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SOIL AND CROP MANAGEMENT IN SELECTED FARMING SYSTEMS OF BURKINA FASO

AGRICULTURAL RESEARCH AND POLICY IMPLICATIONS

YVES COFFI PRUDENCIO

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CHAPTER 1.

INTRODUCTION.

Soil fertility degradation in the current farming systems of the West African Semi-Arid Tropics (WASAT) has recently become, in addition to drought, a major concern for agricultural research and development in the region. The basic argument has been that rising livestock and population pressures lead to a shortening of fallow periods, and since fallow is the major means for regenerating soil fertility within the traditional farming systems of the region, the shortening of fallow periods necessarilly leads to overexploitation and degradation of soil fertility, and thereby to a decline in the productivity of the farming systems in the region.

A more general argument is that farmers in the region use poor and irrational resource management practices which they do not want to change. Such practices and attitude, would be from the point of view of many agricultural researchers and developers, the major constraints to new technology adoption and agricultural development in the region.
Arguments such as these are rarely based on empirical evidence because little is actually known about peasant farm resource management in the region. There has been, until recently, little attempt to identify and measure the basic parameters of farming systems in the region and to understand how the systems function and change so as to assist agricultural research and development.

The present study systematizes, describes and analyses the soil and crop management practices of farmers in four farming systems located in four different agroclimatic zones of Burkina Faso. It discusses the rationale behind the observed soil and crop management systems and the effect of each management system on soil fertility, on yields and on resource productivity in general.
It discusses the adjustment mechanisms of the systems vis a vis land use intensification pressures, the major constraints faced by the systems on their development paths, the types of solutions that might alleviate such constraints and their implications for agricultural research and development in the region.

CHAPTER 2.

THE STUDY SITES, SAMPLES AND THEIR MAIN CHARACTERISTICS.

2.1. Sites and Samples.

In conjunction witht the ICRISAT West African Economics Programme, farm survey data were collected in 1981-82 in Burkina Faso by this author in four locations which are from South to North: Manga, Boromo, Yako and DJibo as shown in Figure 1.

Two villages were selected in each area following a reconnaissance survey (Mc. Intire, 1982, Prudencio 1983). A sample of twenty five farmers was selected in each village. The site and sample selection procedure as well as the data collection procedures are explained in Appendix 1.

2.2. Agroclimatic and Demographic Characteristics of the Study Site.

The studied farming systems are:

(1) The Soudanian Mossi Farming System of the Manga area which has a long term average annual rainfall about 1000 mm.

(2) The Sudano-Sahelian Mossi Farming System of the Yako area, with a long term average annual rainfall about 750 mm.

(3) The Sahelian Peuhl-Rimaibe Farming System of the Djibo area with an annual rainfall of about 600 mm.

(4) The Northern Guinean Bwa-Dagari farming system of Boromo area with an annual rainfall about 1000 mm.

Those four areas were chosen so as to cover the major agroclimatic zones of the WASAT and to insure enough cross-country variability in demographic and agroclimatic conditions, especially in population density, rainfall, and soil types which are believed to be major determinants of soil fertility management systems. The agroclimatic and demographic characteristics of the various farming systems are shown in Table 1 and Figure 1. It is generally accepted that the variability in rainfall distribution increases and that soil quality declines in

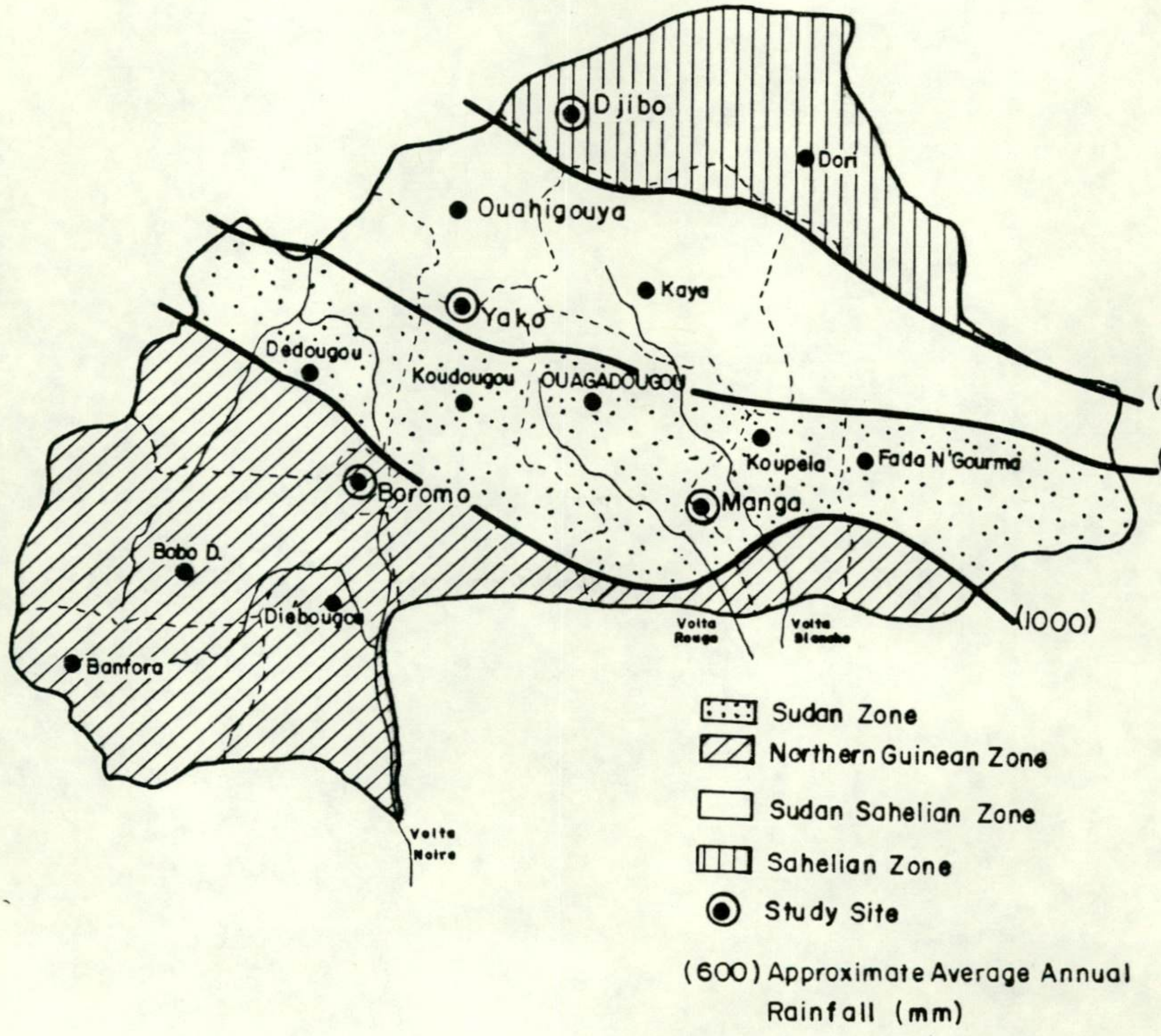
Table 1. Agroclimatic and Demographic Characteristics of the Selected Farming Systems.

Area	Ethnic Group	Selected villages	Rainfall Long term Average (mm) (b)	Soil Type: Top	Soil Type: Depth (cm)	Soil Type: Base	Agroclimatic Zone	Population density (c)	Rural popul. density per sq km of UAL (d)
DJIBO	Peulh-Rimaibe	Ouré Silguey	567	Sandy	40 to 100 and over	Sandy clay or clay	Sahel	14	36
YAKO	Mossi	Kolbila Ouonon	756	Sand and gravels or sandy-clay	Variable	Rock sandy clay or clay	Sudan-Sahel	55	92
MANGA	Mossi	Nonghin Monkin	1197	Sand and gravels or clay	40 to 100	Clay	Sudan	45	103
BOROMO	Bwa and Dagari	Koho Sayero	1000	Sandy	40 to 100	Clay & sand	Northern Guinean	28	23

(a) From Boulet's maps (Boulet, 1976)
(b) From S.M. Virmani (1981)
(c) From INSD (1986) Burkina Faso 1985 Census
(d) From Reij (1983); UAL = Useful Agricultural Land.

Figure 1.

AGROCLIMATIC ZONES OF BURKINA FASO



Source GERDAT, 1983
Adaptation

Burkina Faso as one moves from south to north on a given meridian axis (ASECNA, 1972; Peron and Zalacain, 1975; Boulet, 1976), so that, in general, agroclimatic conditions are more favorable to crop growing activities in Boromo and Manga than they are in Yako and Djibo. As for overall population density, all the statistics on the subject agree that it reaches its highest points in Yako followed by Manga and declines to an average level in Boromo and to a relatively low level in Djibo (CVRS, 1968; INSD 1978; Peron and Zalachain, 1975). The population pressure on arable lands in rural areas is on average above 100 inhabitants/km2 on the Mossi Plateau where Manga and Yako are located and about 36 inhabitants/km2 in the Sahel and in the West where Djibo and Boromo are located (Reij, 1983, P.5).

2.3. The Soils.

The Voltaic soils and the WASAT soils in general belong to the classes of leached ferrugineous and ferralitic tropical soils (Alfisols). According to Boulet, (1976), in the north of the Manga area where the village Nonghin is located, soils are overall sandy and gravelly laying over the ferrugineous gravels and compact clay vertisoils which are found about 40 to 80 cm below the surface. South of Manga where the second village Monkin is located soils are deep vertisoils, often mixed with gravels in the upper layer. In the Yako area two major regional soil types are found as well: (a) soils with variable depth (up to over 100 cm) with sandy clay to clay sandy A layer over clay B layer, sometimes gravelly; and (b) shallow sandy soils (often containing gravel) generally not more than 40 cm deep laying on the hard rock of the parent granitic material which emerges from place to place. Two major soil types are found in the Djibo area: (a) deep arable soils (over 100 cm deep) with a sandy A layer and sandy to sandy-clay B layer, (b) shallow sandy soil (about 40 cm deep) appropriate for pastures with sandy A layer and contrasted clay B layer (solonetz). In the Boromo area, soils are either (a) sandy top soils over clay sandy and gravelly base soils with an average depth varying from 40 cm to 100 cm or (b) deep sandy top soils over clay bases.

At the village level many variations of the regional soil types are found along the toposequence and receive various local denominations based on color, texture, vegetation, situation on the toposequence, physical reactions with water, heat and cultivation tools, runoff and internal hydrolic regimes, etc. The major local soil varieties and their characteristics as determined in farmer interviews and soil surveys are shown in Table 2. Although in this study we shall apply the local denominations to the soils only, such local denominations more accurately within the local body of knowledge refer to ecosystems (including vegetation) of which the soil is only a part.

Table 2. Local Soil Types.

Soil Type N°	Local Denominations in: 1. Djibo	2. Yako	3. Boromo	4. Manga	General Characteristics
10	---	Zingadega	---	Zingadega	Upland shallow ferruginеous rocky soils on top or slopes of small hills. Brown color.
11	---	Zinka	---	Kougri	Upland gravelly soils, mostly quartzite gravels, micas, and sand.
12	Houkawo	Zinka	Kougniguere, Hanin	Kuigdiga	Upland sandy gravelly soils, contain mostly sand and small ferruginеous concretions. Generally preceeds soils 20 and 30 in topsequence from the top to the bottom of slope.
13	---	Rassempoui-Zingadega	---	---	Hillfoot shallow and gravelly soils where trees are unable to grow.
20	Seno	Binsiri	Tamissougo, Fiaho,Hapono	Binsiri	Sandy soils, contain mostly coarse and fine sand found mostly on top of slopes of toposequences. Color light to dark grey.
21	---	Rassempoui-Binsiga	---	Rassempouiga	Shallow sandy areas where no tree grows. Leached white grey sandy hillfoot soils.
30	Bolawo	Zimuougou	Tanzia, Tioro	---	Compact deep lateritic redish soils sandy with relatively high proportions of silt, found mostly on long slopes.
35	---	Tampoure	Tampoure,N'donfi	---	Dark soils of areas used in the past as waste or garbage disposal by the village community.
40	---	---	----	Naka	Vertisols, green compact soils found at bottom of slopes containing relatively high proportions of clay. Contain quartzite gravels in upper layer.
50	---	Kossogho	Zepoko Tingasologo	---	Soil of upland lines of greater slopes along which rainwater flows from uplands to lowlands. Compact dark grey soils.
51	---	---	Soumsoumbi		Dark alluvion soils near lowlands
60	Lomre	Zi Bolle	Ba, Diahon	Zi Bolle	Lowland cuvette and seasonal water courses soils. In general hydromorphic soils with texture depending mostly on texture of adjancent upland soils.
70	---	Baongo	---	Zi Boalga	
71	---	Rassempoui-Boalga	---	---	

CHAPTER 3.

AN OVERVIEW OF THE FARMING SYSTEMS.

An "airplane view" introduction to the farming systems is presented in this section by describing them on the basis of the spatial arrangement of fields vis-à-vis the habitats. This type of description is appropriate as a first step toward the analysis of soil fertility management and land use patterns in the region.

The Mossi Farming System.

The typical land cultivation system in the Mossi farming systems of Manga and Yako is the ring cultivation system found in many parts of the WASAT and described by Pelissier and others (Pellissier, 1966; Rutherberg, 1976; Delgado, 1979; Norman et al., 1981) in terms of housefields, village fields and bush fields.

In the Mossi farming systems, the households live in separate compounds scattered all over the village territory. Small fields right next to the compound walls are usually referred to as "housefields"; fields in between the compounds are usually referred to as "village fields" and fields located behind the frontier where bush fallows begin are usually referred to as "bush fields".

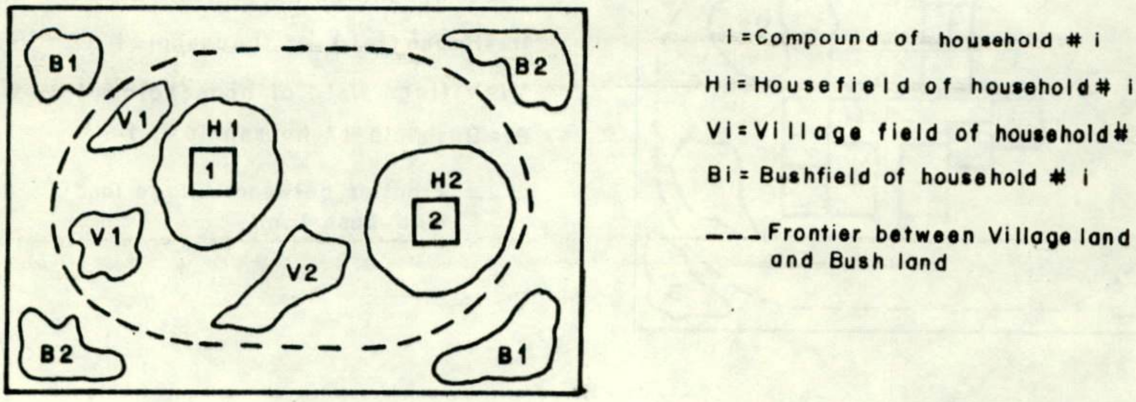


Figure 2. Spatial House and Field Arrangement in the Mossi Farming System.

Maize, tobacco and sauce plants are generally planted on housefields. Red sorghum is generally planted next to them on housefields and village fields. White sorghum and millet are generally intercropped with cowpea on village fields and bushfields. Cotton, is also found both on village fields, and tuber roots, groundnuts, and peas are found both on village and bush fields. These last four crops are mostly used as cash crops along with red sorghum which is used both as a cash crop and as a food crop. White sorghum and millet are used primarily as food crops. In addition to the crop growing activities, the Mossi farmers practice poultry and small ruminants (sheeps & goats) husbandry on their farms. Cattle raising activity is separately carried out by Peulh (or Fulani) herdsmen who transhume with their cattle across the Mossi Plateau. Few Mossi farmers own and keep cattle on their farms. Those who have some cattle generally entrust them to the Peulh herdsmen with the exception of the draft oxen which are often kept on the farms. As shown in Table 3, less than one tenth of farmers use animal traction technology in the Yako villages while over one half of them use it in the Manga villages.

The Bwa-Dagari Farming System.

The Bwa and Dagari household compounds are clustered and form one single village compound with mostly village fields and bush fields. Few house fields exist inside or next to the village compound and belong mostly to the households living in the peripheric houses.

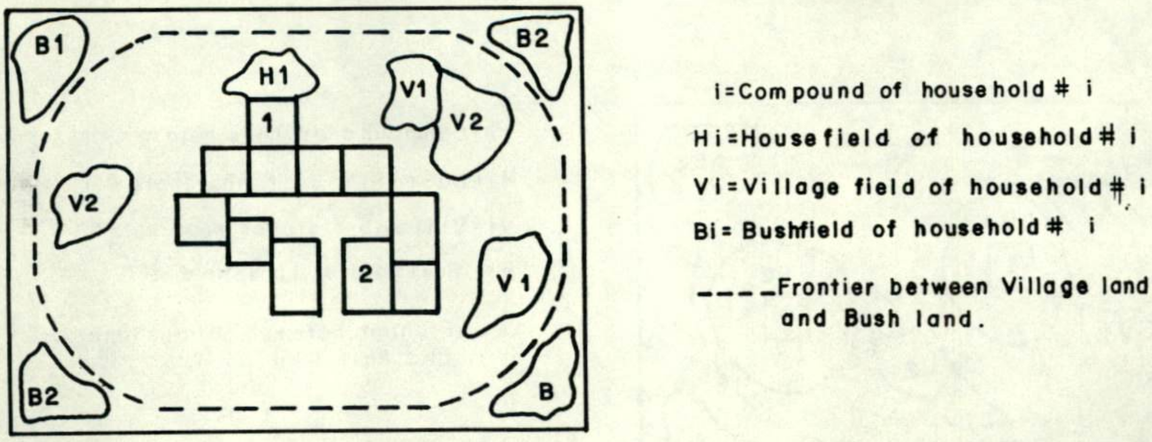


Figure 3. Spatial House and Field Arrangement in the Bwa-Dagari Farming System.

Table 3. Demographic and Technological Characteristics of the Studied Villages Populations and Samples.

Area	Village	Ethnic Group	1981 Population	Village Households			Sample Households		
				Total	Hand Tool	Animal Traction	Total	Hand Tool	Animal Traction
DJIBO	Oure	Rimaibe	377	52	43	9	25	16	9
	Silguey	Rimaibe	481	45	37	8	25	17	8
YAKO	Kolbila	Mossi	905	87	83	3	25	22	3
	Ouonon	Mossi	868	na*	na*	na*	25	16	9
BOROMO	Koho	Bwa & Dagari	962	84	65	19	25	13	12
	Sayero	Bwa	867	77	65	12	25	13	12
MANGA	Monkin	Mossi	671	90	47	43	25	12	13
	Nonghin	Mossi	651	106	37	69	25	6	19

(1) * Not Available.

As in the Mossi farming systems, those farmers who own house fields plant mostly maize, red sorghum and sauce plants on such fields. Dominant crops in village fields are red sorghum, cotton, maize, and groundnuts. Bush fields are mostly planted with millet and white sorghum intercropped with cowpeas. Cotton is the major cash crop in the area. Poultry and small livestock (sheep, goats, pigs) husbandry is also carried out here inside and around the village compound and in association with crop growing activities. In this area, more farmers, especially among the Dagari, own cattle than the farmers on the Mossi Plateau. Most of these are entrusted to the Fulani or Peuhl herdsmen who keep the cattle in the vicinities of the village where they have established a more or less permanent settlement. Draft oxen and cattle for sale are kept in small parks around the household compound. As shown by Table 2, approximately one-fifth of the farmers in this system use animal traction equipment.

The Peuhl Rimaibe Farming System.

The Peuhl Rimaibe spatial organization of habitats and fields looks like a superimposition of both the Mossi and Bwa-Dagari spatial organizations. Some of the farmers live in a central village compound like the Bwa-Dagari while others live in separate household compounds scattered over the village territory like the Mossi.

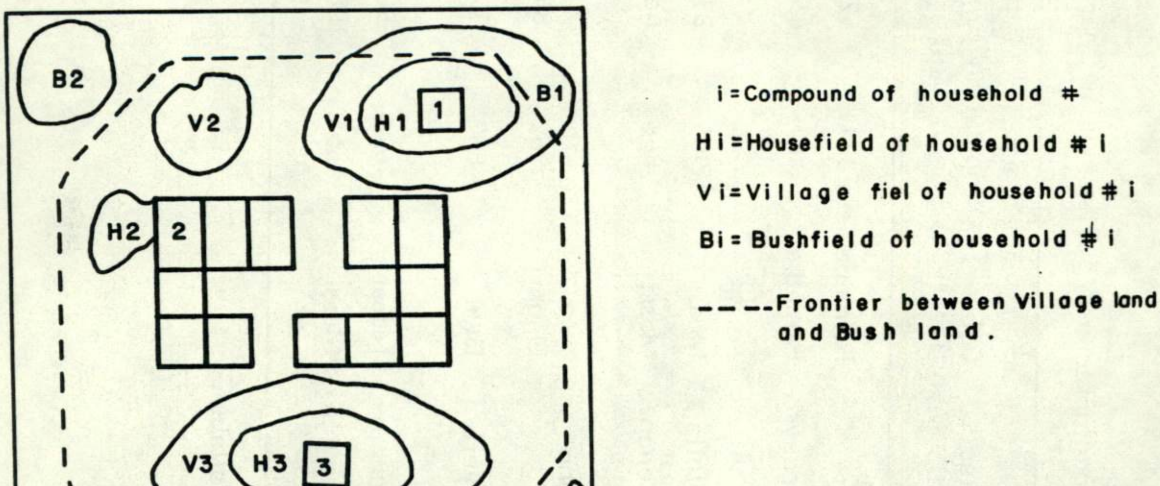


Figure 4. Spatial House and Field Arrangement in the Peulh-Rimaibe Farming System.

About one-half of the sample members are found in each case. This type of spatial organization enables more households to have housefields than in the Bwa-Dagari system but less than in the Mossi system. Households living inside or outside the village compound have village fields as well as bush fields. Housefields and village fields are generally fragmented and dispersed for the former and are generally contiguous for the latter. Maize and sauce plants are planted on housefields like in the previous systems. Millet, intercropped with cowpea, is extensively planted throughout the village fields and bushfields on uplands. Inside the millet fields are found several small areas planted with groundnut, fonio and earth peas. Lowland village and bush fields are planted with sorghum, especially white sorghum.

There exists no predominant cash crop in the area, and almost all of the crop produced is autoconsumed. Poultry and small livestock (goats) husbandry is also practised in association with the crop growing activities. The Peuhl-Rimaibe are former captives of the Peuhl herdsmen, and cattle raising is their second major production activity and is practiced by many though not all. The cattle raising activity in association with crop growing activities is generally carried out by the majority of the households living outside the central village compound.

This appears to be the major reason for their settlement outside the central compound. Farmers living in the central compound in general do not raise cattle and use hand tool technology. About one-tenth of the farmers in the study villages use animal traction technology.

Among the eight villages, four were subjected to more intensive surveys. The more intensive surveys were carried out in one of the two villages in each area, this study analyses primarily the data of three of those village which are Nonghin in the Manga area, Kolbila in the Yako area and Woure in the Djibo area. In the Boromo area complementary data from both villages have been analyzed.

CHAPTER 4.

THE MOSSI FARMING SYSTEM OF NONGHIN (MANGA) IN THE SUDANIAN ZONE.

4.1. The Average Farm Resource-Base.

Each household cultivates on average seven fields on one to four pieces of land (terrains). The average number of lands per household in the sample was 2.5. This allows most households to crop on more than one soil type. The 1981 average farm size in the village sample was about 3.75 hectares. Eighty six percent were cultivated in 1981 while the remaining 14 percent were not. The latter consisted mostly of unfertile and Striga infested areas. 65% of farmers in the village and 76% of farmers in the sample owned donkey and horse drawn animal traction implements. On the average, the hand tool farm measured about 2.70 hectares and 70 percent of its area was cultivated. The animal traction farm measured an average 4.10 hectares and 90 percent of its area was cultivated. About 7.3. people were living on the average farm, 6.2 on hand tool farms and 7.7 on animal traction farms. The cultivated area per capita was then about 0.44 hectares for the sample, 0.29 hectares on hand tool farms, and 0.48 hectares on animal traction farms.

About 30% of the sample households were raising cattle on the farm. The average size of the cattle was about 5 heads. All households were raising small ruminants such as goats and sheep on the farm. The average size of the herds was about 7 heads per household.

4.2. The Local Soils.

Nonghin is located on ferrugineous soils north of Manga. Four major soil types are found in the village territory which can be divided into four major upland zones, each with a dominant local soil type as shown in Figure 5 below. The latter illustrates quite well the large variation in soil types that exists over short distances in the villages and in the area in general.

Zone 1 in Figure 5 is the initial settlement site within the village territory. The predominant soil type in this area is a reddish-brown gravelly sandy soil (S11, see Table 2) containing an average of 43 percent gravel. A coarser variant of the same soil type (S10) appears in some places in the same zone. Zone 2 is, according to the village history, the second settlement site. As the village population increased, fields and compounds were expanded into this area which is covered mostly by a slightly brown sandy gravelly soil (S12) that contains an average of 35 percent smaller gravels. Zone 3, which is chronologically the third settlement site, is mostly covered by a gray sandy soil (S20) that contains an average of 14 percent gravel. The lowlands along the seasonal water courses across the village territory are covered by slightly hydromorphic soils whose textures depend mostly on those of the adjacent soils. The major lowland soils are sandy silt soils (S60) and clayey vertisoils (S40). Zone 4 which consists of relatively recent bush fields, most of which are located far away in other village territories, is mostly covered by upland sandy soils (S20) and lowland clayey vertisols (S40). The major physical and chemical characteristics of the local soils are shown in Tables 4 and 5 below.

4.3. The Soil and Crop Management System.

4.3.1. System identification.

The cropping system in the Manga area is a ring cultivation system. Three major soil-crop management rings can be identified around each household compound in Nonghin on the basis of the following variables.

1. Type of crop sequences or rotations
2. Intercropping system (yes or no)
3. Fertilizer application (yes or no)
4. Use of fallow to regenerate soil fertility (yes or no)

Field history data were used to obtain the values of such variables for each field.

The bulk of fields with identical vectors of the soil crop management variables listed above are found within a certain distance range or ring around each household compound. The three major soil crop management rings that have been so identified in Nonghin may be illustrated as shown in Figure 6 below.

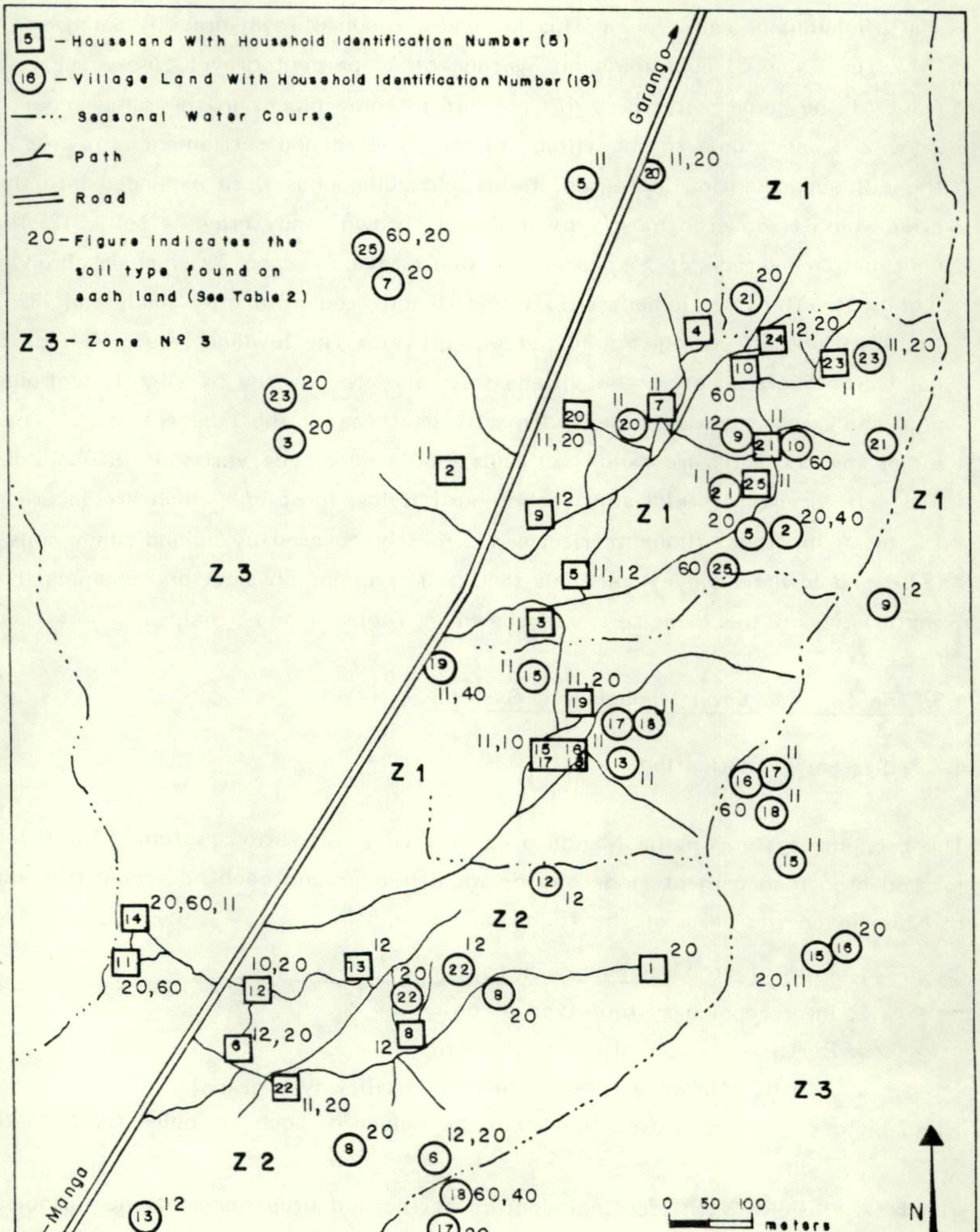


Figure 5. Locations and Soil Types of the Sample Houselands and Village Lands inside the Nonghin Village Territory (Manga).

Table 4. Particle and Chemical Characteristics of Local Soils Under Fallow (Manga-Nonghin).

	S10 Zingadega	S11 Kougri	S12 Kuigdiga	S20 Binsiri	S60 Bollé	S40 Naka
Number of sampled fallows	1	1	2	2	1	1
Sampling depth, cm	20	20	20	20	20	20
Refuses > 2 mm, %	50	43	35	14	14	14
Analysed Fraction (< 2000u)						
Sand (2000 - 50 u) %	66	70	71	70	64	24
Silt (2 - 50 u) %	22	19	18	23	30	35
Clay (2u) %	12	11	11	7	6	41
Organic matter, %	1.15	.67	1.21	.59	1.62	1.67
Total carbon, C %	.67	.39	.70	.34	.94	.97
Total Nitrogen	.052	.033	.037	.031	.042	.074
C/N	12.9	11.8	18.9	11.0	22.4	13.1
Available phosphorus ppm. P	3.34	2.33	1.80	3.4	1.4	.83
Calcium (Ca++) me/100g	2.51	1.58	2.57	1.92	1.40	16.35
Magnesium (Mg++) "	.40	.48	.85	0.42	.32	9.30
Potassium (K+) "	.12	.09	.13	0.13	.17	.31
Sodium (Na+) "	.01	.02	.32	.05	.02	.14
Sum of Bases (S)	3.04	2.17	3.87	2.52	1.91	25.75
Cation Exchange capacity (T) me/100g	4.76	2.57	4.81	2.72	3.30	26.80
PH, H_2O	6.3	6.1	6.7	6.5	6.1	6.7
PH, KCL	5.5	5.4	5.2	5.4	5.1	5.3

Table 5. Moisture Holding Capacities, Useful Water and Permeabilities of the Major Local Soils[a].

	Local Soil Type							
	Binsiri S20		Kougri S11		Bolle S60		Naka S40	
	Upland				Lowland			
	Sampling Depth (cm)							
	5	40	5	25	5	35	5	40
Apparent Density	1.67	1.54	1.62	1.59	1.58	1.73	1.60	na
% Moisture PF 2.5	8.9	21.5	9.6	13.0	13.5	11.0	16.1	21.5
% Moisture PF 3.0	6.9	21.0	8.4	11.8	12.7	9.8	15.3	21.0
% Moisture PF 4.2	2.4	14.7	8.2	6.2	6.5	4.4	9.3	14.7
Useful Water PF 2.5 - 2.5	6.5	6.8	6.4	6.8	7.0	6.6	6.8	6.8
Useful Water PF 4.2 - PF 3.0	4.5	6.3	5.2	5.6	6.2	5.4	6.0	6.3
Permeability m/24 h	186 (220)	129 (140)	2,537 (1,890)	591 (305)	169 (175)	0 (0)	26 (37)	126 (140)

(a) Three samples in metalic rings or clods were taken at each sampling site. Figures shown in this table are the average for all three samples. Except in the case of permeability, standard deviations between the three soil samples are very small and less than .5 in the case of permeability standard deviations are shown in parentheses. All parameters were measured in the laboratory.

The fields in ring 1 are the closest fields to each household compound. The fields in ring 3 are the farthest fields from the household compound and the fields in ring 2 are the intermediate fields.

In contrast with the usual denominations of housefields, village fields and bush fields, it is important to notice that such distinctions are made with respect to the entire village compound, whereas the distinction between the three soil-crop management rings described here is made with respect to each individual household compound.

Although most first ring fields are housefields, a first ring field is not necessarily a housefield, it could be a village field. Similarly a third ring field is not necessarily a bush field, it could be a village field as shown in Figure 7 below, and a second ring field could be a bush field.

4.3.2. The First Ring.

The fileds in ring 1 are used either for continuous planting of maize and sauce plants relayed by tobacco (subring 1A) and/or for rotation of maize/sauce plants and pure red sorghum (subring 1B). These fields are also characterised by almost yearly application of heavy doses of organic fertilizer (on average 9 metric tons per hectare) and by permanent soil-water conservation devices such as rock bunds or earth bunds inside and around the fields to collect water and to reduce erosion by runoff (on 94% of fields). Since the first ring fields are the closest fields to the household compound, most fo them are housefields with an average size around .05 hectares and an average intensity of land use near 100.

