



Encapsulating knowledge from local documents

Time lines of social and environmental drivers of land system changes and their impact in Burkina Faso and Niger since 1960

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Publication date:
2014

Document version
Publisher's PDF, also known as Version of record

Citation for published version (APA):
Reenberg, A., Moussa, I. B., Some, B., & D'haen, S. A. L. (2014). *Encapsulating knowledge from local documents: Time lines of social and environmental drivers of land system changes and their impact in Burkina Faso and Niger since 1960*. Copenhagen: LaSyRe-Sahel, Working Papers, Dep. of geoscience and Natural Resource Management, Copenhagen. LaSyRe Working Paper, No. 11



LaSyRe-Sahel

A region wide assessment of land system resilience and climate robustness in the agricultural frontline of Sahel
- the triple exposure of local livelihood strategies and food provision to climate change, population pressure and globalization

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Time lines of social and environmental drivers of land system changes and their impact in Burkina Faso and Niger since 1960

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LaSyRe is funded by DANIDA, research grant 09-001-KU The project is an interdisciplinary collaboration between the following institutions:

Department of Geoscience and Natural Resource Management, University of Copenhagen
Department of Geography, Abdou Moumouni University of Niamey
Institut de l'Environnement et de Recherches Agricoles (INERA), CNRST, Ouagadougou
Department of Geography and Geology, University of Ouagadougou
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Abstract

Environmental change in the West African Sahel, including land cover change, has been a prominent issue in sustainability and development debates and research for the last half century. This paper provides a reminder that historical changes in the use of land resources are embedded in a complex web of driving forces, which it is crucial to keep in mind in order to appreciate the role of different factors of change.

The article seeks to identify the wide range of influential events that have modified land use decisions in Burkina Faso and Niger for the period from before Independence (1960) until the present day. The material originates from a thorough consultation of local literature as well as from national expert knowledge. A 'timeline heuristic' provides an overview of the co-evolution of major issues characterizing the 'demographic and socioeconomic setting', the 'political and institutional setting' and the 'biophysical setting', which enable and constrain changes in the use of land. When possible, the impact of changes is specified in detail in terms of land use patterns, food security, environment, agricultural practices or pastoral practices.

An overview matrix indicates how environmental and land use related processes in the Sahel are embedded in many constantly changing influential conditions. On this background, the article cautions against translating insights gained from past experience into generic traits of human-environment dynamics, which can be immediately used to predict plausible directions of future changes in pressures on land and the environment.

Key words: Sahel, Sustainability research, institutions, policies

I: Introduction

In the contemporary era of political attention to accelerating global environmental and socio-economic change, it has been stressed that we need to acknowledge that global change processes work across local, regional and global scales (ICSU 2010). In that perspective, exploration of the regional manifestations of global change become valuable contributions to understanding global change processes, with a view to, for example, sustainable development.

Sustainable human use of land is at the centre of some of the most pressing challenges faced by policy makers (e.g. DeFries et al. 2004). Some policies directly influence land use (e.g. nature protection), while others affect land based activities such as agriculture. But a wide range of other policies, not intended to influence land use, has important, indirect implications. They include, but are not limited to, agricultural price policies, trade policies, investment in infrastructure and macroeconomic policies.

The Sahel region has been considered one of the hotspots of environmental change as well as a prototype of functional patterns in a tropical dryland system, especially since severe droughts hit the region in the 1970s, with devastating effects on human livelihoods and the environment (Raunaut 1997 and 2001; Schellnhuber et al. 2002; Reynolds 2007). Given the Sahel region's 'status' as a generic model of change processes in tropical drylands, it becomes specifically interesting to provide an overview of the history of human-environment conditions and events, with the aim of looking critically into the justification of established narratives about interactions between humans and the environment.

The pressure on land resources has been one prominent field of interest in the global change literature. A growing body of academic literature on land use dynamics in developing countries has successfully identified a plethora of proximate and underlying drivers of land use change (Lambin and Geist 2006; Turner et al. 2007), stretching from global market dynamics over national resource management policies to individuals' decisions on land management and occupational activity (Lambin et al. 2007; Birch-Thomsen et al. 2010; Chowdhury 2010; Mena et al. 2011; Rasmussen and Reenberg 2012). This complexity of land change processes is also found in the Sahel (e.g. Mortimore and Turner 2005; Nielsen and Reenberg 2010b); yet, the scientific documentation of land use change and its causal factors is surprisingly limited (van Vliet et al. 2013).

As has been discussed in, for example, the livelihood literature, natural management decisions are embedded in a range of constraints or possibilities imposed by geography, political economy, biophysical reality and historical events (Nooteboom 2003; Nielsen and Reenberg 2010b). Hence, the Sahelian countries have since their independence around 1960 been influenced by changes in the political, social and economic spheres (Batterbury and Warren, 2001), which all impact on the land use decision environment. During the same period, biophysical conditions for land use

decisions have also been fluid. The region experienced several severe drought periods, with indications that the climate may be changing slowly, and degradation of soils and biodiversity has been observed.

