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IS LAND BEING DEGRADED? A MULTI-SCALE INVESTIGATION OF LANDSCAPE CHANGE IN SOUTHWESTERN BURKINA FASO

L. C. GRAY*

Department of Demography, University of California, Berkeley, CA, USA

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ABSTRACT

This paper presents the results of a multi-scale investigation of the social and biophysical dimensions of land degradation in three villages in southwestern Burkina Faso. In this region, technological change in the form of animal traction and cotton has combined with massive migration to create pressure on natural resources. These pressures have, in turn, increased farmed areas and decreased fallow periods. Whether this has resulted in widespread land degradation, however, depends on the scale of analysis. At the broad scale, aerial photos confirm farmers' perceptions that their land resource is degraded, showing decreases in forested land, increases in area under cultivation, and increases in areas characterized as degraded. At the field scale, an analysis of soil samples collected from these farmers' fields in 1988 and again in 1996 indicates that there has not been a widespread reduction of soil quality. Soils under continuous cultivation revealed few changes, while soils that were fallowed during the eight-year period showed improvement in nutrient status. A study of agricultural practices illustrates how some farmers are responding to the lack of fallow land by intensifying their production system. They nurture trees on agricultural fields, use more inputs and construct anti-erosion barriers on sloped fields to prevent erosion.

Changes apparent on one scale are therefore met with responses which are apparent at other scales. The paper illustrates the importance of farmer perceptions, access to resources and local social structures in determining decisions about agricultural practices. These decisions then shape whether land degradation or land improvement characterize the nature of environmental change. Copyright © 1999 John Wiley & Sons, Ltd.

KEY WORDS: land degradation; landscape change; intensification; Burkina Faso; spatial scale; Mossi; Bwa

INTRODUCTION

Researchers and policymakers often blame what is referred to as the 'Agrarian Crisis' in Africa (Watts, 1989) – the phenomenon of declining agricultural productivity and income levels – on land and soil degradation (Brown and Wolf, 1984; Lal, 1988). Recent studies challenge this notion by pointing out how little is known about the causes, processes and direction of changes in land and soil in African agricultural systems. New research has emerged questioning the commonly accepted wisdom of land degradation in areas where it has been presumed to be widespread (Tiffen, *et al*., 1994; Fairhead and Leach, 1996; Howorth and O'Keefe, 1999; Leach and Mearns, 1996). Where degradation is a problem, quantifying processes of change and making generalizations from observations is fraught with complications. Roose and Sarrailh (1990), for example, note vast differences in the rate and scale of soil erosion even within limited geographical areas. Stocking (1987) argues that techniques for measuring rates of processes of soil degradation are frequently unreliable. Blaikie (1989a) contends that social theories of land degradation occur at various levels of abstraction and are rarely directly related to evidence of place-specific changes. Finally, Johnson, *et al.* (1997) discuss the problem of using terms such as degradation without clear and precise definitions. All these

*Correspondence to: Dr L. C. Gray, Department of Demography, University of California, Berkeley, 2232 Piedmont Avenue, Berkeley, CA 94720, USA.

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uncertainties underscore the relevance of addressing the issue of where, why, and for whom land degradation, if it even exists, is a problem (Blaikie, 1989b).

Consider the case of southwestern Burkina Faso. In this important agricultural region, most studies indicate that land degradation is widespread. Many of the studies of change in land are at a broad scale, using aerial photographs and remotely sensed data (Berger, *et al*., 1988; Serpantier, 1992). Such studies generally indicate that land area under cultivation has increased at the expense of forests and fallows. Government agencies, program officials and researchers then use these results to argue that there is widespread land degradation and implement programs based on this. However, when we look at other scales, by, for example, interviewing farmers about their practices, we see that many are responding to reductions in available land by intensifying their agricultural system. The ability of individual farmers to intensify their agricultural system differs and depends on access to resources.

This paper examines three different but related 'environmental stories'[1] in three villages in the cotton-growing region of western Burkina Faso. The first 'story' is about land use at a broad scale, where aerial photos show decreases in forested area, increases in land area under cultivation, and increases in land categorized as degraded. The second 'story' narrows the focus to examine changes in soils in farmers' fields first sampled in 1988 and then again in 1996. The analysis of the soils under continuous cultivation does not indicate a widespread decrease in soil nutrient status, although fields that have been fallowed have significantly higher nutrient status.

The third and final 'story' in this multi-scale investigation considers the agricultural practices on the fields of 106 randomly surveyed farmers in the three villages. Farmers in all three villages are intensifying their production systems by leaving trees on agricultural fields and using inputs such as manure and fertilizer. This particularly appears to be the case both in the village with the least available land and with individual farmers (mostly migrant farmers) with insecure access to land. Agricultural intensification in the form of greater labor and technical inputs, rather than degradation, best characterizes the story at this scale (Boserup, 1965; Kates, *et al*., 1993).

All three 'environmental stories' illustrate different dimensions of changing land use patterns and practices. One implication of these three studies is that one's conclusions about whether land is degraded are influenced by the scope and scale of the analysis.[2] For example, if we examined changes at the local or regional scale using aerial photographs, we would most likely arrive at a different conclusion than if we examined soils at the farm scale. The scale at which studies are undertaken affects the conclusion because 'processes and parameters important at one scale may not be important or predictive at another scale' (Turner, 1989:174). Changes in scale affect the relevant variables (Meentemeyer, 1989).

