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LOCAL PERCEPTIONS OF WOODY VEGETATION DYNAMICS IN THE CONTEXT OF A 'GREENING SAHEL': A CASE STUDY FROM BURKINA FASO

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ABSTRACT

After decades of drought in the Sahel, several studies have reported a '(re)greening' of the area. However, most of these studies were based on large scale climatological or remotely sensed observations, with little or no ground truthing. The aim of this study was to assess the local perceptions of the distribution of socio-economically important tree species in the Sub-Sahel of Burkina Faso. Semi-structured interviews were performed with 87 groups of informants from 20 villages belonging to three ethnic groups (Mossi, Fulani and Samo). Univariate and multivariate statistics were used to compare perceptions between the targeted ethnic groups. According to the locals, more than 80 per cent of the 90 listed species were declining, with over 40 per cent identified as threatened, including numerous plants of great economic value. Increasing species were mostly drought-tolerant plants such as *Balanites aegyptiaca*. A few species were listed as locally extinct. Gender and age did not significantly affect local knowledge, whereas ethnicity did. The major causes of species decline were identified to be drought, deforestation and bushfires. In all ethnic groups, informants observed a southward shift in species distribution. Local perceptions suggest a general decline in woody vegetation. Thus, the alleged (re)greening in the Sahel might not have reversed the degradation of woody species in the area. Data derived from local ecological knowledge were consistent with that of many ecological studies, suggesting the reliability of people's knowledge for obtaining ecological data. Information from this study can be used as baseline for conservation of species identified as threatened. Copyright © 2011 John Wiley & Sons, Ltd.

KEY WORDS: woody species; vegetation dynamics; Sub-Sahel; species shift; local ecological knowledge; 'greening'; remote sensing; Sahelisation; ANOSIM

INTRODUCTION

Because of severe droughts in the 1970s and 1980s, climatic and environmental change in the West African Sahel has attracted much scientific research (West *et al*., 2008). The last decade had been characterized by a controversial debate on the '(re)greening' of the West African Sahel, which is described as a possible reverse of the process of desertification in the area (Rasmussen *et al*., 2001; Olsson *et al*., 2005; Hein and De Ridder, 2006; Prince *et al*., 2007; Olsson and Hall-Beyer, 2008). Numerous studies, mostly based on remotely sensed data, have documented a recovery of the vegetation of the Sudano-Sahelian zone of Burkina Faso (Hountondji *et al*., 2006) and in other Sahelian areas in Africa (Anyamba and Tucker, 2005; Seaquist *et al*., 2008; Olsson *et al*., 2005; Hermann *et al*., 2005). The interpretation of this (re)greening pattern has caused much controversy in the scientific community, which remains unsettled.

Some scientists consider the re-greening as a recovery process of the vegetation from a long period of degradation, recovery that is thought to be correlated with an increase in rainfall (Rasmussen *et al*., 2001; Nicholson, 2005; Eklundh and Olsson, 2003). Another school of thought also acknowledged that rainfall played an important role, but considered changes in land use and land management practices in the Sahel to be the driving factors. Other important influences were identified as cultural issues, ownership of trees, forestry laws and economic opportunities (Reij *et al*., 2009). The latter observed that the (re)greening pattern was associated with a significant increase in tree abundance on private farms.

However, investigations of local ethnobotanical knowledge coupled with botanical investigations consistently indicated a decline, not a recovery, of woody vegetation in the West African Sahel and in Burkina Faso, resulting from both natural and anthropogenic factors (Lykke *et al*., 1999; Wezel and Haidis, 2001; Müller and Wittig, 2002; Kristensen and Balslev, 2003; Lykke *et al*., 2004; Wezel and Lykke, 2006; Ayantunde *et al*., 2008; Paré *et al*., 2010; Sop *et al*., 2010). These contradictory results raised concern over the credibility and the real meaning of the alleged (re)greening pattern and its impact on species diversity and plant abundance on ground. In regards to

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the recent 'greening' of the Sahel, the remotely sensed findings must be reconciled with evidence from local surveys (Giannini *et al*., 2008). Thus, a need to reinvestigate the distribution of native flora became apparent. We focused on the woody component of the vegetation because woody plants are present all through the year and are used as a food storage system, especially during the long dry season when herbs and food become scarce (Le Houérou, 1980; Lykke *et al*., 2004).

The perceptions people have about their environment, how they manipulate it and what factors influence these perceptions and interactions are central questions in ethnoecology (Gaoué and Ticktin, 2009). Local societies harbour important information on the dynamics of vegetation and valuable plant species, which is fundamental for adapting local management strategies aimed at the sustainable use and conservation of (semi)natural vegetation (Lykke, 2000). Local knowledge is widely acknowledged to be a valuable and reliable source of data on the historical distribution range of species, especially rare or endangered species, which are generally difficult to assess using classical ecological methods (Lykke *et al*., 2004). Assessing the perceptions of local people on the trends of woody vegetation in the Sub-Sahel could highlight changes that may have potentially affected the population of local plant species within the past few years. With the exception of Reij *et al*. (2005), there has been little attempt to relate the greening detected with remotely sensed observation to actual woody vegetation distribution. Few comparative studies exist on people's perceptions of vegetation dynamics in the Sahel zone of Burkina Faso. No research had exclusively focused on the Sub-Sahel, the transition zone between the Sahel *senso stricto* and the Sudanian phytogeographic area. Transition zones are known to be highly sensitive to environmental changes and thus make an interesting case study for assessing dynamics of woody species.

The aim of this study was threefold: (i) to compare the perceptions of three ethnic communities of the Sub-Sahel of Burkina Faso, on the dynamics of useful woody species; (ii) to identify the driving factors of vegetation change from the perspective of local people; and (iii) to assess the possible shift of species as well as the general direction of the shift within the region. In the context of the alleged greening of the Sahel, the results of this study should constitute a baseline for a sustainable management and conservation of the detected threatened species.