This paper aims at providing a concrete overview of the evolution of a range of biophysical and socio-economic constraints and possibilities that have very likely had a decisive influence on land use decisions in Niger and Burkina Faso. The trajectories of change are summarized in a matrix of coupled human-environmental timelines (Reenberg et al. 2008), which in a heuristic way collocates information on factors influencing land use changes emerging mainly from a broad screening of the wider francophone, so-called grey literature. By exploring this wide pool of knowledge about the key drivers of importance for land change in Burkina Faso and Niger between 1960 and 2012, we wish to illuminate the challenges involved in translating the co-evolution of natural, social and institutional factors into substantiated claims about generic, causal relations that can be used to guide future sustainable pathways.

II: Land system drivers in the Sahel, a general overview

The Sahel region is characterized by low annual rainfall amounts and has a limited agricultural potential; yet, most of the people living there identify themselves as subsistence farmers or pastoralists. Post-independence land use changes in Sahelian countries have been predominantly explained by rainfall and demographic pressure. The need for food for a growing population has traditionally been regarded as a main driver of unsustainable cropland expansion in this region with low biophysical potential, leading to soil degradation and ultimately desertification (Oldeman et al. 1990; CILSS 1999). However, these so-called 'theories of cumulative change' may overemphasize the role of population pressure in land use change, 'downplaying the importance of the socio-political process of resource management, through interventions of the state, corporations and international price shifts' (Guyer et al. 2007) and overlook inherent ecological processes and indigenous environmental knowledge systems (Mortimore 2009).

Despite the considerable attention paid to the environment and development in the Sahel over the last half century, most insights rest on a rather limited pool of empirical evidence from available case studies and from often inaccurate statistics. Some main traits of change in the Sahelian land systems, with specific emphasis on Niger and Burkina Faso, can, however, briefly be summed up under the headings of land use trends, climate conditions, socioeconomic issues and policy environment.

Land use trends in the Sahel – Burkina Faso and Niger

A recent meta-study of empirical case studies on land use change in the Sahel (van Vliet et al. 2013) demonstrates a significant tendency towards cropland expansion (an increase since 1960 is observed in 73% of the available studies). Field expansion was, in most cases, associated with natural population growth or in-migration. The regional variability is, however, significant. In general terms, cultivated areas have grown since the 1960s, yet the ratio of agricultural population to arable land remains low compared to the average for developing countries (OECD 2009). Land for grazing remains stable, although transhumance corridors have disappeared and turned into farmland (OECD 2009).

In *Burkina Faso*, the cultivation intensity is relatively high seen in a Sahelian perspective. FAO statistics provide a figure of around 17% arable land at the country level in 2001; yet, there is significant regional variation. Specifically, cotton cultivation has increased the pressure on land in the southern part of the country. Ouedraogo et al. (2010) document, for example, an annual rate of cropland increase close to 1 % between 1986 and 2006 in southern Burkina Faso, presumably related to in-migration from the north of the country. Cropland change trends in the northern Sahelian zone of Burkina are, on the other hand, much less clear and may even include traits of contraction (Reenberg 2009; Rasmussen and Reenberg 2012).

In Niger, the southern regions have a relatively high and growing population density (up to 200 inhab. per km²). Cropland expansion has been the norm for many years (Heasley and Delehanty 1996; Amisshah-Arthur et al. 2000; Reenberg et al. 2013a; Reenberg et al. 2013b) and most arable land has been under cultivation for the last three decades (Mortimore and Adams 2001); yet, field expansion is still possible and takes place in an eastern direction in Zinder (central Niger) (Mounkaila 2002). Since 1961, crop expansions have been constrained by an official 'northern cultivation limit'. It was established by law to protect the main pastoral zones of the country situated above this limit. The pastoral component of the land system is important, and traditionally, land has been reserved for a number of 'pockets' of pasture land and cattle corridors in the agricultural zone (Lund 1998). The event of the severe droughts of the 1970s and 1980s transformed, however, the livestock system profoundly (Thebaud 1996). Manuring contracts became scarce as farmers increasingly used crop residues for their own livestock to make ends meet (Banoïn and Guenguant 1999; Turner 1999; Thebaud and Batterbury 2001; Osbahr and Allan 2003). Transhumance during the drought was therefore directed south (Boutrais 2007), and improved veterinary techniques and regular unrest in the north of the country led to a consolidation of this dry season southward route over the traditional rainy season northward transhumance (Augusseau et al. 2006; Boutrais 2007).

Climate conditions

Rain may be considered the most crucial biophysical factor in the Sahelian system because the amount and distribution of rain are decisive for agricultural outcomes. Since the 1950s, the Sahel has undergone roughly three different rainfall regimes: a 20 year wet period from 1950-1969, a 20 year dry period from 1970-1989 and a very variable period since 1990 (Lebel and Ali 2009). Notably the central Sahel (eastern Burkina and southern Niger) has been experiencing a partial recovery of previous wetter conditions over the last 20 years. There are, however, indications that the within-year rainfall cycle might be changing here in ways that have negative implications for plant production. Rainfall in August seems to have changed, and 'the maximum 10 day rainfall is now observed during the first 10 days of August, instead of during the last 10 day period of August' (Lebel and Ali 2009). Because August is a crucial time period for the development and growth of millet, even minor alterations may have significant implications for the harvest.