In Burkina Faso, researchers frequently make the assumption that reduced forest cover necessarily indicates increased 'degradation' (because of the resulting reduction in land available for shifting cultivation), yet this study shows that farmers are reacting to reductions in forest cover by using more inputs to improve the productivity of the soil. Changes apparent on one scale (aerial photographs at the regional scale), therefore, are met with responses which are apparent at other scales (by conducting interviews with farmers or sampling soils at the field scale). This illustrates the importance of a multi-scale perspective, especially as it is often easier to understand the mechanics of problems at a fine scale. Yet, it is also important to recognize that comparing changes across scales is not easy especially in interdisciplinary research, where different disciplines with different perspectives and methodologies attempt to integrate information. In their

[1]This idea of 'environmental stories' is taken from Cronon (1992: 1374) who discusses how different explanations of the effects of the Dust Bowl have depended on the storytellers who express their 'own times and political visions'. My intention here is not to tell the same 'story' from different perspectives, but to examine how different stories may exist in the same space, but at different investigation-scales.
[2]Pieri, *et al*. (1995) define scales of land resource management. They define the *farm scale* as that of individual farms or land holdings, which in developing countries is often about 0·1–10 ha. This is the scale on which farmers' decisions are apparent; decisions on how to manage their land, how many animals to have, etc. Secondly, they define the *local scale* as that of a village or community. This scale covers areas ranging from 10–100 km^2. It is on this scale that decisions about village resources such as land or water are taken. The *district (regional) scale* refers to the administrative units above villages, such as districts. This is the scale on which project planning and implementation frequently takes place. In Burkina Faso, it is also the scale which corresponds to kingdoms or ethnic groups.

study of land-use change, Lambin and Guyer (1994) illustrate the difficulty of coordinating remote sensing data with ethnography. They argue that the scale at which landcover change is easily detected is very different from the scale at which social processes are best elucidated.

Finally, it is important to define the term 'degradation'. Most definitions of degradation generally attribute it to human causes. Many relate degradation to a reduction in productivity. Johnson and Lewis (1995) define land degradation as the 'substantial decrease in either or both of an area's biological productivity or usefulness due to human interference'. Lindskog and Tengberg (1994 : 365) define land degradation as a 'reduction of the physical, chemical or biological status of the land which may restrict its productive capacity'.

Johnson, *et al.* (1997 : 586) recognize the role of perceptions in definitions of land degradation, defining it as 'any change or disturbance to the land perceived to be deleterious or undesirable'. They include the idea of perception because degradation is 'a term whose meaning reflects our perceptions, view points, time frames, and value attachments' (Johnson, *et al.*, 1997 : 583). The authors contend that degradation is relative; levels of acceptability of degradation are related to societal or individually determined standards. For example, similar processes can be described as soil degradation, enhancement, or evolution depending on the perspective of the describer. A newly deforested piece of land may be considered to be in prime condition by a farmer, but a forester would probably consider it to be degraded from its original forested state.

By focusing on processes that ultimately affect the agricultural productivity of the land, the definition used in this paper reflects the perspective of the primary land user in the region, the farmer. In the study area, farmers' views of whether their land is degraded are frequently linked to perceived reductions in soil fertility and yield. To examine whether land degradation is a problem, including the perceptions of the land user provides an important perspective. Zimmerer (1994), for example, relates local classifications of soil types and quality to scientific measures and definitions and finds that local definitions are more detailed and subtle than scientific categorizations of soils that tend to fall into categories of 'degraded' or 'not degraded'. He suggests that these local definitions of degradation may be an inexpensive method of monitoring processes of change in land and soil.

Relying solely on the perceptions of farmers (or of scientists, government or project officials, for that matter), however, can be problematic because perceptions are frequently socially constructed and politically mediated. For example, in the study area, perceptions of degradation are related to interethnic conflicts over land between locals and migrants; each group blames the other for the perceived degradation. Furthermore, environmental development projects offer tangible benefits for peasants who perceive that their resource base is degraded. Analyses of perceptions must consider the historical, societal, and political contexts which determine how people interact with their environments (Watts, 1983).

The paper will proceed as follows. The next section presents the results of a multi-scale, multi-perspective investigation of land degradation, land-use patterns, and agricultural practices. Section three then explains why changes are occurring relating changes in land use and soil quality to a model of farmer decision-making. Finally, the paper concludes by addressing the question posed in the title of whether land is being degraded.

EXAMINING LAND DEGRADATION: A MULTI-SCALE PERSPECTIVE

This section will present the results of a multi-scale study conducted in three villages (Sara, Dimikuy and Dohoun) in the Province of Tui, the heart of the cotton-growing region in southwestern Burkina Faso. This area, along with much of southwestern Burkina Faso, is generally thought of as the breadbasket of the country. Compared to other areas of the country, the study area has higher rainfall (800–1200 mm^{-1} y^{-1}) and the soils are relatively fertile. This area is also characterized by tremendous demographic and agricultural change. In the past decades population of the province of Tui has more than doubled, primarily due to in-migration of migrant farmers from the Mossi ethnic group, and cotton and maize production using plows have come to dominate the agricultural production system.

Migration of Mossi into this area which was historically inhabited by members of the Bwa ethnic group has occurred sporadically since the 1930s, but did not reach large numbers until the droughts of the 1970s.

During that period, Mossi farmers escaped the economic and ecological hardship of their home regions by moving into the land-abundant and agriculturally fertile regions of the southwest. This process has been aided by changes in statutory land laws and national land policy. The Réorganisation Agraire et Foncière (RAF), a set of initiatives first put forward in 1984, and updated several times, decreed that all land belongs to the state. The announcement of the law was widely broadcast over the radio during the 1984 drought, when large numbers of people were migrating out of drought affected areas into the sparsely populated regions of the south and southwest. Several authors argue that this law was instrumental in promoting the widescale in-migration of Mossi farmers (Faure, 1995; Laurent and Mathieu, unpub. paper).

Initially, Bwa farmers welcomed Mossi migrants into the region and granted them land. The Bwa majority saw increasing population as a way to increase the political strength of what was then a very sparsely populated region. This welcoming attitude shifted, however, when as a result of migration, land became scarce in many villages. Relations between Mossi migrants and local Bwa farmers can contemporarily best be described as strained. Local Bwa farmers often blame migrants for much of the perceived environmental degradation; several villages have prohibited new migrants from settling. Migrants, on the other hand, fear being forcibly removed from their land by local Bwa farmers who have customary and ritual authority over land.