MATERIALS AND METHODS

Study Area

The study was conducted in 20 villages all located between 12°55′–14°N and 03°40′W–0°30′E (Figure 1). The villages visited were chosen on the basis of at least four criteria: (1) affiliation to one of a the targeted ethnic group; (2) accessibility by roads; (3) remote location with surrounding vegetation to allow the study; (4) population size of the village shall be large enough (several hundred) in order to allow interviews.

Phytogeographically, the area is known as the Sub-Sahelian sector, which makes the transition zone between the Sudanian zone and the Sahel *sensu stricto*. The relief is generally flat (mean altitude of ca. 350 m a.s.l.) with large peneplains disrupted by numerous inselbergs and shallow depressions. The soils are dominantly tropical ferruginous soils and poorly evolved eroded soils overlying gravels with a low water retention capacity.

The climate is typically Sahelian, with a long dry spell from October to May and a rainy season from June to September. Mean annual precipitation ranges from 500 to 650 mm for the last 30 years (1979–2008), with a slight gradient, increasing from East (Fulani) to West (Samo).

The natural vegetation is sparse and varies from grassy or shrubby steppes to shrubby or woody savannas. Small islands of degraded riparian forest are present along temporal rivers that straddle the Sub-Sahelian band during the rainy season. Agroforestry parklands, which consist of selected and protected trees on agricultural lands, remains the dominant vegetation type in the area and is revealing on the extent of human impact on shaping the existing ecosystems.

The study area is inhabited by four ethnic groups; the Mossi, Fulani, Samo and Gourmantché. The latter were not included in this study because they were underrepresented in the study area. The Mossi represent more than 50 per cent of the total population of Burkina Faso and possess one of the most ancient African kingdoms in West Africa. Their main production system consists of crop agriculture with cereals. The Fulani make up less than 10 per cent of the total population and occupy the Eastern part of the study area (Figure 1). This group is renowned for being a nomadic people, practicing extensive livestock farming. However, the Fulani are increasingly adopting a sedentary way of life by settling in permanent or semi-permanent villages where they combine livestock rearing with subsistence agriculture.

The Samo are a small group that occupies the western part of the study area. Their main production system is historically subsistence agriculture and small-scale gardening and more recently animal husbandry. Bushfires are a very common management practice among the Samo People to clear farmlands and savannas before and after the rainy season.

Ethnobotanical Survey

A total of 87 groups of informants from 20 villages were interviewed (59 groups of men and 28 groups of women)

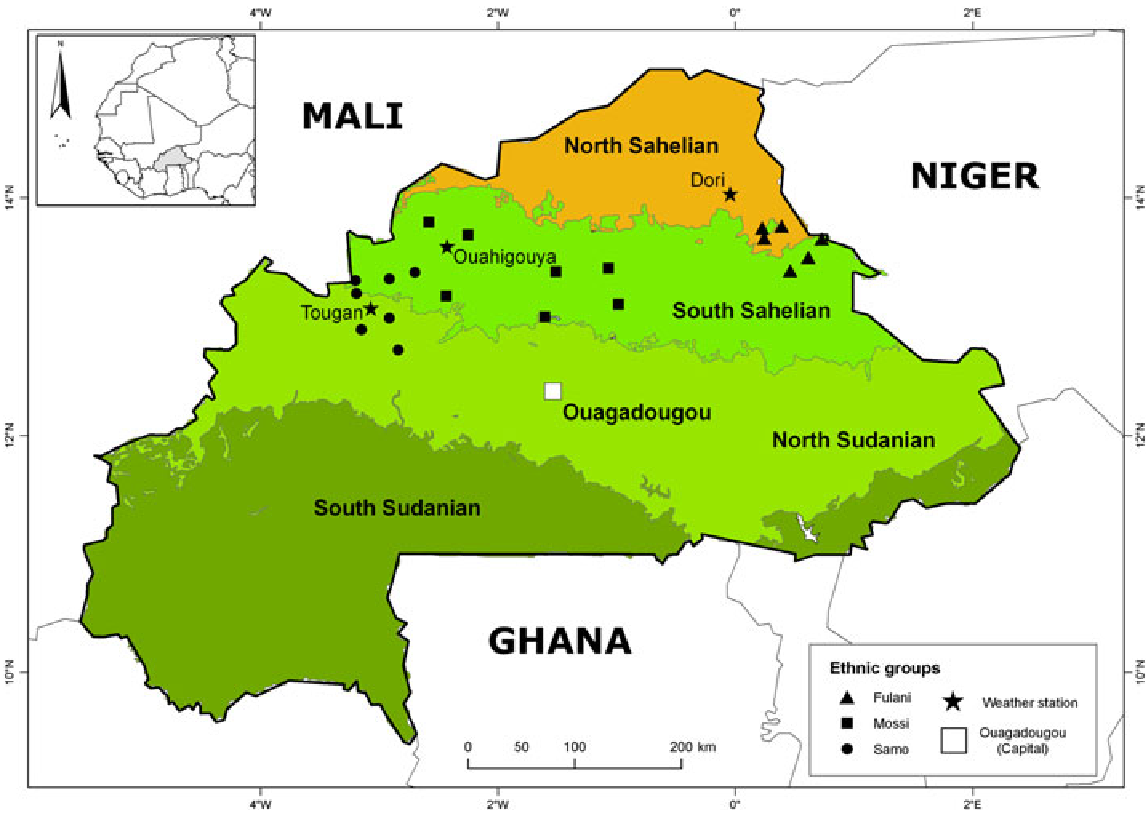

Figure 1. Vegetation map of Burkina Faso (Fontes and Guinko, 1995) illustrating the position of the sampled villages. Different colours indicate the main vegetation zones. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr

using semi-structured interviews. We used the method of 'multiple-use curve' (Balick and O'Brien, 2004; Gouwakinnou *et al*., 2011), which is inspired from the concept of 'species-area curve' (used in ecological studies), in order to detect the minimal number of groups of informants per village, which would be necessary to capture the highest number of woody species known with lowest effort. The asymptote represents the approximate maximum number of species that can be found in an area.