The decrease in potential production of dry cereals and livestock was dramatic in the dry periods; during the early 1980s, for example, the cattle population of Niger dropped by almost 60% because the herds were either decimated or moved towards the South (OECD 2009).

Socioeconomic issues

Demography

Burkina Faso is currently home to around 17 million people, whereas Niger has approximately 16 million inhabitants. The demography in Niger and Burkina Faso is best characterized as having the typical features of a developing country. The Sahelian countries have some of the highest population growths in the world (UN 2011). Burkina Faso and Niger consistently figure in the list of countries with the youngest populations, with a median age below 24. The population has been growing rapidly and is expected to continue to do so due to the current age distribution; by 2100, the population is projected to have increased by 500% (UN 2011). Between 1960 and 2006, the natural population growth rate in Burkina Faso increased from 1.8 % to 3.4 % (mainly due to falling mortality rates), with an accompanying increase in population density from 16 to 52 people per square km respectively (INSD 2011). With more than seven children per woman, Niger has the highest fertility rate and consequently also the highest natural growth rate in the world (3.6% for the period 2005-2010) (UN 2011). Most of Burkina Faso's and Niger's population – 74% and 83%, respectively – live in relatively inaccessible rural areas (Linard et al. 2012). Even though these percentages are projected to be falling (mainly due to very high urban growth rates), the rural

annual growth rates are still around 1.9% and 3.2%, respectively (UN 2012). Hence, the pressure on land resources to sustain local people with food is accelerating.

Mobility and migration

Migration traditionally plays a major role in Sahelian livelihoods, and the ability to meet demands for food from income sources outside local agriculture obviously decouples land requirements from local population pressure. Migration most often concerns younger males, who migrate during the dry season or for shorter time spans while the rest of the family remains in the village of origin. Sahelian dwellers have always been very mobile (Cordell et al. 1996). Burkina Faso has, for example, a long history of circular labour migration to the neighbouring Cote d'Ivoire and Ghana, whereas Nigerien migration has been mainly directed towards Ghana, Cote d'Ivoire, Nigeria and Lybia (Rain 1999; Mounkaila 2002; Reenberg et al. 2013a). During the first 15 years of independence, the government of Burkina Faso tried to stem the international migration flow and to stimulate the local wage economy, without much success (Piche et al. 2011). After 1975, migration was increasingly managed at the regional level. A number of treaties in the 1990s aimed at free movement of people within the Economic Union of West African States (ECOWAS). In practice however, the emerging economic crisis in Cote d'Ivoire has led this country to impose restrictions on the entry, stay and integration of foreign labourers over the last 20 years. Nonetheless, Cote d'Ivoire remains one of the prime destinations of Burkinabé circular migrants (Nielsen and Reenberg 2010b).

A considerable part of the circular migration takes place within the country. Circular migration has long been and remains one of the most important off-farm income generating activities (Saqalli 2008; Nielsen and Reenberg 2010a; Rasmussen et al. 2012). During and after the droughts in the 1970s and 1980s, circular migration from northern and eastern parts of Burkina Faso to the south-western part of the country, for example, increased rapidly (Cordell et al. 1996; Reenberg and Lund 1998; Gray 1999; Henry et al. 2004; Pare et al. 2008; Ouedraogo et al. 2009). Besides easing the pressure on food resources in the village and providing money to the family members remaining in the villages, the migrant associations have had some indirect influence by promoting education and health infrastructure (Mounkaila 2002; Beauchemin and Schoumaker 2009). Investments from migration in agriculture are expected to become more important once social investments have been accomplished.

Economy

The economic perspectives of the Sahelian land use systems are not very promising; yet, the food dependency (i.e. the overall share of imports to regional production in the Sahelian countries) seems almost stable despite the growing population (OECD 2009). The production methods and

lifestyles in the Sahel remain mostly very traditional and essentially defined by auto subsistence, relying on traditional nomadic cattle-raising and millet or sorghum production.

The Sahel is known to have relatively few urban conglomerations (Snrech 1994) and hence few proximate markets for agricultural products. In recent years, this picture has changed somewhat; the number of cities with over 100 000 inhabitants in the Sahel has risen from 30 to 135 over 30 years, with obvious implications for local market opportunities (OECD 2009). This may create incentives for new land use practices.

On the larger scale, only a few cash crops have played a role in the land use patterns. Notably cotton, groundnuts and cattle have attracted attention. After independence, agriculture was considered to be the motor of the economy and numerous state organizations were established to stimulate and direct agricultural production. The resulting shift in crop choice influences both land use and social organization (Guyer et al. 2007). The expansion of cotton has been especially remarkable, with a quadrupling of the area in West Africa over the past 45 years (OECD 2009); Mali and Burkina Faso are the leading countries.