At the same time population increased, new agricultural technologies began to take hold. Until the 1970s, cotton production was not an important part of local agricultural production systems; yield was very low, area under production minimal and inputs unavailable. In 1979, Sofitex, a partnership between the government of Burkina Faso and CFDT (Compagnie Française pour le Développement des Fibres Textiles), replaced CFDT, the French cotton development organization that had been responsible for cotton production. With the creation of Sofitex, external donor resources began to pour into the cotton sector. The price of cotton increased and agrochemical and financial inputs became available. This resulted in a rapid increase in cotton production.

One of the main subsidiary effects of cotton production has been the adoption of maize into the crop production sequence. The production of system surrounding cotton complements maize production very well. Maize benefits from the residual fertilizer left in the soil after the cotton harvest; its early planting and harvest relaxes the schedule of agricultural operations. Farmers plant and harvest maize earlier in the season than both cotton and the other important grain crops, sorghum and millet, that previously dominated the production process.

The emergence of agricultural extension and financial and marketing services are among the key reasons why cotton production and yields increased during the 1980s. In 1980, Sofitex began its motorisation intermédiare program that financed the purchase of animals for traction and plows (Schwartz, 1991). As a result of a majority of farmers in the study area use animal traction. In the study sample, approximately 65 percent of farmers have plows. Plowing has led to an extensification of land area under cultivation as farm families using plows cultivate larger areas. On average, farmers using plows cultivate almost twice the land area of farmers that use hoes. Faure (1994) also notes this in his study of three cotton-growing Bobo villages about 50 km north of Bobo-Dioulasso, where the amount of land under cultivation averages 9·2 ha for households using animal traction and 3·8 ha for households cultivating manually. Simultaneously, farmers were able to obtain fertilizers, seeds and herbicides on credit from village grower cooperatives (Groupements Villageois).

These increases in market services have been a key component in the recent emergence of cotton as the most important cash crop. Cotton production, though, has not been completely without problems. In the early 1990s, world cotton prices dropped while input prices increased. This precipitated a downturn in production and an increase in general indebtedness. Many of the Groupements Villageois went heavily into debt.[3] The situation changed again in January 1994 the French devalued the CFA currency to 50 percent its previous value. While the price of cotton paid to farmers increased, so did the costs of inputs, along with the prices of many other imported goods. Consequently, in the mid-1990s, many farmers abandoned cotton rather than incur or increase their debt.

[3]In several villages in the study area, villagers were put into prison for failure to pay their outstanding cotton debts.

These shifts in the agricultural economy and demographic make-up of villages in the cotton-growing region have had significant ramifications for land availability and land-use patterns. The dominant narrative is that these changes have led to widespread land scarcity which, in turn, has resulted in land degradation. This section examines this issue using three different studies. First, evidence from aerial photographs will determine whether landcover patterns have changed at the broad scale over two time periods. Then soils from farmers fields in one of the three study villages are examined over two different time periods for changes in nutrient status. Finally, household and field surveys indicate differences in farming practices among the three study villages and between Mossi and Bwa farmers.

Is Land Area under Cultivation Increasing? Evidence from Aerial Photographs[4]

Have new production practices led to changes in land area under cultivation? Has this resulted in increased rates of land degradation? Interpretations of aerial photographs allow us to examine these questions for two of the three study villages. Photographs from two different scales 1:50 000 in 1981 and 1:20 000, in 1993 were analyzed and compared for the villages of Sara and Dimikuy. The land area was divided into different land-use categories: cultivated area, fallow area, bush savanna, shrub savanna, tree savanna, savanna woodlands, bare soil, and water. Both fields and fallow land were easily visible on aerial photographs, fallow lands being abandoned fields whose boundaries were still visible. Each of the categories of bush savanna, tree savanna, and savanna woodland represent areas of increasing vegetative cover.[5] The category bare soil denotes sandy soils near water courses. For the purposes of determining whether land degradation has occurred, the category of bush savanna indicates land that is lightly covered by shrub vegetation less than two meters in height. Following Marchal (1983), we have characterized the increased bush savanna land as 'degraded' because of color changes from gray to white or to dark gray or black, indicating a reduction in coverage of shrubs, exposing the lighter or darker colored eroded soil beneath.

Aerial photographs covering the territory of Sara and Dimikuy show many changes in surface area cultivated from 1981 and 1993. Tables I and II indicate changes in land use in Dimikuy and Sara. Table I illustrates that land area in Dimikuy under cultivation has increased from 414 to 901 ha in 12 years, a 115 percent increase. The amount of land under scrub savanna has consequently decreased by 50 percent during this same period, from 1207 ha to 599 ha, primarily due to the expansion of cultivation. Approximately 1 percent of the total area was categorized as bush savanna in 1981 but this increased significantly to 6 percent in 1993, a change of +570 percent, as the amount of land classified as bush savanna increased from 18 to 122 ha. These changes in land use mirrored changes in population in Dimikuy which doubled from 1971 to 1985 and continues to increase at a fast pace.

Table II shows that there were few changes in the area of land under cultivation in the village of Sara from 1981 to 1993. This partially reflects the fact that there are few new areas to be cultivated – land area is largely saturated by farming and the areas that are not under cultivation tend to be uncultivable, located on hills or on soils with hardpans. Despite this, there has been a decrease in area under savanna woodland primarily because of the recent cultivation of an area that was abandoned in the 1940s due to its distance from the village and lack of water. The scarcity of land in recent years has forced farmers to travel long distances to cultivate this area again. Sara, like Dimikuy, experienced an increase in land area categorized as bush savanna, from 60 ha in 1981 to 137 in 1993, an approximately 126 percent increase.