The number of villages surveyed per ethnic group was six for the Fulani, seven for the Mossi and seven for the Samo (Figure 1). Three to five groups of informants, each including three to 15 people, were interviewed in each village. Prior to the interviews, the leaders of the selected villages were consulted, the objectives of the study explained and permission for interviewing villagers granted. In each village, participants were selected with the help of the local delegate that introduced us to the local people. The names of all the volunteers were then recorded, and the first author organized the groups of respondents taking into consideration factors such as gender, age and occupation. An attempt was made to sample an equal number of male and female participants; however, this was often not possible because of a certain conservatism that still rules most of the traditional societies in the Sahel. Respondents to the questionnaires were all adults over 25 years of age.

All interviews were conducted by the first author, in the informant's local languages (Fufuldé, Mooré or San) with the assistance of translators, and lasted between 1 and 2 h. The interviews were moderated to ensure that all the members of a group could equally express their opinion to avoid a bias towards more expressive people, generally inevitable in group situations (Pilgrim 2006). In some rare cases, voting was used to reach agreement. The interviews took place between October and November in 2008 and 2009.

Each group of informants was asked to list all woody plants used as well as their estimated abundances (the following scale was scheduled: 0, locally extinct; 1, very low abundance (rare); 2, low abundance; 3, moderate, 4, common). For each species mentioned, informants were requested to give their perception of its dynamics over the past decades, whether increasing, decreasing or stable (neither increasing nor declining), threatened or disappeared. People were also requested to rank the factors driving the observed changes (drought, deforestation, ageing (senescence) and lack of regeneration, bushfires and other anthropogenic impacts).

A voucher specimen of all plants reported by the informants was collected and identified. The names of the collected specimen were validated and confirmed at the Herbarium of the University of Ouagadougou (OUA). The nomenclature of Arbonnier (2004) and Lebrun *et al*. (1991) was followed. The Latin names of plants were cross-checked using the International Plant Names Index database (IPNI, The International Plant Names Index, 2011). Species that could not be found in the field or species that were reported as 'disappeared' or rare were identified from their local names, using literature (Von Maydell, 1983).

Data Preparation

Data analysis followed the informant consensus model (Martin, 1995), that is, examining the degree of agreement between informants. The importance of each category (increasing, stable, decreasing, disappearing and threatened) was computed as the total number of reports mentioned by informants in that category. Only information mentioned by at least 20 per cent of informants was considered for the analysis. The perception of each ethnic group, gender and age category was computed as the total number of reports mentioned in that category.

Statistical Analysis

Impact of gender, age and ethnicity on the perception of vegetation change

The data were transformed to an informant by category matrix from which the number of species cited by each group of informants in all the perception categories was computed (increasing, declining, stable, threatened and disappeared). To assess differences in local perception of the dynamics of woody species on the basis of age (<50 and >50 years), gender (male and female) and ethnic group (Fulani, Mossi, Samo), we compared the reported number of species in each perception category. To assess differences on the basis of age and gender, we used the Mann–Whitney *U*-test. Comparisons among ethnic groups on documented species were carried out using the non-parametric Kruskal–Wallis test combined with post hoc Mann–Whitney pairwise comparisons with a sequential Bonferroni correction for multiple tests (Quinn and Keough, 2002). The significance level was set at *a priori* to $p = 0{\cdot}05$. All analysis were carried out using the free statistical software PAST v. 2·07 (Hammer & Harper, Oslo, Norway) (Hammer *et al*., 2001).

Perception differences among ethnic groups

To test for overall differences in local perception of woody species dynamics between ethnic groups, we analyzed all the five perception categories for each ethnic group together using a one-way analysis of similarity (ANOSIM) (Clarke, 1993) with Euclidean distances using PAST v. 2·07, on the basis of 9999 permutations (Hammer *et al*., 2001). ANOSIM is a non-parametric multivariate comparison of within-group and between-group variances for groups defined *a priori*. It outputs a global test statistic, *R*, which ranges from -1 to 1 with values close to zero indicating no differences between groups. *R*-values below 0·25 indicate no separation, *R*-values ranging from 0·25 up to 0·5 indicate some separation despite some overlap, *R*-values $>0{\cdot}75$ indicate that the groups are well separated and $R = 1$ indicates total separation of groups (Clarke, 1993). A principal coordinate analysis (PCO) with Euclidean distance was applied to visualize the dissimilarities between the ethnic groups in a Cartesian ordination space.

RESULTS AND DISCUSSION

Local Perceptions of Woody Vegetation Change

For the entire study area, a total of 90 multipurpose woody plant species, from 32 families, were listed by informants of the three ethnic groups (Appendix 1). Recorded species were used for food, medicine, fodder, energy, construction and handcraft by the locals. However, only species listed with a minimum frequency of 20 per cent were considered in the analysis in order to exclude species mentioned by only few respondents and thus might be arbitrary (Wezel and Lykke, 2006). The main drawback in doing this is that rare species, known only by a reduced number of informants, might be overlooked. However, previous studies have shown that there is generally a strong informant consensus on species that are relevant for the community. The Fulani listed 46 species, the Mossi 58 and the Samo 62.

