

**The soils in villages lands in western Niger,
opportunities and constraints for rural development.**
By Pierre Hiernaux

Introduction

As in the rest of Africa population in the Sahelian countries is increasing steadily since the mid of the 20th century. During the last two decades the rate of population growth was still increasing together with the rate of urbanisation. Based on the age and gender composition of the population, levels and trends of fertility and mortality these rates of increase should persist over the next two decades. Demographs predict an increase of the population in south-Saharan West Africa from 215 m in 1990 to 430-470 m in 2020 with 40 % and 63% urban respectively. (Snrech, 1994). Despite the harshness of its climate and the poor natural resource endowment, trends in Niger are similar with close to 10 m inhabitants in 1998 and expected 24 m in 2020 (Banoïn and Guengant, 1998). Up to the 1960s the increasing needs for food was solved by an the expansion of land cropped and the increase in livestock numbers (). However, there are less and less suitable land left uncropped, cropping already expanded to marginal land, either less fertile or more sensitive to erosion. Area cropped expands at the detriment of areas in rangeland and fallow, and lead to a reduction in fallow duration so that livestock population and productivity are increasingly constrained by the availability, quality or accessibility of forage resources, especially during the growing season (). Thus assuring the food security implies an intensification of the agricultural production (). The possible ways of this intensification have been studied in set of villages of Western Niger. Particular emphasis was given to the roles plaid by livestock in the intensification of agricultural systems (). One of the major role of livestock in this environment marked by the inherent low fertility of the soils is manuring. Through forage intake and faeces and urine deposition livestock are transferring organic matter and nutrients from the grazed lands, cropped fields included during crop residue grazing, to crop lands (). Corraling and manuring management contribute to orient this transfer to the benefit of a small fraction of the cropped lands that are heavily manured, allowing for local higher yields and crop diversification (). However, although the land of the village studied share a uniform geological substrate, they are all composed of a range of soils that have contrasted agronomic aptitude (). This rise a set a questions that are tackled in this paper: how the changes in land use and management of natural resources under increasing human pressure is influenced by the diversity of soils, their characteristics and distribution relative to infrastructures (village, hamlets, water points, cattle paths)? How come soils endowment at farm and community levels constrains or favours different options of agriculture intensification? And more specifically, how does it condition the manuring practices and options?

Material and methods

Ten villages grouped in three sites were selected in the Fakara, about hundred kilometres to the East of Niamey the capital town of Niger. The Fakara is a natural region located between the valley of the Niger River to the West, and, to the East, the Dallol Bosso, a fossil valley of a formal tributary of the Niger. Located 15 to 30 kilometres apart from each other the village sites have similar climate and geology but they differ by the land use history and proportion of land cropped which range from 35%

in site centred on the village of Banizoumbou, to 45% in Tigo and 65 % in Kodey.

Climate is tropical semi-arid with annual rainfall average (1921-1990) of 575 mm (sd 138) in Niamey. Rains are distributed in single rainy season from May to October, with 35 (sd 5) rainy days. Annual rainfall recorded in Banizoumbou from 1994 to 1998 were mm respectively.

To help the assessment of the roles of livestock in the management of natural resources and agriculture performances, the soils and the land use were mapped over 500km² (latitude North 13° 20' - 13° 35' ; longitude East 2° 35' -2° 52') using existing aerial photography (). Land use was also mapped in 1994, 1995 and 1996 using low altitude aerial photography done with a plain 24x36 camera from a small aircraft flying at 1200m altitude. Land use maps was systematically verified during the exhaustive field survey of forage resources repeated three times a year from 1994 to 1996 and once a year in 1997 and 1998. The soil map has not been systematically checked on the ground. However, the map was used to stratify sample field sites used in the monitoring of resources and in which soil have been described. Other soil data from experiments (Delabre, Rockström, Sangaré, Gandah,) and surveys (Tropsoil, Chapell, d'Herbes, Loireau, de Row) conducted in the same village lands have been used to complete soil characterisation.

A survey of farmers classification and perception the agricultural aptitudes of the soils was conducted in 1998 among Djerma farmers and Fulani agro-pastoralist of the different sites.

Soil types

The geology, topography and geomorphology settings.

