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AGRO-ECOLOGICAL ZONATION STUDY

NIAMEY DEPARTMENT, NIGER

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1.0 EXECUTIVE SUMMARY

Background

The Niamey Department Development (NDD) Project is an integrated rural development project which has been promoting the acceptance and utilization of a set of non-traditional farming techniques by the subsistence level farmers in the Say, Kolo, Ouallam, and Filingue Arrondissements of the Niamey Department of the Republic of Niger. The technical packaage being extended includes the use of animal traction for plowing and weeding and for ox-drawn carts, the use of chemical fertilizers, varietal selection, seed treatment, thinning, etc. Widespread adoption of the new techniques has not taken place. Recent evaluation of the NDD have questioned the appropriateness of the single technical package as a uniform response to the variety of agro-ecological and socio-economic conditions which exist within the Niamey Department. The need to diversify the technical package, adapting it to local conditions, is generally well accepted both at the project and at higher policy levels. A division of the Department into relatively homogeneous management units is necessary before a rational program of diversification can be effectively planned and implemented.

The specific terms of reference for the agro-ecological zonation study of the Niamey Department state the two major objectives as follows:

1) Permit a diversification of agricultural technical packages for extension in homogeneous farming sub-regions of the Niamey Department. These subzones will be delimited by taking into consideration ecological, agro-climatological, social and economic factors.

2) Assure the selection of village test sites representing typical situations to respond to the priority problems encountered in the agro-pastoral production systems throughout the Department. These villages will then serve as the framework for integrated development activities carried out in the farming district and in close collaboration with the village development committees (CVD).

Accomplishments

The zonation team conceived its role as an interdisciplinary effort to look at the Department's agriculture anew, to evaluate not the project but the project zone.

Rainfall and soil are the two natural factors which most strongly determine the agricultural potential of lands in the Niamey Department, and they form the basis of the agro-ecological zonation. Good socio-economic data on the farming systems of the Department are scanty and do not lend themselves to accurate map portrayal. The farming systems are analyzed in this report by agro-ecological zone.

The Niamey Department was divided into three agroclimatic zones based on rainfall averages over the last 17 years. The agroclimatic zones were then divided into geomorphic subzones of generally homogeneous agro-sylvopastoral potential. The subzones are further subdivided into landscape units with characteristic soil types and toposequences. Each landscape unit has the same general use and management potential for rainfed agriculture. The zones and subzones are shown in Figure 1.

The rainfall regime since 1968 has been markedly different from that of the past 50 years. Rainfall data for 1968-84 were analyzed to define the three agroclimatic zones. The Pastoral Zone, which lies north of the 350 mm isohyet, is unsuited for traditional rainfed agriculture. The Intermediate Zone lies between the 350 mm isohyet and the isoline of 80% probability of having at least 350 mm of rain in a given year. Rainfall is commonly a significant limiting factor to agricultural production. The Intermediate Zone has marginal potential for intensification of rainfed agriculture. In the Agricultural Zone, rainfall is generally adequate. This zone is the best suited for intensification of rainfed agriculture aimed at increasing production.

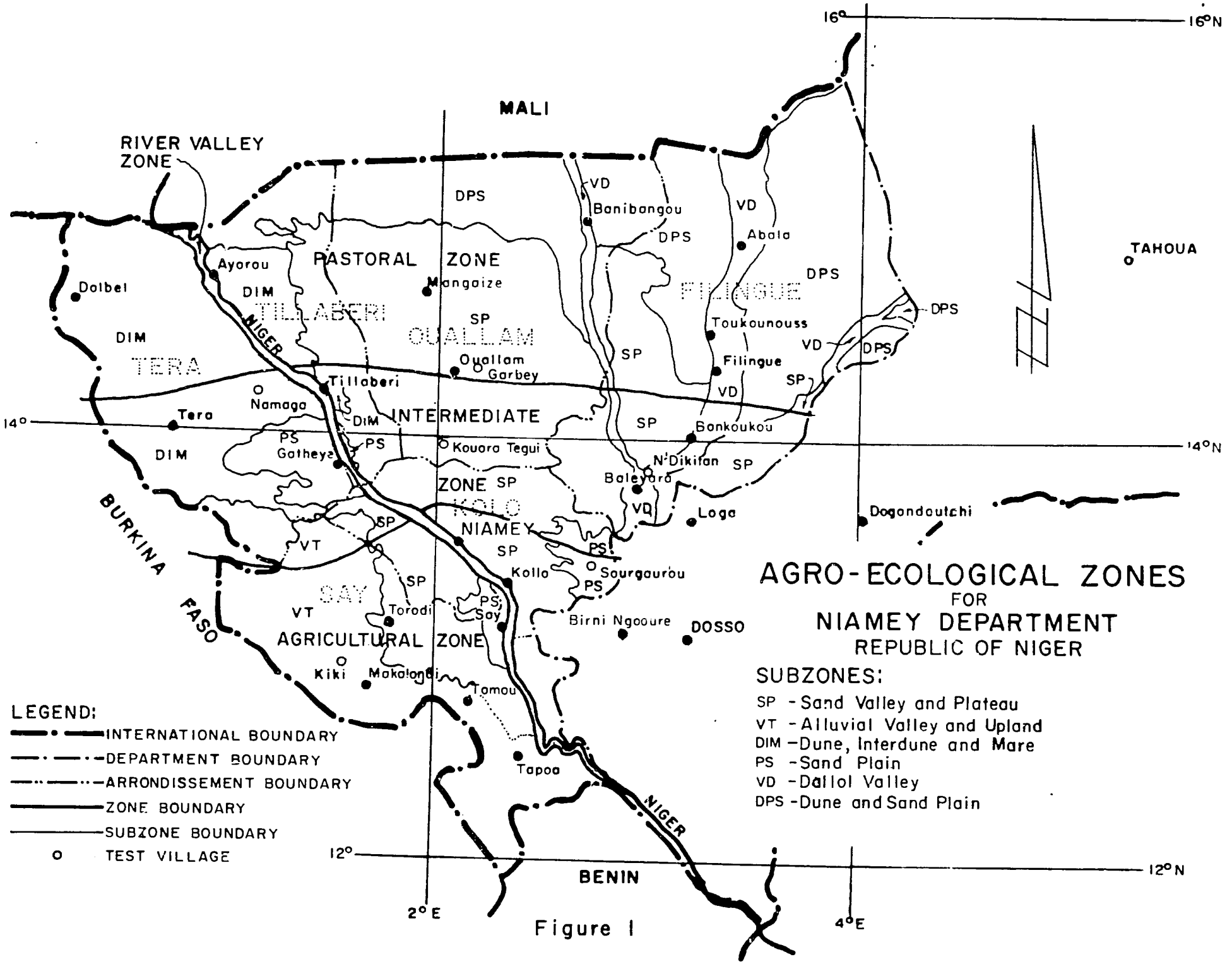

AGRO-ECOLOGICAL ZONES
FOR
NIAMEY DEPARTMENT
REPUBLIC OF NIGER
SUBZONES:
SP - Sand Valley and Plateau
VT - Alluvial Valley and Upland
DIM - Dune, Interdune and Mare
PS - Sand Plain
VD - Dallol Valley
DPS - Dune and Sand Plain
LEGEND:
INTERNATIONAL BOUNDARY
DEPARTMENT BOUNDARY
ARRONDISSEMENT BOUNDARY
ZONE BOUNDARY
SUBZONE BOUNDARY
TEST VILLAGE
MALI
BURKINA FASO
BENIN
TAHOUA
RIVER VALLEY ZONE
PASTORAL ZONE
TILLABERI
OUALLAM
TERA
INTERMEDIATE ZONE
KOLO
NIAMEY
SAY
AGRICULTURAL ZONE
FILINGUE
NIGER
Dolbel
Ayorou
Mangaize
Banibangou
Abala
Toukounouss
Filingue
Ouallam
Garbey
Tillaberi
Namaga
Tera
Gatheye
Kouoro Tegui
Bonkoukou
N'Dikifan
Baleyara
Loga
Dogondoutchi
Kollo
Sourgaurou
Torodi
Say
Birni Ngooure
DOSSO
Kiki
Makalondi
Tomou
Tapoa
16°
16°N
14°
14°N
12°
12°N
2° E
4° E

Figure I

The geomorphic subzones and landscape units were delineated from 1:200,000 scale, computer enhanced, color composite Landsat images. Soils differences, as correlated in the field with the geomorphology, were the main criteria used in defining the subzones and landscape units.

Table 1 summarizes the suitability of the zones, subzones and landscape units for rainfed agriculture.

Individual agro-ecological zonation maps were prepared for each of the Department's six arrondissements. Areas of high and medium dry season gardening potential as interpreted from the imagery are located on these maps. A single color map of the entire Department was prepared at 1:500,000 scale.

Six test villages (see Figure 1) representative of the major subzone were selected. The criteria for village selection were defined in collaboration with the NDD staff to insure that the test villages would be suitable sites for NDD to work in. The test villages should serve as centers at which the NDD and/or others can work towards developing technical packages appropriate for the local conditions in each subzone.

A detailed soils map covering four square kilometers was compiled for each test village using aerial photographs. Thirty-one individual soil map units were identified. Use and management recommendations were prepared for each zone, subzone, landscape unit, soils series (type), and test village.

A socio-economic analysis of the farming systems of the Niamey Department was done by agro-ecological zone and subzone. Each subzone is characterized by the cultural groups which inhabit the area, the production techniques they employ and the environmental limitations relative to these techniques. In general, differences in farming systems correlate well with the major zones and subzones.

TABLE 1: Suitability of the Agro-Ecological Zones for Rainfed Agriculture.

ZONE, SUBZONE, and Landscape Unit	Suitability
AGRICULTURAL ZONE	Well Suited
ALLUVIAL VALLEY AND UPLAND	
Alluvial Valley	Well Suited
Upland	Generally Unsuited
SAND VALLEY AND PLATEAU	
Sand Valley	Well Suited
Plateau	Generally Unsuited
SAND PLAIN	Well Suited
INTERMEDIATE ZONE	Suited
ALLUVIAL VALLEY AND UPLAND	
Alluvial Valley	Well Suited
Upland	Generally Unsuited
SAND VALLEY AND PLATEAU	
Sand Valley	Suited
Plateau	Unsuited
Dune	Suited
Broad Valley Flat	Poorly Suited
SAND PLAIN	Suited
DALLOL VALLEY	Suited
DUNE, INTERDUNE AND MARE	
Dune	Suited
Interdune	Poorly Suited
Outcrop	Unsuited
Mare	Well suited for dry season gardens
PASTORAL ZONE	Poorly Suited
RIVER VALLEY ZONE	Well Suited for Irrigation

Climatic change and population growth are altering the farming systems of the Department. The associated constraints include limited land availability, shortened fallows, declining soil fertility, deterioration of the vegetation, overgrazing, animal mortality and loss of organic fertilizers, increased erosion, and reduced productive potential. The possibilities for agricultural development are directly affected.

Major Findings and Recommendations

1) The agro-ecological zonation of the Department, the use and management recommendations for different soil types, the analysis of the farming systems by subzone and the representative test villages selected should provide a sound basis for the diversification of agricultural technical packages for homogeneous sub-regions of the Niamey Department.

2) All of the soils sampled and analyzed in the course of the study were deficient in phosphorus. The use of phosphate fertilizer could be a key factor in increasing agricultural productivity in the Niamey Department.

3) Most of the Niamey Department is characterized by accelerated soil erosion. Water and wind erosion have already significantly reduced the productive potential of much of the agricultural and sylvo-pastoral lands in the Department. The present technical package does not address this problem in any significant way. Soil and water conservation measures outlined in this report should be integrated into the new technical packages to be developed. These techniques include minimum tillage, grassed waterways, leaving crop residues on fields after harvest, strip cropping, contour farming, water capture techniques, and windbreaks.

4) About 70% of the soils suited for rainfed agriculture in the Intermediate and Agricultural Zones are sandy soils on which millet is the principal crop. Of these millet soils, about 70% are very sandy soils with well-graded soil particles. These soils are susceptible to compaction and may form plowpans under repeated plowing (over 10 centimeters deep). The use of animal traction for tillage should be discontinued on such soils as identified in this report.

5) The marginal and variable rainfall of the Intermediate Zone limits its potential for intensification of rainfed agriculture. In this zone the NDD should shift from an overall emphasis of increasing productivity to one of insuring productivity. Project efforts aimed primarily at agricultural intensification and productivity increases should be concentrated on suitable sites in the Agricultural Zone.

6) Considerable potential exists in the Niamey Department for the further development of dry season gardening. Sites that appear suitable have been identified on the zonation maps. Emphasis on the development of dry season gardening should be placed on the Pastoral and Intermediate Zones. It could become a critical means of alleviating or overcoming food deficits from rainfed agriculture.

7) The use of simple, hand constructed water catchments (contour terraces, microcatchments, tied ridges, etc.) may be an effective means of reducing soil moisture deficits and erosion, particularly in the Intermediate and southern Pastoral Zones.

2.0 INTRODUCTION

2.1 General Characteristics of the Niamey Department

The Agro-ecological Zonation Study covers all of the Niamey Department of the Republic of Niger in West Africa. The geographic location of the Department is shown in Figure 2. The Niamey Department is divided into 6 administrative units called arrondissements which are shown in Figure 3. Each arrondissement is further divided into cantons.

The total area of the Department is 90,072 square kilometers. It is located between Latitudes 11` 50' N and 15` 45' N, and between Longitudes 0` 10' E and 4` 20' E. Elevation differences, while locally important, are not great, ranging from 180 m. where the Niger River leaves the Department, to just over 300 m. south of Tera.

The Niger River, which crosses the Department from the northwest to the southeast, is the only nearly permanent river in the Department (it ceased flowing in 1985). Several important though intermittent streams which have nearly continuous flow during the rainy season occur west of the Niger River with headwaters in the Liptako-Gourma, a geologic-geomorphic region. This region is largely derived from precambrian igneous and metamorphic bedrock. These streams are the Garoual, Dargol, Sirba, Goroubi, Diamangou, and Tapoa. No similar streams are found east of the Niger River; the drainages east of the river usually have flowing water for only a short time after heavy rains. This area of intermittent streams corresponds to the Oulliminden Basin, a geologic basin formed under shallow interior seas with intervening continental periods. It covers all of Filingue, Ouallam, and Kolo Arrondissements and eastern Say and Tillabery Arrondissements. The geomorphic systems of the Department will be further detailed in Section 3.1.

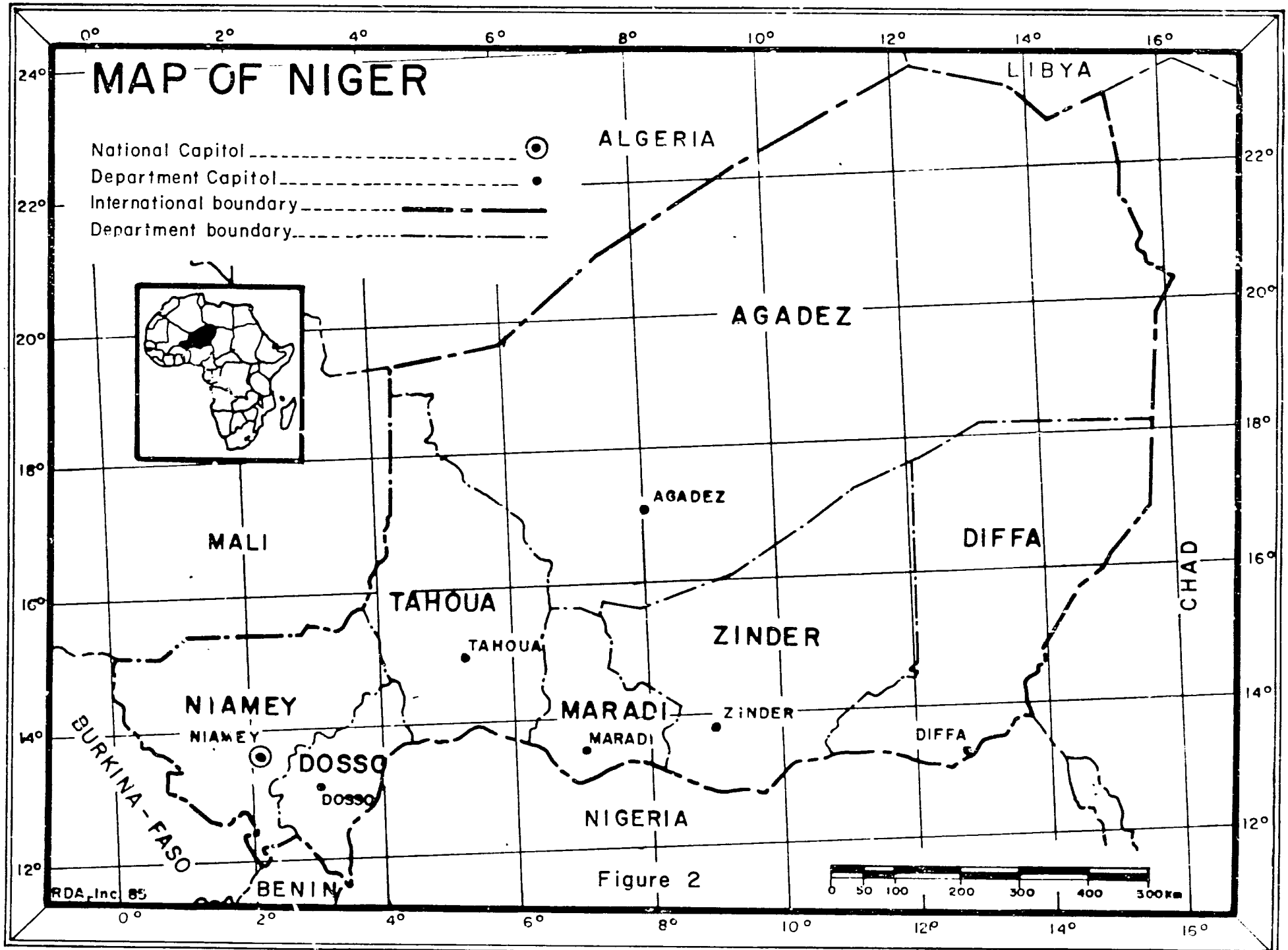

MAP OF NIGER
National Capitol
Department Capitol
International boundary
Department boundary
LIBYA
ALGERIA
AGADEZ
AGADEZ
MALI
DIFFA
CHAD
TAHOUA
TAHOUA
ZINDER
NIAMEY
NIAMEY
MARADI
ZINDER
MARADI
DIFFA
DOSSO
DOSSO
BURKINA-FASO
NIGERIA
BENIN
RDA, Inc. 85
0 50 100 200 300 400 300km
0° 2° 4° 6° 8° 10° 12° 14° 16°
24° 22° 20° 18° 16° 14° 12°

Figure 2

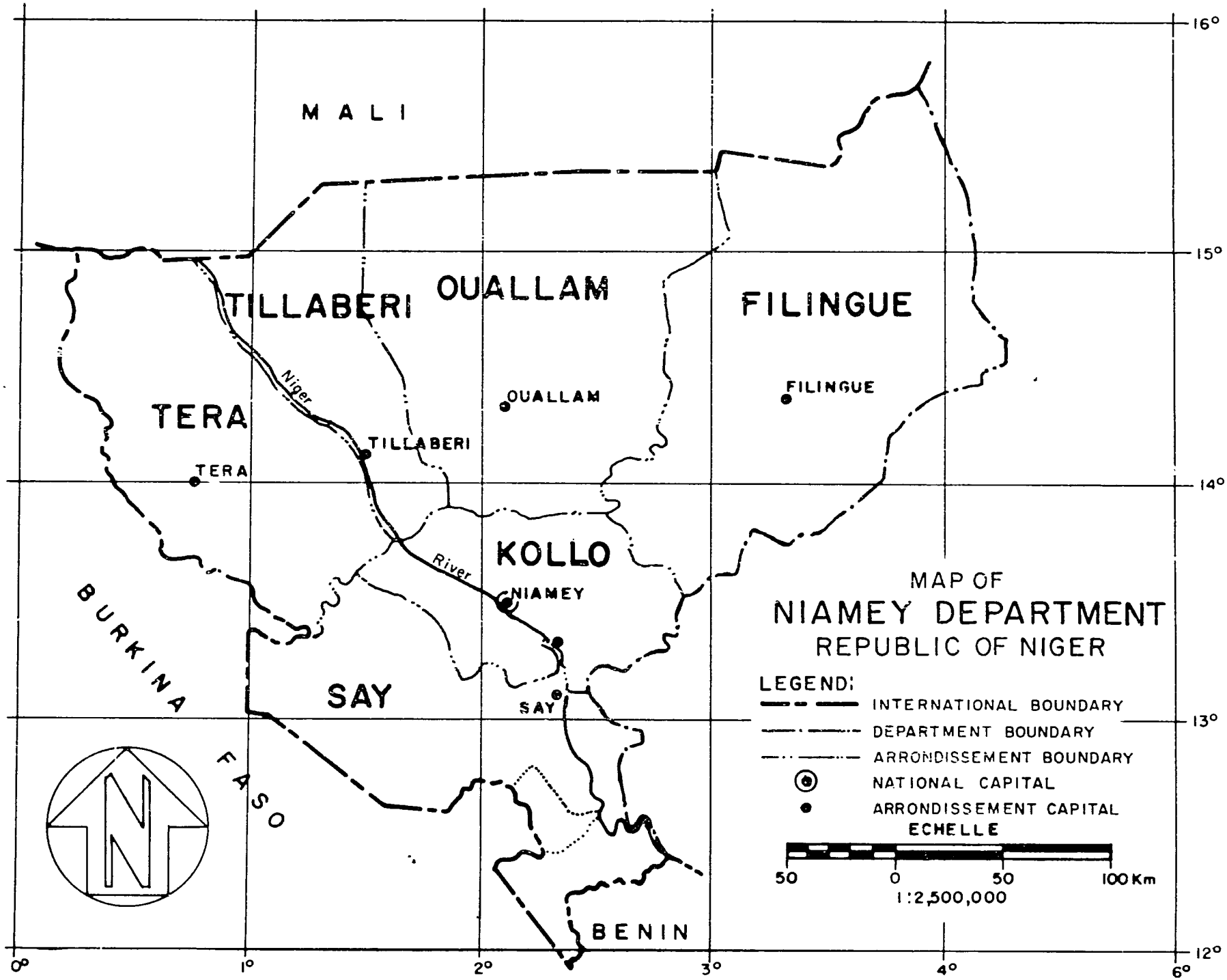

MALI
TILLABERI
OUALLAM
FILINGUE
TERA
Niger
River
OUALLAM
FILINGUE
TILLABERI
TERA
KOLLO
NIAMEY
BURKINA
FASO
SAY
SAY
BENIN
MAP OF
NIAMEY DEPARTMENT
REPUBLIC OF NIGER
LEGEND:
INTERNATIONAL BOUNDARY
DEPARTMENT BOUNDARY
ARRONDISSEMENT BOUNDARY
NATIONAL CAPITAL
ARRONDISSEMENT CAPITAL
ECHELLE
50
0
50
100 Km
1:2,500,000
16°
15°
14°
13°
12°
0°
1°
2°
3°
4°
6°

Figure 3

As in all West African Sahelian countries, the Niamey Department is characterized by steep north-south environmental gradients of climate and associated vegetation formations with relatively minor differences along the east-west axis. There is a single well defined rainy season with 90 to 95% of annual rainfall occurring from June through September. Rainfall varies greatly in time and space, both over the long and short term (see Section 3.1 A -- Agroclimatic Zonation, with specific reference to Figure 4). Available rainfall averages vary widely as a function of the time period over which they were calculated. During the 1950s and early 60s, the rainfall was significantly higher than the 50 year average, making virtually the entire Department suited for rainfed agriculture. The 400 mm isohyet ran close to the northern limit of the Department. The rainfall regime since 1968 has been quite drastically different with severe droughts culminating in 1973 and 1984. The 1968-84 average rainfall has been well below the 30 and 50 year "normals" in Senegal, Mali, Burkina Faso, and Niger, with a lower standard deviation for most stations than for previous periods (Todorov, 1985). The average rainfall for the Niamey Department for this period ranges from less than 250 mm along its northern border to 800 mm at its southern tip.

While the causes of this climatic "change" or "trend" are not understood, the resulting effects on the natural environment, the human populations and the agricultural potential of the Department have been substantial. Farmers who moved north under more favorable conditions to form permanent agricultural villages now suffer repeated crop failures and rely increasingly on dry season out-migration in search of employment and on food aid for subsistence. Previously stable sand dunes in the northern third of the Department have become partially active. Rainfall has become

more of a limiting factor to agricultural production than it was previously throughout the Department.

The natural vegetation of the Department ranges from shrub steppe (average height of grasses less than 80 cm.) in the north to tree and shrub steppe through the central portion to tall grass, tree and shrub savanna in the south. Nearly all the natural vegetation has been greatly altered by the action of man and his animals (cultivation, grazing, fire, wood cutting, etc.) and is undergoing further change as a result of the new climatic conditions.

The population of the Department is approximately one and one half million with about 300,000 in the nation's capital of Niamey. (Projected figures from the Bilan Departemental: Republique du Niger, 1978b). Very few towns outside of Niamey exceed 10,000, leaving about 80% of the population as primarily rural subsistence farmers and herders. The areas of highest population density are found along the Niger River Valley, the Dargol Valley from Gotheye to Tera and the Dallol Bosso/Boboye fossil valley south of Filingue, with population per square kilometer frequently exceeding 140. The people are predominantly nomadic and seminomadic Tuareg, Bella, and Fulani (Peul) herders across the northern reaches of the Department with Djerma-Songhay and Hausaphone farming villages which were established under more favorable climatic conditions. Songhay farmers predominate in the Tera Arrondissement accompanied by Bella farmers and Tuareg and Fulani herders. The Gourmantche predominate in western Say Arrondissement along with sedentary and semisedentary Fulani farmers and herders. Eastern Say includes Djerma farmers and Fulani farmer/herders. The uplands of Kolo Arrondissement and of central and southern Tillabery, Ouallam and Filingue are populated primarily by sedentary Djerma farmers.

The Dallol Bosso/Boboye valley in Filingue Arrondissement is composed of a mix of Hausaphone, Tuareg/Bella, Djerma and Fulani with the southern populations being largely sedentary farmers. The major peoples along the Niger River include the Kurtey, Wogo, Sorko and Kado, all of Songhay descent, along with the Djerma and Fulani.

The economy of the southern two-thirds of the Department is based on primarily subsistence level rainfed agriculture with millet being clearly the principal crop. Most of the cultivated land in the Department is on deep sandy soils; the one main exception is in western Say Arrondissement where clayey and loamy alluvial soils predominate and sorghum is the major crop. Cowpeas are commonly intercropped with millet and a variety of wet season garden crops are produced. Dry season gardening is becoming increasingly important where conditions permit. It is being actively promoted by the Nigerien government as a means of alleviating the recurring food deficits of recent years.

Nearly all farmers in the Department also raise varying numbers and mixes of goats, sheep and cows which are integrated into their production systems in a variety of ways. The nomadic and semi-nomadic pastoralists of the north move their herds of sheep, goats, cows and camels as needed to take advantage of the varying pasture conditions. These conditions are largely determined by the seasonal rainfall distribution. As range and water resources are depleted in the dry season, many of them transhume southward often entering into agreements with farmers to graze their animals on crop residues. When the zonation team arrived in early July of 1985, there were scarcely any pasture grasses remaining from the 1984 growing season in the entire Department. As a result most of the animals had died or had been taken out of the country.

2.2 Need for the Agro-Ecological Zonation Study

The Niamey Department Development (NDD) Project is an integrated rural development project which has been promoting the acceptance and utilization of a set of non-traditional farming techniques by the subsistence level farmers in the Say, Kolo, Ouallam and Filingue Arrondissements of the Niamey Department. The technical package being extended includes the use of animal traction for plowing and weeding and for ox-drawn carts, the use of chemical fertilizers, varietal selection, seed treatment, thinning, etc. These techniques are being taught at regional training centers (CPTs) where husband and wife farm couples are brought in from outlying villages for an entire cropping season and where they practice the new techniques on the center's fields. Recently several village level training programs (CVFs) have been started. In a CVF the extension agents live in the village and the trainees learn to use the new techniques on a common village field. Widespread adoption of the technical package has not taken place.

Recent evaluations of the NDD have questioned the appropriateness of the single technical package as a uniform response to the variety of agro-ecological and socio-economic conditions which exist within the Niamey Department (Poulin et al. 1983, 1984, NDD 1984, Ithaca International 1983). Such an assessment, however, depends on a clear understanding of the agronomic parameters encompassed within the project zone. The need to diversify the technical package, adapting it to local conditions, is generally well accepted both at the project and at higher policy levels. Some modifications have been made, but a division of the Department into relatively homogeneous management units is necessary before a rational program of diversification can be effectively planned and implemented. This, then, is the principal reason for the agro-ecological zonation study.

Some specific examples may better illustrate some of the advantages of such a zonation:

1) For three years the NDD supported a CPT at Tondi Kiwindi 17 km NNE of Ouallam. The CPT trained farmers from villages in the surrounding area which has had an average rainfall of 300 to 350 mm over the last 17 years. After three years of repeated crop failures at the Center, this CPT was abandoned in 1985.

2) In marginal rainfall zones, the relatively high risk of low yields or crop failure may make farmers unwilling to take out relatively large loans for investments, such as for animal traction, and then become unable to pay back the loans when due. Quantification of the probability of adequate rainfall should aid in planning the emphasis to be placed on capital intensive investments by zone.

3) All of the CPTs are located on sandy soils. Thus, none of them has conditions similar to the important agricultural zone in the western part of the Say Arrondissement with its deep alluvial loamy and clayey soils.

4) On the socio-economic side, regional differences in average farm size may determine the economic feasibility of different animal traction systems, and relative land scarcity and the correlated problem of fertility maintenance with decreased fallow periods may determine farmers' interest in the use of chemical fertilizers. In addition, the extent to which women participate in agriculture between different ethnic groups and regions should determine how they are to be included in the extension effort.

The basic purpose of this study is to divide the Niamey Department into relatively homogeneous management units or agro-ecological zones which exhibit similar characteristics, and which, then, require similar management inputs. To these ends the specific terms of reference for the agro-ecological zonation study of the Niamey Department state the two major objectives as follows:

1) Permit a diversification of agricultural technical packages for extension in homogeneous farming sub-regions of the Niamey Department. These sub-zones will be delimited by taking into consideration ecological, agro-climatological, social and economic factors.

2) Assure the selection of village test sites representing typical situations to respond to the priority problems encountered in the agro-pastoral production systems throughout the Department. These villages will then serve as the framework for integrated development activities carried out in the farming district and in close collaboration with the village development committees (CVD).

2.3 General Methodology and Approach

Although the Second Interim Evaluation of the NDD Phase II concluded that it was, "not necessary for the NDD project to have a full-fledged farming systems research program," this does not mean that project activities should not be conceived, within a multi-institutional framework, as contributing to a farming systems approach to research and extension.

The Farming Systems Approach to Research (FSAR), especially when sufficient attention is given to the ecology and socio-institutional environment, provides a useful model in which to consider the generation and extension of new farming technologies. NDD is structured to support the extension capabilities of the Department's technical services. Understanding these extension activities within a farming systems framework will render the zonation study's findings more directly useful to the generation and extension of new technologies.

Hildebrand and Waugh (1983) identify six steps in the Farming Systems Research and Extension (FSR&E):

1) Initial characterization and analysis of existing farming systems through close consultation with farmers.
2) Planning and design of first phase.
3) Selection, generation and evaluation of technologies.
4) Information accumulation and analysis.
5) Programmed reevaluation of research information.
6) Widespread extension.

NDD has pursued step six without sufficient attention to the earlier stages. Supporting institutions carrying out steps three and four confined testing primarily to training center and research station experiments. Thus,

after seven years experience in extension, fundamental uncertainties persist about the on-farm relevance of each of the technical themes to obtaining improved returns to farmer investment. In essence, the major efforts at evaluating the project over the past two years have performed a stage five function by providing feedback into the sequential process. What is evident from these evaluations is that stage one of the process was never adequately addressed at the outset and that rectifying this omission would serve as a basis for planning additional work.

The zonation team conceived its role as an interdisciplinary effort to carry out step one; essentially, that is, to look at the Department's agriculture anew, to evaluate not the project but the project zone. Previous project activities were considered only insofar as they have become components of the existing farming system. The goals of step one of FSR/E are to achieve a tentative partitioning of the rural producers into homogeneous systems or recommendation domains and to characterize the problems and constraints faced by each group. Collinson has explained the logic of this initial zoning:

a) Their existing farming system is a manifestation of a weighted interaction of natural, economic, and historical factors influencing farmers' decisions.

b) The existing farming system is the starting point for development, the base onto which productivity improvements have to be grafted.

c) Farmers with the same farming system have the same priorities and resource endowments and thus the same researchable problems and development opportunities (Collinson 1981:435).

Recommendation domains vary geographically as a function of climate, soils, and other natural factors and with changes in the economic environment as well. A second dimension distinguishes farmers within a single geographical area based on their "resource endowments." Our study

puts an accent on the first of these two dimensions but does not ignore the second. Resource endowments reflect the complex historical unfolding of inter- and intra-household dynamics. Refinement of homogeneous groups of farmers within the broad agro-ecological zones defined in this report should constitute an ongoing element of the adaptive research component of the project. This approach to establishing recommendation domains differs somewhat from that of INRAN-DECOR. Their approach establishes domains based essentially on uniformity of edaphic and climatic factors (Deuson and Swinton 1985). In contrast, we advocate a greater accommodation of socio-economic differentiation within the farming population of a given ecological unit. Additionally, we recommend that more importance be placed on the overall context in which the farm (unite d'exploitation) is situated, especially those elements that constitute sylvo- and pastoral sub-systems. It follows that a broader set of recommendations will be derived.

The zonation team arrived in Niamey at the beginning of July 1985 and completed its work by mid-October. Although field work in the rainy season poses some difficulties, the timing of the study had distinct advantages as it corresponded almost perfectly with the cropping season throughout most of the Department. The team's ecologist and soil scientist remained in country for the duration of the study but the socioligist had only a little over two months to complete his analysis of the farming systems. This led to some difficulties as the final zonation, particularly the agroclimatic portion, was still being refined as the sociologist was completing his report. The team's cartographer worked on the map compilation during the final two months.

After an initial period of meetings and documentation search, a major reconnaissance field trip in mid-July permitted a preliminary zonation of the Department which served as a basis for planning the detailed field collection. It was decided that six test villages could adequately represent the major agro-ecological zones, and that this number was realistic regarding the time available. Criteria for selection of the test villages were defined and much of the field work was centered around the selection and analysis of the six test villages. Late July and all of August were primarily devoted to field data collection. 27 village surveys were conducted and over 150 soil profile observations were made.

Rainfall and soil are the two natural factors which most strongly determine the agricultural potential of lands in the Niamey Department, and they form the basis of the agro-ecological zonation. Good socio-economic data on the farming systems of the Department are scanty and do not lend themselves to accurate map portayal. The farming systems are analyzed in this report by agro-ecological zone as portrayed on the zonation maps produced, but they did not figure directly in the delineations of the zones and subzones.

Rainfall data obtained from the National Meteorological Service were used in the definition of the agro-climatic zones. Satellite imagery provided by the Forestry and Land Use Planning Project (FLUP) was used to divide the agroclimatic zones into progressively smaller units of relatively homogeneous agro-pastoral potential based on their soils and geomorphology. The imagery provided was 1:200,000 scale, computer enhanced, color composite Landsat satellite imagery of generally high quality. This provided an efficient means of dividing the 90,000+ square kilometers of the Niamey Department into homogeneous units.

Throughout the study, the zonation team sought out the advice and assistance of institutions and individuals having pertinent technical expertise and/or experience who could contribute to the study. The list of contributors, by no means exhaustive, includes the NDD project staff, the Ministry of Plan, the Departmental Planning Service, the USAID/Niamey Mission, FLUP, ICRISAT, INRAN, AGHRYMET, National Meteorological Service, IRSCH, TROPSOILS, PVOs, PCVs, local government officials at the arrondissement level, regional project coordinators, and CPT and CVF personnel.

3.0 DEFINITION OF AGRO-ECOLOGICAL ZONES AND ANALYSIS OF FARMING SYSTEMS AND SOILS

3.1 Definition of Zones and Test Village Selection

General Analysis

In the Niamey Department of Niger, as in all the Sahelian countries, water is the principal limiting factor which determines the potential for rainfed agriculture. The spatial and temporal distribution of rainfall and the variability of rainfall over the long and short terms determine in large part what crops can be grown where and also determine much of the risk or probability of achieving a successful harvest. Climate, specifically the rainfall regime, is considered by the zonation team to be the most important factor in the agroecological zonation of the Niamey Department.

After climate, soils are probably the next most important factor in determining agricultural potential. Their texture, structure, depth, available water holding capacity, soil reaction (pH), cation exchange capacity, erodability, etc. will affect their suitability for different crops, have greatly influenced the traditional farming systems that have evolved in the different sectors of the Department and will determine their suitability and their response to the different elements of the technical package(s) extended by the NDD and the technical services. Soil characteristics cannot generally be interpreted directly from imagery, but they can however, be correlated with geomorphology, landscape units and vegetation cover-- elements which can be interpreted from satellite imagery and aerial photography. Thus these geomorphic-soils associations form the second major basis for the agroecological zonation.

Beyond the physical characteristics of the environment, agricultural development must, of course, take place within the context of the pre-existing and continually evolving social/economic/human geographic environment, adapting the approach as a function of the local systems of

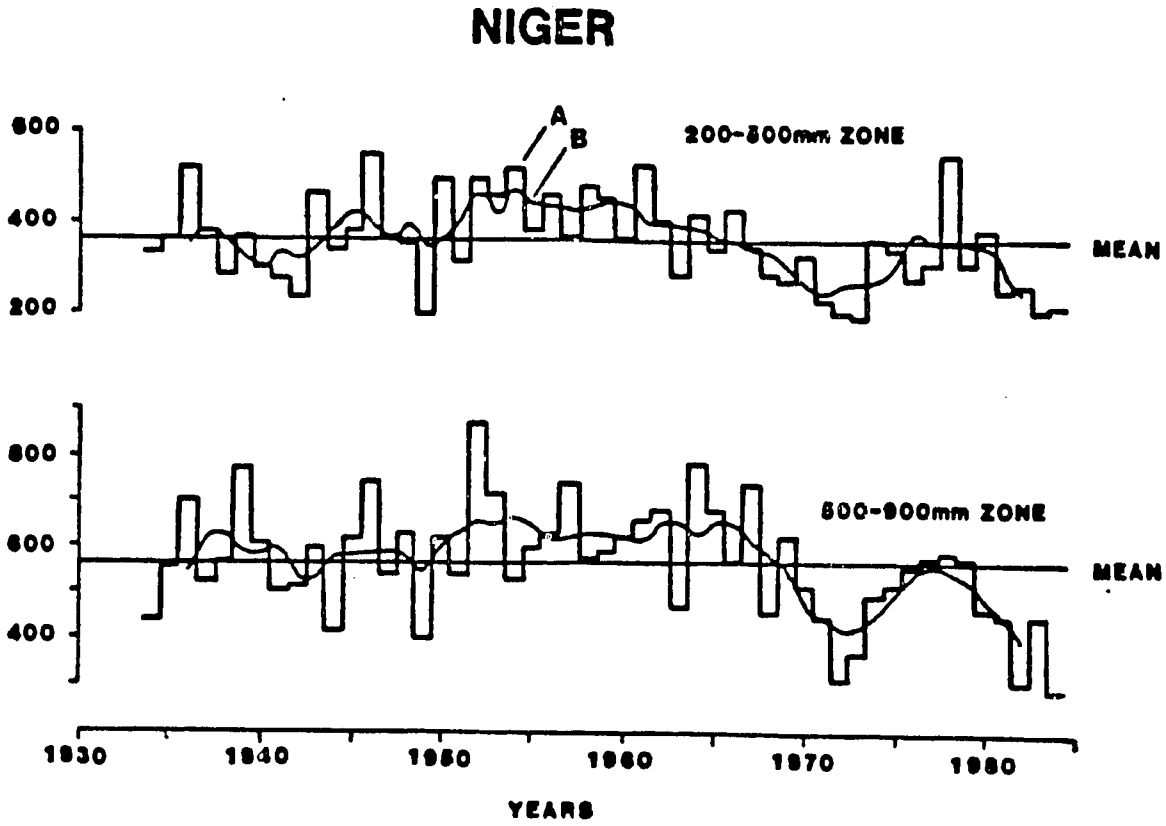
production, land tenure, resource scarcity vis a vis population density, division of labor between men and women, etc. While these factors do not lend themselves readily to accurate cartographic representation, they were found to vary considerably between the major geomorphic and agro-climatic zones and are analyzed in correlation with these zones.

Agroclimatic Zones

All of the Sahelian countries have experienced a period of extended drought of variable severity which has persisted over the last 13-19 years. The nature of the climatic change that has taken place is a complex and controversial topic primarily because the causative factors which bring about such change are understood poorly at best. That change has taken place, however, is obvious. What agroclimatological data, then, from what period of time should be used for agricultural planning?

Todorov (1985) has examined the rainfall regimes for four Sahelian countries including Niger over the past 50 years. Figure 4 shows the 50 year mean annual rainfall, annual amounts of rainfall and the five year running average for the 200-500 mm and the 500-900 mm rainfall zones for Niger. The rainfall for each zone for each year was calculated as the average amount from the stations at Tahoua, Zinder and N'Guigmi and those at Niamey and Maradi for each zone respectively.

The graphs show that the rainfall from 1968 to 1984 has been decidedly less than the 50 year "normal" and that the difference is especially acute when compared with the period of relatively abundant, reliable rains from about 1950-1966. This is not an isolated phenomenon as similar graphs for Senegal, Mali and Burkina Faso show the same trends only more accentuated than for Niger.



Annual amounts of rainfall (A), the five year running average (B) and the mean annual rainfall for the period 1934-1984. (Todorov 1985)

Figure 4. Niger: 50 Year Rainfall Regime

Todorov drew the following conclusions:

1) The rainfall regime in the Sahel has changed considerably since 1968.

2) Mean or normal rainfall data calculated for periods prior to 1968 are obsolete and should not be used for operational agrometeorological purposes. This also applies to confidence limits and the beginning, ending and duration of the rainy season.

3) New mean or normal rainfall values need to be calculated to include all recent years. The length of the time period over which the values are calculated depends on their intended use. Most agricultural decisions are made relative to the immediate rather than the more distant past. Values calculated for the period since 1968 may be best suited for some purposes.

It is intended that one of the main uses of this study will be to help NDD plan where and under what conditions they should promote the intensification of rainfed agriculture. This study will probably realize its greatest use over the next five years. Therefore its recommendations will be based on rainfall values calculated from the period 1968-1984.

Advice was sollicited from agrometeorologists with AGHRYMET and ICRISAT in Niamey concerning the parameters to use for the agroclimatological zonation. The team eventually chose to divide the Department into three agroclimatic zones-- the Pastoral, Intermediate and Agricultural Zones. Although opinions vary somewhat, the 350 mm isohyet is commonly regarded as the northern limit of rainfed agriculture. The Pastoral Zone then is defined as that area north of the 350 mm isohyet where animal herding should generally be considered to be the optimal use of the land. Conventional rainfed agriculture should not be promoted in this zone; extensive rainfed agriculture continued under drought conditions has already led to severe environmental degradation in much of this zone and partial activation of previously stable sand dunes.

The Intermediate and Agricultural Zones both lie south of the 350 mm isohyet and are separated by the isoline of 80% probability of receiving 350 mm of rainfall or more in a given year. In the Intermediate Zone north of this line, rainfall is still a limiting factor to production in many years and farmers may often be more concerned with minimizing risk (i.e. assuring the means of survival) than in investing their resources to maximizing production. In the Agricultural Zone south of the 80% isoline, rainfall is generally an important limiting factor only in years of severe drought; this zone is best suited to agricultural intensification aimed at increasing production.

Annual rainfall data were obtained from the National Meteorological Service for all reporting stations in or near the Niamey Department for which there are at least 11 years of data for the 17 year period of 1968-84. Figure 5 shows the mean rainfall by station and the extrapolated isohyets for the Department.

Most published rainfall maps show the isohyets occurring much farther north. Figure 5 is presented as an example; this rainfall map was extracted from an NDD planning document.

In Figure 6, the towns of Dolbel and Ayorou in the northwestern corner of the Department fall at about the 450 mm isohyet. From 1968 to 1984 the maximum annual rainfall at either of these stations never exceeded 390 mm.

The probability of getting at least 350 mm of rain per year was then calculated for each reporting station. Figure 7 depicts these probabilities as well as the 80% probability isoline and the 350 mm isohyet thus defining the three agroclimatic zones.