Estimated species abundance

More than 70 per cent of the species listed by respondents of all ethnic groups were classified as having a very low and low abundance, whereas less than 10 per cent were classified as 'common' (Figure 2). This is consistent with the high percentages of species listed as declining and threatened and confirms the degree of degradation of woody resources in the Sub-Sahel. Most of the species mentioned as increasing or stable such as *Balanites aegyptiaca*, *Acacia seyal*, *Moringa oleifera*, *Acacia nilotica*, *Eucalyptus camadulensis* and so on had the highest estimated abundance (Appendix 1). There was a relatively high degree of corroboration in species abundance among ethnic groups. The few differences can possibly be explained by variation in local environments and varying degrees of degradation (Lykke *et al*., 2004). In general, perception of species abundance by local people matched the botanical investigations (Sop, unpublished data).

Declining and threatened species

In all three ethnic groups, more than 90 per cent of species were reported to be in a state of decline: 95 per cent by the

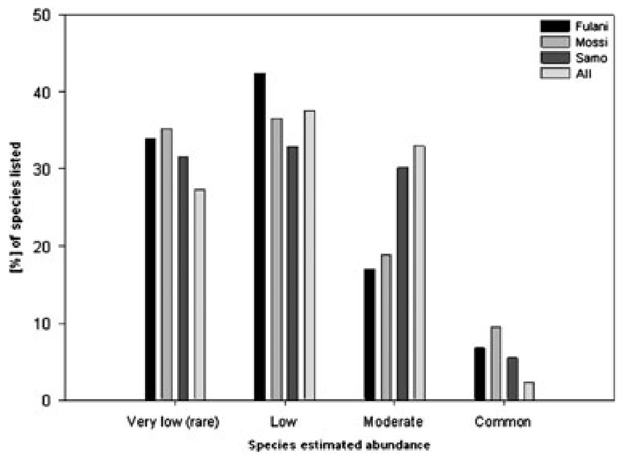

Figure 2. Perception of the relative abundances of woody species by the Fulani, Mossi and Samo ethnic groups in the Sub-Sahel of Burkina Faso.

Fulani, 95 per cent by the Mossi and 93 per cent by the Samo (Figure 3). Most of these species are plants that are intensively harvested for food and construction purposes: *Tamarindus indica*, *Adansonia digitata*, *Mitragyna inermis*, *Pterocarpus lucens*, *Anogeissus leiocarpus*, *Boscia senegalensis*, *Diospyros mespiliformis*, *Parkia biglobosa*, *Vitellaria paradoxa*, *Bombax costatum*, *Combretum micranthum* and *Sclerocarya birrea* (Appendix 2a). The majority of these species are typical parkland species that are generally conserved on new farmlands for their inherent value. Nearly all species in a state of decline were consistently listed by all ethnic groups, indicating that the pattern is similar to the whole Sub-Sahel phytogeographical area.

More than 40 per cent of all reported species were believed to be threatened (Figure 3). Regardless of ethnicity, species perceived to be most threatened were *A. digitata*, *P. lucens*, *A. leiocarpus*, *B. senegalensis*, *M. inermis* and *B. costatum*.

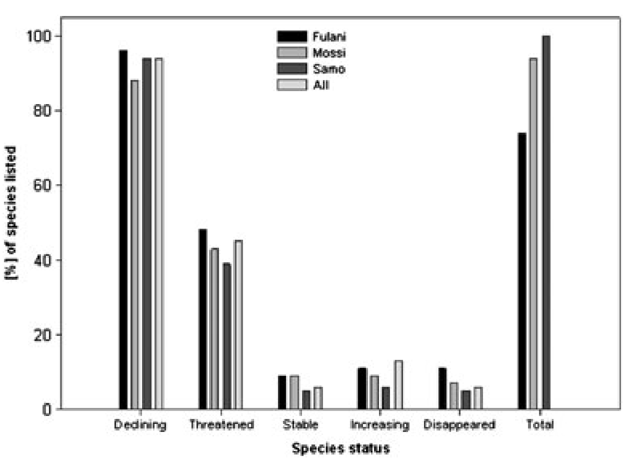

Figure 3. Perception of woody vegetation changes of the Fulani, Mossi and Samo ethnic groups in Burkina Faso. The category ‘total species’ is the total percentage of species listed by each ethnic group.

Taking ethnicity into account, the same species were generally reported, but in a different order. The Fulani listed *B. senegalensis*, *M. inermis*, *P. lucens*, *V. paradoxa* and *Ximenia americana*, whereas the Mossi mentioned *A. leiocarpus*, *T. indica*, *A. digitata*, *P. lucens* and *B. costatum*. The Samo identified *B. senegalensis*, *M. inermis*, *Securidaca longepedunculata*, *A. digitata* and *Pterocarpus erinaceus* as the most threatened (Appendix 2b).

Most species perceived to be declining and threatened include parkland species such as *P. biglobosa*, *A. digitata*, *T. indica* and *B. costatum*. These plants are among the most relevant of Burkina Faso for their importance in supplying local people with food, income and ecosystems services such as soil fertilization, shade and erosion control (Teklehaimanot, 2004; Nikiema, 2005). Many of these species have aging populations and are facing regeneration problems. Other species perceived to be declining and threatened, such as *A. leiocarpus*, *M. inermis* and *D. mespiliformis*, are mostly found in depressions and valleys, or on rivers banks, which are habitats that have been heavily transformed by agriculture in the Sahelian area.

Increasing and stable species

Although more than 90 per cent of species were listed as declining by all ethnic groups, only 13 per cent of woody plants in the entire study area (11 per cent by the Fulani, 9 per cent by the Mossi and 6 per cent by the Samo) were perceived to have increased (Figure 3). The Fulani and Mossi ethnic groups identified the following species: *B. aegyptiaca*, *A. nilotica*, *Faidherbia albida*, *A. seyal* and *Piliostigma reticulatum*. On the other hand, the Samo group listed *Lannea microcarpa*, *A. seyal*, *V. paradoxa* and *P. reticulatum* (Appendix 2c).