The Fakara is located in the bottom part of a large sedimentary basin that extends over most west Niger and south east Mali. This bottom part the basin is dominated by more or less loamy sandstones of thick deposits of the tertiary known as 'Continental Terminal' (Greigert, 1966). The top layers of these sandstones have been weathered during the Pleistocene into a kaolinic mantle that provided the initial material of the ferrallitic soils which deep horizon later indurated into an iron pan that is 5 to 15 metres thick by places. Erosion cleared away most of the material of the top horizons exposing the very flat surface of the iron pan that now caps the plateaux which dominates the landscape. Indeed, erosion during the first humid periods of the quaternary, re-enforced by the proximity of the low altitude level of the Niger, dissected this indurated surface into plateaux separated by a web of valleys that may have followed the major faults (Vicat et al.). Detritic material from the Eocene surface were incorporated in the ferrugineous surfaces that established during the each of the humid periods of the quaternary, each time at a lower altitude level in the valleys, creating a succession of discontinuous and embedded erosion surfaces (). The deep layers of the ferrugineous soils that developed on each of these surfaces indurated with decreasing amplitude as the duration and humidity of these periods was decreasing. In the bottom of the valleys, colluvial and alluvial land forms are also inherited from those humid periods. The humid periods alternated with arid periods during which wind erosion was very active, reshaping the sediments into sand dunes and sand deposits all over the landscape including on top of the iron-pan capped plateau and in the bottom of the valley where

they disrupted water drainage.

The soil types.

As a result of alternating humid and arid periods, landforms and soils are all polygenic. Despite their polygenic nature, the land form and soils vary along the slope, the material found in the soils of the plateau or up-slope is closer to the Eocene kaolinic weathering mantle and ferralitic soils, while down-slope material, when it is not recent colluvium, are highly leached of clay and iron. Except for the content in organic matter more linked to management, the main soil characteristics can be related to land form and topographic position (Table 1). Thus, the depth of the loose soil above either weathered sandstone or iron pan, the texture and colour of the loose material are major characteristics of the soil types. The texture of the top soil also determine, together with the land use, the types and proportions of different soil surface features as defined by Casenave and Valentin (1992) so that a correspondence matrix can be established between soil types and the probability of occurrence of the different soil surface features, including surface crusts, under different management scenarios (Table 2). In turn, the proportions of the different types surface features influence the hydrological properties of the soils and the redistribution of rainfall water in the landscape (Table 3). Finally approximate correspondence with other soil classification systems have been established (Table 4).

Table 1. Soils types and main characteristics.

	Arenic Gleysol	Gleyic Arenosol	Leptic lixisol	Arenic Cambisol	Arenic lixisol	Ferralic arenosol	Skeletal leptosol
Topography	valley	valley	down- slope	flats	mid-slope	up-slope	plateau
Land form	river bed	alluvial deposit	erosion surface	colluvial fan	sand deposit	eroded deposit	plateau cliff
Depth (cm)	> 300	> 300	20 to 80	> 300	> 300	10 to 50	0 to 10
Color (0-20)	10YR5/6	5YR 5/8	7.5YR3/4	10YR6/4	7.5YR4/6	5YR5/6	7.5YR 5/6
<i>Texture at 0-30 cm depth</i>							
gravels (% total)	0	0	0	0 to 5	0	0 to 20	20 to 90
sand coarse%	2-5	45-48	40-50	45-50	40-50	34-36	32-35
sand fine%	35-40	40-45	35-40	38-42	40-50	50-53	32-38
silt %	30-35	2-3	5-8	3-5	2-3	4-7	5-8
clay %	15-25	6-12	7-12	5-10	2-5	4-8	12-17
pH (water)	5.5-6.3	5.0-5.3	5.0-5.5	4.5- 5.5	5.2-6.2	5.0-5.9	5.0-6.0
CEC (meq/100g)	5.0-7.0	1.5-2.0	2.0-2.5	1.0-2.0	0.8-1.2	1-1.6	2.0-2.5
Total N (ppm)	250-350	60-120	150-200	200-250	100-250	150-250	200-300
Total P (ppm)	2.5-5.0	1.5-2.0	1.2-2.5	1.5-2.0	1.5-3.5	0.7-1.5	2.5-5.5
K (meq/100g)	0.20-0.40	0.02-0.03	0.02-0.03	0.03-0.05	0.03-0.06	0.04-0.09	0.20-0.30
OM (%)	0.40-0.80	0.08-0.25	0.25-0.35	0.20-0.70	0.12-0.17	0.15-0.30	0.1-0.5

