5/6) sandy loam, yellowish red (5 yr 4/6) moist; massive structure, slightly hard and slightly sticky; no roots, pH 8.1 strongly effervescent.

Soil Profile S8

Classification: Ustochreptic Camborthids
Location: 16° 14' N. Lat. and 13° 19' W. Long.
Physiography: Upland (below ferruginous plateau)
Topography: Gently sloping (3%) rectilinear shape with a south southeast aspect. Mid-backslope position on a uniform, long slope.
Vegetation: Full cover with grasses and trees. Combretom glutinosum, Aristida spp., Acacia senegal, Cenchrus spp.
Date: 2/13/82
Remarks: Very good range condition, minimal erosion. USDA classification doesn't have a good match for this soil because of sandy texture.

A11 0-19 cm. Yellowish red (5 yr 5/6) loamy sand, yellowish red (5 yr 4/6) moist; weakly cemented to single grain structure; soft and nonsticky; common fine roots; pH 6.2; clear, smooth boundary.

A12 19-32 cm. Yellowish red (5 yr 5/6) loamy sand, yellowish red (5 yr 4/6) moist; weakly cemented to single grain structure; slightly hard and nonsticky; common fine roots, pH 6.1; clear, smooth boundary.

B2 32-46 cm. Yellowish red (5 yr 5/6) loamy sand, yellowish red (5 yr 4/6) moist; weakly cemented to single grain structure; slightly hard and nonsticky; few fine roots; pH 6.9; clear, smooth boundary.

C1 46-74 cm. Yellowish red (5 yr 5/7) loamy sand, yellowish red (5 yr 5/6) moist; weakly cemented to single grain structure; slightly hard and nonsticky; few fine roots; pH 7.0.

Soil Profile S10

Soil Classification: Arenic Aridic Haplustalfs
Location: 16° 04' N. Lat. and 13° 02' W. Long.
Physiography: Rolling uplands
Topography: Moderately sloping (6%) midslope of a uniform, medium-length slope with a west northwest aspect.
Vegetation: Nearly full cover of low grasses and trees, Combretum glutinosum, Commiphora africana, Guiera senegalensis, Eragrostis spp.
Date: 2/14/81
Remarks: Moderate erosion

A1 0-16 cm. Reddish brown (5 yr 5.5/3) sand, reddish brown (5 yr 4.5/3) moist; weakly cemented to single grain structure; soft and nonsticky; few and common fine roots and few medium roots; pH 8.4; clear, smooth boundary.

A21 16-39 cm. Light reddish brown (5 yr 6/4) sand, reddish brown (5 yr 4.5/4) moist; weakly cemented to single grain structure; soft and nonsticky; few fine roots; pH 4.5; gradual, smooth boundary.

A22 39-50 cm. Light reddish brown (5 yr 6/4) sand, reddish brown (5 yr 4.5/4) moist; weakly cemented to single grain structure; soft and nonsticky; few fine roots; pH 4.7; clear, smooth boundary.

B2t 50-90 cm. Reddish brown (5 yr 5.5/4) loamy sand, reddish brown (5 yr 4.5/4) moist; weak, coarse prismatic structure; slightly hard and slightly sticky; few very fine roots; pH 4.6.

Soil Profile S11

Classification: Arenic Aridic Haplustalf
Location: 15° 12' N. Lat. and 12° 11' W. Long.
Physiography: Uplands
Topography: Nearly level, rectilinear slope (2%), south aspect
Vegetation: Nearly full cover of grasses and trees, Combretum spp., Guiera senegalensis, Aristida spp.
Date: 2/14/81
Remarks: Site has evidence of recent burn (within 10 years). Moderate erosion with some hard, barren patches. Low pH may be biased due to type of test, i.e., 1:1 soil-water ratio and coarse textures. The pH tests were rechecked.

A11 0-13 cm. Yellowish red (5 yr 5/6) loamy sand, reddish brown (5 yr 4/4) moist; weakly cemented to single grain structure, weakly crusted; soft and nonsticky; few and common fine and medium roots; pH 4.8; clear, smooth boundary.

A12 13-26 cm. Yellowish red (5 yr 5/6) heavy loamy sand, yellowish red (5 yr 4/6) moist; weakly cemented to single grain structure; slightly hard and nonsticky; few and common fine and medium roots; pH 3.8; clear, smooth boundary.

B1 26-40 cm. Yellowish red (5 yr 5/6) light sandy loam with a few pebbles, yellowish red (5 yr 4/6) moist; weakly cemented to single grain structure; slightly hard and slightly sticky; few and common fine and medium roots; pH 4.0; clear, smooth boundary.

B2t 40-80 cm. Yellowish red (5 yr 5/8) sandy loam, yellowish red (5 yr 4/8) moist; massive to single grain structure; slightly hard and slightly sticky; few and common fine roots; pH 3.7; clear, smooth boundary.

C1 80-90 cm. Yellowish red (5 yr 5/8) loamy sand with small sandstone fragments, yellowish red (5 yr 4/8) moist; massive to single grain structure; soft and nonsticky; few fine roots; pH 4.4.

Soil Profile S12

Classification: Typic Ustropept
Location: 14° 59' N. Lat. and 12° 22' W. Long.
Physiography: Uplands (colluvial fan)
Topography: Toeslope of long, gentle slope. Nearly level (2%) with rectilinear shape and west aspect.

Vegetation: Nearly bare, Cenchrus spp. and Balanites aegyptiaca
Date: 2/14/81
Remarks: Landscape has loose, fixed sands (10-25 cm depth) in places. Barren, hard surface. While situated near a small stream, there is no evidence of deposition, only erosion. Truncated soil and a general, later covering of aeolian sand, which has been partially eroded.

B1 0-13 cm. Brown (7.5 yr 5/3) heavy loam, dark brown (7.5 yr 3/3) moist; strong coarse prismatic structure; hard and slightly sticky; few and common, very fine to medium roots; pH 5.3; clear, smooth boundary.