Lannea microcarpa and *V. paradoxa* were identified to be increasing only in the Samo villages. This is certainly the result of local environmental conditions and land management practices within the Samo area. Seedlings of *L. microcarpa* and *V. paradoxa* were observed to be abundant in the fallows and anti-erosion bunds after the rainy season. However, many seedlings were destroyed at the beginning of the dry season by bushfires, a common traditional land management practice among the Samo. Other species with increasing abundances (*B. aegyptiaca*, *P. reticulatum*, *A. seyal*, *A. nilotica* and *F. albida*) are those that are drought resistant and well adapted to the semi-arid environment of the Sahel. Other studies have also identified these species to be increasing in abundance in the Sahelian area of Niger (Wezel and Haigis, 2000). *B. aegyptiaca*, in particular, is native to the semi-arid areas of West Africa and is regularly cited among the increasing species in the West African Sahel (Müller and Wittig, 2002; Lykke *et al.*, 2004; Vincke *et al.*, 2010). It has the potential of resprouting after cutting and is able to reproduce vegetatively through sucker roots. It often drives bush encroachment, resulting in dense stands on impoverished plains. *B. aegyptiaca* has been identified as an indicator of degradation (Arbonnier, 2004), so its widespread distribution throughout the Sub-Sahel may be an indication of increasing land degradation in the region. The size class distributions (SCDs) of *B. aegyptiaca* and *A. seyal* were examined across the Sub-Sahelian area, and their populations were found to have stable distributions with a good rejuvenation (Sop *et al*., 2010). This underlines the reliability of the local ecological knowledge of local people, expressed through their accurate perceptions of vegetation changes.

Less than 10 per cent of the species were reported to be stable, that is, not increasing or decreasing in abundance (Figure 3). The following species were identified as stable: *Azadirachta indica*, *C. micranthum*, *A. seyal* and *Ziziphus mauritiana*. The pattern differed somewhat among ethnic groups. Fulani respondents listed *A. indica*, *E. camadulensis*, *A. seyal* and *A. digitata*. The Mossi listed *A. indica*, *C. micranthum*, *Acacia macrostachya*, *A. seyal* and *Guiera senegalensis*. The Samo listed *M. oleifera*, *Z. mauritiana* and *B. aegyptiaca* (Appendix 2d). Some of these species, such as *A. indica*, *E. camadulensis* and *M. oleifera*, are exotic, fast-growing species that have been fully domesticated. These species are abundantly used in agroforestry for food, fuel, construction and medicinal purposes. *A. indica*, a drought-tolerant species native to India, is planted near compounds for wood and shade. *E. camadulensis*, native to Australia, is mainly planted for construction material and firewood. *M. oleifera* originates from India and is widely grown in gardens for food and medicinal purposes. Other species such as *C. micranthum* is well adapted for regenerating through coppicing, whereas *G. senegalensis*, *A. macrostachya*, *A. seyal* and *Z. mauritiana* are species well adapted to the semi-arid conditions of the Sahel.

Locally extinct (disappeared) species

Across the entire study area, *B. senegalensis*, *P. biglobosa*, *X. americana* and *S. longepedunculata* were considered to be locally extinct. The Fulani listed *V. paradoxa* and *B. costatum*. *P. biglobosa*, *X. americana*, *B. senegalensis* and *B. costatum* were reported by the Mossi whereas *B. senegalensis* and *S. longepedunculata* were identified by the Samo (Appendix 2e).

The species listed as disappeared do not reflect the reality of the greater study area, because all species were found during botanical investigations (Sop, unpublished data). However, most of the species listed as locally extinct, were very rare in the field or had started receding towards the south. Most notably, *S. longepedunculata*, which has disappeared in most of the areas of the Sub-Sahel, exhibits this trend. Its roots are prized by traditional healers for their medicinal properties and their alleged magico-spiritual potential. *B. senegalensis* is valued for food especially during periods of famine, when the seeds are used to replace lacking cereals. Few individuals could still be found on sandy soils in remote savannas across the study area. This small bushy shrub is also facing high mortality as a result of drought and grazing pressure. *V. paradoxa* was very rare in the Fulani area, potentially because of drier conditions in this area.

Impact of Gender, Age and Ethnicity on the Perception of Vegetation Dynamics

Across all ethnic groups, there appeared to be no gender differentiation in people's perceptions of vegetation change (Table 1). Other studies have observed similar trends in the

Table I. Comparison of the perception of the dynamics of woody plant species (±standard error) among the Fulani, Mossi and Samo ethnic groups in the Sub-Sahel region of Burkina Faso

Factor		*n*	Perception category				
			Declining	Increasing	Disappeared	Stable	Threatened
Gender	Female	30	34·13 ± 1·59	2·30 ± 0.25	2·33 ± 0.27	2·4 ± 0.38	13·66 ± 0.79
	Male	57	36·17 ± 1·24	2·36 ± 0.18	2·68 ± 0.20	2·40 ± 0.26	14·17 ± 0.43
	U		740	854	742·5	847·5	773·5
	z		0.01	0.004	1·02	0.006	0.72
	p-value		0.31	0.99	0·3	0.94	0.46
Age	<50 years	43	31·34 ± 1·08	2·43 ± 0·19	2·52 ± 0·23	2·38 ± 0·33	13.51 ± 0·48
	>50 years	44	39·69 ± 1·39	2·25 ± 0·22	2·60 ± 0·23	2·41 ± 0·27	14·71 ± 0·59
	U		422	876	908	885	762
	z		4·49	0.60	0.32	0.52	1.27
	p-value		<0.001	0.54	0.75	0.60	0.19
Ethnicity	Fulani	26	28·53 ± 1·38a	2·61 ± 0.20a	3·20 ± 0·26a	1·46 ± 0.26a	14·92 ± 0.56a
	Mossi	29	35·41 ± 1·64b	2·89 ± 0.26a	2·79 ± 0·28a	4·03 ± 0.39b	13·48 ± 0.61a
	Samo	32	41·15 ± 1.24c	1·62 ± 0.23b	1·93 ± 0.26b	1·65 ± 0.27a	13·71 ± 0.80a
	p-value		<0.001	<0.001	<0.01	<0.001	0.12

People's perception was measured by the number of species listed for each of the different ecological status categories. Values bearing different letters are significantly different ($p < 0.05$).