Households everywhere in rural Sub-Saharan Africa have been observed to increasingly engage in non-farm activities (Barrett et al. 2001; Bryceson 2002; Wouterse and Taylor 2008; Davis et al. 2010). Gardening, livestock trading, handicrafts and (small) commercial activities are practised all over contemporary Burkina Faso and Nigerian Sahel (Nielsen and Reenberg 2010b). West African patterns of food consumption are changing as a result of the development of the market economy, in which rice and wheat are increasingly valued. This pattern is most prominent in the urban communities; yet, the attraction towards imported cereals also influences the rural communities. Although millet and sorghum remain important staples in the marginal rural areas, local production covers a continuously diminishing proportion of the diet. Therefore, the coupling between local food demand and cereal production has become less tight.

Policy and institutional issues

Political, legal, economic and traditional institutions also influence land use decisions in important ways. In particular, government policy plays a pervasive role in land changes, either directly or in a mediating fashion (Lambin and Geist 2006). It is beyond the scope of this brief account of Sahelian conditions to provide a comprehensive picture of this complex field, but a few selected perspectives deserve to be singled out (i.e. development interventions, land rights issues and agricultural policies).

Development intervention

The poor countries in the Sahelian region have for decades received considerable attention from the international development aid community. The droughts of the 1970s and 1980s were important, as the decimation of cattle herds and major human food crises prompted significant economic and political reforms and extensive international assistance (Batterbury and Warren, 2001). Initially, the international assistance focused on food production systems characterized by various technical interventions designed to boost agricultural and rangeland productivity, including mechanization and an African Green Revolution experimentation with food grains (McMillan 1995; Naudet 2000; Nielsen et al. 2012). Throughout the 1980s and 1990s, assistance came in the form of targeted projects run by northern NGOs (Atampugre 1993, 1997; Nielsen 1999; Batterbury 2002; Samoff 2004), many of which focused on land management and anti-desertification measures. Since the late 1990s there has been a shift towards direct budget support (e.g. DANIDA 1988). Currently, for example, around 85 percent of public investments in Burkina Faso are financed through (multilateral) aid (Affairs 2010).

In addition to the impact of aid, which is aimed directly at improving land use strategies, development interventions can change land use priorities at the local level, because 'working for development projects' has become pivotal in people's income portfolios (e.g. Naudet 2000; Warren et al. 2001; Engberg-Pedersen 2003; Nielsen et al. 2012).

Land Right issues

People's access to land and other natural resources has significant implications for land use choices. Land tenure systems in the Sahel were traditionally connected to kinship, and ethnic adherence, along with status, gender and seniority, determined access and use rights (Migot-Adholla and Bruce 1994: 5). As in other parts of Sub-Saharan Africa, land rights have, however, undergone significant changes as a result of general societal transformations and state policies on land. And rather than replacing customary law, legislation has in many places resulted in a dual legal structure and ample scope for competition over rules as well as institutions (1993; Lund 1995; Platteau 1995).

A series of land reforms were implemented in the decades after independence in the Sahelian countries in which the national governments actively took a stance against the customary system and limited the power of local chiefs in the allocation of lands. These, on the whole, did not work, and in most places the customary system of land tenure continued to operate. The Burkinabé land reforms, for example, are no different in this respect. When the reform (Réorganisation Agraire et Foncière (RAF)) was first formulated in 1984, all land was nationalized. This was modified later (in

1991 and 1996) but the implementation has been riddled with ambiguity (Stamm and Sawadogo 1995; Faure 1996; Lund 1997). Important traits of indigenous land tenure still prevail but land is often subject to multiple claims exercised by members of the social network who can find ways to justify claims in the repertoire of rules that result from this development. Niger adopted their Rural Code in 1993 to support rural livelihood and sustainable management of natural resources. Yet the legislation has proved to be not only inadequate, but actually detrimental to, for example, pastoralists because it does not fully acknowledge the specific nature of pastoral land use (Thebaud and Batterbury 2001).

Agricultural policy

Post-independence agricultural policies in the Sahel focused on promoting export sectors, supporting, for example, cotton and groundnut cultivation, because agriculture was considered to be the motor of the economy. The issue of food self-sufficiency also influenced government policies, in terms of, for example, the creation of the 'Office des Produits Vivriers du Niger'. Especially during the 1980s and 1990s there have been several attempts to implement various sectorial reforms, often with support from the World Bank. Contained in these reforms were measures such as disengaging the state, facilitating competition, and improving productivity, as has been seen in connection with, for example, the cotton sector, yet in different variations across the Sahelian countries (Tschirley et al. 2009). Such agricultural policies have obviously had the most direct impact on land use in the more humid parts of the region, where the agricultural potential is reasonable. In the drier areas, the most prominent land use changes were connected to the pastoral sector policies. These include, but are not limited to the state encouraging herders to settle or the development of deep well systems (concentrating animals in specific locations and initiating a new spatial allocation of land uses).

In general, the prospects for the agricultural sector became marked by the implementation of Structural Adjustment policies in the 1980s, leading to the transfer of certain state activities and powers to private actors (OECD 2009). At the same time, rural development initiatives developed towards greater decentralization, which gives local actors greater influence on initiatives concerning them, including, for example, land management strategies.