B2 13-23 cm. Brown (7.5 yr 5/5) sandy clay loam, dark brown (7.5 yr 4/4) moist; strong coarse prismatic; very hard and sticky; few to common very fine to medium roots; pH 4.9; clear, smooth boundary.

B3 23-43 cm. Strong brown (7.5 yr 5/6) clay loam, strong brown (7.5 yr 4/6) moist; massive structure; very hard and sticky; very few fine roots; pH 5.2; abrupt, clear boundary.

C1 43-63 cm. Reddish yellow (7.5 yr 6/6) light gravelly sandy clay loam; strong brown (7.5 yr 4/6) moist; massive structure; slightly hard and sticky; no roots; pH 4.8.

Soil Profile S13

Classification: Arenic Aridic Hapustalf
Location: 15° 05' N. Lat. and 12° 17' W. Long.
Physiography: Fixed sand dunes
Topography: Hummocky, medium length slopes, gently sloping (5%) midslope with west aspect.
Vegetation: Full cover of grasses and trees, sand grasses and Combretum spp.
Date: 2/17/81
Remarks: Excellent stand of grasses and trees, little livestock grazing. Most sand grains are quartz.

A11 0-19 cm. Brown (7.5 yr 5/4) fine sand, dark brown (7.5 yr 4/4) moist; single grain structure; soft and nonsticky; common, fine roots; pH 5.5; gradual, smooth boundary.

A12 19-35 cm. Brown (7.5 yr 5/5) fine sand, dark brown (7.5 yr 4/4) moist; single grain structure; soft and nonsticky; common, fine roots; pH 4.7; clear, smooth boundary.

B2t 35-49 cm. Reddish brown (5 yr 5/5) loamy fine sand, reddish brown (5 yr 4/4) moist; single grain structure; soft and nonsticky; common, fine roots; pH 4.4; clear smooth boundary.

B3 49-58 cm. Yellowish red (5 yr 5/6) fine sand, yellowish red (5 yr 4/6) moist; single grain structure; soft and nonsticky; common, fine roots; pH 4.7; gradual, smooth boundary.

C1 58-72 cm. Yellowish red (5 yr 5/6) fine sand, yellowish red (5 yr 4/6) moist; single grain structure; few, fine roots; pH 4.5.

Soil Profile S14

Soil Classification: Aridic Hapustalf
Location: 15° 15' N. Lat. and 12° 11' W. Long.
Physiography: Uplands (colluvial fan)
Topography: Nearly level (2%) rectilinear slope with south aspect
Vegetation: Nearly bare, few grasses and trees Balanites aegyptiaca
Date: 2/18/81
Remarks: Truncated soil profile, scattered gravel and cobbles on surface. Barren, hard surface. Transition between Aridisols and Alfisols.

B21t 0-17 cm. Reddish brown (5 yr 5/4) clay loam with reddish brown (5 yr 4/3) clayskins, reddish brown (5 yr 4/3) moist; strong, medium subangular blocky structure; very hard and sticky; common, fine and very fine roots; pH 6.4; abrupt, smooth boundary.

B22t 17-32 cm. Dark brown (7.5 yr 4/3) clay loam with few pebbles, dark brown (7.5 yr 3/3) moist; strong, medium subangular blocky structure; very hard and sticky; few and common, fine roots; pH 7.0; clear, smooth boundary.

B3 32-45 cm. Dark brown (7.5 yr 4/3) gravelly clay loam, dark brown (7.5 yr 3/3) moist; moderate, medium subangular blocky structure; very hard and sticky; very few, fine roots; pH 7.0.

Soil Profile S18

Classification: Ustic Torripsamment
Location: 15° 28' N. Lat. and 11° 46' W. Long.
Physiography: Fixed aeolian sands
Topography: Nearly level (2%) rectilinear slope, east aspect
Vegetation: Nearly full cover, grasses and few trees, Eragrostis spp., Cenchrus spp., few Baobob.
Date: 2/19/81
Remarks: Vegetation covering is good; scattered, small eroded areas with bare, hard surface. Two intermittent periods of sand deposition and reworking. Moisture at 100 cm. Gradation to Alfisol.

A11 0-15 cm. Brown (7.5 yr 5/4) fine sand, dark brown (7.5 yr 3/3) moist; weakly cemented single grain structure; soft and nonsticky; common fine roots; pH 5.8; gradual, smooth boundary.

A12 15-37 cm. Reddish brown (5 yr 5.5/4) fine sand, dark reddish brown (5 yr 3/4) moist; weakly cemented single grain structure; soft and nonsticky; few and common roots; pH 6.6; clear, smooth boundary.

A11b 37-50 cm. Yellowish red (5 yr 4/6) fine sand, yellowish red (5 yr 3/6) moist; weakly cemented to single grain structure; few and common roots; soft and nonsticky; pH 5.1; gradual, smooth boundary.

A12b 50-70 cm. Yellowish red (5 yr 5/6) fine sand, yellowish red (5 yr 4/6) moist; weakly cemented to single grain structure; soft and nonsticky; few and common fine roots; pH 5.3; gradual, smooth boundary.

C1 70-103 cm. Yellowish red (5 yr 5/7) fine sand, yellowish red (5 yr 4/7) moist; weakly cemented single grain structure; soft and nonsticky; no roots; pH 5.4.

Soil Profile S19

Classification: Aquic Haplustalf
Location: 15° 11' N. Lat. and 11° 56' W. Long.
Physiography: Old alluvium
Topography: Nearly level (1%) rectilinear slope with north aspect
Vegetation: Sparse cover of Cassia spp.
Date: 2/19/81
Remarks: Poorly drained

A1 0-12 cm. Brown (7.5 yr 5/4) loam, dark brown (7.5 yr 4/4) moist; weak fine platy structure; slightly hard and nonsticky; common, fine roots; pH 4.5; abrupt, smooth boundary.

