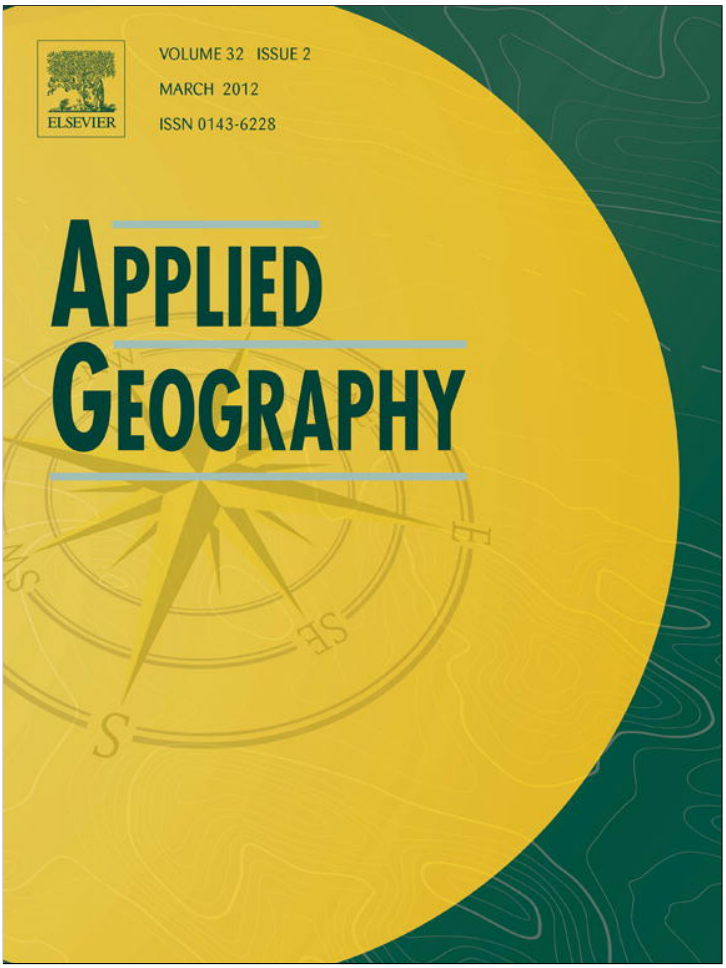

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Applied Geography 34 (2012) 595–605

Contents lists available at SciVerse ScienceDirect

Applied Geography

journal homepage: www.elsevier.com/locate/apgeog

Land use rationales in desert fringe agriculture

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Keywords:
Land cover changes
Land use decisions
Sahel

A B S T R A C T

Population growth has often been suggested to explain field expansion in Sahelian land use systems. Yet recent research increasingly acknowledges that villagers do not necessarily enlarge their fields as a response to increased food requirements. This paper suggests that drivers such as population growth should be connected to land cover changes by taking villagers' individual land use decisions into account. The links between drivers, individual land use decisions and land cover changes are explored in a small village in northern Burkina Faso, Yomboli, for the period 1956–2010. The analysis is based on measurements of the cultivated area, participant observation, interviews and questionnaires. Three waves of land cover changes are identified: field expansion between 1956 and 1991; field contraction from 1991 to 1995; and field expansion and contraction between 1995 and 2010. The results show shifting links between drivers, individual land use decisions and land cover outcomes throughout the period. The paper argues that villagers' earlier decisions on field enlargement have primarily been propelled by the driver of population growth, whilst recent decisions seem to be more influenced by individual rationales than general drivers of change. Moreover, the results show that villagers' decisions on field size are not solely economic judgements of cost and benefit. Rather, their decisions are anchored in three broad categories of rationality: economic, ecological and sociocultural rationality. This does not imply that villagers are economically ignorant, but that the concept of rationality assumes different meanings in a Sahelian context. The findings demonstrate as well the shifting influence of these rationalities as economic rationality has been replaced by sociocultural rationality over the last decade.

Introduction

In the Sahelian region, common understandings of the causes of land cover change are dominated by simplifications (Thomas & Sporton, 1997). For decades, sweeping generalizations about a vicious circle of land degradation and land expansion prompted by population pressure and low rainfall have been used to describe the main trajectories of change (PANA du Burkina Faso, 2007; Reynolds et al., 2007; Stephenne & Lambin, 2001). However, in recent research, the complexity of Sahelian land change processes has increasingly been recognized (Mortimore, 2006; Rasmussen, Rasmussen, Reenberg, & Proud, 2012), supported by evidence from empirical case studies (Nielsen & Reenberg, 2010b; Rasmussen & Reenberg, 2012). These studies challenge single-factor explanations of land cover change such as population growth and land degradation. It has, for example, been acknowledged that although food requirements increase or yields decline, Sahelian villagers do not necessarily expand the field area (Reenberg, 2009). Hence, land cover changes should rather be attributed to complex interactions between the triple exposures of population pressure, climate variability and globalization.

The land use/land cover change community has, on the one hand, made significant conceptual advances by analysing land cover change in relation to underlying and proximate driving forces (e.g. GLP, 2005; Lambin & Geist, 2006; Turner, Lambin, & Reenberg, 2007). On the other hand, it has also been stressed that the individual land use decision making plays an important role in land cover change processes (Lambin, Geist, & Ellis, 2007; Mena, Walsh, Frizzelle, Xiaozheng, & Malanson, 2011). Such recognitions call for approaches that try to reconcile the notion of 'drivers of changes' with a more agent-oriented notion of 'decision makers'. In this theoretical context, it has most often been assumed that individuals make rational land use decisions based on the available information, obligations and expectations (Lambin, Geist, & Lepers, 2003) of an economic, sociocultural or ecological nature. This perspective may be further refined to consider how the influence of these rationales changes in the face of different external exposures of the land system. When trying to explain villagers' behaviour and land use decisions, concepts like adaptive capacity (Adger et al., 2007), risk management, profit maximization, indigenous knowledge,

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doi:10.1016/j.apgeog.2012.03.005

ethnic tradition and range of choice (Kull, 1998; White, 1961) have, for example, been brought into play. In various ways these approaches contain a perspective of rationality in their analysis. By employing such approaches, it is assumed that it makes sense to consider peasants in the desert fringe as rational.