III: Presentation of method

A heuristic, expert based approach has been chosen to generate an overview of the wide range of influential events that have modified the land use decisions in Burkina Faso and Niger in the period from before Independence (1960) until the present day.

Inspired by the notions of 'ecological timelines' (Reid et al. 2000) and 'coupled human-environment timelines' (Reenberg et al. 2008), we have established a simple recording structure to support extensive scrutinizing of the information and knowledge that have been presented primarily in local scientific and consultancy literature. This thorough examination of available documents has been performed by local scientists with in-depth insight into the topics addressed.

First, the topics of interest were defined using a set of keywords, which were decided on in an interactive consultation with an interdisciplinary team of researchers (www.lasyresahel.ku.dk). The keywords comprise those used for the Sahel-wide study of Anglophone literature (vanVliet et al. 2013), including land use, cropland and land cover. In addition, themes such as tenure, land use conflicts, pastoral systems, water resources, forestry and agro-silvo-pastoral systems were identified by locale experts to be important.

Second, a comprehensive search for documents dealing with these key topics was conducted with the aim of creating a pool of all accessible literature dealing with land systems in Burkina Faso and Niger. It included visits to local libraries, project document archives, university thesis archives etc. It should be noted, however, that a rigorous and systematic application of the keywords to search for the literature was not possible, given that a large share of the documents are not recorded in digital databases. Hence, the identification of documents depended heavily on the local experts' familiarity with centres of documentation, project libraries, etc. Two independent searches were made in Niger and Burkina Faso, respectively (Moussa 2011, Some et al. 2011, Some et al. 2013).

Third, the information for the matrix was distilled from these bibliographic databases. The events and conditions of importance for the land system¹ and its development in the course of time are presented, distinguishing three main categories: a) demographic and socioeconomic factors; b) political and institutional factors; and c) biophysical factors. The timeline of exploration runs from before Independence (1960) until the present day, and is sub-divided into time slots of local historical significance (before 1960, 1960-(1970)-1990 and 1990-present).

Furthermore, the screening of the documents distilled, to the extent possible, the proposed impact of the conditions or events, generalized into the following five categories: land use or land

¹ The concept of land system is used as presented in GLP (2005). It depicts land use and land management as influenced by the social as well as the ecological context in a dynamic, coupled human-environmental system, driven by feedback mechanisms.

cover change (LULC), food security (FS), environment (E), agricultural practice (A) or pastoral practice (P).

IV: Encapsulated knowledge: enabling and constraining conditions

The thorough consultation of the locally available literature conducted by experts from the region alerts to a wide range of conditions or events with significant bearing on the land system change in the course of the time period explored. Obviously many of the issues renowned correspond to the general traits of the demographic and socioeconomic setting, the political and institutional setting, as well as the biophysical setting as described in the first part of this paper. The detailed outcome of the inventory is presented in the matrix in Table 1 which should be considered and read as part of this section inasmuch as most of the information conveyed speaks for itself and will not be disentangled in further detail. Bearing in mind the heuristic approach applied, relying heavily on informal expert judgements, the list cannot be claimed to be exhaustive; yet, it is believed to provide a reasonable range of examples of the most pertinent issues. Indeed some of the issues enhanced for one country and not for the other may in fact be worth mentioning in both cases, such as, for example, the impact of the devaluation of the West African currency Franc CFA in 1994. The content of the matrix is, however, presented as first proposed by the national experts. The main attention should be directed towards the richness of issues that are considered, their co-existence and the complexity they represent. This leads to caution against any obvious analysis of correlation or feed back between the various issues because any cause-effect relationships may be questionable.

In more general terms, it is worth noting that the depicted themes represent 'slow' as well as 'fast' variable (using the notion of Lambin and Geist 2006), confirming that land use dynamics are driven by a combination of factors that work gradually and factors that work intermittently. Unpredictable and seemingly random elements can be important in several land change situations as also discussed earlier for the Sahelian land use systems (Reenberg 2001).

Population pressure and climate alterations have had a prominent position when describing the land use changes in the scientific literature. This group of factors is also among the noticeable issues emerging from the present screening, but they are paralleled with a large number of factors of a political, economic or institutional nature. Especially events related to the transformation of the land tenure systems from traditional rights to modern forms seem to be noted as important. In the last decades, internationally initiated action plans (e.g. for climate, biodiversity or water) have been given much attention.

In attempt to indicate the nature of the plausible impacts of the characteristics of the various settings, the experts have tried to distil the information given in the underpinning documents and

‘translate’ it into the set of five predetermined impacts: land use or land cover change (LULC), food security (FS), environment (E), agricultural practice (A), or pastoral practice (P). In the table, these impacts have been listed in the sequence proposed by the experts, indicating to some degree the perceived level of importance; yet, the rigor with which it was possible to implement this exercise does not justify a thorough analysis of this outcome, e.g. in terms of impact-specific cause-effect analyses. The take home message from reading the impact columns seems, most importantly, to be that the land system is affected in several ways simultaneously with a range of implications of interest for sustainability. Land use, food security, agricultural practices, pastoral production and environmental conditions are targeted or influenced in many ways via the socioeconomic, institutional or biophysical settings, and it appears almost impossible to single out simple cause-outcome interrelationships between specific characteristics or events and plausible impacts of importance for the sustainability of the land system (as tentatively captured in the five impacts).