So in both villages where aerial photographs were analyzed, we see a change in vegetation cover. Fields have replaced fallow and forested land, and bush savannas have increased. Do these constitute land

[4]Aerial photographic interpretation was conducted from the whole territories belonging to Dimikuy and Sara.

[5]Bassett (1997:12) cites Riou's (1995) definitions of these different vegetative classes. The least dense vegetation type are shrub savannas which have a presence of shrubs from 2–8 meters in height that cover 15–20 percent of the understorey. This class can be further broken down into dense shrub and open shrub savannas. A tree savanna has tree densities that enclose from 20–50 percent of the upper storey and have trees that range from 8–15 meters. A savanna woodland covers 40–70 percent of upper storey and has trees that range from 5–18 meters in height. Other categories include a closed forest, generally closed canopy forest areas, near water courses. Marchal (1983) in his study of vegetative change in Yatenga also uses the category of bush savanna for shrubs less than 2 meters in height.

Table I. Changes in land use in Dimikuy, 1981–1993 (in hectares)

Land use category	1981	% total area	1993	% total area	% change
Fields	414	21·7	901·9	46·9	+115·1
Fallow	109	5·7	105·7	5·5	−4·2
Bush savanna	18	0·9	122·2	6·3	+570·5
Shrub savanna	1207	63·3	599·5	31·0	−50·9
Tree savanna	160	8·4	201·3	10·4	+24·3
Savanna woodland	0	–	0	–	–
Bare soil	0	–	1·2	–	–
Water	0	–	0	–	–
Total	1908		1931·8		

Table II. Changes in land use in Sara, 1981–93 (in hectares)

Land use category	1981	% total area	1993	% total area	% change
Fields	571·5	22·7	594	23·3	+2·8
Fallow	176	7·0	146·4	5·8	−17·7
Bush savanna	60	2·4	137·2	5·4	+126·2
Shrub savanna	330	13·1	424	16·7	+27·1
Tree savanna	1215·5	48·3	1182·6	46·5	−3·7
Savanna woodland	163	6·5	9·6	0·4	−94·2
Bare soil	0	–	46·4	–	–
Water	0	–	2·8	–	–
Total	2516		2543		

degradation? It is unclear that increases in fields alone represent degradation. The increases in bush savannas do raise concern. Marchal (1983) argues that increases in lightly colored bush savannas represent degraded soil. The emergence of white over lightly colored gray surfaces indicates less coverage on land and increased erosion of sandy soils.

An aerial photographic examination of the third village discussed in this paper, Dohoun, was not undertaken as part of this research study. However, Morant (1991), a French agronomist with CIRAD (Centre de Coopération International pour la Recherche en Agronomie et Dévelopment), a French overseas agricultural research and development organization, interpreted satellite images of Dohoun in 1987. The interpretations shows that 15·6 percent of the land area was cultivated. Morant estimated that about 50 percent of the land area of the region was cultivable and under the form of wooded savannas, while 35 percent of the land area was not or not easily cultivable. This area is dominated by lateritic soils, hilltops, or soils that are too shallow for cultivation. While this does not give us an idea of the changes in land area under cultivation that have occurred with increased migration and mechanization, it does suggest that Dohoun has more land available than the other villages. This perception is supported by farmers from Dohoun who, although they complain of a land shortage, still allow migrants to settle in the village and grant them agricultural land. This contrasts with both Sara and Dimikuy where Bwa villagers for the most part no longer allow Mossi migrant families to settle.

The Effect of Continuous Cultivation and Fallow on Soil Quality[6] in Dohoun

This discussion focuses on the results of a micro-scale study of soil change in one of the three study villages, Dohoun. In the previous discussion we saw from a study conducted by Morant (1991) that land was still

[6]Doran and Parkin (1994: 7) define soil quality as ‘the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health’.

Table III. Means of soil variables on fields under continuous cultivation and fallow: 1988 and 1996

	Year	Continuously cultivated soils	Fallow soils
Number of sites		$n = 34$	$n = 20$
Average field fallow age		16	4·7
Soil organic carbon (%)	1988	0·78	0·75**
	1996	0·77	0·9
Total soil nitrogen (%)	1988	0·71	0·67**
	1996	0·69	0·78
Ca (cmol kg^{-1})	1988	3·83	4·11
	1996	3·48	4·47
Mg (cmol kg^{-1})	1988	1·23	1·44**
	1996	1·18	1·67
K (cmol kg^{-1})	1988	0·23	0·19
	1996	0·19	0·23
CEC (cmol kg^{-1})	1988	5·45	5·98**
	1996	5·19	6·75
P Olsen-Dabsin (ppm)	1988	15·1**	13·52
	1996	8·71	10·37
pH (water)	1988	6·53	6·31
	1996	6·53	6·41
pH (KCL)	1988	5·58	5·37
	1996	5·51	5·34

*$t < 0{\cdot}05$; **$t < 0{\cdot}01$.

largely available in Dohoun. Morant also conducted a study of the soil on 59 farmers' fields in 1988 as a part of agronomic field trials conducted by CIRAD. I located 54 of those agricultural fields and resampled soils from them in February 1996, replicating the original methods as closely as possible. Methods or sampling in 1988 and 1996 were replicated as closely as knowledge of the original protocol allowed (Gray, 1997). Composite soils samples (10 cores per plot) were taken at a depth of 0–20 cm. Both sets of samples were analyzed at the CIRAD laboratory in Montpellier, France.

The main motivation of this restudy was to establish whether, in the span of eight years, soil nutrient status had changed and in what direction. Of the 54 fields originally samples in 1988, 34 were still under cultivation in 1996, while the other 20 had been left fallow. Soils were defined to be under continuous cultivation if they had been farmed for at least seven out of the eight years from 1988 to 1996, and fallow if they were left uncultivated for more than one year. Table III presents the means of the soils for each soil variable for both 1988 and 1996. To investigate the differences between years, paired *t*-tests were conducted. By pairing the 1988 soils with those from 1996, it was possible to test whether the means of the differences of the pairs were significant. Differences between the means of the pairs are indicated when significant and level of significance is noted.