B21t 12-28 cm. Reddish brown (5 yr 4/4) sandy clay loam with some gravel, dark reddish brown (5 yr 3/4) moist, few fine faint reddish yellow mottles (5 yr 4/8); moderate medium subangular blocky structure; very hard and sticky; few, fine roots; pH 5.7; clear, smooth boundary.

B22t 28-42 cm. Yellowish red (5 yr 4/6) clay loam; yellowish red (5 yr 3/6) moist; moderate medium subangular blocky structure; very hard and sticky; few, fine roots; pH 5.7.

PHYSICAL AND CHEMICAL PROPERTIES BRIEF SITE DESCRIPTIONS

Sample Number	Depth cm.	Textural Class	C.E.C. me/100g Soil	Buffer Extract. Acidity	Exchangeable $Ca^{++} + Mg^{++}$ me/100g Soil	Base Saturation %	pH 1:1 extract	E.C. mm hos/cm	Notes
						"C" SAMPLES			
C3	0-25	VFSCL grav.	11	4	7	64	7.5	0.4	6% CaCO3
C5	0-25	CL	8	0	8	100	5.5	1.0	
C6-1	0-8	L (shaly)	9	4	5	56	7.0	0.1	
C6-2	8-25	L (v.shaly)	-	-	-	-	5.3	0.3	
C8-1	0-5	VFSL	5	0	5	100	5.2	0.1	
C8-2	5-20	VFSCL	6	2	4	67	4.6	0.1	
C11-1	0-10	S	3	0	3	100	5.8	0.1	
C11-2	0-15	LFS	4	1	3	75	5.5	0.1	
C11-3	15-25	FSCL	11	3	8	72	5.7	0.4	
C12	0-15	CL (cobbly)	-	-	-	-	5.7	0.3	
C13-1	0-17	L (gravelly)	10	3	7	70	8.3	1.4	6% CaCO3,<10 Na
C13-2	17-30	SCL	10	4	6	60	8.3	4.6	10 me Na
						"B" SAMPLES			
B1-1	0-10	L	5	0	5	100	7.8	1.7	
B1-2	10-20	L	5	0	5	100	7.7	5.4	
B1-3	20-30	L	-	-	-	-	8.3	7.2	
B5-1	0-12	C	-	-	-	-	5.8	0.1	
B5-2	12-47	C	14	5	9	64	6.7	0.1	
B11-1	0-17	LFS	9	6	3	33	5.0	2.6	
B11-2	17-30	SL	12	0	12	100	6.8	1.0	
B11-3	30-49	S	4	0	4	100	7.3	0.3	
B11-4	49-68	S	-	-	-	-	7.7	0.3	
B15-1	0-14	CL-Heavy	18	7	11	61	5.7	0.9	
B15-2	14-22	CL-Heavy	10	0	10	100	6.7	2.0	
B15-3	22-42	SL	-	-	-	-	7.3	0.6	
B16	0-25	C	16	7	9	56	4.6	0.3	

PHYSICAL AND CHEMICAL PROPERTIES BRIEF SITE DESCRIPTIONS

Sample Number	Depth cm.	Textural Class	C.E.C. me/100g Soil	Buffer Extract. Acidity	Exchangeable $Ca^{++} + Mg^{++}$ me/100g Soil	Base Saturation %	pH 1:1 extract	E.C. mm hos/cm	Notes
					"K" SAMPLES				
K1-1	0-6	SL (heavy)	11	6	5	45	7.5	0.4	
K1-2	6-22	L (heavy)	9	2	7	78	5.8	0.1	
K1-3	22-35	SCL	13	7	6	54	5.8	0.1	
K2	0-15	FS	5	2	3	60	6.6	0.1	
K3	0-20	FS	4	1	3	75	6.7	0.1	
K4-1	0-25	C	32	7	25	78	7.6	0.2	
K4-2	25-50	C	52	9	43	83	8.0	0.2	
K4-3	50-75	C	49	7	42	86	8.0	0.1	
K6	0-15	CL	8	2	6	75	6.4	0.4	
K10	0-5	SL (gravelly)	6	3	3	50	5.4	0.1	
K13	0-10	L (gravelly)	8	6	2	25	5.0	0.1	
K17-1	0-10	SiL	9	3	6	67	7.5	0.4	
K17-2	10-15	SL	15	9	6	40	7.0	0.2	
K18	0-15	SIC	14	2	12	86	8.5	0.2	$CaCO_3$,>20%
K20	0-15	SCL	10	7	3	30	7.2	0.8	
K21-1	0-15	LFS	-	-	-	-	7.6	0.1	
K22-1	0-7	SL	9	3	6	67	6.7	0.1	
K22-2	7-15	SCL	6	3	3	50	6.5	0.4	
K23-1	0-13	CL	15	7	8	53	7.2	0.1	
K23-2	13-18	SCL	17	5	12	71	6.8	0.1	
K26	0-10	CL	18	9	9	50	5.6	0.1	
K27	0-15	SiCL	16	6	10	62	6.4	0.1	
					"R" SAMPLES				
R1-1	0-20	FS	4	0	4	100	7.4	0.2	
R1-2	20-40	FS	6	1	5	83	7.5	0.2	
R2	0-25	FSCL	8	2	6	75	7.4	8.4	
R3	0-15	C	13	6	7	54	4.6	0.3	
R4	0-25	SICL	12	5	7	58	5.6	5.0	
R5	0-25	CL (heavy)	15	5	10	67	4.8	>10.0	
R6	0-25	S	12	4	8	67	6.7	0.1	