Table 1

Niger	Demographic and socioeconomic setting		Political and institutional setting		Biophysical setting	
<i>Historical eras</i>	<i>Characteristics and events</i>	<i>Impact</i>	<i>Characteristics and events</i>	<i>Impact</i>	<i>Characteristics and events</i>	<i>Impact</i>
Pre-colonial period						
	Gradual populating and sedentarization (N.7; N.10)	LULC	Significant importance of traditional chiefs: e.g. allocation of land, management of food (N.7; N.8; N.9; N.10; N.11)	LULC, FS LULC, FS, A, P		
	Touareg nomadism (N.7; N.10)	LULC, P	Free access to land, no limitations of grazing and field expansion (N.9)			
	Transhumance tradition (N.7, N.10)	LULC, P	Touareg control of trade routes (N.7; N.10)	LULC		
Colonial period						
	Expansion of the Peul domain to the limit of Sahara (N.6; N.7; N.10)	LULC, FS	Termination of tribal wars. Termination of Touareg dominance of sedentary populations.	LULC; FS	Abundant land resources; Variable rainfall (drought periods around 1913-14; 1931-32; 1951-52) (N.7; N.8; N.9; N.10; N.11)	LULC, FS, A, P

	<p>Tax introduction Development of cash crops (groundnuts; cotton) (N.5; N.11)</p> <p>Generally low population pressure (N.7; N.8; N.9; N.10; N.11)</p> <p>Touareg people in the North promote and adopt cattle rearing (N.7; N.10)</p>	<p>A, LULC</p> <p>LULC</p> <p>P</p>	<p>Actions: Establishment of 'Sociétés Indigènes pour le stockage collective'; re-creation of agricultural villages in places left during wars and attacks; transition from nomadism to transhumance. Free access to land. (N.5; N.6; N.7; N.10; N.11)</p> <p>Traditional chiefs, families and clans play an important role in allocation of land and food (N.7; N.8; N.9; N.10; N.11)</p>	<p>LULC, FS, P</p> <p>LULC, FS</p>		
Independent state – 1960-1970						
	<p>Demographic acceleration; Spatial mobility of people; Spatial consolidation of land access; Nuclearization of family units; Migration; Reduced access to water points provoking conflicts between agriculture and nomads (N.2-11; N.13-15; N.17; N.19; N.20; N.22; N.24; N.26; N.30; N.31; N.34; N.35; N.38; N.40; N.44; N.45; N.47-53; N.54; N.55; N.56-68; N.70)</p>	<p>LULC, FS, E, A, P</p>	<p>1961 laws (No 61-25 of May 26th and no. 61-06 of May 27th) determine the northern limit for cultivation (reserving land toward the north for pastoral use only). (Code Rural)</p> <p>Government policies support transformation of dispersed habitation to a nuclear village settlement structure from 1966 (N.9)</p>	<p>LULC, P</p> <p>LULC</p>	<p>Abundant rain in 1960s (N.7; N.8; N.9; N.10; N.11)</p> <p>Drought in 1967-68 – provokes migration, sedentatization of nomads, soil degradation, change of crop patterns</p>	<p>LULC, FS, E, A, P</p> <p>LULC, E, P</p>

			Modernization of the governance (UNCC – Nigerien credit cooperation); SONERA (groundnut marketing); COPRO-NIGER (trade and production); RINI (rice Niger); SONITEXTIL (textiles); SONERAN (animal resources); SOTRAMIL (millet); BDRN (Niger development bank); OLANI (milk); misc. development plans.	FS, LULC, A		
Independent state – 1970-90						
	Monetization of the economy (starting in the 1960s) creates quest for money and leads to selling of land	LULC, FS	1970-1983: National strategy for self-sufficiency in food (creation of OPVN - Office des Produits Vivriers du Niger); Enhancement of planning and establishment of government institutions (e.g. Five-year programs for the environment and for poverty reduction); Encouragement of sedentarization of nomads; Concentration of animals with adverse impact on environment (N.10; N.15; N.16; N.21; N.32)	LULC, FS, E, P	Droughts in 1973-74 and 1980 – provoke migration, sedentatization of nomads, soil degradation, change of crop patterns	LULC, FS, E, A, P
	1980s increase in agricultural input prices – constrains the expansion of cash crops	LULC				
	Stagnation of agricultural prices (leading to impoverishment of farmers and expansion of cropland) (N.11)	LULC, E	1974: Change of tenure rights (declaration of December 18 th of Chef d’Etat) (the land now belongs to those who use it) (N.35; Code Rural)	LULC		