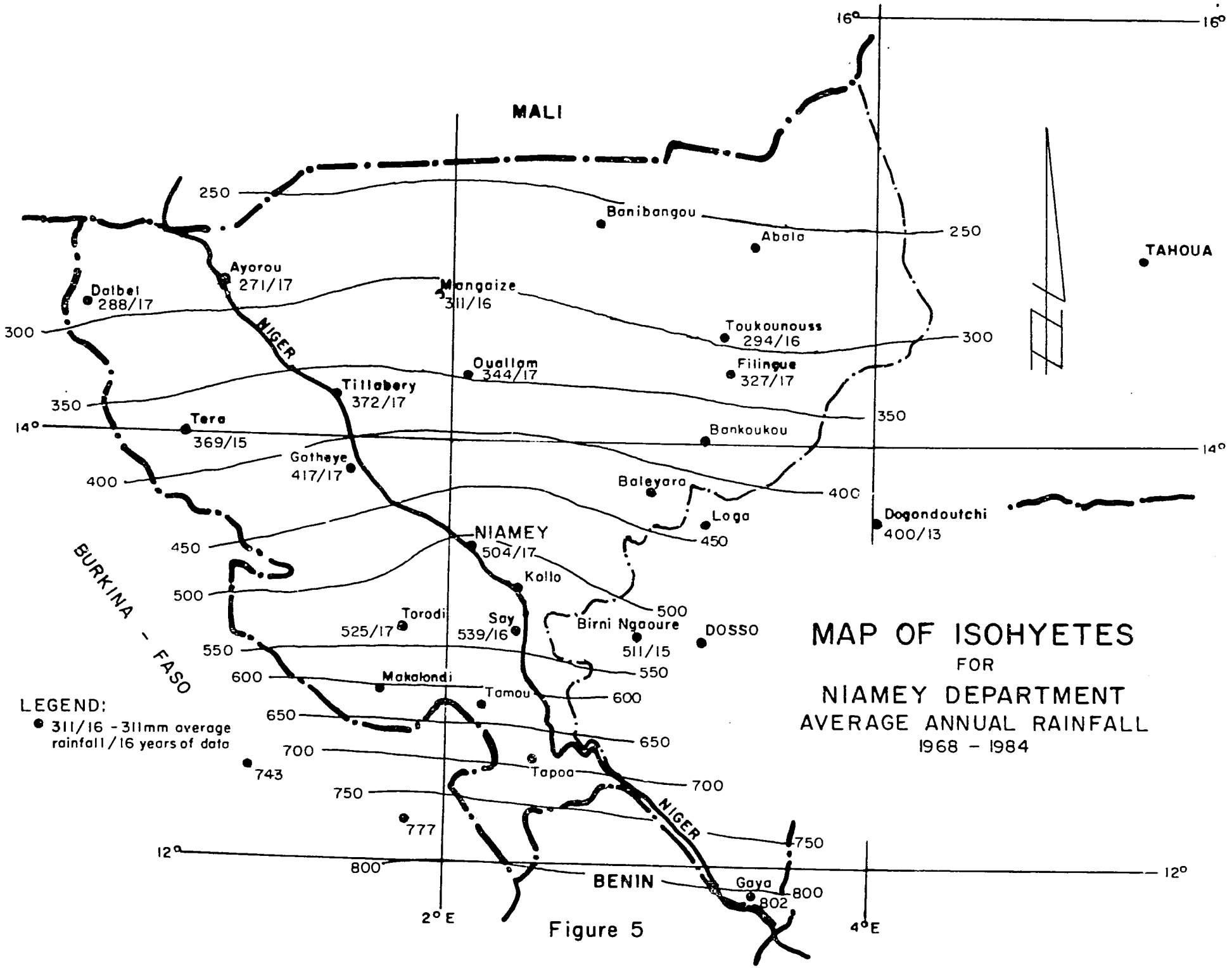
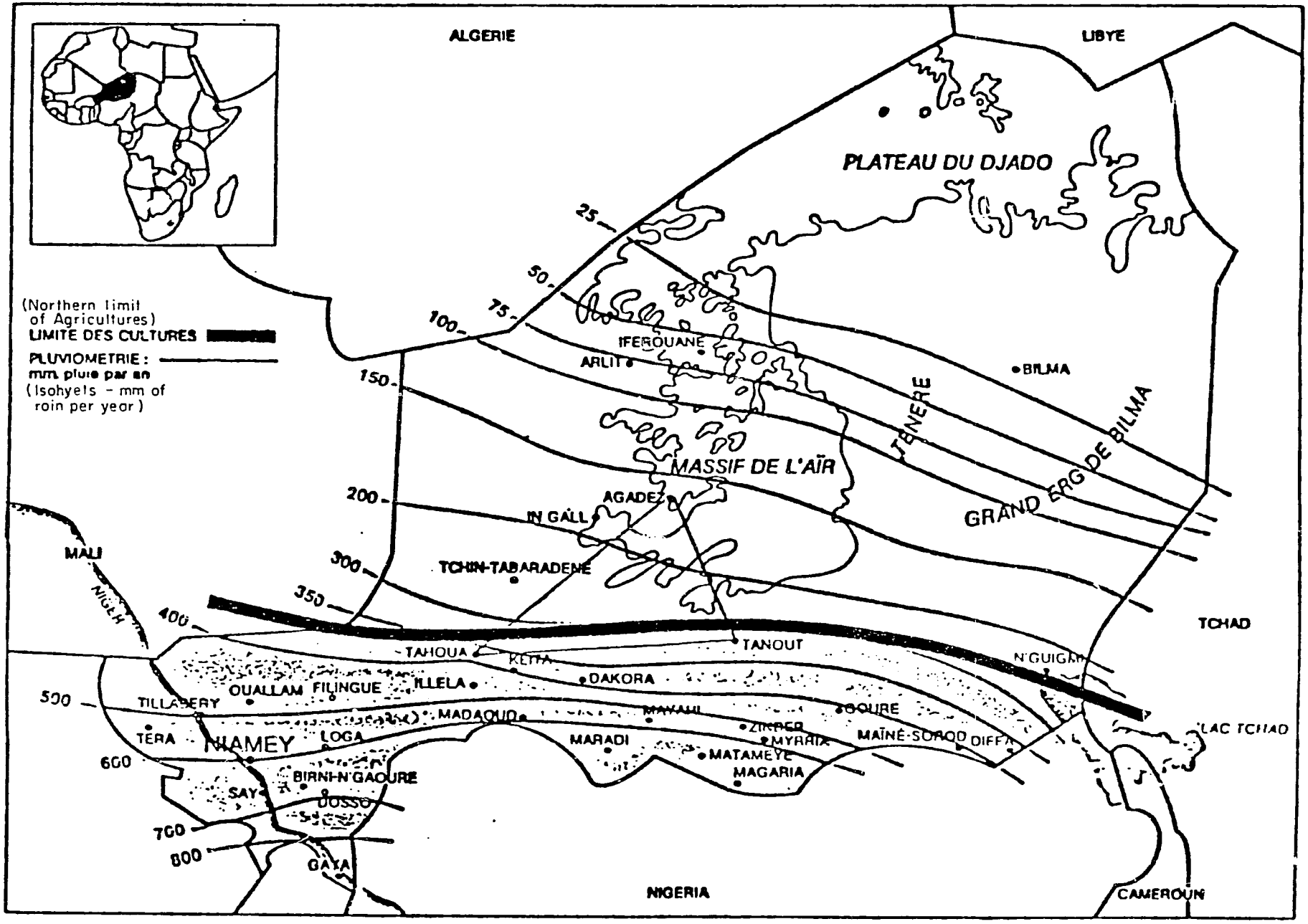

MALI
TAHOUA
BURKINA - FASO
BENIN
NIGER
NIAMEY
DOSSO
16°
14°
12°
2° E
4° E
250
300
350
400
450
500
550
600
650
700
750
800
Banibangou
Abala
Ayorou
271/17
Dalbel
288/17
Mangaize
311/16
Toukounouss
294/16
Filingue
327/17
Ouallam
344/17
Tillaberry
372/17
Tera
369/15
Bankoukou
Gotheye
417/17
Baleyara
Loga
Dogondoutchi
400/13
504/17
Kollo
Torodi
525/17
Say
539/16
Birni Ngaoure
511/15
Makalondi
Tamou
Tapoa
743
777
Gaya
802
LEGEND:
311/16 - 311mm average rainfall / 16 years of data
MAP OF ISOHYETES
FOR
NIAMEY DEPARTMENT
AVERAGE ANNUAL RAINFALL
1968 - 1984

Figure 5

Figure 6: EXAMPLE OF OUTDATED RAINFALL MAP



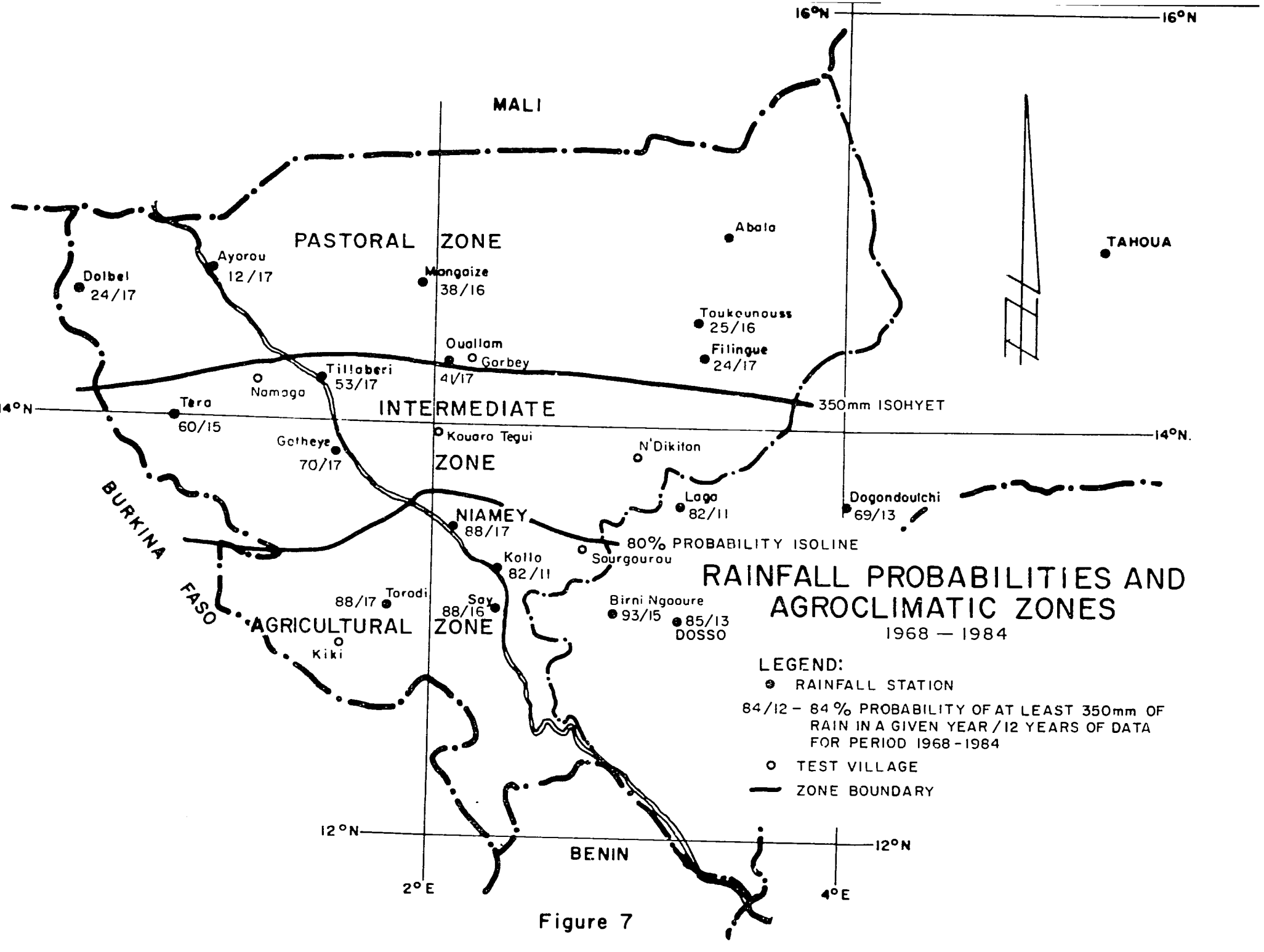

16°N
16°N
MALI
PASTORAL ZONE
Abala
TAHOUA
Ayorou
12/17
Dolbel
24/17
Mangaize
38/16
Toukounouss
25/16
Ouallam
Gorbey
41/17
Filingue
24/17
Tillaberi
53/17
Namaga
14°N
Tera
60/15
INTERMEDIATE
350mm ISOHYET
14°N.
Kouaro Tegui
Gotheye
70/17
ZONE
N'Dikiton
Lago
82/11
Dogondoutchi
69/13
BURKINA
NIAMEY
88/17
80% PROBABILITY ISOLINE
Sourgourou
Kollo
82/11
FASO
Torodi
88/17
Say
88/16
Birni Ngooure
93/15
85/13
DOSSO
AGRICULTURAL ZONE
Kiki
RAINFALL PROBABILITIES AND
AGROCLIMATIC ZONES
1968 — 1984
LEGEND:
RAINFALL STATION
84/12 - 84% PROBABILITY OF AT LEAST 350mm OF RAIN IN A GIVEN YEAR / 12 YEARS OF DATA FOR PERIOD 1968-1984
TEST VILLAGE
ZONE BOUNDARY
12°N
12°N
BENIN
2°E
4°E

Figure 7

Geomorphic/Soils Subzones and Landscape Units

A set of 1:200,000 scale resource inventory maps covering all of the Niamey Department was produced by the USAID sponsored Forestry and Land Use Planning Project (FLUP) in 1982 and 1983. The classification scheme was based on geomorphology or landforms with modifiers for soil depth and degree of aridity. The team was very interested, therefore, to determine to what extent the FLUP maps could be used or modified to meet the needs of this study.

The individual delineations on the FLUP maps (cartographic units) correspond to areas composed of a relatively homogeneous, unique mix of different landform types. These landform types are listed on each cartographic unit along with the approximate percent of areal coverage. The cartographic units often cover hundreds of square kilometers and may include landform types which vary in agricultural potential from high to nil. The only way for the map user to geographically differentiate between landform types is to work on the clear map overlays registered to the Landsat images and to learn to identify (i.e. to interpret) them on the image.

The zonation team therefore concluded that it was desirable to perform our own interpretation of the Landsat imagery using a classification scheme more directly fitted to the needs of the NDD and to produce a set of map products which are more "user friendly." The NDD and technical services staff should be encouraged, however, to make use of the FLUP maps at their offices with the assistance of the Inventory Section personnel who worked on their compilation.

Based on our study of the Landsat imagery, and our field work, complemented by FLUP's resource maps and other documentation, the zonation

team identified six major geomorphic systems (aside from the Niger River Valley) within the Department. Each system is generally characterized by a series of landforms and soil types which occur repeatedly within the zone and which (within a given climatic range) tend to have the same agrosylvopastoral characteristics or potential. The following names were assigned to these systems:

--Sand Valley and Plateau
--Alluvial Valley and Uplands
--Dune, Interdune, Mare
--Sand Plain
--Dallol Valley
--Dune and Sand Plain

These geomorphic systems are shown in Figure 8.

Most of the major geomorphic systems extend across the boundaries between the agroclimatic zones shown in Figure 7. In keeping with the relative importance placed on climate and soils, the agroclimatic divisions will henceforth be called zones and the major geomorphic systems within each zone will be called subzones. These zones and subzones are shown in Figure 9. Because of the unique character of the Niger River Valley with its (nearly) permanent river and the importance of irrigated agriculture not dependent upon seasonal rainfall, it is delineated as a special zone independent of the others.

Most of the subzones within the Intermediate and Agricultural Zones are further subdivided into landscape types of varying agrosylvopastoral potential with the emphasis placed on identifying differences important to agriculture. These landscape types were delineated within the Agricutural and Intermediate Zones but not in the Pastoral Zone where rainfed agriculture should not be promoted.

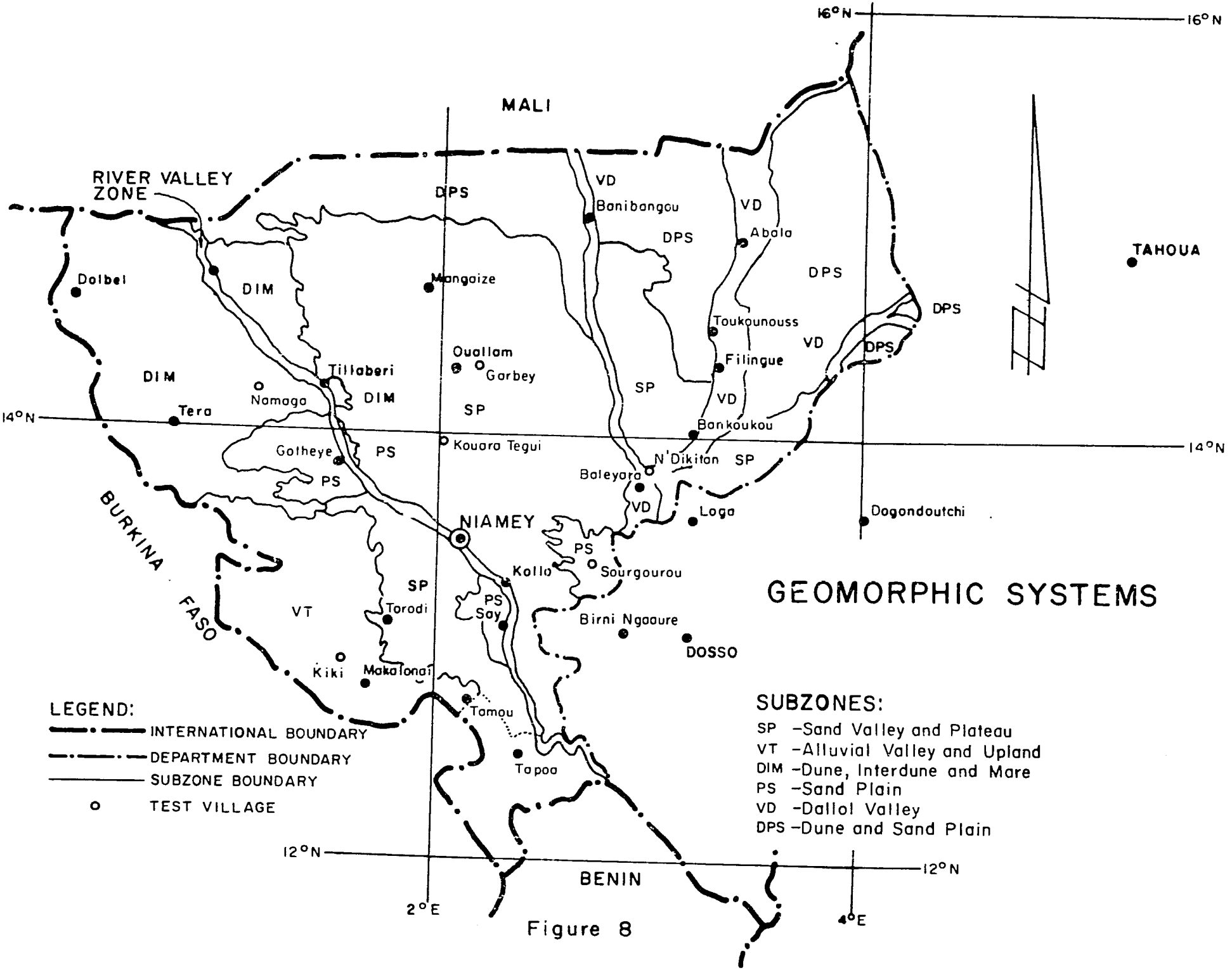

GEOMORPHIC SYSTEMS
MALI
BURKINA FASO
BENIN
NIAMEY
RIVER VALLEY ZONE
16°N
14°N
12°N
2°E
4°E
Dolbel
Tera
Namaga
Tillaberi
Gotheye
Mangaize
Ouallam
Garbey
Kouara Tegui
Banibangou
Abala
Toukounouss
Filingue
Bankoukou
N'Dikitan
Baleyara
Loga
Dogondoutchi
TAHOUA
Kollo
Sourgourou
Say
Torodi
Kiki
Makalondi
Tamou
Tapoa
Birni Ngaoure
DOSSO
DIM
DPS
VD
SP
PS
VT
LEGEND:
INTERNATIONAL BOUNDARY
DEPARTMENT BOUNDARY
SUBZONE BOUNDARY
TEST VILLAGE
SUBZONES:
SP -Sand Valley and Plateau
VT -Alluvial Valley and Upland
DIM -Dune, Interdune and Mare
PS -Sand Plain
VD -Dallol Valley
DPS -Dune and Sand Plain

Figure 8

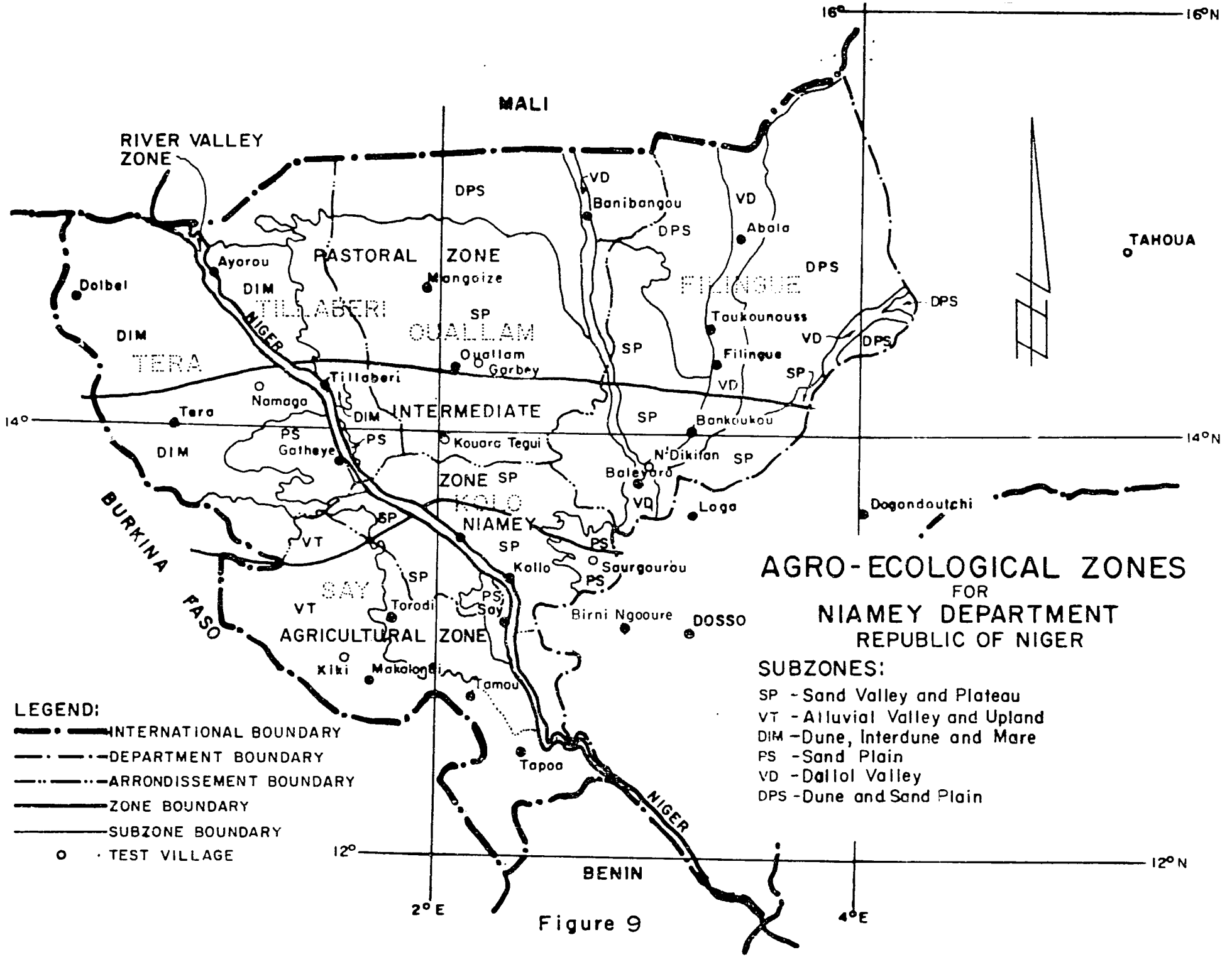

AGRO-ECOLOGICAL ZONES
FOR
NIAMEY DEPARTMENT
REPUBLIC OF NIGER
SUBZONES:
SP - Sand Valley and Plateau
VT - Alluvial Valley and Upland
DIM - Dune, Interdune and Mare
PS - Sand Plain
VD - Dallol Valley
DPS - Dune and Sand Plain
LEGEND:
INTERNATIONAL BOUNDARY
DEPARTMENT BOUNDARY
ARRONDISSEMENT BOUNDARY
ZONE BOUNDARY
SUBZONE BOUNDARY
TEST VILLAGE
MALI
BURKINA FASO
BENIN
TAHOUA
DOSSO
RIVER VALLEY ZONE
PASTORAL ZONE
TILLABERI
OUALLAM
TERA
FILINGUE
INTERMEDIATE ZONE
KOLO
SAY
AGRICULTURAL ZONE
NIAMEY
NIGER
Dolbel
Ayorou
Mangoize
Banibangou
Abala
Toukounouss
Filingue
Ouallam
Gorbey
Tillaberi
Namaga
Tera
Gatheye
Kouara Tegui
Bankoukou
N'Dikilan
Baleyara
Loga
Dogondoutchi
Saurgourou
Kollo
Say
Torodi
Birni Ngooure
Kiki
Makalondi
Tamou
Tapoa
16°
16°N
14°
14°N
12°
12°N
2° E
4°E

Figure 9

Although the subzones will be described in detail in Sections 3.2 and 3.3, a brief description of them will be given here to orient the reader. Again refer to Figure 9 for their geographic locations.

Sand Valley and Plateau

The Sand Valley and Plateau System is the largest geomorphic division in the Department and the only one to occur in all three of the agroclimatic zones. Its most striking feature is the ironstone plateaus or buttes which are separated by broad sand valleys where nearly all of the agriculture is concentrated. The plateaus comprise from about one third to well over half the surface area in different parts of these subzones. The plateau tops are primarily sylvopastoral areas with little or no agricultural potential. The drainage network is poorly developed with few important streams, the water table is quite deep and the potential for dry season gardening fairly limited. In the Intermediate and Agricultural Subzones, most of the suitable deep sandy soils are under cultivation, and with fallow periods continually decreasing, maintaining soil fertility is a major problem. Landscape units identified are Sand Valley, Plateau, Dune and Broad Valley Flats.

Alluvial Valley and Upland

The Alluvial Valley and Upland Subzones in the southwestern corner of the Department are distinctive from all other subzones by their lack of deep sandy soils. The broad alluvial valleys are productive agricultural areas with deep clayey and loamy soils. Nearly all the farmers in this area have adopted the short handled "daba" to cultivate these heavy soils. The uplands are best suited for sylvopastoral management due to their shallow to moderately deep loamy soils that are stony and/or gravelly. The

distinction between alluvial valley and upland is not as clear cut as between the sand valleys and plateaus. The Alluvial Valley and Upland Subzones have a well developed drainage network with sizable streams along which there is considerable dry season gardening potential. Landscape units distinguished are (1) Alluvial Valley and (2) Upland.

Dune, Interdune, and Mare

The most distinctive features of this system are the geologically young, east-west oriented, nearly parallel bands of stabilized sand dunes which have been deposited across a geologically mature landscape obstructing the drainage system in many places to create mares or shallow lakes with fluctuating water levels. The sparsely vegetated interdunal areas are characterized by shallow to moderately deep clayey or loamy soils with a much higher coefficient of runoff than the dunes. Thus nearly all of the rainfed agriculture is practiced on the dunes where infiltration rates are high. Local outcroppings of ironstone, granite, and quartz occur in the interdunal areas. The mares in addition to several large streams which disect the two subzones, provide abundant opportunities for dry season gardening throughout the area. Landscape units identified are Dune, Interdune, Mare, and Outcrop.

Dallol Valley

The Dallol Valleys are broad, nearly flat fossil river valleys 2 to 18 kms. wide which formed under a moister climatic regime. Portions of the Dallol Bosso or Boboye, the Dallol Maouri and the Zigaret traverse the Filingue and part of the Ouallam Arrondissements from north to south. There are no rock outcrops in the Dallol Valleys. They have primarily very deep sandy soils; the Dallol Bosso has in addition numerous clayey

depressions and drainageways. Population densities in the Dallol Valley Subzones run much higher than in adjoining areas and virtually all of the Dallol Valley in the Intermediate Zone is under cultivation with short fallow periods. The water table is deep in the north but rises rapidly in the southern half of the Intermediate Zone to within two meters of the surface providing exzceptional opportunities for dry season gardening.

Sand Plain

The Sand Plains of the Intermediate and Agricultural Zones are broad undulating surfaces of deep sandy soils. Nearly all the land is under cultivation. Therefore population densities are high and there are almost no exclusively sylvo-pastoral areas. The drainage network is poorly developed and dry season gardening potential is limited with the exception of portions of the Sand Plains in the Tera Arrondissement.

Dune and Sand Plain

The Dune and Sand Plains cover vast areas of the northwestern and north central portions of the Department in the Pastoral Zone. They are characterized by deep sandy soils ranging from very sandy on partially active dunes to loamy sands on lower positions on the landscape. Rainfed agriculture is a high risk activity destructive to this environment, but is still extensively practiced by farmers who settled in these areas under more favorable conditions. The drainage network is poorly developed and dry season gardening potential is limited.

Dry Season Gardening Potential

A final feature interpreted from the Landsat imagery was an assessment of the dry season gardening (culture de contre-saison) potential throughout the Department. This was done due to the strong interest in this activity on the part of the Nigerian government, numerous donor agencies, and, as revealed by our village interviews, the rural populations of the Department.

Nearly all of the Landsat imagery used for the analysis was recorded between September 30 and November 22 of different years. These early dry season images provide a nearly optimal contrast between the seasonally flooded drainages, mares, and depressions where most dry season gardening is done and the surrounding uplands. The interpretation of dry season potential was based on position on the landscape and spectral response patterns indicative of open water bodies, dark, moist soils and/or green vegetative cover indicative of moist conditions, this complemented by field experience and available topographic maps.

Two classes of dry season potential, high and medium, are recognized. This is a highly qualitative assessment and the user should be aware that the actual potential can only be evaluated on the ground. It does, however, reveal the very significant differences in dry season potential between the different subzones and should orient the user as to "where to look" on the ground. The principal areas of dry season potential are to be found in the Dune, Interdune and Mare Subzones of the Tera and Tillabery Arrondissement, along the drainageways of the Alluvial Valley and Upland Subzones in the Say and southern Tera Arrondissements and in the Dallol Valley Subzone south of Baleyara in the southern portion of the Filingue Arrondissement.

Given the generally small localized areas with dry season potential, this feature is displayed only on the 1:200,000 scale arrondissement maps accompanying this report; it could not be represented on the 1:500,000 scale zonation map of the Department.

Test Village Selection and Village Surveys

Village Selection

After a period of orientation to the diversity of ecological and sociological conditions prevalent in the Niamey Department, the team undertook an operational division of agricultural space. This provisional zonation, although subject to revision, provided the initial guidelines for selecting different test villages. The villages were selected with the aim of representing the diversity of agro-ecological conditions most characteristic of the Department. An effort was made to ensure that the villages also reflected representative, insofar as the term is applicable, conditions of land tenure, population density, and of the social organization of production within each zone. Due to time and manpower limitations of the team, the number of villages selected was limited to six, thus precluding an exhaustive coverage of all the important sub-zones found in the Department. The six general areas from which test villages were chosen were pre-selected in terms of their likelihood in representing the widest possible range of technical packages appropriate to the Niamey Department. These six general areas were the following:

1) The Alluvial Valley and Upland Subzone in the southwestern Say Arrondissement in the southern part of the Agricultural Zone.

2) The Dune, Interdune, and Mare Subzone in the Intermediate Zone in the Tera Arrondissement with emphasis on choosing a representative village with high dry season gardening potential.

3) The Dallol Boboye in southern Filingue Arrondissement representative of the Dallol Valley Subzone with high water table in the Intermediate Zone.

4) The vast Sand Valley and Plateau Subzones and associated Sand Plain Subzones with three test villages chosen as follows:

   -- one village in the Agricultural Zone in the southern Sand Valley and Plateau or associated Sand Plain Subzone.

   --one typical Sand Valley and Plateau village in the Intermediate Zone.

   --one Sand Valley and Plateau village near the Intermediate-Pastoral Zone transition having dry season gardening potential and representative of the generally degraded environmental conditions of the area.

Within each area a number of different factors were to be examined. These included social and ethnographic background, land tenure, population pressure on resources, traditional land use classification and systems of soil resource management (ITK, indigenous technical knowledge), erosion problems, vegetation change, soil analysis , and current vegetation cover. To these classificatory elements of development potential, the team added consideration of dry season irrigated agricultural potential. The approach thus followed closely the newly established priorities set by the Government of Niger's Maradi and Zinder Conferences which among their conclusions stressed: soil and water conservation (lutte contre la desertification), dry season gardening (cultures de contre-saison), and village level participation.

Following the determination of the agro-ecological zones which were to include test villages, the next step was to enumerate the potential village sites within each zone. This was accomplished by applying a number of somewhat flexible criteria to the realm of possible villages within a given administrative unit. Because most ecological types encompassed more than

one administrative division, an effort was made to insure adequate representation at the arrondissement level. These criteria were established in collaboration with NDD personnel with the intention of providing appropriately selected future sites for Centres Villageois de Formation (CVFs) or other village level agricultural inter-ventions. The following criteria were applied systematically:

1) Using satellite imagery overlain by 1:200,000 scale topographic maps, a list of villages was compiled based on their apparent representativeness of the agro-ecological conditions typical of the zone. Prior reconnaissance had identified typical landscape patterns which facilitated this initial selection.

2) This village list was subject to further qualification based on:
   - sufficient size and concentration to warrant being chosen as a focus point for development activity (arbitrarily defined as approximately 100 family heads)
   - representativeness as to population characteristics and farming systems of the zone
   - presence of a CPT graduate ("ex-stagiare") within the village (except in the case of Tera and Tillabery) who was judged to be "dynamic"
   - relatively easy road access in view of the expected need for close monitoring of extension and applied research programs
   - proximity to existing rural technical service personnel; previous survey work indicated that a 15 km radius defined a maximum threshhold
   - absence of extraordinary elements rendering the village unrepresentative, i.e. Canton seat, existing CPT, existing agricultural research (INRAN), significant ongoing or previous development activities

While many of these criteria could be applied before going out into the field, some elements could only be verified through village interviews. Pre-field procedures included discussions with administrative and technical

service personnel at the arrondissement level. Village lists were reviewed with sous-prefets, project coordinators, and other arrondissement service heads insofar as they were present and available at the time of the mission. Other project personnel including enqueteurs, field agents, CPT staff, as well as current CPT stagiaires were interviewed, further adding to the set of characteristics compiled for each village. This broad approach to soliciting input substantially offset the biases of any one particular group. Through this pre-interview verification procedure many villages were eliminated and others not initially considered were added to the list. The resulting set of village profiles provided the basis upon which a short list was selected. This short list reflected a combination of best possibilities and practical limitations.

The villages on the short list were subsequently visited and informal agricultural surveys were carried out. A total of 27 villages was visited; interviews generally lasted from two to four hours. The final selection of the test village was made after reviewing the results of the fieldwork. This selection was based on a confirmation that village setting encompassed the desired ecological characteristics, that physical access was adequate, and that the social parameters were met. Concerning the latter, proxy measures for social organization and favorable disposition toward development activities were applied. Such measures as democratic participation in village meetings and a well-organized appearance of the village's physical layout, for example, were taken as positive indicators. Conversely, disorganized villages or villages in which the chefferie was contested were rated negatively. It should be noted that most of the villages in which interviews were carried out adequately met the above-outlined criteria. A degree of flexibility was therefore maintained by

choosing an "alternate village" which would be deferred to in the event that subsequent soil analysis determined that the soils of the test village were unrepresentative.

The locations of the test villages selected are shown in Figure 9. A description of each village is given in Section 3.2 -- Farming Systems. These descriptions can be found at the end of the farming systems analysis for the appropriate subzone in which each village is located.

Following the selection of each test village, the village was revisited by the team's soil scientist and ecologist to gather more detailed information. A soils map covering about four square kilometers was prepared for each village along with a profile showing a typical toposequence. These are presented in Annex F. A technical description of each soil identified on the village maps is enclosed in Annex E, entitled Typical Pedon Descriptions. In addition, general descriptions of each soil series, along with use and management recommendations are presented in Section 3.3 under Soil Series Evaluations. Soil suitability and physical characteristics by soil series are presented in the tables that make up Annexes C and D. Soil laboratory test results for selected soils are given in Annex G. General recommendations for NDD interventions for each test village are found in Section 4.0.

Village Surveys

Although following an unstructured format, the village survey attempted to cumulatively build a portrait of the farming systems of each region. The following represent the general lines of inquiry that were explored in our conversations with the area's farmers.

What is the local system of land use classification and landform classification? What is the current pattern of utilization of these habitats and how does this break down by sub group?
Example: Who constitutes units of production and to what extent does the notion of the peasant family farm hold true?

What groups exploit the same niches? To what degree are these groups complementary and to what degree are they in conflict? What are the ongoing processes of change that are or may affect the stability of the interrelationships between different sub-groups of the rural population?

What is the land tenure situation in the region? Who controls access to land and who arbitrates in the case of disputes? What is tree tenure? How do these factors vary for different groups utilizing the area, i.e. herders, sedentary farmers, agro-pastoralists, capitalist farmers from urban areas, etc.

What are the trends in terms of agricultural intensification; what perceptions if any exist of a declining resource base?

What are perceived as principal farming problems for:

-dryland cereal production
-cultures de case
-cultures de contre-saison
-animal production

(i.e. wind erosion, insects, labor shortage, water erosion, etc.)

What is the traditional division of labor and what are the principal crops grown by each group? What changes in this pattern have been taking place in recent years?

The information obtained through the interviews was used both to select test villages and also to supplement the existing published material for each sub-region within the department. Upon selection of the test village, subsequent visits by the soils scientist and ecologist permitted the gathering of additional information on the environment and soils, and further detail on the above topics.

3.2 Farming Systems of the Niamey Department

Overview

Socio-economic Considerations

The approach taken toward the socio-economic analysis of the Niamey Department's rural population assumes (1) the household constitutes the fundamental economic unit, and (2) it is oriented in order of priority toward subsistence security, social reproduction, and finally accumulation. As such the household qua economic unit is at once abstracted from a complex rural milieu, and posited relative to a set of structural conditions including commodity prices, power relations, and markets over which it has little or no control. On the one hand, the household is bound by village social organization, lineage relations, and ethnic identity, and on the other it is defined by the nature of its relations with the "outside world", in essence by its political economy.

As far as successful rural development planning is concerned, two related dangers are posed by assuming the household as the basic unit. First is an all too frequent and usually implicit equation of the household with a "family firm." This leads to the conclusion that the "firm" is directed by a single decision maker (the household head) and is geared toward maximizing the profits of agricultural production. Important historical economic forces that challenge these assumptions become easily overlooked. Recommendations for new practices and innovations that seem logical are not adopted. It is equally important to understand the household's position in the village economy, as well as the integration of the village economy into the world economy. Many issues demand attention in modelling household economic behavior. These include change in village communal labor and resource sharing instititutions, monetization and

individualization of economic strategies, the reduced expectations of agriculture as a means to generate cash and the corresponding disinterest in investing in it as such, increased exposure to risk, dynamic and mostly negative changes in the environment, and the changing motivations and strategies of labor migration.

The second danger results when the observable family unit is reified thereby leading to its conception as permanent and fixed, internally consistent, unified and undifferentiated. In reality, the household is composed of individuals with their own agendas, many of whom enter and exit from the unit for independent reasons. Recommendations appropriate to good of the household are not equally embraced by all its members, often for very good reasons. The household thus constitutes an entity replete with sub-economies. It is able to dissolve and reconstitue itself; it changes in form and composition through the demographic cycle, and is frequently linked to income sources outside the household. While the empirical definition and description of the household is thus problematical, an understanding of its internal dynamics and ties to the larger economy is essential to the formulation of appropriate development and extension efforts.

The major forces which affect households in the Niamey Department include drought, famine, changing ecology, changing technology, and monetary pressure. These will be analyzed on a regional basis. The analysis is of necessity an initial step. It will raise more questions than it will provide answers, suggest more avenues in which to seek solutions than solutions themselves. Increasing production is possible, but new approaches that emphasize ecological stability and account for socio-economic complexity are required.

Zonation

Throughout the Niamey Department, human adaptiveness stands out as the most impressive characteristic relevant to the socio-economic considerations of the agro-ecological zonation. This is particularly evident in view of the local population's response to the extreme climatic and environmental conditions of recent years. Human adaptivity manifests itself regionally as a function of differing historical and cultural antecedents, of variability in local ecology, and in the uneveness of economic development.

The commitment of the peasantry to its lands is striking given the marginal returns to agricultural (including pastoral) labor inherent to the agro-ecology of most of the department, at least under present technologies. Development policy calls for an equally adaptive and creative response to the changing economic and environmental circumstances that define the current parameters of rural development. The present drought, in placing an enormous stress on the rural population's ability to cope, provides a revealing optique in which potential development priorities are sharply defined.

The classical production-oriented approach to agricultural development presently being extended through the CPT and CVF training centers uniformly throughout the agricultultural zones in the department addresses only a small cross-section of the immediate priorities. Not only does the classical program need to be made more flexible to adapt to local variations in soils, ecology, and household economy. It must be

supplemented with additional programs directed to other rural development issues. Redirection of a substantial portion of project resources is implied. The zonation study identifies priority problems as experienced by the rural population and offers guidelines for future actions.

The Nigerien government has already shown its capacity to respond to the changing priorities of rural development. New policies and programs have been defined and are being elaborated as a result of national conferences such as that held in Zinder in late 1982. Its recent effort, for example, to promote dry season gardening, and indeed promoting the idea with vigor, has united the population behind a single theme that (according to many farmers) has produced lasting positive changes in their lives.

The Farming Systems of the Niamey Department

The following section characterizes selected aspects of the cultural groups inhabiting the different agro-ecological zones and sub-zones of the Niamey Department, the production techniques they employ, and the environmental limitation relative to these techniques. Possibly, the most important factors presently confronting agricultural development planning are adaptation to climatic change and population growth. The associated constraints are well-known: limited land availability, shortened fallows, declining soil fertility, deterioration of the vegetation, overgrazing, animal mortality and loss of organic fertilizers, increased erosion, and reduced productive potential. The social consequences constrain development potential as well: increasing proportions of producers subsisting only on borrowed land, limited access to better farmlands, less desire to invest capital in agriculture, monetary needs that remove labor from the household fields, stress and breakdown of a communal or village ethic, and enhanced competition between differing economic/ethnic groups for control of resources and stability of tenure. Macro-economic factors especially of grain and commodity price structures narrow further the available options.

Farmers are aware that the old ways are incapable of effectively dealing with the current agricultural crisis. They perceive that for the past 20 years, good rains or bad, the quality of their environment is declining. Trapped by monetary pressure in a climate of limited opportunity, they are actively searching for and are open to new answers. They are experimenting with new varieties and fertilizers, changing fields from one soil type to another, and changing labor allocation strategies. Expectations are shifting from one season's crops to another's, from rainfed to irrigated agriculture. Economic diversification- commerce,

transport, (hence the greater interest in ox and donkey carts than most other themes of the current package), migration and local wage labor- are increasingly necessary to reinforce rural shortfalls; failing that, only government food assistance mitigates human tragedy in drought years.

The impacts of rural change are not spread evenly by region, nor evenly within the population of a given region; ecology and political economy underlie and accenturate this differentiation. Overcoming the agricultural crisis implies agricultural intensification, but this can only take place if the environment's productive potential is maintained. Development that creates or reinforces certainty and predictability coincides more closely with producers' needs than innovations which create debt and uncertainty. Productivity, therefore, must be conditional to priorities of environmental conservation and, where it is still possible, restoration.

In an environment of increasing aridity, erosion is outpacing the formation of new soils. In some parts of the department, soil loss is irreversible and catastrophic. In others, moving sands threaten productive areas and lakes and thwart young plants by sandshearing. The potential to halt degradation, to institute positive changes, and to raise farmer productivity and incomes exists but cannot successfully be addressed by any one single formula. Problems, farmers, and possible solutions vary from place to place.

Outlining this regional diversity constitutes a first step in refining the priorities for development assistance. The following section addresses the department's farming systems. There is risk of overgeneralization and, at times, oversimplifying the complex mosaic that is the Niamey Department. Where such shortcomings, however unavoidable, are noted, it is hoped that

they provide the stimulus for continued clarification and understanding, thereby leading to the design and implementation of more responsive programs.

The discussion of systems of production does not attempt to be exhaustive, but rather to accent those elements that most clearly expose the current constraints and indicate the most promising development prospects. A general discussion follows which attempts to re-evaluate the applicability of the present productivity package. A final section presents conclusions and recommendations.

Figure 10 depicts the geographic regions referred to in the following analysis of the Department's farming systems. Refer back to Figure 9 for the agro-ecological zones.

Analysis of the Farming Systems by Zone and Subzone

The Pastoral Zone

General Considerations

This zone consists of a variety of different landscapes. The varying geomorphology, hydrology, and vegetation associations are associated with differing seasonal availability of grazing and water resources. The zone includes the northern reaches of the Sand Valley and Plateau sub-zone, the vast Dune and Sand Plains systems of the northern portions of the Filingue, Ouallam, and Tillabery Arrondissements, the northern portion of the Dallol Valleys, and the Dune, Inter-dune, and Mare system of the Northern Tera Arrondissement. Several important valley areas, notably Garoual and the Northern Dallol Bosso and Zgaret, contribute to the diversity of grazing habitats. The zone is populated by Tuareg, Bella, and Peul herders. Important concentrations of sedentary Djerma-songhai and Hausaphone groups were attracted to the region in wetter periods only to be caught by the

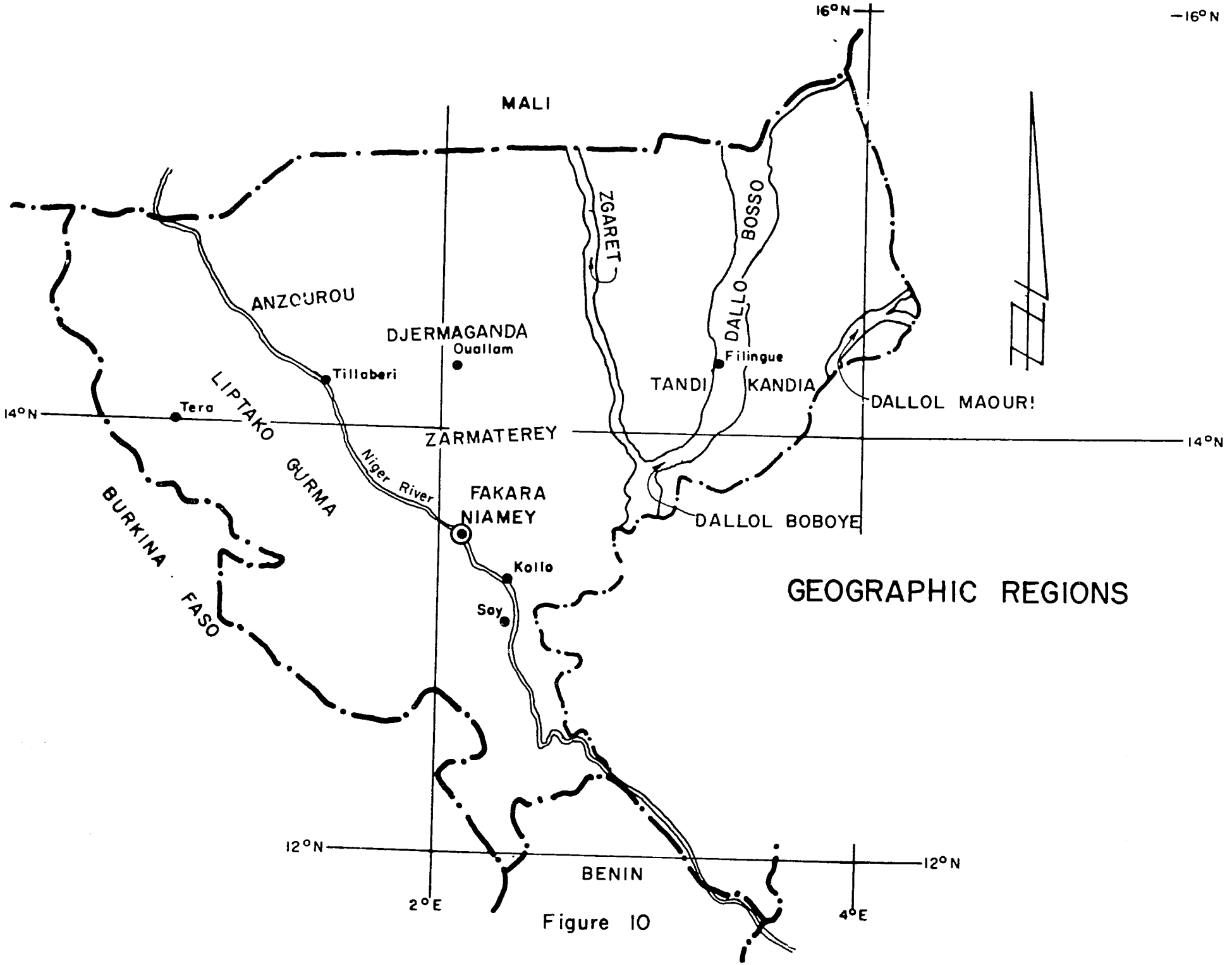

16°N
16°N
MALI
ZGARET
BOSSO
DALLO
ANZOUROU
DJERMAGANDA
Ouallam
Filingue
Tillaberi
TANDI
KANDIA
DALLOL MAOURI
14°N
Tera
LIPTAKO
ZARMATEREY
14°N
GURMA
Niger River
FAKARA
NIAMEY
DALLOL BOBOYE
BURKINA FASO
Kollo
Say
GEOGRAPHIC REGIONS
12°N
12°N
BENIN
2°E
4°E

Figure 10

recent southward migration of West Africa's major climatic belts. The presence of farmers in an area now best suited to livestock production presents an interesting challenge.

