Approaching Local Limits to Field Expansion – Land Use Pattern Dynamics in Semi-arid Burkina Faso

Tina Svan Hansen & Anette Reenberg

Abstract

Land use pattern dynamics at the local level significantly influence land cover changes and thus global environmental change. Expansion of cultivated land may mirror increased demographic pressure, climatic changes and soil degradation.

The paper illustrates how subsistence farmers in semi-arid West Africa may alter their land use patterns in response to increased demographic pressure and environmental constraints. It presents an analysis of land use changes from South-Eastern Burkina Faso. Field measurement, household interviews and interpretation of a series of geometrically corrected aerial photos from 1956, 1972 and 1994 provide the background for a precise characterization of the cultivation expansion process and its relationship to socioeconomic and biophysical conditions for the agricultural system. Field expansions in the order of magnitude of 435% in 40 years are documented. Farmers' options and strategies to respond to rapidly increasing demographic pressure and declining natural resource potential are discussed in the light of theories on transformation of agricultural systems. It is concluded that the land use changes in the study region are approaching a critical point of saturation of arable land. It is, however, also emphasised that a 'Sudano-Sahelian Model' for land use change hardly exists. Sharply contrasting experiences occurring at micro scale need to be incorporated in conceptual models of the evolutionary trends in land use systems.

Key words:

Sudano-Sahelian Zone, Agricultural Systems, Land Use.

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During the latter half of this century the majority of global land cover changes have occurred in the tropical regions, among these, the Sudano-Sahelian region. Land cover and land use changes are environmentally significant in their own right. They degrade or enhance the land's resilience and capacity for sustained use (Turner II et al. 1995). Land cover might be changed by natural processes (Tucker et al. 1991), but increasingly important is the impact of human land use aimed at producing agricultural products. Thus, in the context of human impact on the environment it is a major task to specify the trajectories of land use changes. Inasmuch as agroecosystems are spatially complex, local specificity must be included in the analysis of resource management dynamics.

The objective of this paper is to evaluate in what ways subsistence farmers in semi-arid West Africa contribute to this process of change by altering their land use patterns in response to increased demographic pressure and environmental constraints.

Parameters that measure land use intensification or expansion of agricultural land play an important role in many recent works which address the environment-population nexus (see eg Brookfield 1995) or which discuss the cycle of unsustainability linking degradation of natural resources to human land use strategies (see eg Greenland et al. 1994). Expansion of agricultural land and land use intensification are frequently used indicators of transformation of agricultural systems. Land use intensification caused by demographic pressure is generally associated with environmental degradation (Sanchez & Leakey 1996).

The global validity of conventional wisdom within these areas of natural resource management research has been questioned (Tiffen et al. 1994; Leach & Mearns 1996; Raynaut 1997; Adams & Mortimore 1997). It is still more frequently argued that while global scale population growth is one of the main driving forces of environmental change, there are significant local variations in the interrelationship between people, food production and environmental change (Uitto & Ono 1996). Several key issues need to be revisited in a multidisciplinary context to understand the prevailing resource management strategies and the most probable future development. One important issue to address is land use dynamics with the aim of understanding which forces drive land use changes in various environmental, socioeconomic and cultural contexts. This, in turn, will be a valuable basis on which to develop the much needed conceptual framework for models that are capable of extrapolating and generalising local observations to expected trends at the regional, national and global level (Scoles et al. 1994).

Changes in Agriculture in Response to Population Growth

A comprehensive theoretical literature addresses the process of change in agricultural systems under changing environmental, demographic and socioeconomic conditions.

Simple cause-impact relationships between increased population size, agrarian change or eventual collapse of the ecological system have dominated reflections on the role of population growth. The neo-Malthusian school of thought sees population growth as leading to irreversible degradation or depletion of resources (eg Meadows et al.1972; Scott 1979). Demographic pressure is believed to lead to cultivation of agriculturally marginal land or to unsustainable use of existing fields. However, more optimistic theoretical points of view have been emphasised and exemplified by several researchers. They support the school of thought related to the work of Boserup (1965) who claimed that the increase in population density or land scarcity was an independent variable that could trigger agricultural intensification. They state that there is no simple relationship between population growth, land scarcity and expansion of cultivated land (eg Tiffin et al. 1994; Christiaensen & Tollens 1995). On the contrary, this school of thought sees population pressure as a factor that might drive farmers to innovate agricultural production and mitigate resource degradation with the help of new land use practices. Netting (1993:276-277) underlines in a detailed discussion that the systemic interaction triad of population, environment/land and agricultural methods/ technology has been conceived in different way by Malthus, Marx and Boserup, but also suggests that Malthus and Boserup are not contradictory but complementary.

Turner et al. (1993) suggest an elaboration of Boserup's theory. It asserts that most Third World farmers' behaviour is determined by a composite of consumption and commodity rationales and that agricultural change is driven by the joint demands placed on it. The relative importance of either the consumption or the commodity driven impact depends on the level of subsistence in the system. The access to a local market is important to ensure an incentive to intensify (Lele & Stone 1989; Stroosnijder 1994) and to ease access to production means (Tiffin et al. 1994). Thus, a certain minimum level of regional population density, maybe beyond that found in eg the Sahel, can be seen as crucial to ensure a potential for agricultural intensification (Snrech 1994). Overall, however, it must be acknowledged that it is difficult to translate these global theories into operational characterizations at the local level (Serpantié 1993).

Two parameters, expansion of cultivated land and intensification of land use practice, are crucial in these theoretical considerations of agricultural change.

Geographic expansion is perhaps the most direct reaction to the stress of population pressure caused by population growth or a declining resource base (Netting 1993:276). If vacant land is available or if land is obtained by conflict or forcing out other users, the population density will remain low and allow the cultivators to continue their labour-efficient land use practice. This proposed trend corresponds to the second phase of Bilsborrow and Ogendo's (1992) conceptual framework in which the population driven changes in land use are seen to be manifest in various forms, including land tenure arrangements, expansion of agricultural land and intensification of agriculture, which are, however sometimes consecutive, concurrent or even cumulative. They suggest that the effects of population pressure are likely first to be felt through changes in tenure arrangements. The second phase of adjustment is expansion of land. The third phase is adoption of new technologies, the distinctive features being intensification and increase in land productivity. The last response in the population/land use continuum, the fourth phase, involves a fertility reduction, which can be mitigated by out migration.