Sources: Desconnet, 1994; Gavaud and Boulet, 1967; Rockstöm and Valentin, 1996; Tropsoil, 1991

Table 2. Correspondence between soils classifications

FAO soil classification (ISSS et al., 1998)	French soil classification (Gavaud, 1966)	US soil classification (Soil Survey Staff, 1990)
Skeletal leptosol	Sols peu évolués d'érosion régiques à facies ferrugineux	Petroferric KanhaplustalFs, loamy sands
Ferralic arenosol	Sols ferrugineux peu lessivés, évolués, série très rubéfiée de plateau	Psammentic PaleustalFs, loamy sands
Arenic lixisol	Sols ferrugineux lessivés faiblement différenciés	Pasammentic HaplustalFs, sandy
Arenic cambisol	Sols peu évolués d'apport, facies ferrugineux sur colluvions ,	Psammentic HaplustalFs, sandy
Leptic lixisol	Sols regiques sur gravillons ferrugineux, facies ferrugineux	Petroferric KanhaplustalFs, sandy
Gleyic arenosol	Sols ferrugineux lessivés a pseudogley de profondeur	Psammentic HaplustalFs, sandy
Arenic gleysol	Sols hydromorphes a gley sur colluvium des vallées sèches	Aquic Quartzipsamments lsandy loams

Table 3. Area covered by the different forms of surface features in uncropped lands with the different soil types.

Soil types	Soils surface features (Valentin and Bresson, 1992)						Run-off ratio %	Water retention		Infiltr. mm h ⁻¹
	BIO	DR1	ST3	SED	ERO	GRA		pF 2.5	pF 4.2	
Skeletal leptosols	22	2	13	7	20	26	52	-	-	8-70
Ferralic arenosols			45		50	5	85	3-4	1.6-2.0	5-120
Arenic lixisols		77	5		18		30	2-3	1.3-1.6	300-600
Arenic cambisol	10	40	20	25	5		25	3.5-4.5	2.5-3.0	300-600
Leptic lixisol		5	20		40	35	60	4-6	2-3	5-120
Gleyic arenosol	5	80	10	3	2		20	2-3	1.2-1.5	300-600
Arenic gleysols	10		5	70	15		0	-	-	8-30

Sources: adapted from: d'Herbes and Valentin, 1997; Hammer, 1994;Valentin and Bresson, 1992

The soil map

Soils have been mapped along three criteria: the topographical position, the land form and the soil defined by the depth and the texture of the loose soil. Four main topographical situations have been distinguished: plateau and iron pan flats, up-slope, mid and down slopes, valley). Some land forms such as 'fossil dune' or 'thin sand deposits' are found in different topographic situations, others are specific to one situation such as for the alluvial plains, levees banks and channels only found in the valley (Table 5). A type of texture is associated to each of these land forms allowing to establish a correspondence with the field soil classification.

Table 5. Classification of soils by topographic situation, land form and texture of the top soil, that was used to map soils (codes) and correspondence with soils types.

Topography	Land form	Top soil texture	Soil map code	Corresponding soil type	Farmers classifications	
					Jerma	Fulfulde
Plateau	Dune on the plateau	Coarse sands	Pd	Ferralic arenosol	Labu tjirey	Tjayeri
	Thin sand deposit on the iron pan	Sands	Pe	Ferralic arenosol	Gangani	Ferro yorongo
	Ferruginous iron pan outcrop	Rock, gravels, loamy sands	Pg	Skeletal leptosol	Tondi bon	Korkaje
	Thin loamy layer on the iron pan	Loamy sands	Pl	Ferralic arenosol	Gangani	Lisore
	Rocky cliff of the plateau border	Rock, gravels, loamy sands	Pr	Skeletal leptosol	Tondi kaksia	Daga bao
Up-slope	Thick sand deposits	Sands	Td	Ferralic arenosol	Labu tjirey	Tjayeri
	Erosion surface, gullies	Loamy sands, gravels	Tr	Skeletal leptosol	Gangani	Kollade
	Colluvium fan	Sands, Loamy sands	Tv	Cambic arenosol	Tassi kwarey	Tasi Buttiri
Mid and down-slope (embedded erosive surfaces =	Dune on the flats	Coarse sands	Rd	Arenic lixisol	Labu tjirey	Tjayeri
	Thin sand deposits on the flats	Sands, gravels	Re	Arenic lixisol	Gangani	Ferro yorongo
	Thin loamy layer on the flats	Loamy sands, gravels	Rl	Ferralic arenosol	Gangani	Kollade