The pastoral systems were not studied in any detail by the team. At the time of the fieldwork, furthermore, most of the zone's surviving herds and much of the population had abandoned the sahel for sudanian rangelands to the south. The attempt to stabilize populations within the zone can best succeed through policies which acknowledge the need for periodic long distance movement of livestock. Optimal use of the forage resources offered in the area depends on considerable flexibility. Economic alternatives are limited irrigated gardening and highly risky, environmentally questionable rainy season millet cultivation. Water capture may offer limited means to better assure some harvest from rainfed agriculture, but its potential is limited to a small portion of the area currently being cultivated. A substantial commitment of labor would also be necessary. It is unclear how such innovations would fit into the existing organization of labor, especially among pastoral groups. Further study is necessary to determine the zone's capacity to support irrigated and water harvest agriculture, the potential economic returns to these activities, and the social consequences of their development. It is unclear what portion of the population could be expected to benefit from an active attempt to develop new forms of intensive cultivation.

Settlement History

The nineteenth century marked the height of the southward thrust of Tuareg control in the pastoral zone. All elements of the nomadic society were represented including noble, artisanal castes, and captives. Sidikou (1974:161-162),for example, identifies three Tuareg lineages inhabiting the

zone between the Niger River and the Zgaret. With colonial rule the internal structures of this society were gradually weakened. Many former captives moved southward sedentarizing near the limits of the agricultural zone. This process accelerated after World War II.

At that time various groups of Peul, notably the Djelgobe from the west, the Issabe, and the Peul of the Southern Dallol, migrated into the pastoral zone. In the Filingue area, groups of Wodaabe were pushed northward to and beyond the Abala region in the Dallol and onto the surrounding plateaus. Their settlement stopped at the Zgaret where Djelgobe were encountered. This northward movement of Peul was occasioned by the substantial northward migration of Kourfeye (Beauvilain 1977:70-75, 201). He notes, for example, prior to 1933 almost no Kourfeye resided north of Filingue whereas by 1965 the total had reached 21,391. Only one village existed in the administrative territory of Abala in 1933, but by 1972, forty-two villages were counted.

In the decades preceding the 1968-1973 drought, Tuareg were moving southward which constricted the available rangelands and concentrated animal populations. The reserve at Toukounous further reduced important dry season pastures. The 1972-73 drought served to expose the excessive demands on the area's resources that this concentration of competing production systems had brought about. Prolonged drought has continued to aggravate resource conflicts. In many areas, environmental degradation is severe.

Organization of Production and the Dominant Agro-sylvopastoral System

These northern groups remain strongly nomadic and move over wide areas in order to capitalize on resources widely distributed in both time and space. Traditionally, seasonal migrations are northward during the rainy

season when grazing and water resources are abundant. Also, southern herds transhume into the pastoral zone and graze near the dry season pastures of the nomadic groups. Herds concentrate near water points in the dry season: lakes, bore wells, and shallow traditional wells.

In recent years, the cumulative impact of drought, northward expansion of cultivation, and southern migration of herds have undermined the stability of rangeland exploitation. With resources no longer sufficing, long distance transhumance south to the remaining bush areas in Southern Niger, Burkina Faso, and the neighboring coastal states is becoming increasingly common. These groups supply the Nigerian economy with a substantial quantitiy of meat (despite the ideal of avoiding the sale of animals); their production system should be weighed in conjunction with planning for the agro-pastoral zones in the Say and Southern Kolo Arrondissements.

Sand Valley and Plateau Subzone of the Southern Pastoral and the Northern Intermediate Zones

General Considerations

This portion of the Sand Valley and Plateau system is distinguished by its low rainfall, low agricultural potential and rapidly deteriorating resource base. It covers much of the central portions of the Ouallam and Filingue Arrondissements, and the west-central portion of the Tillabery Arrondissement. This vast agro-ecological unit breaks down culturally into several sub-units, the most important of which is known traditionally as Djermaganda. Portions of Tondikandia and the Kado villages of the Eastern Anzourou region are also included.

Djermaganda comprises the central portion of this low plateau and is bounded in the north by the vast sand plains of the Pastoral Zone, in the west by the Niger River and the linear dune formation of the Tillabery

Arrondissement, in the east by the Zgaret, and in the south by the related region of Zarmaterey. The population is overwhelmingly Djerma (98.4%), but its distribution and settlement density relative to agricultural resources vary greatly throughout the region. A few Peul live interspersed in Djermaganda but constitute only 231 of the Ouallam Arrondissement's 16,597 farms (Republique du Niger, 1980, vol II, p. 395).

After French conquest, the area was grouped into administrative units, evolving to the present division of the Ouallam Arrondissement into the three cantons of Tondikiwindi, Ouallam, and Simiri.

Because of the area's location, the seasonal variability in precipitation renders rainfed millet production especially uncertain in all but the southernmost fringes of the Simiri Canton. Virtually the entirety of the Tondikiwindi Canton falls within the newly delimited Pastoral Zone. The current drought has underscored the vulnerability of the area's farmers and seriously called into question the advisability of approaching agricultural development from a strictly productionist point of view.

Of necessity, the Djerma inhabitants of the region pursue a diversified set of strategies for earning a livelihood. Dryland millet production forms only one aspect of the household economy. "L'exode," or seasonal migration to seek off-farm income, remittances from permanent or long term out migrants (often of the same lineage but not properly a part of the household per se) livestock raising, intermittent wet season wage labor, hunting (now essentially historic), secondary economic activity (generally crafts and commerce) are but some of the "other" income sources. In recent years dry season gardening and acquiring food aid have become important elements of the subsistence strategy. The economic complexity of the rural economy of the region, now being researched, remains a vital

consideration in the design of sensible development efforts aimed at the farmings system of the region.

Settlement History

The origins and duration of settlement of the Djerma in the Djermaganda Plateau remain unclear. The paucity of scholarly attention to the area contributes to the controversy as to whether the Djerma are autocthonous or whether they entered the area only at the zenith of Songhai domination of the Central Niger River Basin. The latter view would hold that Djerma migration continued as the Almoravid Moroccan conquest in 1591 of the Songhai Empire gradually displaced this group to the south. Songhai and Djerma legend both recognize a common ancestry tracing to the Hombori region of Mali. Whichever be the case, the Djerma were firmly established in the region by the nineteenth century when Peul and Tuareg dominance in te country reached its peak.

In the northern reaches of this region of Djerma hegemony, about which we are speaking here, it was the Tuareg who posed the greatest threat to the Djerma farmers. In response, a process of village agglomeration ensued which led to the creation of larger villages such as Simiri. This process gave rise to an embryonic socio-political organization in which wangari, warrior overlords, dominated an approximately equal number of servile families within the village and extending perhaps to a few neighboring hamlets. Farmers at that time seldom ventured far from the immediate village and were constantly alert for surprise attacks from mounted Tuareg raiders. Village sites were thus chosen relative to the degree of protection that they offered. These older villages tended to be nestled near the rims of the ironstone plateaus or along the important drainages where a dense vegetation cover provided protection. Location, coupled with

the deadly arrows for which the Djerma and Songhai were famous, resulted the Tuareg warriors' giving a wide berth to the Djermaganda heartland and pillaging only a few of its northern outliers.

The insular nature of this settlement history resulted in the area showing a considerable degree of cultural homogeneity at the time of French conquest. Direct rule of the conquered territory proved impossible, and the colonial administration attempted to create a political hierarchy by designating the wangari as canton and village chiefs and governing through the newly created structures of power. The unpopularity of certain chiefs and the even greater desire to escape repressive policies led once again toward the dispersion of the Djerma population away from the larger villages toward the vast unsettled expanses, that were still common at that time.

Recurrent famine contributed to this tendency toward dispersion which was further facilitated by the rural pacification imposed during the colonial period. Periodic attempts to regroup villages, first by the colonial administration and later after independence, counterbalanced the trend toward village fission.

Farming Systems and the Organization of Production

The dominant landscape pattern of the region, to repeat, is one of low plateau tops dissected by the valleys of intermittent watercourses. The ensemble is partially overlain by a mantle of aeolian sands of varying depth. The arable soils, described in detail elsewhere in this report, are limited in their distribution as well as in their potential. Moisture deficits, either from lack of precipitation or from the poor water retention capacity of most soils, limit agronomic potential. Intervening pasture and forest lands offer limited possibilities; many areas are

already severely degraded. The dominant agro-pastoral production systems are constrained by these physical limitations as well as by socio-economic and historical factors that define such important determinants as the land tenure system, land availability, and the social relations of production.

The Zarma of the region are overwhelmingly peasant cultivators, but their long tenure in this marginal zone has accustomed them to the risky nature of dryland subsistence farming. Millet, followed by cowpeas, sorghum, and okra are the traditional crops, however, as noted by Stier (1980:14) reliance on other crops and food grown outside the region is characteristic. Although economic data are lacking, it can be concluded that the rural economy is adapted to the overall condition of being a net deficit region as far as cereals production is concerned. This conclusion differs from the qualified 1978 estimation of the area as being approximately at the level of food self-sufficiency (Republique du Niger, 1978). Whatever the exact measure, the past several years have proven disastrous; peasant grain reserves are exhausted as are livestock holdings. Climatic trends portend slim possibilities of returning to pre-drought levels of production.

Sustained levels of food self-sufficiency are not likely to have characterised the past. Sidikou (1973) lists a series of droughts spanning the last century:

Year	Name	Description
1891	Kau-kau	crushing of calabashes for flour
1900-1903	iznere	the "sell your children" drought. Nephews especially were sold in the hopes of saving some family members. Cadavers were too numerous to bury.
1911-1914	yollumoru or gandiberi	the "stroke your hair" or "everywhere present" drought
1929-1931	zamo kano or sudan	the "cutting knife" drought, selectively killing large numbers. Aggravated by poor response by the colonial government.
1954-1955	gari	so-called because manioc flour was widely imported from Benin to prevent starvation
1965-1966	bandabari	"the turn your back drought" because farmers with grain were afraid to help their neighbors.
1968-1972	mata ai ga te	"what shall I do" drought. Systems for coping with drought had broken down.
1982-present	no name	local farmers refuse to give this drought a name until it is over, "it may get worse"

This chronology is repeated to underscore that the current situation is characteristic of the area's agricultural uncertainty. Drought and crop failure are periodic, albeit unpredictably, indicating that development programs should stress reducing risk and not increasing production *per se*.

Land Tenure

The settlement history described above underlies the current system of land tenure in the Djermaganda region. Most villages were formed by a single or several families who began cultivating in previously virgin soils. Land rights were accorded to the first cultivators who expanded their holdings by not returning to fields already cultivated. This practice continued until all village lands were occupied and the village lands extended to the fields of the surrounding villages. Once cultivated, rights to a field remained with the cultivator. As population grew, the earlier fields were passed to newer members of the patrilineage. This process continues to the present. Relative land shortage varies greatly within Djermaganda.

Established villages receive newcomers but these families (frequently tied to the original families through matrilineal relationships) have usually only been able to borrow fields. When the fields are abandoned to fallow, ownership reverts to the lending family.

Garden plots are given freely. Land ownership seems to be defined more in terms of permanent rights to wet season cultivation. Government policy is that access to areas with gardening potential should be granted to those making the request to the field's owner. Tenure on garden plots has not been a problem in the past, however the recent interest in "cultures de contre-saison" and the associated development programs raise new and unanswered questions concerning:

- access to areas of high dry season potential to farmers in nearby villages with low potential
- division of space within fenced perimeters
- loss of farmland to permanently fenced areas
- gender issues

Taking the example of the village of Tokolbaye (20 km south of Ouallam), one can see the interrelated nature of these issues. A fenced perimeter was recently installed adjacent to an area traditionally given to dry season gardening. Tenure was granted on the basis of whether or not a family head decided to sign a petition for the request of land at some time prior to the actual construction. About half the village households (81 of 156) signed. By the time the project was implemented all household heads wanted a plot. The owners of the fields taken out of production received no compensation. Women received no plots despite the fact that they frequently provide the majority of the farm labor for this activity. Ownership was accorded to those who had signed the petition and these had been male household heads. The project appears generally successful, but indicates the need for a greater role in planning this type of intervention.

Organization of Production and the Dominant Agro-sylvopastoral System

Detailed studies quantifying input and outputs of the Djerma farming systems of the zone do not yet exist; data from the ICRISAT research village of Samari in the southern Ouallam Arrondissement should soon fill this lacuna. Comprehensive descriptions of the structures and functioning of the agricultural production systems can be found in Sidikou (1973, 1977) and are summarized by Stier (1980) and Painter (1980). The major elements of the farming system will be touched upon here, but the primary objective is to complement the rather static picture drawn in these accounts with the perceptions of change gathered during the field interviews. The focus on change reveals the current concerns of the peasantry and thus, in large measure, the directions for future research and extension.

The Djerma farm reflects the social organization of the household. Notwithstanding the considerable variation that does exist, agricultural

space may, nonetheless, be broken into the following major divisions: house gardens (kali), in-village fields (koiratie), bush fields (zigi), dry season gardens, and sylvo-pastoral lands. Most of the total wet season cropland falls under collective household management directed, in principle, by the windi koy or household head, but some cultivation of individual plots (kourga) contributes to the evolution of sub-economies within the household. Collective fields (windi fari) under the direction of the windi koy are geared to providing subsistence food grains for domestic consumption despite the inevitable need in most households to sell part of the production to meet cash needs. In surplus years, grain was sold to acquire livestock. The high animal mortality of the 1968-1972 and the 1982-1985 drought coupled with the general recognition of the degraded condition of grazing resources has at least temporarily dampened enthusiasm for investment in livestock.

Millet is overwhelmingly the major crop in the northern Sand Valley and Plateau System. In Ouallam 96.8% of the total cultivated area was planted in millet and only about one half of this area was in association with cowpeas. Data concerning the area of both wet and dry season gardens are non-existent. Specific information concerning intra-household field ownership is also lacking.

There is some evidence that larger farms are employing considerable wage labor; about one third of all cropland is in farms of over 10 ha.; however, as discussed below, "Man ti fari ma beeri ka ti hayni" (It's not the size of the field that determines the production)." (Hama 1978:61).

Farm Size

Stier (1980) estimated that 71% of all farms in the Ouallam Arrondissement were under 3 hectares and 82% were under 4.6 ha. This would render the donkey and oxen traction package uneconomic for the vast majority of the areas farms at their current size. Our interviews would indicate that although additional land is available in some villages, it is generally difficult at the present population densities to adequately fallow fields. The interviews took place in villages that fall in the two major regions of population concentration in the arrondissement, so it would be expected that the capacity for extensification is greater in the more remote portions of the Sand Valley and Plateau zone. (see population distribution map)

The capacity for extensification varies considerably not only from village to village, but equally importantly, it varies as a function of the household's access to resources. The issues that distinguish one household or one individual from another in terms of resource acquisition and resource allocation have not been studied and deserve attention.

Stier gives an average farm size of 2.56 ha. from the 1979 NDD survey, but lists an earlier survey figure of 6.5 ha. A more recent census (Republique du Niger, 1980) concurs more closely with the higher measure in providing a figure of 7.3 ha. cultivated per exploitation. Only slightly over half the farms were under 7 ha. It is possible that declining yields are leading to an increase in area cultivated.

Test Villages

Garbey is located 10 km. east of Ouallam along the unimproved road that connects Ouallam and Filingue. The village exemplifies the pattern of village formation by regroupment of dispersed hamlets in the face of

adversity. The village was formed through the consolidation of the hamlets of Tiloa, Gabikan, and Fandou during the nineteenth century while the region was under threat of Tuareg raids. Initially, the village consisted of five family heads (windi koy). Currently, population growth has brought the total to 101 family production units and a total population of 1,134 inhabitants. The village has a school, a government television center, and a sizeable mosque. Males from the village are participating in an adult literacy program.

Land is relatively available within the village, although the traditional system for soil fertility management is breaking down. Traditionally, fields were cultivated for 4-5 years and fallowed for three, but now must be cultivated almost continuously. Fields may be borrowed from a neighboring village as if they were village lands as the inhabitants from the other village are of the same lineage. Field distribution between households and lineages is largely a function of how one's ancestors chose their initials fields.

The village is situated adjacent to a small lake next to an intermittent stream course which flows southward down the valley bottom. A long ironstone plateau about 4 km. east of Garbey forms the headwaters of several tributary streams which flow westward dissecting much of the village's badly eroded upslope fields. One of these streams recently changed its course threatening part of the village and flowing directly into their lake which is rapidly filling in with sediments eroded from their fields. Over half the lake has been lost in the last three years and it now dries up by January; it used to be nearly permanent.

The villagers seem unified in their desire to protect their lake and to stabilize the degradation of the village's agricultural base. They have

tried four times to divert the stream's course away from their lake and their village by constructing hand built earthen dams; this was done on their own initiative and independently of government intervention. All attempts have failed as they were not integrated with the types of soil and water conservation techniques needed to control the runoff from the stream's watershed.

Dry season gardening around the lake has come to play a major role in village food production. The villagers have practiced it for some time, well before the current political campaign to popularize it. Previously, calabashes, manioc, wild melon, and cotton were grown. Presently, a host of garden crops is produced, depending on what seed is made available by the government.

The village environment typifies the agricultural situation of the Intermediate to Pastoral Zone transition. Gully control, water spreading, contour dikes and/or microcatchments for water capture, windbreaks, plantation of widely spaced Acacia albida field trees and improved dry season garden possibilities could from the cornerstones in a village level program to address the major agricultural constraints.

Dune, Interdune and Mare Subzones and the Sand Plain Subzone of the Tera and Tillabery Arrondissements

General Considerations

The Dune, Interdune and Mare system covers about half of the Intermediate Zone within the Tera Arrondissement and extends north into the Pastoral Zone of the Tera and Tillabery Arrondissements. These subzones include landscape units of Dune, Interdune, Mare and Outcrop. They are characterized by large linear deposits of eolian sands which obstruct or partially obstruct drainage resulting in numerous "mares" or shallow lakes and marshes with a seasonally fluctuating water table. These occur both along major drainages and in basins within the dune formations. The Sand Plain Subzone of the Intermediate Zone in southeastern Tera Arrondissement has a higher population density and a much higher percentage of arable land than the Dune, Interdune and Mare Subzones, but it is generally similar in its socio-economic characteristics, and the following discussion applies to both areas.

The region is populated by Songhai farmers, Bella farmers and herders, and Tuareg and Fulani herders. It is bisected by the Niger River Valley which is treated separately. Agricultural potential varies tremendously from south to north. Figure 9 shows the newly defined Pastoral Zone now dividing the Arrondissements of Tera and Tillabery where it once passed north of the Niger border. Both areas, like Ouallam, have been hard hit by the recent drought.

Settlement History

Songhai migration southward from Mali in the fifteenth and seventeenth centuries initiated a process of Songhai settlement in what is now the Tera Arrondissement. The area's original inhabitants, the Gourmantche, were progressively displaced toward the Sirba River which now

forms the boundary between Tera and Say. During the nineteenth century, these groups expanded their occupation of the zone's better farmlands, forming a series of quasi-states, principally Tera, Kokoro, Ouanzerbe, Namaro, and Dargol. Peul herders also infiltrated the zone occupying bush areas between the major villages and exploiting the rich dune and bas-fond pastures. The same southward push of Tuareg settlement and domination that altered the political scene in Djermaganda and the Dallol Bosso played an equivalent role in the region.

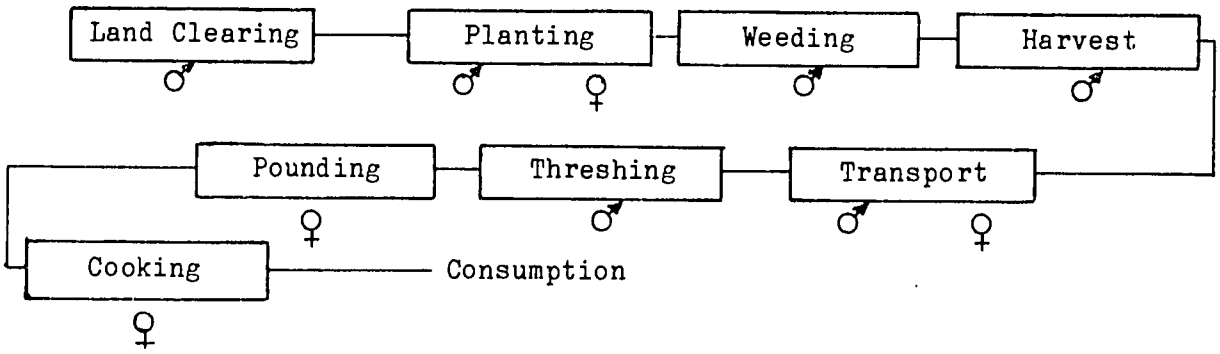
During the nineteenth century there was a series of shifting alliances among these groups, which Olivier de Sardan (1984:62-71) classifies as essentially feudal, for a variety of reasons including raiding to acquire anew or recover stolen cattle, recovery of captives harbored in a rival's village, restitution in crop damage cases, and refusal to pay tribute.

The economy and political structures have undergone a profound transformation in the twentieth century. Monetary pressures and desires were instrumental in stimulating the institution of labor migration. The creation of cantons has reinforced the tendency of land ownership. Nomadic groups have tended to settle more permanently especially those belonging to formerly servile castes.

Organization of Production and the Dominant Agro-sylvopastoral System

The social organization of production among the Songhay closely resembles that described for the Djerma regions located east of the river, as indicated in Figures 11 and 12 (Olivier de Sardan, 1984:111). Several characteristics distinguish the dominant agro-sylvo-pastoral systems from those of Djermaganda. The key differences are environmental. The pasture resources of the zone are both more abundant and of higher quality, water is better distributed and more permanent water sources are

FIGURE 11 Songhay Sexual Division of Labor for Millet Production



Source: Olivier de Sardan, 1984:111

FIGURE 12 Songhay Division of Labor for Other Than Millet Production

MEN	WOMEN
- Hunting	- Gathering
- Rope, thatch, secot production	- Draw and carry water
- Construction	- Collect firewood
	- Gardening
	- Weaving (baskets, mats, etc.)
	- Spinning, rope making

Source: Olivier de Sardan, 1984:111

available. As a result, agriculture and livestock raising are more completely integrated and the production systems have evolved to reflect this fact. The region's growing population, the prolonged dry period of the past nearly two decades, and the accompanying environmental degradation undermined the symbiosis between crop and livestock production. Both systems are breaking down. The following discussion attempts to characterize this transformation from the sedentary Songhay perspective.

Crop mixes and recent changes. Prior to drought in the late 1960's, the main crops grown in household fields were red millet (hainichiri), sorghum (hamo), and "red" long-cycle cowpeas (doungouchiri). Areas planted in sorghum have been greatly reduced. Many farmers no longer cultivate sorghum. Short-cycle millets are beginning to displace the traditional varieties.

The shorter growing season means that harvests of cowpeas are no longer likely as they were inter-planted with, but subsequent to, red millet. Increasingly, short cycle cowpeas ("nasara" doungouri) are being subsitituted for the previous variety. The new varieties are not interplanted because their growth cycle too closely parallels that of the millet; field micro-climate is too humid and shaded. The impact has been two-fold. Less area is being allocated to cowpeas. Secondly, the new varieties produce few leaves and runners which provide the all important forage output. The economic value of cowpea hay (for use or sale) was reported by some farmers to be the primary reason for its cultivation. The new varieties are being grown and the cowpeas are often planted in low-lying areas in the fields which are also where women customarily have their fields. It is not known whether this might portend future conflicts.

Changes in location of fields. The Songhai classify their farmlands into three broad categories: gangani fields, botogo, and hondu fields.

There is a danger in overgeneralizing these local taxonomies. Gangani is defined as either (1) bare exposed ground (non-sandy) devoid of vegetation, (2) relatively bare surfaces closed by a hard crust which can be clayey or sandy (with ferric or argillic materials that permit this crusting), or (3) a seasonally flooded plain such as occurs on many plateau tops.

Botogo refers to dark clays (banco) which are usually found in depressions or in valleys (gorou). Botogo fields are usually women's fields; they are usually more fertile but also much more labor intensive in their cultivation. Hondu is the Songhai (Djerma) term for dune; it translates fairly strictly. Hondu fields are sometimes called tassi. This latter term refers to a much broader set of sandy soils, only a few of which are associated with dunes.

The recent changes may be summarized as follows. Gangani fields are being progressively abandoned. Hondu fields are both much more common and much larger than previously. The implications of this shift to production and farm mangement are profound. To equal the production of a gangani field, a hondu field must be several times larger (as reported). Crops in gangani fields cannot support drought periods during the season.

Sand Valley and Plateau and Sand Plain Subzones of the Agricultural Zone, and the South-central Portion of the Intermediate Zone East of the Niger River

General Considerations

The Central and Southern (Rive Gauche) portions of the Sand Valley and Plateau Subzone and the Sand Plain Subzone in the southeastern portion of the Kolo Arrondissement are treated together. The area is known locally as Fakara in the south and Zarmaterey further to the north. (See figure 10). Also included are portions of the Zigyi east of the Dallol Bosso. Fakara and Zarmaterey occupy the vast majority of the cantons of Koure, Dantiandou, N'Dounga, Libore, Niamey, Karma, and Hamdallaye in the Kollo Arrondissement. The designation Fakara is sometimes confined to the canton of Dantiandou, but here it is used in its broader sense. The area is bounded on the west by the Niger River Valley and on the east by the Dallol Mawri. The southern limit is determined administratively by the boundary with the Dosso Department, and in the north it merges imperceptibly with Djermaganda. The eastern portion is bisected by the Dallol Bosso (Boboye) which is treated as a distinct agro-ecological zone. The Niger River Valley and peri-urban belt around Niamey are outside this zone. The portions of this zone that lie west of the river are discussed separately in a subsequent section.

Settlement History

The same uncertainty that characterizes Djerma settlement of the Ouallam (Djermaganda) applies equally to the Fakara and Zarmaterey. Unfortunately, the ethnographic literature for the region is even more scant than for the area further north. The pervasive XIX century conflicts and competition for hegemony that encompassed virtually the entirety of Niger affected these southern Djerma rather differently than their

northern cousins. The Tuareg threat that drove the northern Djerma to seek refuge in the canyons and valleys did not extend to Zarmaterey and Fakara.

Rather, the plateau's valleys and basins sheltered the Djerma from the expanding Peul domination of much of the southern Dallol Bosso and environs of the Niger River Valley. Olivier de Sardan (1984) speculates that the Djerma of this region are of quite diverse backgrounds. Beauvilain (1977) reports that pacifist Djerma fled the aggressive raids of the Peul under Boubacar Louloudji who represented the expansion of Islam under the tuteledge of the Sokoto Caliphate. Population movements within the zone during the nineteenth century often involved rival groups seeking to establish and maintain villages around defensible water sources. Twentieth century population movements are a product of the forces of village fission and regroupment described in the preceeding section on Djermaganda.

Organization of Production and the Dominant Agro-sylvopastoral System

The dominant agro-sylvopastoral system consists of small household farm units wherein rainfed millet and cowpea cultivation constitute the principal agricultural acitivities. A variety of lesser crops including sorghum, manioc, maize, okra, and sesame are also produced. Dry season gardening is now widespread, but its potential is limited by a general lack of surface water and low water table as well as by massive seasonal labor migration. Small ruminants are kept on and around the farm, but cattle are usually entrusted to Peul agropastoralists who co-inhabit the region. The Peul comprise a relatively higher percentage of the population in the south (Kirtachi) where pasture is more abundant and the Peul enclave of Say is in close proximity. Except for the extreme southern portions of the higher rainfall subzone, land scarcity is, or is becoming, an important constraint to increasing crop <u>and</u> livestock production.

Farm Size

Average farm sizes for the region are based on all farms in the Kolo Arrondissement; nonetheless, they should, insofar as the statistics are accurate, be fairly representative of the sub-zone under discussion. Stier (1980) estimates 56.3% of the Kolo Arrondissement farms to be under 3.0 ha. and 71.2% to be under 4.6 ha. These farm sizes represent hypothetical threshholds above which donkey and oxen traction, respectively, may be profitable. She cites two other surveys (1977 and 1979) which support these figures, both concurring an average farm size of 3.7 ha.

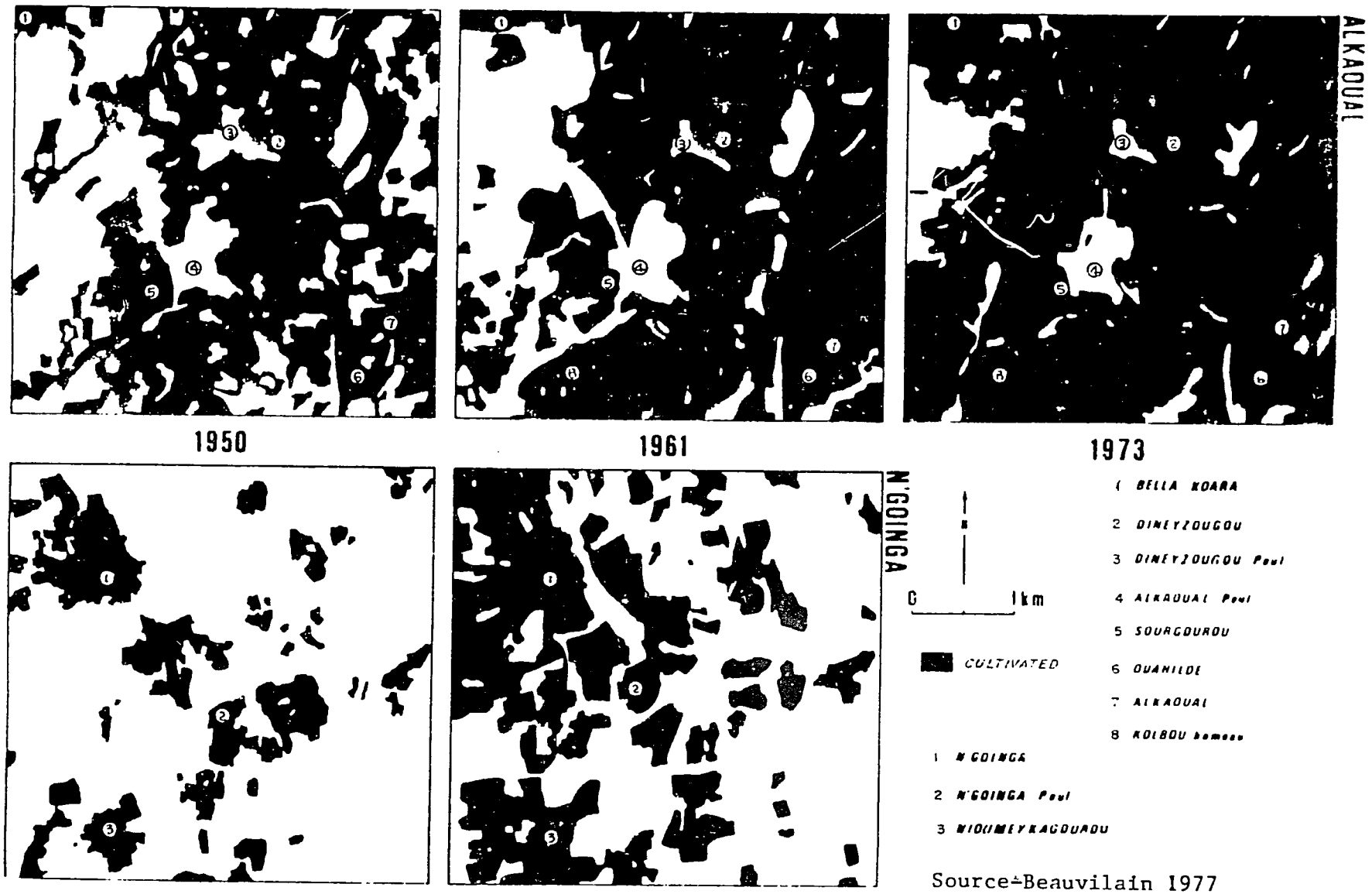
In contrast, the 1980 (vol II:433) agricultural census reported average farm size at 5.2 ha. for an average household size of 8 individuals. 47% of all farms are reported to cultivate less than 5.0 ha. and 32% of all households cultivate less than 3.0 ha. Although less dramatic than the earlier surveys, these figures further reinforce the supposition that the potential profitability of animal traction based intensification is confined to the sub-zone's larger farms. In most areas land resources limit the possibilities for extensification.

These figures are very different from those of the Northern Sand Valley and Plateau Zone (Djermaganda and Tondikandia). In Filingue farms over 9.0 ha. accounted for 53.5% of the total land area under cultivation, in Ouallam 39.4%. In Kolo, by comparison, only 2.4% of the cultivated area occurred on farms larger than 9.0 ha. This probably reflects the greater constraint on land availability reported in the village surveys; more importantly it reflects differences in cropping strategies. The smaller farms and the smaller area cultivated per active member may indicate a greater propensity toward intensification.

It appears that the farming strategy pursued in the riskier northern farmland (Filingue, Ouallam, and Tera) involves planting as large an area as possible with different varieties and in different micro-habitats and to weed only on a priority basis those areas that show the greatest promise of substantial harvest. These may vary from year to year based on the differing combinations of rainfall patterns, soils, and seed (and crop) varieties.

In comparison, the smaller areas cultivated by Kolo farmers are associated with the zone's relatively greater predictability, and a corresponding emphasis on more timely and thorough weeding. Farming systems research would clarify these differences. In the absence of such data, the informal surveys carried out by the zoning team provide surrogate measures that would support these contentions. The reported decline in fallow periods, the difficulty expressed in borrowing fields, and a much higher interest in obtaining fertilizer (with short term credit) are indicative. These same problems were repeatedly stressed in the villages of the Fakara and the southern Dallol Boboye. Figure 13 taken from Beauvilain's 1977 study of the Southern Dallol area indicates the rapidity and recency of the expansion in cultivated lands. He reports that by 1973 N'Goinga was 100% cultivated compared to the only 47% shown on the 1961 map. Overall, the farmers of the region seemed strongly interested in animal traction, but stated that credit was essential if adoption on a large scale was to take place. Concerning CPT trainees, candidates were invariably selected from large families with large holdings who could "afford the risk and lost help in the fields."

EXAMPLES OF CHANGE IN THE AREA UNDER CULTIVATION



Source: Beauvilain 1977

Figure 13

Test Villages

Two test villages were chosen in this area. Sourgourou is located in the Sand Plain Subzone of the Agricultural Zone in southeastern Kolo Arrondissement and Kouara Tegui in the central portion of the Intermediate Zone within the Sand Valley and Plateau Subzone.

Sourgourou is a fairly large closely grouped village which is located in the rolling Sand Plain Subzone. Interest in animal based traction and fertilizers was high. Although some problems had occurred in the supply of previous CPT graduates with their equipment, commitment was strong enough that several wealthier farmers had purchased the major implements of the current package with cash (oxen, charette, cultivateur). Women were represented in large numbers and actively participated in the informal survey.

Kouara Tegui is located in the southern portion of the Simiri canton of the Ouallam arrondissement. It is dispersed into several sub-village clusters and a main concentration of concessions around the village chief's dwelling. It is a fairly young village, the current village chief being only the second. The extreme conditions of the drought in the 1930's prompted the fissioning of a nearby village with one contingent settling in Kouara Tegui. The village was chosen as a CVF site for the 1986 campaign.

Alluvial Valley and Upland Subzones of the Agricultural and Intermediate Zones

General Considerations

The populations of the Alluvial Valley and Upland Subzone are diverse: sedentary and semi-sedentary Fulani live throughout the zone: several Djerma villages reach its eastern limit, a slight penetration of Songhai defines the northern and western extremes, and in the southwest, toward the

Burkina border, the Gourmantche dominate. Some sparsely populated areas are being actively colonized for agricultural purposes. This important spontaneous migration has received no documentation.

Concerning background materials on the populations and farming systems of which they form a part, we are here without guidance.

USAID sponsored a major farming systems research project in the Eastern Region of Burkina Faso, and much of this is probably directly applicable to the conditions found in southwestern Niger. The question should be addressed before conclusions are drawn. Given that the clay valleys offer some of the most promising possibilities for animal traction packages and that considerable scope exists for expanding the areas under cultivation, a better understanding of this part of the Department should constitute a priority. The Say Arrondissement was included in Phase II of the Productivity Project, yet the very different social and ecological conditions which characterize the zone remain to be examined.

Settlement History

The Gourmantche formerly occupied nearly all lands west of the Niger River from the present Malian border in the north to the Burkina and Benin borders in the south. Their population densities were never very high and this made them somewhat easily displaced by aggressive groups, such as the Songhai, in search of new homelands. The Gourmantche are related to the Mossi of Burkina Faso. Both trace their ancestry to the same royal family at Gambaga in what is now Northern Ghana. In the distant past, probably in the thirteenth century, the Mossi conquered the region of Tenkodogo in South-central Burkina from which subsequent generations rapidly extended hegemony over vast areas of the central sudan. One branch of the conquering nobility under Diaba Lampot established its seat at Fada N'Gourma, but

subsequently drifted away from the other Mossi kingdoms. From Fada the Gourmantche dominated Djelgodji and the entire Liptako Gurma for centuries. Only later were they pushed back to their present bounds (during the seventeenth to nineteenth centuries) by the Peul from Djelgodji and Liptako, by the Songhai from the Nigerian portion of the Liptako-Gurma and by various groups from the Niger River Valley. Gourmantche farmers have traditionally lived in small isolated enclaves and continue to do so today.

The Peul who inhabit the region are known as the Fulbe Gourmabe and can be classed as either sedentary or semi-sedentary agropastoralists. The other groups inhabiting this zone include some Hausa farmers who have gradually settled into the zone because of its agricultural potential beginning, they report, as long ago as sixty years. Their migration is not exclusively nor even principally a recent post-drought (1968-1972) phenomenon nor would it have been related to the clearing of the area. Rather, one might surmise that it arose from migrant laborers travelling through the region, and noting the perceived opportunities compared to their homeland.

Organization of Production and the Dominant Agro-sylovopastoral System

Several forms of production co-exist in this agro-ecological zone and will be discussed individually. The major distinguishing features of the traditional farming system are the use of the short-handled hoe or daba instead of the long-handled "hilere" that is employed in most of Niger and the substitution of sorghum for millet as the principal foodgrain. The techniques, tools, and crops common to the area are those associated with the Gourmantche. The Peul (Fulbe Gurmabe) who have for centuries co-inhabited the zone with the Gourmantche apply esentially the same crops and methods. More recent Hausa, Songhai, and Djerma migrants into the area have

also adopted the local Gourmantche practices. This uniformity across ethnic boundaries suggests that soils and other environmental factors and not cultural heritage determine the dominant practices in this region. This contrasts with other regions such as Tera where, upon displacing the Gourmantche, the new residents did not adopt the practices and tools of the previous inhabitants. Phrased unequivocably by one Hausa settler near the Burkina border, "we are obliged to bend over double if we want to cultivate these soils."

The agro-pastoral system of the Peul residing in the region differs from the dominant system in terms of the greater accommodation of livestock raising into the allocation of household labor and in the organization of agricultural space. The resident Peul are either sedentary or semi-sedentary. They keep large herds of sheep and goats and maintain cattle herds of varying size. Commons and animal corridors are maintained within the village and between fields in areas of dense cultivation. In-village fencing is prevalent. Transhumance patterns consist of short displacements of the herd.

Some salient features of Gourmantche agriculture are drawn from Swanson's work (1978, 1979) in Burkina. Individual plots are comparatively more important for the Gourmantche than for the other groups of the Niamey Department. Household organization, however, is strictly patrilineal and dominates major aspects of social reproduction, inheritance, and agricultural decision making. Several households frequently live in a single compound. The diendaano, or senior member of the compound, is distinguished from the dansan-daano (family head) who controls household (dansanu) decisions. Other members of the household (taan sabobi-yenli) occupy varying relations of dependency.

The owner of the crops under cultivation is expected to compensate those who help him on the land, whether these are members of his own family or persons called in from outside the immediate family group (1978:5). Emphasis is given to production of food crops both in terms of labor and land allocation. According to Swanson, 2-25% of total labor time is devoted to cash crops. Surprisingly, however, he concludes that propensity for innovation is greater on cash crop fields than on foodgrain fields. The smaller committment of land and labor mean that the risks associated with innovation and experimentation will have lesser consequences in terms of risk management. A rotation of crops corresponds to the declining fertility of soils. The most fertile lands are planted in corn, when they become less productive sorghum replaces corn, then millet displaces sorghum. Only when soils are depleted are cash crops planted on them; fertilizer is most likely to be applied at this stage.

Figures 14 and 15 illustrate the land classification at the broadest level.

Tinjali or unclaimed lands often occur in seasonally flooded bas-fonds (baagu), but these are increasingly coming into cultivation and permanent ownership. Few baagu lands in proximity of the existing villages in the Say Arrondissement remain unclaimed. Settlement and land cultivation patterns follow watercourses and these best lands are the first to be claimed. This fact has important implications for plans to colonize the 'new' lands (cf Projet Say-mise en valeur).

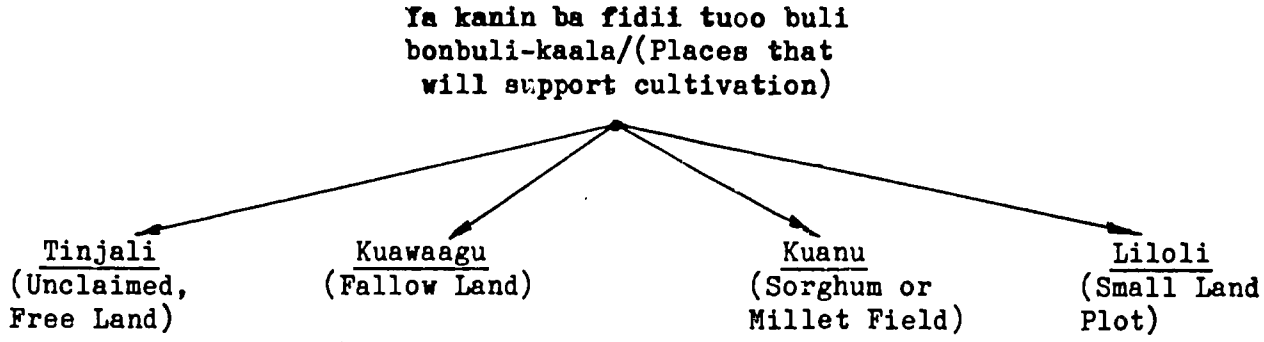
Kuawaagu or fallow lands are divided into five categories:

-n kuawaadi: fallow lands owned by the farmer himself

-n ba kuawaadi: fallow lands owned by one's father- control reverts to the eldest son; as does land which was "owned" by the father's wives upon their deaths

FIGURE 14

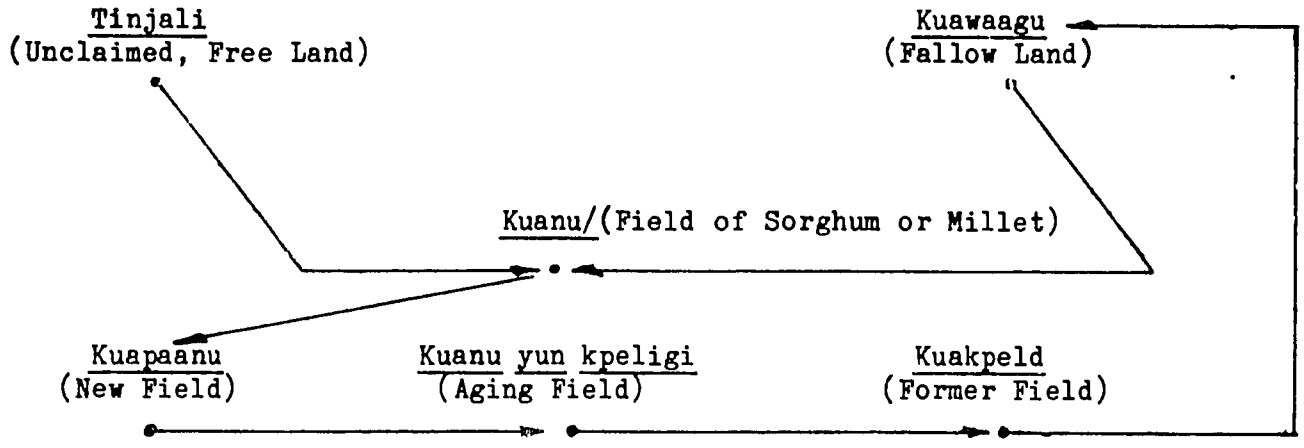
Disposition of Land



SWANSON 1978

FIGURE 15

Stages of a Kuanu/(Grain Field)



SWANSON 1978

-n yaja kuawaadi grandfather's lands, arbitrated by eldest male descendant

-n danba kuawaadi are kinsmen's fallow lands which can be cultivated by male descendants of a given lineage

-nitua ya Kuawaagu fallow lands belonging to someone outside the clan. Permission must be obtained to borrow them but no compensation is demanded

Kuanu, or sorghum/millet fields, consist of a large family field and individual fields (suali-kuanu). The crops of individual fields frequently belong to women and provide added subsistence security and cash income if the family field produced sufficiently. Gourmantche women are active cultivators; family fields are cultivated in the mornings and individual fields in the afternoons.

Liloli or small plots are devoted to an enormous diversity of cash and condiment crops. Liloli are of three types, the compound plot, the small in-village field. The two former categories frequently receive intense manuring. The smallness of these fields belies their importance to individual and family income. Cumulatively, the individuals of the household may cultivate a large number of such fields.

The relatively higher rainfall and moisture availability allows the cultivation of a greater range of soil types, and crop varieties are correspondingly diverse. Sorghum, being self-pollinating, contributes to the maintenance of distinct varieties. The major agricultural soils (discussed in Part III Section C) are Honrou, Batandi, and Lubri corresponding to a gradient moving from sandy loams to clayey soils.

Cheloori, a sorghum variety, is considered the staple and most important foodgrain. No figures were available to determine relative planting percentages. It was grown in the baagu or bas-fond soils with relatively high clay content which local CPT graduates felt were apt for

animal traction. The sandier soils located out of the bas-fond areas were subject to erosion.

Local residents reported that sand carried down off the plateaus had increased dramatically in recent years. Many upslope soils that are particularly prone to erosion are now being cultivated, especially near centers of population concentration. The Gourmantche term pempergou (penpeligu in Swanson's works) refers to denuded areas with hard relatively impervious surfaces often overlying a lateritic hardpan. These soils are non-agricultural but many represent degraded conditions in areas which were formerly productive.

There are many such high risk areas in the Alluvial Valley and Upland Subzone. There is a danger in overlooking the problems of environmental degradation in this zone because of its deceptively verdant appearance compared to the drier portions of the Department. The area is thought of as being very sparsely settled with little pressure on existing resources, but this image ignores the rapid changes that have taken place over the past two decades.

The area has traditionally been host to the third important agro-sylvo-pastoral system, that of the nomadic pastoralists. The area is frequented by diverse pastoralists from the northern areas. The area has thus played an important role historicaly in maintaining the herds from the pastoral zone, especially in times of stress. Transhumance patterns during the current drought give a good indication of the area's importance as a grazing reserve. For example, herds that are normally grazed at the risk of stiff fines in the restricted Parc de W are estimated at 3-4,000 head. During the 1984-1985 dry season, however, wildlife biologists estimated the number of head in the park to have exceeded 10,000, or about three times

the average. With northern rangelands in such poor shape, the southern pastures will be increasingly relied upon. Examples abound wherein southern grasslands are visited by hay cutters from northern towns such as Filingue who come down by pickup truck and resell (apparently at a profit) back in the north. The ineffectiveness of the double fence at the ICRISAT Sahelian Center is another indicator of the intense pressure on grazing resources, which makes some sort of planning and management of the southern rangelands all the more urgent and imperative. Their carrying capacity relative to the increased grazing pressure is highly uncertain.