The degree of intensification of resource utilization in tropical agricultural systems is frequently characterized by the type of fallow that has been adopted. Boserup introduces a suite of fallow types that represent increasing frequency of cropping. Other equivalent suggestions are presented by Ruthenberg (1980). The majority of these rely on a 'land use factor', which relates the length of the cropping plus a fallow phase to the cropping phase. A precondition for this way of characterizing the land use system is that shifting cultivation is practised. Whereas this is certainly a valid assumption for many tropical agricultural systems, it has sometimes been overlooked that it is not always the case. Based on examples from West Africa, Serpantié (1993:62) underlines, however, that permanent and shifting cultivation might correspond individually with different cultures or ecosystems, which are not likely to change because of demographic pressure or diffusion of innovations. Further, he emphasises that the development in West African agricultural systems frequently does not match the one proposed by the Boserupian theory. Rather, when arable land is saturated, the increased pressure on land is compensated for by out migrations (Netting 1993; Webber 1996; Nielsen et al. 1997). Therefore, the application of land use indices for characterization of the state or conditions (degree of pressure) of a certain agricultural system is not as straightforward as theories suggest. This does not, however, imply a general dissociation from the theories. It only proposes an elastic preconceived opinion about the inherent characteristics of agricultural systems.

Boserup's model of intensification is seen to be revolutionary in part because it questions technology as the sole engine of agricultural change (Netting 1993:270). In accordance with such lines of reasoning are reflections and empirical observations of adaption of animal-traction ploughs. Pryor (1985) and Herzog & Huis (1990) have shown that ploughs do not always increase labour- or area productivity; the amount of work input per farm may even rise. Only at higher population densities do ploughs offer substantial advantages (Pingali 1987), as they can be a means to increase production, although not necessarily with regard to yields per hectare. This explains why the introduction of ploughs is not seen as an attractive alternative to hoe cultivation by farmers in low density areas.

Much remains to be looked into to get to grips with the complex process of land use change. Further insight can, however, be obtained through precise recordings of land use changes and other parameters that influence farmers' decisions on agricultural strategies.

Materials and Methods

The Regional Setting

The study site, Ningaré, is located in the Boulgou province in the south-eastern part of Burkina Faso that belongs to the Sudanian agroecological zone (Figure 1 and Figure 2). The average precipitation is 905 mm (1922–1992), but rainfall varies from year to year and a significant decline can be observed in the long-term average since the early 1970s (Figure 3). The region is primarily dominated by agriculture. Parts of it, especially towards the east and in connection with river valleys, are left as natural and semi-

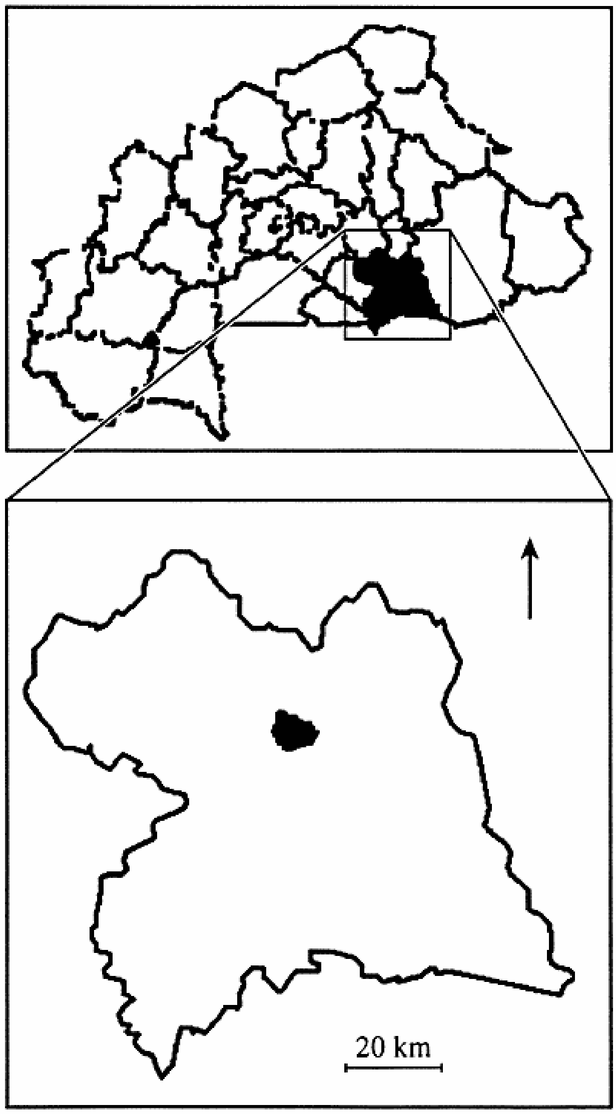

***Figure 1:** The location of the Boulgou Province.*

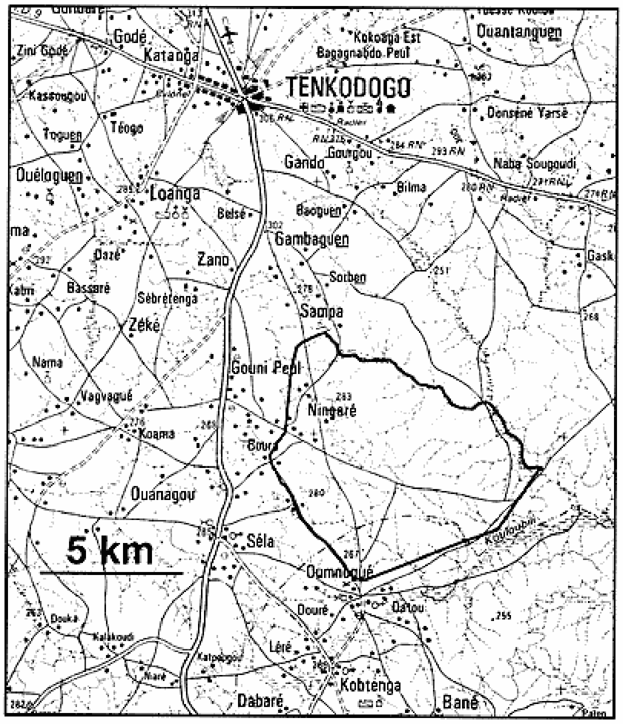

Figure 2: The location of Ningaré village territory (Basis map: I.G.N.- France Topographical map, original 1:200000).