North Sahelian area (Lykke *et al*., 2004). Gender is known to be one of the social factors likely to affect the distribution of knowledge of plant use. This is often a result of the unequal distribution of duties among men and women observed in most traditional societies. That gender did not affect people’s perceptions may be an indication that changes affecting woody vegetation in the area are apparent to everyone, regardless of gender. This may also explain why age was not found to impact people’s opinions on vegetation dynamics. However, in the case of species in decline, older people appeared to be more knowledgeable (Table 1). People over the age of 50 years listed more species than people under the age of 50 years. A hypothesis could be that those who grew up in the 1950s and 1960s (i.e. people above 50) might have seen much more declining species than those who grew up in the 1970s and 1980s. This is not surprising because in most rural communities of the West African Sahel, local ecological knowledge has been shown to be positively correlated with age (Ayantunde *et al*., 2008). However, there is also the possibility that the two age categories were not sufficient to capture variation in knowledge with age. On the other hand, the strong perception consensus among informants demonstrates that local people are all aware of the changes affecting vegetation dynamics in their environment. The high degree of agreement among informants of all ethnic groups reinforces the assumption that the patterns of change affecting woody vegetation are common to the entire Sub-Sahelian area.

With the exception of the species listed as threatened, ethnicity significantly affected people’s perceptions of the ecological status of different species. This variation can possibly be explained by the differences in local environmental conditions experienced in each of the three ethnic territories. For example, the Samo perceived *V. paradoxa* to be increasing in abundance whereas the Fulani considered it to be locally extinct. In this case, the difference in perception of the dynamics of this species (and its abundance) is plausibly the result of the drier conditions experienced in the Fulani territory.

Overall Difference in Perception of Vegetations Dynamics among Ethnic Groups

Results of multivariate test globally showed no separation between the ethnic groups (global $R = 0{\cdot}20$; $p < 0{\cdot}001$). PCO effectively depicted an overall overlap of all three ethnic groups, indicating strong similarities in the general perceptions of vegetation dynamics (Figure 4(a)).

Ethnicity is one of the most likely factors to influence local ecological knowledge and plant use (Ayantunde, 2008; Sop *et al*., submitted). However, no dissimilarity in the perceptions of vegetation dynamics and cause of vegetation decline was found between the targeted ethnic groups in Burkina Faso. This may be an indication that the dynamics of woody plants as well as the driving factors is relatively homogenous across the Sub-Sahel, as evidenced by the similarity of the species mentioned by the informants in the defined categories (declining, increasing, threatened, etc.). This is similar to the results of another study that found that plant species dynamics in the Sub-Sahel were unlikely to be governed primarily by ethnic or cultural settings but rather by regional patterns including anthropogenic causes, climate and soil factors (Sop *et al*., 2010).

Species Shift

Over 60 per cent of all informants reported a generalized shift of species from the north to the south over time. Fewer than 10 per cent noticed a shift towards the north, and 30 per cent were not sure whether/how the shift was taking place (Figure 5). Ethnicity did not have a significant impact on perceptions of species shift.

The reported species shift is consistent with the findings of Sidibé (2004) who reported a swing of the isohyets 100 to 250 km southwards in the Sahel. Wittig *et al*. (2007) later described a ‘Sahelisation’ of the North-Sudanian ecosystems of Burkina Faso, characterized by a spread of several Sahelian species in the Sudanian zone, as a consequence of a latitudinal shift of isohyets in a southerly direction. In addition, this results in the withdrawal of other Sahelo-Sudanian species from the Sub-Sahelian area. In the context of predicted climate change scenarios for the next two decades in the Sahel, the region will face reduced rainfall and increased temperatures (Kandji *et al*., 2006). It is then to be feared that more key species will abandon the Sub-Sahelian band towards the South and will further threaten the livelihood of the local population, which is expected to double in the coming years.

Cause of Vegetation Change

More than 60 per cent of the informants in all ethnic groups listed the major cause of vegetation change to be drought. The relative importance of other factors varied among ethnic groups. The Fulani believed population aging and deforestation to be secondary factors. For the Mossi, deforestation was the second leading cause. The Samo informants rated bushfires to be the most important factor, after drought (40 per cent) (Figure 6).

The multivariate analysis of the cause of decline, using one-way ANOSIM, showed a significant but weak separation between the ethnic groups (global $R = 0{\cdot}31$; $p < 0{\cdot}001$). However, the post hoc tests showed that the Mossi and the Samo ($R = 0{\cdot}46$; $p < 0{\cdot}001$) as well as the Fulani and the Samo ($R = 0{\cdot}44$, $p < 0{\cdot}001$) were separated despite some overlapping. There was no separation between the Mossi and the Fulani ($R = 0$; $p > 0{\cdot}05$). The visualization of the three ethnic groups on the PCO diagram (Figure 4(b))