The evidence is mounting that significant shifts in vegetation composition have already taken place. Herders are starting to bypass these Nigerien rangelands and are continuing further south into neighboring countries. The complex political issues inherent in this movement should continue to receive priority attention as such long distance transhumance is essential to maintaining present levels of livestock production. Even the Sidibe of Tientiende Foulbe, who live just north of the Burkina border and who normally never take their animals beyond the rangelands in the border region, were forced this past year for the first time in living memory to transhume as far as Benin.

Some excellent detailed reconstruction of vegetation and land use changes is being assembled by the Peace Corps Volunteer working with the Projet Forestier in the Foret Classee de Fayra, south of Torodi. His findings should clarify the implications of this ecological change to the area's production systems.

Substantial changes in the composition of the vegetation have taken place. Much of this vegetation change is due to climatic change, but a good deal of it, one must suspect, results from grazing pressure. The ecology of

the area includes extensive rangelands including plateau tops and numerous erosion prone sloping areas. In addition to intensifying crop production, then, some measures to ensure sound environmental management should be applied to preserve the integrated mixed farming/livestock systems that now characterize the area.

Test Village

Kiki-Bomanga and Lilengou. The choice of test village was expanded to include two adjacent villages with minimal environmental variability.

Dallol Valley Subzones

General Considerations

The fossil valleys or Dallols of Niger offer quite an exceptional landscape feature. Geomorphology, vegetation, landuse potential, groundwater resources, and population densities contrast sharply with the seemingly endless repetition of valley and ironstone plateaus through which ancient rivers once cut. The Dallols are well-represented in the Niamey Department. The principal of them is the Dallol Bosso (or Boboye as it is called by the Djerma in the area south of Bonkoukou),but a small section of the Dallol Mawri and much of the Zgaret, a fossil tributary of the Dallol Bosso, are also represented.

The Dallols run primarily north-south across the Pastoral Zone and most of the Intermediate Zone. The Dallol Valley Subzone of the Pastoral Zone is not discussed separately. Within the Intermediate Zone, well depths decrease dramatically from north to south. The water table at Bonkoukou lies at about 10 m and rises to within as little as one or two meters from Baleyara to the south.

Settlement History

Considering the extremely dense populations currently inhabiting the Dallol, its settlement is (for the most part) relatively recent. The extraordinary nature of the geographical resources attracted a wide diversity of different ethnic groups and this is reflected in the current dstribution of the population. Hausaphone Kurfey and Mawri predominate in the Filingue region of Tonikandia, to the south is the Tuareg Canton of Imanan. Guillame (1974:38) describes Tuareg settlement as taking place in the early nineteenth century which is the same period that other Tuareg were establishing themselves to the south in the Tagazar (Tabla, Sandire). Attracted initially by the abundant pasture, shallow water table, relative absence of cultivation and abundance of game, the nomadic Tuareg soon settled and displaced or dominated the original scattered Djerma villages. They did not push their conquest westward into the surrounding plateau regions.

For several centuries until the early 1800's Peul herders from the Say area had infiltrated the southern Dallol area and co-existed peacefully until a Fulbe mounted jihad brought this group to power. The remainder of the nineteenth century witnessed considerable struggle and fleeting alliances between the various groups of the region (Beauvilain 1977:53-58). Most of the Peul reside in Dosso (Birni N'Gaoure) south of the Niamey Department, but isolated Peul villages are scattered amongst the Tuareg and Djerma areas of the Southern Dallol.

The twentieth century has witnessed a tremendous growth in the local populations, especially those of Djerma origin, and this has brought on a considerable intensification in the struggle to gain and maintain agricultural fields. The lack of available agricultural space and the

economic pressure that accompanies it has been a major contributing factor to the high rates of long-term (over 1 year) and seasonal migration.

Organization of Production and the Dominant Agro-sylvo-pastoral System

The Hausaphone, Tuareg/Bella, Djerma and Peul, despite differences in domestic organization, (many Bella women do not cultivate, Peul divide labor more equally between crops and livestock work, etc.) must all confront the combination of unique agricultural circumstances and high population densities prevalent in the Dallol. This density of settlement has given rise to a more intensive approach to soil fertility management. Fallow land has all but disappeared in the past 15 years within the southern Dallol where population densities approach 150/sq km in places. Out-migration has alleviated stress to some extent, but has given rise to a large portion of the rural population for whom lands are either borrowed or rented. (See Goldmark 1977 for a discussion of the different forms of transferring land and land use rights.)

Soil fertility is managed using a combination of different practices which have been carefully orchestrated to maintain satisfactory production. But here as in much of the country these traditional systems are under stress. Soil management combines dry season rotational paddocking of herds on fields, with periodic fallowing, with agro-forestry (abundance of gao trees in fields), and periodic shifting of the concession from one part of the family's fields to another.

Although dispersed settlement exists in other parts of the Department, it is nowhere so characteristic as in the southern Dallol region. An important factor which permits this type of settlement is the uniformly available ground water. In some places cultivators report that until a few years ago they did not even take water to the fields when working; all one

had to do was scoop out a small depression in the sandy soil and drink. It has always been easier to maintain productivity in soils near the compound, but the environment of the Dallol makes movement of the compound a viable means of distributing these advantages more evenly. This pattern is not confined to the more mobile Bella and Peul, but exists, albeit to a lesser degree among the other groups. Dupire noted in 1961 that the Peul were being displaced by Hausa.

Gao (*Acacia albida*) appears to span the width of the southern Dallol valley bottom. The beneficial qualities of the gao are recognized by the area's farmers, although none admitted to planting them intentionally. The policy of selective protection over the past generation has favored their propagation. The Bella offered us a telling proverb that translates approximately, "Three gao trees are worth more than all your wife's livestock." Here, the importance of gao as a fertilizer source "that doesn't burn" is seen as a male controlled asset in contrast to the women's wealth which can not be sold and remains in her lineage through inheritance.

In some areas blow-outs were observed under gao trees which would indicate that tree densities remain insufficient. Wind erosion is a major constraint to improvement of the valley's agriculture. Its control is therefore a priority. A solid basis of gao and other trees exists which could perhaps be complemented with a system of windbreaks.

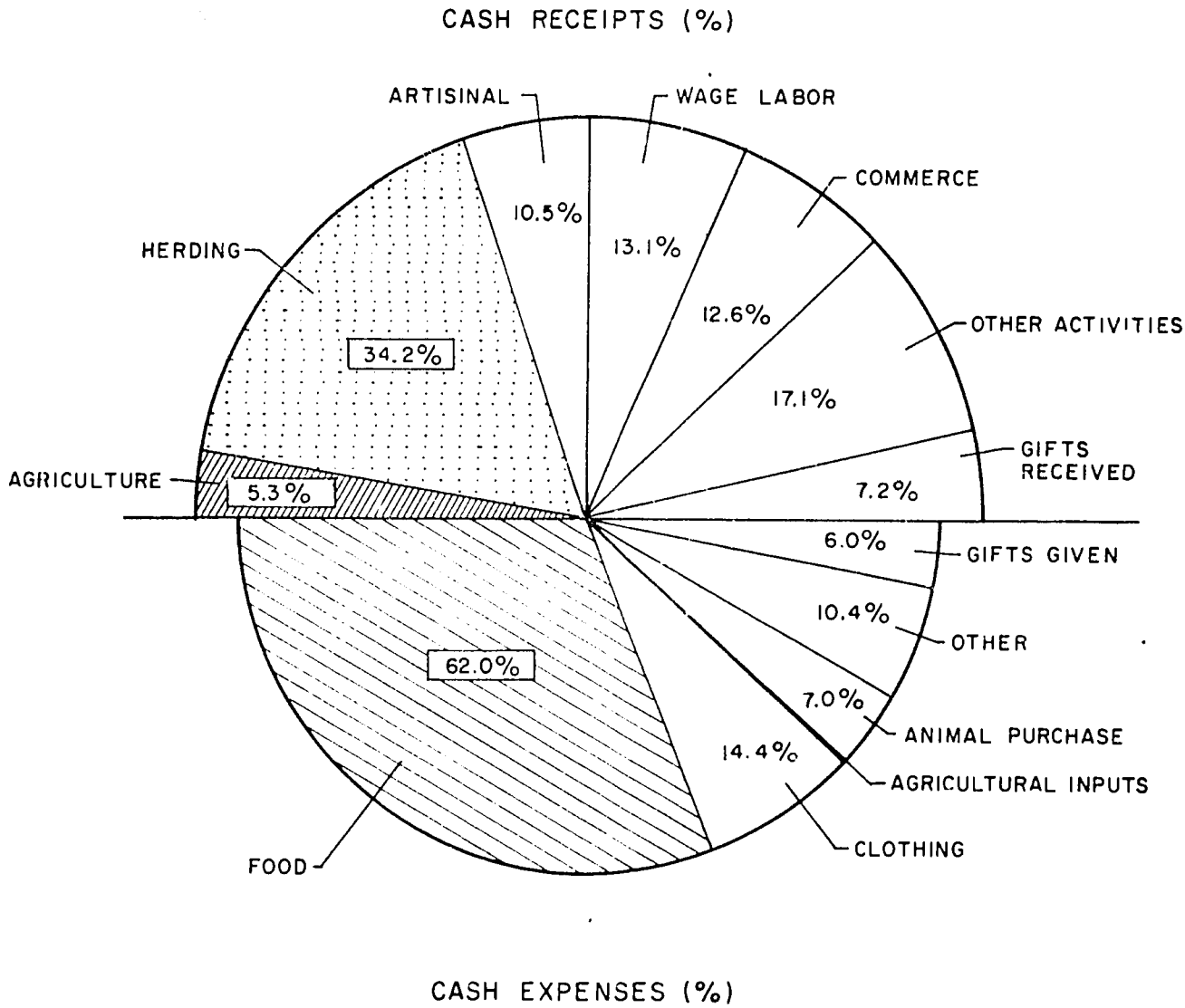
Fallowing and manuring are the elements of traditional soil management under the greatest stress. There no longer exist significant areas to permit adequate fallowing. Strong pressures exist to lend fallow lands to less well-endowed relatives or non-relatives. Manuring of fields is also more difficult to achieve. The area cultivated within the Dallol has

increased dramatically (see Figure 13), thereby reducing the available forage resources and increasing the area to be manured. When the forage resources of the area are insufficient, many of the locally owned cattle herds will continue south in search of adequate grazing. This has happened frequently in recent years according to villagers in Mbama, near Baleyara. Furthermore, the poor grazing conditions in recent years have resulted in serious animal mortality. In sum, there are fewer animals, they are paddocked on local fields less often than before, the area in need of manure has increased both from the larger area under cultivation and the more worn out state of the soils.

Field sizes in the northern Dallol tend to resemble the figure presented for the northern Sand Valley and Plateau Subzone (Ouallam) and those of the southern Dallol are closer to figures given for the southern Sand Valley and Plateau and Sand Plains Subzones. INRAN-DECOR research (1983:114) in the Filingue Arrondissement, including both Dallol and Plateau survey villages indicated (moving from south to north) 58% of the farms in the Tagazar Canton under 5 ha., dropping to 40% in Imanan, and only 32% in the Southern Kourfeye. Average farm size in the Filingue Arrondissement from their survey results was 6.9 ha. About 80% of all millet was planted in association with cowpeas and sometimes the two in association with sorghum; however, only 20% of the farmers planted sorghum (1980 campaign). Secondary crops were more likely to be planted in pure stands. The principal among these were manioc and okra.

The survey year, 1980, was estimated to be a net deficit year of approxiamtely 33%. The following Figure 16 illustrates the household budget structures for that year. Subsequent years have exhausted peasant livestock reserves through mortality and disinvestment. Livestock, which yielded 34% of receipts in 1980, would be much lower today. Harvests have

Figure 16: Household budget structure
Fiiingue Arrondissement 1980



been generally worse since and food purchases will have increased. Numa (1985:34) reports less than one-third of all sample households from the same area met even 50% of their food needs from domestic rainfed agriculture. Similar budget studies would undoubtedly reveal an increase in the percentage of income derived from salaried labor. This is indicative of the economic squeeze trapping the region's farmers who, now mostly without livestock, need saleable agricultural commodities.

One of the most promising prospects for the Southern Dallol lies in the development of its substantial irrigation potential. A high water table and deeper geologic aquifers both present relatively untapped potential. Village interviews indicate that cultures de contre-saison are here becoming an important component of domestic production. Orchard crops seem to be possible. Mangoes, guavas are succeeding in existing gardens and are consumed locally. Some dates have been planted, but tend to drop before ripening. Manioc gardens timed to produce in a range of seasons are well-incorporated into the production cycle of many households. Given the very high potential for irrigation, further detailed analyses and planning would be reccommended.

Test Village

N'Dikitan is a typically dispersed village. Although the village consists of 305 household heads, only a few concessions are to be found in the village's "center" where the school and chief's concession are located. The principal ethnic group is Bella and the village is divided into three quartiers. Two former CPT graduates from the Kabe center live there. It is situated several kilometers south and adjacent to Damana but is under jurisdiction of the Tagazar Canton.

River Valley Zone

General Considerations

The River Valley Zone is classified as a single zone despite the considerable variability that exists from north to south, and between areas where the channel is relatively constricted and those where it is broader. The zone's integrity derives from the possibilities for irrigated agriculture and from the other forms of economic diversification that supplement rainfed agriculture.

Dryland cropping, flood recession agriculture, hand watered gardens, livestock production, and fishing are all concentrated along the river. In some cases, these activities compete or conflict with large scale irrigation schemes which have received the lion's share of development attention.

By all accounts Niger's irrigation potential exceeds 100,000 ha. in the Niger River Valley. Most of this lies within the Niamey Department. Only a small portion of this potential has been thus far developed (see Figure 17); to develop much of this potential it would be necessary to construct numerous dams along the river. Management problems associated with large scale irrigation projects in West Africa have traditionally been a major obstacle to their profitability. It appears from recent improvements that this does not need to be nor will it necessarily continue to be the case. These investments, however, create substantial social inequities which remain to be fully considered. The fit of large capital intensive programs into the overall agricultural environment in terms of their effects on pasture lands and the livestock economy, on dryland farming, on aquatic ecology and fisheries etc., will require increasingly sensitive and accommodative planning. A recent assessment treats these issues in detail (Zalla _et. al._, 1984).

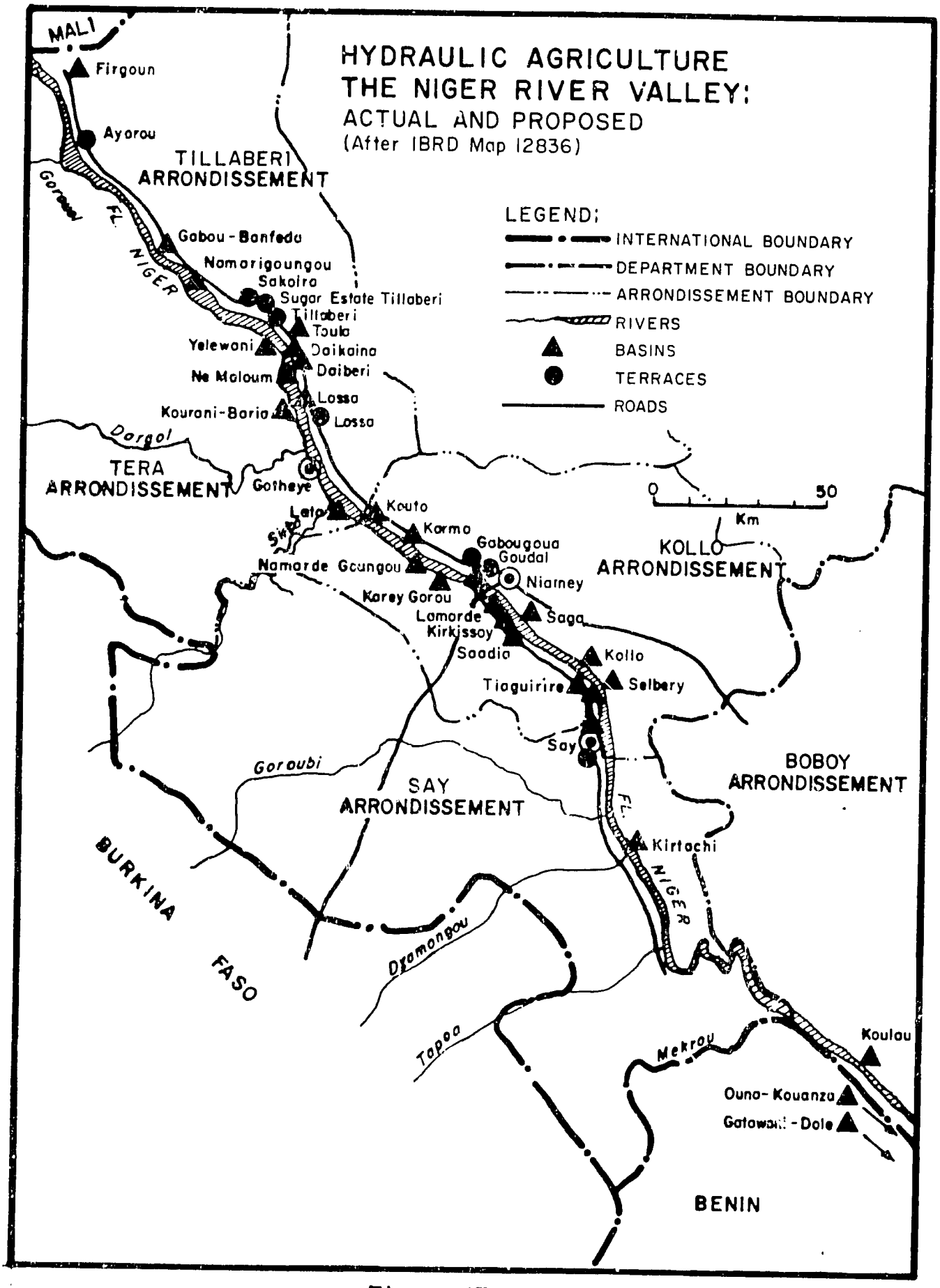

HYDRAULIC AGRICULTURE
THE NIGER RIVER VALLEY:
ACTUAL AND PROPOSED
(After IBRD Map 12836)
LEGEND:
INTERNATIONAL BOUNDARY
DEPARTMENT BOUNDARY
ARRONDISSEMENT BOUNDARY
RIVERS
BASINS
TERRACES
ROADS
0
50
Km
MALI
Firgoun
Ayorou
TILLABERI
ARRONDISSEMENT
Gorouol
FL. NIGER
Gabou-Banfedo
Namarigoungou
Sakoira
Sugar Estate Tillaberi
Tillaberi
Toula
Yelewani
Daikaina
Ne Maloum
Daiberi
Lossa
Kourani-Bario
Lossa
Dargol
TERA
ARRONDISSEMENT
Gotheye
Lete
Kouto
Kormo
Gabougoua
Goudal
Niamey
KOLLO
ARRONDISSEMENT
Namarde Goungou
Karey Gorou
Lamorde
Kirkissoy
Saga
Saadia
Kollo
Tiaguirire
Selbery
Say
Goroubi
SAY
ARRONDISSEMENT
BOBOY
ARRONDISSEMENT
FL. NIGER
Kirtachi
BURKINA
FASO
Dyamongou
Tapoa
Mekrou
Koulou
Ouno-Kouanza
Gatowali-Dole
BENIN

Figure 17

Settlement History

The central role played by the Niger River in the region's history has produced a complex mosaic of settlement in the valley region. The principal ethnic groups of Niger all find at least some representation along the river. Within the Niamey Department the major groups Songhai, Djerma, and Peul are all longstanding residents. The major peoples of Songhai descent include the Kurtey, the Wogo, the Sorko, and the Kado.

The Kurtey, known in pre-colonial times for their role as transporters, are of Songhai/Peul descent. They apparently descended from Mali along the river in the eighteenth century and wrested control of numerous riverine islands form the Gourmantche, who until that time dominated the western side of the river. Throughout the nineteenth century, they intermixed with the Sorko and Kado fishing peoples. The Tuareg threat that affected the Kado and Djerma of the Anzourou and Djermaganda also gave rise to a series of shifting of alliances among the different riverine groups which continued until the French conquest in 1896-1898 (Olivier de Sardan, 1969). The chief of Say, whose religious influence was considerable, was also instrumental in resolving some of these conflicts and assuring the continued existence of the Islamic stronghold at Say. In summary, the riverine groups have penetrated the Nigerien portion of the river valley over the past several centuries mostly from Mali.

Organization of Production and the Dominant Agro-sylvo-pastoral System

The economy of the riverine groups is as diverse as the population. Rice is the central crop and is supported by secondary agricultural acitivities. Generally (among the Kourtey and Wogo at least) the riverine rice growers will also have an upland millet field and gardens in the valley. The principal garden crops are tobacco and manioc, but are becoming

more and more diverse. Crop production is supported by livestock raising and fishing. The Kurtey, being Peul descendents, reportedly guard their own herds (Olivier de Sardan 1984). Women are specialized in the weaving of grass and palm mats. Wage labor migration, here as elsewhere in the country, provides an important source of income and has a powerful effect on social organization. In recent years a coalescence in economic strategies seems to be taking place as the forces of modern economy and technology assert themselves.

Overlain on these traditional activities is an increasing number of irrigated agricultural schemes. NDD has not directed efforts toward developing a technical package that meets the sometimes complementary, sometimes conflicting requirements in modernizing both riverine and upland agriculture simultaneously. To do so in such a way as to preserve the long term productive potential of the river basin requires an integrated approach that considers all factors- technological, social, and environmental- within a single framework.

Thus far, most emphasis has been directed to the economics of irrigated rice cultivation which is too often isolated from the underlying complexity, described above, of the riverine rural economy. Some of these results have been assembled by INRAN/DECOR.

Zonation and the Technical Package

Hal n gondi wi de nmbonjo ka--"Deux precautions valent mieux qu'une."

Two major variables, farm size and rainfall, affect the likely profitability of an animal based traction package in the Niamey Department. Differences in soils, social organization, agricultural policies, pricing and input delivery structures, and crop choices are also important. The marginally productive nature of agriculture in most of the Department means that agro-ecology is fundamental to the determination of potential profitability of a traction based package. Although steps are being taken to improve the data base, actual on-farm results remain minimal. The extremely irregular returns to agriculture that characterize the Department mean that consistent data for a number of seasons will be necessary before anything but tenuous conclusions can be drawn. Risk associated with the high costs of fertilizer, equipment, and traction animals, understandably compel the farmer to experiment on a gradual basis with new practices. It is not clear that the demonstrably improved yields (especially in higher rainfall years) of this experimentation, i.e. partial package adoption, justify the costs. Considerable work remains to be done in steps 3 and 4 (on-farm testing, evaluation, modification) of the farming systems approach outlined in the introduction.

In the absence of significant new data, there is little point in reiterating the conclusions or adding new hypotheses to previous efforts to evaluate traction packages and/or their adoption in the Department (cf. Barnett 1983, Ithaca International 1983, Poulin 1984). Stier concludes "roughly 70-80% of holdings are probably too small for ox-drawn traction to be profitable," and that in the north there is a possibility that "increased tillage would exacerbate wind erosion." The latter supposition

was affirmed by the soil suitability evaluation carried out by the zonation study. Concerning farm size, the 1980 agricultural census and more recent INRAN studies indicate that holdings, overall, are slightly larger than the 1977 and 1979 NDD surveys indicated. Stier probably underestimates the minimum farm size (6 ha.) necessary to cover increased costs. Productivity projects in Burkina (in higher rainfall areas and on heavier soils) are currently recommending bi-bovine traction on farms with access to 8 ha. or more. One study (Poulin et al., 1984) suggests that on sandy soils, mechanical cultivation may be less appropriate and economic. Without subsidies and revenue from ox or donkey cart rental the benefits are even more uncertain.

It would be prudent, therefore, to confine future extension to the Agricultural Zone where the likelihood of success is greater and to farms whose holdings can or do exceed a threshhold size. Farm size would vary with soil type, rainfall, and whether traction is asine, mono-, or bi-bovine based. Bovine traction shows most promise on larger farms, on sorghum fields, and on heavier soils. The zonation team defined the favorable rainfall regime as 80% or greater probability of 350 mm. of rainfall per season. Assuming that 8 ha. are necessary to finance implementation of this package and it is confined to this more promising Agricultural Zone, one can conclude that only 3% of the department's farms currently meet these criteria for the extension of bovine traction (about 4000 of 131,589 holdings).

The Ithaca International report concluded that asine traction provided the highest returns to labor in the north (Intermediate Zone). Following Stier (1980), it is assumed that donkey traction is also most economic on mid-sized farms (4-8 ha.) in the south (Agricultural Zone). On the basis

of these assumptions the potential beneficiary population of a donkey based package is considerably larger. Roughly 53% of the Niamey Department's farms meet the criteria of being south of the 350 mm. isohyet and larger than 4 ha. (or between 4 and 8 ha. in the case of holdings in the Agricultural Zone).

Mono-bovine traction offers additional possibilities that are only recently receiving attention. As it becomes available adaptive research on the agronomic potential and the economic returns to mono-bovine based traction packages should permit a determination of the conditions under which it would be more appropriate than asine or bi-bovine traction. No inputed whole farm budgets were generated for mono-bovine traction by Ithaca International. Neither were any on-farm research results available, thus no attempt is made here to evaluate it with reference to the zonation.

These calculations were deliberately simplified in order to generate only very broad guidelines for further adaptive research. As mentioned at the outset rainfall and farm size are only two of the many factors relevant to the viability of animal traction based technical packages. Other factors such as soil type can in places be overriding. Some soils in the Agricultural Zone are not amenable to even minimal mechanical treatment. Conversely, certain soils such as those found in the Kouara Tegui test village, may be well-suited despite the region's comparatively lower rainfall. Field size is less important where dual cropping, paddy rice, and irrigation come into play. Commodity and input prices and price policies can obviously affect the economics of production. What these calculations do is add some indicators toward following the DAI report's conclusion to "proceed cautiously in recommending animal traction" (Poulin et al., 1984:18).

3.3 Soils

Overview

The soils inventory and investigations performed by the soil scientist during the zonation study provided for sound evaluations of the soils within the Niamey Department. The information and data found in this report, as a result of the soil scientist's evaluations, can be used to adjust land uses to the limitations and potentials of the natural resources and environment of the Department. Also, it can help avoid soil-related failures in land uses.

In preparing these soils evaluations, the soil scientist collected extensive field data about the nature and behavior characteristics of the soils within the Department. The soil scientist collected data on fertility, erosion, droughtiness, wetness, flooding, and other factors that affect various soil uses and management. In addition, soil samples were collected from pits of certain pertinent soils near each test village. Field experience and collected data on soil properties and performance are used as a basis in predicting soil behavior.

Soils information, as a result of this zonation study can be utilized to plan the use and management of soils for agricultural, pastoral, and silvicultural uses. It can be used to identify the potentials and limitations of each different soil type for specific land uses and to help prevent failures as a result of unfavorable soil properties.

Planners of the NDD and others using this information can evaluate the effects of specific land uses on productivity and on the environment in all or part of the Department. This soil evaluation of the zonation study can help planners to maintain or create a land use pattern in harmony with the natural soil.

General Use and Management Concerns

General management needed for agricultural and pastoral use is suggested in this section. Even though this zonation study is aimed at agricultural intensification, certain management concerns affecting pastoral use should also be addressed for the Department. This is especially pertinent where pastoral use is integrated with certain farming methods. However, the emphasis of the overall use and management for the soils of the Department is directed at agricultural use.

The overriding concern throughout the Department is soil erosion. It is a major problem in all areas, whether utilized for agricultural, pastoral, or silvicultural use. The loss of one millimeter of soil surface over one hectare of land is equal to slightly more than 13 tons of soil per hectare being lost. The very deep soils identified within the Department generally have a soil loss tolerance of approximately 12.5 tons/hectare per year. This means that the soil forming factors are generally capable of replenishing the soil lost at this rate. However, soil loss within the Niamey Department by far exceeds the soil loss tolerance of even its very deep soils.

Loss of soil through erosion is damaging in several ways. Productivity is reduced as the surface layer is lost and part of the subsoil is incorporated into the plow layer or cultivation layer. Loss of the surface layer is especially damaging on soils such as Lubri soils, that have a clayey subsoil and on soils that have a layer in or below the subsoil that restricts the rooting depth. Such layers include the brittle underlying material in Chinagohrar soils and the laterite of many other soils such as Pimpergou, Sinsan, and Tondi soils.

Erosion results in sediment that also causes offsite damages. Controlling erosion on areas being farmed will minimize the pollution of drainageways and mares and will improve the quality of water for human use. It will also improve the habitat for fish and wildlife.

Generally, the very sandy soils of the Department (approximately 70 percent of the soils suited to millet production) will form compacted layers known as a plow pan if they are plowed using animal traction or by other mechanical means. This is mostly due to the well graded sands of the subsurface layer or layer immediately beneath the surface layer. The use of animal traction results in compacted layers, normally at a depth of about 5 to 25 centimeters. These plow pans restrict infiltration of water and plant roots. Plants on plow pans may have shallow root systems and suffer the effects of drought when the surface layer dries out. Examples of soils most affected by plow pans would be Dayobu, Moma, N'Dikitan, and Sourgourou. In addition, seedbed preparation and cultivation are difficult on eroded areas because the original friable surface layer has been removed. This condition is quite common in areas of Kiwendi, Labucheri, Pimpergou, Sinsan, and Zogoti soils.

Throughout the narratives of individual soil series and their specific use and management, of this report, certain erosion control practices are identified. These practices will provide a protective surface cover, reduce runoff, and increase infiltration. Generally, a cropping system that keeps a plant cover and crop residue on the surface for extended periods well into the dry season can hold soil losses to amounts that do not reduce the productive capacity of the soils. Where livestock grazing is needed in intensive agricultural areas, legume and grass forage can be incorporated into the cropping system to reduce erosion on sloping areas.

They also provide nitrogen and improve tilth for the crops that follow in the rotation.

Minimum tillage and leaving crop residue on the surface help to increase infiltration and reduce the hazards of runoff. These practices can be adapted to most soils conducive to rainfed agriculture within the Department. No-tillage, or only hand weeding, for millet is most effective in reducing erosion on sloping areas. This practice can be used on areas with short slope lengths where the topography is unfavorable for terracing or contouring.

Terraces (water catchments) and diversions should also be considered to reduce runoff and erosion. They are most practical on deep and very deep, well drained and moderately well drained soils, such as Galiangou, Labucheri, and Tiloa. There are some soils within the Department that are less suitable for terracing because they have irregular slopes or a clayey subsoil, which would be exposed in the terrace channels. Diversions are most practical on toe slopes and benches that intercept surface runoff from steeper side slopes of higher elevation and divert the water from the lower lying fields and gardens. Contour farming would be very effective in reducing erosion on all sloping fields conducive to rainfed agriculture. This practice is best suited to the soils that have smooth uniform slopes.

The Agricultural Zone normally receives an adequate amount of rainfall for rainfed agricultural crops that are commonly grown within the Department. The Intermediate Zone receives somewhat less rainfall during the growing season whereby crop failure may result during any given year. In addition, the distribution of rainfall during the growing season is usually such that periods of drought may occur practically every growing season, for rainfed agriculture.

The Pastoral Zone receives substantially less rainfall during the normal growing season and, as a result, will not support rainfed agriculture. The River Valley Zone transcends a wide range of rainfall distribution within the Department. Therefore, some areas will support rainfed agriculture and other areas would require irrigation to prevent drought stress on certain soils. All soils within the River Valley Zone that are commonly used for rainfed agricultural crops are also suited to irrigation.

Soil fertility is naturally low in most of the soils of the Department. Several of the very deep sandy soils and most all of the moderately deep to shallow soils over laterite are extremely acid. In contrast, most of the clayey soils are only slightly acid to alkaline. The soils along drainageways, mares, and on terraces are generally slightly higher in natural fertility than most of the soils of higher elevations. Generally, the acid sandy soils in the Department need applications of either ground limestone, phosphate, gypsum (calcium sulphate) or some other form of basic nutrient (depending on type available) to raise the pH level sufficiently for optimum utilization of commercial fertilizer (if used) by plants.

Generally, most all the soils within the Department that are suited to rainfed agriculture or dry season gardening respond well to fertilizer. Levels of available phosphorus are very low in most of the soils. However, amounts of potassium, magnesium, and calcium are high.

Refer to Soils Annex G of this report for soil test results of pertinent soils identified in the Department.

When considering seed germination, the soil tilth is an important factor. Tilth affects the infiltration of water into the soil. The soils

of the Department that have good tilth generally have a granular surface structure and a very friable consistence. These characteristics provide for a more porous surface layer.

Most of the soils that are presently utilized for rainfed agriculture in the Department have a sand or fine sand surface layer that is light in color and very low in organic matter content. The structure of these soils is weak, and intense rainfall often causes a crust to form on the surface. This crust is hard when dry and is almost impervious to water, in certain areas of some soils. It reduces infiltration of water and increases runoff. Regular additions of crop residue, manure, and other organic material can help improve soil structure and reduce crust formation.

Pastures are also important in a plan of agricultural intensification. Proper use and management of soils either left fallow or planted for pasture also has an effect on adjacent soils utilized for rainfed agriculture and gardening.

Several management practices are needed on all soils that are used for pasture and hay production. These practices include proper grazing or cutting heights, rotational grazing, and scattering animal droppings. Overgrazing and low fertilization are the two greatest problems associated with pasture production in the Department. Both problems result in weak plants and poor stands that quickly increase the hazard of both water and wind erosion. As a result, the future soil productivity for pasture and/or rainfed agriculture continually decreases.

The following portions of this section give more specific information on the use and management of the zones, subzones, and then individual soils identified in the zonation study.

Methodology of Evaluations

During the zonation study for the Niamey Department the soil scientist conducted various types of field examinations and tests.

Evaluations included investigations of soils over the entire Department and more site specific investigations within the selected six test villages, discussed earlier in this report.

Field evaluations included examination of over 150 soil profiles by the use of a soils auger, shovel, and from excavated sample pits. Descriptions were collected of most of these examinations as they are essential in any soils inventory. The descriptions served as a basis for soil identification, classification, mapping, and development of soil use and management criteria. Standard terminology was utilized to document the soil properties examined. The terminology discussed in the soil section of this report has been utilized and tested throughout many parts of the world, and particularly in West Africa.

The major properties and characteristics examined at the aforementioned soil profiles included slope, soil depth, color, texture, structure, consistence, soil reaction, boundaries, parent material, and kind and degree of erosion.

For the greatest value, the soil pedons that best represent the position of a particular soil's occurrence on the landscape were selected for examination. Each pedon was selected for examination based on external evidence before excavation. During the detailed soils examination within the test villages, typical pedons were selected and examined that had properties near the middle of the range (or near the limits of the range) of the particular soil series it represented.

Soil samples were also collected from at least one particular soil pedon in each test village. The soil selected for sampling had special significance to each test village as it relates to use and management. In some cases, this selected soil for sampling was also the dominant soil of the village area.

A pit exposing a vertical face approximately 1 meter across and approximately 1.5 meters in depth was excavated for collection of soil samples and examination of the pedon. The pit also allowed the soil scientist to render training in the form of visual observations of the soil to the local farmers and, in some areas, agricultural personnel of the NDD that accompanied the zonation team at the test villages.

Photographs were also taken of the soil pits. This was done after the layers were identified but before the pedon was disturbed from collection of samples and further examination.

During examinations in the test villages and throughout the Department the landscape features were evaluated. Landscape features strongly influence the distribution of soils. The features of the landscape and the soil surface were considered, along with the aforementioned internal properties of the soil, in order to make sound predictions about soil use, management, and behavior. In the following soil series portion of this section, the landform that each particular soil occupies was identified. This was addressed so the user of this study would know how each soil fits into the landscape and into each subzone identified.

Accelerated erosion and natural (or geologic) erosion were so intimately interrelated in some of the landscapes that distinguishing was somewhat difficult.

The degree to which accelerated erosion has modified the soil was estimated during soil examinations. The soil examinations recorded the condition of the remaining soil if it differs significantly in use, suitability, or management requirements from the uneroded soil. The examinations focused on the properties of the soil that remains; properties of the material that has been lost can only be inferred and cannot be used to define or classify soils.

In estimating the degree of accelerated erosion of specific soils in the Department, it was virtually impossible to compare properties of the uneroded soil to the same soil in the eroded state. This was due to the extensiveness of erosion throughout the Department. Therefore, it required estimation on some soils as to the amount of surface layer that had been lost. However, many soils were found to be void of their original surface layer and the subsurface layer or, in some cases, the subsoil was exposed.

For soils having clearly defined horizons, differences due to erosion were able to be accurately determined by reference to less disturbed areas. The distinctive horizons and their depths were reliable guides within the limits of their variation from place to place. The physical condition of the material in the cultivated layer, the appearance and amount of fragments on the surface, the number and shape of rills and gullies, and similar evidence were relied on.

Upon completion of field examinations, soil test results, and collection of other pertinent supportive data, the subzones occupied by the various soils and their combinations were then identified. Photo interpretation from the LANDSAT imagery for the Department and medium scale black and white photography of the test villages was then utilized to delineate the subzones and the landscapes in which the various soil types

occur. Delineations were plotted on overlays of each arrondissement within the Department utilizing topographic maps at a scale of 1:200,000 as a base and in order to achieve map accuracy.

This information was merged with climatic data to establish the zones. It was then reduced to a scale of 1:500,000 and plotted on a general zonation map for the Department.

Zone and Subzone Evaluations

Agricultural Zone

Alluvial Valley and Upland

The Alluvial Valley and Upland Subzone is located in the southern and western portions of the Say Arrondissement. This subzone receives a mean annual rainfall of approximately 475 to 700 millimeters.

These areas consist of broad, nearly level to gently sloping valleys and nearly level to steep uplands composed of broad ridges, small isolated hills, and plateaus. The valleys contain soils in drainageways, depressions, and low terraces that formed from predominantly clayey alluvium. Also in the valleys are loamy ridges of slightly higher elevation above the terraces.

The broad ridges of the uplands are composed mostly of moderately deep, loamy and shallow gravelly soils over ironstone and then laterite. The tops of the broad ridges are nearly level and the side slopes are gently to strongly sloping and have developed many gullies due to water erosion. Scattered throughout this landscape of broad ridges are a few small, isolated hills that consist mainly of stone and boulder size ironstone rubble. These small hills are generally strongly sloping to steep and many rise to only about 10 to 15 meters above the broad ridges. The plateaus are higher in elevation and their tops are composed mostly of shallow gravelly to moderately deep loamy soils over ironstone and laterite. The escarpments and steep side slopes of the plateaus are virtually void of soil material and are mostly composed of stone and boulder size ironstone rubble.

Water erosion is the greatest concern pertaining to soil degradation and loss in productivity. The alluvial clayey and loamy soils of the

valleys have a moderate erosion hazard with an estimated annual soil loss of from 2.5 to 10 tons per hectare. Soils within the drainageways have only a slight hazard. Being in a depositional position, these soils receive sediment. However, some surface scouring occurs when these areas are inundated with water.

Even though the alluvial ridges and terraces have slopes less than three percent, there remains at least a moderate erosion hazard. This is due to the higher degree of soil erodability on surfaces containing more clay.

The upland soils generally have a very severe erosion hazard. Many areas are void of topsoil and have formed large gullies on the steeper side slopes of the broad ridges. Runoff velocity from these areas has contributed to increased erosion on the adjacent clayey terraces of lower elevation.

The alluvial valleys of this subzone are suited to rainfed agriculture. In addition the soils of the drainageways and the terraces nearest the drainageways are well suited to rainy and dry season gardening.

It is recommended that plowing be done on the contour on the longer side slopes of the ridges and terraces. Where these slopes are too short to facilitate contour plowing, it is recommended that at least some residue be left on the surface after harvest. The natural water courses within the drainageways should not be cultivated. Instead, they should be left fallow and maintained as a grassed waterway for runoff and flood water.

The broad nearly level ridges of the upland should not be cultivated. They should be left fallow and managed for rotational livestock grazing, in order to control erosion. In addition, the steeper side slopes of these ridges where gullies have formed should be reclaimed. This could be

accomplished by construction of small water-retarding structures (dikes) in their upper reaches, shaping the gully sides to a reduced slope gradient, and vegetating the entire gully. This practice should indirectly control soil loss from the adjacent more conducive soils on lower elevations.

The major soils represented in the Alluvial Valley and Upland Subzone of the Agricultural Zone are: Bantandi, Fayra, Honrou, Lubri, Makalondi, and Pimpergou.

Sand Plain

The Sand Plain Subzone is predominantly in the northeastern portion of the Kollo Arrondissement and also adjacent to the river valley in both the Kollo and Say Arrondissements. Its mean annual rainfall is from about 475 to 600 millimeters.

These areas are mainly composed of a landscape of gently to strongly sloping undulating sand ridges and valleys. The soils of this landscape formed from eolian sand on old stabilized dunes. These very deep sandy soils have a developed subsoil. In addition to these soils, there are also a few isolated areas of young, undeveloped sandy soils that occur in broader valleys. These areas stay saturated during the rainy season from runon of the adjacent sloping soils. However, they dry out fairly soon after the rainy season.

Overall, this subzone has a severe erosion hazard. This is due to both wind and water erosion. The runoff from these soils is enough to cause sheet and rill erosion, even though these soils are quite sandy and have a somewhat excessive internal drainage class. Where rows are oriented on an up-and-down hill configuration instead of on the contour, the hazard for rill and eventual gully erosion is accelerated. Estimated soil loss for these Sand Plain soils is 10 to 25 tons/hectare per year.

This Sand Plain subzone is well suited to rainfed agriculture, specifically millet production. It should be able to support a sustained intensive cropping season if wind and water control measures are implemented. Otherwise, the erosion hazard will lead to reduced yields each year and eventual soil degradation which will render these soils marginal for crop production in future years.

When slope lengths of side slopes are suitable, contour farming is a must. It is also recommended that only hand weeding be practiced along with strip cropping and intercropping with a close growing ground cover. In addition to rotating the strips each year, the entire fields should also be rotated out of production to remain fallow at least one year in three. Attempts should be made to leave as much residue as possible in the fields after harvest and rotate livestock grazing in the fallow fields. These soil conservation practices, if applicable to the slope configuration, should help reduce soil loss to the allowable annual soil loss tolerance (12.5 tons/hectare) for these particular soils.

The major soils represented in the Sand Plain Subzone of the Agricultural Zone are Baboussay, Labucheri, and Sourgourou.

Sand Valley and Plateau

The Sand Valley and Plateau Subzone of the Agricultural Zone occurs in areas throughout the Kollo Arrondissement and in the eastern portion of the Say Arrondissement. It has a mean annual rainfall of from about 475 to 700 millimeters.

This subzone has two major landscapes, one being nearly level to gently sloping valleys, and the other is composed of nearly level to gently sloping plateaus with steep escarpments or side slopes.

The valleys have a microrelief of low ridges with weakly developed, very deep sandy soils, narrow intermittent drainageways of loamy textured soils, and broad benches on the upper side slopes below the ironstone plateaus. Soils on these benches are loamy to sandy textured and deep over laterite.

The plateau landscape is composed of a nearly level to gently sloping soil mantle over ironstone and laterite tops, and escarpments and steep side slopes of shallow bouldery and stony ironstone. The plateau tops contain gravelly, shallow to moderately deep sandy soils over laterite.

The valleys of this subzone are well suited for rainfed agriculture. The plateaus are generally unsuited due to their overall shallow depth which restricts root development. However, some of the deeper sandy soils of these plateaus may also be suited. In addition, the loamy textured soils along intermittent drainageways and its depressions are well suited for both rainy and dry season gardening.

Overall, this subzone has a very severe erosion hazard. Its estimated annual soil loss is approximately 25 tons/hectare or more. This is due to water and wind erosion. As a result, many soils have lost much, if not all, of their surface layers. Where this is evident, the upper part of the subsoil has become crusted and slightly cemented due to exposure and accelerated weathering. This increases runoff velocity and contributes to gully erosion on lower side slopes where the rapid runoff becomes concentrated into natural water courses. This also moves a great deal of sediment into and along drainageways and depressions where it threatens gardening potential.

It is strongly recommended that the sand ridges of the valleys remain fallow and possibly be utilized for rotational livestock grazing. The side slopes and benches should be strip cropped with fallow strips and cultivated using only minimum tillage by animal traction on the less sloping soils of benches and by hand weeding on the steeper side slopes. The slope lengths of these areas also lend well to farming on the contour. Another recommended practice would be the installation of grassed waterways where natural water courses occur on side slopes. These waterways should remain fallow and should not be placed in rotation.

For lower side slope or footslope areas of the valleys, diversion terraces should be considered for installation. This practice would be used to divert upper slope runoff into the grassed waterways away from natural depressions and toe slope areas that have gardening potential. This would reduce sedimentation and increase the life of this gardening potential.

The shallow and moderately deep soils of the plateaus should remain fallow for livestock grazing and firewood production. However, rotational grazing of forage and controlled cutting of wood should be attempted. The deep, sandy soils over laterite should also be placed in a rotation, similar to the valley soils, if utilized for crop production. In addition, as much residue as feasible (considering livestock needs) should be left in the field, since these soils are subject to severe wind erosion.

The major soils represented in the Sand Valley and Plateau Subzone of the Agricultural Zone are: Fayra, Gagani, Kouara Tegui, Labucheri, Sinsan, Tiloa, Tondi, and Zogoti.

Intermediate Zone

Alluvial Valley and Upland

The Alluvial Valley and Upland Subzone of the Intermediate Zone occupies the northern and northwestern portion of the Say Arrondissement and the extreme southern portion of the Tera Arrondissement. This subzone is merely a continuation of the same subzone that occurs in the Agricultural Zone, which it borders to the south. The only difference in this subzone is climatic. As a result, this subzone has a mean annual rainfall of from approximately 450 to 475 millimeters.

These areas consist of broad, nearly level to gently sloping valleys and nearly level to steep uplands composed of broad ridges, small isolated hills, and plateaus. The valleys contain soils in drainageways, depressions, and low terraces that formed from predominantly clayey alluvium. Also in the valleys are loamy ridges of slightly higher elevation above the terraces.

The broad ridges of the uplands are composed mostly of moderately deep loamy and shallow gravelly soils over ironstone and then laterite. The tops of the broad ridges are nearly level and the side slopes are gently to strongly sloping and have developed many gullies due to water erosion. Scattered throughout this landscape of broad ridges are a few small, isolated hills that consist mainly of stone and boulder sized ironstone rubble. These small hills are generally strongly sloping to steep and many rise to only about 10 to 15 meters above the broad ridges. The plateaus are higher in elevation and their tops are composed mostly of shallow gravelly to moderately deep loamy soils over ironstone and laterite. The

escarpments and steep side slopes of the plateaus are virtually void of soil material and are mostly composed of stone and boulder sized ironstone rubble.

Water erosion is the greatest concern pertaining to soil degradation and loss in productivity. The alluvial clayey and loamy soils of the valleys have a moderate erosion hazard with an estimated annual soil loss of from 2.5 to 10 tons per hectare. Soils within the drainageways have only a slight hazard. Being in a depositional position, these soils receive sediment, however some surface scouring occurs when these areas are inundated with water.

Even though the alluvial ridges and terraces have slopes less than three percent, there remains at least a moderate erosion hazard. This is due to the higher degree of soil erodability on surfaces containing more clay.

The upland soils generally have a very severe erosion hazard. Many areas are void of topsoil and have formed large gullies on the steeper side slopes of the broad ridges. Runoff velocity from these areas has contributed to increased erosion on the adjacent clayey terraces of lower elevation.

The alluvial valleys of this subzone are suited to rainfed agriculture. In addition the soils of the drainageways and the terraces nearest the drainageways are well suited to rainy and dry season gardening.