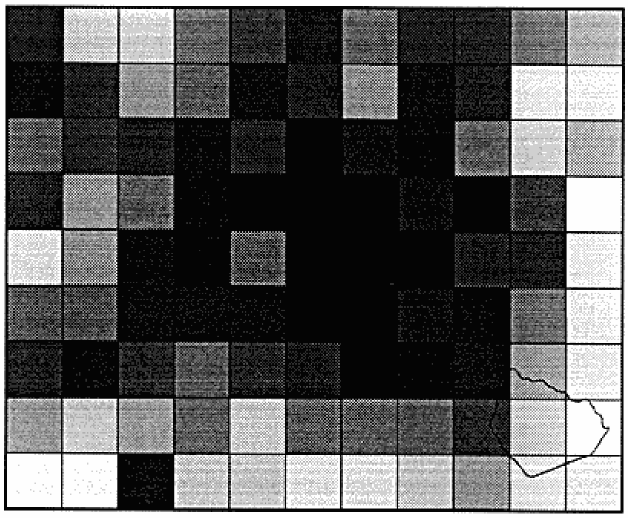

Figure 4: Variation in cultivation density in Ningaré and surroundings (fields as % of total area) calculated from a SPOT satellite image (Sept. 1994). The grid size is 5 km. The UTM-coordinates for the upper left corner are 744.950; 1.326.350. Nine intensity classes are shown; 10-19% (light grey), 20–29%, 30–39%, 40–49%, 50–54%, 55–59%, 60–64%, 65–69%, and 70–74% (black) (Reenberg & Dybkjær 1996).

natural vegetation and used in a more extensive way (a pastoral zone, fuelwood etc.). Cultivation intensity varies, however, significantly. A rough estimate of the percentage of cultivated land calculated from a SPOT satellite image (Reenberg & Dybkjær 1996) reveals a variation between 10% and 74% (Figure 4).

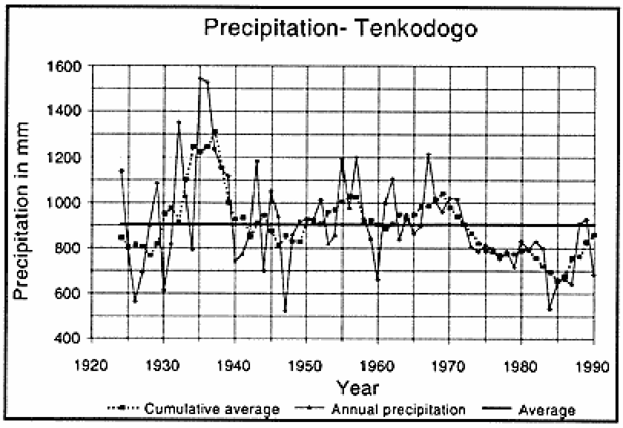

Figure 3: The annual precipitation in Tenkodogo from 1922–1992, yearly figures at five-year cumulative average (Source: C.R.P.A.- C.E. Tenkodogo).

The main agricultural activities are millet and sorghum cultivation, supplemented by cowpeas, groundnuts, peas, rice and a variety of minor crops without any significance with regard to acreage cultivated. The technological level varies considerably within the region. In some villages most farmers own and use ox-ploughs for preparation of the soil and for weeding, whereas ploughs and draught animals are virtually absent in other villages leaving the farmers to use the traditional hoe for all activities. Locally there are almost no possibilities of finding jobs outside the agricultural sector. The absence of remunerative opportunities has stimulated out migration of young men to eg Cote d'Ivoire. Contrary to the migration pattern known from northern Burkina Faso (Claude et al. 1991), where young men return to the villages to participate in cultivation, they are absent throughout the year.

The village, Ningaré, was chosen to represent "a typical village" in terms of not being close to a large market or receiving special attention from development projects, etc. As it appears from Figure 4, Ningaré's village territory is characterized by being located in or at the border to areas with low cultivation intensity. Ningaré is, like the entire region, inhabited by a mix of three ethnic groups, Bissa, Mossi and Peul (Fulani). The population is estimated to be