4.3.3. The Second Ring.

Most of the second ring fields are characterised by a continuous cultivation of red sorghum intercropped with cowpea (subring 2A) accompanied by moderate applications of organic manure (1.3 tons/ha) and of mineral fertilizers (25 kg/ha on 45% of cultivate area per year), but with almost no soil and water conservation devices.

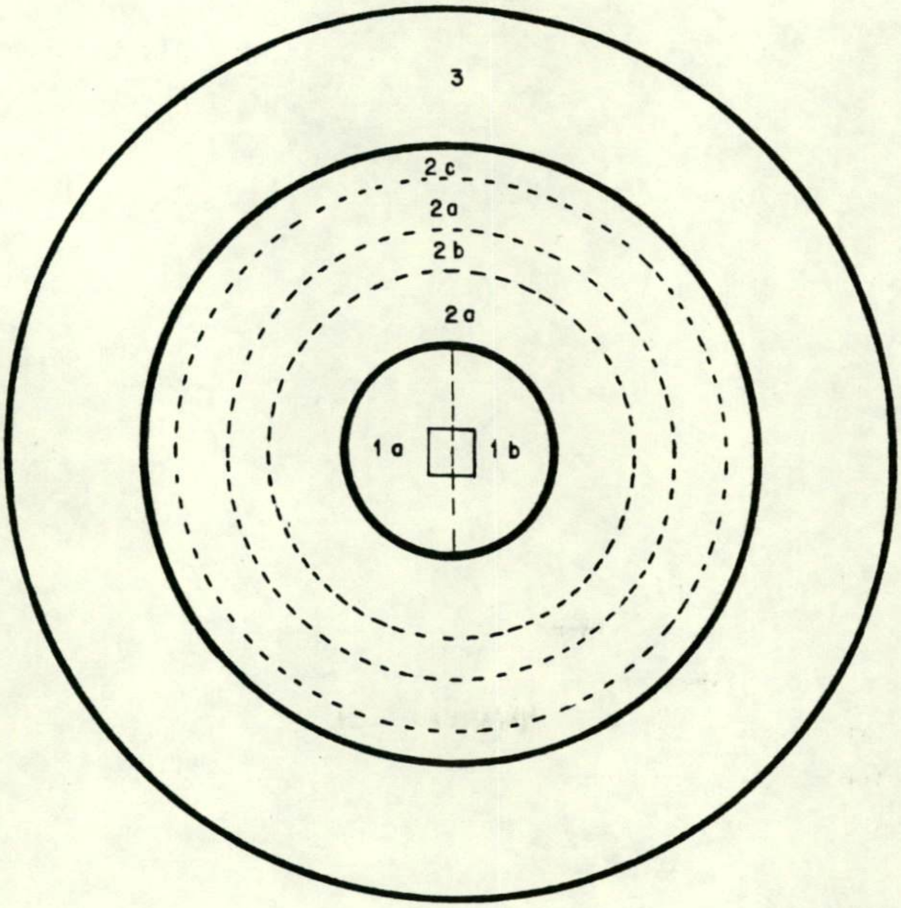


Figure 6. The Soil and Crop Management Rings of the Mossi Farming System in the Sudanian Zone (Manga-Nonghin).

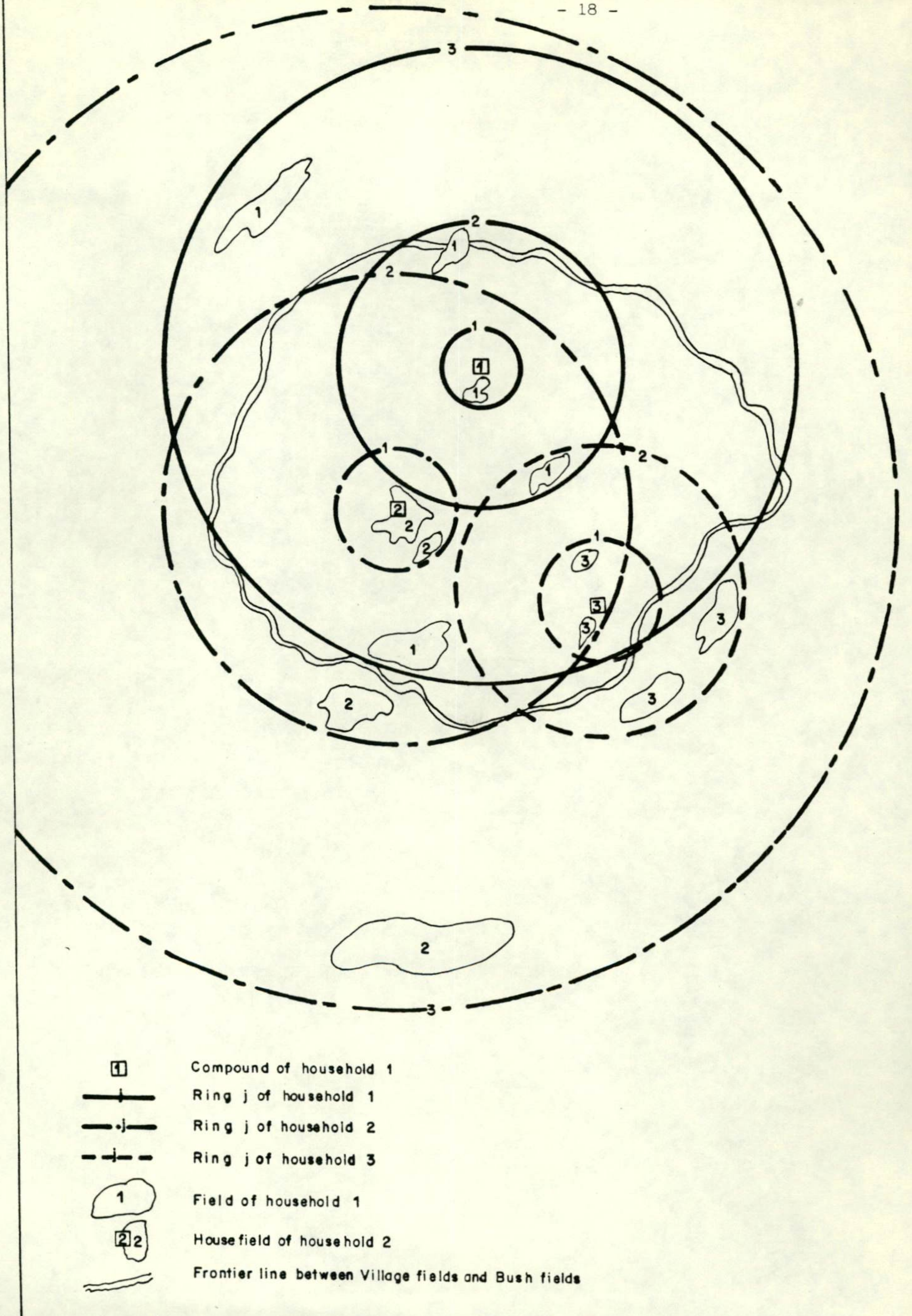


Figure 7. Relationships between Management Rings House Fields, Village Fields and Bush Fields.

The large red sorghum/cowpea fields which are located sufficiently far away from the compound walls so as to minimize crop damages by animals raised in the compound (chickens, goats, sheep) and which are also located on sandy soils are also periodically planted with groundnuts on small or large portions of their areas. These fields constitute the subring 2B fields. 40% of these fields had in 1981 some form of soil water management devices (bunds and mulch) probably because of the sandier nature of the soils in the subring or in order to conserve the soils loose and deep enough for groundnut planting.

The red sorghum fields which are the farthest from the compound walls are not generally pure red sorghum and cowpea fields, they are generally planted with red sorghum intercropped with millet and cowpea, with sometimes more millet than red sorghum. These are the subring 2C fields. The red sorghum and the millet planted in these fields are periodically replaced partly or entirely with groundnuts, earth-peas and tuber roots. Subring 2C is in fact an intermediary stage between the typical ring 2 fields and the ring 3 fields.

Most of ring 2 fields are village fields with an average size around .30 hectares in subring 2A, .50 hectare in subring 2B and .40 hectare in subring 2C. Thus the size of a typical second ring field is around .40 hectare with an average intensity of land use over 80 during the past fifty years.

4.3.4. The Third Ring.

The third ring fields are characterised with an extensive cultivation of millet intercropped with white sorghum and cowpea. Small portions of these fields are periodically planted with groundnuts and earthpeas. Soil fertility is regenerated with fallow, which average length has considerably shortened during the past two decades from twenty to three years, and with chemical fertilizers (on average 20 kg/ha on 26% of the cultivated area per year). 12% of the fields had some form of soil water conservation device (bunds and mulch) in 1981. Most of the third ring fields are bush fields with an average size around .90 hectare and an average intensity of land use about 30 during the past fifty years.

More detailed technical and economic characteristics of the soil crop management rings are presented in Table 6.

Table 6. Major Characteristics of the Soil and Crop Management Rings at Nonghin (Manga) in the Sudanian Zone.

Field characteristics	Ring 1	Ring 2A	2B	2C	Ring 3
1. Number of sample fields	43	42	15	24	61
2. Average distance of the fields from the compound (meters)	25	227	140	456	3024
3. Ring area as a percentage of total cultivated area	2.7	16.4	9.1	10.4	61.4
4. Average field size (hectare)	.052	.30	.51	.42	.89
5. Crop-Mix					
Percentage of cultivated ring area planted in 1981 with					
- Maize/sauce plants	93	-	-	-	-
- Red Sorghum/Cowpea	7	100	92	54	-
- Red Sorghum/Millet/Cowpea	-	-	-	23	-
- Millet/White Sorghum/Cowpea	-	-	-	20	75
- White Sorghum/Millet/Cowpea	-	-	-	-	21
Groundnuts	-	-	8	3	2
Bambara nuts	-	-	-	0	2
All crops	100	100	100	100	100
6. Soil Preparation					
(plowing or scarification) Percentage of field prepared with:					
- Hand tool	65	2	4	4	6
- Animal Traction	20	78*	78*	78*	70*
- Hand Tool and Animal Traction	15	2	2	2	0
	100	82	84	84	76
7. Percentage of ring area that has been fertilized with farmyard manure in 1981 (%)	85	62	60	16	0
8. Average amount of farmyard manure applied in fertilized fields in 1981 (kg/ha)	10,500	1,550	2,200	1,250	0
9. Mean frequency of organic manure application (years of application in all fields during pastsix years)	5.0	3.6	2.4	1.0	0
10. Percentage of ring area that has been fertilized with mineral fertilizer in 1981 (%)	17	45	25	61	26
11. Average amount of mineral fertilizer applied in fertilized fields per hectare (kg/ha)	48	26	16	17	19

* Mostly Scarification.

	Ring 1	2A	2B	2C	Ring 3
12. Average years of application of mineral fertilizer in all fields during past six years.	0.6	1.4	2.6	1.1	0.8
13. Percentage of fields that received both org. and min. fertilizer in 1981 (%)	17	45	25	16	0
14. Percentage of fields fallowed during the past 50 years	35	24	64	56	81
15. Average number of years since the last fallow occured	14	18	14	8	6
16. Average lenght of the last fallow period in years	3	6	13	13	20
17. Adjusted average intensity of land use $\overline{R}$ ***	96	94	80	60	30
18. Planting density of cowpea intercrop per hectare	22	1.065	1.572	4.534	3.887
19. Frequency of cowpea intercropping per field in a six year period	1.0	5.4	5.0	4.0	4.0
20. Total planting density per ha (poquets)	28,407	34,644	37,644	40,256	44,925
21. Total number of plant stems per ha.	42,264	59,196	44,096	57,592	56,242
22. Percentage of fields planted with groundnuts at least once from 1976 to 1981	0	0	100	56	37
23. Average relative time frequency of groundnut planting in above fields (e.g ½ = every other year)	-	-	1/5	1/5	1/2
24. Average size of groundnut field (ha)	-	-	.4500	.4053	.1337
25. Percentage of fields with soil water conservation devices	94	3	40	7	12
Types of devices*	(2;4)	(4)	(4;5)	(5)	(4;5)
26. Distribution of local soil types across each ring, % area					
Upland gravelly soils (Zingadega)	9	9	4	2	1
Upland gravelly-sandy soil (Kougri)	17	30	13	5	21
Upland sandy gravelly soil (Kuigdiga)	20	19	15	17	22
Upland sandy soil (Binsiga)	17	27	62	60	34
Lowland clayey vertisoil (Naka)	6	5	0	12	34
Lowland silty clayey soil (Zi Bolle)	31	10	6	4	8
	100%	100%	100%	100%	100%
27. Average production labor hours per hectare (excludes harvest labor)					
- Hand tool labor	526	405	277	372	288
- Animal Traction Labor	74	186	213	150	117
Total (hours/ha)	600	591	490	522	405
Traction animals working hours per hectare for soil preparation weeding and late ridging	32	83	93	62	47

* Soil and water conservation devices: (2) = earth dykes, (4) = stone dykes; (5) = mulch.

Field Characteristics	Ring 1	2A	2B	2C	Ring 3
28. Yields per Crop (kg/ha), grain					
Maize (ring 1A)	1,382	-	-	-	-
Maize (ring 1B)	2,215	-	-	-	-
Red sorghum	3,479	1,521	1,316	1,281	-
+ cowpea		+30	+35	+31	
Millet and white sorghum	-	-	-	380	350
+ cowpea				33	34
Groundnuts	-	-	317	290	472
Earth Peas (Bambara nuts)	-	-	-	-	543
29. Value of grain output per hectare (CFA francs)**	200,617	61,800	53,400	46,580	24,000
30. Amount of airdried crop residues at harvest (airdried for twenty days) in kilograms per hectare	2,500	7,200	6,500	5,700	4,600
31. Air dried cowpea residues (kg/ha)	-	53	79	227	195
32. Amount of airdried crop residues remaining in fields 150 days after harvest (kg hectare)	50	120	120	120	120
33. Amount of airdried cattle and donkey droppings at the end of the dry season (kg per hectare)	100	200	200	270	300

* All averages per hactare are computed directly by agregating fields in each ring, they are thus adjusted for field size.

** Prices used are post harvest average December 1981 grain prices: These are in CFA francs per kilogram millet: 58.8 f/kg, white sorghum: 56.7 f/kg, red sorghum: 38.9 f/kg, maize: 108 f/kg, groundnuts: 135.1 f/kg, cowpea: 87.5 f/kg, earthpeas: 64.5 f/kg.

*** $\bar{R} = \sum a_i f_i$; $f_i = C_i / T_i$; $a_i = A_i / \sum A_i$

$T_i = C_i + F_i$, with i = field number, C= years of cultivation, F = years of fallow, A_i = area of field i, $\sum A_i$ = total ring area.

CHAPTER 5.

THE MOSSI FARMING SYSTEM OF KOLBILA (YAKO) IN THE SUDANO-SAHELIAN ZONE.

5.1. The Average Farm Resource Base.

On average, each household head had about 10 cultivated common fields under his management in 1981. Such fields were scattered over two to eight lands (terrains) on different soil types. The average household had its cultivated common fields scattered over approximately four lands. About half of the household heads had at least one additional land under fallow. When all individual fields are taken into account the average number of cultivated lands per household was more than five and the average number of fields per household was about 33. The average household controlled about 17 hectares of land, approximately 30% of which was cultivated in 1981. The remaining area consisted mostly of arable fallows.

One third of the households had few or no land area under fallow, while some households, among the remaining two thirds, were controlling over twenty hectares of fallowed land each. The total area cultivated as common fields in 1981 was about 3.82 hectares in the average household. When all individual fields are added, the total area cultivated per household ranged from 3 to 20 hectares and was on average 5.65 hectares. (5.6 ha on hand tool farms and 5.8 ha on animal traction farms).

As shown in Table 3, only 5% of the households in the village owned animal traction implements. 95% were hand tool farmers. The average size of the sampled household was around 13 residents, 55% of which were active people of age between 15 and 60 years. There was no significant difference between the sizes of hand tool households and animal traction households. The cultivated area per resident was .44 ha for the sample .41 ha on the hand tool farm and .50 ha on the few animal traction farms.

About 30% of the farmers in the sample owned cattle, in general two to seven heads per household (3 on average). One farmer exceptionnally had about 30 heads. The cattle is not kept on the farm, it is in most cases entrusted to Fulani herdsmen who may spend part of the dry season padocking their herds on the fields of farmers who own substantial parts of the cattle. Farmers who only own some few heads, like the majority of the farmers in Kolbila do not in general get a chance to benefit from such a practice.

With the exception of one household, all the sample households were raising sheep and goats. The size of the flock ranged between 8 and 90 heads with an average around 28 heads raised on the farm. Every household was raising poultry with the size of the flock ranging between 7 and 140, with an average around 60.

5.2. The Local Soil Types.

Three major and two minor upland soils are found in the village. As in the Manga village, such soils are dominant in specific areas of the village as shown in Figures 8 and 9 below.

The village is located in between ferruginous rocky hills.

- The most dominant soil type is a brown rocky and gravelly shallow ferrugenous soil known as "Zingadega". It is found mostly on slopes within the local topography and is the dominant soil type in the western part of the village.

- The second major soil is a deep redish silty lateritic soil with many termite houses. It is known as "Zimuougou" and is found downslope near lowlands in the eastern part of the village.

- The third major soil type is a deep grey sandy soil known as "Binsiga" or "Binsiri" found on flat lands in between the two major upland soils and toward the south of the village.

The two minor upland soils are known as "Tampouré" and "Rassempouiga".

- "Tampoure" is a gravelly ferrugineous soil ("Zingadega") that has been manured for many years with household refuses. It is characteristic of houselands in the ancient central quarter of the village toward the west central part of the village.

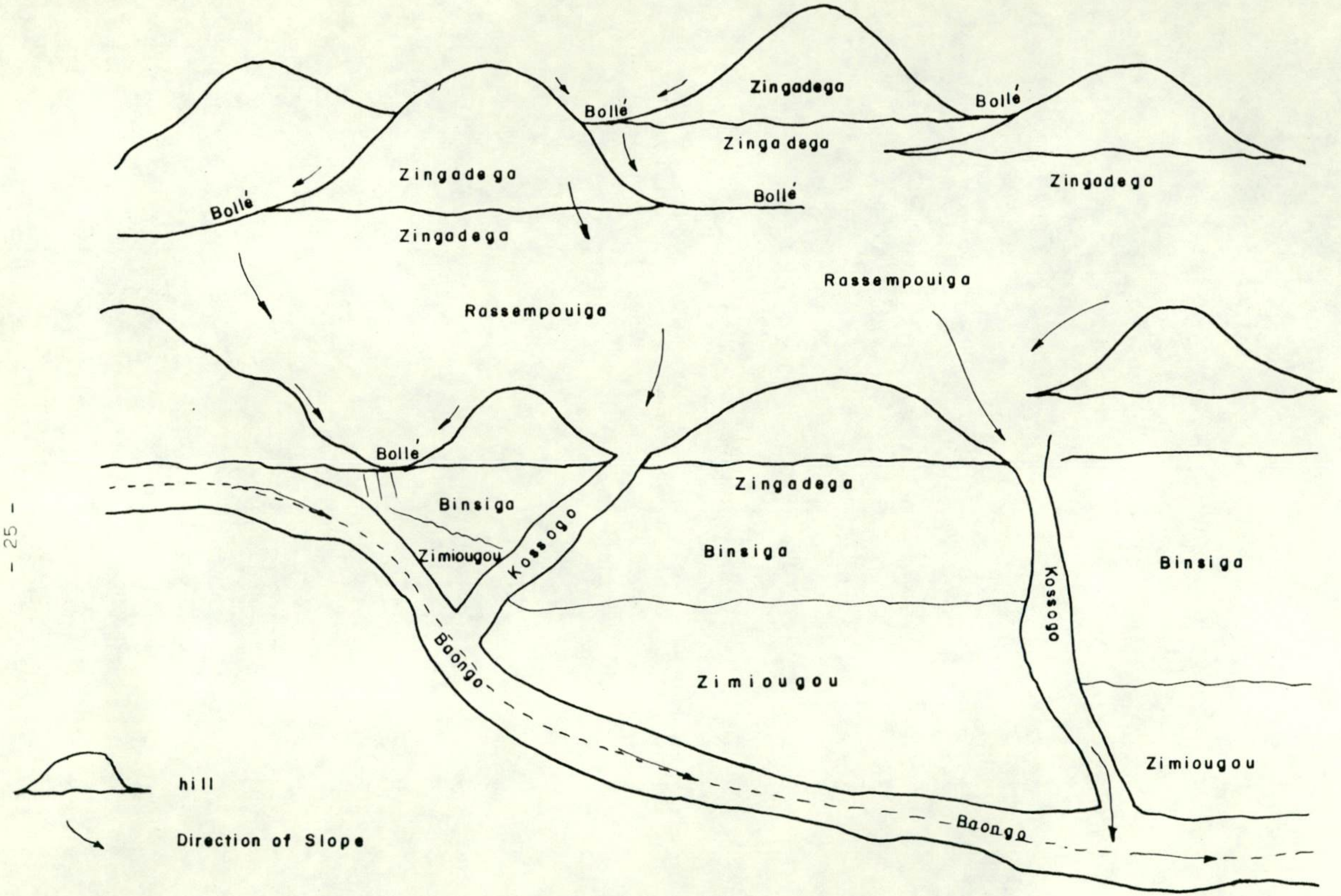
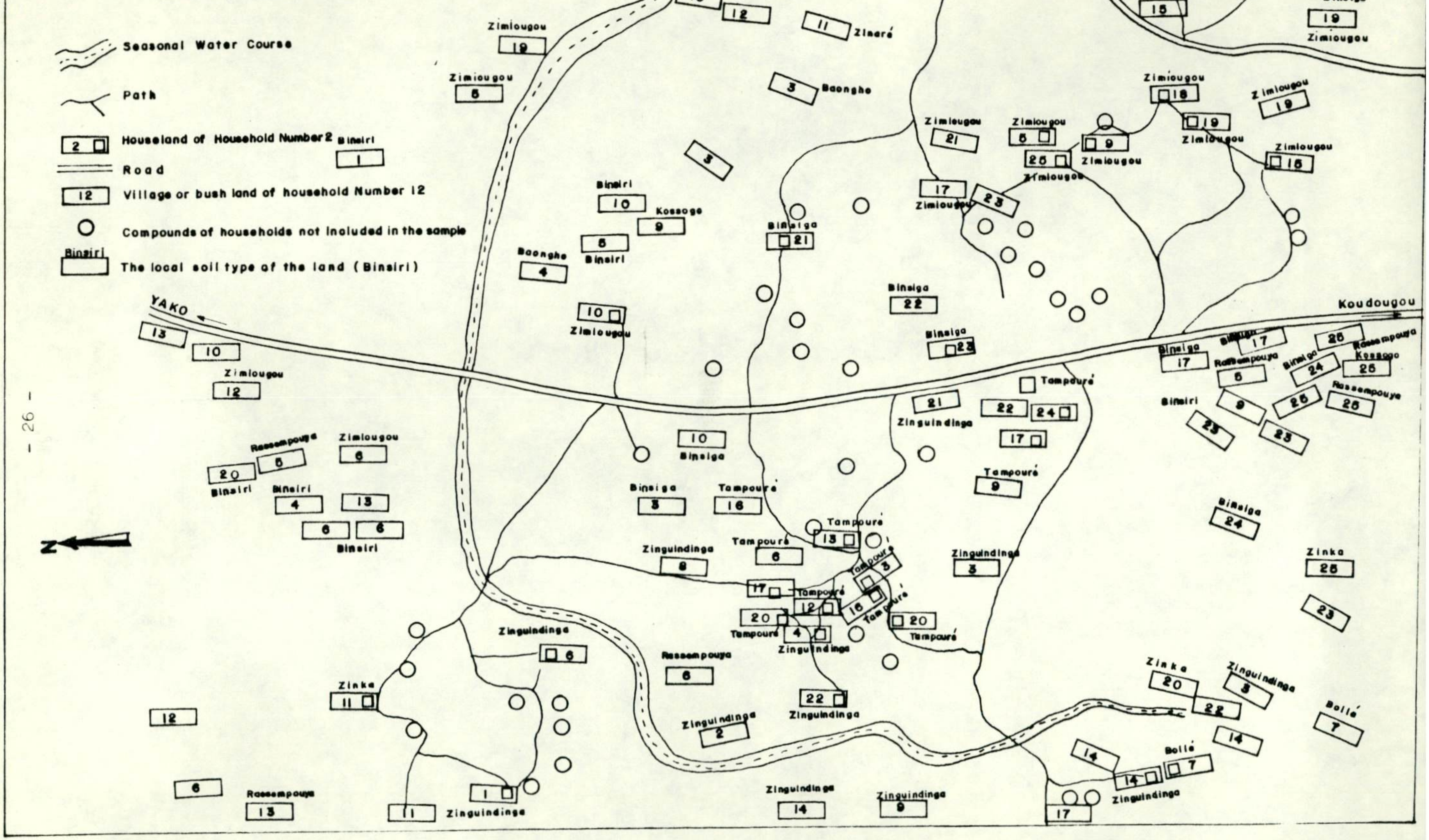


Figure 8. Local Topography and Soils at Kolbila (Yako).

Figure 9. Locations and Soils Types of Sample Fields Inside the Kolbila Village Territory (Yako).



- "Rassempouiga" is a name that applies to leached ferrugineous soils where only grass but no tree grows. It could be sandy (Rassempoui-Binsiga) it could be gravelly (Rassempoui-Zingadega) or clayey (Rassempoui-Boalga). The soil is generally grey-white and is known as a water passage or valley in between rocky and gravelly hills and slopes. As such it is subject to heavy runoffs and is regarded by farmers as the most unfertile soil.

Three main lowland soils are recognized by the farmers. They are named respectively "Kossogho" "Bolle" and "Baongo". "Kossogho" is a "water way" over which rainwater flows from uplands to lowlands to join the seasonal water courses. The grey sandy soils of such water ways are called "Kossogho".

"Bolle" and "Baongo" are typical lowland soils. "Bolle" is known as a grey soil which is compact and slightly cracked on surface when dessicated during the dry season, slippery and sticks to tools during the rainy season. It is a clayey-silty soil found at the bottom of sedimentary depressions or cuvettes in between the hills and near the seasonal water courses across the village.

"Baongo" is the name of the clayey soil which is the bed of the seasonal water courses or rivers in the village.

Figure 8 shows roughly the position of local soils in the village topography. The results of the analyses of the different soil types under fallow are shown in Tables 7 and 8 below.

5.3. The Soil and Crop Management System.

As in the Manga area the soil and crop management system in the area is also a ring cultivation system as in most Mossi farming systems. However the system is more diversified in the Yako area than it is in the Manga area. On the basis of the five soil crop management variables listed in chapter 4 one may distinguish in the studied village (Kolbila) three major soil-crop management rings around each individual household compound. Each ring may be further subdivided into two subrings. The soil crop management rings and subrings (sets of fields with more or less identical vectors of the soil-crop management variables) that have been identified in Kolbila (Yako) are as shown in Figure 10 below.

Table 7. Particle and Chemical Characteristics of Local Soils under Fallow (Yako-Kolbila)

Local soil type / Characteristic	Zingadega	Zimuougou	Binsiga	Tampoure (cultivated)	Rassempouiga Z	Rassempouiga B	Kossogo	Bolle
Number of sampled fallows	4	3	1	3	1	1	1	1
sampling depht, cm	0-20	0-20	0-20	0-20	0-20	0-20	0-20	0-20
Refuses >2 mm%	48.0	1.4	11.2	26.5	29.5	5.1	2.9	15.0
Coarse sand(250-250u)%	21.0	8.1	15.4	18.1	11.3	16.6	34.4	7.3
Fine sand (50-250u)%	19.5	26.8	29.1	32.3	21.7	26.8	18.7	15.6
Silt (2-50u)%	38.5	43.0	35.3	35.0	45.4	39.7	27.0	35.0
Clay (2u)%	21.0	22.0	20.2	14.5	21.6	16.9	19.9	42.1
Organic matter,%	3.40	1.12	1.29	3.13	2.24	1.12	0.97	1.45
Total Carbon, C %	1.98	.65	.75	1.82	1.30	0.65	0.56	0.84
Total nitrogen, N %	.133	.050	.051	.124	.082	.058	.041	0.057
C/N ratio	14.9	13.0	14.7	14.7	15.8	11.2	13.6	14.7
Available phosphorus ppm P	2.25	.97	1.00	66.60	0.60	1.40	0.70	0.30
Calcium (ca++) me/100g	4.22	5.12	2.62	4.29	3.44	2.34	2.99	16.28
Magnesium (Mg++) "	2.38	2.18	2.00	1.41	0.68	2.05	1.51	9.05
Potassium (K+) "	0.15	0.27	0.15	0.14	0.09	0.07	0.17	0.18
Sodium (Na+) "	0.0	0.02	0.01	0.10	0.01	0.01	0.00	0.02
Sum of Bases (S)	6.75	7.59	4.78	5.94	4.22	4.46	4.67	25.53
Cation Exchange capacity (T)	7.25	7.00	5.01	4.78	5.18	5.63	4.17	26.70
PH, H_2O	6.42	6.47	5.9	7.6	5.7	5.6	6.2	6.5
PH, KCL	5.48	5.20	4.6	6.7	4.4	4.2	5.0	5.1

All fallows were at least seven years old, the vegetation was grass only on Rassempouiga and Bolle, it was grass + trees on other soil types.

Table 8. Selected Physical Characteristics of Local Soils (Yako-Kolbila).

Local Soil Type	Zingadega	Zimuougou		Rassemp-Binsiga		Kossogo		Bolle		Rassemp-Boalga
Sampling depht (cm)	5	5	40	5	30	5	25	5	60	5
Apparent Density	1.59	1.45	1.46	1.50	1.46	1.36	n.a	1.59	1.54	1.62
% Moisture PF 2.5	13.81	16.33	19.49	9.44	10.06	20.82	22.79	12.52	22.60	12.15
% Moisture PF 3.0	11.61	13.12	17.67	7.29	7.76	17.35	20.12	11.17	21.58	10.30
% Moisture PF 4.2	7.48	7.97	11.35	4.01	4.26	11.40	11.77	7.89	18.74	6.17
Useful Water PF 2.5 - PF 4.2	6.33	8.36	8.14	5.43	5.80	9.42	11.02	4.63	3.86	5.98
Permeability (K) m/24h	6450	14	707	25	225	0	0	583	1254	1471

All Figures are Average of three samples taken at each site and at each depht with metal rings.

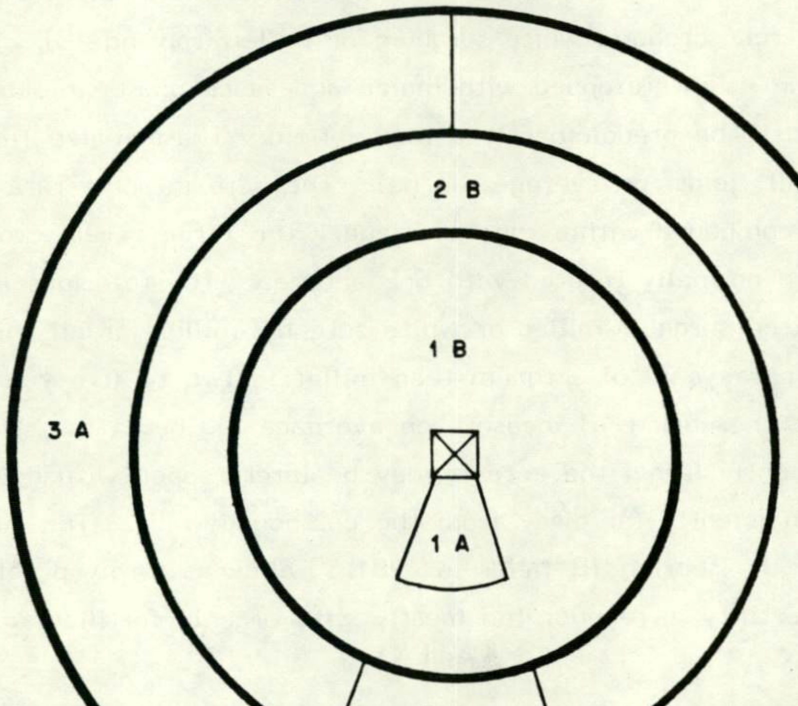


Figure 10. The Soil and Crop Management Rings of the Mossi Farming System in the Sudan-Sahel Zone (Yako-kolbila).

5.3.2. The First Ring.

On the first land around the compound or closest to the compound, each household generally has a small field permanently planted with maize and sauce plants relayed by tobacco (subring 1A) and one or two bigger fields planted with pure stands of either red sorghum, white sorghum or millet (subring 1B). In some few cases red sorghum is intercropped with maize and sauce plants in subring 1A on what is supposed to be predominantly a maize field. These maize fields are generally very small fields (on average .03 ha). They are in some rare cases mobile around the compound within the first land. The three cereal crops planted in subring 1B are normally rotated with one another. The rotations involves either two crops (red sorghum-millet or white sorghum-millet) or all three crops with relatively more years of sorghum than millet in two to five year cycles. The cereal fields in subring 1B measure on avereage .30 hectares. When such fields are sufficiently large, the cereals may be intercropped with cowpea in the area that are sufficiently far away from the compound walls. This has been the case for 20% of the subring 1B fields in 1981. Fallow is rarely practised in the first ring, soil fertility is regenerated mostly with organic fertilizers.

The first ring fields receive the heaviest doses of farmyard manure applied on the farm. All the fields in ring 1 receive some amount of farmyard manure every year. The average applications were about 8 metric tons per hectare in subring 1A in 1981, and about 2 metric tons per hectare in subring 1B in more than 80 per cent of the fields in 1981. Twenty per cent of the maize fields of subring 1A were fertilized with mineral fertilizer in 1981 in addition to 5 to 10 tons of farmyard manure per hectare. Such fields received an average 145 kilogrammes of cotton fertilizer per hectare in 1981. Mineral fertilizers are practically not applied in subring 1B in the mostly pure cereal fields. Soil Water conservation devices are practically absent form most fields in the first ring. All maize fields (in subring 1A) are ploughed before planting. The average intensity of land use in the ring was about 100 during the past forty years.