It is recommended that plowing be done on the contour on the longer side slopes of the ridges and terraces. Where these slopes are too short to facilitate contour plowing, it is recommended that at least some residue be left on the surface after harvest. The natural water courses within the drainageways should not be cultivated. Instead, they should be left fallow and maintained as a grassed waterway for runoff and flood water.

The broad nearly level ridges of the upland should not be cultivated. They should be left fallow and managed for rotational livestock grazing, in order to control erosion. In addition, the steeper side slopes of these ridges where gullies have formed should be reclaimed. This could be accomplished by construction of small water-retarding structures (dikes) in their upper reaches, shaping the gully sides to a reduced slope gradient, and vegetating the entire gully. This practice should indirectly control soil loss from the adjacent more conducive soils on lower elevations.

The major soils represented in this Alluvial Valley and Upland Subzone of the Intermediate Zone are: Bantandi, Fayra, Honrou, Lubri, Makalondi, and Pimpergou.

Dallol Valley

The Dallol Valley Subzone is in the southwestern portion of the Filingue Arrondissement in the Dallol Bosso and Zgaret fossil drainageways. It receives a mean annual rainfall of from about 350 to 475 millimeters.

This subzone consists of gently sloping stabilized dunes of eolian sand, nearly level intermittent drainageways and terraces, and nearly level clayey depressions that remain ponded during the rainy season. The stabilized dunes are undeveloped, very deep, coarse sands. The drainageways and terraces are mostly sandy surfaces with a weakly developed loamy subsoil. Many of these areas surround the clayey depressions that remain ponded.

Soils of the dunes, which are presently being farmed intensively for millet production, have a very severe erosion hazard with an estimated annual soil loss of more than 25 tons/hectare. This is due mainly to wind erosion. The erosion hazard of the drainageways and terraces is moderate

with approximately 2.5 to 10 tons/hectare of soil loss per year. However, the depressions are slight for erosion hazard with less than 2.5 tons/hectare of soil lost each year.

In general, this area is suited to rainfed agriculture. However, the sandy dune areas can not withstand sustained intensive agriculture without the implementation of certain erosion control measures. In addition, the drainageways and areas surrounding depressions are well suited to both rainy season and dry season gardening. The water table is fairly shallow in the Dallol Bosso south of Baleyara. It stays within 2 meters of the surface throughout the year. It falls rapidly to the northeast to about 7 meters at Damana and progressively deeper thereafter.

It is recommended that a program of planting trees for natural windbreaks be implemented for erosion control. This would require a communal effort over several fields. Strip cropping and contour farming should also be stressed on the longer sloping sandy dune areas being utilized intensively for millet production.

The major soils represented in the Dallol Valley Subzone of the Intermediate Zone are Agama, Fandou, Garbey, and N'Dikitan.

Dune, Interdune and Mare

The Dune, Interdune and Mare Subzone of the Intermediate Zone is located in the central and southwestern portions of the Tera Arrondissement. Its mean annual rainfall ranges from about 350 to 475 millimeters.

The landscape is predominantly gently sloping to steep dunes oriented on an east-west axis, nearly level to gently sloping broad, low ridges and valleys between dunes, and nearly level soils surrounding mares that formed from old drainageways and have been bisected perpendicularly by dunes.

The dune areas consist of stabilized sand dunes formed from very deep eolian sand deposits. These sandy soils are either undeveloped or have weakly developed subsoils. The interdunes are composed of broad side slopes and valleys that are mostly loamy and clayey in texture. They are also moderately deep to either granite or ironstone. Also, in the interdune area are isolated outcrops and small peaks, some being quartz and others granite or ironstone outcrops. These areas are surrounded by broad, nearly level to very gently sloping side slopes of very gravelly soil that is shallow to bed rock. Soils underlain by ironstone and laterite are the most extensive.

The mare areas were derived mostly from alluvial clay sediments with some loamy colluvium around its borders of higher elevation. These clayey mare soils become inundated with water in the rainy season and some parts remain ponded well into the dry season.

Erosion hazard for the entire subzone is severe with an estimated annual soil loss of 10 to 25 tons/hectare on the dune areas. These intensively farmed areas are very susceptible to wind erosion. Therefore, implementation of erosion control practices aimed at this would hopefully bring the annual soil loss down to an acceptable rate of approximately 12.5 tons/hectare for these soil types. However, this reduction of soil loss could not be accomplished in a short-term. Certain erosion control efforts would require continuation each year.

The interdune areas are subject to moderate erosion due mainly to water runoff. These finer textured surface soils have a higher degree of soil erodability from water erosion than the sandier soils. In addition,

the soil loss tolerance on these predominantly moderately deep soils is 7.5 tons/hectare per year. The shallow soils of the interdunes have a soil loss tolerance of 2.5 to 5 tons/hectare per year.

The soils of the less sloping side slopes of dunes are suited to rainfed agriculture and erosion could be controlled. However, the steeper soils and soils on the tops of dunes should remain fallow or used for grazing. Even though they may be suited for millet production, erosion would be very difficult to control. In addition, crop failure will occur in many years due to the very low available water capacity of the soil combined with marginal rainfall. Installation of either live or constructed windbreaks is recommended for these dune areas.

The deeper soils within the interdune areas may have potential for certain rainfed agronomic crops. They have a moderate to high available water capacity which should allow ample moisture in the rooting zone throughout the rainy season, in most years.

The mare areas are well suited for rainy and dry season gardening. Most of the soils of these areas could be farmed quite intensively without a great hazard of soil loss. However, erosion could become a serious problem during the rainy season due to runon water from soils of adjacent higher elevations. Safeguards should also be taken to reduce the risk of sedimentation within the mare itself. Otherwise the life of the mare would be shortened.

The major soils represented in the Dune, Interdune and Mare Subzone of the Intermediate Zone are: Agama, Bakala, Dayobu, Gagani, Galiangou, Moma, Namaga, and Zoribi.

Sand Plain

The Sand Plain Subzone of the Intermediate Zone is predominantly near the river valley in the southern portion of the Tillabery and Tera Arrondissements. Mean annual rainfall is from about 375 to 475 millimeters.

This subzone is mainly composed of gently to strongly sloping, undulating sand ridges and valleys. The soils of this landscape formed from eolian sand on old stabilized dunes. These very deep, sandy soils have a developed subsoil. In addition to these soils, there are also a few isolated areas of young, undeveloped, sandy soils that occur in broader valleys. These included areas stay saturated during part of the rainy season from runon of the adjacent sloping soils. However, they dry out soon after the rainy season.

The erosion hazard is severe for the soils of this subzone. This is due to both wind and water erosion. Even though they are sandy with a somewhat excessive internal drainage, the steeper side slopes of the valleys experience enough runoff to cause sheet and rill erosion. Where rows are oriented up-and-down hill instead of on the contour, the hazard for rill erosion is accelerated. Estimated annual soil loss for this subzone is 10 to 25 tons/hectare.

This Sand Plain Subzone is suited to rainfed agriculture, specifically millet production. However, the upper slopes and tops of the undulating ridges may experience crop failure in some years. This is due to seasons of marginal rainfall coupled with insufficient moisture retention ability in the rooting zone. This, in turn, is due to the soils' low available water capacity. In addition, the side slopes of these ridges and valleys can not withstand sustained intensive cultivation without also applying

wind and water erosion control measures. Lack of these measures will lead to continued degradation and loss of soil productivity.

Minimum tillage, strip cropping, and farming on the contour are practices which should be considered if rainfed agriculture is continued in this subzone. In addition, the fields should be rotated out of production to remain fallow no less than one year in three, and some residue should be left in the cultivated fields after harvest. The aforementioned practices should help reduce soil loss to an acceptable tolerance of 12.5 tons/hectare per year.

The major soils represented in the Sand Plain Subzone of the Intermediate Zone are Baboussay, Labucheri and Sourgourou.

Sand Valley and Plateau

This subzone occurs in the southern portions of the Filingue, Ouallam, and Tera Arrondissements, and in the Tillabery Arrondissement. Mean annual rainfall is from about 350 to 475 millimeters.

This area has two major landscapes. One is composed of nearly level to gently sloping valleys between ironstone plateaus. These valleys have a microrelief of low ridges with weakly developed, very deep sandy soils, narrow intermittent drainageways of loamy texture, and broad benches on the upper side slopes below the ironstone plateaus with developed deep soils over laterite. However, some valleys are composed of broad, nearly level flats with moderately deep and deep loamy soils over laterite. These broad flats are generally at higher elevation than low sandy ridges within the same valley.

The other predominant landscape is nearly level to gently sloping ironstone and laterite plateaus with steep escarpments of shallow bouldery and stony ironstone. The plateau tops consist of shallow gravelly soils

over laterite and moderately deep, sandy soils over ironstone gravel and then laterite. Some of these plateaus have adjacent to them stabilized dunes which appear to occur mostly on the eastern side of the plateaus. These dunes are composed of very deep, undeveloped and weakly developed eolian sand. They are predominantly gently to strongly sloping.

In general, the valleys are suited to rainfed agriculture. These areas may experience crop failure in some years due to their lack of moisture. The plateaus are generally unsuited to rainfed agriculture due to the restrictive root zone and lack of moisture. Also, the soils along drainageways and depressions of those drainageways are suited to both rainy and dry season gardening.

This subzone has a very severe erosion hazard with an estimated annual soil loss of more than 25 tons/hectare. Many soils throughout the valleys have lost much of their surface layers, and, as a result, the upper part of the subsoil has become crusted and slightly cemented due to exposure and accelerated weathering. This has increased runoff velocity and contributed to gully erosion where this rapid runoff becomes concentrated at lower elevations. It also poses a threat to some dry season gardening potential due to sedimentation.

The plateaus have undergone a great deal of past erosion and are well degraded. Erosion hazard due to wind appears to be most severe. Some parts of the plateaus have received recent eolian deposits which are now eroding.

It is recommended that the sand ridges of the valleys be left in fallow and the side slopes and benches should be rotated out of production at least one in three years. However, these valleys will not remain productive unless the very severe erosion hazard is dealt with in the near future. Strip cropping, contour farming and minimum tillage should be

implemented. In addition, where natural water courses occur on the slopes these areas should remain fallow and utilized as grassed waterways.

Even though some of the deeper soils of the plateau tops have been cultivated, it is recommended that these areas be managed for pasture and firewood production.

Soils adjacent to many of the intermittent drainageways of valley bottoms are suited to rainy season gardening. Some drainageways have heavier textured soils in depressional areas. In these areas water becomes ponded for long periods and, as a result, provides dry season gardening potential. However, the accelerated erosion from upper sloping soils in the valleys must be controlled prior to development of this dry season gardening potential.

The major soils represented in the Sand Valley and Plateau Subzone of the Intermediate Zone are: Baboussay, Fayra, Gagani, Garbey, Kouara Tegui, Labucheri, Sinsan, Tiloa, Tondi, and Zogoti.

Pastoral Zone

Dallol Valley

The Dallol Valley Subzone in the Pastoral Zone is the upper portion of 3 fossil drainageways of the Filingue and Ouallam Arrondissement. They receive a mean annual rainfall of from 200 to 350 millimeters.

The landscape is characterized by gently to strongly sloping dunes, nearly level to gently sloping terraces, and nearly level depressions and drainageways. The dunes consist of both young stabilized and partially active dunes formed from eolian sand. The terraces are clayey and weakly developed. Drainageways and depressions contain intermittent water and are composed mostly of undeveloped or weakly developed clay.

Soils of the dunes have a severe erosion hazard due to wind erosion throughout the year. It is estimated that 10 to 25 tons/hectare of soil is lost each year from these areas.

The Dallol Valley Subzone of the Pastoral Zone is generally unsuited to rainfed agriculture. In addition any attempt to cultivate this area for such agronomic crops would only accelerate the soil loss. However, some depressions and drainageways that become ponded and remain wet for long periods may be suited for both rainy and dry season gardening. Overall, the best recommended use for this area would be livestock grazing.

The major soils represented within the Dallol Valley Subzone of the Pastoral Zone are Agama, Bakala, and Tuizegorou.

Dune and Sand Plain

This subzone is in the northernmost portions of the Filingue and Ouallam Arrondissements. It receives a mean annual rainfall of from 200 to 325 millimeters.

The Dune and Sand Plain Subzone consists of gently to strongly sloping, partially active dunes and nearly level to gently sloping areas between the dunes. Some dunes are active or have in the past been stabilized and are becoming active. They are composed of undeveloped eolian sand. The sand plains are soils that commonly have a sandy surface and a developed loamy to slightly clayey subsoil. They appear to have derived from older, finer eolian sediment.

The Dune and Sand Plain Subzone has a very severe erosion hazard due to wind erosion. It is estimated that more than 25 tons/hectare of soil is lost each year.

It is unsuited to rainfed agriculture and should not be attempted. However, this area should support a rotational grazing program for livestock production.

Live windbreaks and/or constructed manmade windbreaks may be the best alternative to help reduce soil loss from wind erosion. It is especially recommended if an intensive grazing program is implemented.

The major soils represented in the Dune and Sand Plain Subzone of the Pastoral Zone are Chinagodrar and Tuizegorou.

Dune, Interdune and Mare

This subzone is in the northern part of the Tera Arrondissement and receives a mean annual rainfall of from 250 to 350 millimeters.

The landscape consists of gently sloping to steep dunes that are oriented on an east-west axis, nearly level to gently sloping broad, low ridges and valleys between dunes, and nearly level soils surrounding mares formed from old drainageways that have been bisected perpendicularly by dunes.

The dune areas consist of partially active dunes and stabilized dunes that are becoming active due to erosion. They are composed of very deep undeveloped eolian sand. The interdune areas contain broad side slopes and valleys that are mostly loamy and clayey, broad, shallow ridges that are very gravelly, and isolated outcrops and small peaks of stony areas that lack a soil mantle due to past erosion. Some of these isolated outcrops and peaks are derived from quartz and some from ironstone. Those from ironstone are the most extensive.

The mare areas have derived mostly from alluvial clay sediment with some loamy colluvium around its borders of higher elevation. These clayey mare soils become inundated with water during the rainy season and parts remain ponded well into the dry season.

Overall, the Dune, Interdune and Mare has a severe erosion hazard due mostly to wind erosion. Soil loss ranges from an estimated 10 to 25 tons/hectare per year. However, the mares are in a depositional position and are receiving sediment as a result of water erosion from the nearby sandy dunes and clayey interdunes. Sediment from these areas is threatening the life of most of these mares.

The Dune, Interdune and Mare Subzone of this Pastoral Zone is generally unsuited to rainfed agriculture. Areas where cultivation of such rainfed crops is being attempted is proving futile most every year. This is due mostly to the lack of adequate rainfall and lack of continued available moisture throughout the growing season. However, the mare areas are well suited for rainy season gardening and some of them also have a dry season gardening potential.

The immediate concern is the loss of gardening potential due to sediment from adjoining areas. Attempts to cultivate these adjacent areas for rainfed agronomic crops have intensified the hazard. Therefore, the best erosion control measure would be placement of these areas in fallow and a controlled grazing program. Drainageways leading into the mares should be grassed and ungrazed, if possible, forming grassed waterways. Some drainageways may also require small dikes in their upper reaches to reduce velocity of water entering the waterways.

If possible, it is also recommended that live and/or constructed manmade windbreaks be installed in order to help control erosion of the entire area and improve its overall livestock and gardening potential.

The major soils represented in the Dune, Interdune and Mare Subzone of the Pastoral Zone are Agama, Bakala, Fayra, Gagani, and Tuizegorou.

Sand Valley and Plateau

The Sand Valley and Plateau Subzone is in the northern portion of the Filingue and Ouallam Arrondissements. It borders the Dune and Sand Plain Subzone, which lies further north. It has a mean annual rainfall of from 300 to 350 millimeters.

This area has two landscapes. One is nearly level to gently sloping valleys with a microrelief of sandy, undeveloped low ridges having developed sandy side slopes, and a few isolated low hills of moderately deep to shallow sandy soils over ironstone gravel and laterite.

The other landscape is nearly level to gently sloping ironstone and laterite plateaus with steep escarpments of shallow, bouldery and stony ironstone. The plateau tops vary from shallow gravelly soils over laterite to moderately deep sandy soils over ironstone gravel and laterite. In addition, some plateaus have young, stabilized dunes of deep sand that

bisect the plateau along an east-west axis. The dunes are deepest and most extensive on the northeastern parts of the plateaus on which they occur.

Overall, this area is unsuited to rainfed agriculture. The sand valleys predominantly have a low amount of available moisture in the rooting zone due to its low available water capacity and low amount of rainfall. The plateaus have both soils with a low amount of available moisture for plant uptake and a restrictive rooting depth due to the shallowness to ironstone and laterite. The erosion hazard for this subzone is severe with the sand valleys having the greatest hazard due to wind and water erosion. The plateaus have experienced a great deal of past erosion and are well degraded. Erosion hazard appears to be moderate with some parts of the plateau having received deposits of eolian sand. It is estimated that wind and water contributes to a soil loss of 10 to 25 tons/hectare per year. This is attributed mostly to attempts to cultivate the sand valleys. A shift from farming to livestock production would, in strong probability, be the most important consideration at reducing the overall erosion hazard of this area.

The major soils represented in the Sand Valley and Plateau Subzone of the Pastoral Zone are Fayra, Gagani, Kiwendi, Tondi, and Tuizegorou.

River Valley Zone

This zone encompasses the Niger River flood plain of the Niamey Department. Soils within this zone receive a variable mean annual rainfall of from approximately 250 millimeters in its northernmost part to nearly 700 millimeters in the extreme southern part.

Its landscape is characterized by predominantly nearly level alluvial flats, depressions, natural levees, and terraces. Also included in this landscape are a few short escarpments. These escarpments separate younger,

less developed soils at the lower level (known geologically as a second bottom) from slightly older alluvial flats. The flats and depressions of the flood plain are composed of young and weakly developed clayey soils. The low terraces and natural levees are mostly loamy textured soils with development in their upper portions. These natural levees are merely low ridges within the flood plain which were formed from the sandy and loamy textured sediments. These sediments settled out from fast moving currents of past river overflow from its channel. The higher terraces within the flood plain are older, well developed loamy soils. They are slightly higher than all other soils within the flood plain and, as a result, do not flood as often.

This zone has a moderate erosion hazard due to both water and wind erosion throughout the year. It is estimated that 2.5 to 10 tons/hectare of soil is lost each year due to erosion.

The River Valley Zone is generally suited for rainfed agriculture and well suited for irrigated agriculture. Certain areas of this zone are also well suited for rainy and dry season gardening. In addition, the soils are predominantly well suited for cultivation by animal traction. However, moisture conditions may be a limiting factor on the clayey flats and depressions.

The major soils represented within this zone are Bakala, Galiangou and Namaga.

For more detailed information concerning the soils of the subzones and their specific use and management concerns refer to the following Soil Series Evaluations portion of this section.

Soil Series Evaluations

This portion is devoted to the identification of the major soil series found within the Department, as a result of this zonation study.

First of all, a brief explanation of the term soil series should be addressed.

Soils that have profiles that are almost alike make up a soil series. Except for possible differences in texture of the surface layer or of the underlying material, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, wetness, degree of erosion, and other characteristics that affect their use and management. However, soils within a series have such a degree of similarity that their similar characteristics can be identified and applicable use and management concerns determined.

Given the size of the Niamey Department and its complexity, the soil series level of classification is the lowest level whereby soil suitability, use and management determinations could realistically be made. With the relatively short amount of time for one soil scientist to conduct a soils evaluation for the entire Department, even this level of assigning use and management capabilities requires a great deal of extrapolation.

Therefore, the use and management concerns defined in each of the following soil series may have exceptions. In most cases, however, the exceptions will be a result of factors other than the soil characteristics as defined (such as climate, insects, certain ethnic farming practices, etc.).

Agama Series

These very deep, very poorly drained, nearly level soils are in drainageways and depressions and generally occupy the lowest position on

the landscape. They occur predominantly in the Dallol Valley and the Dune, Interdune and Mare Subzones of both the Intermediate and Pastoral Zones.

Typically, Agama soils have a very dark gray clay surface layer to a depth of approximately 10 centimeters. It has a relatively medium amount of organic matter, as compared to other soils within the Department.

The upper part of the underlying material is black clay that extends to a depth of approximately 120 centimeters. The lower part of the underlying parent material is yellowish brown loamy fine sand that extends to a depth of more than 2 meters.

Soil reaction throughout is neutral through moderately alkaline. It has a high amount of natural fertility and its ability to respond to fertilization is good, if desired.

The runoff rate is ponded and, as a result, these soils remain wet or even flooded for long periods of time during and, in many cases, after the rainy season. Therefore, it is not suited for the production of most rainfed agronomic crops or garden crops during the rainy season and the early part of the dry season. During the dry season these very clayey soils form large cracks downward to depths sometimes greater than one meter from the surface. Suitability to garden crops during the dry season is fair, depending upon wetness and its tilth.

Agama has a fair suitability to animal traction due to the high amount of clay in the surface layer that shrinks when dry and swells when wet (shrink-swell due to high amounts of montmorillonite clay).

These soils pose only a slight hazard to erosion from both water and wind. However, some scouring of the surface does occur during the early part of the rainy season. During the dry season, many cracks receive sand sediment from deposits blown in from other areas.

Baboussay Series

These very deep, somewhat poorly drained, nearly level soils are on depressions and occupy lower positions on the landscape. They occur predominantly in the Sand Plain and Sand Valley and Plateau Subzones.

Typically, Baboussay soils have a grayish brown fine sand surface layer that is approximately 30 centimeters in depth. It has a relatively very low amount of organic matter. The buried surface soil and subsoil is a weakly developed layer of brown and dark brown loamy fine sand to a depth of about 80 centimeters. The underlying material is layers of brown and dark grayish brown fine sand that extends to a depth of more than 2 meters.

Baboussay soils have a soil reaction of from strongly to extremely acid throughout. It contains a low amount of natural fertility and the probable response to fertilization would be fair.

These soils receive runoff and internal drainage from adjacent sandy soils on side slopes. Even though sandy, water stands on parts of the surface during extended periods of the rainy season. The runoff for this soil is very slow. The erosion hazard is slight with most occurring from wind during the dry season. Erosion is being somewhat offset by deposition from runoff of the surrounding, more sloping soils.

Even though low in natural fertility, these soils should have a high degree of suitability to rainy season gardening, and fair suitability for dry season gardening. Suitability to sorghum during the rainy season is fair in areas where water does not stand for prolonged periods.

These soils are well suited to animal traction plowing if sorghum or corn is grown during the rainy season. However, plowing should be avoided immediately after rains and while the surface remains wet to avoid clodding and to make plowing easier. In addition, these soils pack easier if plowed when wet or very moist and would lead to increased compaction.

Bakala Series

These very deep, poorly drained, nearly level soils are on broad, alluvial flats between stabilized dunes. They occur in the Dune, Interdune and Mare Subzone of the Intermediate and Pastoral Zones, and the River Valley Zone.

Typically, Bakala soils have a dark grayish brown sandy clay surface with a relatively medium amount of organic matter. It extends to a depth of about 30 centimeters.

The underlying material is weakly developed dark grayish brown and very dark grayish brown clay and extends to depths greater than 150 centimeters.

Reaction throughout is slightly acid through mildly alkaline. It has a relatively medium amount of natural fertility and its ability to respond to fertilization is good, if desired.

These soils contain high shrink-swell clays which causes large cracks to form up to a meter deep during the dry season. The clay swells and, as a result, cracks close during the rainy season. In addition, the surface runoff rate is very slow.

These soils are unsuited for millet production, have a fair suitability for sorghum, and are well-suited for rice production if irrigation is feasible. In addition, where these soils occur in the Dune, Interdune and Mare Subzone they are unsuited to gardening, but well suited where they occur in the River Valley Zone. They are difficult to till and would be well suited to animal traction without any major contribution to soil loss.

Surface runoff is very slow and the hazard of erosion is moderate. However, the surface has been eroded away and the subsoil is exposed in

many areas, due to past wind erosion. Presently these soils are receiving some windblown sediments from other areas.

These Dakala soils would only be marginally desirable for rainfed agriculture in the Dune, Interdune and Mare Subzones of the Intermediate and Pastoral Zones. As a result, they should be left fallow and managed for rotational grazing. In addition, windbreaks would be the best practice to implement in order to control further wind erosion from it and the adjacent dunes.

However, where these soils occur in the rice producing flood plain of the River Valley Zone they should be managed utilizing water erosion control methods. Field drainage ditches should be installed to carry off excess water and residue should be left to reduce soil loss from surface runoff. Drainage ditches should remain vegetated and grazing prohibited.

Bantandi Series

These are very deep, poorly drained, slightly undulating soils on depressions (bas-fonds) and along intermittent drainageways in alluvial clay valleys of the Alluvial Valley and Upland Subzone.

Typically, Bantandi soils have a dark grayish brown clay surface with a relatively high amount of organic matter as compared to other soils within the Department. It extends to a depth of about 25 centimeters.

The subsoil is olive brown silty clay in the upper part, to a depth of approximately 63 centimeters and strong brown sandy clay loam that extends to a depth of 125 centimeters. Below this is underlying material of stratified strong brown and brownish yellow layers of loamy sand and gravelly loamy sand that extends to depths beyond 150 centimeters.

Bantandi has a soil reaction of from strongly acid on the surface to slightly acid in the subsoil and underlying material. It contains a high

amount of natural fertility and has a very good ability to respond to fertilization, if desired.

These soils have a high degree of suitability to okra and other high moisture tolerant garden crops. They also have a fair suitability to sorghum production. It is subject to frequent flooding of short duration during the rainy season and remains wet for long periods after surface water is removed. As a result the runoff rate is very slow.

They are poorly developed and tilth is also poor due to their clayey nature. These soils are limited for workability under a high moisture condition. Plowing is recommended by animal traction but only after the surface layer is dry enough in order to avoid clodding.

Erosion hazard is slight. These soils are in a depositional position and, as a result, are receiving soil from areas of surrounding higher elevations. There is a severe susceptibility to surface scouring during the rainy season. Therefore, it is recommended that water be diverted at the upper reaches of the fields immediately toward the lowest natural watercourse. This natural, intermittent watercourse should not be planted for production, but native grasses should be allowed to grow without weeding, thus reducing the susceptibility to gully erosion.

Chinagodrar Series

These very deep, somewhat poorly drained, gently sloping soils are on broad low ridges and side slopes of interdunes. They occur predominantly in the Dune and Sand Plain Subzone of the Pastoral Zone.

Typically, Chinagodrar soils have a light yellowish brown fine sand surface layer with a very low amount of organic matter. Its depth is about 20 centimeters.

The subsoil is well developed and consists of brown sandy loam in the upper part, to a depth of about 40 centimeters, and dark brown sandy clay

loam to approximately 80 centimeters. The transitional layer between the subsoil and the underlying material consists of brown sandy loam that is firm and brittle in consistence. It extends to a depth of about 150 centimeters. The underlying material extends beyond depths of 2 meters and is composed of a restrictive layer of very firm and brittle fine sand that is strong brown and reddish yellow in color.

Soil reaction is strongly or very strongly acid in the surface layer and extremely acid in the subsoil and underlying material. It contains a medium amount of natural fertility and its ability to respond to fertilization should be fair.

These soils are unsuited for millet production or most any other rainfed agronomic crop. The consistence of the subsoil and underlying material is restrictive to root development. In addition, these generally do not contain a substantial amount of available moisture in the rooting zone during the growing season suitable for millet of most other rainfed agronomic crops.

Surface runoff on these soils is medium and the hazard of erosion is severe due mainly to wind. Therefore, certain practices aimed at reducing wind erosion should be considered, such as maintaining a grass and legume cover crop with rotational grazing and installation of windbreaks.

Dayobu Series

These very deep, excessively drained, gently sloping to steep soils are on the tops and (mostly) convex side slopes of stabilized sand dunes. These soils are predominant in the Dune, Interdune and Mare Subzone of the Intermediate Zone. However, they are also found in some valleys of the Sand Valley and Plateau Subzones.

Typically, Dayobu soils have a brown sand surface layer that extends to a depth of about 30 centimeters. It has a relatively very low amount of organic matter.

These soils lack a developed subsoil and instead have underlying material of yellowish red sand in the upper part that extends to a depth of about 130 centimeters. The lower part of the underlying material is reddish yellow sand with a high amount of sand that lacks any color. It generally extends to depths much beyond 2 meters.

Soil reaction ranges from very strongly to extremely acid throughout the surface layer and underlying material. It contains a very low amount of natural fertility and its ability to respond to fertilization is poor, as compared to other soils in the Department.

These soils are poorly suited for millet production and most other crops of agronomic importance. Runoff of surface water ranges from slow on gently sloping ridge tops to medium on the steep side slopes.

If used for rainfed agriculture, it is recommended that these soils be cultivated by hand. Use of animal traction or other mechanical means of plowing will increase the probability of plow pan formation due to the well graded sands present in the subsurface layer. As a result the water infiltration rate is reduced and the runoff rate increases.

The erosion hazard, if cropped during the rainy season, is very severe from both water and wind erosion. This will cause rapid soil degradation over a period of continued cropping seasons. Therefore, it is recommended that these soils not be cropped, particularly on steeper slopes. It is recommended that this soil be used for growing a suitable close growing grass cover for livestock grazing and hay production. Grazing should also be managed utilizing a rotational system.

For a more stable long term control of dry season wind erosion, it is recommended that a system of windbreaks be implemented. A canopy cover of at least 20 percent would be most suitable.

Fandou Series

These very deep, somewhat excessively drained, gently sloping soils are on side slopes of sand ridges and may also occupy narrow undulating sand ridges of lower elevation. These soils are predominantly in the Dallol Valley Subzone of the Intermediate Zone.

Typically, Fandou soils have a brown coarse sand surface layer that extends to a depth of approximately 25 centimeters beneath the surface. The organic matter content is relatively very low, as compared to other soils in the Department.

The subsurface layer is dark brown coarse sand to a depth of about 60 centimeters. The subsoil is strong brown sand to about 1 meter, then strong brown loamy sand to depths beyond 2 meters.

Soil reaction is medium acid in the surface layer and medium to slightly acid throughout the subsurface and subsoil. It contains a medium amount of natural fertility and should also yield a good response to fertilization, if desired.

These soils have a high degree of suitability for millet production. However, wind and water erosion is a severe hazard. Runoff from

precipitation is medium during heavy rains of short duration even though these sandy soils have a somewhat excessive internal drainage. Therefore, water and wind erosion control practices should be implemented.

Intercropping with cowpeas and hand cultivating are recommended. These soils are unsuited to animal traction, which would increase erosion. In addition, the coarse sand subsurface layer is somewhat well graded and would contribute to the formation of a plow pan. Farming should be on the contour and, if possible, some residue should be left after harvest to help reduce wind erosion during the dry season.

Where these soils occur on narrow ridges and hills of short slopes the use of a strip cropping system would not be feasible for these small areas.

However, for wind erosion control it is recommended that a multi-field project of establishment of windbreaks be initiated. The zones in which these soils occur most commonly have a water table shallow enough to maintain several varied tree species for establishment of windbreaks.

Fayra Series

These very shallow, excessively drained, strongly sloping to steep soils occur on hills and plateau escarpments and side slopes. This soil is found in all zones of the Department except the River Valley Zone.

Typically Fayra soils have a surface of yellowish red sand between cracks and voids of stones and boulders of ironstone. This surface layer is very low in organic matter content. Its depth is approximately 5 centimeters.

The very weakly developed subsoil is generally yellowish red very gravelly fine sand and extends to a depth of approximately 20 centimeters or less beneath the surface. Beneath this shallow subsoil is hard consolidated ironstone rock.

The soil mantle has a reaction of very strongly or extremely acid throughout. It has a very low amount of natural fertility and a poor ability to respond to fertilization, if desired.

Fayra soils are unsuited for most any type of agricultural use. They are also unsuited for livestock grazing. Its limitations are due primarily to its rockiness, steepness of slopes and very little amount of soil mantle.

Surface runoff is very rapid and, as a result, these soils are very severely degraded from past erosion. Most areas are barren of vegetation.

The erosion hazard is very severe, due primarily to water erosion on these steep slopes. Some areas appear to have received eolian sediment from other areas, however it is constantly being offset by water erosion during the rainy season.

It is recommended that these areas be restricted for use as any agricultural, pastoral, or silvicultural practices. They should remain unused in order to allow for any possible natural regeneration. Regeneration with some vegetative cover would contribute to erosion control of adjoining soils at low elevations that are of more agricultural importance.

Gagani Series

These shallow to very shallow, somewhat poorly drained, nearly level soils are on broad flats of ironstone plateaus and broad low ridges surrounding outcrops of ironstone and, in some areas, quartz. This soil occurs within all zones of the Department except the River Valley Zone.

Typically, Gagani soils have a reddish brown gravelly loamy sand surface layer that extends to a depth of approximately 5 centimeters. It contains a relatively very low amount of organic matter.

The subsoil is yellowish red very gravelly sandy loam that extends to a depth of about 20 centimeters. Below this is an old buried erosional surface of compact laterite which is indurated within its upper portion. This layer is very restrictive to water movement and plant roots and extends to depths well beyond one meter.

The soil reaction ranges from very strongly to extremely acid throughout. It contains a low amount of natural fertility and a poor ability to respond to fertilization, if desired.

Gagani soils are unsuited for rainfed agricultural crops. The shallowness to the restrictive layer of laterite limits root development. In addition, the restrictive laterite causes water to pond on many areas of the surface for long periods after heavy rains.

Runoff is slow, however where the surface has been eroded away and the exposed subsoil has become crusted the runoff is increased. These areas with exposed, crusted subsoils are also void of vegetation. As a result, this also contributes to greater runoff velocity and increased water erosion.

The erosion hazard is severe, due mostly to wind erosion. As a result, it is recommended that these areas remain fallow. Any potential livestock grazing should be controlled through use of a rotational system and wood cutting should be selective. Further erosion and degradation of these soils will also contribute to additional erosion and degradation of more conducive agricultural soils adjacent to these.

Galiangou Series

These very deep, well drained, nearly level soils are on broad lower side slopes and terraces between dunes and mares. They occur in the Dune, Interdune and Mare Subzone of the Intermediate Zone, and in the River Valley Zone.

Galiangou soils have a brown sand surface layer with a relatively low amount of organic matter. Depth of this layer extends to approximately 30 centimeters.

The subsurface is strong brown fine sand that extends to about 50 centimeters in depth. The well developed subsoil is strong brown sandy loam in the upper part, to about 110 centimeters, and reddish yellow sandy loam in the lower part. The subsoil extends to depths beyond 175 centimeters.

Soil reaction is strongly to medium acid in the surface and subsurface layers and slightly acid to neutral in the subsoil. The amount of natural fertility in this soil is relatively medium, as compared to other soils in the Department. In addition, it should yield a good response to fertilization.

Galiangou soils occupy a position whereby they receive runon and internal drainage from adjacent soils on higher side slopes. Runoff from Galiangou soil is slow and the erosion hazard moderate mostly due to wind erosion during the dry season.

These soils dry out somewhat slowly after heavy rains. As a result, they are well suited to sorghum or corn production, and garden varieties during the rainy season. They are poorly suited to dry season gardening due to the limited water supply where these soils occur.

They are well suited for cultivation by animal traction. However, for greater effectiveness plowing should not be conducted immediately after rains while the soil remains in a wet moisture condition. This soil will pack easier if plowed when wet or very moist and increase the probability of compaction.

It is recommended that at least some residue be left in the fields after harvest to help reduce wind erosion during the dry season. Grazing should also be limited after harvest in order to allow some growth of native grasses during the transition period from rainy season to dry season.

Garbey Series

These very deep, moderately well drained, nearly level soils are on concave side slopes of intermittent drainageways and large depressions They are predominantly found in the Dallol Valley and Sand Valley and Plateau Subzones of the Intermediate Zone.

Typically, Garbey soils have a dark brown sand surface with a relatively low amount of organic matter, as compared to other soils within the Department. It extends to a depth of about 10 centimeters.

The subsurface is dark brown sandy loam that extends to a depth of about 30 centimeters over underlying material of light olive brown sandy clay loam. At about 75 centimeters in depth and beneath the underlying material is an older buried surface of dark grayish brown sandy loam to 90 centimeters. Its underlying material is light gray sand that extends to depths beyond 150 centimeters.

Garbey soils have a soil reaction of very strongly to medium acid in the surface layer and slightly acid to mildly alkaline in the underlying layers. It has a relatively medium amount of natural fertility and its response to fertilization would be fair.

These soils receive runon and internal drainage from sandier soils of adjacent higher side slopes and ridges. Surface runoff is slow and some areas are ponded during the rainy season. This is due to the ponding of the adjoining clayier soils in the lower portions of drainageways and depressions.

Erosion hazard is moderate for these soils. The hazard of erosion by water is slight with mostly minor surface scouring during the rainy season. Wind erosion is moderate, however the amount of soil loss is offset somewhat by deposition from other areas both by water in the rainy season and wind sediments in the dry season.

This soil is well suited to both rainy and dry season gardening. It has good tilth and should have an adequate water supply during the dry season from the available shallow water table where it occurs in the Dallol Valley Subzone of the Intermediate Zone. The water table of this soil in the Sand Valley and Plateau Subzone is somewhat deeper.

Cultivation by animal traction is well suited for these soils during the dry season. However, it may not be feasible due to individual garden plot sizes. Use of animal traction during the rainy season is limited by the surface moisture condition. In addition, cultivation by animal traction should not contribute to accelerated soil loss if plowing is performed on the contour. However, if land is available it is recommended that garden areas be placed in rotation with at least one year in three being fallow or planted with a legume cover crop.

Honrou Series

These are very deep, moderately well drained, nearly level soils. They occupy positions on broad convex ridges adjacent to terraces and drainageways. Honrou soils are found within the valleys of the Alluvial Valley and Upland Subzone of the Agricultural Zone.

These soils typically have a dark brown sandy loam surface layer that contains a relatively medium amount of organic matter, as compared to other soils within the Department. This surface layer extends to a depth of approximately 30 centimeters.

The subsoil is dark brown sandy clay loam in the upper part and extends to about 70 centimeters in depth. The middle portion of the subsoil is yellowish red sandy clay to a depth of about 105 centimeters. The lower part os yellowish red clay with red and brownish yellow mottling that extends to depths beyond 150 centimeters.

Honrou soils have a reaction of slightly acid or neutral throughout. They have a relatively high amount of natural fertility and a good ability to respond to fertilization.

These soils are well suited to millet production and most other rainfed agronomic crops common to the Department. They are also well suited to cultivation utilizing animal traction, or other mechanical methods.

These soils have medium surface runoff and the erosion hazard is moderate. Water erosion during the dry season is the predominant contributing factor to soil loss.

These well drained soils can be worked during a wide range of moisture conditions. They are well developed and have good tilth. However, it is recommended that all farming practices be performed on the contour. Residue should be left in the fields after harvest and the fields should be placed in a rotation program whereby they will be fallow at least one growing season in three.

Areas on the lower slopes that have evidence of rill erosion should be left fallow and possibly a diversion terrace constructed above these isolated areas to control runoff and its velocity.

Kiwendi Series

These very deep, somewhat excessively drained, gently sloping soils are on convex side slopes and tops of low ridges within a sandy interdune landscape of the Sand Valley and Plateau Subzone of the Pastoral Zone.

Typically, Kiwendi soils have a strong brown sand surface layer that is relatively very low in organic matter content. Depth of the surface layer extends to approximately 10 centimeters.

The upper part of the subsoil consists of yellowish red sandy loam to about 50 centimeters and reddish yellow loamy fine sand that extends to about 1 meter in depth. The subsoil has fair development. The lower part of the subsoil is weakly developed and intergrades to underlying material. This underlying material is reddish yellow fine sand to depths beyond 175 centimeters.

Soil reaction is very strongly or extremely acid throughout. It contains a low amount of natural fertility and its ability to respond to fertilization should be fair.

These soils are poorly suited for millet production or most other rainfed agronomic crops due to the low amount of available moisture content during the growing season. Even though millet is being grown in some areas on this soil, crop failure due to drought will be more the usual than unusual result. As a result, these soils are best suited to production of grasses and legumes for livestock grazing.

The erosion hazard for this soil is very severe. At present, the subsoil is exposed over approximately 40 percent or more of the surface. Areas where the surface layer remains, it is very shallow. The exposed subsoil becomes crusted due to weathering. On these areas infiltration is reduced and surface runoff is increased. As a result, velocity of runoff water and its erosion hazard increases. The overall surface runoff rate of Kiwendi soils is medium.

If these soils are utilized for grazing, a rotational method should be implemented to control overgrazing and erosion.

Kouara Tegui Series

These very deep, moderately well drained, nearly level soils are along intermittent drainageways. These soils are found in the Sand Valley and Plateau Subzones of both the Agricultural and Intermediate Zones.

Typically, they have a brown sandy loam surface layer with a relatively low amount of organic matter. The surface layer is approximately 10 centimeters in depth.

The subsoil is well developed and is reddish brown sandy clay loam in the upper part, to about 60 centimeters. The lower part of the subsoil is yellowish red sandy loam to a depth of about 110 centimeters. Below this, the subsoil intergrades to underlying material of strong brown loamy fine sand to depths greater than 150 centimeters.

Soil reaction is strongly to very strongly acid throughout. They have a relatively low amount of natural fertility and a fair response to fertilization, if desired.

Surface runoff is slow and the erosion hazard is moderate, due mostly to water erosion during the rainy season. During heavy rains this soil is flooded for short duration and scouring of the surface occurs.

These soils are well suited for gardening during both the rainy and dry seasons. They are also well suited for sorghum production.

Cultivation by animal traction is recommended, as these soils are on slopes where the erosion hazard would not be accelerated, along with poorly graded textures in the plow layer. However, the size of fields and garden plots may restrict its use.

Labucheri Series

These very deep, well drained, gently to strongly sloping soils are on slightly concave side slopes. Labucheri soils are predominantly within

valleys of the Sand Valley and Plateau Subzone of both the Agricultural and Intermediate Zones.

Typically, Labucheri soils have a brown fine sand surface layer with a depth of approximately 20 centimeters. However, there are also some gullied areas of this soil where the surface layer has either been removed or is very thin. Organic matter content is relatively very low.

The subsurface layer, when present, is yellowish red loamy fine sand to a depth of approximately 70 centimeters. The subsoil is yellowish red to red loamy fine sand to about 120 centimeters. Below this, the subsoil intergrades to reddish yellow sandy loam and extends to a depth more than 2 meters beneath the surface.

Labucheri soils have a reaction of strongly or very strongly acid in the surface and subsurface layers and very strongly or extremely acid in the subsoil. It has a low amount of natural fertility and a relatively fair response to fertilization.

These soils are well suited for millet production. However, areas that have eroded surfaces down to subsoils and gullies are less productive and, as a result, less suited. These areas with exposed subsoils have become crusted due to accelerated weathering and somewhat restrict seed germination and emergence.

They have a very severe erosion hazard and surface runoff is medium to rapid. The rapid runoff and reduced infiltration rate are primarily a result of surface loss from past erosion. Both water and wind erosion are major concerns on these soils.

These soils have poorly graded textures that should not contribute to compaction. However, animal traction is not recommended for these soils due to the very severe erosion hazard on these sloping areas. All cultivation should be accomplished by hand.

To help control water erosion, it is recommended that farming be done on the contour combined with strip cropping. Strips should either remain fallow or planted in a close growing ground cover, parallel to the millet rows on the contour. In addition, terraces should be constructed in order to conserve moisture and reduce runoff velocity.

In areas that have eroded surfaces down to subsoil and are truncated with gullies, it is recommended that renovation of drainageways be accomplished. These areas are natural water courses, therefore the gully walls should be shaped to reduce slope gradient and then vegetated to establish a grassed waterway. To reduce velocity and further control erosion after the waterways are constructed, it is suggested that small water-retarding structures (or dikes) be constructed and vegetated. These structures should be placed both upstream near the upper reaches of the gullies and drainageways, and uniformly spaced throughout the length of the grassed waterway.

To control wind erosion, the residue from the crops should be left in the fields after harvest. Also, and if obtainable, it is suggested that an early maturing variety of millet be planted as early as possible in the growing season. This will allow better re-establishment of a ground cover going into the dry season.

A more permanent long term wind erosion control practice that could be implemented in these areas would be the establishment of windbreaks. It could be accomplished utilizing either live or constructed manmade barriers. It would require a joint effort among several farmers within the sand plains and sand valleys in which these soils occur.

Lubri Series

These are very deep, somewhat poorly drained, nearly level soils on broad terraces of elevations slightly higher than adjacent depressions (bas-fonds) and drainageways. They are in the Alluvial Valley and Upland Subzone of the Agricultural Zone.

Typically, Lubri soils have a brown sandy clay surface with a relatively medium amount of organic matter, as compared to other soils within the Department. Depth of the surface layer extends to about 25 centimeters.

Its subsoil is strong brown clay in the upper part, to a depth of approximately 67 centimeters and olive brown clay to a depth of 125 centimeters. The lower part of the subsoil is light olive brown sandy clay with light gray and brownish yellow mottling and contains many pockets of saprolite. Its depth extends beyond 160 centimeters.

Soil reaction throughout is neutral to mildly alkaline and this soil has a high amount of natural fertility. Its ability to respond to fertilization is very good, if desired.

These soils have a high degree of suitability to corn or sorghum. Runoff is medium and the tilth is fair to poor due to the high clay content. This makes plowing difficult even though cultivation by animal traction would be recommended on these soils.

Susceptibility to water erosion is moderate even though slopes are nearly level. This is due to the sandy clay surface. Therefore, plowing should be on the contour. In addition, since internal drainage is somewhat poor, cultivation should not be soon after heavy rains in order to prevent clodding and increase the ease of plowing.

Even though this soil has a high suitability to corn or sorghum the potential for rainy season and (quite possibly in some areas) dry season gardening should not be overlooked.

Makalondi Series

These are shallow, well drained, gently to strongly sloping soils on side slopes of broad ridges. These soils occur in uplands of the Alluvial Valley and Upland Subzone in the Agricultural Zone.

Typically, Makalondi soils have a strong brown gravelly fine sand surface layer with a very low amount of organic matter. Its depth is approximately 15 centimeters.

The subsoil is yellowish red, very gravelly loamy sand that extends to about 35 centimeters over a layer of cemented ironstone gravel. This ironstone gravel layer is only about 5 centimeters in thickness and intergrades to a bed of laterite that extends well beyond 50 centimeters in depth.

Soil reaction is strongly or very strongly acid in the surface layer and very strongly or extremely acid throughout the subsoil. Makalondi soils have a very low amount of natural fertility and a poor ability to respond to fertilization, if desired.

These soils are unsuited for most rainfed agricultural crops of economic importance. The shallowness to the restrictive layer combined with its steepness of slopes are the main limitations.

Runoff is rapid and has created many areas where laterite is exposed on the surface and have become truncated with gullies from erosion.

Erosion hazard is very severe and these soils add to the hazard of erosion to agriculturally important soils on areas of lower elevation. This is primarily due to the concentration and velocity of runoff from this soil, particularly from the areas where the soil is already lost and laterite is exposed.

It is recommended that these areas remain fallow and possibly utilized for rotational grazing of livestock. On severely gullied areas, it is also recommended that the gully walls be shaped to lessen slope gradients, and then vegetated. This will provide a grassed waterway which should help control erosion and reduce velocity of runon to adjacent soils of lower elevations. It is also suggested that small water-retarding structures (dikes) be installed at the heads of large gullies and possibly trees planted upslope of these structures.

Moma Series

These very deep, somewhat excessively drained, strongly sloping soils are on slightly concave side slopes of stabilized dunes. They occur within the dune and mare landscape and are predominant within the Dune, Interdune and Mare Subzone of the Intermediate Zone.

Typically, Moma soils have a brown sand surface layer that is relatively very low in organic matter content. Its depth extends to about 20 centimeters.