The soils in Dohoun are typical of dryland tropical soils. French scientists have characterized most of the soils in the Dohoun area as sold ferrugineux tropicaux (Leprun and Moreau, 1970). This roughly corresponds to Alfisols of the USDA soil taxonomic system (Aubert and Tavernier, 1972). Tropical Alfisols are generally found under woodland or grassland savannas and are characterized by clay accumulation in the B horizon, low levels of carbon and organic matter, and low cation exchange capacities.

Soils from fields that were continuously cultivated showed few differences. The one nutrient where we see significant differences was phosphorus. The level of available phosphorus had decreased over time, from

15·1 ppm in 1988 to 8·71 ppm in 1996. In contrast, even with the small sample size ($n = 20$), soils that were fallowed exhibited many significant changes in soil nutrient status. Many of the nutrient levels were higher in 1996 than in 1988. Total soil organic matter and total soil nitrogen both increased with fallowing as did levels of exchangeable cations. Phosphorus levels were not significantly different, as they had been in soils that had been continuously cultivated. These results indicate that soils under fallow were beginning to regenerate.

How can these results be explained? For soils that were continuously cultivated, two conclusions may explain the fact that we saw only subtle changes in soil nutrient status over time. First, most large changes occurred in the first years of cultivation. Second, the rate of change thereafter was very slow. Eight years may not be enough time to observe changes in soils that have been cultivated for a significant period of time and that change very slowly. Other studies conducted on West African Alfisols also indicated that soil organic carbon and nitrogen levels both decreased quickly at the beginning of the cropping cycle and then leveled off to a steady state (Juo, *et al.*, 1995; Nye and Greenland, 1964). The average length of cultivation for the fields was 7·7 years when the study in Dohoun began in 1988. By 1996 they had been cultivated an average of 15·7 years; the average age of fields when they were fallowed was also 16 years. It may be the case that the soils under continuous cultivation in this study have reached a low-level equilibrium and greater changes in nutrient status were unlikely.

There were large differences in the available phosphorus contents of soils collected in 1988 and 1996. Available phosphorus declined in all fields under continuous cultivation. This reflects the fact that phosphorus is frequently the most limiting soil nutrient in West African semiarid soils, despite the fact that phosphorus levels can be quite high after a field is cleared and burned. Phosphorus levels decrease continually over time due to fixation or removal by crops. Sanchez (1976) suggests that declines in levels of available phosphorus may be one of the more important reasons why farmers fallow their fields.

This study illustrates the benefit of fallowing in restoring soil nutrient status. Fallowed soils examined here were beginning to regenerate. The average age of fallow for the fields was 4·7 years, and already increases in organic carbon, soil total nitrogen, and exchangeable cations were apparent. Even given the increases in these vital soil nutrients, most farmers indicated that the fields had still not recovered sufficiently for cultivation. They judged this not by a visual soil characteristic, but by observing the evolution of vegetative cover; farmers relied on the appearance of large shrubs, small trees and most importantly tall grasses. These grasses, generally *Andropogon gayanas* and *Andropogon ascinodis*, were the most crucial indicators of soil fertility.

A Study of Practices on Farmers' Fields

In this section, the discussion focuses on farmers' agricultural practices, illustrating how farmers are reacting to changes in land-use patterns and land availability. The data presented here were collected in interviews conducted with 106 randomly selected farmers in the three villages during the 1996 agricultural season.[7] Farmers were asked to detail their agricultural practices and different measurements were taken in their fields.

As mentioned earlier, all three villages have experienced both demographic and agricultural change. Both of these changes have exacerbated land scarcity. This land scarcity has, in turn, resulted in more permanent cultivation systems. In the village of Sara, which of all three of the villages faces the most acute land scarcity, farmers indicated that fields around the fields within a half-mile radius of the village have been cultivated almost continually since the 1970s. Most farmers in Sara were reluctant to leave land fallow. There was little new land to cultivate and the social pressure on an individual with an uncultivated field was too great. Many farmers indicated that it would be impossible to refuse a field to a relative or friend if it had been left fallow.

[7]The households were picked randomly from village lists constructed in coordination with village leaders and representatives. The sample was stratified by ethnicity; half of the households picked were from the migrant communities and half from the Bwa community. Households were defined as units that cultivate together – sometimes including more than one nuclear family, for example, brothers farming together, in others, just a husband, wife, and children. Most migrants in all three villages are Mossi farmers.

Table IV. Average age of field (in years) in cultivation by village and ethnic group (n = number of fields)

	Sara (n = 56)	Dimikuy (n = 40)	Dohoun (n = 42)
Bwa	14·8	12·0	11·3
Migrant	16·7	9·0	11·4
Village total	15·8	10·8	11·4

Table V. Average manure application (in sacks/hectare) by village and ethnic group (n = number of fields)

	Sara (n = 80)	Dimikuy (n = 53)	Dohoun (n = 48)
Bwa	4·9	3·2	0
Migrant	3·7	6·2	1·1
Village total	4·3	4·9	0·7

This section argues that land scarcity has led to a classical boserupian intensification; farmers are farming land more frequently and applying more labor to individual fields (Boserüp, 1965). The data collected were not longitudinal, so the intensification hypothesis emerges from a comparative perspective of the three villages with varying land availability: Sara has the least land available, while Dohoun has the most; Dimikuy lies mid-way between the other two. One way of initially examining the differences among the three villages is by looking at the average length of cultivation of fields of farmers surveyed in each of the three villages. Table IV illustrates this by showing how Sara, the village with the most acute shortage of fallow land, had the highest average field age. Farmers interviewed in Sara complained that their fields were completely worn out, but that they had little choice but to keep cultivating them. The lower overall field ages in Dimikuy and Dohoun reflects the relative availability of land in those two villages, although most farmers maintained that land was fast disappearing.