PHYSICAL AND CHEMICAL PROPERTIES BRIEF SITE DESCRIPTIONS

Sample Number	Depth cm.	Textural Class	C.E.C. me/100g Soil	Buffer Extract. Acidity	Exchangeable $Ca^{++} + Mg^{++}$ me/100g Soil	Base Saturation %	pH 1:1 extract	E.C. mm hos/cm	Notes
						"S" SAMPLES			
S2	0-17	CL	15	6	9	60	6.7	0.1	
S5-1	0-13	SL	6	3	3	50	5.5	0.1	
S5-2	13-26	SL (gravelly)	4	1	3	75	5.6	0.1	
S9-1	0-15	L	3	0	3	100	5.7	0.1	
S9-2	15-30	CL (gravelly)	10	4	6	60	4.9	0.2	
S15-1	0-35	C	27	8	19	70	6.5	0.4	
S15-2	35-70	C	36	7	29	80	7.0	0.2	
S16	0-40	SICL	21	7	14	58	6.5	0.2	
S17-1	0-20	SIL	15	2	13	87	5.7	0.1	
S17-2	20-40	SIL	10	3	7	70	5.8	0.1	
S17-3	40-60	SIL	21	3	18	87	5.8	0.2	
S21-1	0-23	CL	20	8	12	60	5.3	0.1	
S21-2	23-40	CL	17	8	19	53	5.8	0.1	

PHYSICAL AND CHEMICAL PROPERTIES "C" SAMPLES

Sample Number	Horizon	Depth Cm.	Textural Class	Cation Exchange Capacity me/100 g Soil	Buffer Extractable Acidity	Exchangeable Bases, me/100 g Soil $Ca^{++} + Mg^{++}$	Base Saturation %	pH 1:1 Extract	Electrical Conductivity mm hos/cm.	Notes
C1 Typic Haplargid										M.U. BP2
	B1	0-15	CL (light)	-	-	-	-	7.2	0.1	
	B2tCa	15-34	CL	10	1	9	90	7.7	0.1	
	C1Ca	35-45	SCL	-	-	-	-	7.9	0.2	6% $CaCO_3$
C2 Typic Haplustalf										M.U. BL4 comp. 2
	A11	0-13	LFS	3	0	3	100	6.4	0.1	
	A12	13-29	SL	5	1	4	80	6.5	0.1	
	B1	29-43	FSL	6	2	4	67	6.9	0.1	
	B2t	43-65	SCL	8	3	5	62	6.9	0.2	
C4 Typic Haplustalf										M.U. AU1 comp. 2
	A1	0-19	FSL (light	3	0	3	100	4.9	0.1	
	B1	19-36	FSL (light)	-	-	-	-	4.5	0.1	
	B21t	36-49	FSL	7	1	6	86	4.7	0.1	
	B22t	49-63	FSL	6	1	5	83	4.9	0.1	
C7 Typic Haplustalf										M.U. AU4 comp. 1
	A1	0-10	CL (light gravelly)	9	2	7	78	6.7	0.1	
	B21t	10-30	CL (heavy gravelly)	9	2	7	78	7.8	0.1	6% $CaCO_3$; <10 me Na
	B22t	30-45	CL (heavy gravelly)	12	2	10	83	8.3	0.2	6% $CaCO_3$
C9 Vertic Eutrochrept										M.U. AU6 comp. 1
	Ap	0-17	SICL (heavy)	11	0	11	100	8.0	0.2	<10 me, Na
	B2	17-35	SIC	17	2	15	88	8.2	0.2	<10 me, Na
	C1Ca	35-55	SIC	13	1	12	92	8.4	0.2	10 me, Na

PHYSICAL AND CHEMICAL PROPERTIES "C" SAMPLES

Sample Number	Horizon	Depth Cm.	Textural Class	Cation Exchange Capacity me/100 g Soil	Buffer Extractable Acidity	Exchangeable Bases, me/100 g Soil $Ca^{++} + Mg^{++}$	Base Saturation %	pH 1:1 Extract	Electrical Conductivity mm hos/cm.	Notes
C10 Ustic Dystropept										M.U. C10 AU2 comp. 1
	A1	0-15	FSL	6	2	4	67	4.6	0.1	
	B1	15-25	VFSL	9	5	4	44	5.0	0.2	
	B2	25-36	FSL	6	2	4	67	5.1	0.2	
	C1	36-60	FSL	5	2	3	60	4.9	0.2	

PHYSICAL AND CHEMICAL PROPERTIES "S" SAMPLES

Sample Number	Horizon	Depth Cm.	Textural Class	Cation Exchange Capacity me/100 g Soil	Buffer Extractable Acidity	Exchangeable Bases, me/100 g Soil $Ca^{++} + Mg^{++}$	Base Saturation %	pH 1:1 Extract	Electrical Conductivity mm hos/cm.	Notes
S4 Mollic Torrert										
	A11	0-3	C (light)	24	7	17	71	6.7	0.2	
	A12	3-15	C (light)	19	8	11	58	7.0	0.2	
	AC	15-50	C (light)	14	5	9	64	7.3	0.1	
	C1	50-70	C (light)	19	8	11	58	7.2	0.1	
S6 Fluventic Camborthid										
	Ap	0-23	SL	8	1	7	88	6.8	0.1	
	B21	23-57	SL	4	1	3	75	6.7	0.1	
	B22	57-77	SCL (light)	11	5	6	54	6.9	0.1	
S7 Ustalfic Haplargid										M.U. BU8
	A1	0-15	LS	4	1	3	75	5.5	0.1	
	B21t	15-40	SL	7	1	6	86	7.2	0.8	
	B22t	40-55	SL	13	6	7	54	8.1	1.1	
S8 Ustochreptic Camborthid										M.U. BU8
	A11	0-19	LS	7	3	4	57	6.2	1.4	
	A12	19-32	LS	6	3	3	50	6.1	0.1	
	B2	32-66	LS	7	3	4	57	6.9	0.1	
	C1	66-76	LS	5	2	3	60	7.0	0.1	