This paper investigates the interplay between large scale driving forces, individual land use decisions and the resulting land cover changes. The paper will specifically investigate how a 'rational villager' can be characterized and how land cover changes may be interpreted when they are explored through the lenses of rationality. In order to do this, the following questions are addressed in the small Sahelian village of Yomboli in Northern Burkina Faso:

- What land cover changes occurred during the period 1955–2010?
- How can these land cover changes be linked to individual rationales and large scale driving forces?
- What are the main objectives when villagers decide to expand, decrease or maintain the size of the field area,[2] and do these objectives correspond to specific forms of rationality of an economic, sociocultural or ecological nature?
- Has there been a temporal shift in the importance of these specific forms of land use rationality?

The paper will try to merge remote sensing and social science in the analysis of land cover changes as suggested by Rinku (2006), Roy Chowdhury and Moran (2012) and Roy Chowdhury and Turner (2006). The paper starts with a brief methodological overview and an introduction to the case village, followed by an analysis organized around three themes. Firstly, we analyse land cover changes that occurred in Yomboli during the period 1955–2010. Secondly, we explore villagers' current and previous land use decisions (expansion, contraction or maintenance of the field area). Thirdly, we identify the possible links between observed land cover changes, individual land use decisions, alterations in large scale driving forces and the rationales that underpin villagers' current and previous land use decisions.

Individual land use decisions vs. large scale driving forces

When individuals make decisions on field expansion or contraction, those decisions are likely to be influenced by a wide range of factors (Miller et al., 2009). An emerging science of land change acknowledges that individual land use decisions may be underpinned by individual rationales as well as broader driving forces (Roy Chowdhury, 2010). Understanding observed land cover changes therefore requires insight into individual aims and rationalities as well as these large scale driving forces.

Individual land use decisions: different forms of rationality

Approaches that seek to understand the individual land use decision process range from the rational decision making of neoclassical economics to household, gender, class and other dimensions common to the social and behavioural sciences (Lambin et al., 2003). In these approaches the concept of rationality takes different forms, as briefly summarized below. In line with Cleveland and Soleri (2007) and Blaikie et al. (1997) we take our point of departure in three broad categories: economic, sociocultural, and ecological rationality.

Economic rationality

Economic models of individuals' land use decisions are based on the assumption that peasants act to maximize outcomes. For example, Bates (1976) argues that "the consistent preference for more income over less strongly shapes behaviour". Peasants are thus assumed to apply their endowments of capital and especially labour to land in such a way as to maximize outcomes (Kremer & Lock, 1993). In relation to labour, the Russian economist Chayanov asserts, however, the importance of differentiating between small peasant families and capitalist farms (Chayanov, 1966). The distinguishing feature of peasant agriculture lies in the pivotal role of household labour, which cannot be calculated in terms of market wage rates and the profits and losses of a capitalist firm (Netting, 1993). Chayanov does not argue that peasant families maximize profits, but that they regularly make decisions designed to maximize gains and minimize costs. The small peasant continues to add labour to the production process even if the marginal returns to a unit of labour are very low. As the peasant does not impute some wage costs to unpaid family labour, Chayanov argues that the behaviour reflects choices that make rational economic sense in the family farm context. In this vein, he also highlights that due to the lack of stimulus from large urban markets, peasants reduce their labour to that necessary for household consumption.

A basic assumption of Chayanov's model is that no opportunity to work outside the household for wages exists. This premise is, however, often violated in a Sahelian context, as dry season wage work is common.

Accordingly, an economically rational peasant is assumed to make decisions based on the trade-off between opportunity costs versus probable benefits of leaving rural areas contra performing farming activities. It is worth noting that Chaynov's model as well as purely economic conceptualisations of farming underpin prominent theoretical lines of thought concerning land use change, for example von Thunen's model, Boserup and Bilsborrow and Ogendo (Robinson, 2004).

Ecological rationality

Netting (1993) has contributed to an alternative view of small peasant rationality by challenging the assumption of peasants as either economically irrational or economically rational. While he shares the assumption about individual utility maximization, he sees utility maximization as modified by the tendency for individual peasants to include the family and wider community in their perception of utility. The peasants thereby prefer to manage resources for the common good. Thus, he emphasizes that a certain ecological rationality may underpin land use decisions. Toledo (1990) argues as well that peasants adopt ecologically rational survival mechanisms that guarantee an uninterrupted flow of goods, materials and energy from ecosystems. This is also the case for several anthropological contributions to human ecology, such as Rappaport (1971). In this context, a use-value rationality is adopted, which in practical terms is represented by a multi-use strategy that maximizes the variety of goods produced in order to provide basic household requirements throughout the year. A key property of this multi-use strategy is variety, in geographical, ecological and biological terms. It is worth emphasizing that there may be a certain overlap between sociocultural and ecological rationality as cultural traditions may be based on indigenous ecological wisdom.

Sociocultural rationality

In part a response to the economic rationality viewpoint, the sociocultural rational farmer perspective rejects the assumption

[2] The field area is defined as the area harvested by villagers. In this paper, land cover changes refer to the spatial pattern and quantity of changes in the field area. As the possibilities of intensification in Yomboli are very limited due to lack of access to mineral fertilizers and water for irrigation, land use changes related to intensification are not addressed here.

that peasants always compare output obtained from one activity with gains from investments in other activities. Vanclay (1993) points out that some aspects of peasants' actions must be considered legitimate even though an economic benefit is not gained. He suggests going beyond an economic rationality concept by acknowledging that peasants may maximize their benefits through ethnic traditions (Kiome & Stocking, 1995). By highlighting the problem of regarding those peasants as ignorant, he rejects the previous assumption of culture and economy as dichotomous (Stein & Wilson, 1993). In many earlier studies of agricultural development, villagers' decision-making processes have been seen as influenced by ethnic traditions, social status and preferences (Berry, 1993; Claude et al., 1991; Mazzucato & Niemeijer, 2002; Snyder, 1996). But the conclusions derived from these studies, stating that traditional cultural knowledge may be a limitation to 'rational' development, are now being challenged. The perception of peasants as culture-bound and irrational has thus changed in recent years, and a number of studies have now shown how decisions based on ethnic traditions may lead to progress (van den Breemer, Drijver, & Venema, 1995; Richards, 1985).

Cross-cutting objectives

Land use decisions made by peasants are assumed to be anchored in one or more of the three forms of rationality (economic, ecological and sociocultural) outlined above. However, these rationalities can be further differentiated into two main cross-cutting assumptions about peasant behaviour: the risk-minimizing peasant and the optimizing peasant.