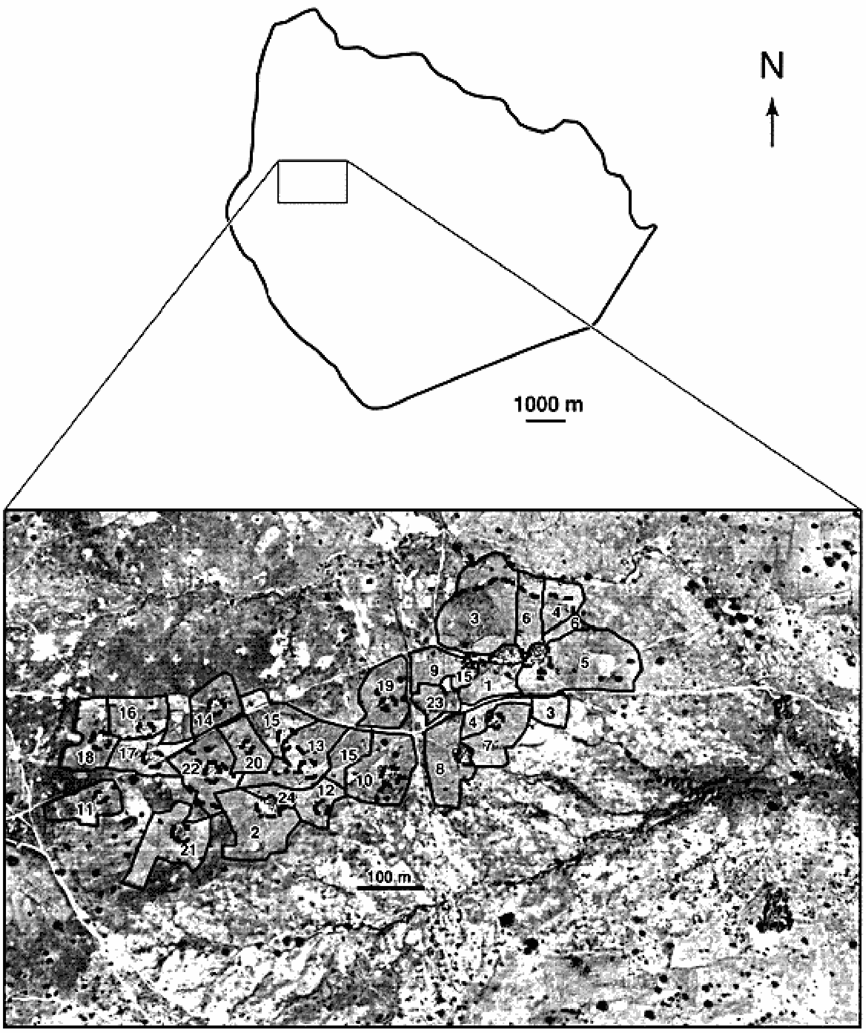

Figure 5: Locations of fields in the sample area (aerial photo from 1994).

862 inhabitants (1995) of which more than 50% below 15 years. The size of the village territory is 62 square kilometres. Hence, the population density is 14 persons per square kilometre.

Land Use System Characterization

The present study concerns changes in agricultural strategies and the corresponding alterations in land use practice and land use patterns. Different aspects of human resource management decisions and their impact can with advantage be referred to different spatial levels (Meentemeyer 1987; Fresco & Kroonenberg 1992; Lambin 1993; Andriesse 1994; Turner II et al. 1995; Reenberg 1996). Therefore, data collection was carried out at regional, village, household and field level.

Household specific information on socioeconomic parameters and land use was obtained from a survey in the autumn of 1995. Baseline information about the area: economic, cultural and religious aspects, as well as information concerning the farming system, was collected in a pilot phase, which also provided the background for a strategic choice of a study village. Ningaré village is large. Thus, only a part of the total village territory was selected for detailed studies at household level (Figure 5) – hereafter called the sample area. All fields (107) cultivated, abandoned or fallowed by the 24 compounds in the sample area were included in the study, despite the location of the fields. Furthermore, fields from 16 of these households were selected for in depth analysis. Quantitative and qualitative data on socioeconomic issues and land use practices

Table 1: Main parameters collected in the household survey. The survey was carried out with a wider scope than the present article. Thus the table lists more information than that reported in the present context.

SUBJECT	*KEY PARAMETERS*
Family size	Number of persons classified according to: sex, age, presence (all year/during agricultural season)
Division of agricultural labour	Type of persons (sex, age) taking part in preparation, seeding, weeding, harvest, and gardening
Off-farm income	Number of persons working outside the village, type of work Number of migrated persons, type of work
Livestock	Type (and number) of animals, grazing patterns
Crops	Importance in terms of consumption, sale and purchase
Field size determinants	Manpower, tools (technology), food requirements, manure availability, land rights
Field-specific characteristics	Location (UTM-coordinates, landscape units, size) Cultivation history (start, fallowing, abandonment) Peasants' perception of soil type and quality Manpower used for weeding (including non-household members) Manuring (strategy, amount and limiting factors) Anti-erosive arrangements Crops

were gathered by a questionnaire survey (cf. Table 1), informal interviews, group interviews, social and wealth ranking surveys, and transect surveys. GPS measurements in the field in combination with visual interpretation of aerial photos were used to geo-refer household/field specific information collected in the questionnaires. All data were entered into a data base in order to facilitate data handling.

Land Use Mapping from Field Measurements and Aerial Photos

Statistical or cartographic information on land use, its spatial distribution and its change in time are not immediately available for agricultural systems in many less developed countries. A combination of mapping in the field and aerial photo interpretation has therefore been applied in the present study.

Aerial photos from the years 1956, 1972 and 1994 provide the material used to monitor the land use pattern dynamics (see Table 2). The photos were scanned into a digital format (300 dots per inch). The 1994-photos were rectified individually to UTM coordinates by identification of corresponding landscape features in a SPOT satellite image covering the village territory. The 1956 and 1972 images were subsequently rectified to the corrected 1994-photo, since aerial photos reveal more details suitable as fix-points. Finally the central part of the photos from each year were assembled by the mosaic function in the CHIPS-programme. CHIPS is an image processing software which has been developed by the CHIPS group at the Institute of Geography, University of Copenhagen.

The mapping of cultivated land for the entire village territory was carried out through visual interpretation. Large variation in greytone level and quality within and between the photos did not allow for a classification based on digital values. The identification of fields was supported by stereoscopic analysis of the photos and ground truth observations from the fieldwork. The latter consist of land use transects as well as individual fields identified on the photos during field work.

The accuracy of the final land use maps digitized on the aerial photos is influenced by the quality and the scale of the photos. The 1994 photos were recorded in October, a sub-optimal time of the year for identification of cultivated land due to the abundance of vegetation on fields as well as in the bush. Photos from 1956 and 1972 were more satisfactorily recorded during the dry season and thus easier to interpret, yet the 1956 photo has an inferior resol-

Table 2: Aerial photos applied in the analysis of land use dynamics.

Year/date	*Mission*	*Scale*	*Number*
dry season 1956	Mission AOF NC 30 XXIV	1:50.000	318, 319 320, 368, 369
dry season 1972	HVO 1972 003/200 P - C.IR	1:20.000	412, 413, 414, 415, 416, 417, 427, 428, 429, 430
21 Oct. 1994	1994 132 - B Boulgou	1:20.000	427, 428, 429, 430, 431, 498, 499, 500, 501, 502

Table 3: The social ranking, made by five selected farmers, divides households in the sample area into six groups. The criteria selected by the farmers for the ranking were, in order: cart, plough, cattle and size of the household.