5.3.3. The Second Ring.

Many farmers in the village have a second maize field where maize, tuber and roots such as sweet potatoes and yams are planted side by side on neighbouring fields and/or are rotated with one another. These maize and tuber root fields are the subring 2A fields. They are generally locally located on the second or third land close to the compound on deep soils such as Binsiga, Rassempouiga and Zimuougou. Small portions of such fields are often left to fallow or are planted with groundnut or cotton. These fields are generally bigger than the maize fields of subring 1A. Their average size is about .06 hectares, such fields are constantly fertilized with farm yard manures. The average application in 1981 was eight (8) tons of farmyard manure per hectare. Thirty percent of the fields in the ring also received some mineral fertilizer in 1981. The average application was about 160 kg per hectare.

No soil water conservation devices were observed in the subring 2A fields.

The average intensity of land use in subring 2A was about 50 during the past fourty years.

Subring 2B includes fields where soil fertility is regenerated primarily with both farmyard manure and mineral fertilizers outside the first land. These fields are either white sorghum fields or millet fields intercropped with cowpea or planted in pure stands. Some few pure rice fields and red sorghum fields are also found within the subring. Most of the fields in the subring have been taken out of fallow less than ten years ago and have since been subjected to a rotation between white sorghum/cowpea (for 1 to 5 years) and millet/cowpea (for 1 to 3 years). Parts of the fields are also occasionally planted with groundnut.

Few farmers are planning to leave such fields to fallow in the future. These are fields that are conveniently close to the household compound and which farmers are trying to transform into permanent cereal fields (such as fields in subring 1B) by upgrading their fertility level. Many of them are located on relatively poor soils (Rassempouiga).

The fields in subring 2B measure on average .80 hectares; in 1981, 20 per cent of the subring area was fertilized with both farmyard manure (1.5 ton/ha) and mineral fertilizer (75 kg/ha), 30 per cent were fertilized with farmyard manure alone (800 kg/ha), 40 per cent were fertilized with mineral fertilizer alone (75 kg/ha). In general only small fields are entirely fertilized almost every year, for large fields a small portion is fertilized in one year followed by another portion the next year etc. Farmyard manure and mineral fertilizer are applied either simultaneously or alternatively from one year to the other.

- Soil water conservation devices such as mulch, rock bounds, dykes and ditches were found in 30 per cent of the subring 2B fields.

The average intensity of land use in the subring was about 50 during the past four decades.

5.3.4. The Third Ring.

The third ring includes fields where soil fertility is regenerated with fallow and mineral fertilizer. There are two types of fields in the third ring.

The first type of fields are those which have been taken out of fallow recently or some few years ago and where farmers are attempting to maintain or improve soil fertility by applying mineral fertilizer. This is either because the soil fertility after fallow is not sufficient to enable the farmer to achieve his production objective or because he intends to permanently cultivate the land in the future. These are the subring 3A fields shown in Figure 10.

The second type are fields which have never been fertilized with mineral fertilizers and where thus fallow has always been the only means for regenerating soil fertility. These are the subring 3B fields (Figure 10).

In general, most of the fields in the third ring are subjected to a rotation between white sorghum/cowpea (1 to 5 years) and millet/cowpea (1 to 3 years). Cowpea intercrop is absent from many of the third ring fields which are village fields generally not farther than 1.5 km from the compound). Red sorghum sometimes enters the rotation in such fields. In subring 3B some of the fields which are relatively new bush fields are planted only with white sorghum/cowpea for three to four years and are left fallow for three to seven years.

Among the third ring fields which periodically receive mineral fertilizers, that is in subring 3A, 40% of the fields were fertilized in 1981 with 20 to 75 kg of mineral fertilizer (cotton complex) per hectare. The average application was about 30 kg per hectare.

Soil water conservation devices, mainly earthern dykes, rock bounds and mulching were observed in 50 per cent of subring 3A fields and in 30 per cent of subring 3B fields.

The average intensity of land use in the third ring was about 50 in subring 3A and about 30 in subring 3B during the past two decades.

More detailed characteristics of the management rings are shown in Table 9.

Table 9. Major Characteristics of the Soil and Crop Management Rings at Kolbila (Yako) in the Sudano Sahelian Zone.

Field Characteristics	Ring 1		Ring 2		Ring 3	
	1A	1B	2A	2B	3A	3B
1. Number of sampled fields	18	35	21	18	27	48
2. Average distance of the fields from the household compound (meters)	18	55	1050	1050	1500	1400
3. Ring area as percentage of total cultivated area	0,8	13,3	1.5	18	36.5	30
4. Average field size (ha)	.035	.30	.057	.78	1.05	.49
5. Percentage of cultivated ring areas planted in 1981 with:						
- Maize/sauce plants	100	0	70	0	0	0
- Tuber roots	0	0	30	0	0.1	0
- Red sorghum	*	34.2	*	4	2	3
- Red sorghum + cowpea	0	0	0	0	0	0
- White sorghum	0	12.6	0	-	0	06
- White sorghum + cowpea	0	15.6	0	53	45	43
- Millet	0	33.1	0	26	0	0
- Millet + cowpea	0	3.5	0	14	47	41
Groundnuts and bambara nuts	0	0	0	1	2	6
Cotton	0	1.0	0	0	3.6	3
Rice	0	0	0	2	0	1
All crops	100	100	100	100	100	100
6. Soil preparation (plowing/scarification) Percentage of ring area prepared in 1981 with:						
- Hand tools (manual)	93	18	100	01	02	02
- Animal Traction (A.T)	07	25	0	14	06	03
- Hand tools and A.T.	0	02	0	05	0	0
All	100	45	100	20	08	05
7. Percentage of ring area that has been fertilized with farmyard manure in 1981 (%)	97	80	85	48	0	0
8. Average amount of farmyard manure applied in fertilized fields per hectare (kg/ha)	7500	1900	8320	1408	0	0
9. Frequency of farmyard manure application in all fields (years of application during the past six years).	5.9	4.8	3.5	2	1	0

* appears as an intercrop in some fields.

Table 9 (continued 1)

Field Characteristics	Ring 1		Ring 2		Ring 3	
	1A	1B	2A	2B	3A	3B
10. Percentage of ring area that has been fertilized with mineral fertilizer in 1981 (%)	20	16	35	61	65	0
11. Average amount of mineral fertilizer (cotton complex) applied in fertilized fields per hectare (kg/ha)	145	42	156	76	30	0
12. Frequency of mineral fertilizer application , years in six	0.5	0.5	0.6	2.2	2	0
13. % ring area that receive both	20	16	28	18	0	0
14. Percentage of fields fallowed during the past 25 years	30	33	100	90	100	100
15. Average number of years since the last fallow occured	40	40	06	13	10	5.5
16. Average lenght of the last fallow period (years)	12	15	10	14	10	13
17. Adjusted av. intensity of land use	100	100	50	50	50	30
18. Planting density of cowpea per hectare in intercropped fields (poquets/ha)	0	170	0	1540	1550	1735
19. Frequency (years) of cowpea intercropping per field with in a six year period for all fields	0	1.5	0	2.3	3.5	2.2
20. Total planting density of cereal per hectare (poquets)	28000	31600	35750	28500	31572	30000
21. Total number of cereal plant stems per hectare	62300	80135	80000	76000	86000	81540
22. Average planting density of tubers (poquets)	-	-	30000	-	-	-
23. Percentage of fields planted with groundnut at least once from 1976 to 1981	0	0	10	20	25	28
24. Frequency (years) of groundnut planting in above fields within a six year period	0	0	1	1.5	1.0	1.0
25. Average size of the groundnut fields (ha)	0	0	-	.15	.50	. 18
26. Average density in groundnut fields (poquets)	-	-	-	37000	60000	
27. Percentage of fields with soil and water conservation devices	30	70	0	30	50	30
main types*		(2),(1)		(1,2,4,5)	(4,5)	(2,4,5)

* Types of soil and water conservation devices: (1)=ditch , (2)= earthen dykes (4)= stone dykes, (5)= mulching.

Table 9 (continued 2)

Field Characteristics	Ring 1		Ring 2		Ring 3	
	1A	1B	2A	2B	3A	3B
28. Distribution of local soil types across each ring (% fields) % aera						
- Upland stony and gravelly soil (Zingadega)	30	58	24	04	38	48
- Upland sandy silty soil (Zimuougou)	16	22	12	24	06	0
- Upland sandy soils (Binsiga)	48	18	17	42	23	29
- Tampouré	6	02	0	-	0	0
- Rassempouiga	0	0	46	21	07	02
- Kossogho	0	0	0	05	12	07
- Bollé	0	0	0	04	0	04
- Baongho	0	0	0	0	0	12
29. Average manual production labor hours per hectare in hand tool fields	1500	1515	2865	1153	674	913
30. % ring area where A.T. was used for soil preparation and weeding	11	25	0	19	06	03
31. Manual labor hours/ha in A.T fields	645	1232	0	710	640	1490
32. Total A.T labor hours/ha in A.T fields	206	123	0	90	25	212
33. Animal working hours for soil preparation and weeding per/ha	66	55	0	41	10	91
YIELDS						
34. Average grain yields per type of field (kg/ha)						
Maize fields (maize)	1500	-	1900	-	-	-
Red sorghum fields						
Red sorghum	-	1605	-	-	770	-
Cowpea	-	-	-	-	4	-
White sorghum fields						
White sorghum	-	1230	-	726	767	675
Cowpea	-	14	-	16	20	54
Millet fields						
Millet	-	1002	-	832	304	476
Cowpea	-	6	-	12	15	15
Yams	-	-	7050	-	-	-
Sweet Potatoes	-	-	8000	-	-	-
Groundnuts	-	-	-	-	-	228
Rice	-	-	-	92	-	-
Cotton		420			80	265

Table 9 (end)

Field Characteristics	Ring 1		Ring 2		Ring 3	
	1A	1B	2A	2B	3A	3B
35. Average value of output per ha, CFA francs	82500	61100	301700	37500	25800	32800
36. Amount of air dried cereal residues at harvest (air dried for 20 days) in kg/ha	2830	5363	3385	4095	3320	3320
37. Air dried cowpea residues (kg/ha)	0	9	0	77	78	87
38. Air dried groundnut residues from groundnuts fields	0	0	0	555	900	0
39. Amount of air dried crop residues remaining in fields 150 days after harvest (kg/ha)	60	580	0	576	350	188
40. Amount of cattle and donkey dropping by the end of the dry season (kg/ha)	02	25	0	12	20	03

CHAPTER 6.

THE PEUHL RIMAIBE FARMING SYSTEM OF OURE (DJIBO) IN THE SAHEL.

6.1. The Average Farm Resource Base.

Each household cultivated one to four lands and had one to four other lands under fallow. The average household cultivated two lands and had about two other lands under fallow.

As stated previously in chapter 3 one distinguishes in the Djibo area two types of households: households living in the central village compound and households living on their farms outside the central village compound. The first (40% of the sample) are all hand tool farmers and do not raise cattle. The second include hand tool farmers as well as animal traction farmers, the majority of them (70%) raise cattle. Mossi migrants are found within the second group.

The average hand tool household cultivated in 1981 six fields over 5.0 hectares, 70% were managed by the household head. The average animal traction household cultivated in 1981 five fields over 10.8 hectares, 75% of which were managed by the household head. These cultivated areas represented respectively 40% and 30% of the total land controlled by the average Rimaibé hand tool and animal traction farms. The remaining consisted of arable land under fallow. Mossi migrants have no or very little land under fallow. In 1981 6.5 people were living in the average hand tool farm, 3.5 of whom were active members of age between 15 and 60 years. 16.7 people were living on the animal traction farm, 8.3 of whom were active members. Thus, the total area cultivated per capita and per active member were respectively .78 hectare and 1.5 hectare on the hand tool farm, .64 ha and 1.3 ha on the animal traction farm. However as suggested by Table 3, only 20% of the farmers in the area had animal traction implements the majority were hand tool farmers.

40% of the farmers were raising cattle on their farm, they were all living on their farm outside the central village compound. The amount of cattle raised per household varies between 2 and 54 animals with an average around 25 animals per household that raise cattle. Practically all the households raise poultry, goats and sheep. The amount of small ruminants raised per household varied between six (6) and 150, and was on average 32 animals per household.

6.2. The Local Soil Types.

Four local soil types are generally found in the area. They are by order of importance and according to their local denomination: Senon, Bolawo, Lomre and Houkawo. They are generally characteristic soils of specific positions within the local topography as shown in Figure 11 below.

- Houkawo is a reddish gravelly ferrugineous soil found on top of slopes within the local topography. It appears as a denudation of the B layer of the regional soil as a result of cultivation and wind erosion, it is found mostly around the central village compound where the soil has been intensively cultivated and manured. Maize is the main crop usually planted on such a soil.

- Senon is a deep grey-white and fine sandy soil that covers more than 80% of the region. It is the typical sahelian soil found on more or less flat uplands with small dune formations.

- Lomre is the typical lowland soil of the region. It is a dark grey sandy-silty soil that covers the banks and the beds of the seasonal water courses in the regions.

- Bolawo also referred to as Garawol is found on long slopes. It is also a sandy soil but appears darker and more compact than Senon. It is usually found near lowland areas.

The spatial distribution of the local soil types and of the sample fields within Oure village are shown in Figure 12 below. The physical and chemical characteristics of the local soils are shown in Table 10 and 11 below.

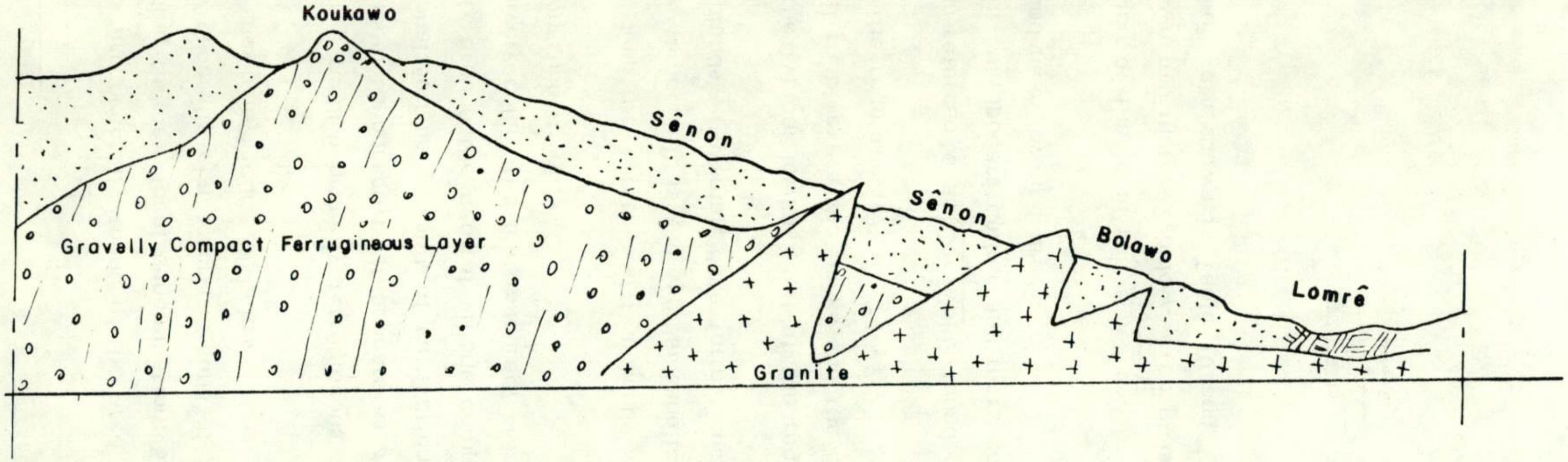


Figure II . Local Soils location on a toposequence at Ouré (Djibo).

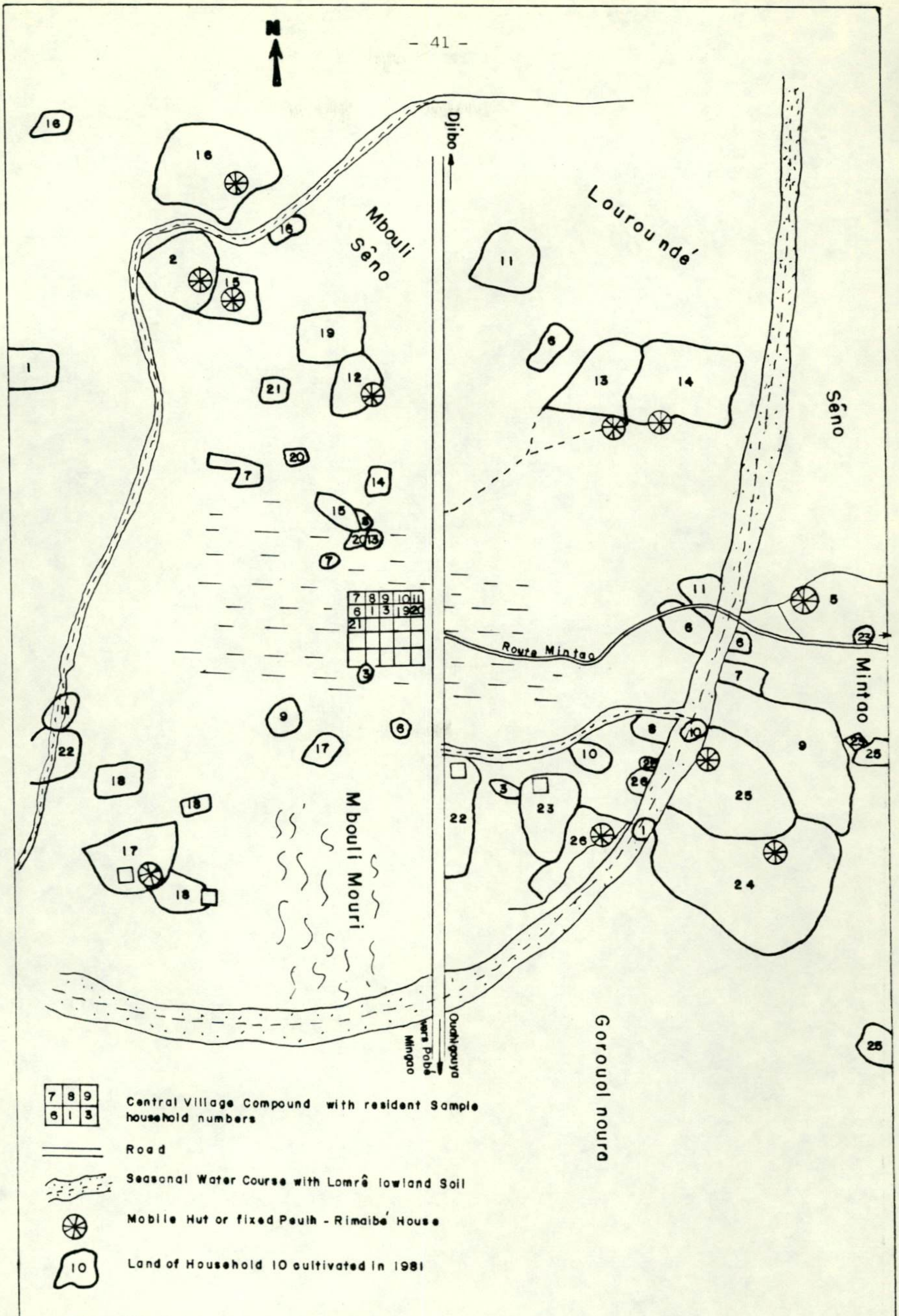


Figure 12. Locations and Soils Types of the Sample Fields Inside the Ouré Village Territory (Djibo).

Table 10. Particle and chemical characteristics of local soils under fallow *
(Djibo-Oure).

Local Soil Type / Characteristics	Houkawo*	Senon	Bolawo	Lomre
Number of sampled fallows	1	4	2	2
Sampling depth (cm)	0-20	0-20	0-20	0-20
Refuses (> 2mm) %	20	0.2	1.0	0.0
Coarse sand (250-2000u)%	28.1	17.9	19.6	9.1
Fine sand (56-250u)%	39.8	68.1	63.6	31.9
Silt (2-50u)%	20.6	8.5	9.8	32.5
Clay (< 2u)%	11.5	5.5	7.0	26.5
Organic matter %	2.19	0.36	.49	1.78
Total carbon, C %	1.27	0.21	.29	1.03
Total nitrogen, N %	0.111	0.018	.023	.071
C/N ratio	11.4	11.7	12.6	14.5
Available Phosphorus ppm	119.4	0.85	1.45	0.50
Calcium (Ca++) meg/100 g	26.66	1.06	1.85	5.87
Magnesium (Mg++) "	3.01	.44	.67	2.47
Potasium (K+) "	3.61	.12	.17	0.35
Sodium (Na+) "	0.11	0.0	0.0	0.0
Sum of Bases (S) me/100 g	33.39	1.62	2.69	8.69
Cation Exchanges Capacity	-	2.17	2.75	8.80
PH, H_2O	8.1	5.5	5.6	6.0
PH, HCL	7.8	4.1	4.3	4.8

* The Houkawo soilsample was taken on a cultivated maize field near the central village compound, there is no fallow with such soil. All other samples are taken from minimum seven year old shruby fallows.

Table 11. Selected Physical Characteristics of Local Soils at Oure (Djibo) in the Sahel.

Local Soil Type	Houkawo		Senon		Bolawo		Lomre	
Sampling depth (cm)	5	30	5	30	5	35	5	40
Apparent density	1.54	-	1.64	1.60	1.77	1.80	1.57	1.60
% Moisture PF 2.5	17.30	11.27	4.56	7.41	8.23	9.92	15.54	16.15
% Moisture PF 3.0	15.02	8.44	2.69	5.80	6.58	7.47	11.78	14.92
% Moisture PF 4.2.	7.33	4.54	.56	3.07	2.66	2.79	6.42	8.35
Useful water PF 2.5-PF 4.2.	10.0	6.73	4.00	4.34	5.57	7.13	9.12	7.80
Permeability m/24h	33226	-	556	513	177	0	0	415

* All figure are averages of data obtained from three samples taken with metalic rings from each site and at each depth.

6.3. The Soil and Crop Management System.

Soil fertility management in the Sahelian farming system of Ouré depends first on whether the household owns or does not own cattle, and secondly on whether the household lives inside or outside the central village compound. On the basis of these two factors and on the basis of the soil-crop management variables previously defined, one may distinguish in the sahel eight types of soil and crop management practices which are as follows and as described in Figure 13 below.

6.3.1. TYPE A. Soil fertility management practices of Peuhl-Rimaibe households who own cattle and live outside the central village compound.

Type 1A:

The whole household or some members of the household live in round shape huts that are continuously moved over the household's lands during the dry season or right before the begining of each new rainy season. This hut movement is carried out within a given land and or by moving from one land to another when the household has more than one land. The hut is stabilized at the begining of the new rainy season generally near the place where the cattle was parked during the previous rainy season, maize and sauce plants are planted in the old cattle park. Such fields measure on average .06 hectares, and are ploughed before planting either by hand or with oxen drawn plows. No specific soil conservation devices are usually observed in such fields.

Type 2A:

Each household usually attempts to improve soil fertility on part of the total uplands it controls with organic manure, so as to install on such lands the millet fields on which it can mostly rely for its food security. The three types of households have different ways of managing the fertility of such security millet fields.

The type A household usually manage soil fertility in such fields by shifting continuously their huts as well as the night parks of their small ruminants and

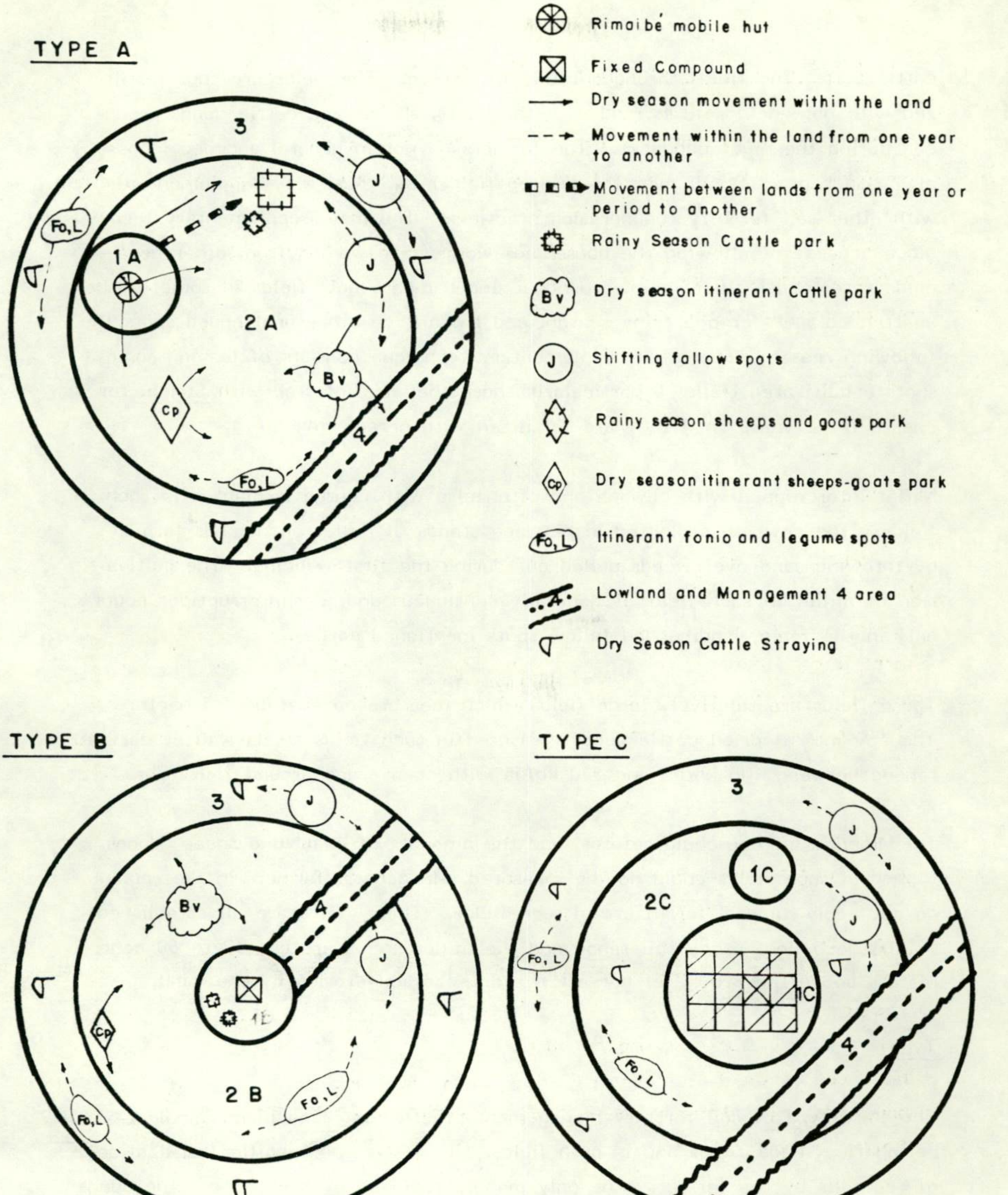


Figure 13. Soil and Crop Management Practices of the Peulh-Rimaibé Farming System in the Sahel (Djibo-Ouré)

cattle across the fields throughout the dry season. The fields are thus fertilized with household refuses, and with the goats, sheep and cattle dungs produced during the night paddocks. The farmers do not in general succeed in applying such practice all over the desired field area, thus, they supplement it with other soil fertility regeneration practices. The main supplementary technique consists of allowing the households women and women from other households to establish their fonio, groundnut and bambara nut fields in some of the unattended spots for one rainy season, and to shift to other unattended spots the following season. The other supplementary technique consists of leaving some spots uncultivated (fallow), particularly those that are infested with Striga, for one to three years until they are fertilized with organic manure.

Millet intercropped with cowpea and often also with courge is planted in such fields. The cowpea is planted in between stands of millet on mounds formed by throwing sand over weeds pulled out during the first weeding. The cultivation of millet in such fields is generally continuous and few interruptions occur only in the fonio, legume and fallow spots mentioned earlier.

These fields are relatively large fields which measure on average 4.3 hectares. The amounts of dried cattle dungs measured in such fields 50 days after harvest ranged between 100 kg/ha and 520 kg/ha with an average around 250 kg/ha.

The amounts of household refuses, and the amounts of goat and sheep dungs dropped in such fields could not be measured. In general farmers in the region do not apply mineral fertilizers in such fields. These fields are all established on the deep light sandy soil senon and the millet stems are cut 30 to 50 centimeters above the ground at harvest to minimize soil erosion by the wind.

Type 3:

The third type of soil fertility management practice is found in marginal or peripheric village fields and in bush fields. It involves no specific fertilization of the soils by the farmer. The only manure received by the soil are the dungs left by goats, sheep and cattle during their daily straiying across the fields. The amount of dried cattle droppings range between zero kg/ha and 200 kg/ha.

The heaviest amounts are found in fields near water points frequented by cattles. The fields are generally planted with millet often intercropped with cowpeas. The main soil improvement technique consists of shifting fonio, groundnuts and bambara nuts spots across the fields and by leaving large areas of the fields under fallow for a relatively long period of time (more than 3 years), or simply by leaving the whole field or land under fallow and by shifting to another land.

As in the type 2A case, cowpea is planted on mounds formed by throwing sand over pulled weeds during the first weeding and millet stems are also cut few centimeters above the ground to minimize wind erosion.

Type 4:

The fourth type of soil fertility management practice is specific of lowland fields on the Lomre and Bolawo soil types. These are fields which are generally continuously planted with sorghum (both red and white sorghum). The sorghum is either planted in pure stands (in 45% of cases) or intercropped with either cowpea or sesame (in 55% of cases) planted on flat land. In some rare cases monocropping of rice is also carried out in such lowland fields.

Farmers do not in general apply manure or mineral fertilizers in such fields because these would be washed away by the flowing water. Fertility is in general naturally replenished with alluvious manure and wastes carried and deposited in the fields by the flowing seasonal waters.

Such fields are either continuously cultivated or left to fallow for short periods of time (one to five years).

No soil conservation device is usually observed in such fields.

6.3.2. Type B: Soil fertility management practices of Peuhl-Rimaibe households who do not own cattle and live outside the central village compound, and of Mossi migrants.

Type 1B:

The type 1B soil fertility management practice is characteristic of the maize fields of the type B farmers mentionned above. Unlike the type 1A fields the type 1B maize fields are in general more or less stationary maize fields around the household compound which is in general fixed. The rainy season parks of the small ruminant are either moved within a very limited area around the compound walls from one season to another or kept fixed many years at a given place outside or inside the compound. The droppings are spread outside the rainy season parks within a limited area around the compound where maize is permanently cultivated along with some sauce plants. The Mossi migrants who own cattle in addition to small ruminants also keep a rainy season cattle park near the compound and use the cattle droppings in the same way as the droppings of small ruminants to fertilize the maize fields.

The size of such fields revolves around .07 hectares. The average amount of manure applied in such fields is about 13 tons per hectare. Like all maize fields such fields are ploughed before planting. No soil conservation devices are usually observed in such fields.

Type 2B:

These are the millet security fields of the type B farmers. These fields are generally adjacent to the maize fields around the compound on the land where the household has established its stationary dwelling.

Soil fertility is maintained in such fields through cattle and small ruminants night paddocking. The night parks of the small ruminants and of the cattle kept on the farm (in the case of Mossi migrants) are shifted periodically accross the fields during the dry season before being immobilized near the compound during the rainy season. Part of the manure accumulated during the rainy season inside the livestock parks is also spread over the millet security fields. Such fields are usually planted with millet and cowpea intercrops. The cowpea intercrops are, as in the previous cases, planted over mounds formed by throwing sand over dead weeds... Low fertility spots within the field are usually planted with fonio and leguminous crops (groundnuts and bambara nuts) for one year at a time or left fallow for one to three years in general. Millet and cowpea are planted in such spots afterward. Sauce plants such as okra and sorrel are also often intercropped with millet and with the leguminous crops in such fields.

The general practice that consists of cutting the millet stems few centimeters above the ground at harvest is also observed in these fields.

<u>Type 3 and Type 4:</u>

The type 3 and type 4 soil crop management practices described earlier are also used by the type B farmers.

6.3.3. <u>Type C:</u> Soil fertility management practices of Peuhl-Rimaibe households who live in the central village compound.

As specified earlier, the households living in the central village compound in general raise only small ruminants and do not raise cattle. The small ruminants are usually parked inside the central village compound.

<u>Type 1C:</u>

These are the maize fields of the type C households. Such fields are generally located around the central village compound on <u>Houkawo</u> soil type, some are located in lowland areas on <u>Lomre</u> soil type. Such fields, particularly those near the central village compound receive heavy doses of organic manure in the form of household refuse, goat and sheep dungs, and night soils. Sauce plants such as okra are often intercropped with the maize. Like most maize fields these fields are permanent fields and are ploughed before planting. No specific soil conservation devices are usually observed in such fields.

<u>Type 2C:</u>

The type 2C fields are the millet security fields of the households living in the central village compound. For each household such fields are generally the closest fields to the central compound following the maize fields. They are frequently manured with household refuse , goat sheep, and chicken dungs. Bella and Fulani herds transhuming through the village territory are often allowed to paddock in such fields.

Millet is planted in such fields either in pure stands or intercropped with cowpea. As in the previous cases, the cowpea intercrops, are planted on mounds formed by throwing sand over dead weeds. Fonio, groundnuts and bambara nuts are also planted in less fertile spots of such fields for one year at a time, and millet is replanted in such spots the following year.

These fields are generally located on the sandy soil, senon, and measure on average 1.8 hectares. At harvest the millet stems are cut few centimeters above the ground to limit wind erosion.

Type 3 and Type 4:

Like other household types, the type C households also cultivate type 3 and type 4 fields.

Table 12. Main Characteristics of the Soil-Crop Management System at Ouré in the Sahel.