surfaces = flats)	Erosive surfaces outcrop	Gravels, loamy sands	Rr	Leptic lixisol	Gangani	Kollade
	Depressions filled with colluvium	loamy sands, sands	Rv	Arenic cambisol	Tombo	Lisore
Valley system	Major river bed or valley banks	Sands	Vr	Arenic lixisol	Tassi Kwarey	Tasi buttiri
	Minor river bed banks	Loamy sands	Vd	Arenic lixisol	Botogo tjirey	Lope bodejo
	Fossil alluvial plain	Sands, leached	Ve	Gleyic arenosol	Tasi kwarey	Tasi buttiri
	Fossil levees	Loamy sands, leached	VI	Gleyic arenosol	Bulungu	Bulunguri
	Fossil chanal and river beds	Loamy sands, clayed loams	Vc	Arenic gleysol	Botogo bi	Lope baledjo
	River bed	loamy sands, clayed loams	Vv	Arenic gleysol	Botogo bi	Lope baledjo

Farmers classification and perception.

Soil classification in the two main languages spoken in the village studied Jerma (Table 6) and Fulfulde (Table 7).

Table 6. The classification of the soils found in the Fakara region by Jerma farmers interviewed in villages of the Canton of Dantiandou (Niger) and approximate equivalent in FAO soil classification (ISSS et al., 1998)

Farmers classification of soils (Jerma)	Approximate equivalent in FAO soil classification	Soils identified by individual informant farmers									
		1	2	3	4	5	6	7	8	9	10
Tondi bon (Gangani kogo) (G. kraw-kraw)	Skeletal leptosol			i	i	i		i	i		
Tondi kaksia	Skeletal leptosol + Ferralic arenosol			i	i						

Lubu tjirey (=Tassi tjirey)	Arenic lixisol	i	i	i	i	i	i	i	i		
Balanga	Arenic lixisol				i	i	i	i	i		
Tassi kwarey (=Tassi bazanga)	Gleyic arenosol	i	i	i	i				i	i	
Gangani (=katami) (G. workuworku) (G. fanfara, tayo)	Leptic lixisol		i	i	i	i			i	i	
Tombo (=Koro banda)	Arenic cambisol				i			i			
Bulungu (=Tassi bulungu)	Arenic cambisol			i	i			i		i	
Botogo tjirey (=bagu tjirey)	Arenic cambisol	i			i	i				i	
Botogo bi (=bagu bi)	Arenic gleysol	i	i	i	i	i				i	

1: TD (Bundu) 2: SH(Bundu) 3: AB (Bundu) 4:T (Yulua) 5: HS (Tjigo) 6: MD (Baniz.) 7: GS (Baniz) 8: MB (kodey) 9: 10:

Tokagule= deflation patch, generally in cropped sandy soils

Table 7. The classification of the soils found in the Fakara region by Fulani farmers interviewed in villages of the Canton of Dantiadou (Niger) and approximate equivalent in FAO soil classification (ISSS et al., 1998)