As stressed by Ellis (1988), peasants make decisions under high levels of uncertainty both natural (e.g. weather hazards and diseases) and socio-economic (e.g. market fluctuations). Peasants are therefore assumed to exhibit risk aversion in their decision making. Likewise, Lipton (1968) disputes the optimizing approach by arguing that the existence of uncertainty and risk erodes the theoretical basis of the optimizing peasant model. He states that peasants are, of necessity, risk averse, because they have to secure their household needs from their current production or face starvation. Hence, there is no room to aim for higher income levels by taking risky decisions. Mirroring the previously mentioned ideas of Chayanov, Boserup (1975) argues as well that the behaviour of subsistence farmers differs from commercial ones. Subsistence farmers respond more to household consumption than market demand and thereby seek to minimize risk to household needs, not maximize gains (Turner & Fischer-Kowalski, 2010).

Specifically related to dryland regions, peasants minimize risks by diversifying their activities rather than intensifying their production (Batterbury & Warren, 2001). The diversification is increasingly connected to off-farm activities like seasonal migration. When peasants embrace off-farm activities, they aim at generating cash that can be used to enhance food security in the household (Mortimore & Adams, 2001). However, peasants may also seek to minimize risk in their land use decisions. Abdoulaye and Sanders (2006) assert that peasants strive to produce as much of their own food production as possible and to avoid being dependent on market purchases. They have shown how farmers in Niger continue to produce millet beyond the point at which their marginal cost of production of millet is equal to the market price as this enables the farmers to feel more food secure and less dependent upon purchases to achieve their consumption goals.

Contrastingly, the 'optimizing peasant' model ignores the effect on household behaviour of the uncertainty and risk involved in peasant production. The optimizing peasant model may be understood in terms of profit maximization as well as utility maximization. In earlier work by e.g. Schultz (1964), the peasant production mode was aligned with the 'economic man', described as profit maximization behaviour, by arguing that peasants are efficient in resource allocation. Economic work on peasant behaviour has, however, evolved along the line of criticisms of a purely profit maximization approach when describing the optimizing peasant (Mendola, 2005). In this vein, Simon's (1982) concept of satisficing behaviour should be mentioned, as he regards it as an alternative to the unrealistic optimizing capacity attributed to 'economic man'. Decision-makers are viewed as considering only a limited number of alternatives and choosing one that is broadly satisfactory rather than optimal, which reflects a 'bounded rationality' (see also Pred, 1967). These lines of thought have later influenced behavioural geography (Strauss, 2008). Moreover, the existence of trade-offs between profit maximization and other household goals has been recognized. The utility maximization approach encompasses, for example, the dual nature of peasants as both families and enterprises, thereby taking account of the consumption side of peasant decisions. This model conceives of peasant decisions as decisions made by converting purchased goods and services as well as own resources into use values. Thus, the peasants are assumed to maximize utility through the consumption of all available commodities (e.g. home-produced goods, market-purchased goods and leisure) (Scoones & Toulmin, 1995).

Large scale driving forces

A large body of recent theoretical literature addressing land use change processes prefers to analyse changes in relation to a number of proximate and underlying drivers that operate across a range of spatial scales (Lambin & Geist, 2006). Such approaches do not take their point of departure in the individual land use agent. Proximate drivers are defined as human activities or immediate actions at the local level, while underlying drivers are fundamental forces, such as human population dynamics or agricultural policies. Underlying drivers underpin local actions and operate at the local, national or global level. Some drivers are 'slow variables' that work gradually, whereas others are 'fast variables' that change rapidly, e.g. in connection with events such as a drought or an economic crisis (Lambin & Geist, 2006).

In a Sahelian context, conceptualisations of main drivers have focussed on single-factor causation, and underlying drivers such as population pressure (see e.g. Boserup, 1965; Malthus, 1970) and climate variability (Olsson, Eklundh, & Ardo, 2005) have been suggested. Laying these narratives to rest as a universal description of causalities has thus proven difficult despite new evidence documenting that there is no simple link between population growth and expansion of field area (Reenberg, 2009). Recent literature has, for example, emphasized a number of economic, social or political drivers that underpin individual land use decisions beyond what is implicitly assumed in Boserup's simple model of population driven land use changes (Brookfield, 2001; Stone, 2001). These studies argue that when a farming system becomes part of a larger setting, new variables are introduced, which may override the possible effects of population growth. Market access can, for example, play a significant role in land use changes (Birch-Thomsen, Reenberg, Mertz, & Fog, 2010; Netting, Stone, & Stone, 1993). For the Sahel, Reenberg (2009) suggests three main drivers: population growth, climate variability and globalization.

A framework for analysing land cover change

In order to further refine our understanding of observed land cover change, we apply a conceptual framework that acknowledges the significance of individual human agents as well as large scale driving forces. The need to refine existing approaches to land cover change has been highlighted, for example, in relation to the

prevailing 'proximate underlying' framework (Geist, 2006). The 'proximate underlying' framework has most prominently been used in analyses of tropical deforestation, whereas experience with the explicit application of the framework in other types of land cover change is more limited. A thorough evaluation of the approach has not been reached (Geist, 2006). It has, however, been pinpointed that modifications of the 'proximate underlying' framework may be needed as most alterations to land cover are the result of individual human decision making. The significance of human agents has thus been acknowledged, but their full incorporation into the 'underlying proximate' framework has not yet occurred. This may be due to the fact that individual land use decisions are included as one of many proximate drivers and are thus not ascribed primacy in the analysis of land cover changes. In line with Roy Chowdhury and Turner (2006), we propose a framework in which land cover changes are explored through an 'individual agent-large scale driving forces' binary (Fig. 1). While Geist and Lambin (2002) use the term (proximate) driver for individual land use decisions, the proposed framework applies the term driver only to broader structural forces that are largely external to and beyond the management of the individual villager: in other words, those forces that control the larger rural economy or that differentially empower and constrain villagers' decisions. The framework thus recognizes that focussing on large scale driving forces or individual decisions alone may lead to inadequate understandings of land cover change (Miller et al., 2009; Roy Chowdhury, 2010).