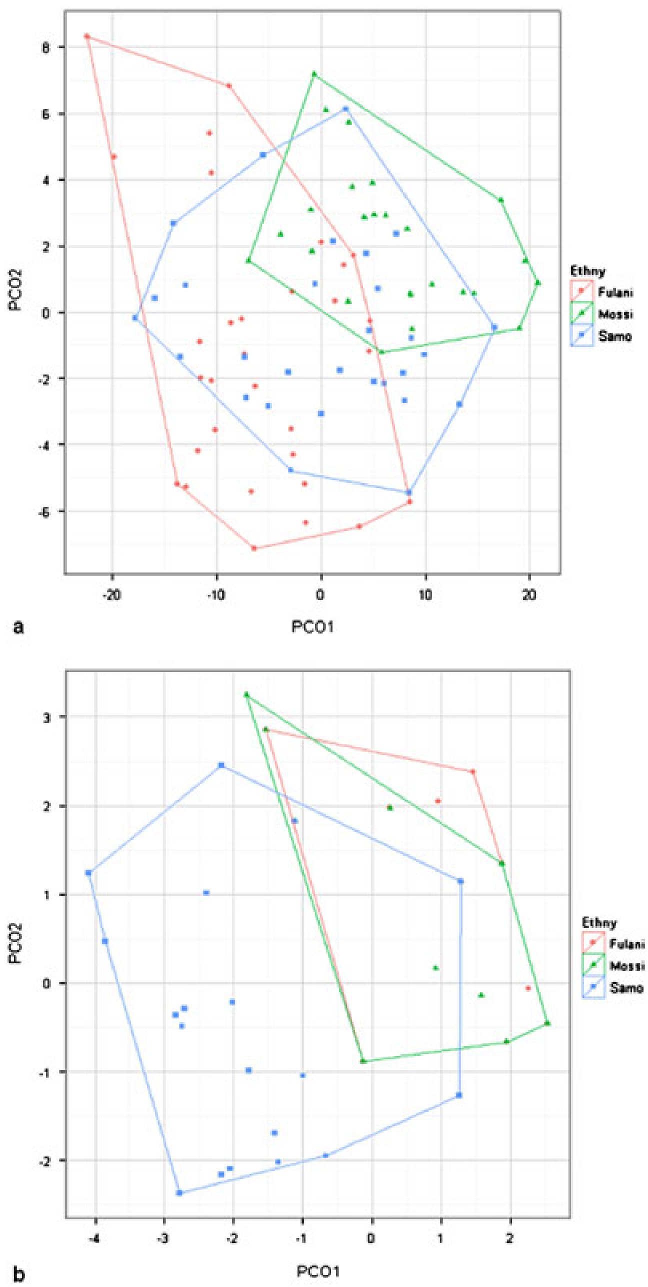

Figure 4. (a) Principal coordinates ordination (PCO), showing a high degree of overlap, for the number of species listed by all informants in the three ethnic groups ($n = 87$). The first and second axes of the PCO are displayed. Eigenvalue axis 1 = 81 per cent; eigenvalue axis 2 = 10 per cent. (b) PCO of the cause woody vegetation decline in relation to the number of informants. The Samo group is relatively good separated from the Fulani and Mossi. Eigenvalue axis 1 = 49 per cent; eigenvalue axis 2 = 24 per cent. This figure is available in colour online at wileyonlinelibrary.com/journal/ldr

further confirmed that the Fulani and the Mossi shared similar perceptions of the driving factors of vegetation dynamics.

Although an increase in rainfall in the West African Sahel has been recorded over the last decade (Hountondji *et al*., 2006; Hermann *et al*., 2005; Olsson and Hall-Beyer, 2008), drought is still considered, by local populations, to be the major cause of vegetation decline. This is consistent with results of West *et al*. (2008) and Mahamane and Mahamane (2005) on the Central Plateau of Burkina Faso and in a semi-arid area of Niger, respectively. It is argued that the alleged re-(re)greening of the Sahel is correlated with an increase of rainfall in the area, making rainfall the dominant factor driving vegetation dynamics (Hermann *et al*., 2005). Unlike in the Sahel, deforestation, bushfires and other anthropogenic factors such as extensive agriculture were perceived to be the key factors driving vegetation change in the Sudanian zone of Burkina Faso (Wittig *et al*., 2007; Paré *et al*., 2010). The results of these independent studies appear to indicate that the perceptions of local people are closely linked to what is occurring in reality,

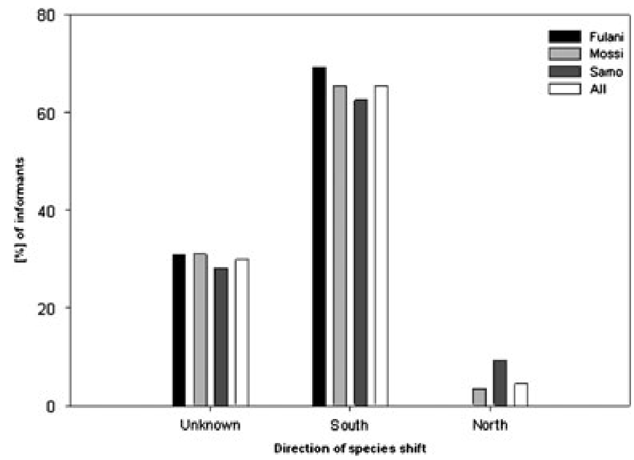

Figure 5. Perception of the shift in species distribution among the Fulani, Mossi and Samo ethnic groups in Burkina Faso.