	1A	1B	1C	2A	2B	2C	3	4
Number of sampled fields	11	11	12	8	13	13	63	9
1. Average distance of the field from the household compound (meters)	65	66	105	25	7	1000	800	1420
2. Ring area as percentage of total cultivated area	0.5	0.6	0.4	24.3	29.7	12.8	27.2	4.5
3. Average field size (ha):								
-cereals (maize,millet, sorghum)	.06	.07	.05	4.32	3.81	1.78	2.13	0.70
-fonio	-	-	-	-	.09	.20	.08	-
-legumes	-	-	-	-	-	-	.03	-
4. Percentage of cultivated ring area planted in 1981 with:								
-maize sauce plants	100	100	100	0	0	0	0	0
red sorghum		*	0	0	0	0	0	0
white sorghum	0	*	0	*	*	1	*	4
white sorghum + cowpea + sauce plants	0	0	0	0	0	0	0	96
millet	0	0	0	0	8.6	6	27.9	0
millet + cowpea + sauce plants	0	0	0	100	91.2	92	65.5	0
groundnuts + earthpeas	0	0	0	0	0	0	1.8	0
fonio	0	0	0	0	0.2	1	4.3	0
cotton	0	0	0	0	0	*	0	0
5. Soil preparation: Percentage of ring area prepared in 1981 with:								
- hand tools	93	74	100	0	0	3	6	0
- Animal Traction (A.T)	7	26	0	44	31	0	9	0
- hand tool and A.T	0	0	0	0	9	0	0	0
All	100	100	100	44	40	03	15	0
6. Percentage of ring area that has been fertilized with transported manure in 1981 (%)	30	30	80	86	95	80	0	0
7. Average amount of transported manure applied in fertilized fields per hectare (kg/ha)	6,000	13,250	22215	850	250	285	0	0

Table 12 (continued 1)

	1A	1B	1C	2A	2B	2C	3	4
8. Frequency of farmyard manure application in all fields (years of application during the past six years)	5	5	5	6	4	4.2	0	0
9. Percentage of ring area that has been fertilized with mineral fertilizer in 1981 (%)	0	0	0	0	20	0	0	0
10. Average amount of mineral fertilizer (cotton complex) applied in fertilized fields per hectare (kg/ha)	0	0	0	0	2	0	0	0
11. Freq. years of mineral fertilizer application in all fields during the past six years	0	0	0	0	0.2	0	0	0
12. Percentage of ring area that received both farmyard manure and mineral fertilizer in 1981	0	0	0	0	20	0	0	0
13. Percentage of fields fallowed during the past 25 years	20	64	17	50	100	100	100	100
14. Average number of years since the last fallow occured	27	14	40	20	10	3	5	5
15. Average lenght of the last fallow period (years)	12	6	na	6	6	3	4	6
16. Planting density of cowpea per hectare in intercropped fields (poquets/ha)	0	0	0	268	522	1847	300	739
17. Av. years of cowpea intercropping per field during the past siw years for all cereal fields	0	0	0	3	3	4.3	3	3
18. Total planting density of cereals crops per hectare (poquets)	na	na	na	13485	12856	12245	12690	12714
19. Av. total number of cereal stems per hectare	na	na	na	91600	78781	78112	83210	62000

Table 12 (continued 2)

	1A	1B	1C	2A	2B	2C	3	4
20. Av. total number of sauce plants poquets per hectare in intercropped fields	na	na	na	120	2075	231	300	5025
21. Percentage of fields planted with groundnuts/ep. at least once during the past six years	0	0	0	0	0	0	13	0
22. Av. years of groundnuts and earthpeas planting in above fields during the past six years	-	-	-	-	-	-	1	-
23. Av. size of the groundnut and bambara nuts fields (ha)	-	-	-	-	-	-	.033 027	-
24. Av. density of groundnut and bambara nuts fields (poquets)	-	-	-	-	-	-	52173 73222	-
25. Percentage of fields with anti-erosion devices	0	0	0	0	0	0	0	0
26. Distribution of local soil types across each ring % area:								
- Upland gravelly ferrigeneous soil (Houkawo)	5	0	65	0	0	1	0	0
- Upland sandy soil (Senon)	65	100	0	100	100	98	96	0
- Bolawo	30	0	0	0	0	0	4	5
- Lo`wland soil (Lomré)	5	0	35	0	0	1	0	95
27. Average manual production labor hours per hectare in manual fields (excludes harvest labor)	360	594	1060	261	300	229	276	520
28. % ring area where A.T* was used	10	26	0	45	60	0	18	0
29. Manual labor/ha in A.T fields	146	564	-	153	353		150	-
30. A.T labor hours/ha in A.T fields	83	98	-	28	21	-	38	-
31. A.T annual production hours/ha	28	72	-	8	9	-	11	-

* A.T = Animal Traction.

Table 12 (end)

	1A	1B	1C	2A	2B	2C	3	4
32. Average grain yield of main crops (kg/ha) per type of field:								
Maize fields:								
Maize	532	500	306	-	-	-	-	-
Sorghum	02	206	0	-	-	-	-	-
Sauce plants	13	74	0	-	-	-	-	-
Okra Fields	115	1722	527	-	-	-	-	-
Pur Millet Fields	-	-	-	-	400	425	564	-
Intercropped millet fields:								
Millet	-	-	-	675	485	468	462	-
Cowpea	-	-	-	0	03	03	1.5	-
Sauce plants	-	-	-	7	31	10	10	-
Pure white sorghum fields	-	-	-	-	-	-	-	500
Intercropped W. Sorghum fields:								
Sorghum	-	-	-	-	-	-	-	343
Cowpea	-	-	-	-	-	-	-	25
Sauce plants	-	-	-	-	-	-	-	25
Groundnut fields	-	-	-	-	-	-	105	-
Earthpeas fields	-	-	-	-	-	-	388	-
Fonio fields	-	-	-	-	356	1125	963	-
33. Av. value of grown output CFA/ha:	39200	54250	21750	37850	29500	28100	29800	26200
Crop residues:								
Millet Sorghum fields (+ cowpea):								
Air dried cereal crop residues (kg/ha)	na	na	na	3600	3094	3070	3270	4904
Air dried cowpea intercrop residues (kg/ha)	-	-	-	27	52	185	30	74
Groundnut fields residues (kg/ha)	-	-	-	-	-	-	1085	-
Amount of air dried crop residues remaining in fields 50 days after harvest (kg/ha)	0	0	0	800	540	370	100	135
Amount of cattle droppings								
50 days after harvest (kg/ha)	2,000	200	0	250	102	50	15	25
- By the end of dry season (estimation)(kg/ha)	6,000	600	0	750	306	150	45	75

CHAPTER 7.

THE BWA-DAGARI FARMING SYSTEM OF SAYERO AND KOHO (BOROMO) IN THE NORTHERN GUINEAN ZONE.

7.1. The Average Farm Resource Base:

During the 1981 crop season the average household in both studied villages (Koho and Sayero) cultivated about five lands and had about five other lands under fallow in Sayero. The average hand tool household cultivated about 5.0 ha. The animal traction household cultivated about 7.0 ha. Overall less than 30 percent of total available land is cultivated per year in the region.

As suggested by Table 3 about 20 percent of households own animal traction implements in the region. The average hand tool household contained in 1981 about 7 and 9 members in Sayero and Koho respectively. The average animal traction household contained about 12 and 24 members in Sayero and Koho respectively. About 35 percent were children with less than ten years of age. Cultivated land per household resident was around .70 ha in Sayero with no significant difference between the hand tool households (.71 ha) and the animal traction households (.65 ha).

Regarding livestock. Practically all households in the region raise poultry, pigs and small ruminants, within and around the village compound.

In 1981, 90 percent of the households were raising one to 37 small ruminants, with an average around eight small ruminants (goats and sheep) per household. Many farmers, especially among the Dagari, own a pair of oxen, which they keep inside or next to their compound, and cattle which they entrust in general to Fulani herdsmen who have settled down around the village or in the region. 60 percent of the sample farmers revealed that they own cattle with a size ranging from one to seven heads (including oxen for plowing) for the majority of them. The village chief of Koho (who is a Dagari) exceptionally had 40 heads of cattle entrusted to Fulani herdsmen in the village area. The average number of cattle heads owned by those farmers who admitted that they own cattle is about five (5). Some of the Dagari farmers appeared to be actively engaged in cattle trading.

Fourty (40) percent of the sample farmers had each a donkey for transportation.

7.2. The Local Soil Types:

As indicated in Table 2 four major local soil types can be identified in the Boromo area. Because of coexistence in the area of two ethnic groups with different dialects each local soil generally bears more than one local denomination. There are four major upland soils and one major lowland soil in the area.

The four major upland soils are:

1. Kuïgniguerė (in Dagari) or Hanin (in Bobo): This is a grey-redish and more or less compact ferrugineous sandy gravelly soil that characterises the slopes and proximities of small wide hills or elevations within the local topography. The parent granitic material often appears on top of such hills referred to as "Tanga" or "Diguê".

2. Tamissougo (in Dagari) is the deep grey sandy and silty soil found in between the small wide ferrugineous hills or elevations mentioned above on the highlands. The Bobo refer to it as Hapono when it contains few silt and as Fiaho when it contains a relatively large amount of silt.

3. Tanzia (in Dagari) or Tioro is a compact deep lateritic redish soil with a relatively high proportion of silt and which is generally found on long slopes between the two upland soils mentioned above and the lowlands.

4. Zepoko or Tingasologo in Dagari. It is a deep grey dark sandy clay soil also found between the first two upland soils and the lowlands. It is found on relatively flatter or less slopy soils comparatively to and area where Tanzia is found. It is known as a soil on which a lot of trees grow and on which water flows less rapidly than on Tanzia.
   A similar soil type which is characterised by alluvious deposits is referred to as Soumsoumbi by the Bwa.

5. A minor upland soil, referred to as Tampouré (Dagari) and N'donfi (in Bwa) is any soil that has been heavily manured in the past or a place which was used in the past as a deposit place for household refuse and wastes.

The major lowland soils is referred to as Ba in Dagari or as Mbarami or Diahon in Bobo dialect. It is a dark-grey sandy, silty or clayey hydromorphic soil found along rivers, seasonal water courses and inside depressions of highlands.

The geographical distribution of local soil across the sample fields are shown in Figure 14 and the chemical and physical characteristics of such soil types as measured on fallowed land appear in Table 13 and 14.

7.3. The Soil-Crop Management System.

The global land occupation aspect of the soil-crop management system in the Boromo area can be schematised as shown in Figure 15 below.

Once again different soil and crop management practices can be identified by looking accross concentric rings around the individual household compounds.

7.3.1. The First Ring.

The fields inside the first ring are fields on which the households rely mostly to attain their food and cash income objectives. As such they are the best managed fields. Organic fertilizer is applied only in the first ring. Five major soil-crop management practices are found in ring 1:

Subring 1Ai.

These are fields subjected to rotations and intercroppings between maize and red sorghum on the first household's land closest to the compound. They are heavily manured with organic fertilizers and measure on average .10 ha. They are mostly house fields.

Subring 1Ap.

These are fields planted every season with maize intercropped with sweet potato and sauce plants and few stands of sorghum. They are generally located on the household's land which is closest to the compound. They are in general heavily manured with organic fertilizer and measure on average .13 ha. They

Table 13. Particle and Chemical Characteristics of Local Soils Under Fallow (Boromo-Koho).

Local soil type / Characteristic	Kongniguéré Hanin	Tamissougo Hapono Fiaho		Tanzia Tioro	Zepoko Tingasologo Soumsoumbi	Ba Diahon
Number of sampled fallows	5	5	1	1	2	2
Sampling depht (cm)	20	20	40	20	20	20
Refuses > 2 mm %	42.0	2.6	-	7.1	0	6.1
Coarse sand (250-2000u) %	35.2	38.0	23.5	34.2	17.0	43.7
Fine sand (50-250u) %	24.0	20.8	14.9	18.1	17.0	22.2
Silt (2-50u) %	28.9	30.7	20.8	28.0	47.3	24.6
Clay (< 2u) %	12.0	10.6	40.8	19.7	18.7	9.8
Organic matter, %	1.04	1.20	.76	1.81	1.30	1.15
Total carbon, C %	.60	.70	.44	1.05	.76	.67
Total Nitrogen N %	.044	.043	.041	.062	.050	.044
C/N ratio	13.6	16.3	10.7	16.9	15.2	15.2
Assimilable Phoshporus ppm P.	3.4	2.9	0.6	0.9	2.1	2.8
Calcium (Ca++) me/100 g	1.10	1.78	1.86	4.99	3.01	1.31
Magnesium (Mg++)	.79	.58	1.14	1.07	0.78	.61
Potassium (K+)	.06	.13	.06	.09	0.13	.06
Sodium (Na+)	.02	.01	0	.08	.02	0.1
Sum of Bases	1.97	2.50	3.07	6.23	3.94	1.99
Cation Exchange Capacity	2.86	2.92	3.09	6.41	4.31	2.75
PH, H_2O	5.6	6.5	5.1	6.6	6.1	6.0
PH, KCL	4.2	5.5	4.0	5.4	5.2	4.9

Table 14. Selected Physical Characteristics of Local Soils (Boromo-Koho).

Local soil type / Sampling depht	- Kongniguéré - Hanin	- Tamissougo - Hapono - Fiaho		- Tanzia - Tioro		- Zopoko - Tingasologo - Soumsoumbi	
	5	5	25	5	30	5	25
Apparent density	1.53	1.70	n.a	1.59	1.66	1.58	n.a
% Moisture PF 2.5	9.57	10.54	16.12	12.23	13.25	11.49	13.40
% Moisture PF 3.0	6.93	8.74	11.62	10.27	11.11	9.32	8.90
% Moisture FP 4.2	3.33	5.06	7.46	6.53	8.09	4.98	3.93
Useful water PF 2.5 - PF 4.2	6.24	5.46	8.66	5.70	5.16	6.51	9.47
Permeability (K) m/24h	1920	587	n.a	44	21	33	n.a

All figures are averages of three samples taken at each site and at each depht with metal fings.

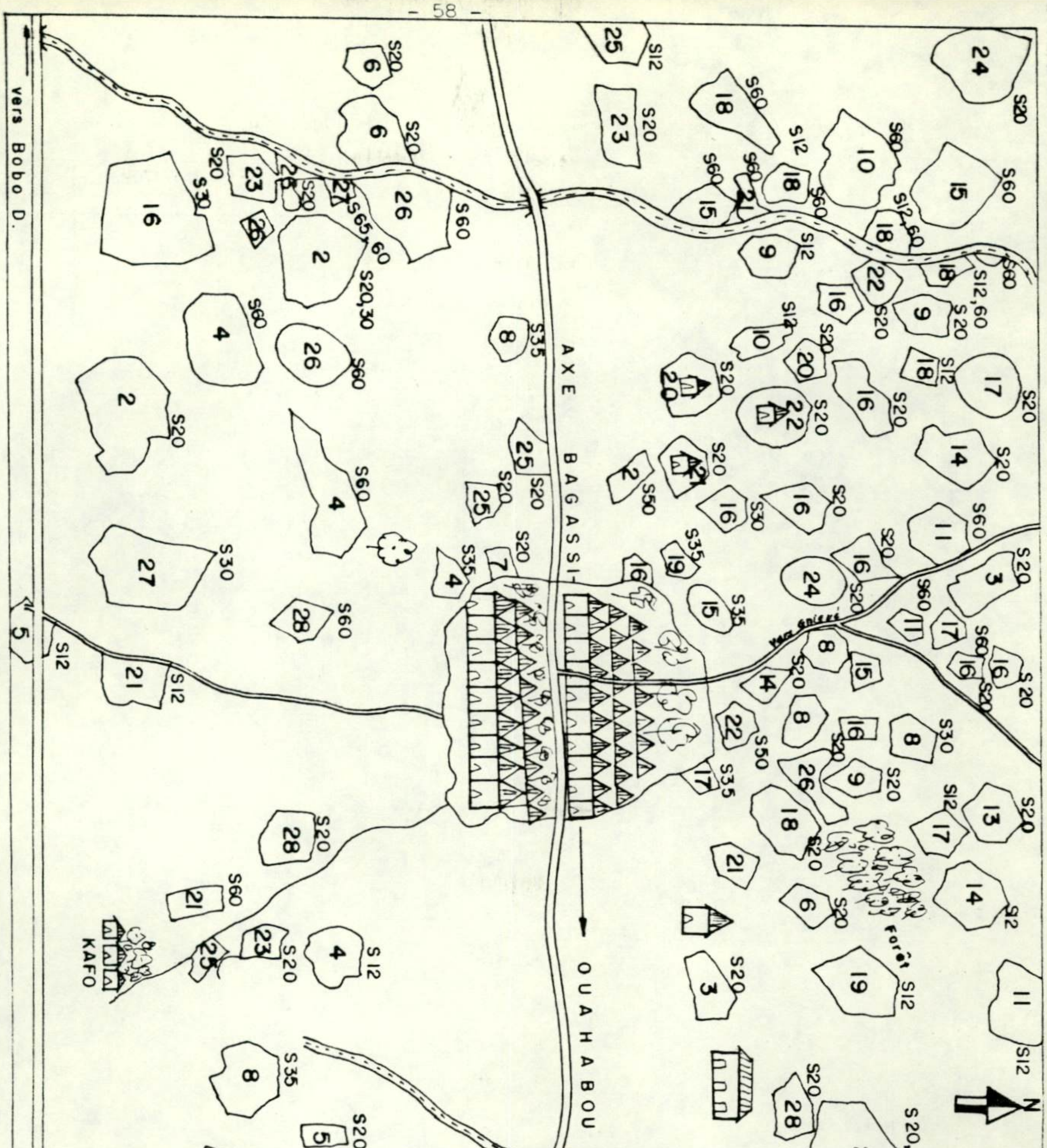


Figure 14 . Locations and Soil Types of Sample Fields Inside The Koho Village Territory (Boromo).

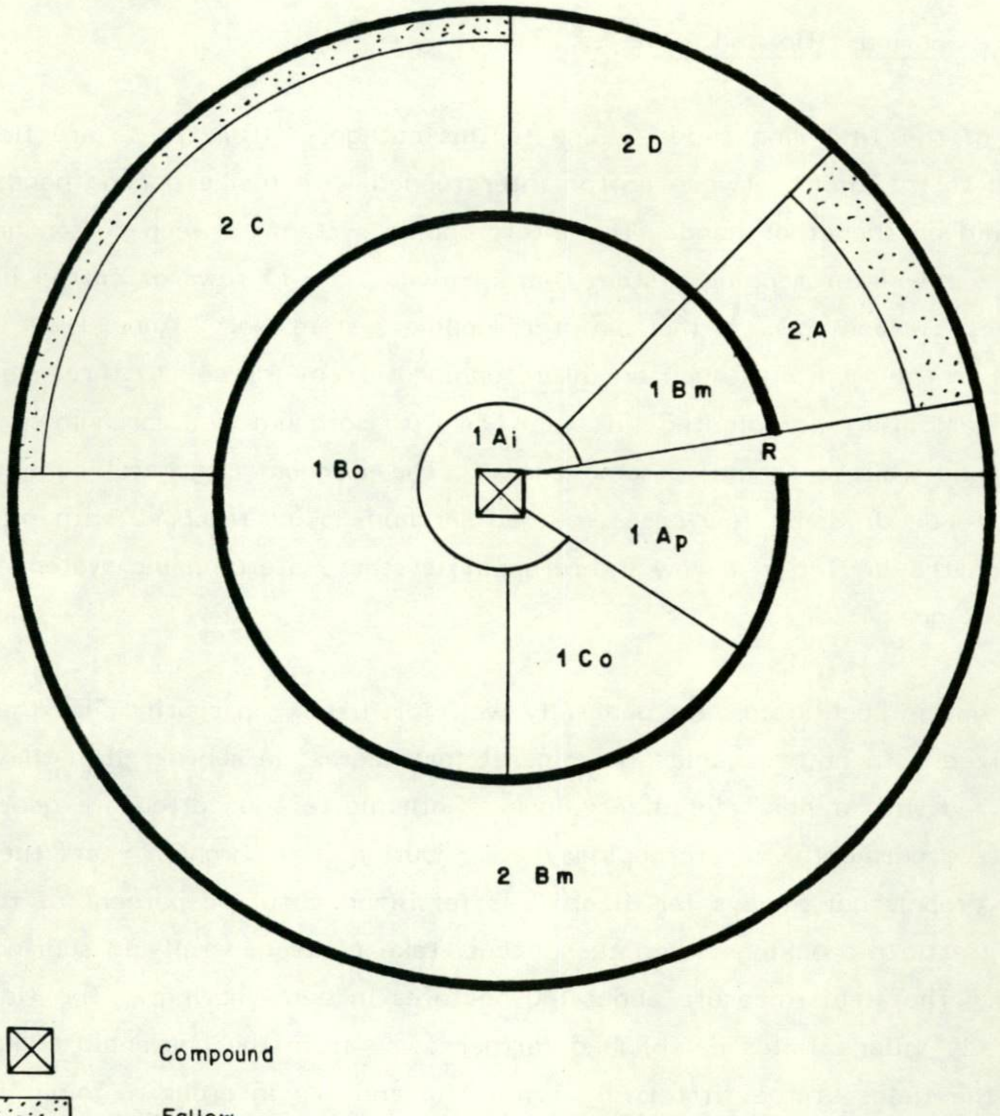


Figure 15. The Soil and Crop Management Rings of the Bwa-Dagari Farming System in the Northern Guinean Zone (Boromo).

cover about 9 percent of the first ring area. They are mostly house and village fields.

Subrings 1Bo and 1Bm.

Most of the first ring fields belong to this category (1B). These are fields subjected to rotations between cotton intercropped with maize on one hand, and sorghum on the other hand. The intercropping system between cotton and maize is a row intercropping system that involves 8 to 13 rows of cotton intercropped with 1 to 4 rows of maize (intercropping system No. 3 Annex B). The fields are planted with such an intercropping system for one to three years. Afterwards they are planted for one year with sorghum (red sorghum in most cases and white sorghum in some cases). The sorghum is generally planted in pure stand. In some few cases the red sorghum is intercropped with maize either on the line or in a row intercropping system (intercropping systems No 6 and 8, Annex B).

All crops in such fields are generally well fertilized. In subring 1Bo they are fertilized with both organic and mineral fertilizers. In subring 1Bm they are fertilized with mineral fertilizer alone. Both maize and cotton are generally fertilized during the intercropping years. During the "sorghum year" the sorghum crop is not always fertilized it is fertilized about 50 percent of the time. Cattle paddockings when they occur, take place generally in subring 1Bo fields. The fields measure about .60 hectares in both subrings. The fields are generally village fields established farther away from the household compound than the fields of the first two subring 1Ap and 1Ai in order to minimise the risk of poisoning with cotton insecticides.

Subring 1Co.

Here the fields are the objects of rotations between cotton/sorghum or cotton, for one to three years, and sorghum, for one to two years. They are manured with both organic and mineral fertilizers, particularly during the years when cotton is planted. The main difference with the management of fields in subring 1Bo is that, maize hardly enters intercroppings or rotations in subring 1Co, and as a result much less organic manure is applied in subring 1Co (800 kg/ha) as compared to subring 1Bo (7400 kg/ha).

7.3.2. The Second Ring.

These are village and bush fields located on lands other than the first land closest to the compound ,which are never fertilized with organic manure.

Subring 2A.

These fields are planted with legumes (cowpeas, groundnuts and bambara nuts) in pure stands or intercropped with sesame and other sauce plants for one to five years following a fallow and are returned to fallow afterwards. The fallow period varies between 2 and 8 years. No fertilizer is applied in such fields. They measure on average .20 ha. They are village and bush fields managed generally by women (women fields).

Subring 2Bm.

These fields are subjected to rotations between cotton one one hand and sorghum and/or millet on the other hand. The strategy consists of planting cotton (generally in pure stands) for one or two years and of following it up with sorghum (generally white sorghum) or millet (generally intercropped with cowpea or groundnuts) for one to three years so as to pick up the residual effects of the mineral fertilizer applied on cotton during the "cotton year". No fertilizer is in general directly applied on the cereals during the "cereal years". The fields measure on average one hectare.

Sixty percent (60%) of the fields are bush fields and the remaining 40% are village fields. The average intensity of land use in the subring has been about 25 during the past two decades. Only 15 percent of the fields carry some form of antiérosion or soil-water conservation devices.

Subring 2C.

These are bush fields (75%) and village fields (25%) planted with millet and/or white sorghum. They are generally planted in pure stands and sometimes intercropped with cowpea. The major characteristic of these fields is that they are not fertilized. Soil fertility is regenerated mostly with fallow and with rotation or intercropping with legumes such as groundnuts and bambara nuts. These are relatively large fields which measure on average .80 ha. The average intensity of land use in the subring has been about 30 during the past three decades, and about 55% of such fields have some form of antiérosion or soil water conservation device.

Subring 2D.

The fields are planted with cotton following a fallow period and one year of sesame, or of sesame + cowpea, or of other legume such as groundnut and bambara nuts. The cotton is either planted in pure stand or intercropped with a legume, generally cowpea, for one to three years. These are fields recently taken out of fallow. In 40% of the observed cases, the farmers are planning to return the field to fallow for 4 to 10 years. In 60% of the observed cases farmers are not planning to return the fields to fallow. Mineral fertilizer is generally applied on cotton during the cotton years. The fields are mostly bush fields and measure on average one hectare.

Subring R.

These are lowland fields which are either sown with maize intercropped with rice, or with rice in pure stands. Most of the fields in ring R (80%) are continuously planted with rice intercropped with maize. The remaining are continuously planted with rice. The fields are fertilised about once every two years with organic as well as mineral fertilizer. They are small fields which measure on average .05 hectare.

Detailed characteristics of the various management rings are presented in Tables 15 and 16 below.

Table 15. Soil Fertility Management and Input-Output Characteristics of the Soil Crop Management Rings in the Northern Guinean Zone (Boromo : Sayero Village).

Field Characteristics	Management Categories									
	1Ai	1Ap	1Bo	1Co	1Bm	2A	2C	2Bm	2D	R
1. Number of sample fields	7	13	41	10	8	8	18	44	10	7
2. Av. distance of field from household compound	130	1500	1500	1500	2300	2800	3400	4200	4700	1870
3. Ring area as percent of total cultivated area	1-	2	21	6	5	1+	13	42	9	1-
4. Average field size (ha)	.11	.13	.55	.65	.63	.19	.83	1.05	1.00	.05
5. Percentage of cultivated ring area planted in 1981 with:										
- maize/sweet potatoes/spices	-	100	-	-	-	-	-	-	-	-
- maize/red sorghum	100	-	5	-	-	-	-	-	-	-
- red sorghum	-	-	10	25	20	-	10	10	-	-
- white sorghum	-	-	6	3	-	-	35	41	-	-
- white sorghum + legumes	-	-	14	-	-	-	20		-	
- millet	-	-	10	-	-	-	20	20	-	-
- millet + legumes	-	-	-	-	-	-	-	9	-	-
- legumes + sesame	-	-	4	2	1	100	15	2	3	-
- cotton	-	-	7	12	23	-	-	8	52	-
- cotton/maize	-	-	42	-	13	-	-	-	-	-
- cotton/sorghum	-	-	-	58	-	-	-	-	-	-
- cotton/legumes	-	3	-	-	43	-	-	10	45	-
- rice	-	-	-	-	-	-	-	-		13
- maize/rice	-	-	-	-	-	-	-	-	-	87
	100	100	100	100	100	100	100	100	100	100
6. Soil preparation:										
Percentage of ring area prepared with:										
- hand tools	12	35	27	16	22	25	17	27	55	63
- animal traction	56	10	38	80	26	35	3	3	0	11
- hand tools and A.T.	32	53	19	0	47	0	0	2	27	16
All	100	98	84	96	95	60	20	32	82	100
7. Percentage of ring area that has been fertilized with farmyard manure in 1981 (%)	75	96	56	94	0	0	0	0	0	55
8. Average amount of farmyard manure applied in fertilized fields per hectare (kg/ha)	11300	23600	7360	800	0	0	0	0	0	30000
9. Frequency of farmyard manure application in all fields (years of application over six years)	4	4	4	1.2	0	0	0	0	0	2.3
10. Percentage of ring area that has been fertilized with mineral fertilizer in 1981	40	24	47	60	80	40	0	25	100	40
11. Average amount of min. fertilizer in fertilized fields (kg/ha)	40	62	96	96	103	43	0	76	75	55
12. Frequency of min. fertilizer application (years in six), all fields	0.2	0.2	0.5	2	3	0.2	0	2.3	1.2	1
13. % ring area that received both org. and min. fertilizer in 1981	40	24	37	55	0	0	0	0	0	40
14. Percentage of fields fallowed during the past 25 years	na	40	100	100	100	100	100	100	100	100
15. Ave. number of years since the fast fallow occured	na	28	8	4	9	3	10	6	2	4
16. Av. lenght of the last fallow period in years	na	21	25	25	27	7	23	23	35	30
17. Percentage of fields planted with cowpea on groundnuts at least once between 1976 and 1981	0	0	30	50	50	100	70	47	40	0
18. Av. frequency (years) of cowpea planting in such fields from 1976 to 1981.	0	0	0.3	0	0.5	0.2	0.5	1.3	0.5	0

Table 15 (continued 2)

Field Characteristics	1Ai	1Ap	1Bo	1Co	1Bm	2A	2C	2Bm	2D	R
19. Av. frequency years of nuts planting in such fields from 1976 to 1981	0	0	1.2	1.2	1	2.5	1.6	0.5	1	0
20. Average size of legumes fields (ha)	0	0	.18	.12	-	0.19	0.30	0.34	0.20	0
21. Distribution of local soil types across each ring in % of ring area:										
- Kougniguéré, Hanin	0	0	0	4	17	0	0	15	3	0
- Tamissougo, Hapono, Fiaho	0	30	43	70	70	60	38	48	43	0
- Tanzia, Tioro	0	0	0	0	0	0	0	0	0	0
- Soumsoumbi	31	10	35	26	7	40	62	37	54	75
- Tampouré, Ndonfi, Ndomsé	17	30	15	0	5	0	0	0	0	0
- Ba, Diahon	52	30	7	0	1	0	0	0	0	25
22. Average manual production labour hours/ha in hand tool fields	610	804	480	350	375	980	430	340	280	600
23. % ring area where A.T was used in 1981 for soil prep. and/or weeding	90	65	56	80	72	36	03	14	30	26
24. Manual labor hours in A.T fields/ha	702	754	470	320	410	310	-	280	366	2850
25. Animal traction labor hours in A.T. fields/ha	77	115	40	30	48	50	-	40	40	480
Animal soil prep + weeding hours/ha	21	33	11	8	12	16	-	16	13	96
26. YIELDS (kg/ha).										
Maize fields (kg/ha):										
- Maize	1650	2030	-	-	-	-	-	-	-	-
- Sorghum	700	70	-	-	-	-	-	-	-	-
- Sweet potatoes	-	103	-	-	-	-	-	-	-	-
- Sauce plants	-	146	-	-	-	-	-	-	-	-
Cotton/Maize Fields:										
- Cotton	-	-	1300	-	900	-	-	-	-	-
- Maize	-	-	210	-	390	-	-	-	-	
Pure cotton fields:	-	-	1600	1000	950	-	-	600	500	-
Red sorghum fields:	-	na	1000	500	1560	-	65	825	-	-
White sorghum fields:										
- White sorghum	-	-	563	400	-	-	585	485	-	-
- Legumes	-	-	17	-	-	-	03	-	-	-
Millet fields:										
- Millet	-	-	703	-	-	-	370	512	-	-
- Legumes	-	-	-	-	-	-	-	18	-	-
Cotton/Legumes/Sorghum										
- Cotton	-	-	-	560	405	-	-	460	320	-
- Legumes	-	-	-	-	0	-	-	12	03	-
- Sorghum	-	-	-	152	-	-	-	-	-	-
Legume fields:			370	350	-	250	450	780	0	
Rice/Maize fields										
- Rice	-	-	-	-	-	-	-	-	-	650
- Maize	-	-	-	-	-	-	-	-	-	1750
27. Average value of output CFA/ha	101700	107100	65350	39000	47200	30000	28900	29750	26200	114200
Amount of air dried crop residues remaining in fields 90 days after harvest	na	na	2790	1160	3740	na	5200	5000	na	na
Amount of air dried cattle dungs in fields 90 days after harvest.	na	na	82	80	261	na	89	05	na	na

Table 16. Plant Densities, Crop Residues and Soil Water Conservation in the Northern Guinean Zone [a], (Boromo; Koho village)

Management Ring	1Ai	1Ap	1Bo	1Co	1Bm	2A	2C	2Bm	2D	R
Numer of sample fields:	12	14	40	17	16	18	58	101	3	34
Av. distance from household compound (meters)	137	640	550	520	525	1300	1500	1200	na	1000
DENSITES										
Maise e Maize/sorghum Fields:										
Maize : Poquets	9400	24400	17100	-	14100	-	-	-	-	-
: Stems	18200	50000	43000	-	27500	-	-	-	-	-
Sorghum : Poquets	14500	-	21900	-	17000	-	-	-	-	-
: Stems	40700	-	50000	-	37000	-	-	-	-	-
Cotton/Maize Fields:										
Cotton : Poquets	-	-	45000	-	72400	-	-	-	-	-
Maize : Poquets	-	-	5600	-	3100	-	-	-	-	-
: Stems	-	-	10200	-	6100	-	-	-	-	-
Pure cotton fields (Poq.)	-	-	-	54300	-	-	-	54600	48000	-
Pure Red Sorghum Fields:										
: Poquets	-	-	32200	25000	22200	-	21300	20700	-	-
: Stems	-	-	44800	82300	70000	-	64000	59000	-	-
Red Sorghum/Cowpea Fields:										
Red Sorghum : Poquets	-	-	-	-	22600	-	24700	22600	-	-
: Stems	-	-	-	-	55250	-	83300	68500	-	-
Cowpea : Poquets	-	-	-	-	200	-	300	2750	-	-

Table 16 (continued)

Management Ring	1Ai	1Ap	1Bo	1Co	1Bm	2A	2C	2Bm	2D	R
Pure White Sorghum:										
: Poquets	-	-	19300	21100	-	-	21300	20600	-	-
: Stems	-	-	66400	71000	-	-	65000	65600		
White Sorghum/Cowpea:										
White Sorghum : Poquets	-	-	12600	19200	-	-	20800	22600	-	-
: Stems	-	-	26200	60000	-	-	61600	61300	-	-
Cowpea : Poquets	-	-	10000	400	-	-	1500	1250	-	-
Pure Millet Fields:										
: Poquets	-	-	-	19600	-	-	19500	18000	-	-
: Stems	-	-	-	69000	-	-	63000	68000	-	-
Millet/Cowpea Fields:										
Millet : Poquets	-	-	-	18600	-	-	19600	19500	-	-
: Stems	-	-	-	64500	-	-	65600	70200	-	-
Cowpea : Poquets	-	-	-	900	-	-	1500	512		
Cotton/Sorghum/Legume	-	-	-	-	-	-	-		-	-
Cotton : Poquets	-	-	-	-	-	-	-	40000	-	-
Sorghum : Poquets	-	-	-	-	-	-	-	-	-	-
Cowpea : Poquets	-	-	-	-	-	-	-	1250	-	-
Legume Fields (pq)	-	-	-	41000	-	58000	20000	31000	na	-
Pure Rice Fields										
: Poquets	-	-	-	-	-	-	-	-	-	17350
: Stems	-	-	-	-	-	-	-	-	-	1300000

Table 16 (end)

Management Ring	1Ai	1Ap	1Bo	1Co	1Bm	2A	2C	2Bm	2D	R
Rice/Maize Fields										
Rice : Poquets	-	-	-	-	-	-	-	-	-	19300
: Stems	-	-	-	-	-	-	-	-	-	1650000
Maize : Poquets	-	-	-	-			-	-	-	110200
: Stems	-	-	-	-	-	-	-	-	-	22000
RESIDUES (kg/ha)										
Pure Cereal Fields	6650	5500	4300	9500	13000	-	6825	6050	-	5800
Cereal/Legume Fields										
Cereals	-	-	-	6750	8750	-	7283	7700	-	-
Legumes	-	-	-	50	06	-	60	50	-	-
Cotton/Cereal Fields										
Cotton	-	-	3950	2850	-	-	-	-	2850	-
Cereals	-	-	465	-	-	-	-	-	-	-
Legumes Fields	-	-	-	-	-	950	1170	1000	na	-
- ANTI EROSION DEVICES										
% Fields where used	6	8	45	35	0	0	20	15	0	5
Types of devices *	1.	1.	1.3.2	1.2	-	-	4.3.2.1	1.2.4.5	-	1.2.