PHYSICAL AND CHEMICAL PROPERTIES "S" SAMPLES

Sample Number	Horizon	Depth Cm.	Textural Class	Cation Exchange Capacity me/100 g Soil	Buffer Extractable Acidity	Exchangeable Bases, me/100 g Soil $Ca^{++} + Mg^{++}$	Base Saturation %	pH 1:1 Extract	Electrical Conductivity mm hos/cm.	Notes
S10	Arenic Aridic Haplustalf									M.U. BU6
	A1	0-16	S	6	3	3	50	6.8	0.2	
	A21	16-39	S	2	0	2	100	4.5	0.1	
	A22	39-50	S	5	2	3	60	4.7	0.1	
	B2t	50-90	LS	4	1	3	75	4.6	0.1	
S11	Arenic Aridic Haplustalf									M.U. BU4 comp. 1
	A11	0-13	LS	3	1	2	67	4.8	0.1	
	A12	13-26	LS (heavy)	4	2	2	50	3.9	0.1	
	B1	26-40	SL (light)	5	2	3	60	4.0	0.1	
	B2t	40-80	SL	7	3	4	57	4.0	0.1	
	C1	80-90	LS	5	2	3	60	4.4	0.1	
S12	Typic Ustropept									
	B1	0-13	L (heavy)	11	4	7	63	5.3	0.6	
	B1	13-23	SCL	12	4	8	67	4.9	0.1	
	B2t	23-43	CL	9	4	5	56	5.2	0.2	
	B3	43-63	SCL (light gravelly)	9	3	6	67	4.8	0.1	
S13	Arenic Aridic Haplustalf									M.U. AE1
	A11	0-19	FS	3	1	2	67	5.5	0.1	
	A12	19-35	FS	5	3	2	40	4.7	0.1	1 neutral salt extractable acidity
	B2t	35-49	LFS	3	1	2	67	4.4	0.1	
	B3	49-58	FS	6	3	3	50	4.7	0.1	1 neutral salt extractable acidity
	C1	58-72	FS	7	4	3	43	4.5	0.1	1 neutral salt extractable acidity

PHYSICAL AND CHEMICAL PROPERTIES "S" SAMPLES

Sample Number	Horizon	Depth Cm.	Textural Class	Cation Exchange Capacity me/100 g Soil	Buffer Extractable Acidity	Exchangeable Bases, me/100 g Soil $Ca^{++} + Mg^{++}$	Base Saturation %	pH 1:1 Extract	Electrical Conductivity mm hos/cm.	Notes
S14 Aridic Haplustalf										M.U. AU3 comp. 1
	B21t	0-17	CL	20	5	15	75	6.4	0.4	
	B22t	17-32	CL	26	6	20	77	7.0	0.4	
	B3	32-65	CL (gravelly)	17	7	10	59	7.0	0.1	
S18 Ustic Torripsamment										
	A11	0-15	FS	3	1	2	66	5.8	0.1	
	A12	15-37	FS	4	1	3	75	6.6	0.1	
	A11b	37-50	FS	4	1	3	75	5.1	0.1	
	A12b	50-70	FS	5	2	3	60	5.3	0.1	
	C1	70-103	FS	-6	2	4	67	5.4	0.1	
S19 Aquic Haplustalf										M.U. AU5
	A1	0-12	L	8	3	5	62	5.0	0.1	
	B21t	12-28	SCL	13	4	9	69	5.7	0.1	1 neutral salt extractable acidity
	B22t	28-62	CL	10	2	8	80	5.7	0.1	1 neutral salt extractable acidity

PHYSICAL AND CHEMICAL PROPERTIES "B" SAMPLES

B2 Typic Torripsamment										M.U. C1E9
	C1	0-26	FS	3	0	3	100	7.8		
	A1	26-57	FS	3	0	3	100	7.4		
	C2	57-80	FS	-	-	-	-	7.4		
	C4	80-120	FS	3	0	3	100	7.6		

PHYSICAL AND CHEMICAL PROPERTIES "B" SAMPLES

Sample Number	Horizon	Depth Cm.	Textural Class	Cation Exchange Capacity me/100 g Soil	Buffer Extractable Acidity	Exchangeable Bases, me/100 g Soil $Ca^{++} + Mg^{++}$	Base Saturation %	pH 1:1 Extract	Electrical Conductivity mm hos/cm.	Notes
B3 Typic Torripsamment										
	A1	0-45	FS	4	1	3	75	7.4	0.1	
	AC	45-73	FS	6	2	4	67	6.9	0.1	
	C1	73-95	FS	5	2	3	60	7.5	0.1	5% $CaCO_3$
B4 Ustollic Camborthid										
	A11	0-23	LFS	4	1	3	75	7.0	0.1	
	A12	23-45	FSCL	15	2	13	87	7.4	0.2	
	B2	45-75	SCL (light)	18	3	15	83	7.0	0.2	
	C1	75-90	SL (light gravelly)	4	0	4	100	7.8	0.2	6% $CaCO_3$
B6 Typic Camborthid										M.U. BU9
	A1	0-11	CL	10	0	10	100	6.0	0.1	
	B2	11-18	SICL	6	1	5	83	6.5	0.1	
	B3ca	18-45	CL	10	3	7	70	7.8	0.1	6% $CaCO_3$
	C1ca	45-57	CL (gravelly)	13	2	11	85	8.0	0.1	6% $CaCO_3$
B7 Vertic Haplargid										
	A1	0-19	CL	8	2	6	75	6.9	0.1	
	B21tca	19-33	CL (heavy)	5	0	5	100	7.8	0.1	6% $CaCO_3$
	B22tca	33-40	CL (heavy)	19	4	15	79	7.6	0.1	6% $CaCO_3$
B8 Ustic Torripsamment										M.U. BE15
	A11	0-10	FS	4	0	4	100	7.0	0.1	
	A12	10-40	FS	3	0	3	100	5.5	0.1	
	AC	40-57	FS	9	4	5	56	5.7	0.3	
	C1	57-97	FS	3	0	3	100	6	0.3	