The case area

The study was carried out in a small village (Yomboli) with 1040 inhabitants located in the Oudalan province of northern Burkina Faso. The nearest meteorological station is in Gorom-Gorom. The rainy season lasts about five months, from May to September, and the mean annual rainfall for the period 1955–2010 was about 450 mm. The area is, however, characterized by high inter-annual variability with an inter-annual coefficient of variation calculated to be 30%.

Agricultural and pastoral production are the main sources of sustenance for the population in Yomboli and the land use system can be characterized in brief as a combination of cultivated fields and pastures. The village is situated on a longitudinal East–West oriented dune that is superimposed on a pediplain cut by temporary river valleys. The dunes occasionally make barriers across natural drainage structures and create more or less temporary lakes (in French: mare) (Reenberg, Nielsen, & Rasmussen, 1998). The main crops are pearl millet and sorghum, while cowpeas are grown to a lesser extent. Villagers in Yomboli distinguish between two main locations of their fields: the dune and other locations (which include the pediplain, the piedmont and the border of the mare). The majority of the fields are located on the sandy soils on the dune, where millet is cultivated as the sole crop. The soils on the pediplain, the piedmont and the border of the mare are loamier and the fields are characterized by mixed cropping of sorghum and millet.

Since 1984 all land has been considered state property due to the Agrarian and Land Reorganization (RAF) (McCauley, 2003). The idea was to give 'land to the worker' through usufruct rights, enabling those currently working on the land to use it and benefit from it (Nielsen & Reenberg, 2010a; McCauley, 2003). Anyone seeking access to land must in theory apply for use rights from the state, but on the other hand, it is widely recognized that local communities tend to regard themselves as the true owners of their land by virtue of their ancestral rights (Ouedraogo, 2005). Thus, it is the heads of household who are responsible for distributing land to extended family members, and an effect of this system is the subdivision of plots. Villagers who were born in the village have in principle free access to establish fields on uncultivated or unclaimed land. Villagers without entitlement to land through lineage can have land assigned through the village chief or borrow land from other villagers.

Cropping activities and pastoralism are traditionally integrated, the most important links being income, feed and manure (see e.g. Petit, 2003). The use of livestock manure sustains soil fertility, and crop residues provide feed for livestock during the dry season (Claude et al., 1991). Moreover, villagers engage in circular migration, whilst working for development projects is another off-farm strategy of importance. Abidjan, Côte d'Ivoire, surpassed

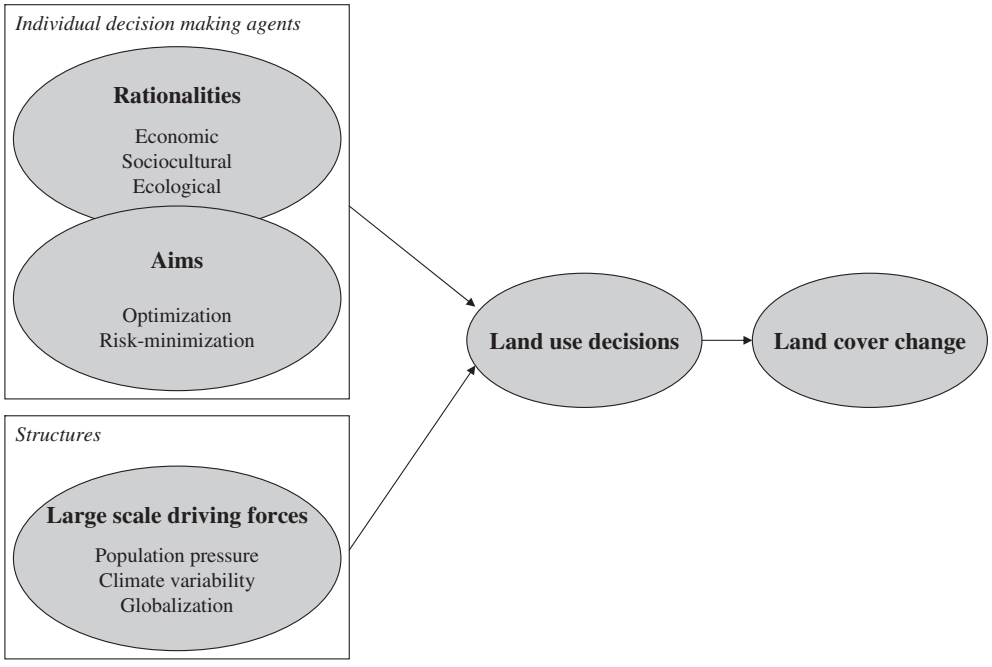

Fig. 1. A framework of the interplay between large scale drivers of change, individual land use decisions and the resulting land cover changes in Sahelian land use systems.

Ghana and Saudi Arabia as the major migration destination in the 1970s and has remained so ever since, despite unrest in Côte d'Ivorie since 2002 (Nielsen & Reenberg, 2010a). After the crop harvest in November, a large proportion of the men depart on migration to work as security guards or to engage in small commerce.

Methodology

The quantification of land cover changes at the village level rested on the use of aerial photos from 1955 and 1956, SPOT satellite images from 1988, 1989 and 1991 and GPS measurements carried out in the village of Yomboli in 1995 and 2010, see Table 1. A more detailed description of the analysis of aerial photos and satellite images is provided in Reenberg et al. (1998).

The observations used to assess villagers' land use decisions and their embracing of specific strategies stem from two rounds of fieldwork conducted in 1995 and 2010. More specifically, semi-structured interviews and focus group interviews were used to assess land use strategies and the reasons for choosing them, whilst questionnaires were employed to provide the basis for a quantitative characterization of the land use strategies embraced. In the first round of fieldwork, participant observation and semi-structured interviews were the main methods used, whilst participant observation, semi-structured interviews, focus group interviews and questionnaire interviews were employed during the second round of fieldwork, see Table 1.

Participant observation was chosen as a means to facilitate rapport with the villagers being studied and to gain insights into daily household behaviour. The basic insights obtained through participant observation were further explored in semi-structured interviews. A total of 45 interviews were conducted in 1995 and 32 in 2010 with elderly, middle-aged and young men and women covering socio-economic groups with different access to labour, land and remittances. Focus group interviews were also carried out in 2010 with 10 groups (of 7–10 persons each) differentiated by age and socio-economic status. The semi-structured interviews and the focus group interviews were structured so that the respondents were asked to: (a) describe their perceptions of major land cover changes in the village over the past 50 years; (b) describe the main changes (if any) in their own land use strategies over the past 50 years; and (c) identify the main causes of these changes and their main considerations when making a land use decision. The five categories of rationality and aims described in the previous section were then used to systematically index these qualitative data sets so that all mentions or indications of considerations related to these five types of rationality and aims were easily retrievable. The coexistence of several categories in one interview was not unusual. The aim of this coding process was not to produce variables that could be used in a quantitative analysis. Instead it was intended to give an overview of some of the contours and the range of characteristics of the villagers' land use decisions.