(a) - Plant densities were measured in October 1981. Crop residues were air dried for about 20 days.
* 1) ditch, 2 = earthen diguette, 3 = wood or tree trunk, 4 = Stone bunds, 5 = mulching.

CHAPTER 8.

TYPOLOGY, DETERMINANTS OF THE MANAGEMENT PRACTICES AND RELATIONSHIPS WITH LAND TENURE.

8.1. Typology and Determinants of the Management Practices.

Overall, the major factors which explain the differences between the soil and crop management practices observed on a given farm in each agroclimatic zone are: (1) the farmer's production/consumption objectives, (2) the distance between the household compound and the field, (3) soil type and quality.

With the farmer production/consumption objective as the leading criterion, one may classify the household fields in four groups.

1. The hungry season relief and spices fields
2. The minimum food (cereal) security fields
3. The complementary food (cereal) security fields
4. The cash and social obligations fields.

Some fields have a double function of cash and minimum food security; particularly in the Boromo area.

8.1.1. The Hungry Season Relief and Spices Fields.

The hungry season relief and spices fields are in general located within the first ring. They are subrings 1A and 1B at Nonghin (Manga), subrings 1A and 2A at Kolbila (Yako), rings 1A, 1B and 1C at Ouré (Djibo), subrings 1Ai, 1Ap and R at Koho and Sayero (Boromo). Maize is by far the dominant crop in such fields followed by sauce plants (spices) tuber roots and some few stands of early varieties of sorghum and/or millet.
Other major characteristics of such fields are as follows:

- They are small fields
- They are in general the first field closest to the household compound
- They are in general ploughed before planting,
- They are heavily fertilized with farmyard organic manure
- They are the best attended fields or are among

the best attended fields on the farm, with total production labor per hectare being the highest or among the highest on the farm.

The fields are planted with maize known as the hunger season crop because it has among the local crops the shortest growing cycle and is the first crop harvested during the season. It suffers little from birds' attacks which is a major problem faced by early cereal crops in the region and is at least the second most preferred crop behind millet or white sorghum when it is not the most preferred crop. Early varieties of sorghum or millet are too vulnerable to birds' attacks and are only planted in few stands across the field or around the field. In the latter case they also serve as windbreaks to protect the maize stands from falling, a consequence of the generally shallow nature of the soils, particularly on the Mossi Plateau.

Whether the farmer still has some grains in his granaries or not the new season's fresh maize is highly valued, it is the crop to taste before any other crop during the new season,practically no farmer is willing to do without it. However, it can properly grow only on well manured soils. The availability of farmyard manure, generally limited, determines the size of the maize field and the high cost of transportation of such manure, especially in absence of adequate means of transportation, encourages the farmer to plant maize on the field which is closest to the compound.

Sauce plants are also known by farmers to be very demanding in soil fertility and to provide their best yields on organically manured soils. They are highly valued as the indispensable spices used to make the sauce, the complement of the <u>Tô</u> (cereal meal) in the daily diet. Failure to obtain a good harvest of sauce plants means failure to provide a complete diet to the household for the whole year. Consequently, the housewives prefer to intercrop the sauce plants with maize to maximize the chances of crop success. Sweet potatoes are also planted sometimes, as in the Boromo area, in such fields to obtain an additional source of energy during the hunger season. At Kolbila (Yako) yam is intercropped or rotated with maize partly for the same reason and partly for acquiring cash.

For a good chance of success of such highly valued crops, a timely use of labor to plough, plant, weed, ridge, guard the field against birds and harvest is imperative. This can be best done when access to the field is not a limiting factor. The closer the field to the compound, the better it can be managed. Soil conservation measures are used wherever the incidence of soil erosion is high. These fields being the most intensively cultivated fields and being generally ploughed face the highest risk of soil erosion, particularly on the Mossi Plateau. Wherever soil conservation measures are used (mostly dykes around the field) they also serve as water conservation devices and have in general significantly positive effects on yields. Leguminous crops (such as cowpea, useful for soil fertilisation)conservation purposes are not planted in general in such fields for reasons that appear in the next section.

The growth cycle of the crop varieties planted in such fields do not in general exceed ninety days.

8.1.2. The Minimum Food (cereal) Security Fields.

The minimum food (cereal) security fields are always located within the first or second ring. They are located in ring 2, particularly ring 2A, at Nonghin (Manga), subring 1B and 2B at Kolbila (Yako), rings 2A, 2B, 2C and type 4 fields at Ouré (Djibo), subrings 1Bo, 1Bm and 1Co in the Boromo area. Red sorghum is the dominant crop in this group of fields in the sudanian zone. Red sorghum, white sorghum and millet are equally important minimum food security cereals in the sudano sahelian zone. Millet intercropped with some sauce plants is the dominant food security cereal in the Sahel. Maize and sorghum are the main minimum food security cereals in the northern guinea zone of Boromo.

These fields make up in general about 30 percent of total cultivated areas or less, and yet provide up to 50 percent of the total grain output per year. They are the best managed fields following the hungry season relief fields. Here the typical farmer tries to maximize the chances of crop success on a limited and easily accessible portion of his land. The whole field or at least part of it is generally tilled before planting when the household owns an animal traction implement. The fields in general receive some moderate amount of organic manure and the highest doses of inorganic fertilizers when the latter are used in the village. The fields are generally located in conveniently close areas to facilitate organic manure applications and timely use of labor. The total amount of labor used in such fields is often as high as that used within the hungry season relief fields. These are the fields where animal traction implements are the most used when the household owns or uses such implements. When cattle night paddocking occurs on the farm, it is generally done in such fields. Red sorghum is favoured in such fields for the following reasons.

1 - It is viewed by most farmers as the crop most responsive to moderate applications of organic and mineral fertilizers. Under the management conditions that prevail in such fields it would provide better and more stable productivities in food grains than other crops.

2 - The growth cycles of the local varieties of red sorghum commonly used by the farmers are on average intermediate (90 to 120 days) between the shorter growth cycles of the local varieties of maize (70 to 90 days) and the longer growth cycles of local varieties of white sorghum and millet (120 to 180 days).
Since maize requires a higher level of management (more organic fertilizers and tillage), red sorghum has the shortest cycle varieties that can be successfully cultivated in such fields. They can be more successfully replanted than the existing varieties of white sorghum and millet in case of an early drought during the rainy season. In other words they allow more replanting when necessary to escape drought than the local varieties of white sorghum and millet. This partly explains the first reason stated above.

3 - Red sorghum is tastewise the least preferred cereal crop, consequently smaller amounts are consumed per meal and per individual than millet and white sorghum after the latter have been completely exhausted. Most farmers see this as an advantage in case of a bad cropping season, because the amount of red sorghum harvested can then provide the household with additional food for more days than an equivalent amount of white sorghum or millet. If sufficiently produced it can carry the household to the beginning of the new season, a time when it serves as a good source of energy for the early season activities.

4 - Red sorghum is the crop most used for producing the local beer "dolo" as such it is subjected to a relatively high and stable market demand and can thus serve also as a reliable cash crop. In case of a good cropping season with sufficient production of millet and white sorghum to feed the household, the red sorghum production can be easily sold to provide the household with cash to acquire other goods.

However, moisture availability restrains the relative importance of red sorghum in the minimum food security fields as one moves from the south to the north. Consequently, it is restricted to lowland fields in the Sahel where millet is by far the major minimum food security crop. In the soudano sahelian region white sorghum, millet and red sorghum are equaly important food security crops. In the northern guinean zone better rainfall, better soil quality and technological level allow maize and white sorghum to compete with red sorghum as minimum food security crops.

Cowpea intercrops are not generally planted in the hungry season relief and spices fields of the first ring. They are also scarce in the red sorghum fields and in the minimum food security fields in general. The main reasons are as follows:

1 - When planted in such fields cowpea is easily damaged by the small livestock (poultry, sheep, goats and pigs) that are raised inside and around the compound. Such damages occur mostly after the harvest of maize and red sorghum, the growth cycles of which are shorter than those of the local varieties of cowpea. Additional labor is then needed to guard the animals at a time when labor is relatively scarce.

2 - When planted on the heavily manured maize fields, cowpea grows quickly, produces less grains than elsewhere, and prevents the proper development of other crops.

3 - On the Mossi Plateau maize in the first rings is generally relayed by tobacco which is highly valued by farmers. Tobacco can properly grow only on the heavily manured soils of the first ring. Planting cowpea in the first ring would prevent many farmers from obtaining their yearly supply of tobacco.

Explicit soil and water conservation devices (dykes, ditches, mulching) appear mostly where either soil erosion or soil compaction is a major problem. Implicit soil conservation measures such as late ridges at Nonghin (Manga) and cutting of plants stems at 30-50 centimeters above the ground at Ouré (Djibo) are widely practiced in the minimum security fields of those areas and are believed by farmers to reduce soil erosion.

8.1.3. The Complementary Food Security Fields.

They are generally located in the outer ring. These are for instance ring 3 at Nonghin (Manga), ring 3 at Kolbila (Yako), type 3 fields at Ouré (Djibo) and subrings 2Bm and 2C in the Boromo area. Millet and white sorghum, both intercropped with cowpea, are the major crops in such fields. They are in general the largest fields managed by the household. Management levels in these fields are generally the lowest on the farm. The principal goal is to plant on as much land as allowed by labor availability in the household and ability to hire labor. Land is not generally a major constraint. When it is a constraint in the village territory such as in Nonghin (Manga), the fields are established on borrowed lands in distant and less populated villages in the region. The marginal productivity of land is expected to be much higher than that of labor in such fields. The crops planted in these fields, are expected by farmers to provide some "acceptable" yield under minimum management. Millet is believed to be the most tolerant to minimum management, it is planted on the poorer soils while white sorghum is planted on the better soils. Cowpea intercrops are mostly found in this type of fields. This is because the probability of crop damages on cowpea by livestock is lower due to the long distance between the fields and the compound and also due to the fact that the growth cycle of the local varieties of cowpea are shorter than those of the local varieties of millet and white sorghum planted in such fields. Consequently, the cowpea plants are protected by the cereals up to maturity and are thus less exposed to damages by livestock.

Such fields cover in general 60 to 70 percent of the total areas planted with food crops and provide 40 to 50 percent of the total food grain output. Fallow or shifting cultivation, intercropping and partial rotations between cereals and leguminous crops are the major means of regenerating soil fertility in these fields. Soil and water conservation measures are more scarce in such fields than in other types of fields. Mulching is the most important technique used because of easier access to grass in the surounding bushes and because the long distance between the compound and the fields limits the use of the crop residues as fuel and as livestock feed supplement.

8.1.4. The Cash and Social Obligation Fields.

Leguminous crops such as groundnuts and bambara nuts are cash crops in all four farming systems. In addition they are often planted to fulfill social obligations in the forms of gifts and ceremonies. These fields are mostly located on small plots inside the complementary food security fields where they are rotated with the cereals. However they are also found where suitable in some peripheric minimum food security fields where they are also rotated with the cereal crops. In the Boromo area they are also sometimes intercropped with the cereals.
Cotton is the dominant cash crop in the northern guinean zone where it is mostly planted in association or in rotation with the cereals, in both the minimum and the complementary food security fields. Thus fields in subring 1Bo and 2Bm have a double and interannually variable status of cash and food security fields. Other fields such as fields in subrings 2A and 2D are purely cash fields.

Sesame, another important crop is often intercropped with groundnuts and bambara nuts, and is viewed both as a spice and as a cash crop by the women who manage most of the legume fields.

Rice fields are mostly viewed everywhere as cash and social obligations fields. In normal and good years, surpluses from all food crop fields are sold to obtain cash. However, this is a circumstancial additional character of the outputs from such fields which does not fundamentally affect their status of food security fields.

The management level of the cash fields depends mostly on how efficient the input supply system for the crop is, or how reliable the marketing system is, and on the stability of the producer price. Cotton is in Burkina Faso the cash crop which benefits from the best input supply system and the best pricing and marketing policies. The crop is handled by a parastatal agency (SOFITEX) which supplies the inputs and buys directly from the producer at a relatively stable price.

Consequently, cotton is the best managed cash crop in the Boromo area. It is subjected to high management in the purely cash fields and in the minimum food security fields where it is intercropped or rotated with the cereals. It is also subjected to lower management where it is rotated with the cereal crops in the complementary food security fields. Elsewhere on the Mossi Plateau and in the Sahel, cotton production is a less profitable activity because of less favourable rainfall, lower soil fertility and greater land constraint.

Rice fields and tuber roots fields are as well managed as the hungry season relief and spices fields, particularly in terms of labor inputs. This is due to additional labor requirements for seedlings preparation and transplantation, for plowing lowland heavier soils or for mounds construction.

Legume fields are not generally better managed than the complementary food security fields. In general they are not fertilized but require more labor for weeding and for plowing. Legume fields and fonio fields are generally plowed before planting.

8.2. Relationship Between Management and Land Tenure.

The land tenure system in all studied areas may be generalised as follows:

The lignage, including its dead, living and unborn members, owns or holds the permanent usage right of the land, which has in general been acquired on first occupancy basis or as a result of military conquest. The political leader (lignage head) or the religious leader (earth priest) of the lignage acts as the land right holder and grants production usage rights to the individual male members of the lignage, mostly to those who are heads of households. The usage right so granted is normally temporary and is returned to the land right holder when the user dies, or forfeits his usage right. The latter is then granted to another needy member of the lignage.

The land right holder may also donate or lend the usage rights to non-members, such as new settlers, on request. Individual members also donate or lend the land use right they have acquired to wives, friends and relatives during their lifetime. As a result of increasing population pressures and of increasing market integration, the tendency has been during the last decades for individual members to pass their land use rights directly to their heirs, in general to the oldest son or to a younger brother. (Drabo and Vierich, 1983; Sanou 1986, Kholer, 1971).

Overall one may distinguish three different levels of security of land tenure in recent years:

- The highest security of land tenure is obtained when the usage right has been inherited from a father, an uncle or a brother, or when the land use right has been granted by the land right holder to a member of the lignage.
- A relatively high but lower security of land tenure is obtained when the land use right has been donated by the land right holder or by a member of the lignage to a wife or to someone outside the lignage, such as a friend, a neighbour or a new settler.
- The lowest security of land tenure is obtained when the land use right has been borrowed from anyone.

Security of tenure for donated land use rights is not as high as that of inherited or legally granted land use rights, because the donation is valid and secure mostly during the time period when both the donor and the receiver are alive. If either the donor or the receiver deseides, problems may arise or not arise depending on the relationship between their heirs. However, it is in general a fairly secure land tenure that can last more than fifty years or generations. Some farmers view it as a long term borrowing.

Borrowed usage rights are the least secure because they can be withdrawn anytime, provided that the lender notifies his intention to the borrower before the new season planting activities begin. Usage rights are often borrowed by women to plant legumes for one or two years, and by men to plant cereals for one to three years or more depending on the quality of the land and the relationships between the two parties involved.

The relationships between the management practices and the security of land tenure as observed in the studied villages are shown in Tables 17A, B, C and 17 D below.

At Nonghin (Manga) the lowest security of land tenure is observed in the third ring, where the complementary food security fields are found. It thus coincides with the lowest management level. The fields have been mostly borrowed from farmers in distant villages within the Manga region. The hungry season relief and spices fields in ring 1 and the minimum food security fields in ring 2 have a fairly high security of land tenure, which thus coincides with the best management levels on the farm.

At Kolbila (Yako) the security of land tenure is relatively high for all management types. However some borrowed fields are found under both high and low managements, particularly in subring 2A where about 40 percent of the fields are borrowed fields. This is due to the higher pressure on village land which forces some farmers to borrow a piece of land from more fortunate friends or relatives so as to have their maize fields conveniently close to their compounds. Some of the borrowed fields were even better manured than the non borrowed fields.

Table 17. Relationship between management and security of land tenure. (Percentages of fields per management type).

A. Nonghin (Manga).

Type of Land use right acquisition	Ring 1	Ring 2			Ring 3
		2A	2B	2C	
Inherited	51	55	69	76	40
Received as Donation	42	43	31	15	17
Borrowed	7	2	0	9	43
	100	100	100	100	100

B. Kolbila (Yako).

Type of Usage Right Acquisition	Ring 1		Ring 2		Ring 3	
	1A	1B	2A	2B	3A	3B
Inherited	82	88	56	94	84	89
Received as Donation	6	6	5	6	4	2
Borrowed	12	6	39	0	12	9
	100	100	100	100	100	100

C. Ouré (Djibo)

	Type 1			Type 2				
	1A	1B	1C	2A	2B	2C	3	4
Inherited	100	na	na	71	30	43	53	83
Received as Donation	0	na	na	29	10	14	7	17
Borrowed	0	na	na	0	60	43	40	0
	100	na	na	100	100	100	100	100

D. Koho (Boromo)

	1Ai	1Ap	1Bo	1Co	1Bm	2A	2C	2Bm	2D	R
Inherited	94	100	97	94	83	61	67	68	33	69
Donated	6	0	0	6	0	11	15	20	67	23
Borrowed	0	0	3	0	17	28	18	12	0	8
	100	100	100	100	100	100	100	100	100	100

At Ouré (Djibo) it appears clearly that the type A farmers enjoy a better security of land tenure than the type B and type C farmers. This may be linked to the fact that they are native Rimaibe who own cattle, which implies a higher social status than the other types of farmers. They control most of the uplands, type B and type C farmers borrow land use rights from them. Type B and type C farmers enjoy a relatively low security of land tenure. At least 40 percent of their minimum food security fields are borrowed fields, as for all complementary food security fields (type 3). The security of land tenure is very high on lowland fields, that is in type 4 fields. Paradoxically, one notices when further investigating the data that about all lowland fields (type 4) are controlled by type C and type B farmers. Type C farmers control 60 percent of such fields, 30 percent are controlled by type B farmers and only 10 percent are controlled by type A farmers.

At Koho (Boromo) where land is more plentiful, the security of land tenure is fairly high under all managements. It is higher in the high management fields of the first ring than in the second ring fields. Among the latter, borrowed fields are mostly found in subring 2A which fields are legumes fields mostly managed by women.

Overall, in all the studied villages, higher management levels coincide whith higher securities of land tenure. However the truth of this statement increases with the availability of land and declines otherwise. As suggested by the observations made at Kolbila (Yako), a high security of land tenure is not necessary for a high management if the production objective is a vital first priority objective, such as hungry season food relief, if high management is necessary for a minimum crop success and if the size of the field is relatively small (i.e. maize fields).

CHAPTER 9.

EFFECTS OF THE SOIL AND CROP MANAGEMENT SYSTEMS ON SOIL FERTILITY.

9.1. Objective and Methodology.

In order to apraise the effects of the soil and crop management systems on soil fertility, soil samples were taken from bush fallows around the villages and from samples of cultivated fields in each management ring at a 20 centimeters depht. The soil samples were then sent to the laboratory for mechanical and chemical analyses. Soil samples were taken from more than fifty fields in each village.

Once the laboratory results obtained, they have been classified by ring and by soil type. The chemical and mecahnical characteristics of the soil in each management ring have been compared with those of the oldest fallows around the village for each given local soil type. Statistical differences have been identified by using the T-test. The methodology used is thus based on cross-section variabilities and on the hypothesis that soil fertility as observed in the selected fallows is well representative of the soil fertility of the cultivated fields at their initial stage of exploitation by the current generations of farmers.

Such hypothesis is supported by the following observations:

- The fallows used as references are seven to over 40 year fallows, among the best and oldest fallows in the region, as indicated by the vegetation.

- First settled extended families tend to control the best quality lands and to keep many of such lands under fallow as long as possible when lending or donating lands to new settlers.

- If a deliberate selection of best quality lands for cultivation is effective, and if a land has been cultivated in the past, then its soil had a good quality at the time it was cultivated. If the length of the fallow period is at least equal to the minimum length of fallow required to regenerate soil fertility (at least seven years of fallow after three to four years of cultivation), then there should be no major difference between the current quality of the land and its previous quality if one accepts the view that a sufficiently long fallow period regenerates soil fertility.

9.2. Chemical Fertility.

Changes in the chemical fertility of the soil as observed in the four farming systems are shown in Tables 18, 19 to 21 below. The managements rings or practices are ordered in the table so that the intensity of land use increases from the left to the right of the tables.

At Nonghin (Manga) in the Sudan zone, the chemical fertility of the soils increases from fallows to the first ring on uplands, as more land use intensive practices are utilised by the farmers. However a decline in the organic matter content of the soil is observed on lowlands, but with a simultaneous increase in available phosphorus. On all soil types the PH increases with the intensity of land use from fallows to the first ring.

At Kolbila, in the sudano-sahelian zone a decline in the organic matter content of the gravelly soil (Zingadega) is observed from fallows to the first ring but with significant increases in available phosphorus,in exchangeble bases and in the PH. On other soil types (Zimuougou, Rassempouiga), the organic matter content of the soil is maintained or is slightly improved, with a significant increase in the available phosphorus content of the soil. However slight declines in exchangeable bases and cation exchange capacity are observed on silty soils (Zimuougou) in contrast with increases on Rassempouiga soils.

At Ouré in the Sahel the organic matter content of the upland soil Senon is more or less maintained with sensible increases in the available phosphorus content of the soil, in exchangeable bases, cation exchange capacity and PH, as farmers use more land use intensive management practices.

Table 18. Effect of Management on Soil Fertility at Nonghin (Manga) in the Mossi Farming System of the Sudanian Zone.

Management Ring	Fallow	Ring 3	Ring 2	Ring 1
Soil: Binsiri (S20)				
Number of sample	2	5	9	5
Organic matter %	.60	.74	.60	1.45**
Available phosphorus, ppm	3.4	2.2	6.3	84.2**
Exchangeable bases, me/100g	2.5	2.5	2.4	10.1
C.E.C. me/100g	2.7	3.0	2.5	5.0**
PH, Water	6.5	6.2**	6.8	7.8**
Soil : Kuigdiga (S12)				
Number of samples	2	-	3	5
Organic matter %	1.2	-	1.34	1.62
Available phosphorus, ppm	1.8	-	20.3**	49.3**
Exchangeable bases, me/100g	3.8	-	4.7	9.7
C.E.C. me/100g	4.8	-	4.2	5.6
PH, Water	6.7	-	7.0	7.6**
Soil: Kougri (S11)				
Number of sampled fields	1	3	8	-
Organic matter %	.67	.72	1.38***	-
Available phosphorus, ppm	2.3	15.0	65.2**	-
Exchangeable bases, me/100g	2.2	3.3	7.7**	-
C.E.C. me/100g	2.6	3.56	5.1***	-
PH, Water	6.1	6.3	7.3***	-
Soil: Bollé (S60) (Lowland Soil)				
Number of sampled fields	1	2	-	3
Organic matter %	1.62	.69	-	1.20**
Available phosphorus, ppm	1.4	2.33	-	40.5
Exchangeable bases, me/100g	1.9	2.4	-	10.1
C.E.C. me/100g	3.3	2.52	-	4.6
PH, Water	6.1	6.1	-	7.4**
Soil: Naka (S40) (Lowland Soil)				
Number of sampled fields	1	1	-	-
Organic matter %	1.67	.96	-	-
Available phosphorus, ppm	.83	3.8	-	-
Exchangeable bases me/100g	25.7	18.5	-	-
C.E.C. me/100g	26.8	12.9	-	-
PH, Water	6.7	6.9	-	-

*** Difference with respect to Fallow Significant at .01 level
** Significant at .05 level
* Significant at .10 level.

Table 19. Effect of Management on Soil Fertility at Kolbila (Yako) in the Mossi Farming System of the Sudano-Sahelian Zone.

Management Ring	Fallow	3B	3A	2B	2A	1B	1A
Soil: Zingadega.							
Sampled fields	(4)	(5)	(5)	(1)	-	(5)	(6)
Organic Matter %	3.4	2.2	2.6	1.3	-	2.2	2.7
N %	.13	.10	.09	.06	-	.09	.12
Av. P. ppm	2.3	3.2	2.8	10.6 **	-	22 **	57 **
Exch. bases me/100g	6.8	8.1	7.0	4.0	-	10.6	17.8
C.E.C. me/100g	7.3	7.1	7.1	2.7	-	7.8	9.5 *
PH, Water	6.4	6.9	6.8	7.6	-	7	7.4
Soil: Zimuougou							
Sampled fields	(3)	(6)	-	(2)	-	(9)	(4)
Organic Matter %	1.1	1.2	-	1.2	-	1.1	1.3
N %	.05	.05	-	.04	-	.05	.06
Av. P. ppm	.96	1.3	-	1.6	-	4 *	30.5 **
Exch. bases me/100g	7.6	5.4	-	4	-	5.4	7.9
C.E.C. me/100g	7	6.6	-	4.7	-	4.7	5.4
PH, Water	6.5	6.3	-	6.5	-	7	7.4
Soil: Tampouré							
Sampled fields	-	-	-	-	-	3	-
Organic Matter %	-	-	-	-	-	3.1	-
N %	-	-	-	-	-	.12	-
Av. P. ppm	-	-	-	-	-	67.0	-
Exch. bases me/100g	-	-	-	-	-	5.9	-
C.E.C. me/100g	-	-	-	-	-	4.8	-
PH, Water	-	-	-	-	-	7.8	-
Soil: Rassempouiga							
Sampled fields	3	1	1.	1	-	-	-
Organic Matter %	1.7	1.9	1.6	1.8	-	-	-
N %	.07	.08	.06	.7	-	-	-
Av. P. ppm	1.0	1.2	.9	1.7	-	-	-
Exch. bases me/100g	4.3	3.8	15.1 *	29.3 **	-	-	-
C.E.C. me/100g	5.4	3.8	18.1 *	30.0 **	-	-	-
PH, Water	5.7	6.1	5.7	6.8	-	-	-

Table 21. The Effect of Management on Soil Fertility at Koho (Boromo) in the Bwa-Dagari Farming System of the Northern Guinean Zone.

	Fallow	2C	2Bm	1Co	1Bo	1Ap	1Ai
Soil: Tamissougo.							
Number of sampled fields	5	9	15	3	4	1	3
Organic Matter %	1.20	0.9	1.1	1.5	0.9	0.9	1.20
Total Nitrogen N %	.043	.04	.05	.06	.04	.043	.05
Available Phosphorus, ppm	2.9	5.8	7.5	17.1	10.4***	5.7**	40.4***
Excahngeable Bases (me/100g)	2.5	3.74	4.8	4.5**	4.2**	4.9**	7.6***
C.E.C. me/100g	2.9	3.7	5.0	3.8	2.8	2.8	6.4**
PH, H_2O	6.5	6.3	6.3	6.9	7.1**	7.5**	7.6**

Table 21 (continued)

	Fallow	2Bm	1Co	1Bo	1Ap
Soil: Ba-Diahon (Lowland soil)					
Number of sampled fields	2	3	2	2	-
Organic Matter %	1.15	1.0	1.1	0.70**	-
Total Nitrogen N %	.044	.040*	.042	.025***	-
Available Phosphorus, ppm	2.8	3.8	8.5**	8.1***	-
Exchangeable Bases (me/100g)	1.99	3.6**	4.8**	3.2***	-
C.E.C. me/100g	2.75	3.0	3.6**	2.4	-
PH, H_2O	6.0	6.5	7.1	6.9	-

- Soil - Ring	Soil: Hanin Fallow	2 C			Soil: Tampoure 1Ap
Number of sampled fields	5	1	-	-	1
Organic Matter %	1.04	1.24	-	-	2.97
Total Nitrogen N %	.044	.045	-	-	.126
Available Phosphorus, ppm	3.4	2.7	-	-	93.5
Exchangeable Bases (me/100g)	1.97	3.83	-	-	50.4
C.E.C. me/100g	2.86	4.75	-	-	9.63
PH, H_2O	5.6	6.1	-	-	8.2

At Koho, in the northern guinean zone soil fertility is more or less maintained or improved on uplands with often significant increases in available phosphorus, exchangealbe bases, cation exchange capacity and PH. However significant declines in the organic matter content are observed in lowland soils (Ba, Diahon) with significant increases in available phosphorus and exchangeable bases.

In conclusion, the present soil and crop management practices observed in the four villages in general maintain or even improve the chemical fertility of the soils on uplands. Although some few declines in the organic matter content of the soils are observed, they are not statistically significant, whereas significant increases in at least the available phosphorus content of the soils are observed everywhere.

On lowlands however, the current soil and crop management practices may lead to declines in soil fertility, as significant declines in the organic matter content of the soils are observed along with slight increases in available phosphorus.

Overall the chemical fertility of the soils is low. It is however well maintained or improved in the cereal security fields where organic manures are applied, and particularly within the first rings. The latter do not make up in general more than 30 percent of cultivated areas, therefore about 70 percent of cultivated areas, do not receive adequate amounts of organic and mineral fertilizers to imporve their fertility levels.

9.3. The Physical Status of the Soil.

In the Nonghin village (Manga) farmers claimed that prior to settlement in zone 2 (Figure 5) the soil was sandy (Binsiri) and that it became sandy gravelly (Kuigdiga) only after many years of cultivation. This implies that cultivation may induce serious changes in the soil physical status. Investigations through soil profiles analyses and analyses of fields ages (years of cultivation since the last long fallow period) showed that fields in zone 1 had been cultivated longer than fields in zone 2 and that the B layer of sandy soils (Binsiri) is made of cimented quartzite gravels and ferrugineous concretions. Since the A sandy layer is shallow (20-30 cm), cultivation could have led to a destabilisation of the B layer thus causing some of the gravels and ferrugineous concretions of the B layer to mixt up with the sandy A layer. As suggested by Table 5 and the compact nature of the B layer, the change from Binsiri soil to Kuigdiga soil could lead to a drop in the fields moisture retention capacity of the soil, thereby worsening the drought related problems faced by the farmers.

To investigate the possible effects of management on the physical status of the soil the particle compositions in the various management rings have been compared for each given soil type. In addition, the degrees of soil erosion observed in each field have been subjectively evaluated as either low, medium or high during the surveys, and have been compared across the management rings.

The results shown in Table 22 suggest that in Nonghin (Manga) a greater intensity of land use may indeed lead to some increase in the gravels or ferrugineous concretions content of the soil, but with no significant effect on the analytical fraction of the soil (particles with diameter equal or less than 2 mm). As previously explained this may be due not only to erosion but also to some mixage of the two adjacent upper layers made possible by the fact that the first sandy layer is shallow, that most farmers in the village use animal traction implements, that fields in ring 1 are frequently ploughed before planting, that when harvesting maize or ploughing the field the roots are pulled off the ground and thus may be seen as a soil destabilisation factor.

In contrast, at Kolbila, less ferrugineous concretions are observed on the rocky gravelly soil Zingadega when moving closer to the compound. This could be explained by the fact that ferrugineous concretions of Zingadega can be broken down with more intensive cultivation whereas quartzite gravels of the soils in Nonghin cannot.

At Kolbila, there is overall a slight decline (generally not significant) in the clay content of the two major soils (Zingadega and Zimuougou) when moving from fallows to cultivated lands. The same observation applies to the major soil at Koho (Boromo).

Table 22. Effect of Management on Soil Texture in All Villages.

A. Nonghin (Manga) in the Sudan Zone.

	Fallow	Ring 3	Ring 2	Ring 1
Soil Binsiri (S20)				
Refuses %	14	13	13	22*
Sand %	70	65	76	71
Silt %	23	23	17	22
Clay %	7	12	7	7
Soil Kougri (S10)				
Refuses %	43	33	47	-
Sand %	70	72	71	-
Silt %	19	18	19	-
Clay %	11	10	10	-

B. Kolbila (Yako) in the Sudano Sahelian Zone.

	Fallow	3B	3A	2B	2A	1B	1A
Soil Zimuougou							
Refuses %	1.4	2.3	-	0.8	-	4.5	1.7
Sand %	35	32	-	36	-	38	43
Silt %	43	49	-	48	-	42	38
Clay %	22	19	-	17	-	20	16
Soil Zingadega							
Refuses %	44	50	44	22	-	24	24
Sand %	41	48	30	54	-	49	47
Silt %	38	37	42	32	-	34	38
Clay %	21	16 *	18	14*	-	17	16*

Table 22 (continued)

C. Ouré (Djibo) in the Sahel.

	Fallow	3	2C	2B	2A	1B	1A
Soil Senon							
Refuses %	0.14	0.4	0.4	0.3	0.6	0.2	1.1
Sand %	75	84	86	85	88	85	87
Silt %	19	11	9 **	9 **	6.5 **	9.8 **	8 **
Clay %	5.6	5.2	5.4	5.3	5.8	5.0	5.6

D. Koho (Boromo) in the Northern Guinean Zone.

	Fallow	2C	2Bm	1Bo	1Ap	1Ai
Soil Tamissougo - Hapono - Fiaho.						
Refuses %	2.6	0.7	2.4	3.5	1.1	8.1
Sand %	59	67	64	64	63	66
Silt %	31	26	28	29	35	26
Clay %	11	7	9	8	8	8

At Ouré, in the Sahel, an often significant decline in the silt content of the sandy soil Senon is observed from fallows to cultivated lands.