Farmers classification of soils (Fulfulde)	Approximate equivalent in FAO soil classification	Soils identified by individual informant farmers									
		1	2	3	4	5	6	7	8	9	10
Korkaje, Karral (=Karanga)	Skeletal leptosol	i		i	i	i	i				
Ferro yorongo (= Kollade burde) (= Djolde tassire)	Ferralic arenosol + Skeletal leptosol	i		i		i	i				
Kollade (K. bodedjo)	Leptic lixisol + Ferralic arenosol	i	i	i	i	i	i				
Tasiri seuni (= Seuni tjayeri) (=leydi wodere)	Arenic lixisol + Arenic cambisol	i	i		i	i	i				
Leydi banndi	Arenic lixisol			i		i	i				
Lisore	Arenic cambisol	i		i	i	i	i				
Bulunguri (=Budlaldi)	Arenic cambisol			i							
Tasiri buttiri (=tasiri danedji)	Gleyic arenosol + Arenic cambisol	i	i								
Lope bodejo (Dangarma)	Arenic cambisol	i	i								
Lope balejo (=luggere)	Arenic gleysol	i	i		i	i	i				

1: AS (Baniz) 2:AM (Bundu) 3:OB (Katanga) 4:AS(Banka) 5: DA (Baniz) 6: coll. (Kodey)
7: 8: 9: 10:

Characterisation and correspondence with scientific classification

Perception of soil agronomic aptitudes

Table 8 Farmers perception of soil agronomic aptitudes following the Jerma classification of soils.

Farmers classification of soils (Jerma)	Possible crops*	Yields, levels and regularity	Risks for water balance	Risks for soil fertility
Tondi bon	None	-	-	-
Tondi kaksia	M	Low, very variable	Drought	
Lubu tjirey (Tasi tjirey)	M/N/H, Z, V, G	Average, stable		Need fallowing
Balanga	M/N	Low, variable		Need manure
Tasi kwarey	C, P, D	Low, variable	Flood	Need manure
Gangani	M	Low, variable	Drought	
Bulungu	M/N, G, V, H, S	average, variable		Need long fallow
Botogo tjirey	M/N, S/G	Good, variable	Flood	
Botogo bi	All (S, I, G, N, C, P, D)	High, very variable	Flood, drought	

* M: millet with MI long-cycle millet and Ms short-cycle millet; N: Cowpea; H hibiscus; S: Sorghum; I: Maize; G: groundnuts; V: voandzu; Z: sesamum; C: cassava; O: ochra; P: pumpkin; D: gourd; M/N = associated crops: millet/cowpea; All (S,G)= all crops possible crop and especially Sorghum, groundnuts).

Table 9 Farmers perception of soil agronomic aptitudes following the Fulani classification of soils.

Farmers classification of soils (Fulfulde)	Possible crops*	Yields, levels and regularity	Risks for the water balance	Risks for soil fertility
Korkaje	None	-	-	-
Ferro yorongo	None	-	-	-
Kolade	M	Low, very variable	Drought	Need fertilizers
Tasiri seuni (=Tjayeri)	M/N/H, Z, V, G	Average, stable		Need manure
Leydi banndi	MI	Low	Resist drought	Need manure
Lisore	MI/N/H, S/G, Z, O	Good, variable	Flood	
Budlaldi	Ms/N/H, V, Z	Average	Drought	need long fallow
Tasiri buttiri	C, P, D	Low, variable	Flood	need manure
Lope bodejo	MI/N, S/G	Good, variable	Flood	
Lope balejo	All (S, I, G, N, C, P, D)	High, very variable	Flood, drought	

* M: millet with MI long-cycle millet, Ms short-cycle millet ; N: Cowpea; H hibiscus; S: Sorghum; I: Maize; G:groundnuts; V: voandzu; Z: sesamum; C: cassava; O: ochra; P: pumpkin; D: gourd ; M/N/O = associated crops; All (S/G)= all crops possible and especially associated crop of Sorghum with groundnuts).

The soil agronomic aptitudes

The soil types defined on the base of topography, land form and top soil texture are grouped by level of agronomic aptitude. For this purpose the soil types have been ranked along a soil chemical fertility gradient in considering CEC, pH and organic matter content, and a soil infiltration gradient considering depth, topographical position, texture and crusting. The two gradients are combined in a matrix (Table 10). This empirical ranking allowed the grouping of soil types into five categories of soil aptitude to crop:

- The loamy sands and clayed loams in colluvial and alluvial depression (Tv, Rv, Vv) they constitute the 'rich' soil group. These soils offer the highest potential for cropping, however because of their down position these soils are susceptible to flood rich can ruin the crop and the relatively fine texture of the soil render them more difficult to till.
- The thick sandy soils moderately leached (Pd, Td, Rd, Vr, Vd), they constitute the 'fair' soil group. These soils are very easy to till and offer a fair potential to crop millet and cowpea providing either manure inputs or regular fallowing.
- The thick sandy soils highly leached (Rd, Vr, Vd), they constitute the 'poor' soil group. These soils are very easy to till but offer a poor potential for cropping because of the poor inherent fertility of their very sandy material.
- The shallow sandy and loamy sand soils, and the highly leached alluvial sandy soils (Pl, Rl, Tr; Rr, Pe, Re, Ve), they constitute the 'marginal' soil group. These soils offer a marginal cropping potential, they are very susceptible to erosion.
- The indurated and rocky soils (Pg, Pr) they constitute the 'nil' soil group. These soils are normally not arable.

Table 10. Matrix of soil agronomic potential defined by the inherent fertility and the physical propriety driving the soil water infiltration

Soil agronomic potential		Water infiltration in the soil (Run-on + permeability)			
		High	Medium	Low	Very low
Soil inherent fertility	Fair	Tv, Rv, Vv	Pd, Td	Pl, Rl	Tr, Rr
	Poor		Rd, Vr, Vd	Pe, Re, Ve	Pg, Pr

Soil response to fertility management

Starting from a pristine land, suitable for cropping, farmers consider that the yield of the first crop season ('sakara') is poor and irregular (good growth in spots were trees or shrubs were located), it improves in the second year and peaks in the third. Then some fertile soils ('Gabbo') can be crop for a long series of years before yield decreases (case of the clayed soils). In most soils however if manure is not applied yields are maintained for another 1 to 3 years before declining. Then, depending on soil type, land need either to be fallowed for 3 years (case of labu tjirey), 5 years (case of 'balanga'), or more than 10 years (case of 'bulungu'). Manuring is an

alternative to fallowing (Fulani say it the other way round: fallowing is an alternative to manuring when you have not enough livestock). The effect of manuring is accounted over 3 to four years. The crop yield response to manure is maximum the first year after manuring and decline afterwards. Regular manuring suppresses need for fallowing (examples of fields are given that keep good level of yields after 60 year of continuous cultivation). Risks of 'burning' crops by excessive manuring is recognised, especially in 'hard soils' (PI, RI, Tr; Rr), but occurrence is rare.

Soil response to tillage and sensitivity to erosion

Soil tillage either manually with a hoe or with a plough using animal traction is felt useful in marginal lands which surfaces are indurated (in 'kollade' and 'Gangani'), in order to promote water infiltration.

Effect of wind erosion is felt responsible for the bare and crusted soils patches that develop in cropped sandy soil (called 'tokagule' in Jerma). Local application of manure, house wastes or branches allows to stop the erosion and trap sand in order to recover soil fertility.

Soils and land use

There are five main land use systems prevailing in the Fakara (table 11). The short-fallow consist in alternating five ($yy \pm$) consecutive years of cropping without manuring with three year ($xx \pm$) of fallowing. The duration of the cropping period is the same in the long-fallow system but the duration of the fallow is much longer, $17 \pm$ years in the sample of sites surveyed in the village. Continuous cropping of more or less regularly manured land constitute the third category of land use, it is the most common in the field that just surround the village, the water points and the pastoral camps. Forestry and pastoral management (communal grazing, harvesting of dead wood, selective and whole wood cutting) is the land use system of un-arable lands. The last system gather all the areas build and the roads.

Table 11. Prevailing practices in the main land use systems of the Fakara region, names in Djerma and Fulfulde.

Land use	Practices	Names in Djerma	Names in Fulfulde
Fallowing	Fallow	Farey zenu	Karia, dantjirey
	1st crop after fallowing	Sakara	Gussa kesa
	2d or more crop after fallowing	Lali banda, Kwari-kwari	-
	Poor soil after many crop	Labu farga	Leydi tampune
	Arable land never cropped	Bossey	Ferro
Manuring	Manured field near village	Kwaratje	-
	Field manured by corralling	Birgi nugu	Gesa ka birgi
Range management	Night corralling spot	Gah	Bille
	Livestock path	Haw lawol	Gurtol

nt	Pond	Bangu	wendu
	Well	Dey	Bundu

Potential crops in each type of soil (Table 12) and potential millet grain yield for each of the three main cropping system and in each class of soil agronomic potential (Table 13).