Group	*Household number*	*Cart*	*Plough*	*Cattle*	*Producer/ consumer units*	*Weed help*	*Fields > 4 km*	*Field area (hectare)*	*per. Prod.*
1	1	owned	owned	+	6/13.2		+	2.36	0.39
	3	owned	owned	+	10/10.4		+		
	5	owned	borrowed	+	10/18	+	+	4.54	0.45
2	2	owned	owned	+	3/4.6	+	+	2.65	0.88
	13	owned	owned	+	6/12.4	+		2.65	0.44
	8	owned	owned	+	9/11.4		+		
	15	borrowed	borrowed	+	4/8.8	+		2.2	0.55
	17	owned	owned	+	5/9.8	+			
	23	borrowed	owned	+	10/14.8	+			
3	4	borrowed	owned		6/10.8		+	2.13	0.36
	7	borrowed	borrowed		4/4.8			0.75	0.19
	24	borrowed	borrowed		3/6.2	+	+	1.27	0.42
4	6	borrowed	borrowed		3/5.4		+		
	9	borrowed	owned		4/4.8			0.88	0.22
	21	borrowed	borrowed		2/2			1.41	0.70
	16	borrowed	rented		3/8.6				
	10	borrowed	rented		3/5.4			1.25	0.42
5	11	borrowed	borrowed/ rented		3/3.8	+			
6	19	borrowed	rented		4/4.8			1.72	0.43
	22	borrowed	rented		2/2			0.32	0.16
	12	borrowed	owned	+	2/2.8	+		2.54	1.27
	14	borrowed	rented		5/6.6	+			
	18	borrowed			3/6.6			1.9	0.36
	20	borrowed	rented		3/3	+		0.95	0.32

ution. The programme calculated accuracy of the entire rectified images is below 50 metres for the 1956 photos and 23 metres for 1972 and lower for the applied, central part of the images.

The fields selected for detailed registration were identified on an overlay on the aerial photos from 1994 during the fieldwork and subsequently digitized on the assembled aerial photo from 1994. Thus, for this subsample of households the material collected enables a direct reference between the parameters that characterize the decision units (the households) and those that characterize the land use pattern (field size and field location) (cf. Reenberg & Fog 1995).

Results

Labour Constraints

Only inhabitants of the village take part in the agricultural work. Thus, the labour force is to be found among the 205 persons that live permanently in the 24 households. The average household size was 8.54 persons; this figure covers a considerable variance of 2–20 persons per household. 113 persons participate actively in the agricultural production. All farming operations, except soil preparation and weeding by plough, are carried out by all adults (over the age of 12–14 years), regardless of sex. In 15 households one or more sons were on migration (in total 25 persons). Thus, nearly 20% of the potential working force was unavailable. Whether this is compensated for by money sent back to the family is difficult to estimate, because the subject is taboo. Only one head of household officially stated that he received money from migrated sons. However, according to him and the 'Chef du Terre' the number is considerably higher.

Four parameters (cart, plough, cattle, and size of the household) were selected as classification criteria by the farmers in a social ranking survey in which the 24 households were ranked according to their social rank (Table 3). The number of adults was decisive for the ranking. Household number 12 ranked in group number 6 is an excellent example. The farmer owned a plough and cattle, the only reason given for the placement of his household was the farmer's unfortunate capability to reproduce. The key parameters were all characteristic of the individual households' capacity and constraints to expand the cultivated area.

Various factors influence the size of fields. Labour is considered the most limiting factor by all households. Especially the most labour demanding activity, weeding, constrains the size of the cultivated area. Further, factors such as the amount of food needed to feed the family and availability of a plough were mentioned as having a significant influence on the field size. On the other hand, availability of land was not considered a constraint, and only in one exceptional case distance to the fields was claimed to limit expansion.

Households which are able to to do so, supplement their available labour force by inviting other farmers from the village. The invitations are solely carried out in the labour demanding weeding period, but they may have a high impact on the yield if the timing is right and the attendance is considerable (over 10–15 persons). The payment for one day's work is a meal. Farmers who accept invitations are often 'poor' farmers that save food for the family by accepting the invitation. 11 households had invited other persons to help weeding. Most of these were among the highly ranked households, yet three belonged to the group of 'poor' households (secondary informants explained that

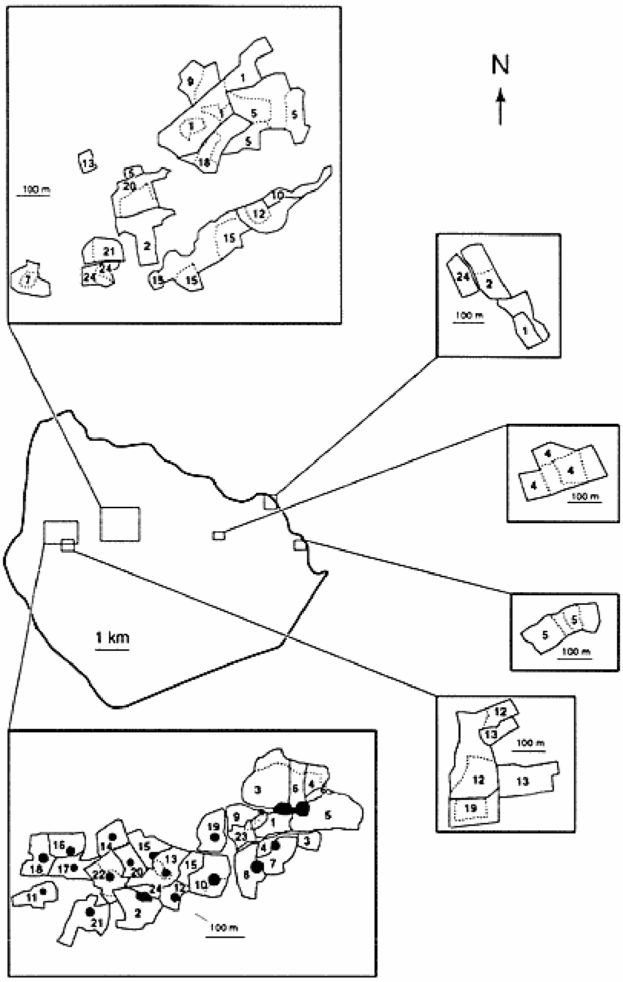

Figure 6: *The map shows; a)The location of the fields in the sample area (24 households) = the rectangle located in the eastern part of the territory; and b) the location of the bush fields of the 16 households that were selected for further investigation = the five rectangles located in individual parts of the bushterritory. Actively cultivated fields (1995) are hatched.*

this was made possible by money received from migrating sons).