Overall the observed changes in the soil texture are likely to have adverse effects on the moisture retention capacities of the soils. Given the prevailing semi arid conditions this could agravate the adverse effects of drought on food crop production in the future.

Furthermore analysis of the subjective evaluation of the degrees of soil erosion (Table 23) across the management rings suggest that:

At Nonghin (Manga) the degree of soil erosion is lower where the intensity of land utilisation is higher. This implies that the explicit and implicit soil conservation measures such as dykes and late ridges which are assosicated with greater intensity of land utilisation in the village help to reduce soil erosion and/or that land use intensification is higher mostly in areas where the incidence of soil erosion is lower.

At Kolbila (Yako) the degree of soil erosion in the less intensively cultivated rings (2B, 3A, 3B) is also on average higher than the degree of soil erosion in the more intensively cultivated rings (1A, 1B, 2A). The implication is the same as above; however the average degree of soil erosion is substantially higher at Kolbila, in the northern part of the Mossi Plateau. This is probably due to the fact that the topography is more accidented at Kolbila, in the north, than at Nonghin, in the south, this leading to a greater incidence of soil erosion at Kolbila. This may also be explained by the fact that implicit soil protection measures such as late ridging perpendicularly to the slopes is notpracticed in the Yako region while it is a commun practice in the Manga region.

At Ouré (Djibo), soil erosion is a serious problem in the lowlands where the type 4 fields are found. On uplands, contrary to what was observed in the Mossi Plateau, the degree of soil erosion appears lower in the less intensively cultivated millet and legumes fields (type 3, complementary food security fields) than in the more intensively cultivated millet fields (type 2, minimum food security fields). This is probably due to the shifting livestock padockings in the type 2 fields, which may speed

Table 23. Management and Degrees of Soil Erosion (Percentages of fields per management type for all soil types).

A. Nonghin (Manga) in the Sudanian Zone.

Degree of Soil Erosion	Management Ring		
	Ring 3	Ring 2	Ring 1
Low	72	84	100
Medium	28	16	0
High	0	0	0

B. Kolbila (Yako) in the Soudano-Sahelian Zone.

Degree of Soil Erosion	Management Ring					
	3B	3A	2B	2A	1B	1A
Low	48	50	55	71	42	57
Medium	16	25	29	19	53	43
High	36	25	16	10	04	0

C. Ouré (Djibo)

Degree of Soil Erosion	Management Type							
	Lowland	3	2C	2B	2A	1C	1B	1A
Low	0	68	33	40	12	100	100	80
Medium	45	23	55	60	76	0	0	20
High	55	9	12	0	12	0	0	0

D. Koho (Boromo)

Degree of Soil Erosion	Management									
	2D	2Bm	2C	2A	1Bm	1Co	1Bo	1Ap	1Ai	R
Low	33	77	74	75	100	77	85	69	79	04
Medium	67	23	24	13	0	23	15	23	21	87
High	0	0	2	12	0	0	0	8	0	9

E. Sayero (Boromo)

Degree of Soil Erosion	Management									
	2A	2Bm	2C	2A	1Bm	1Co	1Bo	1Ap	1Ai	R
Low	100	95	93	100	90	100	60	60	60	33
Medium	0	5	7	0	10	0	37	40	40	67
High	0	0	0	0	0	0	3	0	0	0

up the erosion of the soil by the wind. It may also be due to the fact that fonio, viewed by most farmers as a soil conserving and improving crop is mostly planted in the type 3 fields. The degree of soil erosion in the maize fields (type 1) is the lowest because of the more compact nature of the soil in such fields. The compaction is due either to the soil type itself (i.e. Houkawo soil) or to the fact that most maize fields are wet season livestock parks.

In the northern guinean zone (Boromo), contrasting results are obtained for the two villages. At Koho, the degree of soil erosion is on average lower in the first ring, which is more intensively cultivated, than in the second ring which is less intensively cultivated. The opposite case is observed at Sayero. The explanation of this contrast may be the fact that Sayero is located on lower and less flat lands than Koho, with most first ring fields located on Soumsoumbi or Ba soils near or inside the lowlands. Therefore, the incidence of soil erosion is much higher at Sayero than at Koho, and the intensive management practices of the first ring do not in such a case help to conserve the soil. On the contrary, they appear to speed up its erosion. This appears to be particularly true in the rice/maize fields of subring R as suggested by Table 23 E.

One may conclude that on the generally flat uplands of the sudanian and northern guinean zones, the Mossi and Bwa soil and crop management practices do not in general lead to greater soil erosion when cultivation is intensified. The more intensive management practices, because of some few accompanying explicit or implicit soil conservation measures, appear to result in less soil erosion than the less intensive management practices. The reverse appears to be true in the millet fields of the Peuhl-Rimaibe farming systems in the Sahel. In any case, the less flat the local topography the less succesful the management practices are in reducing soil erosion. This is particularly true in lowlands where soil erosion is in general fairly high.

CHAPTER 10.

LABOR UTILISATION AND RETURNS TO LABOR.

10.1. Planting Strategy and the Crop Calendar.

As shown by Table 24, in the villages of the Mossi Plateau and of the Sahel, seedbed preparation and planting generally begin in the minimum food security fields. These are followed by the complementary food security fields in a second position, by the cash and social obligation fields in a third position and finally by the hungry season and spices fields. In the Sahel however, the legumes fields (groundnuts and bambara nuts fields) which are the major cash and social obligation crops are planted after the hungry season maize and spices fields.

In the northern guinean zone, planting begins with millet and sorghum in the complementary food security fields before the minimum food security fields. It ends in the hungry season fields and in the cash and social obligations fields. One reason is because the risk of crop failure by moisture stress is much lower in the northern guinean zone, comparatively with the other agroclimatic zones. Consequently less replantings are necessary for a good crop success, thus, there is less need to start planting early in the minimum food security fields so as to maximize the chances of crop success with as much replantings as needed. Another reason is that in the zone, soil preparation (plowing or scarification) is rarely practiced in the complementary food security fields during the cereal years of the rotations. It is practiced in such fields only during the legumes and cotton years of the rotations, whereas a relatively deep soil preparation is commonly practiced in most minimum food security fields even during the cereal years of the rotations. Co nsequently planting starts later in the minimum food security fields to allow sufficient humidification of the soil and to prepare the soil before planting.

In all four agroclimatic zones, planting within each of the defined groups of fields usually starts on the soils with the best field moisture retention capacity and with the crops or varieties which have the longuest growth cycles. The latter principle is a major guide of the global planting strategy and it explains why maize, the major hunger season cereal is planted after sorghum and millet which have longer growth cycles. Nevertheless, medium cycle sorghum varieties which can be sufficiently replanted during the season to escape drought are prefered and planted first (Mossi Plateau) or later (northern guinean zone) in the minimum food security fields.

Furthermore, the planting strategy is also sometimes influenced by the probability of crop damage by livestock where there is a shortage of children labor to guard the fields and/or the livestock. There is a tendency, in such a case, to plant fields where such a probability is low earlier than fields where such a probability is high, awaiting a greater availability of labor to guard the fields and/or the livestock.

In the most general case of the Mossi Plateau and of the Sahel, planting in the minimum food security fields begin right after the first "good" rains as one may notice by comparing the rainfall distributions in Table 25 with the crop calendars in Table 24. Planting in the complementary food security fields is done after the following good rains. However, dry planting is also often practiced in both the minimum and the complementary food security fields to save time and plant as much area as possible once the rains begin. Weeding also generally begin in the minimum food security fields followed by the complementary food security fields and finally by the maize and legume fields.

In all the agroclimatic zones, maize of the hungry season fields is always the first crop harvested during the season, followed by the legumes of the cash and social obligations fields, in addition to fonio in the Sahel.
Afterwards, the major cereals of the minimum food security fields are harvested. Cereals of the complementary food security fields and other cash crops such as cotton and tubers or roots are generally harvested last.

Table 24. Management and Timing of Season Activities.

A. Nonghin (Manga) in the Sudanian Zone.

Activity for Major Crops	Hungry season and spices fields Ring 1	Minimum food security fields Ring 2	Complementary food security & cash fields Ring 3
Soil Preparation (May 1=Day 1)			
Maize	45 (6)	-	-
Red sorghum	-	18 (14)	-
Millet	-	-	25 (20)
Groundnuts	-		49 (9)
Date of First Planting			
Maize/sauce plants	49 (14)	-	-
Red sorghum	-	20 (14)	-
Millet/white sorghum	-	-	29 (20)
Groundnuts	-	42 (16)	42 (16)
Date of First Weeding(May 1=1)			
Maize	67 (13)	-	-
Red sorghum	-	46 (14)	-
Millet/white sorghum	-	-	64 (20)
Groundnuts			79 (9)
Date of Late Ridging(May 1=1)			
Red sorghum	-	112 (29)	-
Millet/white sorghum	-	-	136 (29)
Harvest			
Maize	125 (9)	-	-
Red sorghum	-	157 (9)	-
Millet/white sorghum	-	-	190 (9)
Groundnuts			

* Figures in parentheses are the standard errors.

Table 24 (continued)

B. Kolbila in the Sudano Sahelian Region.

Dates, beginning May 1 and crops	Hungry season and spices + cash tubers.		Minimum food security and cash		Complementary security and cash	
	1A	2A	1B	2B	3A	3B
<u>Date of Soil Preparation</u>						
Maize	72 (6)	63 (5)	-	-	-	-
Tuber-roots	-	124	-	-	-	-
Sorghum & Millet	-	-	26 (5)	34 (5)	-	-
Cotton	-	-	39	-	60	45
Rice	-	-	-	54 (9)	-	68
Groundnuts	-	-	-	-	-	64
<u>Date of 1st planting 1st crop</u>						
Maize	74 (5)	65 (5)	-	-	-	-
Tuber roots	-	45	-	-	-	-
Sorghum & Millet	-	-	33 (7)	37 (10)	38 (11)	38 (11)
Cotton	-	-	39	-	61	46 (8)
Rice	-	-	-	63 (3)	-	70
Groundnuts	-	-	-	-	-	67 (14)
<u>date of First Weeding</u>						
Maize(& tubers roots)	93 (6)	89 (6)	-	-	-	-
Sorghum & Millet	-	-	62 (14)	72 (9)	74 (16)	78 (16)
Cotton	-	-	70	-	92	85 (10)
Rice	-	-	-	96 (15)	-	110
Groundnuts	-	-	-	-	-	105 (3)
<u>Date of Harvest</u>						
Maize	140 (6)	135 (9)	-	-	-	-
Tuber roots	-	209 (13)	-	-	-	-

Table 24 (continued)

C. Ouré (Djibo).

Dates of Activities May = 1 Day 1	Hungry season and spices fields			Minimum food security fields			Compl. food security & cash	Minimum food security
	1A	1B	1C	2A	2B	2C	3	4
Date of soil preparation								
Maize/spices	69 (127)	67 (19)	77 (10)	-	-	-	-	-
Millet	-	-	-	-	-	-	-	-
Sorghum	-	-	-	-	-	-	-	-
legumes	-	-	-				84 (8)	-
Fonio	-	-	-	-	67	-	64 (3)	-
Rice	-	-	-	-	-	-	-	50
Date of 1st planting 1st crop								
Maize/spices	69 (13)	67 (10)	77 (10)	-	-	-	-	-
Millet	-	-	-	52 (3)	56 (9)	59 (10)	58 (7)	-
Sorghum	-	-	-	-	-	-	-	60 (5)
Legumes	-	-	-				84 (3)	-
Fonio	-	-	-	-	67	-	64 (13)	-
Rice	-	-	-	-	-	-	-	65
Date of 1st weeding								
Maize/spices	98 (10)	89 (7)	99 (9)	-	-	-	-	-
Millet	-	-	-	78 (8)	75 (9)	84 (7)	85 (11)	-
sorghum	-	-	-	-	-	-	-	86 (7)
Legumes	-	-	-	-	-	-	126 (10)	-
Fonio	-	-	-	-	-	-	-	-
Rice	-	-	-	-	-	-	-	100
Date of Harvest 1st crop								
Maize/spices	138 (8)	133 (11)	145 (11)	-	-	-	-	-
Millet	-	-	-	171 (6)	173 (5)	175 (9)	177 (7)	-
Sorghum	-	-	-	-	-	-	-	186 (4)
Legumes							171 (8)	-
Fonio					151		157 (6)	-
Rice								168

* Figures in parentheses are the standard errors.

Table 24 (continued) Management and Crop Calendar.

D. Sayero (Boromo) in the Northern Guinean Zone.

Type of field and ring	Hungry season and spices		Minimum food security and cash			Complementary food security and cash		Cash		Hungry season and cash
	1Ai	1Ap	1Bo	1Bm	1Co	2C	2Bm	2A	2D	R
Date soil preparation										
Maize	32 (13)	na								16 (3)
Cotton			28 (16)		33 (17)		43 (14)		53 (16)	
sorghum			33 (21)		29 (24)	-	-			
Millet						-	-			
Rice										13 (8)
Legumes					31	32 (9)		48	89	
Date 1st planting 1st crop										
Maize	43 (10)	36 (11)	47 (19)	23 (3)						21 (2)
cotton			36 (14)	47 (9)	53 (8)		43 (14)		49 (17)	
Sorghum			33 (19)	44 (19)	39 (12)	18 (8)	27 (19)			
Millet						18 (4)	13 (7)			
Rice										28 (14)
Legumes					51	36 (11)		59	104	
Date First Weeding										
Maize	71 (22)	50 (10)	63 (14)	44 (7)						58 (18)
Cotton			63 (16)	74 (9)	76 (22)		75 (18)		81 (22)	
Sorghum			62 (25)	70 (3)	74 (33)	65 (15)	62 (21)			
Millet						59 (13)	63 (9)			
Rice										65 (25)
Legumes					84	62 (16)		94	154	
Date Harvest.										
Maize	137 (10)	125 (10)	142 (13)	125 (6)	-					115 (7)
Cotton			185 (14)	189 (16)	199 (18)		205 (17)		201 (18)	
Sorghum			172 (8)	173 (1)	169 (2)	200 (7)	185 (14)			
Millet			-			206 (10)	204 (6)			
Rice										178
Legumes					168	160 (4)		168		

Table 25. 1981 Rainfall Distribution in the Study Villages (mm of rainfall)

A. Nonghin (Manga) in the Sudanian Zone (884 mm, 57 days).

Week of the month	Day of the month	March	April	May	June	July	August	Septem	Octob
1	1 - 7	37.5	-	19.2	18.1	54	42	60	4
2	8 - 14	-	-	26.0	14.2	57	82	55.2	6.4
3	15 - 22	-	1	-	48.2	72	81	25	-
4	23 - 30	-	10.3	58.5	26.0	68.2	18	-	-
Monthly Rainfall (mm)		37.5	11.3	103.7	106.5	251.2	223	140.2	10.4
Days of Rains		1	2	6	9	15	14	8	2

B. Kolbila (Yako) in the Sudano-Sahelian Zone (716 mm, 53 days).

Week of the month	Day of the month	March	April	May	June	July	August	Septem	Octob
1	1 - 7	-	-	23.5	44	54	14.5	11.5	-
2	8 - 14	-	-	-	5	64	106.5	55.0	-
3	15 -22	-	-	10.8	8	5	35.0	-	-
4	23 - 30	9	-	23.5	71	77	59.5	39	-
Monthly Rainfall (mm)		9	0	57.8	128	200	215.5	105.5	0
Days of Rains		1	0	8	10	11	17	6	0

Table 25. (continued)

C. Ouré (Djibo) in the Sahel. (445 mm, 35 days)

Week of the month	Day of the month	March	April	May	June	July	August	Septem	Octob
1	1 - 7	-	-	43	-	11.5	25	15	-
2	8 - 14	-	-	-	-	24.5	15	5	4
3	15 - 22	-	-	-	10	4.5	35	45	-
4	23 - 30	-	-	6	54.5	74	46	31	-
Monthly Rainfall (mm)		0	0	49	64.5	114.5	121	96	4
Days of Rains		0	0	2	4	10	10	8	1

D. Sayero (Boromo) in the Northern Guinean Zone (916 mm, 46 days).

Week of the month	Day of the month	March	April	May	June	July	August	Septem	Octob
1	1 - 7	-	-	6	17	16	61	71.5	9
2	8 - 14	-	-	13	9	72	104	60	-
3	15 -22	-	-	45	27	64	49	-	-
4	23 - 30	-	-	30	56.5	103.5	102	-	-
Monthly Rainfall (mm)		0	0	94	109.5	255.5	316	131.5	9
Days of Rains		0	0	6	6	15	14	4	1

10.2. The Labor Profile.

In general, the largest amounts of production labor per hectare are recorded in the hungry season and spices fields, followed by the minimum food security fields. The smallest amounts of production labor per hectare are recorded in the complementary food security fields. Labor used in cash and social obligations fields is in general greater than that used in complementary food security fields. It is sometimes as much or greater than labor used in minimum food security fields. This is particularly true for tuber-roots and rice fields.

In both manual and animal traction fields, significant changes in labor allocation across the different types of fields are observed mostly for the following activities: soil preparation, soil fertilization and weeding.

Soil preparation labor is generally greatest in the hungry season and spices fields, and in the legumes and tuber-roots cash fields. In the food security fields, it is generally greater in the minimum food security fields than in the complementary food security fields.

Soil fertilization labor is in any case greatest in the hungry season and spices fields, followed by the minimum food security fields. It is lowest in the complementary food security fields where it is used for mineral fertilizer applications only.

Weeding labor is in general greater in the minimum food security fields than in the complementary food security fields. It is greatest in the hungry season fields of the two most humid agroclimatic zones (i.e. the northern guinean and sudanian zones).

Where animal traction implements are not widely used, such as at Kolbila (Yako) and Ouré (Djibo), more soil preparation is observed in animal traction food security fields as compared with hand tool food security fields. The adoption of animal traction implements thus begins in the minimum food security fields with the emphasis placed on soil preparation (mostly line tracing scarification and some plowing).

Since soil preparation is not commonly practiced in food security fields in absence of animal traction implements, the shift to animal traction implement, by enhancing this activity leads to an increase in the amount of labor allocated to soil preparation. The tendency therefore is for total production labor to increase because the other activities such as planting and weeding continue to be done manually. However this does not happen in most cases because the amount of labor allocated to the other activities done manually tend to fall either because they are done less intensively (or less carefully) as compared with hand tool fields or because they are made easier by the row planting which results from the soil preparation itself.

The learning process for the use of the animal traction implements also has a major influence on labor required to complete the activities. Where the animal traction technology has been introduced for a long time and is well mastered such as in Boromo and particularly in Manga, the animal traction technology is extended to other activities and types of fields, and has a depressing effect on labor requirements in most cases.

In any case the animal traction implements are more intensively used in minimum food security fields and in cash fields than in complementary food security fields.

A summary of the labor data, from which the above conclusions are drawn, is presented in Tables 26, 27, 28 and 29 below.

Table 26. Management and Labor Profiles at Nonghin (Manga) (Animal Traction Fields.)

Labor Hours/ha per Activity	Hungry season and spices fields	Minimum food security and cash fields	Complementary food security and cash fields
	Ring 1	Ring 2	Ring 3
Manual Field cleaning	39	44	43
Seedbed Preparation with A.T.	56	49	45
Manual Seedbed Preparation and Planting	171	141	101
- Weeding			
- with hand tools	300	191	112
- with Animal Traction	14	81	45
Late Ridging *			
- with hand tools	15	23	32
- with Animal Traction	4	47	27
Production Labor Hours/ha	600	576	405
Harvest Hours/ha	200	150	100
A.T. Equipment Hours/ha			
- Seedbed Preparation	24	21	17
- Weeding	5	35	20
- Late Ridging	3	26	10

* Both Animal Traction implements and hand tools are used in the same fields to complete these operations.

Table 27. Management and Labor Profiles at Kolbila (Yako).

A. Hand Tool Fields. (Hours/ha)

Type of Fields	Hungry season spices and cash fields		Minimum food security fields		Complementary food security and cash fields	
	1A	2A	1B	2B	3A	3B
Field clearing	110	38	89	58	40	71
Manual soil preparation	412	1343	34	3	4	4
Planting	186	365	261	285	178	256
Fertilization	421	845	91	34	12	0
Weeding	368	275	1040	773	440	600
Production Labor	1497	2866	1515	1153	674	931
Harvest	223	332	314	379	256	233
Total Labor	1720	3198	1829	1532	930	1164
Animal Hours, Manure Transport	16	18	01	02	0	0

B. Animal Traction Fields. (Hours/ha)

Field clearing	51	-	45	25	69	71
Manual soil preparation	0	-	13	12	0	0
A.T. soil preparation	206	-	123	73	25	213
Planting	154	-	377	176	107	175
Fertilization	184	-	44	44	0	0
Manual weeding	253	-	753	450	464	1245
A.T. weeding	0	-	0	20	0	0
Production Labor	848	-	1355	800	665	1704
Harvest	162	-	353	283	520	331
Total Labor	1010	-	1708	1063	1185	2035
A.T. Equipment Hours-soil Prep.	66	-	55	34	10	91
- weeding	0	-	0	7	0	0
- Manure transportation	0	-	3	14	0	0

Table 28. Management and Labor Profiles at Ouré (Djibo)

A. Hand Tool Fields. (Hours/ha)

Type of Fields	Hungry season and spices fields			Min. food security fields			Compl.food sec. and cash fields		Min.food security fields
	1A	1B	1C	2A	2B	2C	millet	other	4
Field clearing	0	6	0	11	3	2	3	3	55
Soil preparation	120	172	185	0	0	2	0	93	0
Planting	59	100	82	27	32	24	36	85	75
Fertilization	44	139	543	12	11	5	0	0	0
Weeding	137	196	250	210	254	196	240	64*	390
Production Labor	360	613	1060	260	300	229	279	245	520
Harvest Labor	88	140	64	100	56	62	74	203	175
Total Labor	448	753	1124	360	356	291	353	448	695
Animal Hours Manure Transp.	0	0	0	0	0	0	0	0	0

* Low value because include fonio and legumes fields fonio fields are not weeded.

B. Animal Traction Fields (Hours/ha)

Manual field clearing	0	0	-	8	3	-	0	0	-
Manual soil prep.	0	0	-	0	0	-	0	13	-
A.T. soil prep.	83	98	-	8	22	-	19	39	-
Manual planting	82	204	-	27	50	-	34	53	-
Fertilization	0	74	-	10	5	-	0	0	-
Manual weeding	65	262	-	108	244	-	138	96	-
A.T. weeding	0	34	-	20	9	-	0	0	-
Production Labor	230	672	-	181	333	-	191	201	
Harvest	115	74	-	65	97	-	41	220	
Total Labor Hours	345	746	-	246	430	-	232	421	
A.T. Equipmt Hours									
soil crop	28	40	-	3	8	-	9	23	
weeding	0	17	-	5	3.5	-	0	0	
manure transport.	-	0	-	1	1	-	1		

Table 29. Management and the Labor Profiles at Sayero (Boromo)

A. Hand Tool Fields. (Hours/ha)

Type of Field	Hungry season and cash			Minimum food security and cash			Complementary food sec. and cash		Cash and social obligations	
Labor Hours/ha per Activity	1Ai	1Ap	R	1Bo	1Co	1Bm	2C	2Bm	2D	2A
Field clearing hrs/ha	0	44	0	37	12	38	38	30	107	195*
Manual soil preparations	120	138	96	60	51	72	17	14	36	58
Planting	160	96	151	74	51	40	77	60	36	432*
Fertilization	na	124	64	37	16	4	0	4	16	2
Weeding	330	403	283	275	220	220	300	232	83	295
Production Labor	+610	805	594	483	350	374	432	340	278	982
Harvest	100	300	208	470	215	253	178	220	153	347
Total Labor	+710	1105	802	953	565	627	610	560	432	1229
Manure Transport with A.T. hrs	-	21	17	4	5	0	0	0	0	0

* Labor requirement = high in newly opened sesame fields.

B. Animal Traction Fields. (Hours/ha)

	Hungry season and cash			Minimum food security and cash			Complementary food sec. and cash		Cash and social obligations	
	1Ai	1Ap	R	1Bo	1Co	1Bm	2C	2Bm	2D	2A
Field clearing	18	10	100	37	21	44	-	22	42	5
Manual soil prep.	90	114	740	11	0	9	-	17	29	0
A.T. soil prep.	77	113	478	40	22	47	-	45	39	49
Manual planting	110	117	453	64	85	87	-	73	69	61
Fertilization	16	302	442	66	20	28	-	5	15	0
Manual weeding	471	211	1103	292	194	242	-	132	211	246
A.T. weeding	0	0	0	0	8	0	-	7	2	0
Production Labor	782	869	3316	510	350	457	-	301	407	361
Harvest Labor	208	210	1480	772	192	314	-	302	523	340
Total Labor	990	1079	4796	1282	542	771	-	603	930	701
A.T. Equipment Hours										
soil preparation	21	33	96	11	5	13	-	14	13	16
weeding	0	0	0	0	2	0	-	2	1	0
manure transport	17	20	0	9	3	0	-	0	6	0

10.3. Returns to Labor.

Return to labor was overall highest in the hungry season maize and spices fields, followed by the minimum food security fields. It was overall lowest within the complementary food security fields and within the cash and social obligations fields planted with legumes or cotton. Consequently, it was moderately high in double function fields such as hungry season and cash field, and minimum food security and cash fields.

In other words, and as suggested by Table 27 below, the return to labor generally increases with the level of management and with land use intensification in a given village. The return to one hour of total labor, including production and harvest labor, in the minimum food security fields generally revolves around the harvest period value (producer price) of one kilogram of cereals food grain.

At Nonghin (Manga), it was slightly above the harvest period value of one kilogram of food grain (millet and white sorghum). At Kolbila (Yako) it was about two thirds of the harvest period value of one kilogram of food grain, which roughly coincides with the value of the daily consumption of food grain per head (about .70 kg, see Appendix C). At Ouré (Djibo) and Sayero (Boromo) it was fairly above the average harvest period producer price of one kilogram of cereal.

The return to one hour of total labor in the complementary food security fields was in general less than the harvest period producer price of one kilogram of cereal in the complementary food security fields. It was in most cases equal or greater than the harvest period value of 0.5 kilogram of cereal food grain. It was exceptionally greater than the harvest period value of one kilogram of cereal at Ouré (Djibo) in the Sahelian extensive farming system, where the minimum labor requirement to achieve an average millet grain yield of about 400 kg per hectare appears to be the lowest of all four farming systems.

On the Mossi Plateau and in the Sahel, the return to animal traction labor appears as high or greater than the return to hand tool labor mostly in the older and better manured hungry season and minimum food security fields. With the exception of the Sahelian system, the opposite case is observed in the complementary food security fields where the animal traction implements are mostly used for breaking the soil surface in newly cleared bush fields during the seed-bed preparation activity. Regarding the northern guinean zone, the evidence from Sayero does not fully support this conclusion.

Tableau 30 . Management and Returns to Labor (CFA/hour).

A. Nonghin (Manga) A.T. Fields.

Type of field	Hungry season and spices Fields	Minimum Food Security Fields			Complementary Food Security and cash fields
	1A	2A	2B	2C	3
Return to 1 hour of Production Labor (excludes harvest) CFA/hour	326	92	90	79	50
Return to 1 hour of total labor (includes harvest) CFA/hour	244	73	66	62	38

B.1. Kolbila (Yako) Hand Tool Fields.

Type of field	Hungry Season and cash Fields		Minimum Food Security Fields		Complementary Food Security and Cash Fields	
Management	1A	2A	1B	2B	3A	3B
Return to 1 hour of Production Labor CFA/hour	51	73	40	30	36	34
Return to 1 hour of total labor CFA/hour	44	65	32	22	26	27

B.2. Kolbila (Yako) Animal Traction Fields.

Return to 1 hour of Production Labor CFA/hour	87	-	43	39	36	17
Return to 1 hour of Production Labor CFA/hour	73	-	33	29	20	14

C.1. Ouré (Djibo) - Hand Tool Fields.

Type of field	Hungry Season and Spices Fields			Minimum Food Security Fields			Compl Food Secu. & cahs	Minimum Food Security
Management	1A	1B	1C	2A	2B	2C	3	4
Return to 1 hour of Production Labor	100	89	15	144	97	120	104	50
Return to 1 hour of Total Labor	81	72	14	104	82	94	82	37

C.2. Ouré (Djibo) - Animal Traction Fields.

Return to 1 hour of Production Labor CFA/hour	132	57	-	198	80	-	142	-
Return to 1 hour of Total Laobr CFA/hour	88	51	-	145	62	-	116	-

D.1. Sayero (Boromo) Hand Tool Fields

Type of field	Hungry Season and Spices Fields			Minimum Food Security and Cash Fields			Complementary Food Security and Cash		Cash and Social Obligations	
Management	1Ai	1Ap	R	1Bo	1Co	1Bm	2C	2Bm	2D	2A
Return to 1 hour of Production Labor. CFA/hour	163	123	168	121	90	105	61	79	64	26
Return to 1 hour of Total Labor CFA/hour	140	90	126	62	56	62	44	48	42	21

D.2. Sayro (Boromo) Animal Traction Fields.

	Hungry Season, Spices and cash Fields			Minimum Food Security and Cash Fields			Complementary Food Security and Cash		Cash and Social Obligations	
	1Ai	1Ap	R	1Bo	1Co	1Bm	2C	2Bm	2D	2A
Return to 1 hour of Production Labor. CFA/hour	120	104	29	108	86	82	-	82	42	65
Return to 1 hour of Total Labor CFA/hour	94	84	20	43	55	49	-	41	20	34

(a) These are actually the returns to land and labor, taken as returns to labor because of the zero explicit cost of land. The returns were computed by deducting from the value of output per hectare, the following costs per hectare: The cost of mineral fertilizer, the cost of seeds, and the service costs of Animal traction equipments. The latter include the animal maintenance and feeding cost, all evaluated at 13000 CFA/year for donkey equipment, at 5000 CFA/year for cart alone, at 13000 CFA/year for oxen drawn equipment because of the appreciation of the oxen. (Barett et al, 1982). The total number of hours of use of the animal traction implements on the average farm were used to obtain the A.T. service cost per hour. In the Boromo area, insecticide spraying capital and labor costs were evaluated at 3500 CFA per hectare planted with cotton in 1981. Crop prices used are shown in Appendix C. Fertilizer price was 55F/kg at Boromo and 50F/kg in other zones (subsidised prices).

CHAPTER 11.

ADJUSTMENT MECHANISMS, CONSTRAINTS AND POSSIBLE SOLUTIONS. IMPLICATIONS FOR AGRICULTURAL RESEARCH AND DEVELOPMENT.

11.1 The Adjustment Mechanisms of the Farming Systems.

The question being addressed in this section is: how do the farming systems described above react to changes in their physical and socio-economic environments? More specifically the section deals with the adjustment mechanisms of the systems with respect to greater demographic pressure and market integration which press for land use intensification.

The adjustment mechanisms used by farming systems in the region to minimize the negative effects of exogenous changes on their production/consumption objectives have three major components which are: technological changes or innovations, structural changes mostly in the form of resource reallocation, and institutional changes (Prudencio, 1986).

Structural changes are the major components of the adjustment mechanisms vis à vis land use intensification pressures. Under such pressures the studied farming systems naturally react by increasing the farm area shares of the minimum food security fields in particular, and of the hungry season fields at the expenses of the complementary food security fields. The farm area share of the cash and social obligations fields tend to decline or increase depending on which factor is most responsible for land use intensification. Graphically, this may be described as an expansion of the inner rings with a simultaneous shrinking of the outer ring(s).

Besides these interfield structural changes, other structural changes occur at the household level, such as changes in the composition of the household population, changes in resource allocation among crop production activities, livestock production activities and off farm production activities. The most remarkable of such structural changes are emigrations and greater investments in livestock (particularly in small ruminants) and in small trade.

The major institutional change observed is an increasing individualisation of the land tenure systems in some areas, as mentioned in Section 8.2.

Regarding the interfield structural changes, the expansion of the inner rings at the expenses of the outer rings implies that the management practices that characterise the inner rings are being extended to a greater portion of the farm area. Consequently the major changes that result from such an adjustment as one may observe by looking across farms with different intensities of land use, are:

(a) An extension of organic manure applications to a larger portion of the farm area with an increase in quantities applied where only small amounts were formerly applied.

(b) An increase in mineral fertilizer applications, particularly in distant fields, with a progressive substitution of mineral fertilizers to fallow as a means of regenerating soil fertility in the outer rings.

(c) Extension of soil preparation activities (scarification or plowing) to a larger portion of the farm area mostly with animal traction implements.

(d) A greater use of soil conservation practices along with the greater use of soil tillage techniques.

(e) Substitution of crops and/or varieties: The expansion of the inner rings at the expense of the outer rings leads to a progressive substitution of the food crops and varieties preferably planted in the inner rings (hungry season fields and minimum food security fields) for those preferably planted in the outer rings (complementary food security fields). Food crops and varieties planted in the inner rings are, as discussed in section 8.12, generally viewed by farmers as:

- being more management responsive, particularly more responsive to moderate management than other crops or varieties in terms of food grain.

- having relatively shorter growth cycles than other crops or varieties, so as to allow sufficient flexibility in the date of planting and as much replantings as needed for a good crop success.

This exigence is further reinforced by the greater use of soil tillage practices and by the increasing risk of moisture stress in recent years.

- being easily sold at a relatively stable and profitable producer price when cash is needed.

(f) Intensification of cultivation in lowlands.

The search and adoption of shorter cycle varieties and intensification of cultivation in lowlands are also reactions to rainfall declines and to the greater frequency of drought in recent years.

If successfully completed such an adjustment mechanism would, as suggested by the results discussed in the previous chapters and sections, lead to an improvement of land quality management in most cases, to greater returns to labor and hence to an increase in the productivity of the farming systems. However many constraints are likely to limit or prevent the successfull completion of the adjustment process.

11.2. Constraints, Possible Solutions and Implications.

The major constraints that might prevent the successful completion of the adjustment process described above may be listed as follows:

- Low availability of organic manure
- High cost of transportation and application of organic manure
- Difficulties in acquiring mineral fertilizer for food crop production and associated risks
- Low technical efficiency of soil and water conservation practices as presently used by farmers, particularly in lowland areas
- Insufficient availability of labor saving technologies for timely seedbed preparation, planting and weeding
- Shortage of food crop varieties with adequate growth cycle and with sufficiently high and stable yields at low and moderate management levels

A - Low availability of organic manure.