The subsoil has fair development and consists of yellowish red loamy sand and loamy fine sand. Depth of the subsoil extends beyond 175 centimeters.

Soil reaction in the surface is medium acid and the subsoil ranges from strongly to slightly acid. It contains a low amount of natural fertility. Its ability to respond to fertilization is fair.

These soils are suited for millet production over a sustained number of years only if applicable erosion control measures are taken. Otherwise, the soil will be further degraded by water and wind erosion and its production ability greatly reduced.

Surface runoff is medium. Even though these sandy soils have a somewhat excessive internal drainage its surface water runoff is increased during periods of heavy rainfall. As a result, all farming practices should be performed on the contour and without the use of animal traction or any other means of mechanical plowing. Plowing on these well graded sands will increase compaction and the probability of plow pan formation. This compaction would reduce water infiltration rate and increase the rate of runoff.

Due to the severe erosion hazard, it is recommended that strip cropping of a close growing ground cover be implemented with the millet crop. This will reduce the velocity of surface runoff, serve as a filter for sediment load in the runoff water, and will reduce surface uptake by wind during the rainy season. Strips within the fields should also be rotated from cropping season to season.

To control wind erosion during the dry season, it is recommended that at least some residue from the crop be left in the field. It is also suggested that an early maturing variety of millet crop be used and planted very early in the growing season. This will allow better re-establishment of a ground cover, either naturally or by seeding, after millet harvest.

Namaga Series

These very deep, somewhat poorly drained, nearly level soils are on low broad terraces adjacent to mares on the dune side, and on terraces and natural levees in the river flood plain. These soils are found in the Dune,

Interdune and Mare Subzone of the Intermediate Zone, and in the River Valley Zone.

Typically, Namaga soils have a brown fine sand surface layer with a relatively very low amount of organic matter. It extends to a depth of approximately 25 centimeters.

The subsurface layer is pale brown sandy loam to about 50 centimeters in depth. The subsoil is a well developed layer of yellowish brown sandy clay loam. It extends to a depth of about 80 centimeters. The underlying material consists of mottled, strong brown and yellowish brown sand to 150 centimeters, and varigated yellowish brown, pale brown and strong brown fine sand which extends to a depth beyond 175 centimeters.

Namaga soils have a soil reaction of neutral to mildly alkaline throughout. They have a relatively medium amount of natural fertility and a good response to fertilization, if desired.

Surface runoff from this soil is slow and its erosion hazard is slight, being predominantly due to wind erosion. The wind erosion is reduced on this soil due to the presence of fences and windbreaks around areas that are being utilized for gardens.

These soils are well suited for gardening during both the rainy and dry seasons. They are also well suited to animal traction. However, the size of garden plots being cultivated may render plowing by animal traction impractical.

These soils have a seasonal water table at less than two meters below the surface during the duration of the rainy season and well into the dry season. As a result, these soils are ideal for gardening during both seasons.

N'Dikitan Series

These very deep, excessively drained, gently sloping to steep soils are on convex side slopes and tops of sand ridges. They occur within the Dallol Valley Subzone of the Intermediate Zone.

Typically, N'Dikitan soils have a yellowish brown coarse sand surface layer that extends to approximately 15 centimeters. Organic matter content is very low, compared to other soils within the Department.

The subsurface layer is brown coarse sand to about 30 centimeters. The underlying material is reddish yellow sand to 80 centimeters and then various shades of pink sand that extends to a depth of more than 230 centimeters. The underlying material lacks any development and contains more than 50 percent of coarse uncoated sand at depths below 1 meter.

Soil reaction is medium to extremely acid throughout the surface, subsurface and underlying material. It contains a low amount of natural fertility and also should yield only a poor response to fertilization, if desired.

These soils have a fair degree of suitability for millet production. Surface runoff is slow. However it is medium during heavy rains of short duration on the steeper slopes.

Wind erosion is a very severe hazard and soil loss from water erosion is somewhat severe. Therefore, water and wind erosion control practices should be implemented. If these areas are cropped for millet, it is recommended that they be intercropped with a close growing ground cover legume and only hand cultivation be utilized.

Animal traction should be avoided on these well graded coarse sands in order to reduce the hazard of compaction and formation of a plow pan. In addition, all farming practices should be done on the contour. If enough land area is available, it is also recommended that the millet be strip

cropped with a close growing grass cover crop and at least some of its residue be left in the field after harvest. This will help reduce wind erosion during the dry season.

Another soil management consideration to reduce wind erosion would be the establishment of windbreaks in a multi-field project.

Pimpergou Series

These are moderately deep, well drained, nearly level soils that occur on broad upland ridges and on some plateau tops. These soils are found in the Alluvial Valley and Upland Subzone of the Agricultural Zone.

Typically, Pimpergou soils have a brown loamy fine sand surface layer that is approximately 15 centimeters in depth. The organic matter content in this surface is relatively very low.

The subsoil is yellowish red sandy loam to about 40 centimeters in depth and yellowish red sandy clay loam that extends to a depth of approximately 70 centimeters. The subsoil is underlain with approximately 10 centimeters of cemented ironstone gravel over a thick bed of laterite. It extends to depths beyond 150 centimeters.

Pimpergou soils have a reaction of from strongly acid on the surface to extremely acid at the depth where it comes in contact with the laterite. These soils have a low amount of natural fertility and a fair ability to respond to fertilization, if desired.

These soils have a poor suitability to most agronomic crops common to the Department. The depth to the ironstone layer and laterite varies from approximately 50 to 100 centimeters beneath the surface. As a result, this somewhat restricts root development of most agronomic crops. In addition, the surface becomes somewhat crusted and compact due to the exposure of subsoil in many areas that have been eroded.

Surface runoff is medium. However, in areas that have crusted and compact surfaces the infiltration rate is reduced and runoff is increased.

The erosion hazard is severe, due primarily from water erosion. Therefore, it is recommended that cultivation be accomplished by hand if farming is attempted. Also, the attempted crops should be intercropped with a close growing ground cover, such as cowpeas. This will not only help control erosion during the growing season but also increase tilth and fertility in these marginally productive soils. Residue should be left in the fields after harvest.

The best recommendation for use of these soils would be to leave fallow and managed for livestock grazing with a rotational grazing program.

Sinsan Series

These moderately deep, well drained nearly level soils occur on low hills and broad level flats of sand valleys. Sinsan soils occur in the Sand Valley and Plateau Subzones of the Agricultural and Intermediate Zones.

Typically, Sinsan soils have a light yellowish brown fine sand surface layer with a very low amount of organic matter. Depth of the surface layer is approximately 15 centimeters.

The upper part of the subsoil is yellowish red sandy clay loam and is well developed. It extends to approximately 50 centimeters in depth. The lower part is weakly developed yellowish red, very gravelly sandy loam to a depth of approximately 90 centimeters over laterite that is very firm and cemented. This laterite extends to depths well beyond 1 meter.

Sinsan has a soil reaction of strongly or very strongly acid in the surface layer and the upper part of the subsoil. The lower part ranges from medium to strongly acid over extremely acid laterite. It has a low

amount of natural fertility and a fair ability to respond to fertilization, if desired.

These soils are suited to millet production with only a fair degree of suitability. The depth to laterite may vary from 50 to 100 centimeters in depth and, as a result, somewhat restricts root development of most agronomic crops.

Surface runoff is medium and they have a very severe erosion hazard. Past erosion is the cause of the shallow surface layer and, in many areas, the subsoil has become exposed. These areas with exposed subsoil have become crusted and slightly cemented due to accelerated weathering. As a result, infiltration rate is reduced and surface runoff is increased.

Due to the very severe erosion hazard, it is recommended that cultivation be accomplished using minimum tillage with animal traction or by hand, if farming is attempted. If hand cultivated, the crops could be intercropped with a close growing ground cover, and the residue from the crops should be left in the fields after harvest. The fields will also require a rotation into fallow at least once in three years, if not more.

However, if other more suitable soils are available for agronomic crops it is recommended that these areas remain fallow at least two years in three, and be managed for rotational livestock grazing and hay, during the fallow periods.

Sourgourou Series

These very deep, somewhat excessively drained, nearly level to gently sloping soils are on narrow ridges and on broad benches below ironstone plateaus of higher elevation. They are predominantly within the Sand Plain Subzones of both the Agricultural and Intermediate Zones.

Typically, Sourgourou soils have a strong brown fine sand surface layer that extends to a depth of approximately 22 centimeters beneath the surface. Amount of organic matter is relatively very low, compared to other soils within the Department.

The subsurface layer is yellowish red fine sand to a depth of approximately 50 centimeters. The subsoil is red loamy fine sand and extends to depths beyond 2 meters.

Sourgourou soils have a soil reaction of from medium to very strongly acid throughout. It contains a low amount of natural fertility but should have a fair ability to respond to fertilization, if desired. These soils are well suited for millet production.

Surface runoff is slow. However on the steeper gradients it is medium even though these sandy soils have a somewhat excessive internal drainage.

Erosion hazard is severe. Therefore, water erosion control measures are very necessary, such as farming on the contour and strip cropping with a cover crop such as cowpeas.

It is also highly recommended that at least some crop residue be left in the fields, if possible. This will improve tilth, increase organic matter and more importantly contribute to the reduction of soil loss by wind erosion during the dry season.

Minimum tillage by hand is recommended. These soils are not suited to animal traction cultivation. Plowing will increase the hazard of erosion and compaction. As a result, it will cause substantial yield reductions over a period of years. Weeding by hand tools only is recommended.

Tiloa Series

These very deep, well drained, nearly level to gently sloping soils are on low ridges and side slopes adjacent to drainageways in sand valleys. Tiloa soils are found in the Sand Valley and Plateau Subzones of both the Agricultural and Intermediate Zones.

Typically, Tiloa soils have a light brown fine sand surface layer with a relatively low amount of organic matter, as compared to other soils within the Department. Depth of this layer extends to approximately 20 centimeters.

The upper part of the subsoil is strong brown loamy fine sand to a depth of about 90 centimeters. The lower part is strong brown sandy loam to approximately 125 centimeters and then it intergrades to sandy clay loam to a depth greater than 175 centimeters. The lower part of the subsoil is well developed.

Tiloa soils have a reaction of strongly to extremely acid throughout. They contain a relatively medium amount of natural fertility and should have a good ability to respond to fertilization.

These soils are well suited to millet production and most other rainfed agronomic crops. In addition they are suited to minimum tillage utilizing animal traction. Plowing should be avoided during periods when the soil is wet or very moist, as the soils would pack easier and increase the probability of compaction.

The surface runoff is medium and the erosion hazard is moderate. Wind erosion during the dry season is the predominant contributing factor to soil loss. Therefore, erosion control measures aimed at such should be implemented.

To control wind erosion, it is recommended that residue be left in the field after harvest. Fields should also be rotated into fallow to improve

tilth and control erosion. Plowing should also be done on the contour to control water erosion. Intercropping with a close growing ground cover, such as cowpeas, is an erosion control practice that could be implemented if cultivation is by hand. This would also increase tilth and fertility.

Tondi Series

These moderately deep to shallow, moderately well drained, nearly level soils are predominantly the northeastern portion of the tops of broad ironstone plateaus. They are predominantly within the Sand Valley and Plateau Subzones of the Agricultural and Intermediate Zones.

Typically, Tondi soils have a yellowish red fine sand surface layer that extends to a depth of approximately 20 centimeters. Organic matter content is relatively very low.

The subsoil is red loamy fine sand that extends to approximately 50 centimeters. This subsoil is underlain over an old buried erosional surface of compact laterite which contains cemented ironstone gravel in the upper 10 centimeters. The laterite extends to depths beyond 150 centimeters.

The soil reaction ranges from very strongly acid in the surface to extremely acid at the point of laterite contact. It has a low amount of natural fertility and a fair ability to respond to fertilization, if desired.

These soils are poorly suited to most agronomic crops common to the area. The depth to laterite varies from 30 to 90 centimeters beneath the surface and, as a result, restricts root development. This soil also has several eroded areas where the subsoil is exposed. These exposed areas of subsoil have become crusted and somewhat cemented due to the oxidation of the iron contained in the subsoil. They are not suited to animal traction, as it would only accelerate soil loss more.

Runoff is medium and the hazard from both water and wind erosion is severe. These areas, even though not well suited for agronomic crops, should be planted in a suitable cover for either rotational grazing or selected timber cutting or both. However, a cover should be maintained even throughout the year in order to control further erosion.

Tuizegorou Series

These very deep, excessively drained, gently to strongly sloping soils are on tops and side slopes of stabilized and active dunes. They occur predominantly in all three subzones of the Pastoral Zone.

Typically, Tuizegorou soils have a brown sand surface layer with a very low amount of organic matter. Depth of the surface layer is approximately 25 centimeters.

The underlying material consists of undeveloped, yellowish red and then reddish yellow sand that extends to depths well beyond 2 meters.

Soil reaction ranges from very strongly to extremely acid throughout. The amount of natural fertility is low and its ability to respond to fertilization is low.

These soils are unsuited for millet production or most other rainfed agronomic crops. This is due to its droughtiness during the normal growing season. Even though millet farming is being attempted on this soil in some areas, it is not recommended. The amount of soil moisture available during the rainy season is not sufficient enough in most years.

These soils are best suited for livestock grazing and then only in rotation to prevent overgrazing.

Surface runoff is slow and the hazard of erosion from wind is very severe, which is another consideration for avoiding agronomic crop production. Wind erosion control practices should be implemented even if utilized for grazing.

If possible, a system of live or manmade windbreaks should be installed and protected. In addition to grazing rotation of pastures during the growing season, areas should selectively remain fallow and ungrazed at least one year in three. Being active and young somewhat stabilized dunes, these soils are the most fragile to wind erosion.

Zogoti Series

These deep, somewhat excessively drained, gently sloping soils are on upper benches and side slopes below ironstone plateaus. These soils occur in the Sand Valley and Plateau Subzones of both the Agricultural and Intermediate Zones.

Typically, Zogoti soils have a strong brown fine sand surface layer that extends to a depth of approximately 15 centimeters. Organic matter content is relatively very low.

The subsoil is a well developed layer of yellowish red and red loamy fine sand that extends to at least 1 meter in depth. Below this is an older subsoil that has been weathered to red very gravelly loamy fine sand that is cemented and intergrades to laterite at depths greater than 150 centimeters.

Soil reaction is from very strongly acid in the surface and upper part of the subsoil to extremely acid in the lower subsoil and underlying laterite. It contains a low amount of natural fertility but should yield a fair response to any desired fertilization.

These soils have a high degree of suitability to millet production. However, erosion is a very severe hazard to the steeper slope gradients due to increased runoff of surface water. Overall, runoff is medium.

Cultivation by animal traction or other mechanical means is not recommended. All available water erosion control measures should be

implemented, such as contour farming, no tillage or minimum tillage, intercropping with cowpeas, construction of terraces and establishing grassed waterways where natural waterways and gullies have formed. If at all possible it is recommended that at least some crop residue be left in the field after harvest. This will contribute to the reduction of wind erosion during the dry season and water erosion during rains that may occur before and after the growing season. The residue left will also improve organic matter and moisture retention. In addition, the practice of strip cropping millet with a low growing grass cover would reduce soil loss considerably.

If suitable erosion control measures are not implemented then millet or other types of cereal crop production should be avoided on this soil.

Zoribi Series

These moderately deep, somewhat poorly drained, nearly level to gently sloping soils are on broad side slopes below low ridges and hills with outcrops. They occur predominantly in interdune areas and on side slopes opposite the dune side of mares. The subzone in which they are predominant is the Dune, Interdune and Mare Subzone of the Intermediate Zone.

Typically Zoribi soils have a strong brown fine sand surface layer with a relatively low amount of organic matter. Its depth extends to approximately 25 centimeters.

The upper part of the subsoil is a developed, reddish brown sandy clay. It extends to about 60 centimeters. The lower part of the subsoil is more developed and has evidence that part of it and the original surface layer have been eroded away and then the present upper subsoil and surface layer was re-deposited on this erosional surface. This lower subsoil is olive brown clay that extends to a depth of approximately 90 centimeters. Beneath the subsoil is hard and consolidated quartz bedrock.

Reaction of the surface layer is medium or strongly acid. The upper part of the subsoil has a reaction that ranges from medium acid to neutral and the lower part is slightly acid to mildly alkaline. Zoribi soils have a relatively medium amount of natural fertility, as compared to other soils in the Department. Its ability to respond to fertilization is fair.

These soils have a high available water capacity and surface runoff is rapid.

Zoribi soils are unsuited for millet production and have a poor suitability for sorghum. In addition, they mostly have a poor potential for gardening even though some areas are adjacent to mares and drainageways. The high amount of clay in the lower subsoil and depth to bedrock are very restrictive to root development.

The erosion hazard is severe for Zoribi soils. Many areas have most of the surface soil eroded away and the clayey subsoil exposed. Where this has occurred, the soil has been truncated with many small and a few medium size gullies.

These soils would not be suited to animal traction related to agricultural intensification of either rainfed agriculture or dry season gardening. These areas could best be utilized by leaving fallow and managing rotational grazing of livestock. In areas adjacent to mares which have formed gullies flowing into the mares, it is recommended that the gully walls be shaped and grassed. In addition to construction of grassed waterways, consideration should also be given to constructing small water-retarding structures (dikes) at the upper reaches of the gullies. These conservation practices will help reduce degradation of mares and adjacent soils with gardening potential by helping to control sedimentation.

Soils Glossary

Alluvium (alluvial material). Material, such as sand, silt, or clay, deposited on land by streams.

Available water capacity (available moisture capacity). The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity and the amount at wilting point. It is expressed as centimeters of water per centimeter of soil. The capacity, in centimeters, in a 150-centimeter soil profile or to a limiting layer (such as bedrock) is expressed as --

	Centimeters
Very low	Less than 7.5
Low	7.5 to 15.0
Moderate	15.0 to 22.5
High	22.0 to 30.0
Very high	More than 30.0

Base saturation. The degree to which material having cation exchange properties is saturated with exchangeable bases (sum of Ca, Mg, Na, K), expressed as a percentage of the total cation exchange capacity.

Bedrock. The solid rock that underlies the soil and other unconsolidated material or that is exposed at the surface.

Cation exchange capacity. The total amount of exchangeable cations that can be held by the soil, expressed in terms of milliequivalents per 100 grams of soil at neutrality (pH 7.0) or at some other stated pH value. The term, as applied to soils, is synonymous with base exchange capacity, but is more precise in meaning.

Clay. The mineral soil particles less than 0.002 millimeter in diameter. As a soil texture class, it is soil material that is 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Clay film. A thin coating of oriented clay on the surface of a soil ped or lining pores or root channels in the soil.

Colluvium (colluvial material). Material moved by creep, slide, or local wash and deposited at the base of slopes.

Consistence, soil. The feel of the soil and the ease with which a lump of soil can be crushed by the fingers. Consistence describes the cohesion among soil particles and the adhesion of soil to other substances. Consistence is the strength or degree of resistance to breaking or crushing when force is applied. It is evaluated under three different moisture conditions. Terms commonly used in this report to describe consistence are--

Loose-- Noncoherent when dry or moist, does not hold together in a mass.

Friable-- When moist, crushes easily under gentle pressure between thumb and forefinger and can be pressed together into a lump.

Firm-- When moist, crushes under moderate pressure between thumb and forefinger, but resistance is distinctly noticeable.

Brittle-- When dry, moderately resistant to pressure; can be broken with difficulty between thumb and forefinger.

Cemented-- Hard; little affected by moistening. Caused by some cementing agent other than clay (such as calcium carbonate or oxides of iron and aluminum).

Contour stripcropping. Growing crops in strips that follow the contour. Strips of grass or close-growing crops are alternated with strips of clean-tilled crops or fallow.

Cover crop. A close-growing crop grown primarily to improve and protect the soil between periods of regular crop production, or a crop grown between strips of clean-tilled crops.

Diversion (or diversion terrace). A ridge of earth, generally a terrace, built to protect downslope areas by diverting runoff from its natural course.

Drainage class (natural). Refers to the frequency and duration of periods of saturation or partial saturation during soil formation, as opposed to altered drainage, which is commonly the result of artificial drainage or irrigation but may be caused by the sudden deepening of channels or the blocking of drainage outlets. Seven classes of natural soil drainage are recognized:

> Excessively drained. Water is removed from the soil very rapidly. Excessively drained soils are commonly very coarse textured, rocky, or shallow. Some are steep. All are free of the mottling related to wetness.
>
> Somewhat excessively drained. Water is removed from the soil rapidly. Many somewhat excessively drained soils are sandy and rapidly pervious. Some are shallow. Some are so steep that much of the water they receive is lost as runoff. All are free of the mottling related to wetness.
>
> Well drained. Water is removed from the soil readily, but not rapidly. It is available to plants throughout most of the growing season, and wetness does not inhibit growth of roots for significant periods during most growing seasons. Well drained soils are commonly medium textured. They are mainly free of mottling.
>
> Moderately well drained. Water is removed from the soil somewhat slowly during some periods. Moderately well drained soils are wet for only a short time during the growing season, but periodically they are wet long enough that most mesophytic crops are affected. They commonly have a slowly pervious layer within or directly below the solum, or periodically receive high rainfall, or both.

Somewhat poorly drained. Water is removed slowly enough that the soil is wet for significant periods during the growing season. Wetness markedly restricts the growth of mesophytic crops unless artificial drainage is provided. Somewhat poorly drained soils commonly have a slowly pervious layer, a high water table, additional water from seepage, nearly continuous rainfall, or a combination of these.

Poorly drained. Water is removed so slowly that the soil is saturated periodically during the growing season or remains wet for long periods. Free water is commonly at or near the surface for long enough during the growing season that most mesophytic crops cannot be grown unless the soil is artificially drained. The soil is not continuously saturated in layers directly below plow depth. Poor drainage results from a high water table, a slowly pervious layer within the profile, seepage, nearly continuous rainfall, or a combination of these.

Very poorly drained. Water is removed from the soil so slowly that free water remains at or on the surface during most of the growing season. Unless the soil is artificially drained, most mesophytic crops cannot be grown. Very poorly drained soils are commonly level or depressed and are frequently ponded. Yet, where rainfall is high and nearly continuous, they can have moderate or high slope gradients.

Dunes, sand. Ridges that characteristically consist of sand, especially fine or medium sand, that is very rich in quartz and low in clay-forming materials. Sand dunes may (in some cases) consist of large amounts of calcium carbonate. Dunes are formed from eolian (or wind-deposited) material.

Eolian. Refers to deposits of soil material (primarily sand). Eolian sand is commonly but not always in dunes.

Erosion. The wearing away of the land surface by water, wind, ice, or other geologic agents and by such processes as gravitational creep.

Erosion (geologic). Erosion caused by geologic processes acting over long geologic periods and resulting in the wearing away of mountains and the building up of such landscape features as flood plains and coastal plains. Synonym: natural erosion.

Erosion (accelerated). Erosion much more rapid than geologic erosion, mainly as a result of the activities of man or other animals or of a catastrophe in nature, for example, fire, that exposes the surface.

Soils of a particular area can be ranked according to their relative susceptibility to erosion and placed into a small number of groups that differ significantly in susceptibility. The following is a list of the erosion hazard classes defined in terms of annual soil loss in metric tons (t) per hectare (ha). The erosion hazard classes are--

None----------0 t/ha.
Slight--------Less than 2.5 t/ha.
Moderate----------2.5 to 10 t/ha.
Severe----------10 to 25 t/ha.
Very severe----More than 25 t/ha.

Fertility, soil. The quality that enables a soil to provide plant nutrients, in adequate amounts and in proper balance, for the growth of specified plants when light, moisture, temperature, tilth, and other growth factors are favorable.

Flood plain. A nearly level alluvial plain that borders a stream and is subject to flooding unless protected artificially.

Foot slope. The inclined surface at the base of a hill.

Grassed waterway. A natural or constructed waterway typically broad and shallow, seeded to grass or left fallow as protection against erosion. Conducts surface water away from cropland.

Gully. A miniature valley with steep sides cut by running water and through which water ordinarily runs only after rainfall. The distinction between a gully and a rill is one of depth. A gully is an

obstacle to farming practices and is too deep to be obliterated by ordinary tillage; a rill is of lesser depth and can be smoothed over by ordinary tillage. Gullies form in exposed natural drainageways, in plow furrows, in animal trails, in vehicle ruts, between rows of crop plants, and below broken man-made terraces.

Layer, soil. A layer of soil, approximately parallel to the surface, having distinct characteristics produced by soil-forming processes.

Leaching. The removal of soluble material from soil or other material by percolating water.

Loam. Soil material that is 7 to 27 percent clay particles, 28 to 50 percent silt particles, and less than 52 percent sand particles.

Microrelief. Refers to the differences in relief measured over distances of meters. In areas of similar relief, the surface may be nearly uniform or it may be interrupted by hills, valleys, or depressions that contrast sharply with the broad pattern of relief. Examples of microrelief are dunes that have formed at the base of plateaus in sand valleys or depressions along flood plains that are produced by expansion and contraction (shrink-swell) of clayey soils.

Minimum tillage. Only the tillage essential to crop production and prevention of soil damage.

Mottles, soil. Irregular spots of different colors that vary in number and size. Mottling generally indicates poor aeration and impeded drainage. Descriptive terms are as follows: abundance-- few, common, and many; size-- fine, medium, and coarse; and contrast-- faint, distinct, and prominent. The size measurements are of the diameter along the greatest dimension. Fine indicates less than 5 millimeters (about 0.2 inch); medium, from 5 to 15 millimeters (about 0.2 to 0.6 inch); and coarse, more than 15 millimeters (about 0.6 inch).

Organic matter. Plant and animal residue in the soil in various stages of decomposition.

Outcrops, rock. Rock outcrops are exposures of bedrock on the surface. The effects of rock outcrops on land use depend on the part of an area occupied by outcrops, the size and spacing of the outcrops, the manner in which the outcrops protrude above the surface of the surrounding soil, and the properties of the soil between the outcrops.

Parent material. Refers to the great variety of unconsolidated mineral materials in which soils form. Unconsolidated mineral matter such as the underlying material beneath subsoil is parent material, but consolidated bedrock is not. Soils form from parent material. Parent material forms from bedrock.

Ped. An individual natural soil aggregate, such as a granule, a prism, or a block.

Pedon. The smallest volume that can be called "a soil." A pedon is three dimensional and large enough to permit study of all horizons. Its area ranges from about 1 square meter to 10 square meters, depending on the variability of the soil.

pH. See Reaction, soil.

Plowpan. A compacted layer formed in the soil directly below the plowed layer.

Ponding. Standing water on soils in closed depressions. The water can be removed only by percolation or evaoptranspiration.

Poorly graded. Refers to a coarse grained soil or soil material consisting mainly of particles of nearly the same size. Because there is little difference in size of the particles, density can be increased only slightly by compaction.

Productivity, soil. The capability of a soil for producing a specified plant or sequence of plants under specific management.

Profile, soil. A vertical section of the soil extending through all its horizons and into the parent material.

Reaction, soil. A measure of acidity or alkalinity of a soil, expressed in pH values. A soil that tests to pH 7.0 is described as precisely neutral in reaction because it is neither acid nor alkaline. The degree of acidity or alkalinity is expressed as--

	pH
Extremely acid	Below 4.5
Very strongly acid	4.5 to 5.0
Strongly acid	5.1 to 5.5
Medium acid	5.6 to 6.0
Slightly acid	6.1 to 6.5
Neutral	6.6 to 7.3
Mildly alkaline	7.4 to 7.8
Moderately alkaline	7.9 to 8.4
Strongly alkaline	8.5 to 9.0
Very strongly alkaline	9.1 and higher

Relief. The elevations or inequalities of a land surface, considered collectively.

Rill. A steep sided channel resulting from accelerated erosion. A rill is generally a few inches deep and not wide enough to be an obstacle to farming practices.

Runoff. The precipitation discharged into stream channels from an area. The water that flows off the surface of the land without sinking into the soil is called surface runoff. The rate and amount of runoff are determined by internal and external soil characteristics and by climate and plant cover. The classes of runoff rate are--

Ponded: Little of the precipitation and runon escapes as runoff, and free water stands on the surface for significant periods. The amount of water that must be removed from ponded areas by movement through the soil, by plants, or by evaporation is usually greater than the total rainfall.

Very slow: Surface water flows away slowly, and free water stands on the surface for long periods or immediately enters the soil. Most of the water passes through the soil, is used by plants, or evaporates.

Slow: Surface water flows away slowly enough that free water stands on the surface for moderate periods or enters the soil rapidly. Most of the water passes through the soil, is used by plants, or evaporates.

Medium: Surface water flows away fast enough that free water stands on the surface for only short periods. Part of the precipitation enters the soil and is used by plants, is lost by evaporation, or moves into underground channels.

Rapid: Surface water flows away fast enough that the period of concentration is brief and free water does not stand on the surface. Only a small part of the water enters the soil.

Very rapid: Surface water flows away so fast that the period of concentration is very brief and free water does not stand on the surface. Only a small part of the water enters the soil.

Sand. As a soil separate, individual rock or mineral fragments from 0.05 millimeter to 2.0 millimeters in diameter. Most sand grains consist of quartz. As a soil textural class, a soil that is 85 percent or more sand and not more than 10 percent clay.

Series, soil. A group of soils that have profiles that are almost alike, except for differences in texture of the surface layer or of the underlying material. All the soils of a series have horizons that are similar in composition, thickness, and arrangement.

Sheet erosion. The removal of a fairly uniform layer of soil material from the land surface by the action of rainfall and runoff water.

Shrink-swell. The shrinking of soil when dry and the swelling when wet. Shrinking and swelling can damage roads, dams, building foundations, and other structures. It can also damage plant roots.

Silt. As a soil separate, individual mineral particles that range in diameter from the upper limit of clay (0.002 millimeter) to the lower limit of very fine sand (0.05 millimeter). As a soil textural class, soil that is 80 percent or more silt and less than 12 percent clay.

Slope. The inclination of the land surface from the horizontal. Percentage of slope is the vertical distance divided by horizontal distance, then multiplied by 100. Thus, a slope of 5 percent is a drop of 5 meters in 100 meters of horizontal distance. The slope classes and percent identified in this study are--

	Percent
Nearly level	0 to 2
Gently sloping	2 to 5
Strongly sloping	5 to 10
Steep	10 to 30

Soil. A natural, three-dimensional body at the earth's surface. It is capable of supporting plants and has properties resulting from the integrated effect of climate and living matter acting on earthy parent material, as conditioned by relief over periods of time.

Soil depth. The thickness of the soil profile to restricting or contrasting layer as measured from the soil surface. Soil depth is important to water and nutrient supplying capacity and root penetration. Depth has an important effect on how a soil behaves when used for various purposes and how it responds to management. The soil depth classes are--

	Depth
Very shallow	Less than 25 cm.
Shallow	25 to 50 cm.
Moderately deep	50 to 100 cm.
Deep	100 to 150 cm.
Very deep	More than 150 cm.

Stripcropping. Growing crops in a systematic arrangement of strips or bands which provide vegetative barriers to wind and water erosion.

Structure, soil. The arrangement of primary soil particles into compound particles or aggregates. The principal forms of soil structure are--platy (laminated), prismatic (vertical axis of aggregates longer than horizontal), columnar (prisms with rounded tops), blocky (angular or subangular), and granular. Structureless soils are either single grained (each grain by itself, as in dune sand) or massive (the particles adhering without any regular cleavage, as in many hardpans).

Subsoil. Technically, the B horizon; roughly, the part of the profile below the surface layer and, in some cases, a subsurface layer.

Subsurface layer. Technically, the E horizon. Generally refers to a leached horizon lighter in color and lower in content of organic matter than the overlying surface layer.

Surface layer. The soil ordinarily moved in tillage, or its equivalent in uncultivated soil, ranging in depth from 10 to 25 centimeters. Frequently designated as the "plow layer," or the "Ap horizon."

Terrace. An embankment, or ridge, constructed across sloping soils on the contour or at a slight angle to the contour. The terrace intercepts surface runoff so that water soaks into the soil or flows slowly to a prepared outlet. A terrace in a field is generally built so that the field can be farmed. A terrace intended mainly for drainage has a deep channel that is maintained in permanent fallow.

Terrace (geologic). An old alluvial plain, ordinarily flat or undulating, bordering a river, a lake, or a drainageway.

Texture, soil. The relative proportions of sand, silt, and clay particles in a mass of soil. The basic textural classes, in order of increasing proportion of fine particles, are sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay. The sand, loamy sand, and sandy loam classes may be further divided by specifying "coarse," "fine," or "very fine."

The following are mineral particles less than 2 mm in equivalent diameter and ranging between specified size limits. The names and sizes of these particles are recognized by most soil scientists internationally.

	Millimeters
Very coarse sand	2.0 to 1.0
Coarse sand	1.0 to 0.5
Medium sand	0.5 to 0.25
Fine sand	0.25 to 0.10
Very fine sand	0.10 to 0.05
Silt	0.05 to 0.002
Clay	less than 0.002

Tilth, soil. The physical condition of the soil as related to tillage, seedbed preparation, seedling emergence, and root penetration.

Toe slope. The outermost inclined surface at the base of a hill; part of a foot slope.

Upland (geology). Land at a higher elevation, in general, than the alluvial plain or stream terrace; land above the lowlands along streams.

Weathering. All physical and chemical changes produced in rocks or other deposits at or near the earth's surface by atmospheric agents. These changes result in disintegration and decomposition of the material.

Well graded. Refers to soil material consisting of coarse grained particles that are well distributed over a wide range in size or diameter. Such soil normally can be easily increased in density and bearing properties by compaction. Contrasts with poorly graded soil.

4.0 RECOMMENDATIONS

4.1 Recommendations by Zone and Subzone

Guidelines

1. Using the agro-ecological zonation of the Niamey Department as a base, develop appropriate agricultural technical packages which are adapted to the conditions in each agro-climatic zone, geomorphic subzone, landscape unit and individual soil series.

2. Use the representative test villages identified in this report as centers for developing technical packages adapted for the major subzones.

3. The importance of phosphate fertilizer for increasing agricultural productivity should be stressed. All soils sampled and analyzed during the course of this study were deficient in phosphate.

4. Appropriate soil and water conservation techniques should be fully integrated into the agricultural technical packages for each zone.

Water and wind erosion have already significantly reduced the productive potential of much of the agricultural and sylvo-pastoral lands in the Department. The present technical package does not address this problem in any significant way. It should be expanded to include soil and water conservation measures as outlined in this report. These techniques include minimum tillage, grassed waterways, leaving crop residues on fields after harvest, strip cropping, contour farming, water capture techniques, and windbreaks.

5. Discontinue the use of animal traction for deep plowing and/or cultivating on the very sandy soils with well-graded particles identified in this report which are susceptible to compaction and may form plowpans under repeated mechanical cultivation. This includes roughly 70% of the sandy millet soils in the Intermediate and Agricultural Zones. Conduct further soils analysis and tillage tests to better define the risks (such

as a yearly monitoring and testing of certain fields for degree of compaction).

6. Promote the rational development of dry season gardening on suitable soils and sites throughout the Department. Emphasis should be placed on the Pastoral and Intermediate Zones where dry season gardening is becoming a critical means of alleviating or overcoming food deficits from rainfed agricultural production.

Agricultural Zone

1. Concentrate project efforts aimed at agricultural intensification and productivity increases on those sites well suited for rainfed agriculture within this zone. Rainfall is less often an important limiting factor to production except in years of severe drought.

2. Develop suitable animal traction packages for the loamy and clayey soils of the Alluvial Valleys in western Say Arrondissement. This landscape unit has the highest percentage of soils which, from a physical standpoint, are well suited for animal traction. Average farm size is small, however. Therefore an economic analysis weighing farm size and yields expected against the costs of different animal traction packages should be an important consideration in developing appropriate techniques.

3. Integrate suitable soil conservation measures into the technical packages for this zone.

4. Develop the significant dry season gardening potential of stream valleys west of the Niger River.

5. A special emphasis on agro-pastoral management should be included in the Alluvial Valley and Upland Subzone and in parts of the Sand Valley and Plateau Subzone west of the Niger River. The sedentary Fulani farmers of this area have closely integrated livestock and agricultural production. This is also an important area for northern pastoralists in the dry season.

Intermediate Zone

1. In this zone, the NDD should shift philosophically from an overall emphasis of increasing productivity to one of insuring productivity. The marginal and variable rainfall of this agroclimatic zone limits its potential for intensification of rainfed agriculture.

2. Promote the development of dry season gardening wherever conditions permit, especially in the Dune, Interdune and Mare Subzone and in the Dallol Bobeye south of Bankoukou.

3. Integrate appropriate soil and water conservation measures into the improved agricultural techniques extended. Promote the use of simple water catchment techniques (contour terraces, microcatchments, tied ridges, etc.) on suitable soils. Such techniques can serve both as a means of offsetting periods of moisture stress which may be expected to occur during the growing season in this zone and as a means of controlling water erosion.

4. De-emphasize the extension of capital intensive techniques such as bi-bovine animal traction which require farmers to incur large debts. The risk of reduced crop yields or crop failure in years of insufficient rainfall may make farmers unable to repay large loans.

5. Exercise caution in the use of urea fertilizer in this zone. Urea may "burn" the crops if moisture stress occurs following its application.

Pastoral Zone

1. Support and recognition of extensive pastoral nomadism as possibly the optimal means of utilizing the majority of the zone's exploitable resources.

2. Explore possibilities for economic diversification including the development of dry season gardening where feasible and limited rainfed agriculture based on water capture techniques on equitable soils. Dry season gardening potential is generally high in the Dune, Interdune and Mare subzone.

3. Where little potential for economic diversification exists, particularly for sedentary agriculturalists in the northern Pastoral Zone, consider support for resettlement of these populations to areas which can viably support them. Traditional rainfed agriculture in the Pastoral Zone has become a very high risk operation under the climatic conditions which have prevailed over the last 17 years. Its continued practice has led to severe environmental degradation over large areas. The zonation team has not identified areas suitable for resettlement.

4. As herds are rebuilt, explore means of limiting the size of the herds as a function of the carrying capacity of the range resources available.

4.2 Test Village Recommendations

1. Work in the test villages should begin with a period of significant dialogue between the NDD staff and the village population. This should be done at the same level of intensity and in the same spirit of mutual exchange of information as that which characterized the zonation team's visits. Particular emphasis should be placed on defining the villagers' perceived needs and desires and their indigenous technical knowledge. This exchange of dialogue should be continued throughout the duration of project activities in each village.

2. The initial dialogue should be followed by visits of multidisciplinary teams which may include agronomists, animal traction specialists, soil scientists, agroforesters, sociologists, range and livestock specialists, etc. as suited to the needs and potential of the village. This should be done during the 1985-86 dry season with a work plan prepared for the 1986 cropping season.

3. Training workshops for the extension agents who will work in the villages should be conducted as necessary to familiarize them with new techniques which are not part of the present technical package.

4. The soils information herein and the enclosed soils inventory maps by test village should be utilized in the initial planning stages for development of technical packages for each test village incorporated into the NDD program. Specifically, the following items as far as its use and suitability should be adhered to, as it applies to each test village. These items are:

1) Erosion control measures needed.
2) Suitability for rainfed agriculture and kind of crop.
3) Suitability for rainy season and dry season gardening.
4) Applicability of animal traction for specific soils.
5) Soils which will yield the best results from fertilization.
6) Fertilization requirements for specific soils.

More site specific soil sampling of the individual fields in each test village would be desirable. This sampling program would then be utilized to determine the best methods of cultivation for each specific field and it would facilitate the establishment of a fertilization program tailored for particular fields within the test villages.

5. The immediate corrective actions identified for each test village should be addressed and action taken as appropriate. Activities which are not perceived as important by the village but which are felt to be so by the project staff should be attempted on a small trial or demonstration basis.

6. After each cropping season, assess the effectiveness of each element of the technical packages seeking input, as always, from the villagers. Modify and adapt the practices as necessary.

4.3 Specific Recommendations by Test Village

GARBEY

SUITABILITY FOR:
- RAINFED AGRICULTURE-----POORLY SUITED
- RAINY SEASON GARDENING--WELL SUITED
- DRY SEASON GARDENING----WELL SUITED
- ANIMAL TRACTION---------SUITED ON GARDEN AREAS IF SIZE OF PLOT PERMITS

EROSION:
- HAZARD----------VERY SEVERE
- TYPE----------WIND AND WATER
- CONTROL MEASURES:
  - --CONTOUR FARMING
  - --HAND WEEDING ONLY FOR RAINFED CROPS
  - --LEAVE RIDGES FALLOW AND ROTATE GRAZING
  - --LEAVE RESIDUE IN FIELD AFTER HARVEST
  - --INSTALL DIVERSION TERRACES AND WATER CATCHMENTS
  - --STRIP CROPPING WITH FALLOW STRIPS
  - --PLANT WIDELY SPACED GAO TREES IN FIELDS
- IMMEDIATE CORRECTIVE ACTIONS:
  - --RE-SHAPE GULLIES, INSTALL WATER-RETARDING STRUCTURES AT HEADS OF GULLIES AND VEGETATE
  - --INSTALL WINDBREAKS

KIKI

SUITABILITY FOR:
- RAINFED AGRICULTURE-----WELL SUITED
- RAINY SEASON GARDENING--WELL SUITED
- DRY SEASON GARDENING----WELL SUITED
- ANIMAL TRACTION---------WELL SUITED

EROSION:
- HAZARD--------MODERATE (2.5 TO 10 TONS/HECTARE PER YEAR SOIL LOSS)
- PRIMARY TYPE--WATER
- CONTROL MEASURES:
  - --CONTOUR PLOWING
  - --CROP ROTATION TO FALLOW 1 YEAR IN 3
  - --LEAVE CROP RESIDUE IN FIELD AFTER HARVEST
- IMMEDIATE CORRECTIVE ACTIONS:
  - --RE-SHAPE GULLIES, INSTALL WATER-RETARDING STRUCTURES AT HEADS OF GULLIES AND VEGETATE WITH GRASS COVER

KOUARA TEGUI

SUITABILITY FOR:
RAINFED AGRICULTURE-----SUITED
RAINY SEASON GARDENING--SUITED
DRY SEASON GARDENING----SUITED
ANIMAL TRACTION---------SUITED FOR MINIMUM TILLAGE ON TILOA SOILS AND WELL SUITED FOR GARDEN AREAS

EROSION:
HAZARD-----VERY SEVERE
TYPE-------WIND AND WATER
CONTROL MEASURES:
--CONTOUR FARMING
--MINIMUM TILLAGE PLOWING ON CONTOUR
--LEAVE RIDGES IN FALLOW
--STRIP CROPPING WITH FALLOW STRIPS
--PLANT WINDBREAKS
--LEAVE RESIDUE IN FIELD AFTER HARVEST
--ROTATE CROPS INTO FALLOW 1 YEAR IN 3
--PLANT GAO TREES IN FIELDS
IMMEDIATE CORRECTIVE ACTIONS:
--INSTALL TERRACES AND OTHER WATER CATCHMENTS
--INSTALL GRASSED WATERWAYS IN NATURAL WATER COURSES
--VEGETATE SEVERELY ERODED AREAS AND LEAVE FALLOW

NAMAGA

SUITABILITY FOR:
RAINFED AGRICULTURE-----SUITED
RAINY SEASON GARDENING--WELL SUITED
DRY SEASON GARDENING----WELL SUITED
ANIMAL TRACTION---------WELL SUITED FOR GARDEN AREAS ONLY

EROSION:
HAZARD--SEVERE (10 TO 25 TONS/HECTARE PER YEAR SOIL LOSS)
TYPE----WIND (MAJOR) AND WATER (MINOR)
CONTROL MEASURES:
--INSTALL WINDBREAKS
--LEAVE DUNE TOPS FALLOW
--CONTOUR FARMING
--LEAVE CROP RESIDUE IN FIELD AFTER HARVEST
--PLANT WIDELY SPACED GAO TREES IN FIELDS
IMMEDIATE CORRECTIVE ACTIONS:
--INSTALL GRASSED WATERWAYS AND WATER-RETARDING STRUCTURES IN NATURAL WATER COURSES TO REDUCE SEDIMENTATION AND DEGRADATION OF GARDENING POTENTIAL
--CONSTRUCT SMALL DAM ON OUTLET TO LAKE (OUTLET WAS DEEPENED BY RECENT ROAD CONSTRUCTION PARTIALLY DRAINING THE MARE)

N'DIKITAN

SUITABILITY FOR:
RAINFED AGRICULTURE-----SUITED
RAINY SEASON GARDENING--WELL SUITED
DRY SEASON GARDENING----WELL SUITED
ANIMAL TRACTION---------UNSUITED

EROSION:
HAZARD--VERY SEVERE (MORE THAN 25 TONS/HECTARE PER YEAR SOIL LOSS)
TYPE----WIND (MAJOR) AND WATER
CONTROL MEASURES:
--CONTOUR FARMING
--STRIP CROPPING WITH FALLOW STRIPS
--ESTABLISH WINDBREAKS
--LEAVE RESIDUE IN FIELD AFTER HARVEST
IMMEDIATE CORRECTIVE ACTIONS:
--DISCONTINUE PLOWING
--PLACE TOPS OF RIDGES IN FALLOW

SOURGOUROU

SUITABILITY FOR:
RAINFED AGRICULTURE-----WELL SUITED
RAINY SEASON GARDENING--SUITED
DRY SEASON GARDENING----UNSUITED
ANIMAL TRACTION---------UNSUITED

EROSION:
HAZARD--------SEVERE (10 TO 25 TONS/HECTARE PER YEAR SOIL LOSS)
PRIMARY TYPE--WIND AND WATER
CONTROL MEASURES:
--CONTOUR FARMING
--STRIP CROPPING WITH FALLOW STRIPS
--INTERCROPPING WITH COWPEAS
--LEAVE CROP RESIDUE IN FIELD AFTER HARVEST
--PLANT WINDBREAKS
--CROP ROTATION TO FALLOW 1 YEAR IN 3
--PLANT GAO TREES IN FIELDS
IMMEDIATE CORRECTIVE ACTIONS:
--LEAVE SEVERELY ERODED AREAS FALLOW
--ROTATE LIVESTOCK GRAZING ON FALLOW AREAS

4.4 General Observations and Recommendations for Future Interventions

1. Recognizing that the existing farming systems in the Department are the starting point for development onto which productivity improvements have to be grafted, conduct more detailed studies to further define the farming systems within the NDD project area.

2. Support efforts which broaden the scope of current farming systems research to better represent (1) house garden and dry season garden crops, (2) the animal sub-systems which form a part of nearly every farm-type found in the country, (3) the role of trees and agro-forestry potential in local farming systems, and possibly most importantly (4) the very real concerns of soil conservation and associated water management in the farming systems (DRS-CES).

Almost all funding is currently directed to research and trials which assume a completely cleared destumped field which will then be planted in monocropped millet, sorghum, cowpeas, or perhaps occasionally groundnuts or sesame. This approach to research and technology development is unnecessarily narrow. The problem is not that such farming systems research is inappropriate or unuseful, to the contrary, it is quite essential; the problem is that this is often the <u>only</u> type of research being done.

3. Support interventions which increase the overall availability of forage resources relative to the number of on-farm livestock.

This would include crop residues, herbaceous species, and agro-forestry. Values used by Ithaca International indicate the importance of crop bi-products (principally millet and sorghum stover and peanut and cowpea hay). Current selection for cowpeas is based on cycle length, photoperiod sensitivity, and bean yield. As a consequence, the main economic product, hay production, has been largely overlooked.

Mono-bovine and asine traction would place less demand on forage than the pre-dominant bi-bovine based package.

The feasibility of reseeding rangelands should be examined as should the intoduction of economically valuable perennial grasses into the field agro-ecosystem. Semi-domestication of Andropogon gayanus is common and successful in other parts of the Sahel and would seem appropriate in many parts of Niger. Farmers expressed interest in this proposition; a few had already collected seed from thatch weavers and planted it in their fields.