Table 12. Crop and crop associations possible per classes of soil agronomic potential under different cropping systems: all (long or short fallow and permanent systems with manure), Manured (only if manured), Long (only with long fallow when not manured)

Crops	Classes of soil agronomic potential				
	Rich	Fair	Poor	Marginal	Nil
Millet	All	All	Long	Long	-
Millet (\pm cowpea / Hibiscus)	All	All	Long	No	-
Sorghum (\pm peanut)	All	No	No	Manured	-
Peanut, Voandzu, Sesamum	Manured	Manured	Manured	Manured	-
Cassava, Pumkins, onions	Manured	Manured	Manured	No	-

Table 13. Potential millet grain yield under average climatic conditions in the year of cropping depending on the class of agronomic potential

Cropping system	Millet grain yield per class of soil agronomic potential				
	Rich	Fair	Poor	Marginal	Nil
Long fallow	650	450	400	250	-
Short fallow	550	350	300	150	-
Permanent, manured	750	550	500	-	-

Sources: adapted from deRouw, 1997; Tropsoil, 1991 and ILRI data 1994-1998

Soils and farm types

The land tenure system.

Access to cropping land.

Access to pasture.

Table xx Matrix of the binary combinations between soil types used to map soil mosaic that were simplified into a single code given in the cells of the matrix for each viable combination (example the mosaic Td-Tv was simplified in Tv).

Mapped soil types		Plateau					Up slope			Mid/down slope					Valley					
		Pd	Pe	Pg	Pl	Pr	Td	Tr	Tv	Rd	Re	Rl	Rr	Rv	Vc	Vd	Ve	VI	Vr	Vv
P l a t e a u	Pd	x	Pd	-	-	Pr	Td	-	-	Rd	-	-	-	-	-	-	-	-	-	-
	Pe	Pd	x	Pe	Pl	Pr	-	-	-	-	Re	-	-	-	-	-	-	-	-	-
	Pg	-	Pe	x	Pl	Pr	-	Pg	-	-	-	-	-	-	-	-	-	-	-	-
	Pl	-	Pl	Pl	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	Pr	Pr	Pr	Pr	-	x	-	Pr	-	-	Pr	-	-	-	-	-	-	-	-	-
U p - S l o p e	Td	Td	-	-	-	-	x	Td	Tv	-	-	-	-	-	-	-	-	-	-	-
	Tr	-	-	Pg	-	Pr	Td	x	Tv	-	-	-	-	-	-	-	-	-	-	-
	Tv	-	-	-	-	-	Tv	Tv	x	-	Tv	-	-	Tv	-	-	-	-	-	-
M i d a n d d o w n s l o p e	Rd	Rd	-	-	-	-	-	-	-	x	Rd	-	Rd	-	-	-	-	-	-	-
	Re	-	Re	-	-	Pr	-	-	Tv	Rd	x	Rl	Re	Rv	-	-	-	-	Vr	-
	Rl	-	-	-	-	-	-	-	-	-	Rl	x	Rl	Rv	-	-	-	-	-	-
	Rr	-	-	-	-	-	-	-	-	Rd	Re	Rl	x	Rv	-	-	-	-	-	-
	Rv	-	-	-	-	-	-	-	Tv	-	Rv	Rv	Rv	x	-	-	-	-	-	-
V a l l e y	Vc	-	-	-	-	-	-	-	-	-	-	-	-	-	x	Vd	Vc	VI	Vr	Vv
	Vd	-	-	-	-	-	-	-	-	-	-	-	-	-	Vd	x	Ve	VI	Vr	Vv
	Ve	-	-	-	-	-	-	-	-	-	-	-	-	-	Vc	Ve	x	Ve	Vr	Vv
	VI	-	-	-	-	-	-	-	-	-	-	-	-	-	VI	Ve	Ve	x	Vr	Vv
	Vr	-	-	-	-	-	-	-	-	-	Vr	-	Vr	-	Vr	Vr	Vr	Vr	x	Vv

Vv	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Vv	Vv	Vv	Vv	Vv	x
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