	Introduction of new farming methods (fertilizer, intercropping)	A	Liberalization of the economy since 1984, and liquidation of government institutions (except OPVN)			
	Tax (personal and animal) abolished by government from 1974		Development project interventions (e.g. irrigation, dry season crops, environmental protection)	A, LULC		
Independent state – 1990-present						
	Development project influence (new techniques/agroforestry; experimental intensification; new role of women)	LULC, FS, E	1993: adoption of decree No. 93-015 of March 2th (code rural, consolidating principles for land, natural resources and organization of rural communities) In the 2000s: establishment of community groups; Decentralization; Programs for poverty reduction and sustainable development; Programs for climate change;	LULC; FS, E, P FS, LULC	Improved rainfall conditions, larger variability between dry years (1996, 2005, 2009) and wet years (1994, 1998, 2004, 2010)	LULC, FS, E, A, P

Burkina Faso	Demographic and socioeconomic setting		Political and institutional setting		Biophysical setting	
<i>Historical eras</i>	<i>Characteristics and events</i>	<i>Impact</i>	<i>Characteristics and events</i>	<i>Impact</i>	<i>Characteristics and events</i>	<i>Impact</i>
Colonial period						
<p>Military territory 1896-1904</p> <p>Member of the colonies of Haut-Senegal and Niger 1904-1919</p> <p>Colony of Haute Volta 1919-1932</p> <p>Divided between Ivory Coast, Mali and Niger until reconstruction of Haute Volta in 1947</p>	Progressive sedentarization (BF.6; BF.67)	LULC, FS	Social and economic development plans (agricultural modernization; introduction of cash crops (cotton, groundnuts); forest management; infrastructure) (BF.36; BF.37; BF.48-BF.53; BF.71-72; BF.102; BF.140; BF.141; BF.146; BF.150; BF.169)	A, P, FS, E	Drought 1912-1915	LULC, FS

	Establishment of forced labor; Population exodus to Gold Coast	LULC, FS	<p>Four year plan (FIDES 1952-1956) for modernization of agriculture (BF.141)</p> <p>Traditional land right systems (BF.121); Transformation towards modern land access rights, e.g. decree of 4 July 1935 and of 20 May 1955 defining protected forest land. Ensured land rights (BF.120)</p> <p>Establishment of agricultural research stations (e.g. cotton seed station in Saria 1900, rice seed station in Niangoloko (1949), sisal, sorghum and maize in Farako-Ba (1950).</p> <p>Hydro-agricultural management mapping and education (BF.169)</p>	<p>A, FS</p> <p>LULC, E, FS</p> <p>A, FS</p>	Locust invasion 1930-1935	FS
Independent state – 1960-1973						
			<p>Establishment of mentoring and supervision to promote agricultural development, food self-sufficiency, access to credit: (e.g. 13 regional development bodies (ORD); National Agency for cereals (OFNACER); National Development Bank (BND);</p> <p>International NGO actions against degradation and food insecurity (e.g. GERES)</p>	<p>FS, A</p> <p>LULC, FS, E</p>	Major drought 1972-1973	FS, P, A, LULC

Independent state – 1973-1983						
	Reduction of livestock migration; movement towards the South; improvement of drinking water provision in the Sahel. Use of irrigation. (BF.10; BF.85; BF.129; BF.133; BF.147; BF.174-175; BF.178-180).	A, P, LULC, FS, E	National policy for water (PNE), first version from 1997, later elaborations in 1982, 1985 and 1992. Establishment of a ministry for higher education and research within agronomy (IRA) in 1978.	E	Significant variations in precipitation between years	FS, P, A, LULC
Independent state – 1983-1992						
	Population pressure, atomization of production units Organization in village communities (rural Development Fund (FDR) 1975-85), e.g. gender interest groups, small scale irrigations, livestock watering, anti-erosion measures (BF.9; BF.13) Village based attention to natural resource management: improving long-term awareness of environment impact; research-development actions to improve local livelihoods (BF.100; BF.152; BF172)	A, P, LULC, FS, E LULC, FS, E, P A, P, LULC, FS, E	International NGO actions against degradation and food insecurity (e.g. CES/AGF 1988-2003; PSB-Sahel 1990-2005) Launching campaigns like 'Les trois luttes' 1984: fighting against bush fires, tree cutting and migratory livestock. Other initiatives: 'one village, one garden' (1984), 'improved stoves' (1984), 'manure pits'. Adoption of the R.A.F. 1984 (later modifications in 1996, 2008 and 2012) – Reorganization of agriculture and land rights. The laws deal with specific sectors: environment, forest, mining, water.	LULC, FS, E E, LULC, S, FS LULC, E	Persisting low rainfall	FS, P, A, LULC

			National Action Plan for Desertification (PAN/LCD) 1996 Forest policy driven introduction of 'assisted natural regeneration principles' (RNA), i.e. local people's responsibility of resource management (BF.100)	A, P, LULC, FS, E		
Independent state – 1992-present (The democratic regime)						
	Currency devaluation of Franc CFA 1994	LULC, FS, E	Endorsement of: 'Programme National de gestion des Terroirs (PNGT) 1992 – supporting collective village territory management plans; 'Sahel Integrated Lowlands Ecosystems Management' (SILEM) 2005 – aiming at supporting sustainable watershed management; 'Strategie Nationale de gestion Intégrée de la Fertilité des Sols (SNGIFS) 1999	LULC, FS	Dwindling precipitation, desertification (BF.15; BF.17; BF.20; BF.26; BF.32-33) Increasing trends in some years	A, P, LULC, FS, E
	Butane gas extension, supported by government supported gas price	E, FS	<i>Water issues:</i> Decree concerning water politic and strategies, 1998; program for integrated water resources management (GIRE), 1999; Action plan for integrated water resources management, following international principles (PAGIRE) 2003, including agro-hydrology management policies (AHA)	E, A	Biophysical environmental improvement by adoption of new techniques in the agricultural system, e.g. zai, anti-erosion dikes, improved stoves	A, P, LULC, FS, E