The next two subsections examine this question by examining farmer input use and trees in agricultural fields.

Use of Agricultural Inputs

How are farmers reacting to this loss of fallow land? One of the ways that farmers offset fallowing fields is by using inputs which both substitute for the beneficial soil-restoring processes of fallow and for the loss of nutrient status. Farmers in all three villages regularly applied manure and fertilizer to their fields, and constructed bunds, ridges, and terraces to stop soil erosion. In this section the differences are examined for each of the villages and between ethnic groups.

Many farmers applied manure obtained from household animals, family herds, or through barter or purchase to their agricultural fields. Farmers were quite explicit about using manure as a substitute for fallow. Several Mossi farmers in Dimikuy even applied manure to fallow fields so that they could bring them back into production after a year or two of fallowing. Approximately 27 percent of fields in both Sara and Dimikuy were manured, while only 19 percent of fields in Dohoun had manure applied to them. Table V shows the average number of sacks[8] of manure applied to fields by village and by ethnic group. Farmers in Sara and Dimikuy applied higher quantities of manure to their fields. During the 1995 agricultural season, farmers in Dimikuy used on average approximately 4·9 sacks per hectare while farmers in Sara used on average 4·3.

[8]The sacks that are filled with manure are 100 kg grain sacks. The weight of one of these sacks filled with manure will obviously be lighter than were it filled with grain, although exact weights were not calculated.

Table VI. Average fertilizer application (in sacks/hectare) by village and group (n = number of fields)

	Sara (n = 81)	Dimikuy (n = 53)	Dohoun (n = 53)
Bwa	2·7	1·8	2·3
Migrant	2·6	1·2	0·7
Village total	2·6	1·4	1·2

Migrant farmers in Dimikuy and Sara used manure as a substitute for fallow. Migrant farmers in general were hesitant to leave land fallow for fear that their landlord will reclaim it. In Dohoun, migrant farmers used very little manure even though they faced land scarcity similar to that of the other two villages. Migrants in Dohoun were poorer and had little access to livestock or manure. Bwa farmers in Dohoun used little manure because they were still able to use shifting cultivation for soil regeneration.

Farmers also applied fertilizer to their agricultural fields. Only farmers who grew cotton obtained fertilizer on loan from their grower cooperatives (Groupements Villageois). Others had to purchase fertilizer outright. Table VI indicates the differences in fertilizer use among ethnic groups and villages. As the table shows, farmers in Sara applied the most fertilizer to their fields. The lower use of fertilizer in Dohoun can be explained by the fact that migrant farmers in Dohoun, because of their relatively recent arrival to the village, tended to be poorer than their Bwa counterparts. They arrived very recently and were not as involved in cotton or maize production. Instead, they concentrated their efforts on low-input millet and sorghum fields. Migrants who have been in the region longer tend to be wealthier and grow cotton. This is reflected in Sara, and to a lesser extent in Dimikuy, where the migrant community was fairly well-established and fertilizer use was similar between local Bwa farmers and migrant Mossi.

Finally when asked about the construction of antierosion barriers such as bunds, ridges, or terraces, farmers reported in Sara that they constructed structures on 14 percent of their fields, while farmers in Dimikuy constructed structures on only 6 percent of their fields. This reflects the abundance of flat land in Dimikuy. In Dohoun, however, where many fields were on sloped land fully 27 percent fields had some sort of antierosion improvement made to them.

To summarize, farmers in all three villages implemented agricultural practices that improved soil quality. On the whole, farmers in Sara, the village with the most acute land shortage, used the most inputs. They used manure and fertilizer to improve the soil quality of their fields, and constructed antierosion barriers. We see that migrant farmers also tended to use higher levels of inputs than did local Bwa farmers, in part because they were unable to fallow their fields without having them reclaimed.

Trees in Agricultural Fields

Trees in agricultural fields are a distinctive feature of the Sahelian and Sudanian landscape. Gijsbers, *et al.* (1994) define the farmed parkland (parc arboré in French) found in farmers' fields throughout Burkina as 'scattered well-grown trees, in a regular pattern, on cultivated or recently fallowed fields' (1994: 1). These trees are not specifically planted, but are left on fields after fallow or tended because of their economic value. The tree species found in parklands are multi-functional; they provide shade, fruit, food, wood, and medicinal products. In western Burkina Faso, the dominant species in parklands are *Vitellaria paradoxa* (karité), *Parkia biglobosa* (néré) and *Acacia albida*.

Several authors assert that tree numbers in farmed parklands are declining because of animal traction and the accumulation of livestock wealth (Gijsbers, *et al.*, 1994; Kessler, 1992). Trees in fields are an obstacle to farmers using plows, so they are removed. Animals graze and browse young seedlings and trees reducing their overall numbers.

These assertions that tree densities on farmer fields are declining are important because trees play an important role in the local agroecology. They maintain and increase organic matter through leaf and root decay, recycle nutrients and water from deeper layers of the soil, and decrease rates of erosion (Kessler

Table VII. Density of trees per hectare by village and ethnic group (n = number of fields)

	Sara (n = 78)	Dimikuy (n = 46)	Dohoun (n = 53)
Bwa	20·2	8·3	9·3
Migrant	15·9	12·5	13·5
Village total	18·0	10·5	12·1

and Breman, 1991; Young, 1989). One tree in particular, *Acacia albida*, a nitrogen-fixing species, plays a particularly important role in increasing crop yields. Farmers adamantly asserted that Acacia trees increased yield, both directly from the effects of the tree itself, but also because of the manure deposited by the animals that congregate under the shade provided by the trees during the hottest time of the year.