The plough is considered a labour saving tool, since fields prepared with a plough need one less weeding. 91 out of the 107 fields were prepared with a plough. All manually prepared fields, except one household, were owned by socially low ranking households. These households are forced to hire the plough or to borrow the plough by paying back in labour (cf. Table 3). The number of prepared fields is thus determined by the financial capacity of the households.

Thus, in various ways different processes that relate

Table 4: Year of establishment of fields versus distance in kilometres from the compounds in the sample area.

	0 km	*1 km*	*2 km*	*3 km*	*4 km*	*5 km*	*6 km*	*7 km*	*8 km*	*9 km*	*10 km*
ancient	21	4	10	3	2						
1950	1		1	1							
1960	3										
1970	2	1	1	1							
1980–84	2		2	2	3	1				1	5
1985–89			1	15		3	1	1	3		2
1990–95		3	2	3		2				1	
Total number of fields	***29***	***8***	***17***	***25***	***5***	***6***	***1***	***1***	***3***	***2***	***7***

more or less directly to the issue of labour constraint contribute to enhance the gap between enabled and less enabled households in the village.

Spatial Distribution of Fields

The principal structure of a farm unit is a compound surrounded by its fields, all of which are cultivated annually. In addition, most households in the sample area cultivate one or several bush fields. A bush field is a field outside the compound area. These fields may be only a hundred metres away, within a short walking distance, or up to ten kilometres away. Households that cultivate remote bush fields have huts which one or several household members inhabit more or less frequently during the cultivation season. Fields close to the compound are the ones first prepared and sown and the only ones directly supplied with manure.

105 out of the 107 fields recorded in the questionnaire survey are located within Ningaré's own territory. The average number of fields per household is 4.46, but this figure covers considerable variations. Most women have a plot that they crop individually. It is normally small and placed as a prolongation of one of the household fields in the bush area and is not included separately in the mapping.

Figure 6 shows in detail the location of fields in the sample area. The actually cultivated land is hatched (and marked with the household number), while black circles indicate compounds. Areas within the full drawn lines are land that can be cultivated by the farmer without interference or permission from others. Further, the map shows five subsections of the bush territory which farmers from the sample area cultivate, yet fields in the bush area represent only 16 households selected out of the 24. People who are born within the village territory have in principle free access to establish fields on uncultivated or unclaimed land. However, the larger households which have occupied the land for many generations have the claimed right to selected areas both in the residential and the bush areas. A villager or a stranger can be granted permission to cultivate claimed land by the 'land owner', but does not get a claimed right to the land. Further, the 'landowner' has the right to reclaim the land if he plans to start cultivating the given area. Any extension of the field is to be discussed with the person who has the claimed right to the land. Moreover, the field cannot be inherited by the next generation. However, it is unusual not to let the next generation take over the land as it is difficult to reclaim land cultivated for a long time by another family (Reenberg & Lund 1997). A rejection of a demand for land is considered an insult, as is reclamation of land if it is unnecessary.

Land in the bush contributes considerably to the overall acreage. The average cultivated area per household is 1.79 hectares, of which two thirds is in the bush. The average acreage per producer (defined as an adult person, mostly over 12–14 years, participating in agricultural production) is 0.44 hectares. Yet it varies considerably (0.16–1.27 ha), depending on the available tools, the strength and health of the person and ability to invite persons during weeding.

Field Histories

Before 1980 none of the households had established fields at a distance of more than 4 kilometres from the compounds (cf. Table 4). In the 1980s, the number of new fields increased considerably in the already cultivated zone as well as in the bush area more than 4 kilometres from the compounds. The rate of expansion has decreased again in the 1990s.

The expansion pattern can be related to several factors. The increase in the 1980s was partly due to a new trend: women established their own individual fields. In 19 out of 24 households women now cultivate an individual field that, with few exceptions, was established in the late 1980s or early 1990s, primarily between 2 and 4 km from the compound and in a prolongation of the households' existing fields. The establishment of these fields was caused by a 'push-pull' effect: A lowering of the ground water level forced the women to abandon their small vegetable gardens in the hollow sites near the streamlets. To compensate for the loss in personal income, they started to cultivate individual fields in the bush area, helped well on the way by favourable market prices for groundnuts at the same time. Within a few years the individual fields became 'status' and a new way of obtaining personal income, and thus nearly all women established a field.

The fields established more than 4 kilometres from the compounds are larger fields cultivated by entire households. It is typically the most enabled farmers (Table 3) that have been able to cultivate the distant bush, since

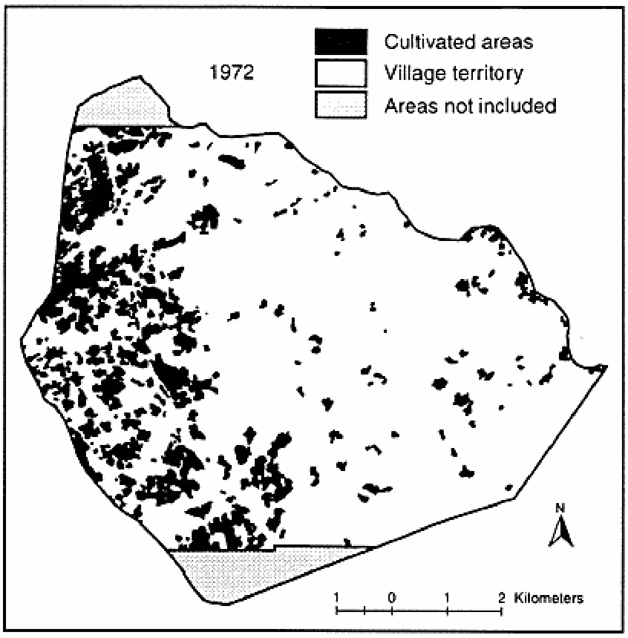

Figure 8: Land use map 1972.

cultivation presupposes frequent access to a cart in order to transport the plough, the harvest and typically also water for personal supply. Farmers that cultivate in the bush mention different, but always specific, incentives to do so. They might want to start rice cultivation in the valley