Questionnaire interviews were conducted in 2010 with 43 out of 128 heads of households (there were 106 households in 1995). The questionnaire interviews were structured in such a way that the respondents were asked firstly to assess their current land use strategies. Secondly, respondents compared the past four decades and described major changes (if any) to these strategies since the major drought in the mid-1970s. Finally, yearly differences (if any) in current strategies were assessed by comparing the strategies employed in rainy and dry years. This last category of rainfall related questions was included in order to (a) uncover whether rainfall variability had an impact on present and former land use strategies and (b) construct a historical line of changes in land use strategies. It should, however, be noted that the collection of historical data on the basis of respondents' memory is often difficult. Due to possible recall errors among the respondents, it was obviously not possible to ask them about changes in land use strategies each year over the past 35 years (Beckett, DeVanzo, Sastry, Panis, & Peterson, 2001). However, they seemed more reflective and confident when asked to describe changes in 'dry year strategies' and 'rainy year strategies', which explains why these rainfall related questions were included in the questionnaire interviews.

Table 1
Synthesis of methods employed; their key themes, data acquisition time, temporal span covered and quantitative density.

Methodology	Data characteristics			
	Key themes	Data acquisition time	Period vs. snapshot covered	Quantitative density
Participant observation	Land use strategies embraced by villagers Household production system Millet storage and purchase Livestock maintenance and sale	October to December 1995 February and Marts 2010 October to December 2010	Snapshot in 2010	Constant presence in the village and visits to the weekly market in Oursi
Focus group interviews	Land use strategies embraced by villagers The land use decision process Causes of land cover change	February and Marts 2010 October to December 2010	Snapshot in 1995 and 2010 The period 1955–2010	10 groups
Questionnaire-interviews	Land use strategies embraced by villagers	February and Marts 2010 October to December 2010	Snapshot in 2010 The period 1975–2010	43 out of 128 heads of households
Semi-structured interviews	Land use strategies embraced by villagers The land use decision process Household production system Millet storage and purchase Livestock maintenance and sale Causes of land cover change	October to December 1995 February and Marts 2010 October to December 2010	Snapshot in 1995 and 2010 The period 1955–2010	45 interviews in 1995 32 interviews in 2010
GPS measurements	Size of field area	October 1995 Marts 2010 November 2010	Snapshot in 1995, 2009 and 2010	Total field area in Yomboli
Aerial photos	Size of field area	December 1955 January 1956	Snapshot in 1955	Total field area in Yomboli
Satellite images (SPOT)	Size of field area	September 1988 January 1989 October 1991	Snapshot in 1988 and 1991	Total field area in Yomboli

Results and discussion

Observed land cover changes in Yomboli during the period 1956–2010

Fig. 2a and b show the location of the field area within the territory of Yomboli over the last six decades. A substantial real-location of fields is revealed. From 1956 to 1988 the field area expanded, primarily on the dune north of the mare. Yet during the same period, villagers abandoned southern fields on the pediplain. Since 1991 the location of fields has shifted southwards again and reversed the trend of abandoning the pediplain fields. Villagers explained the recultivation of the pediplain as being due to different yield potentials in different locations with varying rainfall amounts. Since it was impossible to predict the rainfall amount, as was often mentioned, villagers preferred to sow fields on both the dune and the pediplain. The pediplain fields were most productive in years with adequate rainfall but also had the highest risk of production failure in very dry years, whereas millet cultivated on the dune was more resistant to low rain. This new flexibility of field location was well demonstrated in the more scattered field patterns in 2009 and 2010 (Fig. 2b).

During the GPS measurements it became clear that the sowed area differed widely from the field area as villagers in general preferred to sow as big an area as possible. In cases of labour shortage they tended to use only the more productive sites within the fields, so that instead of leaving a whole field uncultivated they invested their labour in small parcels. The practice of sowing all fields implied that fields were permanently sowed and no regular fallow system was observed. Scattered fields have also been observed in other Sahelian villages (Graef & Haigis, 2001).

The total field acreage in Yomboli more than doubled from 1956 to 1991 (Fig. 3), which corresponded to the immediate expectations of common responses to population growth. More surprising was the reversed trend from 1991. The expansion of the fields stopped and total field acreage in 2010 was half of what it had been in 1991. In summary, three main waves of land cover changes were thus identified; (1) A period of land expansion lasting from 1956 to 1991; (2) Contraction of the field area during the period 1991–1995; (3) A decade of fluctuations occurring between 1995 and 2010.

Large scale driving forces during three waves of land cover changes

The main large scale driving forces in Yomboli during the three waves of land cover changes were explored by drawing on the notion of multiple exposures (Liechenko & O'Brien, 2010; Reenberg, 2009), more specifically, the changes in population pressure, globalization and climate variability.

Although no official demographic statistics were available at village level, population growth occurred throughout the period in the Sahel (Raynaut, 2001). Accordingly, it is reasonable to assume that this was also the case in Yomboli. In the first wave between 1956 and 1991, the rising population was, in fact, considered by villagers to be the main reason for the field expansion. Villagers emphasized that population growth meant increased household size as well as more households in Yomboli. The increased household size was mirrored in the land use pattern by the broadening of existing field boundaries (where possible) and cultivation of one or