PHYSICAL AND CHEMICAL PROPERTIES "B" SAMPLES

Sample Number	Horizon	Depth Cm.	Textural Class	Cation Exchange Capacity me/100 g Soil	Buffer Extractable Acidity	Exchangeable Bases, me/100 g Soil $Ca^{++} + Mg^{++}$	Base Saturation %	pH 1:1 Extract	Electrical Conductivity mm hos/cm.	Notes
B9 Ustollic Haplargid										
	A1	0-27	L	11	2	9	82	7.8	0.2	8% $CaCO_3$
	B2t	27-37	CL	9	2	7	78	7.8	0.2	12% $CaCO_3$
	B3ca	37-57	L	18	8	10	56	7.8	0.4	>20% $CaCO_3$
B10 Ustertic Haplargid										
	A1	0-13	SCL	12	5	7	58	5.8	1.8	
	B1	13-24	SL (heavy)	11	2	9	82	6.2	0.3	
	B2t	24-45	SCL	19	4	15	79	6.2	0.3	
	C1	45-65	SL	6	1	5	83	6.7	0.1	
B12 Cumulic Haplustoll										M.U. BE18 Minor soil
	A11	0-3	LFS	6	1	5	83	6.2	0.1	
	A12	23-37	LFS	7	1	6	86	6.5	0.1	
	AC	37-62	LFS	8	2	6	75	6.6	0.4	
	C1	62-104	LFS (heavy)	11	3	8	73	6.7	2.2	
B13 Ustic Torripsamment										M.U. BE18 comp. 2
	C1	0-8	FS	7	4	3	43	7.3	0.2	
	C2	8-65	FS	6	1	5	83	7.2	0.1	
	C3	65-85	FS	6	1	5	83	7.2	0.1	
B14 Typic Natrargid										
	A1	0-11	LS	3	0	3	100	7.4	0.2	
	B21t	11-22	CL	7	2	5	71	7.3	1.6	
	B22tca	22-50	SCL (heavy)	13	7	6	46	8.5	2.0	80 me Na

PHYSICAL AND CHEMICAL PROPERTIES "K" SAMPLES

Sample Number	Horizon	Depth Cm.	Textural Class	Cation Exchange Capacity me/100 g Soil	Buffer Extractable Acidity	Exchangeable Bases, me/100 g Soil $Ca^{++} + Mg^{++}$	Base Saturation %	pH 1:1 Extract	Electrical Conductivity mm hos/cm.	Notes
K5	Ustic Torripsamment									M.U. BE6
	A1	0-10	LFS	12	8	4	33	6.8	0.1	
	AC	10-30	FS	4	2	2	50	7.0	0.1	
	C1	30-50	FS	4	2	2	50	7.0	0.1	
K7	Ustic Torripsamment									
	A11	0-5	S	6	4	2	33	7.5	0.1	
	A12	5-28	LS	9	1	3	75	6.7	0.1	
	AC	28-40	LS	4	1	3	75	6.8	0.1	
	C1	40-60	LS	8	5	3	22	6.5	0.1	
K9	Ustic Torripsamment									
	A11	0-5	LFS	3	1	2	66	6.0	0.1	
	A12	5-25	LFS	5	2	3	60	6.0	0.1	
	C1	25-40	LFS	3	1	2	67	5.9	0.1	
K11	Aridic Haplustalf									
	A11	0-14	LS	5	3	2	40	5.8	0.1	
	A12	14-26	LFS	9	5	4	44	4.9	0.1	
	B2t	26-50	SL	4	0	4	100	5.8	0.1	
	IIC1	50-70	SL	5	0	5	100	6.0	0.1	
K14	Ustic Torripsamment									M.U. BE2
	A11	0-11	FS	8	5	3	38	6.0	0.1	
	A12	11-21	FS	4	2	2	50	6.4	0.1	
	A3	21-50	FS	7	2	5	71	7.0	0.1	
K15	Typic Torrifluvent									M.U. BE5
	A11	0-15	FS	8	4	4	50	7.3	0.1	
	A12	15-30	FS	3	0	3	100	7.4	0.1	
	C1	30-46	FS	4	1	3	75	7.4	0.1	

PHYSICAL AND CHEMICAL PROPERTIES "K" SAMPLES

Sample Number	Horizon	Depth Cm.	Textural Class	Cation Exchange Capacity me/100 g Soil	Buffer Extractable Acidity	Exchangeable Bases, me/100 g Soil $Ca^{++} + Mg^{++}$	Base Saturation %	pH 1:1 Extract	Electrical Conductivity mm hos/cm.	Notes
K16 Typic Torrifluvent										
	C1	0-5	S	4	1	3	75	7.5	0.1	
	C11	5-24	S	4	1	3	75	7.5	0.1	
	C111	24.50	S	-	9	5	35	7.5	0.1	
K19 Typic Torripsamment										M.U. BE11 comp. 1
	C1	0-15	FS	3	0	3	100	7.5	0.1	
	C11	15-30	FS	4	2	2	50	7.6	0.1	

Appendix D

Taxonomic considerations and correlation among USDA, French, and FAO classification

SOIL TAXONOMY

Six soil orders are represented in the study area. Entisols, Aridisols and Alfisols are the most common. There are 12 Entisol profiles, and 10 each of Aridisols and Alfisols. Three profiles represent the Inceptisol order while the Vertisols and Mollisols are each represented by one profile.

ENTISOLS

The central concept of Entisols is that of soils that have little or no evidence of development of pedogenic horizons. The main reason for lack of horizons in the Entisol soils of the study area is the extreme sandiness of the parent materials. The materials essentially are inert and there is no release of elements essential for horizon development. Ten of the 12 profiles studied fall into this sandy grouping called psamments. The remaining two Entisols occur on flood plains that receive new deposits at frequent intervals. This frequent deposition precludes the development of pedogenic horizons.