Measurements of the total amounts of organic manure produced on each farm in 1981-1982 revealed that the average amount of farm yard manure produced per head and per year was 430 kg at Nonghin (Manga) and 340 kg at Kolbila (Yako). Given the fact that the area cultivated per head was .44 hectare in both villages, this implies that farmyard manure availability was about 980 kg per hectare at Nonghin (Manga) and 780 kg per hectare at Kolbila (Yako). Thus, manure availability was well below the minimum recommended level of 5000 kg per hectare and per year to raise and maintain soil fertility at an average level, in conjunction with mineral fertilizer application (Seze, 1979; Pichot et al, 1981).

There is therefore a need to increase manure availability to the farm for a safe land use intensification. Possible solutions include:

- Improvement of herders - peasants symbiotic relatinship so as to increase the availability of cattle manure to the farm. This could be done by encouraging the sedentary settlement of Peulh herdsmen around villages on the Mossi Plateau and in the western region. A prerequisite for such settlement would be a reliable availability of forage and water during the wet season as well as during the dry season in the village area to feed and water the cattle. This would require a clear delimitation of cattle routes and pasture lands around the village during the rainy season. The cattle may be fed on such pasture lands during the rainy season. Cattle manure produced during the wet season may be collected by herdsmen in wet season night parks for use in their millet fields or for sale to farmers. During the dry season, night or day padockings of the cattle on farmers fields could take place within a system whereby farmers would exchange forage produced during the rainy season for cattle manure. Water sources that do not dry up during the dry season should also be available in the village area for watering the animals during that period.

Small ruminants and draught animals kept on the farm could provide additional sources of organic manure. Research and development efforts to increase the supply of good quality forage to the animals, particularly during the dry season will certainly have a positive impact on manure production and availability.

Such efforts include improved forage production and conservation as well as improvement and rational exploitation of natural pasture lands across the country.

As the demographic pressure increases, the intensification of cultivation leads to a rarefaction of natural pastureland, to more frequent herdsmen-farmers conflicts and consequently to less and less contacts between farmers and herders. This case has been observed in the Manga area where most farmers keep their cattle on the farm and put their children in charge of guarding and feeding the animals particularly during the rainy season. At Nonghin for instance children from different households were taking turn to guard pooled herds composed of cattle and small ruminants that belong to their households. Thus under such conditions this model of livestock-cropping integration might be more feasible and more efficient. than the former.

In either case, composting using household refuses, bush grass and the dungs from cattle, donkeys and small ruminants might be the most effective way of increasing manure production on the farm. Research efforts to develop cost effective composting techniques and development efforts to promote the alternative need to be encouraged. However high cost of manure transportation and application remain a major constraint.

B - <u>High cost of organic manure transportation.</u>

High opportunity cost of organic manure transportation prevents an optimum allocation of organic manure across the various rings. Production fonction estimates shown in Appendix D suggest for instance. In the case of Nonghin (Manga) that the marginal physical productivity of one kilogram of organic manure is about .08 kg of foodgrain in the second ring and only .008 kg of food grain in the first ring. This implies that substantial gains in aggregate farm output could be achieved through a more even allocation of organic manure across the various rings so that gretear quantities are applied in fields more distant from the habitats. Such a reallocation could lead to greater economic efficiency if the opportunity cost of manure transportation and application is lowered by providing farmers with better facilities to acquire or rent means of transportation such as carts and wheel-barrows. Livestock padocking in the fields with installation of compost pits directly in the fields, and use of mineral fertilizers are other alternatives.

C - Difficulties in acquiring mineral fertilizers and associated risks.

- Mineral fertilizer supply, financing and price:

Mostly because of its low cost of transportation and application, cotton complex or NPK (14-23-15) which is the most commonly used mineral fertilizer in the country is applied across most management rings as shown in Tables 6, 9 and 15. Unlike organic manure, its use is not affected by the distance between the field and the habitat. It is used in all types of fields, but areawise and quantitywise it is mostly used in minimum food security fields and in cotton fields. As shown in Tables 6, 9, 12 and 15, the percentages of total cultivated areas where the mineral fertilizer was applied in 1981 are 34 percent at Nonghin (Manga), 38 percent at Kolbila (Yako), only 5 percent at Ouré (Djibo) and about 50 percent at Sayero (Boromo). Average quantities applied per hectare range from 16 to 46 kg in the Sudanian village (Nonghin), 30 to 76 kg in the Sudano sahelian village (Kolbila), only 2 kg in the Sahelian village (Ouré) and 40 to 100 kg in the northern guinean village (Sayero).

These doses are well bellow the widely recommended dose of 100 kg NPK + 50 kg of urea (Pichot et al 1981). Besides, such doses were applied at a time when the price of the mineral fertilzer was subsidized. Since 1987 the subsidy has been lifted and the price of the fertilizer has climbed from 50 CFA/kg in 1981 to about 120 CFA/kg in 1986. Meanwhile crop prices have practically remained the same. Consequently the doses currently used by farmers might have declined.

Production function estimates (Appendix D) show for instance in the case of Nonghin that the marginal physical product and the marginal value product of mineral fertilizer are much higher in the inner rings or red sorghum fields than in the outer ring or millet/white sorghum fields. This and the overall greater allocation of mineral fertilizer to the inner ring fields suggest that the demand for mineral fertilizer will increase with land use intensification. So far, the best facilities for acquiring mineral fertilizers are offered only to cotton producers. Improvement of the mineral fertilizer supply and financing system so as to make it easily accessible for food crop production, and appropriate fertilizer pricing policies to lower the price paid by farmers are needed for a successful completion of the adjustment process.

Development of poultry and small ruminants production, which generally provide the bulk of cash resource used to purchase fertilizers in non-cotton based systems could also help. In any case, since mineral fertilizers are obtained with cash in the market, the improvement of mineral fertilizer consumption is linked with the development of a profitable cash product, preferably backed up by reliable and effective input-supply, marketing and pricing policies.

The cash product could be livestock or any crop. The cash crop could preferably be a leguminous crop such as cowpea, soybean, groundnut or bambaranuts. In accordance with farmers' usual practice, leguminous crops could be intercropped with sesame, another potentially important cash crop of the country. The development of leguminous crops production as cash crops, if domestic and foreign market conditions permit, could allow substantial reductions in quantities of nitrogen fertilizers purchased, and be one of the most effective ways of improving soil fertility in the region.

- Leguminous crops:

Although within the present cropping systems leguminous crops are mostly planted in the outer rings, agricultural policy incentives to develop the production of leguminous crops and of livestock as major cash products will increase the scope of intercroppings and rotations between grain-forage legumes and cereals in the inner rings, like cotton-cereals intercroppings and rotations in the northern guinean zone.

Besides their ability to fix nitrogen, leguminous crops also protect the soil against splash erosion and runoff. Results of agronomic experiments in the region have shown possible positive long term effects of leguminous crops on both soil fertility and yields (Stoop and Van Staveren, 1980). Consequently research efforts to improve the technical and economic efficiencies of the current cereals-legumes intercropping and rotation practices of farmers, and to adapt proposed practices to farmers conditions need to be encouraged together with development efforts to promote legumes and livestock production and marketing.

A major constraint that prevents a better integration of leguminous crops within the cropping systems is a frequent shortage of legumes seeds during the planting period. Consequently one alternative policy could be for rural development agencies or farmers associations to purchase legumes seeds at harvest to treat and sell the seeds back to farmers so as to increase the supply of legumes seeds during the planting period. National seed multiplication units could also intervene by making available improved legumes seeds to farmers during the planting period through rural development agencies or farmers' associations.

- Leguminous trees:

The important role that leguminous trees and shrubs can play in soil conservation, in environmental protection and in reducing the demand for nitrogen fertilizers need to be emphasized. Acacia Albida, a leguminous tree present in many farmers fields in the region appears practically as a miracle tree with multiple solutions to deal with most of the soil conservation and environmental protection problems encountered in the region. Besides its ability to fix nitrogen, the tree loses its leaves during the rainy season to provide the soil with organic matter and does not compete with crops planted underneath for sunlight or water. The leaves return with the vegetative activity during the dry season to protect the soil against direct sunlight. It supplies forage for the small ruminants, and wood for the household fuel needs. The Acacia tree is known to double cereal yields wherever it is present (Lahuec, 1980). This has been confirmed by yield plot tests carried out at Kolbila (Yako) in the Sudano Sahelian Zone and at Koho (Boromo) in the northern guinean zone during the 1981-82 farm survey. The results are shown in Table 3.1 below.

Table 31. Effect of Acacia trees on Millet and Sorghum yields (a).

Region and pairs of observations	Crop	Grain Yield (kg/ha) Near Acacia	Outside Acacia area	Effect of Acacia percentage change in yield.	Statistic and significance level
Kolbila (Yako)					
9 pairs	Red Sorghum	2,532	1,263	+100%	t= 3.63
		(961)	(419)		.01
Koho(Boromo)					
5 pairs	Millet	1,720	1,163	+48%	t= 2.92
		(400)	(149)		.05

(a) Figures in parentheses are standard deviations. Density was less than 20 trees per hectare and control yield plots were set at least 20 meters away from any Acacia tree in the same field.

As shown by Table 31, the percentage increase in grain yield that results from the presence of Acacia Albida in the field is about 50 percent for millet and 100 percent for sorghum. Nevertheless few of such trees are observed in the fields. They are mostly observed within the inner rings.

Over 100 farmers interviewed, 70 would like to have a small number of such trees in their fields while the remaining 30 would prefer to have none. The major reason advanced by the latter is that the presence of a large number of Acacia trees in the fields would increase the incidence of crop damage by birds and monkeys. The other major reason often advanced is that lateral roots of Acacia interfere with animal traction implements and therefore reduce the productivity of animal traction labor. There might be a need to check such constraints and deal with them as necessary.

In any case, substantial increases in harvested grain yields are generally observed and point to the development of crops and Acacia Albida associations as a viable alternative for effective soil conservation and environmental protection in the region. Agroforestry research efforts that aim at improving the feasibility and the efficiency of such types of association, using other species of leguminous trees and shrubs as well, need to be encouraged. This, in addition to development efforts to promote this type of solution are likely to considerably reduce the cropping systems dependency on imported nitrogen fertilizer, and to bring about substantial social benefits to both present and future generations as the intensity of land use increases.

- Fertilizer combinations and risks:

Soils in Burkina Faso are known to be deficient mostly in Phosphorus. Utilisation of cheaper and locally available rock phosphate in conjunction with legumes for nitrogen fixation appears as a serious alterntive that could help the farming systems to maintain or improve their productivities as the intensity of land use increases.

Such an alternative and the peasant practice that consists of applying jointly both mineral and organic fertilizer in the inner rings appear to be wise ones in light of research findings that suggest that applications of the cotton complex fertilizer alone at usually recommended doses might have adverse effects on the cation exchange capacity of ferruginous soils through acidification and aluminium toxicity (Pichot et al. 1981).

In most farmers' opinions, where mineral fertilizer is not used in conjunction with organic manure, the interseasonal yield variability is very high, especially in millet fields. The intraseasonal and interseasonal variabilities in moisture availability which create such financial risks of mineral fertilizer use are particularly high in the Sahel and explain why the mineral fertilizer is practically not used there (Table 12). This points to the development and use of appropriate soil water management practices as a necessary condition for the maintenance of soil fertility with purchased mineral fertilizers in the region.

D - Shortage of Labor Saving Technologies.

As suggested by the timing of seasonal activities, labor profiles and labor allocations across the management rings discussed in Chapter 10, a greater demand for labor and a greater need for timely completion of seasonal activities will result from land use intensification. Labor saving technologies would be mostly needed for seedbed preparation, timely planting and weedings.

This is partly demonstrated by the high proportion of farmers who use animal traction implements in the Manga villages, with the highest demographic pressure, and in the Boromo villages with the greatest market integration.

Labor saving technologies for seedbed preparation and timely planting will become even more needed in the future if the declining trend and the increasing variability of rainfall continue.

There is a need to adapt soil preparation implements and techniques to the different soil types so as to increase the productivity of labor in that activity. There is also a need to introduce adapted manual as well as animal traction implements to speed up planting and enable farmers to plant on time on as much land as possible. This calls for agricultural engeneering research to design new manual and animal traction implements such as plowers, scarifiers, ridgers, planters, ridge tiers, weeders etc, for on farm adaptative research to test and adapt such implements to farm conditions, particularly to soil types, with farmers' participation.

As shown by the labor profiles in Tables 26 through 29, except the Manga village where the use of animal traction implements is well mastered by most farmers, farmers in other regions use the implements mostly for seedbed preparation and hardly for weeding. This is often due to lack of row planting or to inadequate intercropping between the rows, but also to insufficient training of both draught animals and farmers. As suggested by the same tables, labor demand for weeding often increases with the intensity of land use. There is therefore a need to determine conditions under which mechanical weedings is profitable and to place an emphasis on training programmes to help draft animals and farmers perform seasonal activities more efficiently with animal traction implements.

High cost of animal traction equipments and low availability of credit to purchase the equipments are other major constraints. The first could be lifted with training programs that teach local iron smiths to manufacture and repair the implements so as to bring down their prices. The second may require innovations in agricultural financing at the village level through farmers organisations or lignage leaders. Reliable input supply, pricing and marketing facilities to support cash products might also be helpful.

E - Poor Efficiency and Availability of Soil and Water Conservation Devices.

The tendency and need to use more fertilizers and mechanical tools on the soils as the intensity of land use increases, together with the greater importance of soil and water conservation devices in the inner rings (Tables 6, 9 and 15) suggest that soil and water conservation devices will be more needed in the future if the intensity of land use increases. Traditional soil and water consefvation devices used include earthen diguettes, stonebunds, ditches, mulching, grass strips, small barriers with tree trunks etc... Such practices as traditionnally used are in general poorly efficient and need to be improved. Research efforts to improve such traditional techniques and to introduce better ones need to be encouraged. Improved practices such as stone diguettes on contour lines, tied ridges and others might be needed to correct the possible adverse effect of land use intensification on soil texture and moisture holding capacity that was pointed out in section 3 of Chapter 9. Research results have demonstrated the ability of such improved practices to increase grain yields by 20 to over 100 percent (FSU/SAFGRAD, 1984; ICRISAT 1985).

As suggested by the survey results discussed in Chapter 9, adverse effects of land use intensification on soil quality exist mostly in lowlands. Due to their poor efficiency, traditional soil conservation practices are unable to prevent severe soil erosion in lowlands, consequently research and development efforts to limit soil erosion should be focussed mostly around lowland areas. As indicated by the adjustment process outlined earlier, cultivation of lowland is likely to be intensified, not only because of greater demographic pressure and market integration, but also because of the greater occurence of drought which pushes many farmers to install hungry season and minimum food security fields in lowlands.

Individual actions to deal with soil conservation problems are inefficient, particularly in lowlands and areas with accidented relief. Therefore collective actions by village communittees with technical guidance from development agencies to tackle the problem are most advisable.

F - Shortage of Adequate Food Crop-Varieties for Low and Moderate Management Levels.

A successful completion of the adjustment process vis a vis land use intensification implies a progressive increase of the average level of soil and crop management which in turn will develop a need for more management responsive crops and varieties. However the adjustment process can only take place progressively. Consequently all three management levels, low, moderate and high will continue to coexist on the farm for a long time and should be separately taken into account by crop selection programmes in order to develop plant materials that will succesfully help to complete the adjustment process.

The level of management can be autonomously raised only, if marketable surpluses can be realised to acquire capital resources such as livestock for manure production, fertilizers and labor saving technologies. A prerequisite for increasing the level of management is an improvement of the financial capability of the farmer and this may be best done through the promotion of an appropriate cash product subjected to substantial domestic and foreign demands, and backed up by efficient input supply, price and marketing systems. The ability of food crops to serve as cash crops to increase the farmer's financial capability is very limited, because unlike the case of western marked economies, the bulk of the food demand (80% or more) comes from the farm and foreign demand for food grain produced in the region is practically nil.

In other words, as the main consumer of his food crop within a subsistance economy, the farmer is obliged to finance and bear most of the cost of any new food production technology. His capacity to finance the inputs required for an efficient use of a new food production technology may be best improved through the development of an adequate cash product other than food crop.
However, since whatever the cash product, it will have to compete with food crops for available farm resources and require even more of such resources in

order to develop, the productivity of food crop production must be first increased at the present levels of management and input use, to make room for the cash product and trigger the capital accumulation process that will raise the soil and crop management levels on the farm.

Crop selection programmes can help to speed up the process by selecting food crops and cash crops varieties that can increase productivity at all three management levels, with a particular emphasis on the low and moderate management levels in the short run. This implies selecting crops and varieties for low management, moderate management and high management.

The relationships between the different types of fields and their characteristics, which are summarized in Table 32 below, may be helpful in designing appropriate food crop seleciton programmes to assist the small farmers in the region. As previously discussed, one may identify three types of food crop fields in the region: hungry season and spices fields, minimum food security fields and complementary food security fields.

The hungry season food and spices fields are subjected to the highest management on the farm. They are usually located within the first management ring and are thus among the fields that are closest to the farmer's habitation point. They are planted with the shortest cycle crops and varieties and are the smallest fields on the farm. They occupy less than five percent of the total cultivated area.

Minimum food security fields are subjected to a moderate management. They are usually located within the intermediate rings and are thus found within medium distances from the farmer's habitation point.
They are preferably planted with medium cycle food crops and varieties, but are also planted with longer cycle crops and varieties particularly in lowlands or on soils with better moisture holding capacities. They are medium size fields which generally occupy about one third of the total cultivated farm area.

The complementary food security fields are subjected to the lowest management on the farm. They are usually located within the outer ring and are thus generally the farthest fields from the farmer's habitation point. They are generally planted with the longuest cycle food crops and varieties. They are generally the largest fields on the farm and occupy in general about sixty percent of the total cultivated area.

Table 32. Relationships between the various types of fields and their predominant charactetistics.

Type of Field	Ring	Soil Type	Cycle of crops and varieties	Cultivated area	Distance to compound	Management
1. Hungry Season and Spices	First	All	Short	Small	short	High
2. Minimum Food Security	Intermediate	Lowland	Long	Medium	Medium	Moderate
		Upland	Medium	Medium	Medium	Moderate
3. Complementary Food Security	Last (Outer)	All	Long	Large	Long	Low
4. Cash and Social Obligations	Intermediate and Last	All	Mostly Short to Medium	Variable	Medium to Long	Variable

The farther the field is from the habitation point, the more difficult or costlier itis to apply organic manure and to intervene on time to plant, to guard the seeds and young plants against birds and livestock attacks, to weed, to ridge and harvest, and vice versa. The shorter the growth cycle of the crop, the greater the pressure on labor for timely accomplishment of the post planting activities. However, with a short growth cycle, the pressure on labor can be lowered by reducing the size of the area planted. With a long growth cycle, the pressure on labor for timely accomplishment of the post planting activities is lower and more area may be planted. Short and medium growth cycles allow for more replanting to guarantee minimum yields than long growth cycles. Factors such as these together with the farmer's global strategy that consists of minimising risk through diversification explain the partitionning of the cultivated farm area into the different types of fields mentionned above and their various characteristics.

Knowledge of basic management factors such as these and fields differentiation with respect to farmer goals and risk minimising strategies may help in selecting more appropriate crops and varieties to assist small farmers in the region.

In the case of complementary food security fields for instance, crop selection programmes may screen and select the local photosensitive varieties that perform best under low management, and possibly improve their performances. Such programmes may also select local or exotic medium cycle varieties that perform well under moderate management for recommendation in minimum food security fields. With the previsible increase in management level in minimum food security fields, such programmes may also progressively emphasize selection of short and medium cycle varieties that perform best under high management for the hungry season fields and for the emerging highly managed minimum food security fields. Given the recent tendency of farmers to install some of their hungry season and minimum food security fields near lowlands or inside lowlands, the growth cycle of varieties selected for such fields need not to be too short or too medium.

This points to the role that environmental heterogeinity may play in crop selection programmes. With the recent decline in rainfall, shortening of rainfall period and greater frequency of drought periods within the season, it may be necessary to systematically take into account the differences in field moisture retention capacities of local soils when attempting to select drought tolerant varieties.

Similarly, when selecting for drought tolerant varieties by looking for shorter cycle varieties at all levels of management, it is essential that the proportionality relatinships that exist between the growth cycles of crops in the different types of fields be respected in order to avoid a worsening of the labor bottlenecks. With these factors in mind, successful selection of appropriate crop varieties for each management level could be achieved.

Within this framework, other measures of performance to take into account besides grain yield level and stability might be: stalk yield and quality, grain suitability for storage and for making most prefered consumer dishes or drinks, suitability for agro industrial purpose and consequent ability to serve as a reliable cash crop when necessary.

G. The Security of Land Tenure.

The results of the present study clearly indicate that in general, the level of soil and crop management increases with the security of land tenure. Overall, the security of land tenure is relatively high in the studied farming systems. Low security of land tenure arises mostly when land is borrowed in neighbouring village territories where good arable land is less scarce, and in the case of migrant households who borrow land from native farmers. The low security of land tenure obtained in such cases is not likely to affect the use of mineral fertilizers but may affect the use of organic fertilizers and of soil conservation devices in large fields. This is mostly because the latter types of investment are more expensive and have longer lasting effects than the former. However, with land use intensification, the security of land tenure is likely to increase with native land lenders claiming their lands back from borrowers, or with the latter acquiring more secure use rights over the lands, for instance by purchasing such rights.

In either case, land use intensification is likely to result in improved land quality management over the long run, if the constraints specified earlier are successfully lifted. However, land reform policies that will increase the security of land tenure for those who are forced to borrow lands to cultivate might help to speed up the process.

CHAPTER 12.

SUMMARY AND CONCLUSIONS.

With soil and crop management defined in terms of soil fertility management and in terms of other variables including the timely utilisation of labor, to complete the seasonal cropping activities, the major conclusions of this study may be listed as follows:

1. Many levels of soil and crop management coexist on the farm in Burkina Faso. At least three levels of management: low, moderate and high, may be observed on the typical farm.

On the basis of thefarmers' production and consumption objectives, one may distinguish in general among four types of fields. These are: the hungry season and spices fields, the minimum food security fields, the complementary food security fields and the cash and social obligation fields.

The hungry season and spices fields are usually subjected to high management, the minimum food security fields are usually subjected to moderate management, the complementary food security fields are usually subjected to low management. The cash and social obligations fields are subjected to either one of the three levels of management, depending on the type of crop and on its socio-economic value.

On the basis of land utilisation , the cultivation systems may be described as ring cultivation systems, or systems composed of management rings. By drawing concentric rings around a given household compound (the habitation point during the rainy season) one observes that fields belonging to the household, which are located within the same ring are subjected to practically the same type of management, and that the intensity of land use and the level of management in the fields decline as one moves away from the compound, that is from the first to the last ring. Fields in the first ring are mostly hungry season and spices fields subjected to high management. Fields in the intermediate rings are mostly minimum food security fields subjected to moderate management and fields in the last rings are mostly complementary food security fields subjected to low management. Cash and social obligations fields are mostly found within the intermediate and last rings.

Furthermore, it has been noticed that there exists considerable differences in soil types at the village and farm levels. Fields in a given farm are located on two or more types of local soils with different physical and chemical properties, especially in terms of field moisture retention capacity. Such differences along a toposequence or otherwise are exploited by farmers within a diversification strategy to minimise production risks.

By taking into account such difference in objectives, management and soil types, that exist between fields, research and development efforts in the region might be able to assist small farmers more efficiently.

2. Within the farming systems, as described above, there is an horizontal exportation of plant nutrients from the fields and fallows in the outer ring to the fields inside the inner rings, through human production and consumption activities. Such activities include, livestock feeding in fallow fields and other pasture lands around the village, night padocking of the livestock around the compound or within the inner rings, horizontal expoetation of nutrients through crops harvested in the outer ring and consumed in the compound. Reexportation of nutrients from the compound to the inner rings through night soils and manure applications.

All these activities lead in general to a progressive replenishment and build up of soil fertility, rather than to a depletion of soil fertility within the inner rings, where the most intensively cultivated fields are found.

In the outer rings, soil fertility is regenerated mostly through leguminous plants and fallow. The latter allows vertical exportation of plants nutrients from deeper soil layers to upper layers. However, with the progressive shortening of fallow periods, more and more mineral fertilizers are being used in the outer ring, except in the Sahel. Consequently, the outer ring, which is the least intensively cultivated ring, is the ring where soil fertility is most likely to decline if land use intensification leads to a shortening of fallow periods without sufficient applications of fertilizers by the farmers.

In the specific case of the studied villages, no significant difference has been observed between the chemical fertility in the upper layer of soils in the cultivated fields of the outer ring and soil fertility in old fallow fields around the village. This is mostly true for upland soils. Negative differences (indicating fertility declines) have been observed in the case of lowland soils. Regarding the chemical fertility of soils in the inner rings it is in general about equal or significantly greater than that recorded in the old fallow fields.

Land use intensification might have some adverse effects on the physical status of soils, which might in turn lead to a decline in their moisture retention capacities. This has been suspected in one of the studied villages, but little evidence has come from other villages to strongly support the hipothesis. Increase in soil erosion as a result of land use intensification has hardly been observed on uplands, which are generally flat lands, but appears in lowlands. It thus seems that the current cultivation practices are succesful in preventing an increase in soil erosion when land use is intensified on upland but not in lowlands. Therefore soil conservation techniques which are more efficient than the local ones are urgently needed in lowlands.

Overall, there is little evidence from the studied villages to support the conventional argument that traditional farming systems in the region necessarilly mine the natural chemical fertility base of soils when they evolve torward more permanent cultivation practices. As stated in general terms, the argument may be misleading. If the chemical fertility base of soils declines at all as a result of land use intensification, it is most likely to do so in the outer ring, particularly in lowlands, and not on the entire farm area. The major problem with the chemical fertility base of soils in the region is that it is naturally low, especially in the outer ring which makes up about sixty to seventy percent of the farm area, and needs to be improved to allow a safe land use intensification.

However, risks of deterioration of the physical fertility of the soil do exist in some areas and must be primarily taken into account with appropriate soil conservation measures, because a decline in the chemical fertility of the soil results in general in much lower social costs than a decline in the physical fertility of the soil; the first phenonmenon being much more reversible than the second.

3. Peasant farming systems are not stagnant systems, indifferent to changes in their physical and socio-economic environments. They have adjustment mechanisms which enable them to react positively to exogenous changes so as to minimise the negative effects that such changes might have on their produc-

tion and consumption objectives.

However, rapid changes in the exogenous factors may not allow the systems to adjust fully on time and in an optimal way. Research and development efforts to assist small farmers in the region should take into account such adjustment mechanisms, first by identifying them and by trying to understand their logic, secondly by helping farmers to improve upon the technological structural and institutional solutions or strategies that result from such adjustment processes, and to implement them more efficiently.

This approach by itself might not achieve the dramatic production break throughs impatiently wished by most agricultural researchers and developpers, but it will certainly lead progressively to such breakthroughs if properly combined with conventional search and transfer of more efficient exotic technologies.

In the specific case of the studied villages, the types of research and development actions that are most needed to enable the farming systems to properly adjust to land use intensification pressures include:

- Increasing the availability of organic manure and lowering the cost of manure transportation and application.
- Increasing the availability of other sources of plants nutrients at cost or prices that are accessible to most farmers.
- Promotion and support of at least one cash product with appropriate and reliable input supply, pricing and marketing policies in order to improve the financial capability of farmers in acquiring marketed inputs.
- The design of appropriate labor saving technologies for timely seedbed preparation, planting and weeding.
- Improvement of the efficiency of traditional soil and water conservation practices, and introduction of cheaper and more efficient ones.
- Selection of more productive crops and varieties for all management levels, particularly for low and moderate levels of management.

The results of this study clearly indicate that management is a major constraint for food crop production in the region. As suggested by Tables 6, 9, 12 and 15 in the preceding chapters, yields and thus crop output may be doubled or even tripled with improved management, using the same crops and varieties that are currently used by the farmers. The improvement of management is itself mostly constrained by a poor availability of capital resources on the farm and by a limited off-farm demand for food crops. The six types of research and development actions mentioned above might help to improve management and facilitate the land use intensification process if they are properly combined and synchronised.

Regarding crop and varietal selections, there is a need to take into consideration not only the various soil types and the various levels of management that exist on the farm but also the functions fulfilled by each crop within the systems and the implications of the growth cycle of each crop on the labor bottlenecks during the season.

In view of the preceding point, it might be judicious as indicated in chapter 11 to select relatively short cycle crops and varieties for high management in the hungry season and spices fields, to select medium cycle crops and varieties for moderate management in the minimum food security fields (particularly those located on uplands) and to select the crops and varieties with the relatively longuest growth cycles for low management in the complementary food security fields and also for moderate management in the minimum food security fields that are located in lowlands.

The more labour saving technologies will be available on the farm, the less pressure there will be on labor, and the more farmers will be able to adopt crops and varieties with shorter and less different growth cycles at all levels of management.

The above conclusions rest on the basic principle that any development process is a progressive process. The first step to be accomplished in improving farming systems in the region is to increase their productivity at their current stage of development by introducing more productive technologies that are adapted to their current resource and management conditions and which can be easily adopted by the farmers now. Asking a farmer to adopt on "advanced" technology for which he has at the moment neither the adequate resource capability, nor the adequate technical or managerial capability is like asking a man sitting down to make a long jump without standing up first. There is a need for both agricultural research and development to help the farmer stand up and take off for the final jump, before focussing all the attention on the final jump.

An increase in productivity at the present levels of management will enable farmers to progressively accumulate surpluses and technical knowledge which they will invest to upgrade the management levels on the farm. This will in turn enable them to adopt technologies which require higher levels of inputs and management, so that the farming systems will reach a higher stage of development at the end of each round and so forth.

The results of the present study of farming systems indicate the need for agricultural research and development to carefully access the parameters of farming systems, to comprehend the way the systems function and change, and to identify the constraints they face on their growth and development paths in order to better help farmers to face the challenger of the future.

Within or outside of a multidisciplinary team, the best way the individual researcher or developper could help might be to first be aware of all the major constraints of all kinds (technical, social, economic etc...) facing the farmers, secondly to address the constraints he is most competent to tackle, and finally try to find for such a constraint a solution which is feasible by the farmer now and which does not aggravate any of the other constraints. In other words, the optimality rule would be to search for a feasible solution which would make the farmer better off now with respect to at least one constraint without making him worse off with respect to any of the other contraints.

REFERENCES

ACECNA. (1972). Tableau Climatologiques: Periode 1961-1970, Ouagadougou, Haute Volta.

Barret, V. ; Gregory L.; Wilcock D. (1982): "Animal Traction in Eastern Upper Volta: A Technical, Economic and Institutional Analysis." MSU International Development Paper No. 4. East Lansing. Michigan.

Bonkian, A. (1981). Utilisation du Fumier à Nakamtenga et Nabitenga. ICRISAT,Up.Volta

Boulet, R. (1981). Cartes de Resources en Sols de la Haute Volta et Notice des Cartes de Resources en Sols de la Haute Volta. ORSTOM, Paris.

Boutiller, J.L. (1972). "Relations entre les systèmes de Tenure des Terres, la Hierarchie Villageoise et les Systèmes Familiaux: Exemple de la République de Haute Volta." Paper presented at a Seminar on Land Tenure at the University of Ibadan, Nigeria July 24-28, 1972.

Boutillier, L.L.; Quesnel, A.; Vaugelade, J. (1977). "Systèmes Socio-Economiques Mossi et Migrations." Cahiers de l'ORSTOM, serie Sci. Hum. vol. XIV. No. 4. pp. 361-381.

CVRS. (1968). Atlas de Haute Volta: Carte Densitées de Population, Centre Voltaïque de la Recherche Scientifique, Ouagadougou, Haute Volta.

CVRS. (1970). Cartes des Elements Climatiques, Centre Voltaique de la Recherche Scientifique, Ouagadougou, Haute Volta.

Collinson, M.P. (1972). Farm Management in Peasant Agriculture. A Handbook for Rural Development Planning in Africa. Praeger, New York.

Collinson, M.P. (1982). Farming System Research in Eastern Africa: The Experience of CIMMYT and Some National Agricultural Research services, 1976-81. MSU International Development Paper No. 3. Dept. of Agric. Economics, Michigan State Univ. East Lansing.

Charreau, C. (1969). "L'Influence des Techniques Culturales sur le Développement de l'Erosion et du Ruissellement en Casamance." L'Agronomie Tropicale, Vol. 24, No. 9, pp.

Charreau, C. (1972). "Problèmes Posés par l'Utilisation Agricole des Sols Tropicaux par des Cultures Annuelles." L'Agronomie Tropicale, vol. 27, No. 9, pp. 905-929.

Delgado, C.L. (1977). "Economic Interactions between Peasants and Herders in the West African Savannah: A Case Study from Tenkodogo, Upper Volta." USAID Contract Report NO. REDSO/WA 77-104. CRED, University of Michigan, Ann Arbor.

Delgado, C.L. (1979). Livestock versus Foodgrain Production in Southeast Upper-Volta: A Resource Allocation Analysis. Ann Arbor, University of Michigan, CRED, Livestock Production and Marketing in the Entente States of West Africa, Monograph No. 1.

Diatta, S. (1978). Etude de l'Evolution sous Culture des Sols de Plateau en Casamance Continentale. Bilan de Six Années d'Etude. Institut Sénégalais de Recherches Agricoles, Bambey, Senegal.

Drabo M.; Vierich, H. (1983) "Les Régimes Fonciers dans Trois Zones Agro-Climatiques de Haute Volta - Rapport Preliminaire - Etudes Villageoise - Rapport No 10 ICRISAT, Ouagadougou. Burkina Faso.

Eddy, E.D. (1979). Labor and Land Use on Mixed Farms in the Pastoral Zone of the Niger. Ann Arbor, University of Michigan, CRED, Livestock Production and Marketing in the Entente States of West Africa, Monograph No. 3.

Eicher, C.K. and Baker, D.C. (1982). Research on Agricultural Development in Sub-Saharan Africa: A Critical Survey. MSU International Development paper No. 1. East Lansing.