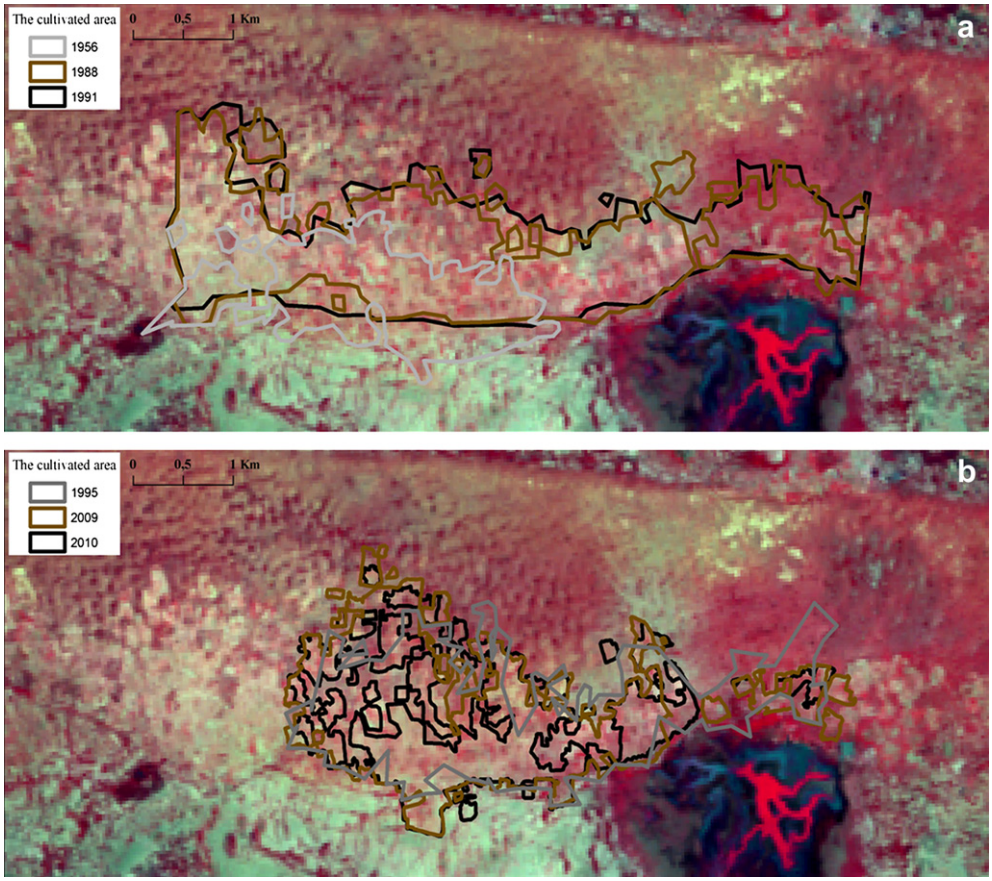

Fig. 2. Land cover pattern of Yomboli in 1956, 1988, 1991, 1995, 2009 and 2010. Field limits were mapped from aerial photos (1956), satellite images (1988 and 1991), and GPS measurements (1995, 2009 and 2010).

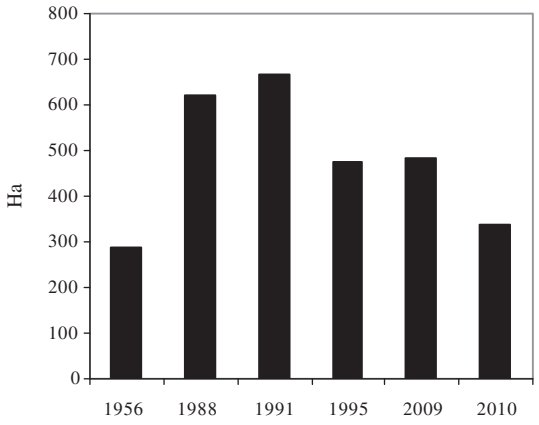

Fig. 3. The total field acreage in Yomboli in 1956, 1988, 1991, 1995, 2009 and 2010. The field limits were determined on the basis of interpretation of aerial photos (1956), SPOT satellite images (1988 and 1991) and GPS measurements (1995, 2009 and 2010).

more plots at different locations. The greater number of households implied field expansion on the dune as new households could only obtain access to land through the village chief, who allocated small dune plots, which were cleared and used for cultivation. During this first wave of land cover changes, the village of Yomboli was moved from the pediplain to the dune in order to reduce the distance to water resources. This happened around 1970. In 1990 the village was moved back to the pediplain as it occupied too much cultivable land on the dune. However, villagers reported an abundance of land in Yomboli throughout the period.

Whereas the rising population explained most of the field expansion seen between 1956 and 1991, this was not the case in the early 1990s as continued population growth was accompanied by a declining field area. The average field area per person declined from 0.58 ha in 1995 to 0.33 ha in 2010. Intensification would be a plausible explication for this decline but there was no evidence of significant yield increases or adaptation of new technologies. On the contrary, villagers reported declining yields. Although the harvest met only five months (on average) of the households' food requirements even in the rainiest years, villagers did not work the land more intensively by increasing the number of working hours per person or involving more people. In light of the substantial population growth in Yomboli, allocating more people per hectare would nevertheless have been a reasonable strategy. These observations implied that field acreage may not be as closely tied to population patterns as classical scholars once assumed. Instead, Yomboli seemed to be more influenced by the arrival of development projects and the construction of a cereal bank promoted by FAO in 1989, which provided villagers with millet on credit or at highly subsidized prices. Such economic changes were mediated by institutional factors and policies that were influenced by global factors (Lambin et al., 2003). Hence, these new drivers of change, which emerged during the second wave, can be associated with the exposure to globalization. This tendency is also observable in many other rural communities in the northern Sahel (Atampugre, 1997).

During the third wave of land use changes, villagers emphasized the increasing unpredictability of the rainy season. This was confirmed by a rainfall dataset from the meteorological station in Gorom-Gorom that showed greater inter-annual rainfall variability in the late 1990s and early 2000s, which is a general trend seen elsewhere in the Sahel (Proud & Rasmussen, 2010). Rainfall variability was thus a major concern in this third period. Moreover, population pressure was also a prominent driver of change. All households were recorded in 2010, and comparison with population enumeration done in 1995 by Reenberg et al. (1998) showed that Yomboli had had an annual population growth rate of 1.6% since then. It must, however, be emphasized that the collected data are two snapshots in time that tell us little about the dynamics in the intervening period. Finally, globalization acted as a driver as well, as villagers were e.g. highly concerned about varying millet and livestock prices. Out-migration to Abidjan was embraced by villagers, but it was not a response to scarce land resources as suggested by Bilsborrow and Geores (1994). On the contrary, villagers reported an abundance of land, and it was often stated that: "the dune is big enough for everybody".

It should, however, be noted that villagers reported low soil fertility. The land cover changes during this period can thus not only be ascribed to population pressure.

Shifting rationalities in Yomboli during three waves of land cover changes?