To examine the role played by trees in agricultural fields, trees were counted in the surveyed fields of all farmers participating in the study. Karité was the most common tree found on farmers' fields. About 75 percent of trees counted on fields were karité, while only 6 percent were néré, and 2 percent *Acacia albida*. The other 17 percent were tree species about which farmers had no opinion as to their economic or ecological value.

Table VII presents data on the density of trees in agricultural fields in the three villages. Sara, with an average of 18·0 trees per hectare, had the highest number of trees. An ANOVA analysis indicates that the difference between the means of total village trees was highly significant ($p < 0{\cdot}01$). A LSD (least significant difference) analysis among means indicates that the means of Dimikuy (12·1 trees/ha) and Dohoun (10·49 trees/ha) were significantly different ($p < 0{\cdot}05$) from Sara but not from each other. There were also some differences between the surveyed fields of migrants and local farmers, but these differences were not significant.

The fact that farmers in Sara left more trees on their fields reflects land scarcity in that village. If we break down trees by ages of trees we see that tree numbers on older fields in the three villages were similar. It was on the newer fields in Sara that farmers appeared to be leaving more trees. Furthermore, there were many more stumps on newer fields in both Dimikuy and Dohoun than in Sara. This indicates that farmers in Sara were actively keeping more trees in their fields, reflecting the perception of farmers in Sara that trees are beneficial both economically and ecologically, especially as land and fallow has become scarce.

IS LAND DEGRADATION A PROBLEM? EXPLAINING CHANGES IN LAND USE

The three studies above provide a multi-scale, multi-perspective investigation of changes in land-use patterns, soil quality, and agricultural practices in three villages in the cotton-growing region of south-western Burkina Faso. At the broad scale, we see from aerial photographs that land under cultivation increased in the village of Dimikuy at the expense of forest and fallow. In Sara, where most arable land is already under cultivation, there was little expansion in land area, but in Dimikuy, land under cultivation had more than doubled from 1981 to 1993. Also the increases in bush savanna in both villages indicate that land area that is eroded, lightly covered and possibly degraded has increased.

The other two studies narrow the scope of analysis to farmers' fields. An analysis of soil samples collected from these farmers' fields in 1988 and again in 1996 indicates that there has not been a widespread reduction of soil quality. Soils under continuous cultivation reveal few changes, while soils that were fallowed during the eight-year period showed improvement in nutrient status. A study of agricultural practices illustrates how some farmers are responding to the lack of fallow land by intensifying their production system. They nurture trees on agricultural fields, use more inputs and construct antierosion barriers on sloped fields to prevent erosion.

What explains the different results of these studies at different spatial scales? At a broad scale, it appears that degradation is a problem, especially as land under bush savanna has increased, while at the narrow scale

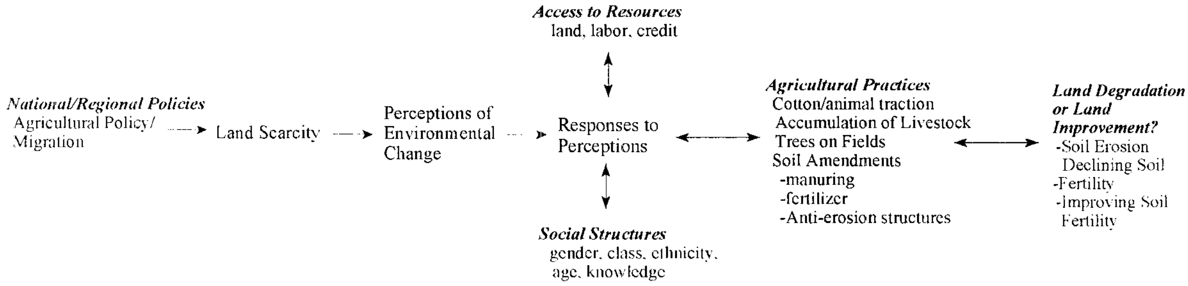

Figure 1. Explaining Farmer Decisions about Responses to Perceived Land Degradation in Southwestern Burkina Faso

it appears that farmers are improving their farm fields using inputs and leaving trees. To answer this question, it is important to examine farmer decision-making processes.

Figure 1 presents a conceptual model for summarizing farmer decision making regarding agricultural practices. The model relates national/regional agricultural and migratory settlement policy to increases in land scarcity. Land scarcity and the resulting shortening of fallow periods has led to the perception that land degradation is a problem. Farmer's responses to perceptions of land degradation are conditioned by local social structures and access to resources. These shape decisions about agricultural practices and ultimately determine whether land degradation or land improvement characterize the nature of agricultural change.

This model is partially based on Blaikie's (1989b) 'chain of causality'. While the model is presented as linear, many of the variables are simultaneously determined and interact to produce particular outcomes. This is illustrated well when we look at the affect of national/regional agricultural and migration patterns on land-use patterns. Decreasing fallow periods could be directly linked to the in-migration of new farmers. However, while migration and the resulting population increase are responsible for increases in area under cultivation, other processes such as the emergence of the plow have also been responsible for increases in farmed area. Farmers using plows cultivate more land area than farmers using hoe cultivation.

Perceptions are the key link in the chain connecting changes in land to farmer decisions to improve their agricultural systems. Farmers in all three villages perceived that their resource base was degraded. The reasons that farmers articulated that land degradation was a problem fell into two general categories. Many farmers, especially migrants, tended to blame reductions in vegetative cover and the resulting declines in soil quality on reduced rainfall. Other farmers, especially local Bwa, tended to blame reduced vegetative cover and soil quality on the increased demand for land due to the influx of migrants. One farmer, a Bwa man from Dimikuy, argued that 'before there were lots more trees in the area of Dimikuy than now. The migrants have come and destroyed our vegetation. Fallows don't last as long as they used to because we have less space now.' Because of shortened fallow periods, farmers contended that their fields were overwhelmed by weeds and soil quality was poorer than in the past. Despite this, most farmers believed that yields were much higher than they used to be primarily because of modern inputs.