4. Support further research which will clarify the differences between farming households within each of the agro-ecological zones and subzones.

The goal of the project should not be to define and extend the optimal technical package for each major subzone but to define a range of packages that corresponds to the discernible sub-groups of farmers or farming households. Resource "endowments" should not only be defined but the dynamic processes of resource acquisition and resource allocation need to be understood.

Define recommendation domains for (1) households with access to large fields (over 6 ha./year), (2) households with access to smaller fields (3-6 ha./year), (3) households cultivating small fields (under 3.0 ha./year), (4) households depending only on borrowed fields, and (5) individual farmers' fields (including cultures de cases).

5. Promote the use of crop varieties adapted to the shortened growing season. AGRHYMET is currently analyzing the length and variability of the growing season for the Niamey Department using meteorological data over the last 17 years. Obtain their results as soon as they become available and use this information in planning what varieties to extend in each zone.

6. Dry season gardening development should include adaptive research and extension of garden varieties adapted to specific soils/sites, emphasis on crops which are relatively easy to store, and analysis of storage technology, processing techniques, marketing potential and means of pest control. Questions of land tenure on gardening sites need to be addressed. Techniques for well construction and water lifting should be improved upon. Local materials suitable for fencing dry season gardens (thorn branches, brush, millet stalks) are often in critically short supply. Promote the use of live fencing with species such as Acacia nilotica (withstands considerable flooding and has long sharp thorns) or Balanites aegyptiaca (hardy, resistant to browsing, long, thick thorns, cut branches resist decay). Also open grown field trees such as Balanites or Acacia albida could be managed for thorn branch production through selective cutting of branches throughout the tree canopy if forest legislation prohibiting such cutting were amended.

7. Consider the use of windbreaks as a means of reducing wind erosion and moisture deficits wherever these are a problem.

The CARE Maggia Valley project should be used as a model. This should only be attempted where general village interest and motivation are high. Issues of land and tree tenure should be resolved before beginning such a project. Windbreaks are particularly well suited where other sources of firewood and small poles are in short supply. An overall increase in crop production of about 20% has been documented in the Maggia Valley for fields protected by windbreaks. Windbreaks should be particularly well suited on sandy soils in the Intermediate and southern Pastoral Zones.

8. Promote the plantation and protection of Acacia albida on sandy millet fields. Acacia albida fixes nitrogen, adds organic matter to the soil, reduces wind erosion, produces seed foods highly valued for livestock and loses its leaves during the cropping season.

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SOILS ANNEX A

ZONATION FLOW CHART

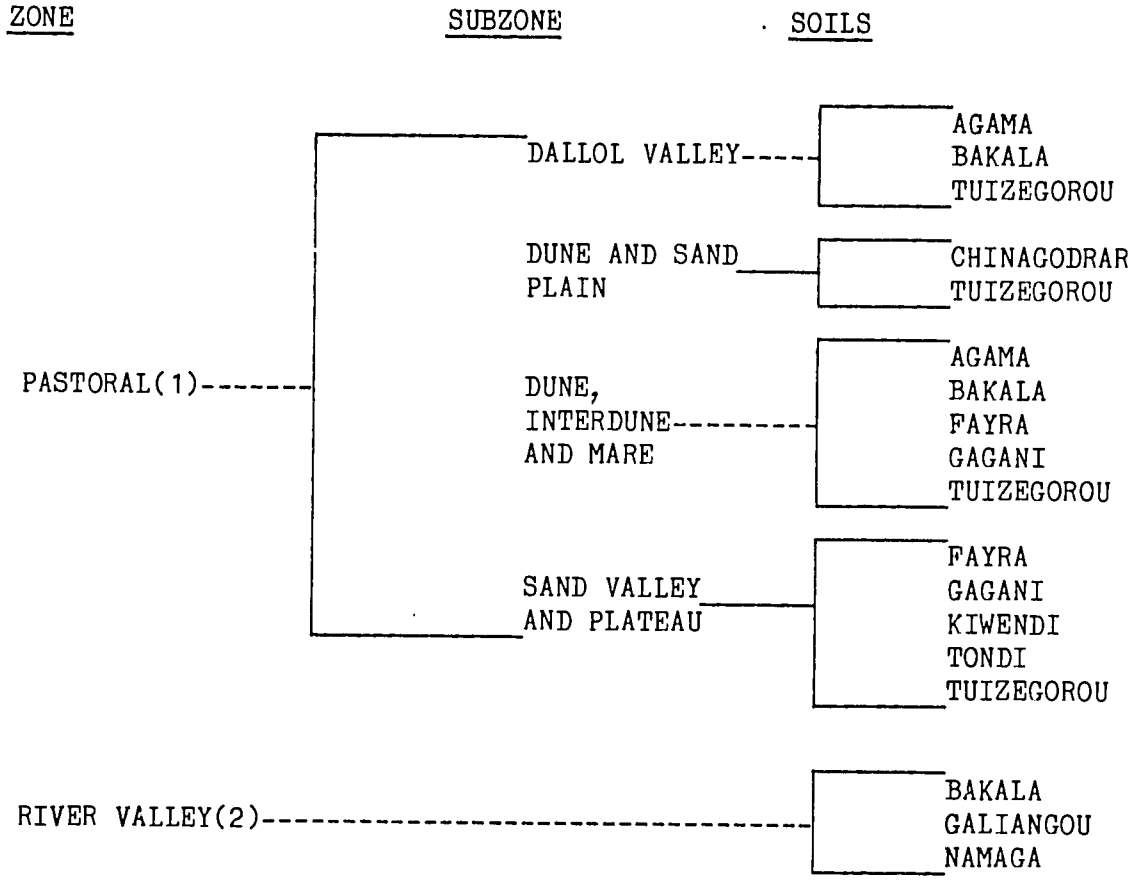
ZONATION FLOW CHART

AGRICULTURAL ZONE

SUBZONE	LANDFORM	SOILS
ALLUVIAL VALLEY AND UPLAND	UPLAND	FAYRA MAKALONDI PIMPERGOU
	VALLEY	BANTANDI HONROU LUBRI
SAND PLAIN	SAND PLAIN	BABOUSSAY LABUCHERI SOURGOUROU
SAND VALLEY AND PLATEAU	PLATEAU	FAYRA GAGANI TONDI
	VALLEY	KOUARA TEGUI LABUCHERI SINSAN TILOA ZOGOTI

INTERMEDIATE ZONE

SUBZONE	LANDFORM	SOILS
ALLUVIAL VALLEY AND UPLAND	UPLAND	FAYRA MAKALONDI PIMPERGOU
	VALLEY	BANTANDI HONROU LUBRI
DALLOL VALLEY	VALLEY	AGAMA FANDOU GARBEY N'DIKITAN
DUNE, INTERDUNE AND MARE	DUNE	DAYOBU MOMA
	INTERDUNE	BAKALA ZORIBI
	MARE	AGAMA GILIANGOU NAMAGA
	OUTCROP	GAGANI ZORIBI
SAND PLAIN	SAND PLAIN	BABOUSSAY LABUCHERI SOURGOUROU
SAND VALLEY AND PLATEAU	BROAD FLAT	BABOUSSAY SINSAN TONDI ZOGOTI
	DUNE	DAYOBU MOMA
	PLATEAU	FAYRA GAGANI TONDI
	VALLEY	GARBEY KOUARA TEGUI LABUCHERI SINSAN TILOA ZOGOTI



(1) Pastoral zone is not considered significant for agricultural intensification, therefore identification of specific landforms was not necessary.

(2) The River Valley Zone consists of one flood plain with only microrelief of narrow terraces and natural levees (as described in the text), therefore it was not feasible or necessary to separate this zone into subzones or landforms of subzones.

SOILS ANNEX B

GENERAL SUITABILITY FOR AGRICULTURAL INTENSIFICATION

GENERAL SUITABILITY FOR AGRICULTURAL INTENSIFICATION

ZONE	SUBZONE	RAINFED AGRICULTURE	DRY SEASON GARDENING	EROSION HAZARD
AGRICULTURAL	ALLUVIAL VALLEY AND UPLAND	SUITED (valleys) UNSUITED (uplands)	WELL SUITED (valleys) UNSUITED (uplands)	MODERATE (valleys) VERY SEVERE (uplands)
	SAND PLAIN	WELL SUITED	UNSUITED	SEVERE
	SAND VALLEY AND PLATEAU	WELL SUITED (valleys) UNSUITED (plateaus)	POORLY SUITED	VERY SEVERE
INTERMEDIATE	ALLUVIAL VALLEY AND UPLAND	SUITED (valleys) UNSUITED (uplands)	WELL SUITED (valleys) UNSUITED (uplands)	MODERATE (valleys) VERY SEVERE (uplands)
	DALLOL VALLEY	SUITED	WELL SUITED	SEVERE
	DUNE, INTER-DUNE, AND MARE	POORLY SUITED	WELL SUITED	SEVERE
	SAND PLAIN	SUITED	UNSUITED	SEVERE
	SAND VALLEY AND PLATEAU	SUITED (valleys) UNSUITED (plateaus)	POORLY SUITED	VERY SEVERE
PASTORAL	DALLOL VALLEY	UNSUITED	POORLY SUITED	SEVERE
	DUNE AND SAND PLAIN	UNSUITED	UNSUITED	VERY SEVERE
	DUNE, INTER-DUNE, AND MARE	UNSUITED	SUITED	SEVERE
	SAND VALLEY AND PLATEAU	UNSUITED	UNSUITED	VERY SEVERE
RIVER VALLEY	NONE	SUITED	WELL SUITED	MODERATE

SOILS ANNEX C

SOIL SUITABILITY

SOIL SUITABILITY

SOIL NAME	FERTILITY STATUS	EROSION HAZARD	ANIMAL TRACTION SUITABILITY	RAINFED AGRICULTURE SUITABILITY	GARDENING SUITABILITY RAINY SEASON	GARDENING SUITABILITY DRY SEASON
AGAMA	HIGH	SLIGHT	SUITED	UNSUITED	UNSUITED	SUITED
BABOUSSAY	LOW	SLIGHT	WELL SUITED	SUITED	WELL SUITED	SUITED
BAKALA	MEDIUM	MODERATE	SUITED	POORLY SUITED*	UNSUITED*	UNSUITED*
BANTANDI	HIGH	SLIGHT	SUITED	SUITED	WELL SUITED	WELL SUITED
CHINAGODRAR	MEDIUM	SEVERE	UNSUITED	UNSUITED	UNSUITED	UNSUITED
DAYOBU	VERY LOW	VERY SEVERE	UNSUITED	POORLY SUITED	UNSUITED	UNSUITED
FANDOU	MEDIUM	SEVERE	UNSUITED	WELL SUITED	UNSUITED	UNSUITED
FAYRA	VERY LOW	VERY SEVERE	UNSUITED	UNSUITED	UNSUITED	UNSUITED
GAGANI	LOW	SEVERE	UNSUITED	UNSUITED	UNSUITED	UNSUITED
GALIANGOU	MEDIUM	MODERATE	WELL SUITED	WELL SUITED	WELL SUITED	POORLY SUITED
GARBEY	MEDIUM	MODERATE	WELL SUITED	SUITED	WELL SUITED	WELL SUITED
HONROU	HIGH	MODERATE	WELL SUITED	WELL SUITED	UNSUITED	UNSUITED
KIWENDI	LOW	VERY SEVERE	UNSUITED	POORLY SUITED	UNSUITED	UNSUITED
KOUARA TEGUI	LOW	MODERATE	WELL SUITED	WELL SUITED	WELL SUITED	WELL SUITED
LABUCHERI	LOW	VERY SEVERE	UNSUITED	WELL SUITED	UNSUITED	UNSUITED
LUBRI	HIGH	MODERATE	SUITED	WELL SUITED	SUITED	POORLY SUITED

MAKA-LONDI	VERY LOW	VERY SEVERE	UNSUITED	UNSUITED	UNSUITED	UNSUITED
MOMA	LOW	SEVERE	UNSUITED	SUITED	UNSUITED	UNSUITED
NAMAGA	MEDIUM	SLIGHT	WELL SUITED	SUITED	WELL SUITED	WELL SUITED
N'DIKI-TAN	LOW	VERY SEVERE	UNSUITED	SUITED	UNSUITED	UNSUITED
PIMPER-GOU	LOW	SEVERE	UNSUITED	POORLY SUITED	UNSUITED	UNSUITED
SINSAN	LOW	VERY SEVERE	UNSUITED	SUITED	UNSUITED	UNSUITED
SOUR-GOUROU	LOW	SEVERE	UNSUITED	WELL SUITED	UNSUITED	UNSUITED
TILOA	MEDIUM	MODERATE	SUITED	WELL SUITED	UNSUITED	UNSUITED
TONDI	LOW	SEVERE	UNSUITED	POORLY SUITED	UNSUITED	UNSUITED
TUIZE-GOROU	LOW	VERY SEVERE	UNSUITED	UNSUITED	UNSUITED	UNSUITED
ZOGOTI	LOW	VERY SEVERE	UNSUITED	WELL SUITED	UNSUITED	UNSUITED
ZORIBI	MEDIUM	SEVERE	UNSUITED	POORLY SUITED	POORLY SUITED	POORLY SUITED

*THESE SUITABILITY RATINGS FOR BAKALA SOILS DO NOT APPLY WHERE THEY OCCUR IN THE RIVER VALLEY ZONE.

SOILS ANNEX D

SOIL PHYSICAL CHARACTERISTICS

SOIL PHYSICAL CHARACTERISTICS

SOIL NAME	PERCENT SLOPE	DEPTH	TEXTURE AND SOIL REACTION SURFACE	SUBSOIL/SUBSTRATA
AGAMA	0-1	VERY DEEP	CLAY NEUTRAL	CLAY/LOAMY FINE SAND MODERATELY ALKALINE
BABOUSSAY	0-1	VERY DEEP	FINE SAND STRONGLY ACID	LOAMY FINE SAND EXTREMELY ACID
BAKALA	0-1	VERY DEEP	SANDY CLAY SLIGHTLY ACID	CLAY MILDLY ALKALINE
BANTANDI	0-1	VERY DEEP	CLAY SLIGHTLY ACID	SANDY CLAY LOAM/LOAMY SAND SLIGHTLY ACID
CHINAGODRAR	2-5	VERY DEEP	FINE SAND STRONGLY ACID	SANDY CLAY LOAM/FINE SAND EXTREMELY ACID
DAYOBU	2-30	VERY DEEP	SAND VERY STRONGLY ACID	SAND EXTREMELY ACID
FANDOU	2-8	VERY DEEP	COARSE SAND MEDIUM ACID	LOAMY SAND SLIGHTLY ACID
FAYRA	10-30	VERY SHALLOW	STONY SAND EXTREMELY ACID	IRONSTONE NONE
GAGANI	0-1	SHALLOW	GRAVELLY LOAMY SAND VERY STRONGLY ACID	LATERITE EXTREMELY ACID
GALIANGOU	1-3	VERY DEEP	SAND STRONGLY ACID	SANDY LOAM NEUTRAL
GARBEY	0-1	VERY DEEP	SAND MEDIUM	SANDY CLAY LOAM/SAND MILDLY ALKALINE
HONROU	1-3	VERY DEEP	SANDY LOAM NEUTRAL	SANDY CLAY LOAM/CLAY MILDLY ALKALINE
KIWENDI	2-5	VERY DEEP	SAND VERY STRONGLY ACID	SANDY LOAM/FINE SAND EXTREMELY ACID
KOUARA TEGUI	0-1	VERY DEEP	SANDY LOAM STRONGLY ACID	SANDY CLAY LOAM/ LOAMY FINE SAND VERY STRONGLY ACID
LABUCHERI	2-15	VERY DEEP	FINE SAND STRONGLY ACID	LOAMY FINE SAND/SANDY LOAM EXTREMELY ACID

LUBRI	0-2	VERY DEEP	SANDY CLAY NEUTRAL	CLAY/SANDY CLAY MILDLY ALKALINE
MAKALONDI	5-15	SHALLOW	GRAVELLY FINE SAND STRONGLY ACID	VERY GRAVELLY LOAMY SAND/ LATERITE EXTREMELY ACID
MOMA	5-10	VERY DEEP	SAND MEDIUM ACID	LOAMY SAND STRONGLY TO SLIGHTLY ACID
NAMAGA	0-1	VERY DEEP	FINE SAND NEUTRAL	SANDY CLAY LOAM/SAND MILDLY ALKALINE
N'DIKITAN	2-5	VERY DEEP	COARSE SAND MEDIUM ACID	SAND EXTREMELY ACID
PIMPERGOU	0-2	MODERATELY DEEP	FINE SAND STRONGLY ACID	SANDY CLAY LOAM/LATERITE EXTREMELY ACID
SINSAN	1-3	MODERATELY DEEP	FINE SAND STRONGLY ACID	SANDY CLAY LOAM/ VERY GRAVELLY SANDY LOAM STRONGLY/EXTREMELY ACID
SOURGOUROU	2-5	VERY DEEP	FINE SAND MEDIUM ACID	LOAMY FINE SAND VERY STRONGLY ACID
TILOA	1-3	VERY DEEP	FINE SAND STRONGLY ACID	SANDY LOAM/SANDY CLAY LOAM EXTREMELY ACID
TONDI	0-2	MODERATELY DEEP	FINE SAND VERY STRONGLY ACID	LOAMY FINE SAND/LATERITE EXTREMELY ACID
TUIZEGOROU	5-15	VERY DEEP	SAND VERY STRONGLY ACID	SAND EXTREMELY ACID
ZOGOTI	2-5	DEEP	FINE SAND VERY STRONGLY ACID	LOAMY FINE SAND/LATERITE EXTREMELY ACID
ZORIBI	0-2	MODERATELY DEEP	FINE SAND MEDIUM ACID	SANDY CLAY TO CLAY/QUARTZ SLIGHTLY ACID TO MILDLY ALKALINE

SOIL PHYSICAL CHARACTERISTICS
(CONTINUED)

SOIL NAME	AVAILABLE WATER CAPACITY	INTERNAL DRAINAGE	SURFACE RUNOFF	SURFACE ORGANIC MATTER CONTENT
AGAMA	VERY HIGH	VERY POOR	PONDED	MEDIUM
BABOUSSAY	LOW	SOMEWHAT POOR	VERY SLOW	LOW
BAKALA	VERY HIGH	POOR	VERY SLOW	MEDIUM
BANTANDI	HIGH	POOR	VERY SLOW	HIGH
CHINAGODRAR	MODERATE	SOMEWHAT POOR	MEDIUM	VERY LOW
DAYOBU	VERY LOW	EXCESSIVE	SLOW TO MEDIUM	VERY LOW
FANDOU	LOW	SOMEWHAT EXCESSIVE	MEDIUM	VERY LOW
FAYRA	VERY LOW	EXCESSIVE	VERY RAPID	VERY LOW
GAGANI	LOW	SOMEWHAT POOR	SLOW	VERY LOW
GALIANGOU	MODERATE	WELL	SLOW	LOW
GARBEY	MODERATE	MODERATELY WELL	SLOW TO PONDED	MEDIUM
HONROU	HIGH	MODERATELY WELL	MEDIUM	MEDIUM
KIWENDI	LOW	SOMEWHAT EXCESSIVE	SLOW	VERY LOW
KOUARA TEGUI	MODERATE	MODERATELY WELL	SLOW	LOW
LABUCHERI	VERY LOW	WELL	MEDIUM*	VERY LOW
LUBRI	VERY HIGH	SOMEWHAT POOR	MEDIUM	MEDIUM
MAKALONDI	VERY LOW	WELL	RAPID	VERY LOW
MOMA	VERY LOW	SOMEWHAT EXCESSIVE	MEDIUM	VERY LOW

NAMAGA	MODERATE	SOMEWHAT POOR	SLOW	VERY LOW
N'DIKITAN	VERY LOW	EXCESSIVE	SLOW	VERY LOW
PIMPERGOU	MODERATE	WELL	MEDIUM	VERY LOW
SINSAN	MODERATE	WELL	MEDIUM	VERY LOW
SOURGOUROU	VERY LOW	SOMEWHAT EXCESSIVE	SLOW TO MEDIUM	VERY LOW
TILOA	MODERATE	WELL	MEDIUM	LOW
TONDI	LOW	MODERATELY WELL	MEDIUM	VERY LOW
TUIZEGOROU	VERY LOW	EXCESSIVE	SLOW	VERY LOW
ZOGOTI	LOW	SOMEWHAT EXCESSIVE	MEDIUM	VERY LOW
ZORIBI	HIGH	SOMEWHAT POOR	RAPID	LOW

*LABUCHERI FINE SAND, 5 TO 10 PERCENT SLOPES, GULLIED HAS A RAPID SURFACE RUNOFF DUE TO PAST EROSION.

SOILS ANNEX E

TYPICAL PEDON DESCRIPTIONS

TYPICAL PEDON DESCRIPTIONS

In this annex each soil map unit recognized during the test village soils inventory is described. The typical pedon descriptions are arranged in numerical order as they were evaluated at each test village, Kiki being the first test village where the detailed soils inventory was performed.

Characteristics of the soil and the material in which it formed are identified for soil map units. The soil is compared with similar soils and soils of other series. A pedon, a small three-dimensional area of soil, that is typical of the map unit and soil series in the Department is described. The detailed description of each soil follows standards in the U.S. Department of Agriculture, National Soils Handbook (July, 1983).

1 - Bantandi clay, 0 to 1 percent slopes, frequently flooded.

Typical pedon description of Bantandi clay, 0 to 1 percent slopes, frequently flooded near the village of Kiki within the valley portion of the Alluvial Valley and Upland Subzone.

Ap-- 0 to 25 cm., dark grayish brown (10YR4/2) clay; weak medium subangular blocky structure; firm; slightly acid, clear smooth boundary.

Bw--25 to 63 cm., olive brown (2.5Y4/4) silty clay; common fine prominent brownish yellow (10YR6/8) mottles; weak medium prismatic structure parting to moderate medium subangular blocky structure; very firm; few iron stains; medium acid; gradual wavy boundary.

BC--63 to 125 cm., strong brown (7.5YR5/8) sandy clay loam; weak fine subangular blocky structure; friable, common black stains; common fine mica flakes; medium acid; gradual wavy boundary.

C--125 to 150 cm., mottled strong brown (7.5YR5/8) and brownish yellow (10YR6/6) loamy sand; single grain; very friable; few ironstone pebbles; common fine black stains; slightly acid.

U.S. Soil Taxonomic Classification:
fine, mixed, isohyperthermic Typic Ustropepts

2 - Honrou sandy loam, 1 to 3 percent slopes.

Typical pedon description of Honrou sandy loam, 1 to 3 percent slopes near the village of Kiki within the valley portion of the Alluvial Valley and Upland Subzone.

Ap--0 to 30 cm., dark yellowish brown (10YR4/4) sandy loam; weak medium granular structure; very friable; neutral; clear wavy boundary.

Bt1--30 to 70 cm., dark brown (7.5YR4/4) sandy clay loam; moderate medium subangular blocky structure; friable; patchy distinct clay films on faces of peds; mildly alkaline; clear wavy boundary.

Bt2--70 to 105 cm., yellowish red (5YR4/6) sandy clay; moderate medium subangular blocky structure; firm; continuous distinct clay films on faces of peds; mildly alkaline; gradual wavy boundary.

Bt3--105 to 150 cm., yellowish red (5YR4/6) clay; common fine prominent red (2.5YR4/8) and brownish yellow (10YR6/8) mottles; weak medium subangular blocky structure; firm; patchy distinct clay films on faces of peds; few ironstone concretions; mildly alkaline.

U.S. Soil Taxonomic Classification:
fine-loamy, siliceous, isohyperthermic Udic Paleustalfs.

3 - Lubri sandy clary, 0 to 2 percent slopes.

Typical pedon description of Lubri sandy clay, 0 to 2 percent slopes near the village of Lilingou within the valley portion of the Alluvial Valley and Upland Subzone.

Ap--0 to 25 cm., dark brown (7.5YR4/4) sandy clay; weak medium subangular blocky structure; friable; neutral; clear smooth boundary.

Bt1--25 to 67 cm., strong brown (7.5YR5/6) clay; moderate medium subangular blocky structure; firm; patchy distinct clay films on faces of peds; few black concretions; neutral; clear wavy boundary.

Bt2--67 to 125 cm., olive brown (2.5Y4/4) clay; weak coarse subangular blocky structure; very firm; patchy distinct clay films on faces of peds; common pressure faces; common fine and medium black concretions; mildly alkaline; gradual irregular boundary.

BC--125 to 160 cm., light olive brown (2.5Y5/4) saprolite; many medium prominent light gray (10YR7/1) and brownish yellow (10YR6/8) mottles; weak medium subangular blocky structure; firm; mildly alkaline.

U.S. Soil Taxonomic Classification:
very fine, mixed, isohyperthermic Vertic Haplustalfs.

4 - Pimpergou loamy fine sand, 0 to 2 percent slopes.

Typical pedon description of Pimpergou loamy fine sand, 0 to 2 percent slopes near the village of Lilingou within the upland portion of the Alluvial Valley and Upland Subzone.

A--0 to 15 cm., brown (10YR5/3) loamy fine sand; weak medium granular structure; very friable; strongly acid; clear wavy boundary.

Bt1--15 to 40 cm., yellowish red (5YR5/8) sandy loam; weak medium subangular blocky structure; very friable; patchy faint clay films on faces of some peds; very strongly acid; gradual wavy boundary.

Bt2--40 to 70 cm., yellowish red (5YR5/6) sandy clay loam; moderate medium subangular blocky structure; friable; patchy distinct clay films on faces of peds; extremely acid; abrupt wavy boundary.

2Bt--70 to 80 cm., yellowish red (5YR5/8) very gravelly loamy fine sand; weak fine subangular blocky structure to massive; very firm, brittle and compact; approximately 70 percent by volume of ironstone gravel; extremely acid; abrupt irregular boundary.

2Bsm--80 to 100 cm., red (2.5YR4/6) and dark red (2.5YR3/6) laterite; massive; cemented and compact; extremely acid.

U.S. Soil Taxonomic Classification:
fine-loamy, siliceous, isohyperthermic Petroferric Haplustults.

5 - Makalondi gravelly fine sand, 5 to 15 percent slopes.

Typical pedon description of Makalondi gravelly fine sand, 5 to 15 percent slopes near the village of Kiki within the upland portion of the Alluvial Valley and Upland Subzone.

A--0 to 15 cm., strong brown (7.5YR5/8) gravelly fine sand; weak medium granular structure; very friable; strongly acid; clear wavy boundary.

Bt1--15 to 35 cm., yellowish red (5YR5/6) very gravelly loamy sand; weak medium subangular blocky structure; friable; approximately 70 percent by volume of ironstone gravel; patchy faint clay films on faces of some peds; very strongly acid; abrupt wavy boundary.

Bt2--35 to 40 cm., yellowish red (5YR4/6) very gravelly loamy sand; weak fine subangular blocky structure; very firm, compact and cemented; extremely acid; abrupt irregular boundary.

2Bsm--40 to 50 cm., red (2.5 YR4/6) laterite; massive, cemented and compact; extremely acid.

U.S. Soil Taxonomic Classification:
sandy-skeletal, siliceous, isohyperthermic, shallow Petroferric Haplustults.

6 - Fayra very stony sand, 10 to 30 percent slopes.

Typical pedon description of Fayra very stony sand, 10 to 30 percent slopes near the village of Kiki within the upland portion of the Alluvial Valley and Upland Subzone.

A--0 to 5 cm., yellowish red (5YR5/8) very stony sand; weak fine granular structure; very friable; approximately 50 percent 50 centimeters to 2 meters in diameter of ironstone on surface; very strongly acid; clear irregular boundary.

Bw--5 to 20 cm., yellowish red (5YR4/6) very gravelly fine sand; weak fine subangular blocky structure; firm; approximately 75 percent by volume of ironstone gravel; extremely acid; abrupt irregular boundary.

R--20 cm., hard, consolidated ironstone.

U.S. Soil Taxonomic Classification:
fragmental, siliceous, isohyperthermic Lithic Dystropepts.

7 - Sourgourou fine sand, 2 to 5 percent slopes.

Typical pedon description of Sourgourou fine sand, 2 to 5 percent slopes, near the village of Sourgourou, within the Sand Plain Subzone.

Ap--0 to 22 cm., strong brown (7.5YR5/6) fine sand; weak fine granular structure; loose; medium acid; clear smooth boundary.

BE--22 to 50cm., yellowish red (5YR5/6) fine sand; weak fine subangular blocky structure; very friable; very strongly acid; clear wavy boundary.

Bt1--50 to 105 cm., red (2.5YR5/8) loamy fine sand; weak medium subangular blocky structure; very friable; few sand grains coated and bridged with clay; very strongly acid; gradual wavy boundary.

Bt2--105 to 150 cm., red (2.5YR5/8) loamy fine sand; moderate medium subangular blocky structure; friable; few clay bridges on sand grains; very strongly acid; gradual wavy boundary.

Bt3--150 to 200 cm., red (2.5YR4/8) loamy fine sand; moderate medium subangular blocky structure; friable; few sand grains bridged with clay; few uncoated sand grains; very strongly acid.

U.S. Soil Taxonomic Classification:
sandy, siliceous, isohyperthermic Oxic Paleustalfs.

8 - Labucheri fine sand, 2 to 8 percent slopes.

Typical pedon description of Labucheri fine sand, 2 to 8 percent slopes near the village of Sourgourou within the Sand Plain Subzone.

Ap--0 to 20 cm., brown 10YR5/3) fine sand; weak fine granular structure; loose; strongly acid; clear wavy boundary.

BE--20 to 70 cm., yellowish red (5YR5/6) loamy fine sand; weak fine subangular blocky structure; very friable; very strongly acid; clear wavy boundary.

Bt1--70 to 95 cm., yellowish red (5YR4/6) loamy fine sand; weak medium subangular blocky structure; very friable; patchy faint clay films on faces of some peds; very strongly acid; gradual wavy boundary.

Bt2--95 to 120 cm., red (2.5YR4/6) loamy fine sand; moderate medium subangular blocky structure; very friable; patchy faint clay films on faces of some peds; extremely acid; clear wavy boundary.

Bt3--120 to 200 cm., reddish yellow (5YR6/8) sandy loam; moderate medium subangular blocky structure; friable; patchy faint clay films on faces of peds; extremely acid.

U.S. Soil Taxonomic Classification:
sandy, siliceous, isohyperthermic Psammentic Paleustalfs.

9 - Baboussay fine sand, 0 to 1 percent slopes, ponded.

Typical pedon description of Baboussay fine sand, 0 to 1 percent slopes, ponded, near the village of Sourgourou within the Sand Plain Subzone.

Ap--0 to 30 cm., grayish brown (10YR5/2) fine sand; weak fine granular structure; very friable; strongly acid; clear smooth boundary.

2Ab--30 to 50 cm., brown (10YR4/3) loamy fine sand; weak medium granular structure; very friable; strongly acid; clear wavy boundary.

2Bwb--50 to 80 cm., dark brown (7.5YR4/4) loamy fine sand; weak medium subangular blocky structure; friable; very strongly acid; clear wavy boundary.

2Cb1--80 to 130 cm., brown (10YR5/3) fine sand; structureless; friable; extremely acid; gradual wavy boundary.

2Cb2--130 to 200 cm., dark grayish brown (10YR4/2) fine sand; structureless; friable; extremely acid.

U.S. Soil Taxonomic Classification:
sandy, siliceous, isohyperthermic Typic Ustifluvents.

10 - Zogoti fine sand, 2 to 5 percent slopes.

Typic pedon description of Zogoti fine sand, 2 to 5 percent slopes near the village of Kida Bazagaize, within the Valley portion of the Sand Valley and Plateau Subzone.

Ap--0 to 15 cm., strong brown (7.5YR5/8) fine sand, weak medium granular structure; very friable; very strongly acid; clear wavy boundary.

Bt1--15 to 60 cm., yellowish red (5YR5/6) loamy fine sand; weak medium subangular blocky structure; very friable; patchy faint clay films on faces of peds; very strongly acid; gradual wavy boundary.

Bt2--60 to 100 cm., red (2.5YR4/6) loamy fine sand; moderate medium subangular blocky structure; friable; patchy distinct clay films on faces of peds; extremely acid; clear wavy boundary.

2Bt--100 to 115 cm., red (2.5YR4/8) very gravelly loamy fine sand; weak medium subangular blocky structure; firm, compact and slightly brittle; approximately 60 percent of ironstone gravel less than 2 centimeters in diameter; extremely acid; abrupt wavy boundary.

2Bsm--115 to 150 cm., reddish brown (2.5YR4/4) laterite, massive; very firm, compact and cemented; extremely acid.

U.S. Soil Taxonomic Classification:
sandy, siliceous, isohyperthermic Psammentic Paleustalfs.

11 - Tondi fine sand, 0 to 2 percent slopes

Typical pedon description of Tondi fine sand, 0 to 2 percent slopes, near the village of Goguieize Kouara, within the plateau portion of the Sand Valley and Plateau Subzone.

A--0 to 20 cm., yellowish red (5YR5/8) fine sand; weak medium granular structure; very friable; very strongly acid; clear wavy boundary.

Bt--20 to 50 cm., red (2.5YR5/6) loamy fine sand; weak medium subangular blocky structure; very friable; patchy faint clay films on faces of peds; extremely acid; abrupt wavy boundary.

2Bt--50 to 60 cm., red (2.5YR4/6) very gravelly loamy sand; weak medium subangular blocky structure; firm and compact; contains many isolated pockets of reddish brown (2.5YR4/4) laterite; approximately 50 percent by volume of ironstone gravel less than 2 centimeters in diameter; extremely acid; clear wavy boundary.

2Bsm--60 to 150 cm., reddish brown (2.5YR4/4) laterite; massive; very firm, brittle and cemented; extremely acid.

U.S. Soil Taxonomic Classification:
sandy, siliceous, isohyperthermic Petroferric Haplustults.

12 - Gagani gravelly loamy sand, 0 to 1 percent slopes.

Typical pedon description of Gagani gravelly loamy sand, 0 to 1 percent slopes near the village of Goguieize Kouara within the plateau portion of the Sand Valley and Plateau Subzone.

A--0 to 5 cm., reddish brown (5YR4/4±) gravelly loamy sand; weak fine subangular blocky structure; friable; approximately 15 percent by volume of ironstone gravel less than 3 centimeters in diameter; extremely acid; clear smooth boundary.

Bt--5 to 20 cm., yellowish red (5YR4/6) very gravelly sandy loam; weak medium subangular blocky structure; firm and slightly cemented; patchy faint clay bridges on some sand grains; approximately 50 percent by volume of ironstone gravel from 1 to 3 centimeters in diameter; extremely acid; abrupt wavy boundary.

2Bsm--20 cm., dark red (2.5YR3/6) laterite; massive, cemented and compact; upper boundary is indurated and has accumulation of Fe-Mn stains; extremely acid.

U.S. Soil Taxonomic Classification:
loamy-skeletal, siliceous, isohyperthermic, shallow
Petroferric Haplustults.

13 - Agama clay, 0 to 1 percent slopes, ponded.

Typical pedon description of Agama clay, 0 to 1 percent slopes, ponded, near the village of N'Dikitan within the Dallol Valley Subzone.

Ap--0 to 10 cm., very dark gray (10YR3/1) clay; weak medium subangular and angular blocky structure; firm; contains cracks extending vertically from surface and approximately 1-3 centimeters in width; neutral; clear wavy boundary.

C--10 to 120 cm., black (10YR2.5/1) clay; massive; very firm and plastic; contains cracks extending downward beyond 100 centimeters and from 1 to 2 centimeters in width; cracks are filled with light olive brown (2.5Y5/6) sand from recent deposition; mildly alkaline; clear wavy boundary.

2C--120 to 200 cm., yellowish brown (10YR5/8) loamy fine sand; structureless; friable; moderately alkaline.

U.S. Soil Taxonomic Classification:
very fine, montmorillonitic, isohyperthermic Typic Pellusterts.

14 - Fandou coarse sand, 2 to 8 percent slopes.

Typical pedon of Fandou sand, 2 to 8 percent slopes, near the village of N'Dikitan within the Dallol Valley Subzone.

Ap--0 to 25 cm., brown (10YR4/3) coarse sand; weak fine granular structure; loose; medium acid; clear wavy boundary.

BE--25 to 60 cm., dark brown (7.5YR4/4) coarse sand; weak fine subangular blocky structure; very friable; strongly acid; gradual wavy boundary.

Bt1--60 to 100 cm., strong brown (7.5YR5/6) sand; weak medium subangular blocky structure; very friable; few sand grains bridged with clay; medium acid; gradual wavy boundary.

Bt2--100 to 200 cm., strong brown (7.5YR5/8) loamy sand; weak medium subangular blocky structure; very friable; few sand grains coated and bridged with clay; slightly acid.

U.S. Soil Taxonomic Classification:
sandy, siliceous, isohyperthermic Psammentic Paleustalfs.

15 - N'Dikitan coarse sand, 2 to 5 percent slopes.

Typical pedon description of N'Dikitan sand, 2 to 5 percent slopes, near the village of N'Dikitan within the Dallol Valley Subzone.

Ap--0 to 15 cm., yellowish brown (10YR5/6) coarse sand; weak fine granular structure; loose; medium acid, clear wavy boundary.

A2--15 to 30 cm., brown (7.5YR5/4) coarse sand; weak medium granular structure; loose; strongly acid; clear wavy boundary.

C1--30 to 80 cm., reddish yellow (7.5YR6/8) sand; single grain and structureless; loose; approximately 20 percent uncoated sand grains; strongly acid; gradual wavy boundary.

C2--80 to 200 cm., reddish yellow (7.5YR7/6) sand; single grain and structureless; loose; approximately 50 percent of uncoated sand grains; strongly acid; clear wavy boundary.

C3--200 to 230 cm., pink (5YR8/4) coarse sand; single grain and structureless; loose; approximately 75 percent uncoated sand grains; strongly acid.

U.S. Soil Taxonomic Classification:
isohyperthermic, coated, Ustoxic Quartzipsamments.

16 - Garbey sand, 0 to 1 percent slopes.

Typical pedon description of Garbey sand, 0 to 1 percent slopes, near the village of N'Dikitan within the Dallol Valley Subzone.

Ap--0 to 10 cm., dark brown (10YR4/3) sand; weak medium granular structure; very friable; medium acid; clear wavy boundary.

A2--10 to 30 cm., dark brown (7.5YR4/2) sandy loam; weak fine subangular blocky structure; very friable; neutral; gradual wavy boundary.

C--30 to 75 cm., light olive brown (2.5Y5/4) sandy clay loam; common medium distinct grayish brown (2.5Y5/2) and few fine prominent strong brown (7.5YR5/8) mottles; massive; friable; mildly alkaline; clear wavy boundary.

2Ab--75 to 90 cm., dark grayish brown (10YR4/2) sandy loam; common medium prominent dark reddish brown (5YR3/4) and few medium prominent yellowish red (5YR5/6) mottles; friable; approximately 10 percent by volume of ironstone gravel; neutral; clear wavy boundary.

2Cb--90 to 150 cm., light gray (10YR7/2) sand; few fine prominent reddish yellow (7.5YR6/8) mottles; single grain and structureless; loose; approximately 50 percent uncoated sand grains; mildly alkaline.

U.S. Soil Taxonomic Classification:
fine-loamy, siliceous, isohyperthermic Typic Ustifluvents.

17 - Moma sand, 5 to 10 percent slopes.

Typical pedon description of Moma sand, 5 to 10 percent slopes, near the village of Namaga within the Dune, Interdune and Mare Subzone.

Ap--0 to 20 cm., brown (7.5YR5/4) sand; weak fine granular; very friable; medium acid; clear wavy boundary.

Bt1--20 to 60 cm., yellowish red (5YR4/6) loamy sand; weak medium subangular blocky structure; very friable; patchy faint clay films on faces of some peds; strongly acid; gradual wavy boundary.

Bt2--60 to 120 cm., yellowish red (5YR4/8) loamy fine sand; moderate medium subangular blocky structure; very friable; patchy distinct clay films on faces of some peds; medium acid; gradual wavy boundary.

Bt3--120 to 175 cm., yellowish red (5YR5/8) loamy fine sand; weak medium subangular blocky structure; very friable; many sand grains bridged and coated with clay; slightly acid.

U.S. Soil Taxonomic Classification:
sandy, siliceous, isohyperthermic Oxic Paleustalfs.

18 - Dayobu sand, 2 to 5 percent slopes.

Typical pedon description of Dayobu sand, 2 to 5 percent slopes, near the village of Namaga within the Dune, Interdune and Mare Subzone.

Ap--0 to 20 cm., strong brown (7.5YR5/6) sand; weak fine granular structure; loose; strongly acid; clear wavy boundary.

A2--20 to 40 cm., strong brown (7.5YR5/8) sand; weak fine subangular blocky structure; very friable; very strongly acid; clear wavy boundary.

C1--40 to 110 cm., yellowish red (5YR5/8) sand; single grain and structureless; loose; approximately 20 percent uncoated sand grains; strongly acid; gradual wavy boundary.

C2--110 to 175 cm., reddish yellow (5YR6/8) sand; single grain and structureless; loose; approximately 40 percent uncoated sand grains; medium acid.

U.S. Soil Taxonomic Classification:
isohyperthermic, coated Ustoxic Quartzipsamments.

19 - Dayobu sand, 15 to 30 percent slopes.

Typical pedon description of Dayobu sand, 15 to 30 percent slopes, near the village of Namaga within the Dune, Interdune and Mare Subzone.

Ap--0 to 30 cm., brown (7.5YR5/4) sand; weak fine granular structure; very friable; very strongly acid; clear wavy boundary.

C1--30 to 80 cm., yellowish red (5YR5/6) sand; single grain and structureless; loose; very strongly acid; gradual wavy boundary.

C2--80 to 130 cm., yellowish red (5YR5/8) sand; single grain and structureless; loose; approximately 30 percent uncoated sand grains; extremely acid; gradual wavy boundary.

C3--130 to 175 cm., reddish yellow (5YR6/8) sand; single grain and structureless; loose; approximately 50 percent uncoated sand grains; extremely acid.

U.S. Soil Taxonomic Classification:
isohyperthermic, coated Ustoxic Quartzipsamments.

20 - Galiangou sand, 1 to 3 percent slopes.

Typical pedon description of Galiangou sand, 1 to 3 percent slopes, near the village of Namaga within the Dune, Interdune and Mare Subzone.

Ap--0 to 30 cm., brown (10YR4/3) sand; weak fine granular structure; very friable; strongly acid; clear wavy boundary.

BE--30 to 50 cm., strong brown (7.5YR5/6) fine sand; weak fine subangular blocky structure; very friable; medium acid; clear wavy boundary.

Bt1--50 to 110 cm., strong brown (7.5YR5/8) sandy loam; moderate medium subangular blocky structure; friable; patchy faint clay films on faces of some peds; slightly acid; gradual wavy boundary.

Bt2--110 to 175 cm., reddish yellow (7.5YR6/6) sandy loam; weak medium subangular blocky structure; friable; patchy faint clay films on faces of some peds; neutral.

U.S. Soil Taxonomic Classification:
coarse-loamy, siliceous, isohyperthermic Udic Paleustalfs.

21 - Namaga fine sand, 0 to 1 percent slopes.

Typical pedon description of Namaga fine sand, 0 to 1 percent slopes, near the village of Namaga within the Dune, Interdune and Mare Subzone.

Ap--0 to 25 cm., grayish brown (10YR5/2) fine sand; weak medium granular structure; very friable; moderately alkaline; clear smooth boundary.

EB--25 to 50 cm., pale brown (10YR6/3) sandy loam; many medium prominent strong brown (7.5YR5/6) mottles; weak medium subangular blocky structure; friable; mildly alkaline; clear wavy boundary.

Bt--50 to 80 cm., yellowish brown (10YR5/4) sandy clay loam; common medium distinct strong brown (7.5YR5/8) mottles; moderate medium subangular blocky structure; firm; patchy distinct clay films on faces of peds; neutral; abrupt smooth boundary.

C1--80 to 150 cm., mottled strong brown (7.5YR5/8) and yellowish brown (10YR5/4) sand; structureless; very friable; neutral; gradual wavy boundary.

C2--150 to 175 cm., varigated yellowish brown (10YR5/6), pale brown (10YR6/3) and strong brown (7.5YR5/8) fine sand; single grain and structureless; very friable; saturated with water; neutral.

U.S. Soil Taxonomic Classification:
fine-loamy, siliceous, isohyperthermic Udic Haplustalfs.

22 - Bakala sandy clay, 0 to 1 percent slopes.

Typical pedon description of Bakala sandy clay, 0 to 1 percent slopes, near the village of Namaga within the Dune, Interdune and Mare Subzone.

A--0 to 30 cm., dark grayish brown (10YR4/2) sandy clay; weak medium subangular blocky structure; firm; slightly acid; clear wavy boundary.

C1--30 to 80 cm., dark grayish brown (2.5Y4/2) clay; ped exteriors of very dark grayish brown (10YR3/2); weak medium prismatic structure parting to weak medium angular blocky structure; very firm; vertical closed cracks containing light olive brown (2.5Y5/4) fine sand; neutral; gradual wavy boundary.

C2--80 to 150 cm., very dark grayish brown (2.5Y3/2) clay; ped exteriors of very dark gray (10YR3/1); weak fine prismatic structure to massive; very firm and plastic; mildly alkaline.

U.S. Soil Taxonomic Classification:
very fine, montmorillonitic, isohyperthermic Paleustollic Chromusterts.

23 - Zoribi fine sand, 0 to 2 percent slopes.

Typical pedon description of Zoribi fine sand, 0 to 2 percent slopes near the village of Zoribi within the Interdune portion of the Dune, Interdune and Mare Subzone.

Ap--0 to 25 cm., strong brown (7.5YR5/6) fine sand; weak medium granular structure; very friable; strongly acid; clear wavy boundary.

Bt--25 to 60 cm., reddish brown (5YR4/4) sandy clay; moderate medium subangular blocky structure; firm; patchy distinct clay films on faces of peds; medium acid; clear wavy boundary.

2Bt--60 to 90 cm., olive brown (2.5Y4/4) clay; moderate coarse subangular blocky structure; very firm and plastic; patchy distinct clay films on faces of peds; slightly acid; abrupt irregular boundary.

R--90 cm., hard, consolidated quartz bedrock.

U.S. Soil Taxonomic Classification:
fine, mixed, isohyperthermic Udic Haplustalfs.

24 - Sinsan fine sand, 1 to 3 percent slopes.

Typical pedon description of Sinsan fine sand, 1 to 3 percent slopes near the village of Kouara Tegui within the valley portion of the Sand Valley and Plateau Subzone.

Ap--0 to 15 cm., light yellowish brown (10YR6/4) fine sand; weak medium granular structure; very friable; very strongly acid; clear wavy boundary.

Bt1--15 to 50 cm., yellowish red (5YR5/8) sandy clay loam; moderate medium subangular blocky structure; friable; patchy distinct clay films on faces of peds; very strongly acid; clear wavy boundary.

Bt2--50 to 80 cm., yellowish red (5YR5/8) very gravelly sandy loam; weak medium subangular blocky structure; firm; patchy faint clay bridges on sand grains; approximately 50 percent by volume of ironstone gravel from 5 millimeters to 3 centimeters in diameter; medium acid; gradual wavy boundary.

Bt3--80 to 94 cm., yellowish red (5YR4/6) very gravelly sandy loam; weak medium subangular blocky structure parting to weak fine subangular blocky structure; firm and slightly cemented; patchy distinct clay bridges on sand grains; approximately 70 percent by volume of ironstone gravel from 2 millimeters to 1 centimeter in diameter; strongly acid; abrupt wavy boundary.

2Bsm--94 to 110 cm., dark red (2.5YR3/6) laterite, massive; very firm and cemented; extremely acid.