Table 2 outlines the main large scale driving forces and rationales which have underpinned villagers' land use decisions during the three identified waves of land cover change.

A period of field expansion: 1956–1991

It was apparent during the first wave of land cover changes that individual land use decisions were closely tied to large scale driving forces. Villagers' decisions were significantly propelled by population growth and the resulting bigger household size. Importantly, household size was mentioned as the major determinant of field size in all of the 32 semi-structured interviews. According to the villagers, the larger households implied increased food requirements as well as additional labour. With increased food requirements, villagers became highly focused on securing food production and avoiding dependency on market purchases. They clearly expressed that food security was their main objective when cultivating the fields. Despite the fact that food security is increasingly related to risk minimization in the scientific literature, no villagers thought of the period as a risky and uncertain time. Contrastingly, there had been a stimulus to increase production. This was very surprising as the period included major droughts in the 1970s and 1980s, but villagers simply did not expect the major droughts to hit after the relatively wet decades of the 1950s and 1960s. The respondents explained that they invested all their labour in the fields in order to optimize the millet production.

Moreover, economic rationality may also explain villagers' land use decisions. Villagers considered the marginal benefit of additional children. It was for example stated: "In that period more children meant more labour; we could cultivate large fields as we were not hungry and we had to fulfil the food requirements". Thus, villagers acquired additional land to make sure that child labour

Table 2
Land cover trends, individual rationales and aims and main large scale driving forces apparent in Yomboli during the period 1956–2010.

Period	Land cover trends	Individual rationalities	Individual cross-cutting objectives	Large scale driving forces
1956–1991	Expansion of field area	Economic	Optimization: Food security for humans	Population growth
1991–1995	Contraction of field area	Economic	Risk minimization: Food security for livestock	Population growth Globalization
1995–2010	Expansion and contraction of field area	Economic Sociocultural	Risk minimization: Food security for livestock	Population growth Globalization Climatic variability

was used as efficiently as possible. They did not enlarge their fields in order to manage risks.

A period of field contraction: 1991–1995

In the second wave, a cereal bank was constructed in Yomboli, which provided the villagers with cheap millet. As subsistence needs could be secured through the bank, fields were abandoned. The period was characterized by a declining field area, but no households gave up cereal cultivation altogether. They all maintained a small cultivated plot on the field. The practice of sustaining a small plot was not related to human food security; villagers wanted to ensure that they had some crop residues as feed for livestock during the dry season. These findings show that the aim of farming thereby moved beyond food security for the family. This shifting objective was expressed by the interviewees in three ways: (1) Cultivating many fields was hard work; it was not worth the effort when millet could be bought very cheaply; (2) Other sources of income became not just increasingly important, but also a necessity in this period; (3) Provision of fodder for livestock was a major concern as one never knew whether there was enough.

The earlier emphasis on fields as providers of millet grains for human consumption was replaced by the recognition that fields had a dual purpose: they also provided crop residues that could be used for livestock feed. The new perception of crop residues as the most important output and millet grains as a by-product cannot be explained in solely economic terms. If Nettings' (1993) argument that peasants do not impute wage costs to family labour is accepted, a rough comparison can be made between the economic value of 1 ha millet production and 1 ha crop residues without taking labour allocation into account. It should, however, be noted that villagers in fact gain both the value of millet grains and crop residues. Millet yields were in the order of 200–400 kg, which compares fairly well with values reported in the literature (Krogh, 1997) and by the agricultural extension office in Gorom-Gorom. As a 100 kg bag of millet was said to cost around 15,000–25,000 FCFA in the mid-1990s, the value of 1 ha millet is estimated to be 30,000–100,000 FCFA when the reported yield is taken into account. This value may then be compared with the price of crop residues from 1 ha, which ranged between 15,000 and 40,000 FCFA. The higher value of millet grains indicates that villagers' preference for crop residues might be better explained by the 'risk minimizing peasant model' than the 'optimizing peasant model'. The significance of risk minimization was also emphasized in the focus group interviews: with the severe livestock losses during the droughts in mind, a small cultivated plot with crop residues offered some security in a highly risky and uncertain environment for fodder resources.

Although risk minimization underpinned villagers' land use decisions, it did not influence their engagement in off-farm activities. The villagers explained that their previous dependency on cultivation had simply been replaced by a dependency on cash income. Thus, they did not pursue off-farm activities in order to become involved in activities with different risk profiles or because it was a less risky activity than cultivation. Instead, the argument seemed to be more closely related to the 'optimizing peasant' model as villagers explained that they migrated in order to gain 'something' and that it was more profitable than staying in the village. These findings are in conflict with the common image in the scientific literature of West African farmers who minimize risk by diversifying income through off-farm activities (see e.g. Mortimore & Adams, 2001; Scheffran, Marmer, & Sow, 2012).

As shown above, villagers' arguments for maintaining a small cultivated plot were anchored in risk minimization. In contrast, their arguments for the general tendency to abandon fields during the period indicated economic rationality – albeit of a different form than what was seen in the previous period. The previous considerations of marginal benefits of additional child labour were now replaced by a wish to lessen the workload during the growing season in order to maximize returns from labour investments later on. Surprisingly, many villagers did not relate the abandoning of fields to a "surplus" of labour that potentially could be used for other tasks during the growing season. Within their households the total number of labourers engaged in cultivation remained the same, but each individual worked fewer hours a day and less hard during each hour. According to the interviewees, the main reason for employing this strategy was that it gave them more energy to engage in other activities during the dry season and in agricultural activities the following year. Although the abandoning of fields indicates economic rationality, it can be questioned whether or not these land use decisions reflect the 'optimizing peasant'. One may argue that the 'optimizing peasant' would work during the whole year instead of preferring leisure over agricultural work in the growing season.

Finally, villagers also mentioned the field location with reference to economical rationality. Recultivation of the dune was explained by villagers as a strategy to ensure the best possible outcome from their labour input.

A period of field expansion and contraction: 1995–2010

During the third wave of land use changes, there was no tendency to either expand or contract fields. Contrastingly, villagers embraced different land use decisions from year to year. The questionnaire interviews revealed that in dry years, 49% of the respondents preferred to keep the field area constant, whilst 44% abandoned their fields (Table 3). The remaining 7% enlarged their fields. As opposed to dry years, the land use decisions appeared more uniform in rainy years as there was a clear tendency to enlarge fields (72% of the respondents).