The solution to this problem of reduced land availability according to many farmers was the use of inputs such as manure and the construction of different soil conservation structures. Farmers acknowledged that these technologies were not available to everyone: only wealthier farmers with livestock could apply large amounts of manure. Not all forms of intensification require large amounts of capital and labor. For example, the decision to leave trees on agricultural fields was more related to perceptions of the economic and ecological benefit of different tree species than to income, although some wealthier farmers using tractors and plows did not want trees in fields. Farmers also acknowledged the beneficial practices of leaving trees on agricultural fields, particularly the nitrogen fixing *Acacia albida*.

The decision to intensify is related to social and economic status and is embedded in several recent institutional and socio-economic transformations. First, like Tiffen and Mortimore (1994) describe in Kenya, intensification is related to increases in investments in technological improvements. These improvements, fertilizer use and cultivation using the plow, have become available because of improved information, infrastructure, investment, marketing, and technologies surrounding cotton production. Second these new opportunities have been key in producing wealth and the subsequent investment in livestock, which has resulted in larger numbers of farmers applying animal manure to their farm fields.

These social and economic changes have led to socio-economic differentiation. In all three villages there were important differences between resource rich and resource poor farmers and among villages, similar to what Turner and Ali (1996) find in their study of intensification in Bangladesh. There was tremendous variation in the ability of wealthy and poor farmers to respond to reductions in fallowing land by intensifying their farm fields. Wealthier farmers were able to use manure and fertilizer on all their fields, poorer farmers used manure only on household fields where goats and sheep were stabled. There were also differences among the three villages which were very much related to each village's land availability. Farmers in Sara, the village with the most acute land scarcity problem, used more inputs than did villagers in the other two villages.

There were important differences between the two ethnic groups. These differences, however, were not related to an essential characteristic, but were very much related to the length of time a migrant had resided in a village and to the general inability of migrants to formally control land. Newer migrants tended to be poorer and not to adopt new technologies immediately. They grew sorghum and millet and were not overly involved in the cotton economy. We saw these differences in each of the three villages. Migrants in Dohoun, where the average length of residence of farmers samples was 13 years, tended to be poorer than their Bwa counterparts. In Sara, where the migrants sampled have resided for an average of 28 years, migrants were as wealthy as their Bwa hosts, actively participated in cotton production and animal traction and invested in soil improving technologies.

The other situation that migrants faced is that they did not have customary or statutory control over land. All land used by migrants was technically considered to be borrowed, although security of tenure increased with the length of time of cultivation. This also affected the decision-making processes of migrant farmers. Most migrants were hesitant to leave land fallow, for the fear that the Bwa lineages or individuals who had customary and ritual control over land would reclaim it. The inability to fallow fields had serious implications, because, as the soil data illustrates, fallowing a field unquestionably improves soil quality. Mossi migrants were then in many circumstances forced to intensify because they could not leave fields fallow and were unable to borrow new still-fertile fields. This ability was constrained furthermore by wealth; while migrants accumulated livestock more than did local Bwa farmers, many poorer newly arrived migrants were unable to.

In summary, national and regional agrarian policy, access to resources and social structures all combined to influence farmer decision-making concerning agricultural practices. These practices then determined whether a field was degraded or improved.

CONCLUSION

In much of Africa the driving force behind environmental policy is the commonly accepted wisdom of environmental degradation (Batterbury and Bebbington, 1999; Leach and Mearns, 1996). Few studies, however, connect biological, physical, and chemical processes of land degradation to social explanations at the appropriate scale of analysis. Even without evidence of processes and direction of change, governmental and donor organizations implement environmental management programs that alter how resources are allocated and controlled.

The studies presented in this paper from aerial photos, soils, and farming practices on agricultural fields indicate that while the environment is changing in southwestern Burkina Faso, it is unclear that these changes are the unbridled environmental degradation that is often predicted in this area. Many of these predictions are based on examinations conducted at a broad scale where changes in land cover are associated with widespread land degradation. One of the points of this multi-perspective approach to study land degradation is that within a very small geographic area, there are different stories of environmental change. Examinations and explanations of processes of change depend on the scale of enquiry and on the 'teller' of the story. Even though the stories and their conclusions are different, they are interconnected. Processes that we can detect at one scale, using aerial photos for example, are met with responses at other scales. The intensification responses illustrated by this paper are best illuminated at a much narrower scale, by examining the decisions and actions of individual farmers. This observation has important practical implications because most assumptions of environmental change are based on a uni-dimensional perspective. For example, in Burkina Faso aerial photographs are a significant component of landscape analysis in projects favored by many development organizations and government agencies (Gray, unpub. paper). Because of the lack of a perspective that encompasses variation among villagers, most organizations are unaware of the steps farmers take themselves to cope with the effects of reduced land availability.

Is land being degraded in the study area? The answer depends on scale and scope of enquiry. It also depends on how land degradation is defined. The way it is defined in this paper takes into account the interests of the primary land user in the area, the farmer. Farmers are generally concerned with any changes in soil and land quality that affect their productive capacity. Most farmers believe that land is degraded. They blame perceived reductions in yield and increases in weeds on the fact that fallow and forested land are no longer available and they can no longer shift from one field to another. They perceive that weeds in fields have worsened and that soil erosion is a problem.

An important point that this study makes is that people experience degradation very differently. These differences are shaped by ethnicity, wealth, and locality. Wealthier farmers with access to livestock use manure to improve their fields. Migrant farmers frequently are not able to fallow their fields. Wealthier migrants cope by using more inputs; poorer migrants must compensate according to their economic means. Farmers in the village of Sara, with their disappearing land resource, experience reductions in available land differently and use different management strategies than do farmers in Dimikuy and Dohoun. Therefore, at the same time and often in the same places, degradation both is and is not a problem; it depends on the scale and associated biophysical process measured, the perceptions of the observer, and access of individual farmers to resources.

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