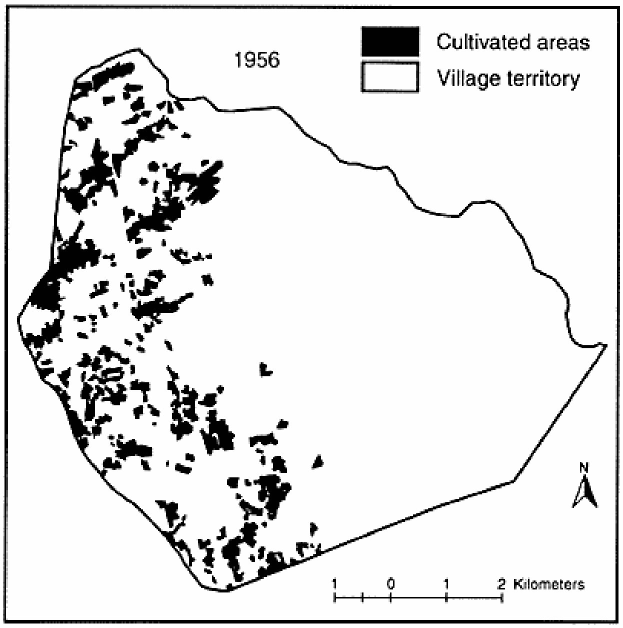

Figure 7: Land use map 1956.

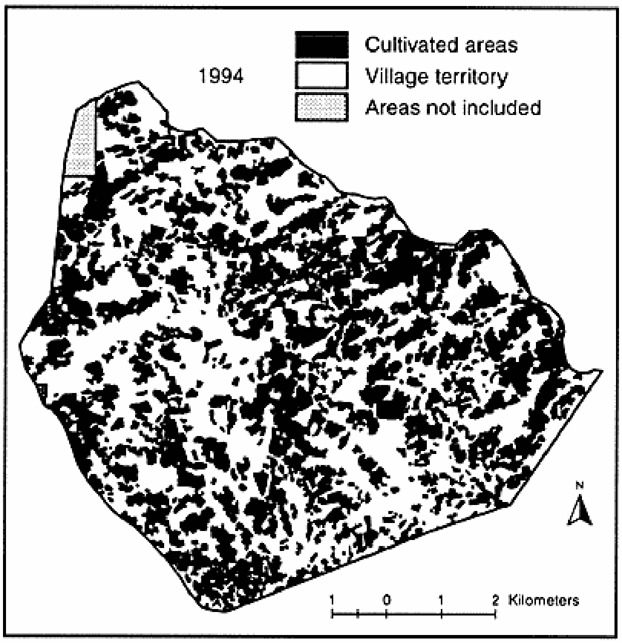

Figure 9: Land use map 1994.

areas; need to abandon or fallow old fields because of loss in fertility; or be prevented by neighbours from expanding the already cultivated fields to meet food requirements. A priori, the farmer tends to expand the already existing fields rather than establish a new field. This is due to both the initial cost of removing trees from new land and to the fact that the farmers seek to have their fields as connected as possible. Coherent fields facilitate the control in terms of weeds and matureness of the crops.

Land Use Pattern Dynamics at Village Level

The scanned, geometrically corrected aerial photos permit precise monitoring of the field pattern changes in Ningaré from 1956 to 1994. Figures 7 to 9 reveal how the cultivated land has expanded from its original location in the western part of the territory to a more uniform distribution that covers most of the village territory. As documented above, the expansion to more remote parts of the territory can be seen as a result of a gradual increase in the acceptable travel distance between field and compound, which in part is made possible by new technology. The eradication of river blindness in 1970s has further contributed to make the low-lying regions in the eastern part more attractive to farmers.

This process of field encroachment is in accordance with the increased demand for land caused by a higher population pressure and by decline in the biophysical production potential. Precise population figures are not available.

***Tabel 5a:** The size of the cultivated areas in square kilometres as well as % in respectively 1956, 1972, and 1994.*

	Cultivated areas (CA)	*Cultivated proportion*
1956	5 km^2	9%
1972	8.11 km^2	14%
1994	21.79 km^2	37%

***Table 5b:** The increase in cultivated areas in the periods between 1956–1972, 1972–1994, and 1956–1994 in square kilometres and per cent. Growth rate, r, calculated as $CA_t = CA_0 (1 + r)^t$ (Figures are based on part of the village territory (58.4 km^2) which is covered in the three years).*

	Expansion of cultivated areas	*Annual expansion = rate*
1956–1972	3.11 km^2	3.1%
1972–1994	13.68 km^2	4.6%
1956–1994	16.79 km^2	4.0%

***Table 6:** Land use change categories: site specific development of land use classes from 1956 to 1972 and 1994 (letters indicate the use of land in the corresponding year).*

1956		*1956–1972*		*1956–1972–1994*	
C	8.6%	C-C	3.6%	C-C-C	1.5%
				C-C-NC	2.1%
		C-NC	5.0%	C-NC-C	1.8%
				C-NC-NC	3.2%
NC	91.4%	NC-C	10.3%	NC-C-C	3.3%
				NC-C-NC	7.0%
		NC-NC	81.1%	NC-NC-C	27.3%
				NC-NC-NC	53.8%

C = cultivated, NC = not cultivated

Official population statistics and forecasts normally suggest a yearly increase in the order of magnitude of 2.7% The rate of field expansion (Table 5) is 3.1% in the early phase (1956–1972), thus, a figure that corresponds to the generally accepted estimates of the population increase in the region. In the second phase, the field acreage expansion (4.6%) exceeds by far the population increase. The reason for this may be the persistently low rainfall in the years 1973 to 1988 (cf. Figure 3) which influenced the yield level. Further, there has been an immigration of new farmers to the territory beyond the normal level for villages in the region. Finally, it is likely that soil nutrient depletion contributes to a decrease in the biophysical production potential, yet the present study does not provide the empirical evidence needed to verify this.

Findings based on farmers' information during the household survey reveals that only 11 out of 107 fields are perceived by farmers as abandoned or fallowed in the time period investigated. 7 of these have been recultivated. Various reasons such as water logging, soil degradation, migration and age were mentioned as reasons for giving up cultivation.