Since some respondents maintained their field area and others abandoned fields in dry years, the main rationales of each group of respondents needed to be explored. The fraction of villagers who maintained their field area argued that they preferred to stay in Yomboli and postpone migration until after the harvest, as they usually did. But with insufficient rain they would cultivate less hard and thereby be able to 'build up energy for the approaching off-farm activities and next years' agricultural work. As in the previous period, these considerations about the maximization of returns later in the year mirrored economic rationality. However, the villagers also expressed that they prayed for more rain. By

Table 3
1995–2010 land use decisions vs. yearly rainfall conditions.

	Land use decisions	Fraction of villagers taking the decision	Rationalities	Cross-cutting rationalities
Dry years	Expansion	7%		
	Decrease	44%	Economic	Risk minimization: Food security for livestock
	No change	49%	Economic Sociocultural	Risk minimization: Food security for livestock
Rainy years	Expansion	72%	Sociocultural	Risk minimization: Food security for livestock
	Decrease	5%		
	No change	23%		

wishing to stay in Yomboli and cultivate the fields, they signalled a sense of hope and individuality to the other villagers, it was often explained. Thus, to some extent, the villagers responded passively to the changing rainfall conditions.

It may be argued that their focus on hope and individuality reflected sociocultural rationality.

When looking at the fraction of villagers who abandoned their fields, the main rationales at stake were slightly different. Respondents reported that insufficient rain in August would probably ruin the millet plants and it was therefore not worth the effort to continue the hard agricultural work. They could just as well abandon the fields and leave for labour migration before the harvest. These villagers also pieced together their decisions by incorporating thoughts on the economic feasibility of their actions. These arguments resembled the reasons for abandoning fields that were put forward in the second period of land use changes.

Turning to the rainy years, the tendency to expand field acreage was driven by reasons of prestige and may thus be associated with sociocultural rationality. A large well-cultivated field and more importantly, a big harvest showed superiority to neighbouring households, the villagers explained. Surprisingly, this was the sole argument mentioned for field enlargements. This finding runs contrary to common expectations of field expansion as a response to population pressure, low yields or as an individual decision taken to maximize profit. Importantly, villagers seemed more eager to emphasize the prestige and status they would gain if they were not forced to sell livestock in order to buy food. They were fully aware that this was probably not the most profitable labour investment, but as it enabled them to gain this prestige, it was the preferred strategy.

Similarly to the previous period and in dry as well as rainy years, all respondents emphasized the value of crop residues. Their argument for doing so was likewise the same: 'it is necessary in times with uncertain fodder conditions'. Accordingly, the risk minimizing peasant model most likely explains the maintenance of small cultivated fields, while the engagement in off-farm activities should instead be attributed to the optimizing peasant model.

It should, however, be noted that the division into dry year land use decisions and rainy year land use decisions became more blurred if the previous year had been very dry. This was for example seen in 2009 and 2010. As 2010 was a rainy year, agricultural expansion was expected to take place. But due to very dry conditions in 2009, many young men were forced to go on transhumance towards Mali and Niger in order to find pasture and water for the animals. The extremely dry conditions triggered lengthening of both routes and duration, and the men stayed away for longer and did not return until August–September the following year. Hence, there was a lack of labour in Yomboli in 2010, especially during the labour-intensive weeding. This constrained the possibilities of field enlargements despite the good rain. In addition, villagers emphasized that when the animals had been away for so long, fields were not properly supplied with manure and it was thus not worth the effort to cultivate. These conditions reflect a situation in which the influence from a single driver, a drought, has overruled the usual tendency to make individual land use decisions anchored in sociocultural rationality in rainy years.

Conclusion

The common views of Sahelian field expansion triggered by population growth fail to account for the rationales in villagers' land use decisions. This paper goes beyond that notion by suggesting a framework that takes the individual land use agent into account. Three waves of land cover changes were identified in Yomboli: field expansion between 1956 and 1991; field contraction from 1991 to 1995; and field expansion and contraction between 1995 and 2010. This provided a basis for an analysis of the links between large scale drivers, individual land use decisions and the resulting land cover changes, as well as an exploration of possible shifts in those links.

Four main conclusions can be derived from the empirical findings of this study:

1. Villagers' decisions on field size were not based solely on economic judgements of cost and benefit. On the contrary, land use decisions were anchored in two broad rationality categories: economic and sociocultural rationality. Surprisingly, ecological rationality was not prominent.
2. The influence from different rationalities has shifted during the three waves. Economic rationality underpinned individual land use decisions during the first two waves of land cover changes, but it was accompanied by sociocultural rationality in the third wave.
3. The aim of farming moved beyond food production during the second wave as fodder security for livestock overruled the importance of food security for humans. Villagers do not intensify crop production, and it has been shown that they minimize risk by maintaining a small field with crop residues. Contrastingly, the engagement in off-farm activities is not explained by risk minimization. The common image in the scientific literature of West African farmers who minimize risk by diversifying income through off-farm activities may thus be misleading.
4. The interplay between large scale driving forces, individual land use decisions and the resulting land cover changes has been altered. Earlier land cover changes were primarily propelled by the driver of population growth, whilst recent land cover changes seem to be more influenced by individual rationales than by large scale driving forces. For example, field expansion during the last decade was undertaken for individual reasons of prestige rather than influenced by population growth and globalization.

In light of the results obtained, this work calls for a refined focus on the reconciliation of large scale driving forces, individual land use decisions and the resulting land cover changes. The results show that by including the ultimate agents of land use change, the individuals, in the analysis, we may enhance our understanding of land cover changes in the Sahel. Acknowledging this must thus be a first step for researchers if Sahelian land cover changes are to be fully understood. Moreover, the results have some important policy implications. Possible interventions should recognize that during the last decade there has been a shift in the rationales that underpin villagers' land use decisions. Thus, field expansion as a strategy to enhance food security for humans must not unreservedly be assumed to be the most prominent characteristic of Sahelian villagers.

Acknowledgements

The field research was funded by a grant from the DANIDA-FFU, 09-001KU, and contributes to the ERC project Waterworlds. The study was part of the project: A region wide assessment of land system resilience and climate robustness in the agricultural frontline of Sahel (LASYRE). Detailed information on scientific coordination and funding is available on the LASYRE web site: http://www.lasyre.dk. We thank the villagers of Yomboli. Very helpful comments given by two anonymous reviewers are gratefully acknowledged.

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