Profiles K5, K7, K9, K14, S18, B8, B13, K19, B2 and B3 all lack the poor drainage conditions of Aquents, or lack the presence of fragments of diagnostic horizons of Arents and thus fall into the suborder of Psamments. These soils are loamy fine sand or coarser. Two profiles, K15 and K16 are finer in texture and have colors that indicate that organic matter contents decrease irregularly. They thus fall into the suborder of Fluvents.

The psamments of the study area have a hot and dry climate thus fall into the Great Group of Torripsamments. These are sands of arid climates, many are in dunes, some stabilized, some moving. The central concept of Torripsamments is of soils having little available water for plant growth, that lack evident cementation by silica, and have a moderately thick or thick regolith. Three profiles fit this subgroup called Typic Torripsamment - K19, B2 and B3.

The remaining profiles - K5, K7, K9, K14, S18, B8 and B13 all have a moisture regime bordering on Ustic. This is indicated by the darker colors due to slightly higher organic matter contents. The subgroup classification for these profiles is Ustic Torripsamment.

The two profiles classified as Fluvents (K15 and K16) also have a Torric moisture regime and thus are classified as Torrifluvents. The central concept of this great group lacks any cementation by silica and also lacks deep wide cracks. The concept is of the drier part of the range of Torrifluvents. Profiles K15 and K16 appear to fall into the central concept and thus are classified in the subgroup Typic Torrifluvents.

ARIDISOLS

Aridisols are soils that do not have water available for mesophytic plants for most of the time the soil is warm enough for plant growth. This moisture regime is called aridic and characterizes the Aridisol order. However, even though Aridisols are deficient in water for plant growth, they may have one or more pedogenic soil horizons. These may include ochric, cambic, argillic or natric horizons. These horizons may be relic from past, more humid climates.

Two suborders occur with Aridisols. Argids have argillic or natric horizons while orthids lack either of these horizons. Samples C1, S7, B7, B9 and B10 all have argillic horizons while B14 has a natric horizon. Thus these 6 profiles all are Argids. Profiles S6, S8, B4 and B6 all lack argillic or natric horizons, thus are orthids.

One of the profiles (B14) which has a natric horizon is placed with the Natrargids. The remaining Argids lack a duripan and the clay necessary to be Paleargids and so are classified as Haplargids.

The central concept of Haplargids is centered upon soils with no ground water within one meter. They lack much cementation by silica, have little organic matter or available moisture, and have little evidence of soil movement. This concept reflects the driest part of the range of moisture content in Haplargids. Profile C1 fits this concept. Several profiles show by evidence of having darker colors that they have a moisture regime bordering on Ustic. Profile S7 is classified as a Ustalfic Haplargid and B9 as a Ustollic Haplargid. Profile B10 shows evidence both of a more moist regime than aridic and finer textures than typical so is classified as a Ustertic Haplargid. Profile B7 has cracks present with 18 cm spacing that are 40 cm deep and 2 cm wide at the surface. This evidence places this profile in the Vertic Haplargid subgroup.

The remaining Argid, profile B14, has a natric horizon thus is classified as a Natrargid. The profile is considered to represent the central concept so is classified as a Typic Natrargid.

The Orthids represented in the study area lack salic horizons, petrocalcic horizons, duripans, gypsic or petrogypsic horizons or calcic horizons. They do, however, have cambic horizons so they are classified as Camborthids. Profile B6 represents the central concept so is classified as a Typic Camborthid. Profile S6 resembles typic except that the dark colors decrease irregularly. Thus it is classified as a Fluventic Camborthid. Profile B4 has darker colors at the surface indicating more organic matter than typic so is classified in the Ustollic Camborthid subgroup. Profile S8 has a moisture regime marginal to Ustic so is classified in the Ustochreptic Camborthid subgroup.

ALFISOLS

The central concept of Alfisols is that of a soil that has an ochric epipedon, an argillic horizon, moderate to high base saturation, and in which there is some available water each year for plant growth. Where the soil temperature is thermic or warmer the Alfisols tend to form a belt between the Aridisols of arid regions and the Inceptisols, Ultisols and Oxisols of warm humid regions.

The Alfisols of the study area have argillic horizons, a high base saturation, and a Ustic moisture regime. They thus fall in the suborder Ustalf. They lack duripans, plinthite, natric horizons, lithic or paralithic contacts, and red hues, thus they fall in the Great Group Haplustalf. None of the soils appear to be in the typic subgroup. Profiles S10, S11, S13, S18, and S19 are Arenic Aridic Haplustalfs since they are coarser than loamy fine sand and are drier than the limits set for typic. Profiles S14 and K11 are Aridic Haplustalfs because they are drier than the limits set for typic.

INCEPTISOLS

The central concept of Inceptisols is that of soils of humid regions that have altered horizons that have lost bases or iron or aluminum but retain some weatherable minerals. Only the most humid region of the study area - Soil Region A - has Inceptisols present. They have ochric epipedons and cambic horizons. They lack aquic moisture regimes, volcanic ash and have isohyperthermic temperature regimes. With these characteristics they fall into the suborder Tropepts. Since they have a Ustic moisture regime and one profile is rich in bases it falls in the great group Eutropept. The central concept of Eutropepts is fixed on

freely drained soils that have high base saturation and that are rarely dry for long periods of time. Profile C9 has a clayey texture, cracks and slickensides which is evidence that it is in the Vertic Eutropept subgroup. Profile C10 is acidic with low base saturation; it therefore falls into the Great Group Dystropept. Since profile C10 has a ustic rather than udic moisture regime, its subgroup is Ustic Dystropept.