The digital format of the aerial photos facilitates analysis of land use rotation. Land use maps digitized from 1956, 1972 and 1994 respectively are easily superimposed in the GIS. Thereby different patterns of land use change can be identified and their location and relative importance in terms of areal extension can be calculated. In the present context it has been chosen to distinguish between two land use classes only; cultivated land and non-cultivated land. This leads to eight land use change classes – or development paths for the land use in course of the three registration years, as sketched out in Table 6. With the reservations needed because of the inaccuracy of the overlays that remains in spite of the correction of the photos (see above), some interesting observations can be made from the areal statistics. A large proportion (> 80%) of the land that was cultivated in 1956 was abandoned or fallowed some time in the years that followed. As regards more recently cultivated land, the land use class which represents land cultivated only in 1972 plays a major role, only surpassed in acreage by the class that represents cultivations after 1972. These figures indicate more dynamics in land use than revealed from the farmers' reports on field histories. On the other hand they do not show the regularity in alteration that would indicate the existence of real rotational fallow.

These observations points to some interesting characteristics of the land use changes, and illustrate at the same time how farmers' responses in interviews might not suffice to characterize land use patterns in detail. The results derived from the comparison of the series of land use maps reveal a significant micro-rotation between cultivated land and fallow within the individual farm unit. Thus, the role of rotation is much more prominent than expressed in the interviews. Apparently, farmers do not report uncultivated parts of their main territory as fallow land. The rotation is not perceived and explained by farmers as a fallow practice. The micro-rotation is rooted in the pressing need for restoration of a declined soil fertility caused by a certain number of years of continuous cultivation. Yet, land is also abandoned due to erosion or lack of labour at the household level.

Discussion and conclusion

Possibility, Incentive and Capacity to Expand

The study of Ningaré has shown that field expansion onto idle bush land dominates farmers' current response to changing conditions. Seen from a theoretical point of view (eg Brouwers 1993; Tiffin et al. 1994), the low population/arable land ratio within the village territory itself favours such a decision, yet the survey reveals that other parameters highly influence the possibility, incentive and capacity to expand cultivated land.

It was consistently emphasised in the survey that manpower available for agricultural work is the most significant bottleneck. However, the considerable between household variation in the average area cultivated per producer emphasises that many other parameters determine the actual conditions at the household level.

The households' expansion strategies are in reality closely related to access to ploughs and carts. Households that have been able to create a sufficient surplus from agriculture or from off-farm influx of capital (eg by credits or from migrating family members), can invest in or hire new technology. Although the use of ploughs may increase the labour input per hectare (Serpantié 1993) it may also allow the farmers to cultivate a larger surface to compensate for decreasing yields.

Minor, although significant, alterations in land use patterns at the micro-level are related to women's shifting priorities. More favourable market conditions for groundnuts have in combination with deteriorating environmental conditions inspired new, gender specific land use strategies. These will have an impact on the overall future development trends.

Land rights are frequently expected to constrain possibilities of expanding cultivation already at an early stage (Bilsborrow & Ogendo 1992), yet in the present case, access to idle land is best characterized as almost free to all, even people coming from outside the village. Also in more densely populated village territories in the region, access to land has so far been ensured by culturally determined, informal agreement with other territories in which land is more abundant (Reenberg & Lund 1997).

The land use changes may be characterized as presently approaching a critical point of saturation of arable land. The development seems, however, to take place in a way that enhances the gap between enabled and less enabled farmers' relative importance as users of land. The better-off farmers pocess the capacity to expand their fields and will dominate land use decisions in an increasing proportion of the territory. It will be important to incorporate such new trends at the farm level in models, if they are to effectively capture possible, future evolutionary trends.

Does a "Sudano-Sahelian Model for Land Use Change" Exist?

Sweeping generalisations have been brought forward to describe the development trends in contemporary Sudano-Sahelian agriculture. Cultivation is expanded onto marginal land (Scott 1979; Vierich & Stoop 1990; Snrech 1994; Webber 1996); increased degradation of upland

fields leads subsequent abandonment (Vierich & Stoop 1990); demographic pressure causes decreases in fallow length and leads to a vicious circle of degradation (Greenland et al. 1994), etc. These observations naturally hold true for the empirical background on which the statements are based. The example presented in this article reminds us, however, that a "Sudano-Sahelian Model for Land Use Change" can hardly be sketched out.

In many parts of the Sudano-Sahelian zone, land of approximately the same quality as the one presently cultivated is in abundance. Under such conditions demands for crops can be satisfied by bringing more land into production, land that is only more marginal as to travel distance between the fields and the homestead or water supply. In the case of Ningaré such options exist even within the village territory. At province level, sharply contrasting conditions of field density were observed. Examples from more saturated village territories reveal, however, that similar mechanisms might be based on socially/culturally land tenure arrangements with neighbouring villages (cf. Reenberg & Lund 1997).

Rotational fallow and land abandonment rarely play a significant role in shaping land use pattern dynamics. It is mainly confined to areas degraded by gully erosion. Continuous cultivation dominates in Ningaré and in other villages in Boulgou, in spite of relatively low population densities. This corresponds to observations made in other parts of the Sudano-Sahelian zone as well (Serpantié 1993; Reenberg & Fog 1995; Bolwig 1996). The detailed, location specific monitoring of land use history supports the view that rotation plays a minor role in bringing land into cultivation. Likewise, radical shifts in emphasis between different landscape units, caused by environmental impacts, are not a typical feature, as known from other examples (Vierich & Stoop 1990; Reenberg 1994; Reenberg & Paarup-Laursen 1996).

Though farmers are rational (Richards 1988), they do not run a business but rather manage a household. Their land use strategies are based on risk minimizing practices, but they are also influenced by other factors such as ethnic traditions (Claude et al. 1991; Reenberg & Paarup-Laursen 1997) and social status and preferences (Berry 1993; Snyder 1996). Therefore, the susceptibility of land use to external changes cannot be completely understood without considering such issues. This supports the observation made by Mortimore (1995:63) on a Northern Nigerian case - "that the regional association of rising rural population densities with agricultural expansion hides sharply contrasting experiences at micro-scale".

Thus, perception of land use dynamics should include a hierarchy of spatial scales (Reenberg 1996). Scenarios for land use change at a national or continental scale will be a valuable contribution to the analysis of global environmental change. On the other hand, these changes have to be seen as a result of a diversity of parameters and processes that can only be analysed at a much finer scale. The development of a tool to effectively capture the evolutionary trends in agricultural systems has been neglected (Gerrity & Augustin 1995). Location specific land use studies will make a useful contribution in this context.

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