FAO. (1974). "Shifting Cultivation and Soil Conservation in Africa." Soils Bulletin No. 24, Swedish International Development Authority, FAO, Rome.

IRAT. (1967). Colloque sur la Fertilité des Sols Tropicaux. Paris.

IRAT. (1975). Rapport Annuel 1975 de l'IRAT. IRAT, Paris.

INSD. (1978). Recensement General de la Population de la Haute Volta, Institut National de la Statistique et de la Demographie, 3 vol., Ouagadougou, Upper Volta.

Joosten, J.H.L. (1962). Wirtschaftliche und agrarpolistische Aspekte tropischer Landbausysteme (mimeo). Institut fuer Landwirtschaftliche Betriebslehre, Gottingen.

Kohler, J.M. (1971). Activités Agricoles et Changement Sociaux dans l'Ouest Mossi ORSTOM, Paris.

Lahuec, J.P. (1980). Le Terroir de Zaongho, les Mossi de Koupela (Haute Volta). ORSTOM, Paris.

McIntire, J. (1981). Reconnaissance Surveys in North and West Upper Volta. Village Studies Report No. 3. ICRISAT, Upper Volta.

Matlon, P.J. (1977). The Size, Distribution, Structure, and Determinants of Personal Income among Farmers in the North of Nigeria. Ph.D. Thesis, Cornell University.

Matlon, P.J. (1980). Profile of Farm Units in Two Villages of Central Upper Volta. ICRISAT, Upper Volta.

Norman, D.W.; Newman, M.D; and Ouedraogo, I. (1981). Farm and Village Production Systems in the Semi-Arid Tropics of West Africa. ICRISAT Research Bulletin No. 4, Vol. 1. Hyderabad, India.

Pelissier, P. (1966). Les Paysans du Senegal. Imprimerie Fabregue, Saint Yrieux, France.

Peron, Y. and Zalacain, V. (1975). Atlas de la Haute Volta. Editions Jeune Afrique, Paris.

Pichot, J.; Sedogo, M.P.; Poulain, J.F.; Arrivets, J. (1981). "Evolution de la Fertilité d'un Sol Ferrugineux Tropical sous l'influence de Fumures Minerales et Organiques." Agronomie Tropicale, 36-2, pp. 122-133.

Poulain, J.F. (1977). Les Residus de Culture dans les Systèmes Culturaux Tradigionnels de l'Afrique de l'Ouest. Effets sur le Bilan Mineral et le Statut Organique des Sols. Propositions pour leur Meilleure Gestion in FAO/SIDA (1977).

Prudencio, Y.C. (1983). "A Village Study of Soil Fertility Management and Food Crop Production in Upper Volta" Unpublished Ph.D Thesis. University of Arizona, Tucson.

Prudencio, Y.C. (1986). "Some Adjustment Mechanisms of Farming Systems in Burkina Faso. Implications for Agricultural Research and Development". Paper presented at the SAFGRAD Drought Symposium Nairobi, Kenya 19-23 May 1986.

Prudencio, Y.C. (1986). "Quelques Mecanismes d'Ajustement des Systèmes de Production Agricole au Burkina Faso. Implications pour la Recherche et le Développement Agricole." Communication au Symposium sur la Sécheresse du SAFGRAD, Nairobi, Kenya, du 19 au 23 Mai 1986.

Reij, C. (1983) : L'Evolution de la Lutte Antierosive au Burkina Faso (Haute Volta) depuis l'Indépendance - vers une plus grande participation de la population. Institute for Environmental Studies, Free University, Amsterdam.

Sanou, S. (1986): "Land Tenure Structures in the Agricultural Sector of Hounde, Burkina Faso: A Study in Rural Social Change and Development." Unpublished Ph.D. Dissertation, Michigan State University.

Seze, O.P. (1979). "Premières interpretations essais courbe de reponse au fumier." Institut Senegalais de Recherches Agricoles, Bambey, Senegal

Stoop, W.A. and Van Staveren, J. Ph. (1980). "Effects of cowpea in cereal rotations and in cereal intercropping systems on maintaining soil fertility under semi-arid conditions in Upper Volta." ICRISAT Staff research paper. Ouagadougou.

Virmani, S.N.; Reddy, S.J.; Bose, M.H.S. (1980). A Handbook on the Rainfall Climatology of West Africa: Data for Selected Locations, ICRISAT, Hyderabad.

FSU/SAFGRAD (1984) Annual Report, Farming Systems Research Unit. Ouagadougou.

GERDAT (1983) "Contribution à la Détermination des Objectifs Agronomiques et Technologiques à Long Terme. Burkina Faso". (Document de Travail) Paris.

ICRISAT (1985) Annual Report Economics Programme. Ouagadougou.

APPENDIX A.

SITE SELECTION, SAMPLING, DATA COLLECTION AND AGGREGATION.

Area and village Sampling.

The study areas and villages were chosen following extensive reconnaissance surveys in over thirty villages of Burkina Faso. The surveys were carried out by the author and the West Africa ICRISAT Economics team. Those surveys led to the selection of four study areas and a total of eight villages, with two villages in each study area. These are from the north to the south of the country, the Djibo, Yako, Boromo and Manga areas. The methodology and assumptions used in conducting the survey and in selecting the villages are exhaustively discussed elsewhere (McIntire, 1981).

The major assumption behind the area sampling was that the variance in the cropping systems between agroclimatic zones is significantly greater than within agroclimatic zones. The latter are normally defined on the basis of climatic variables such as rainfall, evapotranspiration, photoperiodism, temperature and natural vegetation. In this study the sampling strata were defined on the basis of the rainfall, which normally coincides with different natural vegetations and cropping systems, since the rainfall pattern (amount and distribution) allows only the survival and the cultivation of those plants whose growth and development fit into it. The survey areas were selected within four agroclimatic zones that cover most of the West African Semi-Arid Tropical (WASAT) regions; these are from the south to the north of the country, the northern guinean agroclimatic zone, with an average rainfall between 1250 mm and 100 mm, the Sudanian agroclimatic zone with an average rainfall between 1000 mm and 800 mm, the Sudano-Sahelian zone with an average rainfall between 800 mm and 600 mm and finally the south Sahelian agroclimatic zone with an average rainfall between 600 mm and 400 mm (Peron and Zalacain , 1975; Boulet, 1976).

One survey area with relatively good access during the rainy season was selected in each agroclimatic zone and was subjected to the reconnaissance survey. The purpose of said survey was to gather, in short village visits, information on resources endowment and cropping systems in villages located on different soil types within the survey area. The main stratification variables used in selecting the surveyed villages were soil type and population density. On the basis of soil maps by ORSTOM (Boulet, 1976) and on the basis of a 1975 census (INSD, 1978), the surveyed villages were selected within the modal region of the surveyed area soil type and population density distribution curves. Finally two study villages in each area were selected in the modal interval of the village population size distribution, so as to be representative of the typical cropping systems in the area (judging from the information gathered during the reconnaissance survey). The selected two villages in each area were not separated by more than thirty kilometers and were more or less identical in terms of cropping systems.

Household Sampling.

A sample of 25 households was drawn in each of the eight villages. In the Djibo, Yako and Boromo areas, the village population was stratified into hand-tool technology households and animal traction technology households. In villages where the animal traction (AT) equipment households were greater than twelve, twelve of them were randomly selected. In villages where the number of such households turned out to be less than or equal to twelve, all the AT households in the village were included in the village sample. This sampling method was chosen by ICRISAT economists in order to study both farming technologies and to test the adoption and performance of improved crop varieties under both types of technologies. In the Manga area, where AT equipment was relatively more common than in the rest of the country, the samples were randomly drawn from the village populations without stratification.

The data were obtained through interviews supplemented with direct measurements and observations. Details on data collection methods are given in Table A1 below. One enumerator permanently installed in each village to collect the data was assisted from time to time by other enumerators who intervened temporarily to collect specific sets of data.

In-depth interviews, surveys of local soil types and soil sampling were carried out by the author with the assistance of soil laboratory technicians continuous controls of data on the field were carried out during the data collection phase by the author and the ICRISAT program economist, Dr. Peter Matlon.

Measurement and Aggregation of Labor.

Labor data were recorded per specific task, sex and age groups of the laborers. It is generally assumed that the productivity of labor varies accross individuals, tasks, sex and age, and there is no doubt that the ideal measure of aggregate labor is an homogenous measure that takes into account such differences in productivity if they exist. To measure the availability of labor in the household, the French tradition has been to count the number of Actifs in the household. An Actif being defined as a person between ages 15 and 59. The French measure ignores productivity differences and the labor force provided by children between 10 and 15 years of age, and by people above 60 years of age. The Anglo-Saxon approach accounts for all individuals in the household and for productivity differences with the concept of "Man-Equivalent". However, as pointed out by Eicher and Baker (1982), "Most studies have used fairly arbitrary approaches for deciding on the weights to be used in aggregating labor inputs" (idid., P. 78), and as pointed out by Collinson (1974, P. 201) no one has been able to demonstrate that age-sex differences in productivity exist in sub-Saharan peasant agriculture. According to the farmers themselves, the household labor is allocated in such a way that children, women and elderly people are generally involved in doing what they do best, most of which they do better than male adults in their prime (e.g., gathering and burning of crop residues, planting, bird scaring, thinning and transplanting, guiding of animals during animal traction works, harvesting, etc.). Differences in endurance do exist on the most difficult tasks such as weeding and ridging, but not necessarily in productivity. Such differences in endurance are reflected in the number of hours of work in the field.

Weights assigned to weeding and ridging labors by some authors are generally the most variable weights across sex and age. They vary between .5 and 1 for laborers above 10 years of age (Malton 1977, p. 171, Crawford, 1982, p. 121), otherwise they vary between .75 and 1 for other tasks. Observations and subjective evaluations by the author places doubts on the validity of such weights in the study area. In the Nonghin village, for instance, the usual scene witnessed during weeding or ridging, which are generally done with animal traction equipment, is a child guiding the donkey which is pulling the weeder or the ridger across the field, an adult male young or old holding the weeder and women following behind using hoes to replenish the work done by the animal traction equipment. It is doubtful that a man in front to guide a donkey through the narrow alleys between the crop lines would have done a better job than the child. Because of such complexities and the arbitrariness involved in selecting any set of weights, many authors of recent studies have adopted a simple summation of working hours on the field by individuals of all ages and sex (Delgado 1979, Eddy, 1979). The same approach has been adopted in this study in aggregation labor hours spent on each field by workers of ten and above years of age.

Table A1.

Summary of Types of Data Gathered, Methodology and Personnel Used.

	DATA	METHODOLOGY	PERSONNEL
1.	Village history and land tenure	One Shot Interview	Author
2.	Demographic data and household history	One Shot Interview	Author & Enumerators
3.	Farm AT equipment inventories	One shot interview	Enumerators
4.	Field history & tenure from 1976-1981	Repeated one shot interview (twice) in Farmers' fields	Enumerators, Author
5.	Input-output data for 1981 season	Cost-route weekly interviews, weights of local units used, & field size measurement	Enumerators
6.	Field Characteristics (plant densities, soil types, field slopes, etc.)	Field observations and measures	Enumerators
7.	Farm yard manure production	Measures	Enumerators
8.	Inputs obtention (fertilizers, seeds, tools, etc.)	One shot interview	Enumerators
9.	Acacia Albida yield plots tests	Measures inside yield plots	Enumerators
10.	Crop and livestock purchases and sales	Weekly interviews	Enumerators
11.	Local market prices for crops	Interview and measures on market days.	Enumerators

Summary of Types of Data Gathered, Methodology and Personnel Used, Continued.

12.	Local soils survey and soil sampling	Mapping, surface morphology and profiles analyses. A-horizon sampling on 1/3 of all sample fields and fallows. Samplings with rings on pit sites	Author, soil lab technicians, enumerators
13.	Soil samples physical and chemical analyses	Standard	F.A.O. Project Soil Lab. (BUNASOL) Ouagadougou.
14.	On-farm livestock inventories	Interviews and countings	Enumerators
15.	Factors affecting soil and crop management.	Repeated interviews and informal discussions with farmers, farmer's organizations, extension agents and agencies.	Author, Enumerators
16.	Daily food consumptions and transformation ratios for various crops.	Measures	Author, Enumerators
17.	Secondary experimental data from research stations.	Literature review	Author

APPENDIX B: Major Intercropping Systems in the Boromo Area (Northern Guinean Zone)

Management Ring	Intercropping System Number 1	2	3	4	5	6	7	8	9	10	11
1Ai	05	03	05/18	05//24	05//03	03**/**05	05**/**03/24				
1Ap	05	05/24	05//18	05/20/32	05//02	05/22	05/44/18/25	05/03/22			
1Bo, 1Bm	03	02	31///05	02//09	03//08	03**/**05	31/// **/**05	03//05			
1Co	31//03	03	31	31//08	02/09	02	03/08/12	08/12	12		
2A	09/11	08	12	09/23	08/12	08/02					
2C	01	02	01/09	02/09	02//09	01//08	01///09	08	12	08/03	11**/**09
2Bm	01	02	31	31//03	03	31//09	02/09//12//08	02/09	01//08	01/09	01/02
2Bm ctnd	03/09	03**/**09	12	08	03**/**08	02//09	08/09/12				
2D	11	31	31//09	31//08	08	12	09/11				
R	06	05//06	06/05	05/06							

Crop codes: 01 = millet; 02 = white sorghum; 03 = red sorghum; 05 = maize; 06 = rice
08 = groundnut; 09 = cowpea; 11 = sesame; 12 = bambara nut; 18 = pepper;
22 = okra; 23 = sorrel; 24 = sauce herbs; 25 = aubergine; 31 = cotton.

Intercropping codes: /05/ : Monocropping of maize; / : random intercropping with no specific order.
//: row intercropping; **/**: Intercropping in the line
/// : row intercropping with many more rows of the crop on the left hand size.

APPENDIX C. Harvest Period Producer Prices of Selected Food Crops in 1981 CFA/kg.

	MANGA	YAKO	DJIBO	BOROMO
Maize	108	55	71	40
Millet	58.8	51	55	53
White Sorghum	56.3	45	57	51
Red Sorghum	38.9	47	-	42
Cowpea	87.5	105.4	161	80
Groundnut	135.1	60.6	114	120
Bambaranut	64.5	-		
Cotton	-	62	-	62
Yams	-	96.5	-	
Sweet Potatoes	-	105.4	-	75
Rice	-	118	145	68
Fonio	-	-	75	-

- Manga prices are average 1981 December prices.
- Prices for other locations are 1981 average prices from October to December.

APPENDIX D.

THE PRODUCTION FUNCTIONS ESTIMATES OF NONGHIN (MANGA).

Table D1. Regression Coefficients of the Linear Production Function for the Management Systems. dependent Variable=Value of Output (CFA francs). Model 1.2.

	Management System					
	M1	M2	M3	M4	M5	M6
R^2	.806	.761	.660	.876	.892	.692
$\bar{R}^2$	.667	.654	.605	.823	.837	.412
F	5.8	7.10	11.8	16.5	16.1	2.5
Degrees of Freedom	36	58	158	57	37	22
Land (hectares)	5658+ (1.49)	3391 (1.09)	6442** (2.35)	23127*** (4.24)	35554*** (5.25)	10703 (.29)
Field Age (years)	166.9 (.66)	-.098 (0)	-81.4 (-.79)	172.3 (1.19)	-37.2 (-.11)	132.1 (.68)
Organic Fertilizers (kg)	--	-3.13 (-.44)	2.11 (1.23)	2.52 (1.15)	1.08 (.43)	.52 (.09)
Mineral Fertilizers (kg)	-93.0 (-.49)	110.4 (.76)	315*** (2.56)	177 (.82)	322 (1.02)	-1440 (-.82)
Frequency of Fertilizer Application (years)	426.8 (.29)	2019** (2.06)	1208*** (2.58)	1052* (1.90)	988+ (1.45)	-34 (-.03)
Frequency of Groundnut Planting (years)	10581*** (2.78)	5520** (1.94)	4346* (1.75)	1575 (.56)	-778 (-.21)	--
Date of Planting (days)	11.1 (.10)	15.3 (.19)	31.9 (.55)	-42.7 (-.51)	-99.0 (-.78)	667* (1.84)
Time Lag Planting-First Weeding (days)	20.3 (.20)	58.6 (.70)	-21.9 (-.77)	-14.0 (-.58)	-24.4 (-.93)	412.8 (1.15)
Hand-Tool Labor for Seedbed Preparation and Planting (hrs)	23.4 (.77)	-13.3 (.48)	-65.4*** (2.85)	-13.6 (-.39)	-14.1 (-.30)	686.6+ (1.64)
A.T. Labor for Seedbed Preparation (hrs)	42.0* (1.79)	56.5*** (2.66)	60.5*** (2.80)	-15.5 (-.30)	23.9 (.33)	187.5 (.26)
Hand Tool Labor for Weeding (hrs)	-4.6 (-.18)	30.6+ (1.53)	75.4*** (5.62)	19.4 (1.01)	-.46 (-.02)	-70.7 (-.37)
A.T. Labor for Weeding (hrs)	-36.8+ (-1.50)	.55 (.03)	46.3** (2.00)	186.5*** (3.37)	181.9** (2.35)	-932.4 (-.38)
Hand-Tool Labor for Late Ridging (hrs)	80.7+ (1.56)	107.7*** (2.73)	71.7** (1.90)	67.9 (1.24)	-52.3 (-.70)	-509.8 (-.88)
A.T. Labor for Late Ridging (hrs)	.55 (.0)	78.1+ (1.61)	89.0* (1.84)	-47.4 (-.57)	-7.5 (-.06)	-12764*** (-3.08)

Table D1, Continued.

Independent Dummy variables	Management System					
	M1	M2	M3	M4	M5	M6
Upland Rocky Soils (S10)	-5438 (-.77)	-7515+ (-1.30)	-6793** (-1.97)	-4991 (-1.19)	-3098 (-.62)	-10850+ (-1.59)
Upland Gravelly Soils (S11)	4803 (.90)	557 (.13)	-621 (-.22)	788 (.23)	1905 (.46)	1847 (.27)
Upland Sandy Gravelly Soils (S12)	964 (.20)	-437 (-.12)	-2600 (-.93)	-125 (-.04)	132 (.03)	-9215+ (-1.43)
Upland Sandy Soils (S20)	0	0	0	0	0	0
Leached Sandy Soils (S21)	-9274 (-1.17)	-10988+ (-1.44)	-9254 (-1.07)	--	--	--
Lowland Vertisoil (S40)	8041+ (1.57)	-406 (-.10)	-2567 (-.72)	1323 (.27)	2803 (.37)	-12157+ (-1.46)
Lowland Sandy Soil (S60)	-1037 (-.25)	819 (.22)	-2215 (-.83)	-1147 (-.30)	-1042 (-.21)	-8103+ (-1.39)
Maize	--	--	1499 (.43)	--	--	-56174*** (-4.46)
Red Sorghum	--	7654** (2.01)	8208*** (2.99)	6118+ (1.49)		2755 (.46)
White Sorghum	8329** (2.17)	6522** (2.01)	3743 (1.14)	439 (.09)	--	--
Millet	-8399+ (-1.33)	-12272*** (-2.72)	-2037 (-.65)	1638 (.47)	--	--
Groundnuts	-4596 (-.94)	-2150 (-.58)	3554 (.97)	11894** (2.14)	--	--
Earth Peas	14217 (1.20)	12179 (1.09)	18197+ (1.43)	--	--	--
Constant	7878.8 (.77)	9500 (1.16)	2361 (.46)	-10045 (-1.26)	2799 (.86)	20848 (1.05)

The management systems are various combinations of the management rings and are characterised by different average intensities of land use. The average intensity of land use $\overline{R}$ increases from M1 to M6.

M1 = Ring 3 ($\overline{R}$ = 30); M2 = Rings 3 and 2c ($\overline{R}$= 45) , M3 = All rings ($\overline{R}$= 50) ; M4 = Ring 2 (i.e. 2a + 2b + 2c) ($\overline{R}$= 80) ; M5 = Rings 2a + 2b ($\overline{R}$ = 94) ; M6 = Ring 1 ($\overline{R}$ = 96)

Source:Prudencio (1983).

Table D2. Regression Coefficients of the Linear Production Function for the Management System. Dependent Variable=Grain Output (kilograms). Model 1.1.

	Management System					
	M1	M2	M3	M4	M5	M6
R^2	.837	.744	.704	.874	.916	.734
$\bar{R}^2$	.721	.629	.655	.820	.861	.493
F	7.2	6.5	14.5	16.2	16.8	3.0
Degrees of Freedom	35	58	158	56	37	22
Land (hectares)	93.10⁺ (1.54)	59.3 (.91)	118.4** (2.04)	552*** (3.99)	872*** (5.29)	106.7 (.31)
Age (years)	2.65 (.66)	.583 (.16)	-1.20 (-.55)	6.18* (1.68)	.82 (.09)	1.54 (.85)
Organic Fertilizer (kg)	--	.032 (.21)	.053⁺ (1.47)	.080⁺ (1.43)	.028 (.47)	.008 (.15)
Mineral Fertilizer (kg)	-1.38 (-.45)	1.19 (.39)	7.73*** (2.95)	3.87 (.71)	7.95 (1.03)	-16.52 (-1.02)
Ferquency of Fertilizer Application (years)	-1.07 (-.05)	38.74* (1.89)	20.58** (2.07)	22.9* (1.63)	26.08 (1.58)	-1.04 (-.10)
Frequency of Groundnut Planting (years)	185.9*** (3.06)	112.0* (1.88)	92.8* (1.76)	27.50 (.39)	-24.9 (.27)	--
Date of Planting (days)	.15 (.09)	-.008 (-.005)	-.55 (-.44)	-1.06 (-.50)	-2.25 (-.73)	5.97* (1.78)
Time Lag Planting-First Weeding (days)	-.033 (-.02)	.309 (.18)	-.694 (-1.15)	-.355 (-.57)	-.58 (-.91)	3.58 (1.08)
Manual Labor for Seedbed Preparation (hrs)	.40 (.77)	-.237 (-.41)	-1.72*** (-3.54)	-.20 (-.23)	-.36 (-.32)	6.58* (1.70)
A. T. Labor for Seedbed Preparation (hrs)	.58⁺ (1.54)	.813* (1.83)	1.05** (2.30)	-.63 (-.48)	.61 (.35)	1.39 (.20)
Manual Labor Weeding (hrs)	-.06 (-.14)	.554⁺ (1.32)	1.85*** (6.50)	.254 (.53)	-.02 (-.03)	-.96 (-.55)
A. T. Labor Weeding (hrs)	-.58⁺ (-1.48)	.260 (.56)	1.56*** (3.17)	5.50*** (3.92)	5.00*** (2.65)	-10.2 (-.45)
Manual Labor Late Ridging (hrs)	1.35* (1.64)	2.70*** (2.51)	1.57** (1.96)	2.15⁺ (1.55)	-1.19 (-.65)	-4.77 (-.89)
A. T. Labor Late Ridging (hrs)	-.05 (-.05)	1.72* (1.69)	2.38** (2.31)	-1.77 (-.84)	-.70 (-.21)	-114.9*** (-3.00)

Table D2. Continued.

	Management System					
	M1	M2	M3	M4	M5	M6
Upland Rocky Soils (S10)	-59 (-.52)	-79 (-.65)	-109^{+} (-1.49)	-79 (-.74)	-71 (.59)	-103^{+} (-1.65)
Upland Gravelly Soils (S11)	89 (1.04)	0 (0)	-28 (-.47)	24 (.28)	47.0 (.47)	20 (.32)
Upland Sandy-Gravelly Soils (S12)	43 (.58)	55 (.72)	-21 (-.37)	15 (.16)	8 (.08)	-78^{+} (-1.32)
Upland Sandy Soils (S20)	0	0	0	0	0	0
Leached Sandy Soils (S21)	-114 (-.90)	-123 (-.78)	-102 (.567)	--	--	--
Lowland Vertisoils (S40)	162** (1.98)	20 (.25)	-34 (-.45)	124 (.99)	82.9 (.45)	-109^{+} (-1.43)
Lowland Sandy Soils (S60)	-5.5 (-.08)	56 (.71)	-8 (-.14)	7.1 (.07)	-19.9 (-.17)	-77^{+} (-1.45)
Maize	--	--	-11 (.15)	--	--	-577*** (-4.97)
Red Sorghum	--	274*** (3.43)	235*** (4.03)	218** (2.09)	0	33 (.61)
White Sorghum	153** (2.51)	108^{+} (1.58)	5.5 (.08)	-32 (-.25)	--	--
Millet	-87.67 (-.87)	-218** (-2.31)	-46 (.69)	59 (.67)	--	--
Groundnuts	-57 (-1.24)	-73 (-.94)	22 (.28)	246* (1.74)	--	--
Earthpea	248* (1.32)	208 (.89)	321 (1.19)	--	--	--
Constant Term	74.3 (.45)	131.0 (.76)	34.2 (.31)	-396.4** (1.96)	67.5 (.20)	259.0 (1.42)

Figures in parentheses are the t-statistics

+=Significant between .10 and .20

*=Significant at .10

**=Significant at .05

***=Significant at .01

Source: Prudencio (1983).

Table D3. Regression Coefficients of the Linear Production Function for Major Crops. Dependent Variable=Value of Output (CFA francs). Model 4.1.

	Crops			
	Maize	Red Sorghum	Millet/White Sorghum	All Cereals
R^2	.635	.785	.736	.639
$\overline{R}^2$	.306	.690	.605	.580
F	1.9	8.3	5.6	10.9
Degrees of Freedom	20	50	40	148
Land (hectares)	-9605 (-.47)	34379** (4.20)	6312** (2.06)	7510*** (2.73)
Age (years)	11.5 (.10)	532** (1.85)	-79.2 (-.76)	-23.9 (-.19)
Organic Fertilizers (kg)	-2.92 (-.98)	.62 (.20)	--	2.64+ (1.48)
Mineral Fertilizers (kg)	-1174 (-1.14)	448 (1.20)	85.5 (.51)	311.3** (2.39)
Frequency of Fertilizer Application (years)	602 (.98)	1698** (2.17)	1252 (1.00)	1322*** (2.64)
Frequency of Groundnut Planting (years)	--	-1482 (-.20)	7295** (2.02)	4818+ (1.48)
Date of Planting (days)	41.0 (.18)	22.0 (.16)	16.1 (.19)	11.0 (.18)
Time Lag Planting - First Weeding (days)	36.0 (.17)	-22.7 (-.63)	-43.6 (-.50)	-32.7 (-1.09)
Hand Tool Labor for Seedbed Preparation and Planting	592*** (2.81)	-22.6 (-.41)	-28.3 (-.90)	-68.0*** (-2.81)
A. T. Labor for Seedbed Preparation (hrs)	114.2 (.29)	-15.7 (-.19)	65.4*** (2.93)	62.2*** (2.87)
Hand Tool Labor for Weeding (hrs)	119.1 (1.02)	-.80 (-.03)	31.5 (1.28)	74.1*** (5.19)
A. T. Labor for Weeding (hrs)	718.8 (.62)	164.7** (2.02)	-2.06 (-.09)	53.5** (2.27)

Table D3, Continued.

	Crops			
	Maize	Red Sorghum	Millet/White Sorghum	All Cereals
Hand-Tool Labor for Late Ridging (hrs)	-275.5 (-.87)	123.6 (1.26)	66.9^{+} (1.40)	75.5* (1.79)
A. T. Labor for Late Ridging (hrs)	--	-39.0 (-.21)	65.2 (1.20)	73.7^{+} (1.45)
Upland Rocky Soils (S10)	3594 (.85)	-7065 (-1.06)	-5028 (-.61)	-6122^{+} (-1.55)
Upland Gravelly Soils (S11)	9886** (2.50)	1258 (.25)	672 (.14)	-30 (-.01)
Upland Sandy-Gravelly Soils (S12)	502 (.13)	-5603 (-1.10)	-3458 (-.78)	-2241 (-.76)
Upland Sandy Soils (S20)	0	0	0	0
Leached Sandy Soils (S21)	--	--	-15641^{+} (-1.42)	-12165 (-.96)
Lowland Vertisoil (S40)	-1017 (-.20)	4408 (.50)	3028 (.62)	-2504 (-.63)
Lowland Sandy Soil (S60)	4414 (1.20)	-1270 (-.23)	-2255 (-.52)	-2192 (-.76)
R_1 R_{1a}	0			
R_1 R_{1b}	2659 (1.00)	22704*** (2.91)	--	481 (.10)
R_{2a}	--	0	--	4312 (.93)
$R2_b$	--	5323 (.53)	--	2566 (.41)
$R2_c$	--	10400 (1.30)	-5862 (-1.16)	2349 (.66)
R 3	--	--	0	0
Cereal-Cowpea Density Ratio	--	-1203^{+} (-1.40)	-42.7 (-.12)	--
Constant	-6005 (.42)	-22013^{+} (-1.64)	8733 (1.23)	3420 (.80)

Source Prudencio (1983).

Table D4. Regresion Coefficients of the Linear Production Function for Major Crops. Dependent Variable=Grain Output (kilograms). Model 3.1.

	Crops			
	Maize	Red Sorghum	Millet/White Sorghum	All Cereals
R^2	.629	.865	.722	.695
$\bar{R}^2$	.295	.806	.582	.646
F	1.9	14.6	5.2	14.1
Degrees of Freedom	20	50	40	148
Land (hectares)	-103 (-.54)	837.0*** (5.43)	134.2*** (2.46)	130.1** (2.26)
Age (years)	.29 (.26)	8.38 (1.54)	-1.75 (-.47)	-1.22 (-.46)
Organic Fertilizers (kg)	-.030 (-1.07)	.047 (.78)	--	.068* (1.82)
Mineral Fertilizers (kg)	-12.95+ (-1.33)	11.07+ (1.58)	1.16 (.39)	8.17*** (2.99)
Frequency of Fertilizer Application (years)	5.26 (.91)	31.5** (2.13)	24.5 (1.09)	26.63*** (2.54)
Frequency of Groundnut Planting (years)	--	-16.1 (.11)	124.1* (1.94)	72.4 (1.06)
Date of Planting (days)	.40 (.19)	-.34 (-.14)	.184 (.12)	-.15 (.12)
Time Lag Planting First Weeding (days)	.37 (.18)	-.55 (-.80)	-1.08 (-.70)	-.75 (1.19)
Hand Tool Labor for Seedbed Preparation (hrs)	5.96*** (3.00)	-.53 (.52)	-.66 (1.20)	-1.74*** (-3.44)
A. T. Labor for Seedbed Preparation (hours)	.56 (.15)	-.61 (.39)	.96** (2.41)	1.11*** (2.43)
Hand Tool Labor for Weeding (hours)	1.07 (.98)	-.02 (.02)	.59+ (1.35)	1.88*** (6.28)
A. T. Labor for Weeding (hours)	7.43 (.68)	3.92*** (2.55)	-.014 (-.03)	1.60*** (3.24)
Hand Tool Labor for (hours)	-2.77 (-.92)	2.80+ (1.52)	1.05 (1.25)	1.68** (1.90)
A. T. Labor for Late Ridging (hours)	--	-.26 (.08)	.95 (1.03)	1.61+ (1.54)

Table D4, continued.

	Crops			
	Maize	Red Sorghum	Millet/White Sorghum	All Cereals
Upland Rocky Soils (S10)	32 (.80)	-108 (-.86)	-83 (-.57)	-111+ (-1.35)
Upland Gravelly Soils (S11)	93** (2.51)	46 (.48)	19 (.21)	-18 (-.30)
Upland Sandy/Gravelly Soils (S12)	10 (.26)	-33 (-.35)	-59 (-.72)	-9 (-.14)
Upland Sandy Soil (S20)	0	0	0	0
Leached Sandy Soils (S21)	--	--	-274+ (-1.40)	-178 (-.67)
Lowland Vertisoils (S40)	-.13 (-.28)	145 (.87)	50 (.58)	-73 (-.88)
Lowland Sandy-Silt Soils (S60)	40 (1.15)	19 (.18)	-45 (-.58)	-18 (-.30)
R1a	0	00	--	--
R1b	27 (1.06)	214+ (1.46)	--	6 (.06)
R_{2a}	--	0	--	260*** (2.67)
R_{2b}	--	63 (.34)	--	260*** (1.93)
R_{2c}	--	122 (.81)	-91 (-1.01)	162** (2.18)
R_3	--	--	0	0
Cereal Cowpea Density	--	--	--	--
Constant Term	-61.97 (-.46)	-340.4 (1.35)	157.07 (1.27)	-2.86 (.03)

Source Prudencio (1983).

Table D5. Regression Coefficients of Farm Level Linear Production Functions.

Variables Used in The Estimation	Dependent Variable					
	Grain Output (kilograms)			Value of Output (CFA francs)		
	Inter-Farm Variations		Inter-Field Variations	Inter-Farm Variations		Inter-Field Variations
Statistical Model	(5.1)	(5.2)	(5.1)	(5.1)	(5.2)	(5.1)
Degrees of Freedom	19	19	179	19	19	179
Land (A) in hectares	82.25 (.60)	9.80 (.06)	-74.6 (-1.42)	8,884$^+$ (1.43)	4,295 (.59)	1,416 (.62)
Organic Fertilizers Applied (Q_{ma}) in kg	.102$^+$ (1.38)	--	.104*** (2.82)	6.3* (1.88)	--	4.50*** (2.81)
Organic Fertilizer Produced (Q_{mp}) in kg	--	.084 (.74)	--	--	5.4 (1.01)	--
Mineral Fertilizer Applied (Q_f) in kg	12.69** (2.17)	10.58$^+$ (1.48)	8.58*** (3.16)	579** (2.18)	443$^+$ (1.33)	300.0*** (2.53)
Hand Tool Labor (MN) in hours	.84** (2.77)	.88*** (2.62)	.86*** (5.72)	38.2*** (2.77)	40.9** (2.60)	30.9*** (4.70)
Animal Traction Labor (ATN) in hours	.706 (1.01)	1.19*** (1.72)	1.26*** (4.74)	25.8 (.81)	55.8* (1.74)	49.5*** (4.28)
Constant Term	471.0$^+$ (1.37)	403.1 (.94)	116.6*** (4.33)	19,527 (1.25)	14,994 (.75)	7,488*** (6.38)
R^2	.737	.719	.551	.783	.756	.558
$\bar{R}^2$	.668	.645	.538	.726	.691	.546
F	10.65	9.71	43.8	13.72	11.75	45.30

Source Prudencio (1983)

1987-03

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