VERTISOLS

The central concept of Vertisols is that of clayey soils that have deep wide cracks sometime during the year and have high bulk densities between the cracks. Most Vertisols occur in temperature regimes that are thermic or warmer. Generally Vertisols have gilgai and/or slickensides.

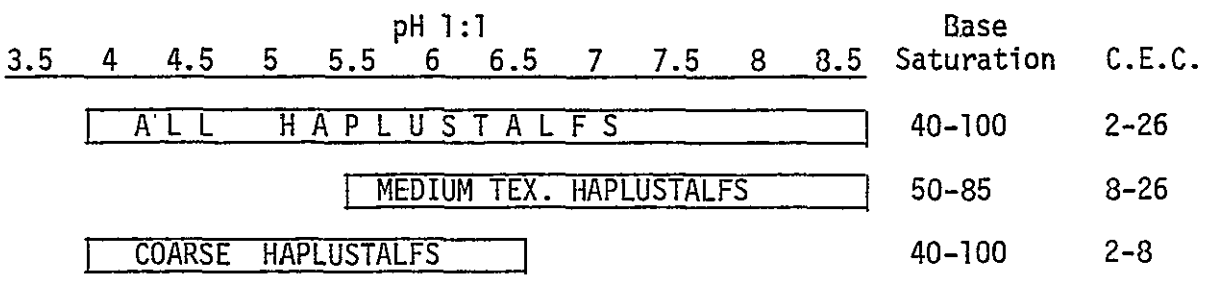
The Vertisol of the study area occurs in a dry and very warm climate thus should be classified in the Torrert suborder. There are no subdivisions of Torrerts at the Great Group level. Profile S4 has a color value moist of 4 in the surface horizon and thus qualifies as a Typic Torrert.

MOLLISOLS

Mollisols are mainly dark-colored, base-rich soils of the steppes. Mollisols generally lie between Aridisols and soils such as Alfisols of more humid climates. Mollisols may have any defined moisture and temperature regime but enough available moisture to support perennial grasses seems to be essential. One profile (B12) from the study area appears to have the characteristics necessary for classification into the Mollisol order. This profile has dark colors, high base saturation and sufficient depth to have a mollic epipedon. It lacks an albic horizon, and aquic moisture regime, high lime parent materials but it has an aridic moisture regime that borders on Ustic. Thus it is classified as in the Ustoll suborder.

The soil lacks a duripan, a natric horizon, a petroclacic horizon, a calcic horizon, an argillic horizon and evidence of worm activity. The profile occurs in landscape positions that receive runoff. The profile resembles typic except that the dark colored surface is thicker than the central concept so the profile is placed in the Cumulic Haplustoll subgroup.

DISCUSSION OF PROFILE DATA



HAPLUSTALFS

The Haplustalfs were sampled in the Guidimaka and southern Gorgol Regions. The soils as a group have pH ranges from 3.9 to 8.5, base saturation ranges from 40 to 100 and C.E.C. ranges of 2-26 me/100 g. soil.

The medium-textured Haplustalfs have pH ranges from 5.5 to 8.5; somewhat higher than the coarse-textured Haplustalfs which have pH ranges of 3.9 to 6.5. The medium textured Haplustalfs have a narrower range in base saturation and a wider range in C.E.C. than the coarse-textured Haplustalfs.

CAMBORTHIDS

	pH	Base Saturation	C.E.C.
'B' Samples	6.8-7.8	70-100	4-18
'S' Samples (Profile S8)	6.0-7.0	50-90	5-11

The Camborthids were sampled in the Brakna and Gorgol Regions. The Soil Profile S8 Camborthid is more acidic, has a lower base saturation and lower C.E.C.'s than the profiles from the B Samples. These data all point to a more humid climate in this area.

HAPLARGIDS

	pH	Base Saturation	C.E.C.
'B' Samples	5.8-8.0	60-100	6-19

The Haplargids were sampled in the Gorgol and Brakna Regions. Their data spanned the range of the Camborthid data. In pH, base saturation and C.E.C. the Haplargids and Camborthids appear similar.

TORRIPSAMMENTS

	pH	Base Saturation	C.E.C.
'K' Samples	5.0-7.5	20-75	3-12
'B' Samples	5.5-7.8	45-100	3-9

The Torripsamments were sampled in the Assaba, Brakna, and Trarza Regions. The Assaba Region soils are slightly more acidic and have lower base saturations than the soils of the Brakna and Trarza Region. The soils from the two areas appear similar in C.E.C.

INCEPTISOLS

	pH	Base Saturation	C.E.C.	
'S' Samples	4.5-5.2	44-67	5-12	Ustropept, Dystropept
	8.0-8.5	88-100	11-17	Eutrochrept

The Ustropept and Dystropept sampled both were acidic, had base saturations near 50% and had C.E.C.s from 5-12 me/100g of soil. The Eutrochrept, by contrast was alkaline, had high base saturations and C.E.C.'s from 11-17 me/100g soil.

HAPLUSTOLL

	pH	Base Saturation	C.E.C.
Trarza Region (B12 Profile)	6.2-6.7	73-86	6-11

The single Haplustoll was sampled south of Mederdra. In chemical makeup it resembles the Camborthids of the Gorgol Region. It is a loamy fine sand in texture, however, rather than the finer textures of the Camborthids.

APPROXIMATE EQUIVALENTS IN OTHER TAXONOMIES

Comprehensive System USA	France	FAO
Psamments	Sols mineraux bruts	Arenosols
Fluvents	Sols mineraux d'apport alluvial	Fluvisols
Argids	Sols bruts xeriques morganisés	Yermosols
Natrargids	Solonetz solodisés	Orthic solonetz
Camborthids	Sols bruns subarides	Haplic xerosols
Haplustalfs	Sols bruns eutrophes	Calcic Luvisols
Dystrochrepts	Sols bruns acides	Dystric Cambisols
Vertisols	Vertisols	Vertisols
Haplustoll	Sols châtains modaux	Haplic Kastanozems