	Increasing human pressure on resources; increasing conflicts about resources and land (BF.15; BF.17; BF.20; BF.26; BF.32-33)	LULC, FS, E	(BF.116) <i>Forest, Biodiversity and Pastoral issues: National Action Plan for the Environment (PANE) 1991; Biodiversity Action Plan 1993; Law of 2002 addressing principles for sustainable development of the pastoral sector; National Forest Management program (PNAF) 1996.</i> <i>Strategic Plan for Scientific and Technological research 1997</i>	E, P, LULC		
	Enhancement of local people's capacity to manage resources, formation of associations, e.g. Naam/FNGN, SEMUS, etc.). (BF.42-43)	E, FS, A, P	National Adaptation plans for climate change (PANA) 2007			
	Establishment of local resource management projects, incl. awareness, ecotourism, focus on forest and biodiversity conservation (BF.5-7; BF.42-43)	E, FS	National decentralization, creation of 302 rural communes and 49 urban; elaboration of local level development plans (PCD) and regional level development plans (PRD)			

Table 1: The matrix encapsulates main traits of characteristics and events in the socioeconomic, political/institutional and biophysical settings in Niger and Burkina Faso from pre-colonial to present time. Specific attention is given to issues considered to have a bearing on the land system and its sustainability. The content is derived from a screening of a broad range of documents available in the region; the final accentuation is chosen by local experts. Likewise, local experts have extracted the possible impacts as proposed in the documents. The impacts are categorized in five types: LULC (land use and land cover), FS (food security), E (environment conditions), A (agricultural practices), and P (pastoral practices).

Key references for the information are indicated in the formats N.x and BF.y respectively. The documents are listed in the supplementary material to the article.

V: Conclusion

The value of national and international environmental policy documents for sustainable development depends critically on accurate knowledge about the coupling of human actions and the environment. Recently, the environmental and climate change debate has brought new momentum to written documentation of and research into the dynamics of social-environmental interaction, e.g. related to land use system sustainability. Experience shows that the complexity of causal relations is high; yet, in order to guide sustainable development strategies and interventions, it is crucial to acknowledge such complexity in order to avoid simplistic interpretations (Reenberg et al. 2012).

In this article, the main attention has been directed at presenting information of relevance for the management of land resources in the Sahel. In this region, land remains an important resource to provide food for local people as well as other important ecosystem services and to support sustainable development. Within this field of knowledge, there is a glaring need for more systematic documentation of the processes of change in the land systems in these world's poorest nations with fast-growing populations.

While some documentation has been made available in traditional, scientific journals (e.g. Batterbury & Warren 2001; VanVliet et al. 2013), a large pool of knowledge remains poorly accessible, presented in the so-called 'grey literature', such as consultancy reports, university theses etc. Hence, important nuances are not readily available.

The heuristically established overview matrix presented above hints at how environmental and land use related processes in the Sahel are embedded in many constantly changing, influential conditions. As stressed by Lambin and Geist (2006), it is critical that good information about the causes and consequences of land system change reaches policy makers so that they can make more effective policies and understand policy impacts. On the background of the apparently poorly transmitted knowledge, it seems justified to caution against adopting simplistic narratives about causal relationships in social-environment interactions to create sustainable strategies for future development. Furthermore, there seems to be scope for recommending harvesting, in a more systematic fashion, the unexplored pool of information that remains in local archives.

Acknowledgements

The work presented in this paper is financed by LaSyRe (Land System resilience and climate robustness in the agricultural frontline of Sahel), a DANIDA-FFU project, 09-001KU. Furthermore, it contributes to the ERC project Waterworlds.

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Supplementary material

Reenberg et al.: *Encapsulating knowledge from local documents: Timelines of social and environmental drivers of land system changes and their impact in Burkina Faso and Niger since 1960*

As explained in the article, the information presented is based on a comprehensive search in documents that are not always readily available. A special effort has been made to identify material from local libraries, project document archives, university thesis archives etc. It should be noted, however, that a rigorous and systematic application of the indicative key words for the search was not possible, given that a large share of the documents is not recorded in digital data-bases. Hence, the identification of documents relied on the local experts' familiarity with the various archives. Two independent searches were made in Niger and Burkina Faso, respectively.

The total pool of documents is listed below, as bibliographically accurate as possible given the material available. The numbering in the lists corresponds to the references given in Table 1 in the article, i.e. N.1 refers to reference number 1 in the Niger list, and BF.1 to reference number 1 in the Burkina Faso list, etc.

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