U.S. Soil Taxonomic Classification:
fine-loamy, siliceous, isohyperthermic Petroferric Haplustults.

25 - Tiloa fine sand, 1 to 3 percent slopes.

Typical pedon description of Tiloa fine sand, 1 to 3 percent slopes near the village of Kouara Tegui within the valley portion of the Sand Valley and Plateau Subzone.

Ap--0 to 20 cm., light brown (7.5YR6/4) fine sand; weak medium granular structure; very friable; strongly acid; clear wavy boundary.

BE--20 to 38 cm., strong brown (7.5YR5/6) loamy fine sand; weak fine subangular blocky structure; very friable; very strongly acid; clear wavy boundary.

Bt1--38 to 90 cm., strong brown (7.5YR5/8) loamy fine sand; weak medium subangular blocky structure; very friable; patchy faint clay bridges on sand grains; extremely acid; gradual wavy boundary.

Bt2--90 to 125 cm., strong brown (7.5YR5/8) sandy loam, moderate medium subangular blocky structure; friable; patchy faint clay films on faces of peds; extremely acid; gradual wavy boundary.

Bt3--125 to 175 cm., strong brown (7.5YR5/8) sandy clay loam; moderate medium subangular blocky structure; friable; patchy distinct clay films on faces of peds; extremely acid.

U.S. Soil Taxonomic Classification:
coarse-loamy, siliceous, isohyperthermic Ultic Paleustalfs.

26 - Kouara Tegui sandy loam, 0 to 1 percent slopes, frequently flooded.

Typical pedon description of Kouara Tegui sandy loam, 0 to 1 percent slopes, frequently flooded, near the village of Kouara Tegui within the valley portion of the Sand Valley and Plateau Subzone.

Ap--0 to 10 cm., brown (7.5YR5/4) sandy loam; weak medium subangular blocky structure; friable; very strongly acid; clear smooth boundary.

Bt1--10 to 60 cm., reddish brown (5YR4/4) sandy clay loam; moderate medium subangular blocky structure; firm; patchy distinct clay films on faces of peds; strongly acid; gradual wavy boundary.

Bt2--60 to 110 cm., yellowish red (5YR5/6) sandy loam; moderate medium subangular blocky structure; friable; patchy faint clay films on faces of some peds; strongly acid; clear wavy boundary.

BC--110 to 150 cm., strong brown (7.5YR5/8) loamy fine sand; weak medium subangular blocky structure; very friable; very strongly acid.

U.S. Soil Taxonomic Classification:
fine-loamy, siliceous, isohyperthermic Ultic Haplustalfs.

27 - Garbey sand, 0 to 1 percent slopes, ponded.

Typical pedon description of Garbey sand, 0 to 1 percent slopes, ponded, near the village of Garbey, within the valley portion of the Sand Valley and Plateau Subzone.

Ap--0 to 15 cm., light brown (7.5YR6/4) fine sand; weak fine granular structure; very friable; strongly acid; abrupt wavy boundary.

C1--15 to 40 cm., stratified layers of strong brown (7.5YR5/6) and reddish yellow (7.5YR6/6) sandy clay loam; structureless; friable; strongly acid; clear wavy boundary.

C2--40 to 60 cm., reddish yellow (7.5YR6/6) sandy loam; common medium prominent red (2.5YR4/8) iron stains; structureless; very friable; very strongly acid; clear smooth boundary.

2Ab--60 to 85 cm., yellowish red (5YR5/8) fine sand; few medium prominent red (2.5YR4/8) mottles; weak fine and medium granular structure; friable; strongly acid; clear wavy boundary.

2Cb--85 to 200 cm., stratified layers of red (2.5YR4/8) sandy loam and brown (7.5YR5/4) fine sand; structureless; friable; very strongly acid.

U.S. Soil Taxonomic Classification:
fine-loamy, siliceous, isohyperthermic Typic Ustifluvents.

28 - Labucheri fine sand, 5 to 10 percent slopes, gullied.

Typical pedon description of Labucheri fine sand, 5 to 10 percent slopes, gullied near the village of Garbey within the valley portion of the Sand Valley and Plateau Subzone.

AB--0 to 10 cm., reddish yellow (7.5YR6/8) fine sand, weak medium subangular blocky structure; friable and slightly crusted on the surface; strongly acid; clear wavy boundary.

Bt1--10 to 60 cm., yellowish red (5YR5/6) loamy fine sand; weak medium subangular blocky structure; friable; patchy faint clay films on faces of some peds; very strongly acid; gradual wavy boundary.

Bt2--60 to 120 cm., reddish yellow (5YR6/6) loamy fine sand; weak medium subangular blocky structure; friable; patchy faint clay films on faces of some peds; extremely acid; gradual wavy boundary.

Bt3--120 to 175 cm., reddish yellow (5YR6/8) loamy fine sand; weak medium subangular blocky structure; friable; common clay bridges on sand grains; extremely acid.

U.S. Soil Taxonomic Classification:
sandy, siliceous, isohyperthermic Psammentic Paleustalfs.

29 - Kiwendi sand, 2 to 5 percent slopes.

Typical pedon description of Kiwendi sand, 2 to 5 percent slopes near the village of Tondi Kiwendi within the valley portion of the Sand Valley and Plateau Subzone.

AB--0 to 10 cm., strong brown (7.5YR5/6) sand; weak fine subangular blocky structure; very friable; very strongly acid; clear wavy boundary.

Bt1--10 to 50 cm., yellowish red (5YR5/8) sandy loam; weak medium subangular blocky structure; friable; patchy faint clay bridges on sand grains; extremely acid; gradual wavy boundary.

Bt2--50 to 100 cm., reddish yellow (7.5YR6/8) loamy fine sand; weak medium subangular blocky structure; very friable; few sand grains bridged with clay; extremely acid; gradual wavy boundary.

BC--100 to 175 cm., reddish yellow (7.5YR6/8) fine sand; weak fine subangular blocky structure; very friable; extremely acid.

U.S. Soil Taxonomic Classification:
coarse-loamy, siliceous, isohyperthermic Aridic Haplustalfs.

30 - Tuizegorou sand, 5 to 15 percent slopes.

Typical pedon description of Tuizegorou sand, 5 to 15 percent slopes near the village of Tuizegorou within the dune portion of the Dune and Sand Plain Subzone.

Ap--0 to 25 cm., brown (7.5YR4/4) sand; weak fine granular structure; loose; very strongly acid; clear wavy boundary.

C1--25 to 70 cm., yellowish red (5YR5/6) sand; weak fine granular structure parting to structureless; very friable; very strongly acid; gradual wavy boundary.

C2--70 to 120 cm., yellowish red (5YR5/8) sand; single grain and structureless; loose; approximately 20 percent uncoated sand grains; extremely acid; gradual wavy boundary.

C3--120 to 175 cm., reddish yellow (7.5YR6/8) sand; single grain and structureless; loose; approximately 40 percent uncoated sand grains; very strongly acid.

U.S. Soil Taxonomic Classification:
isohyperthermic, coated Ustic Torripsamments.

31 - Chinagodrar fine sand, 2 to 5 percent slopes

Typical pedon description of Chinagodrar fine sand, 2 to 5 percent slopes near the village of Tuizegorou within the sand plain portion of the Dune and Sand Plain Subzone.

Ap--0 to 20 cm., light yellowish brown (10YR6/4) fine sand; weak medium granular structure; very friable; very strongly acid; clear wavy boundary.

Bt1--20 to 40 cm., brown (7.5YR5/4) sandy loam; weak medium subangular blocky structure; friable; patchy faint clay films on faces of some peds; extremely acid; clear wavy boundary.

Bt2--40 to 80 cm., dark brown (7.5YR4/4) sandy clay loam; moderate medium subangular blocky structure; firm; patchy distinct clay films on faces of peds; extremely acid; gradual wavy boundary.

BC--80 to 150 cm., brown (10YR4/3) sandy loam; common medium distinct strong brown (7.5YR5/6) and gray (10YR6/1) mottles; weak medium subangular blocky structure; firm and brittle; extremely acid; gradual wavy boundary.

C--150 to 175 cm., stratified strong brown (7.5YR5/6) and reddish yellow (7.5YR6/8) fine sand; massive and structureless; very firm and brittle; extremely acid.

U.S. Soil Taxonomic Classification:
fine-loamy, siliceous, isohyperthermic Aridic Haplustalfs.

SOILS ANNEX F

SOILS INVENTORY OF THE TEST VILLAGES

SOILS INVENTORY OF THE TEST VILLAGES

The following maps are a soils inventory of each of the six selected test villages within the Niamey Department.

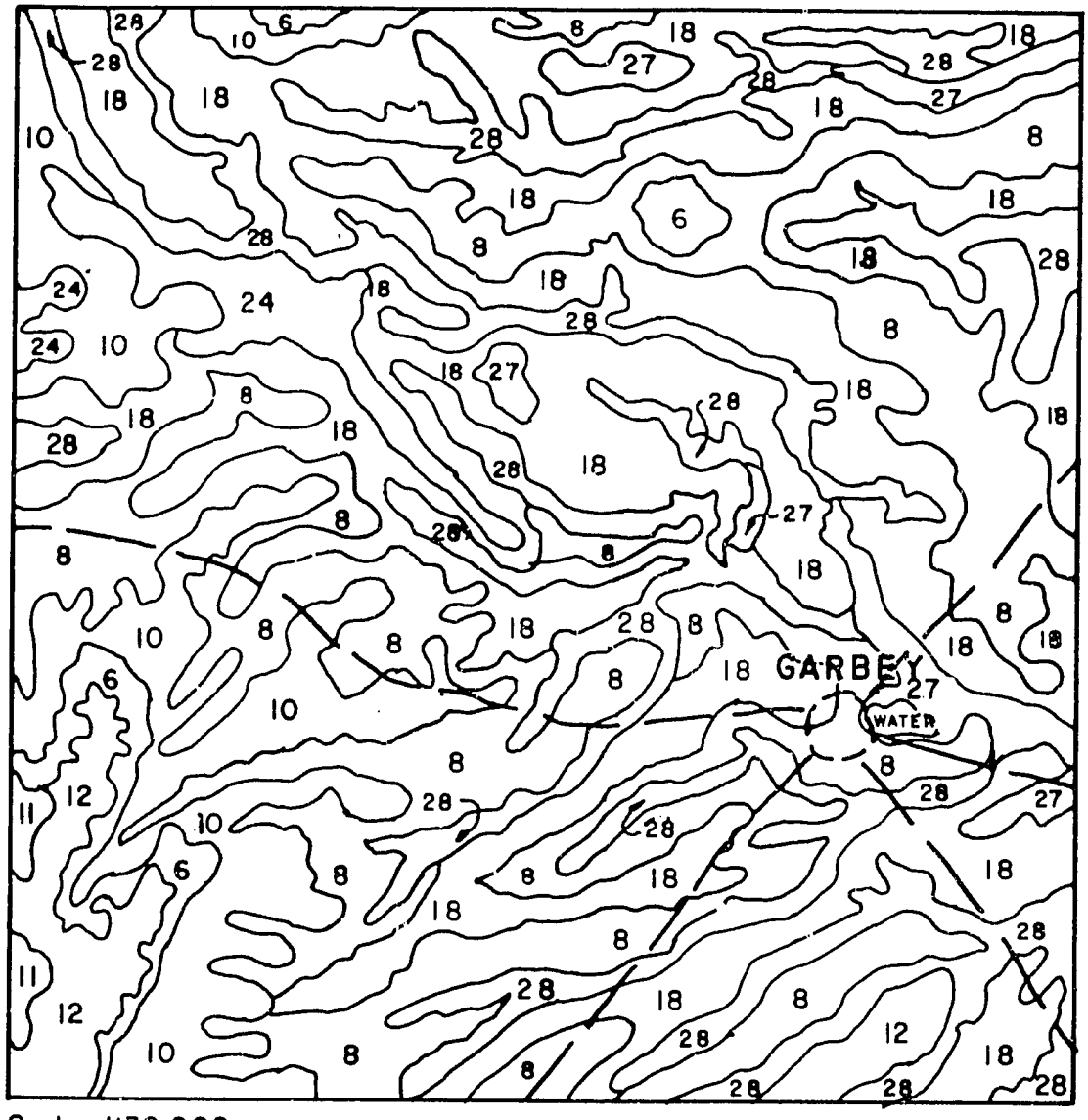
The symbols on these maps identify a particular soil map unit identified at that location. The soil map unit name, represented by a symbol, indicates the major soil series (or soil type) found, the texture of the surface layer and the percent of slope gradient of this particular soil type.

Of particular note, soil map unit number 28 on the Garbey Test Village soil inventory map also includes "gullied" in its name (28 - Labucheri fine sand, 5 to 10 percent slopes, gullied). Gullies are capable of being present in many of the soils identified. However, the areas identified on the Garbey Test Village map as number 28 have extensive gullies and are at such a state of erosion that it makes up the major percentage of the soil map unit. In addition, these areas required identification since a special soil reclamation program will be necessary in order to return these soils to their productivity potential previously experienced. Other significant features such as ponding or frequent flooding have also been identified on selected soil map units.

The delineations of soil map units on these maps include small scattered areas of soils other than those for which the map unit is named. Some of these included soils have properties that differ substantially from those of the major soil identified. Such differences could significantly affect use and management of a specific area. However, due to the scale of the map these inclusions of other soils could not be separated.

The enclosed toposequence of the test villages is merely a graphic depiction of the soils of the test village area and their particular location on the landscape, and to adjacent soils. Therefore, these toposequences are a visual aid and should not be used for specific field comparisons. The village test area maps along with Soils Annex C, Soils Annex D, and the report subsection "Soil Series Evaluations" will serve as the best guide for future site specific soil observations.

GARBEY

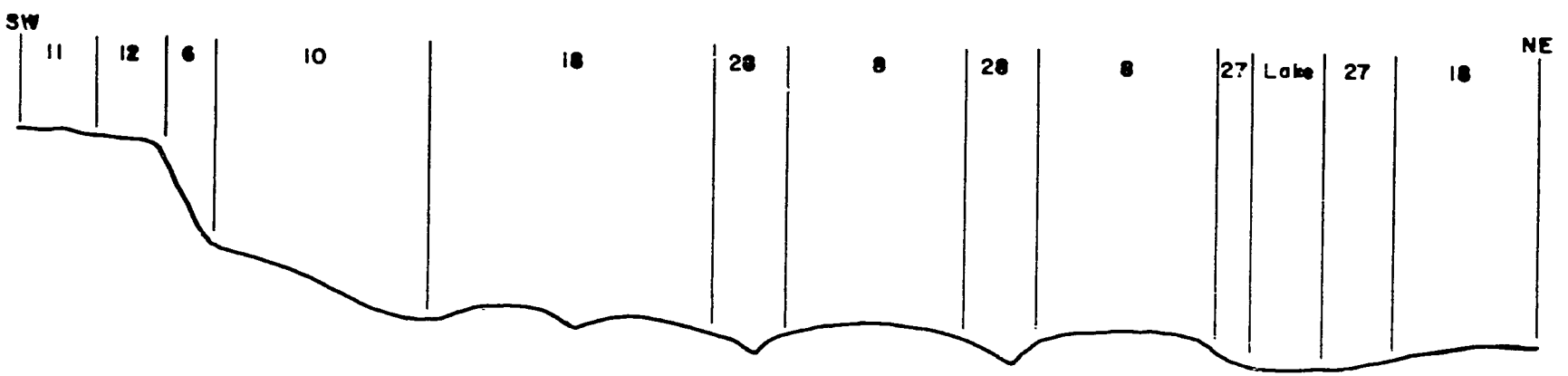


Scale 1:30,000

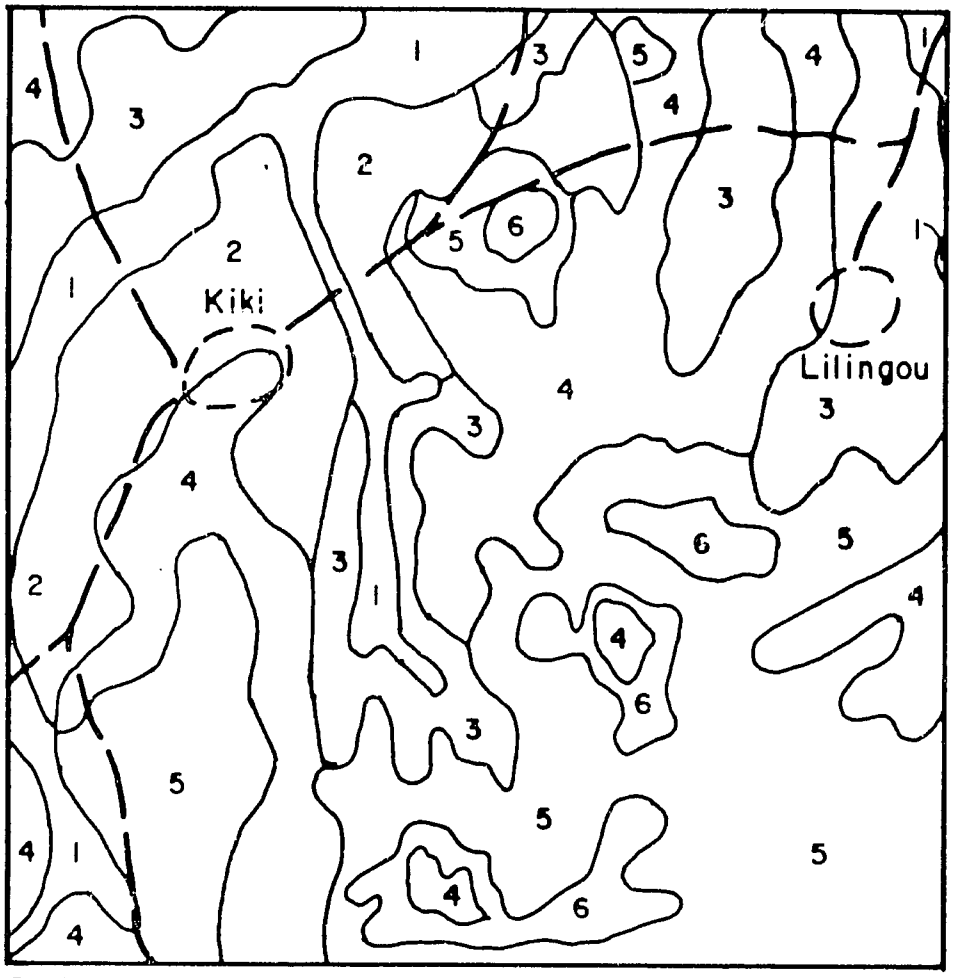
Village — — Roads

6 - Fayra very stony sand, 10 to 30 percent slopes
8 - Labucheri fine sand, 2 to 8 percent slopes
10 - Zogoti fine sand, 2 to 5 percent slopes
11 - Tondi fine sand, 0 to 2 percent slopes
12 - Gagani gravely loamy sand, 0 to 1 percent slopes
18 - Dayobu sand, 2 to 5 percent slopes
24 - Sinsan fine sand, 1 to 3 percent slopes
27 - Garbey sand, 0 to 1 percent slopes, ponded
28 - Labucheri fine sand, 5 to 10 percent slopes, gullied

TOPOSEQUENCE OF GARBEY REGION



KIKI



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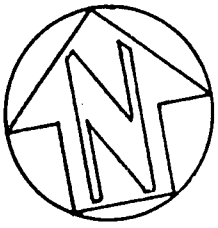
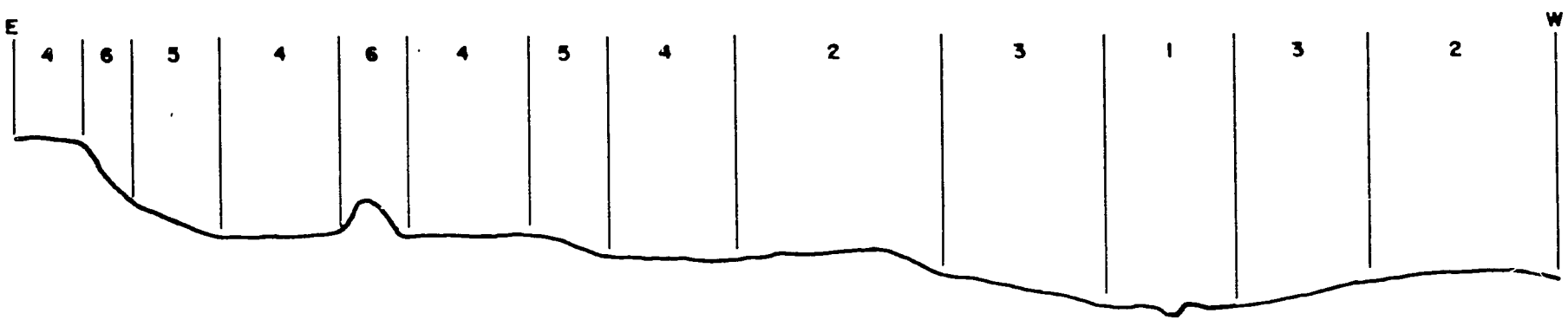
village

roads

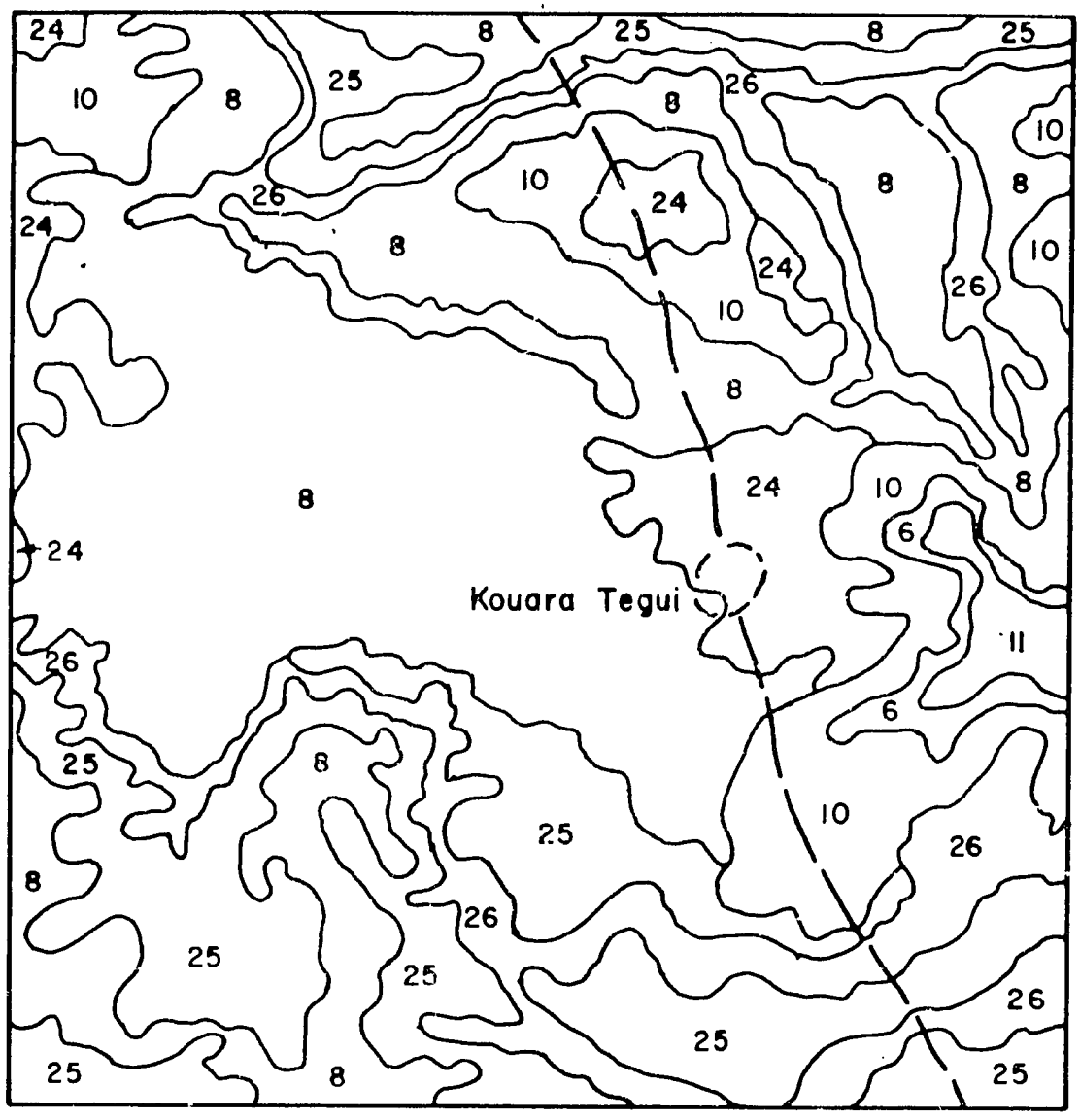


- Bantandi clay, 0 to 1 percent slopes, frequently flooded
2 - Honrou sandy loam, 1 to 3 percent slopes
3 - Lubri' sandy clay, 0 to 2 percent slopes
4 - Pimpergou loamy fine sand, 0 to 2 percent slopes
5 - Makalondi gravelly fine sand, 5 to 15 percent slopes
6 - Fayra very stony sand, 10 to 30 percent slopes

TOPOSEQUENCE OF KIKI REGION



KOUARA TEGUI



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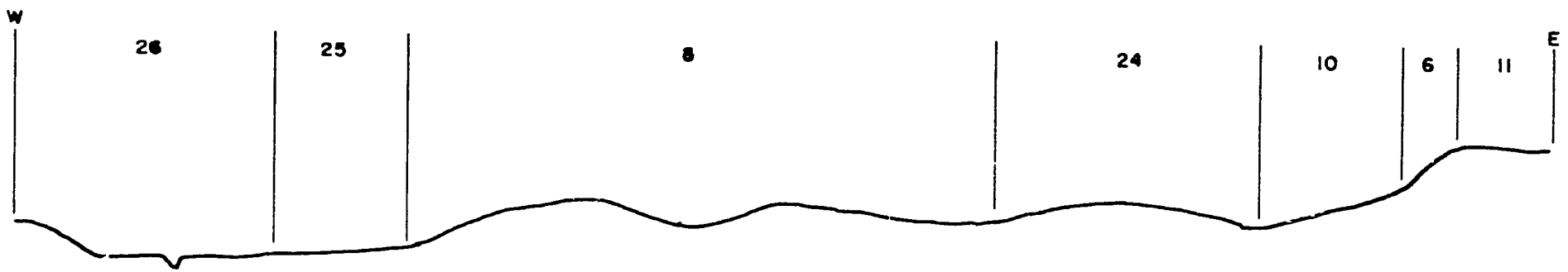
Village

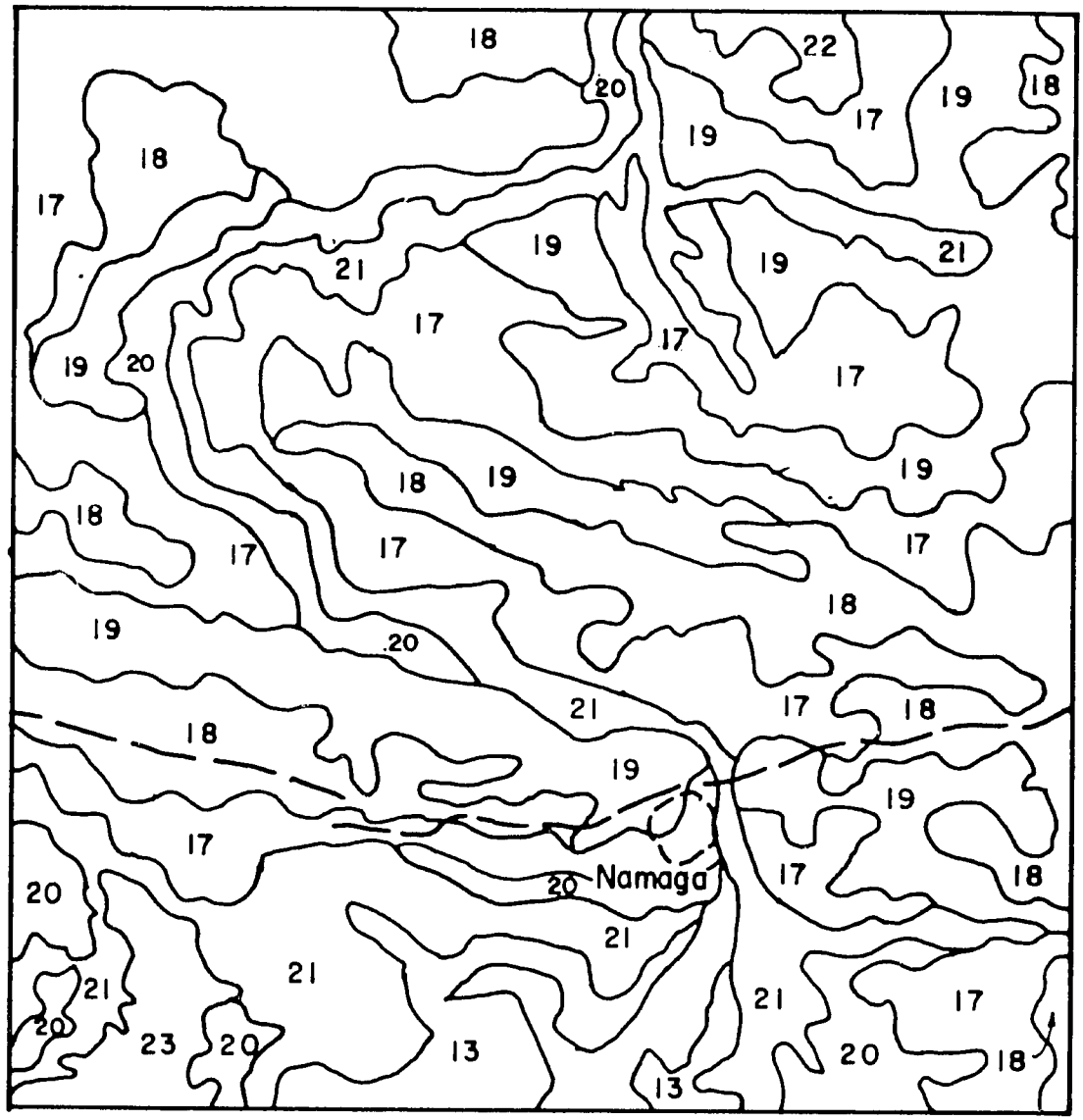
Road

6 - Fayra very stony sand, 10 to 30 percent slopes
8 - Labucheri fine sand, 2 to 8 percent slopes
10 - Zogoti fine sand, 2 to 5 percent slopes
11 - Tondi fine sand, 0 to 2 percent slopes
24 - Sinsan fine sand, 1 to 3 percent slopes
25 - Tiloa fine sand, 1 to 3 percent slopes
26 - Kouara Tegui sandy loam, 0 to 1 percent slopes, frequently flooded

TOPOSEQUENCE OF KOUARA TEGUI REGION



NAMAGA



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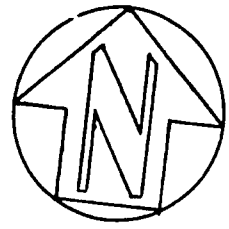
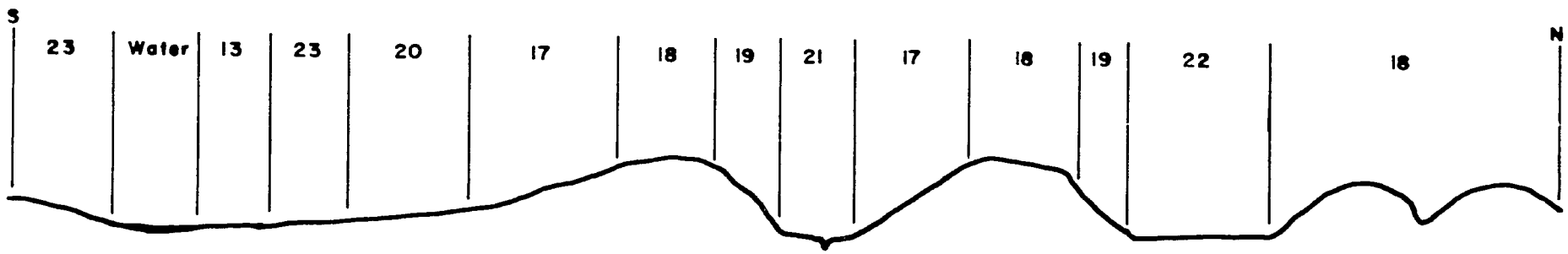
Village — — Roads

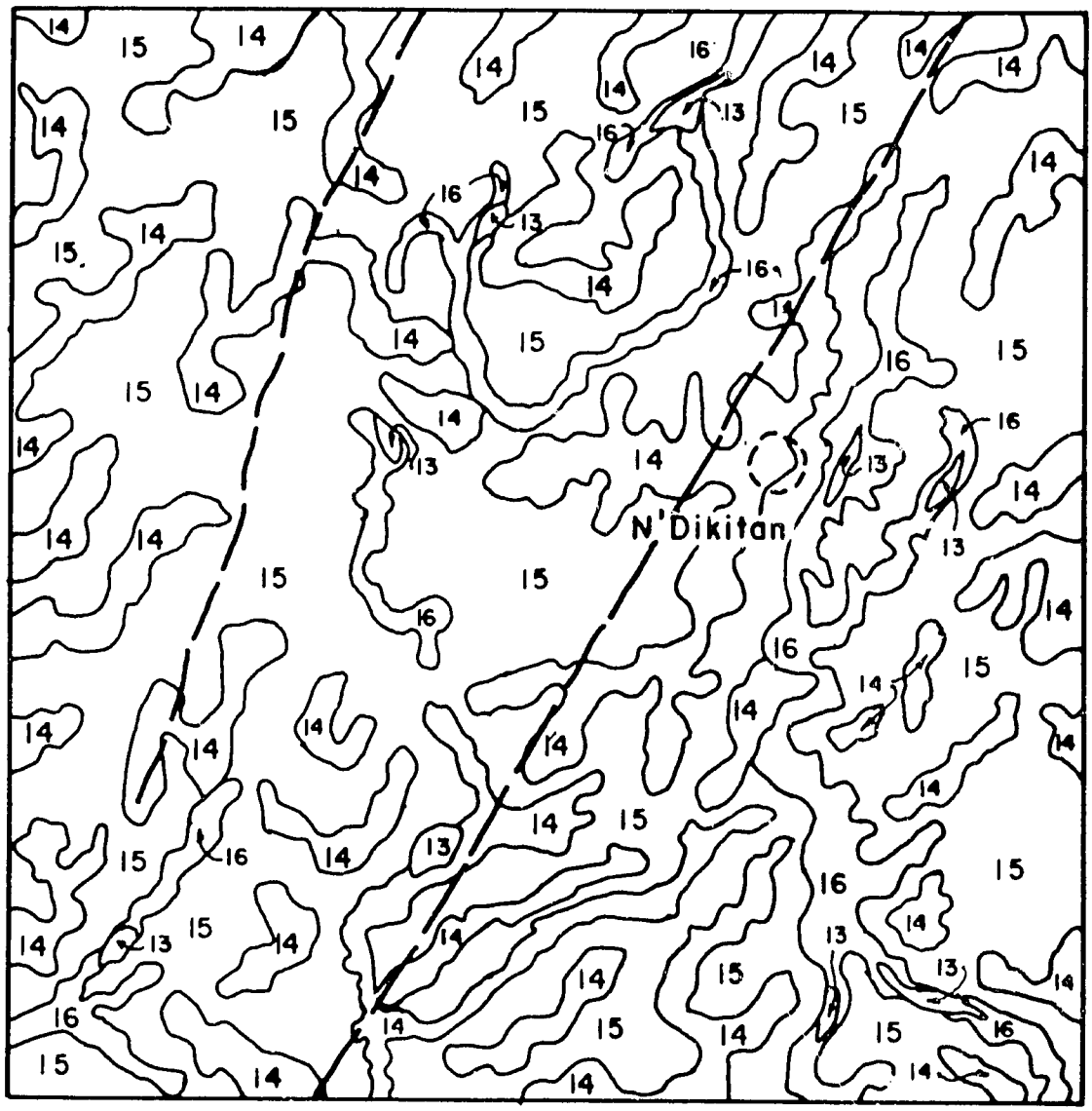


13 - Agama clay, 0 to 1 percent slopes, ponded
17 - Moma sand, 5 to 10 percent slopes
18 - Dayobu sand, 2 to 5 percent slopes
19 - Dayobu sand, 15 to 30 percent slopes
20 - Galiangou sand, 1 to 3 percent slopes
21 - Namaga fine sand, 0 to 1 percent slopes
22 - Bakala sandy clay, 0 to 1 percent slopes
23 - Zoribi fine sand, 0 to 2 percent slopes

TOPOSEQUENCE OF NAMAGA REGION



N'DIKITAN



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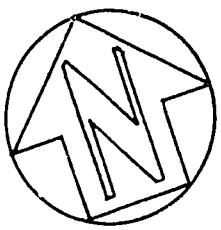


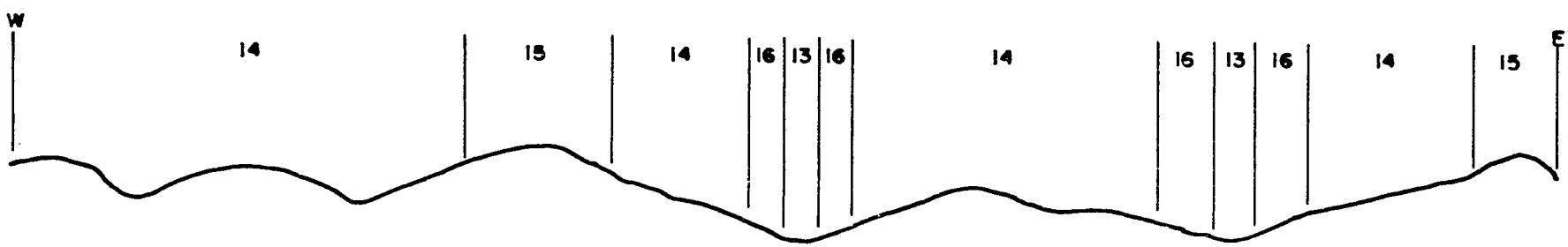
13 - Agama clay, 0 to 1 percent slopes, ponded
14 - Fandou coarse sand, 2 to 8 percent slopes
15 - N'Dikitan coarse sand, 2 to 5 percent slopes
16 - Garbey sand, 0 to 1 percent slopes

Village

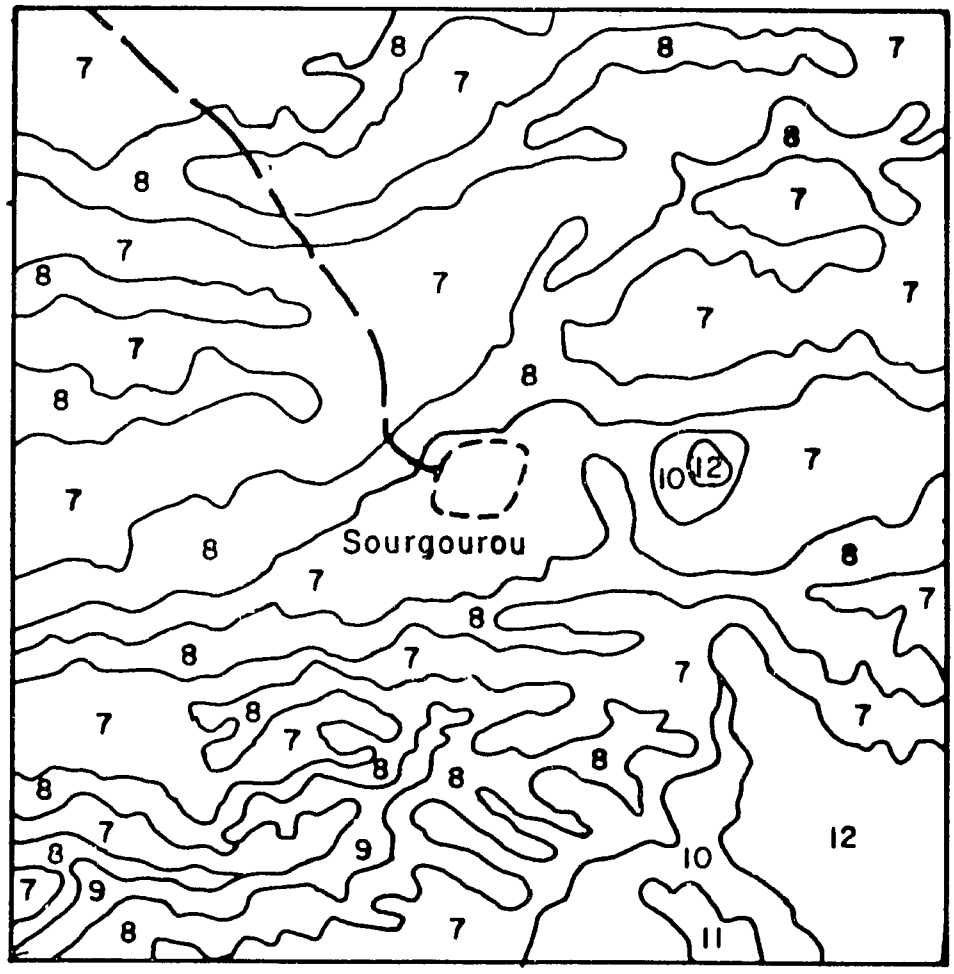
School

Roads

TOPOSEQUENCE OF N'DIKITAN REGION



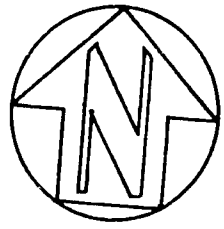
SOURGOUROU



Scale 1:30,000

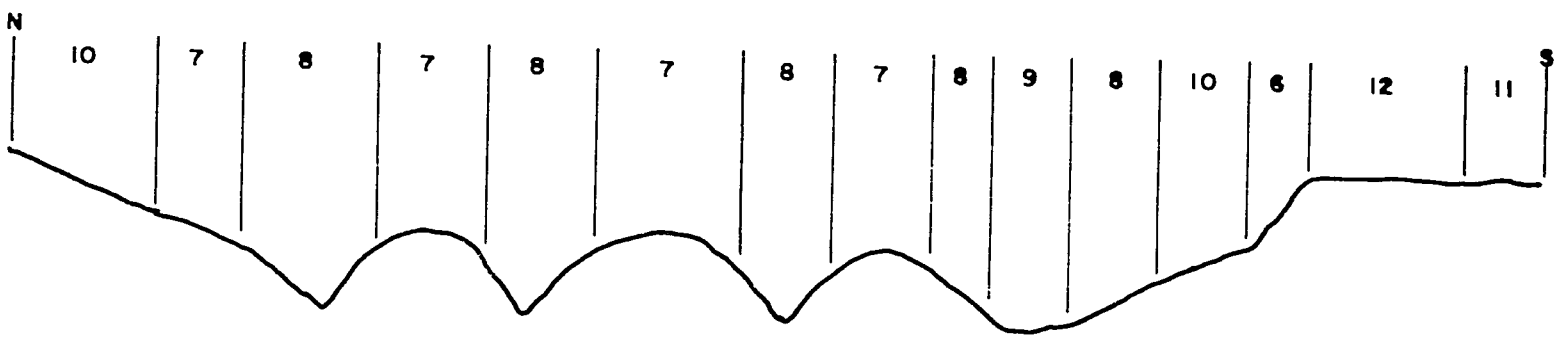
village

road



7 - Sourgourou fine sand, 2 to 5 percent slopes
8 - Labucheri fine sand, 2 to 8 percent slopes
9 - Baboussay fine sand, 0 to 1 percent slopes
10 - Zogoti fine sand, 2 to 5 percent slopes
11 - Tondi fine sand, 0 to 2 percent slopes
12 - Gagani gravelly loamy sand, 0 to 1 percent slopes

TOPOSEQUENCE OF SOURGOUROU REGION



SOILS ANNEX G

SOIL TEST RESULTS

SOIL TEST RESULTS

SOIL NAME	DEPTH (cm.)	O.M. (%)	ENR (kg/ha)	P	K	Mg	Ca	S	SOIL pH
				------ppm----------					
BANTANDI	0-25	1.5	85	4	116	427	1870	--	6.1
HONROU	0-30	0.9	70	3	156	125	540	16	7.2
	30-70	0.6	63	3	96	90	700	--	7.5
	70-105	0.4	58	2	80	139	640	--	7.7
	105-150	0.3	53	2	96	172	700	--	7.7
LUERI	0-25	1.2	78	11	707	558	1380	--	7.3
SOURGOUROU	0-22	0.4	58	6	63	26	100	6	6.0
	22-50	0.3	53	17	50	13	30	--	4.8
	50-105	0.2	50	24	36	14	20	--	4.8
	105-200	0.2	50	4	33	16	30	--	5.0
AGAMA	0-20	0.7	65	10	350	330	1460	--	9.2
N'DIKITAN	0-30	0.2	50	19	76	47	150	--	5.9
	30-80	0.2	50	5	69	22	80	--	5.2
	80-200	0.1	48	4	51	28	40	--	5.2
	200-230	0.1	48	4	31	14	40	--	5.3
NAMAGA	0-25	0.2	50	3	95	56	230	--	7.9
KOUARA TEGUI	0-30	0.6	40	7	91	62	260	--	5.1
GARBEY	0-40	0.5	60	11	92	44	150	--	5.1

Ca=CALCIUM
ENR=ESTIMATED NITROGEN RELEASE (AMOUNT OF NITROGEN IN THE ORGANIC MATTER THAT WILL BE AVAILABLE)
K=POTASSIUM
Mg=MAGNESIUM
P=PHOSPHORUS (BY WEAK BRAY METHOD WHICH DETERMINES THE AMOUNT THAT IS READILY AVAILABLE)
S=SULFUR
O.M.=ORGANIC MATTER
ppm=PARTS PER MILLION (METHOD OF MEASUREMENT OF INDIVIDUAL ELEMENTS)
pH=NUMERICAL VALUE OF SOIL ACIDITY OR ALKALINITY

SOIL TEST RESULTS
(CONTINUED)

SOIL NAME	DEPTH (cm.)	H (meq/100g)	CEC (meq/100g)	BASE SATURATION (%) K	Mg	Ca	H
BANTANDI	0-25	2.1	15.4	1.9	23.2	60.9	14.0
HONROU	0-30	0.0	4.1	9.7	25.2	65.1	0.0
	30-70	0.0	4.5	5.5	16.7	77.8	0.0
	70-105	0.0	4.6	4.5	25.4	70.1	0.0
	105-150	0.0	5.2	4.8	27.7	67.5	0.0
LUBRI	0-25	0.0	13.4	13.6	34.8	51.6	0.0
SOURGOUROU	0-22	0.2	1.0	15.6	21.0	48.4	15.0
	22-50	0.3	0.7	17.6	14.9	20.5	47.0
	50-105	0.3	0.6	15.8	20.0	17.2	47.0
	105-200	0.3	0.6	13.6	21.4	24.0	41.0
AGAMA	0-20	0.0	10.9	8.2	25.1	66.7	0.0
N'DIKITAN	0-30	0.3	1.6	12.1	24.3	46.6	17.0
	30-80	0.4	1.2	15.2	15.8	34.5	34.5
	80-200	0.3	0.9	15.2	27.1	23.2	34.5
	200-230	0.2	0.6	13.8	20.3	34.9	31.0
NAMAGA	0-25	0.0	1.9	13.1	25.1	61.8	0.0
KOUARA TEGUI	0-30	1.3	3.3	7.1	15.6	39.3	38.0
GARBEY	0-40	0.8	2.2	10.8	16.8	34.4	38.0

H=HYDROGEN
CEC=CATION EXCHANGE CAPACITY