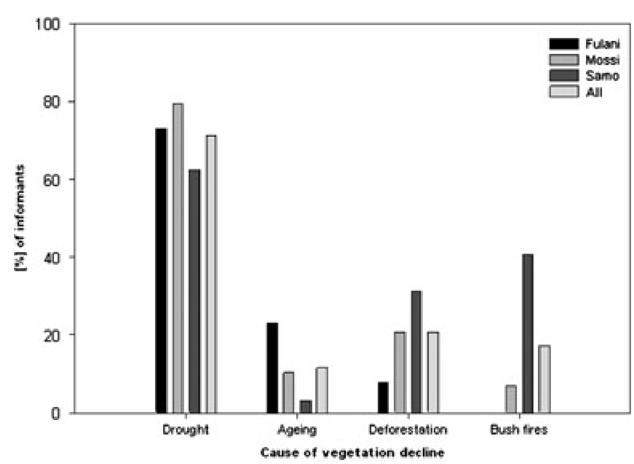

Figure 6. The perceived main drivers of vegetation change reported by the informants of three ethnic groups in the Sub-Sahel of Burkina Faso. Fulani ($n = 26$); Mossi ($n = 29$); Samo ($n = 32$).

although Reij *et al*. (2009) argued for Maradi and Zinder (400–600 mm rainfall) in Niger that human management is a more determining factor for re-greening than rainfall. The Sudanian savannas are more densely vegetated than the Sahelian ecosystems as a result of higher rainfall. The importance of bushfires mentioned by the Samo can be explained by the fact that Samo territory harbours dense savannas because of its proximity to the North-Sudanian area where bushfires are far more frequent. In addition, bushfires form an important part of management practices in these savanna ecosystems (Sawadogo *et al*., 2002).

Vegetation Dynamics in the Context of a Greening Sahel

Evidence from the literature indicates a (re)greening of the Sahel in Burkina Faso (Hountondji *et al*., 2006) and of the West African Sahel (Olsson *et al*., 2005; Olsson and Hall-Beyer, 2008). This has been suggested to be a result of the recovery from the Sahelian droughts of the 1970s and 1980s (Eklundh and Olsson, 2003; Olsson *et al*., 2005; Hermann *et al*., 2005). In this study, more than 80 per cent of the species identified by informants were considered to be declining, and more than a third of the species listed were declared to be endangered. This suggests that the degradation of woody vegetation is not a localized problem, but is widespread across the Sub-Sahelian area. Some species such as *B. aegyptiaca* and *A. seyal* have been recorded to be increasing in abundance. However, the general perception appears to be that most species are in decline. Similar trends have been found in the North Sahelian and Sahelo-Sudanian zones of Burkina Faso, as well as in the West African Sahel (Lykke *et al*., 2004; Wittig *et al*., 2007; Lykke, 2000; Wezel and Lykke, 2006; Ayantunde *et al*., 2008; Vincke *et al*., 2010). Perceptions of the local people suggest that the woody vegetation is not in fact recovering and that if such (re)greening process exists in the Sahel, it might be rather a marginal phenomenon. Sop *et al*. (2010) documented that some woody species, such as *A. seyal*, were locally and quite spontaneously forming extensive stands in valleys and on the alluvial plains of the Sub-Sahel. This phenomenon may locally be producing a signal seeming to indicate a (re)greening process at local scale whereas in fact, vegetation recovery across the Sub-Sahel remains marginal at best. The research of Reij *et al*. (2005) on the northern part of the Central Plateau of Burkina Faso and that of Reij *et al*. (2009) in neighbouring Niger found that re-greening occurs under specific conditions as they observed more trees and higher woody species diversity on rehabilitated degraded land than on adjacent cultivated non-treated fields. These findings suggest that, where it occurs, the (re)greening is likely to be a human-driven process. On the contrary, other scholars (Hermann *et al*., 2005) support that the improvement of rainfall may be the driving factor behind the (re)greening in the Sahel. On the other hand, the aggravation of land degradation in the Sahel has even led some scientist to argue that a '(de)greening' process rather than a (re)greening is occurring in the Sahel (UNCCD, 2010). As argued by Reij *et al*. (2009), based on their case study in Niger, it is most likely that both situations of (re)greening and (de)greening do occur in the Sub-Sahel of Burkina Faso, depending on the scale considered. But the extent of species mentioned by the respondents as declining and threatened is an indication that the (de)greening might be the dominant process. However, before drawing a definitive conclusion, it is recommended that further studies be carried out. Future research should combine local knowledge, botanical investigations, historical data and remote sensing with a high spatial, temporal and spectral resolution. This would be necessary to accurately assess the relationship between the remotely observed increase of biomass production in the Sahel and what is actually happening on the ground.

CONCLUSIONS AND CONSERVATION IMPLICATIONS

This study has shown that the local people of the Sub-Sahelian area are well aware of the ecological status of the woody vegetation, as well as the potential driving factors influencing plant dynamics. Our results provide a baseline for the development of local conservation and management strategies for key species that have been mentioned as threatened. Most species were reported to be in a state of decline, suggesting further degradation of woody resources and not a recovery of woody vegetation as suggested by recent remote sensing studies.

As a large majority of the population relies on woody plants for food, continuous degradation of woody resources may have major economic consequences. This may include migrations of populations and ecological impacts such as soil degradation. It would be unrealistic to claim that conservation efforts should focus on any single species. In such situations, where a large number of species are declining, it has been suggested that conservation efforts should rather focus on an entire ecosystem or habitat (Lykke *et al*., 2004). Furthermore, many vulnerable species are still wild, with inherently slow regeneration. Efforts should perhaps be focused on domestication of key species to improve regeneration and enhance production.

This study demonstrates the reliability of local ecological knowledge for assessing vegetation dynamics and environmental change over time. The increase in abundance of *B. aegyptiaca* and *A. seyal*, reported by the locals, corroborate previous findings, which also reported stable populations. These studies used more conventional methods of SCD. A Southward shift of species was independently perceived by local people, supporting the concept of the Sahelisation of the Sudanian Zone (Wittig *et al*., 2007). It is concluded that the integration of local people's perceptions and priorities into policy making is of crucial importance in woody resources management and for sustainable conservation strategies. Lastly, the consistency of the results obtained independently from both local ecological knowledge and ecological surveys is an indication that local knowledge could be directly used for vegetation assessments. This would be most valuable in cases where data cannot be collected using classical ecological methods.

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APPENDIX

Appendix 1 List of species reported by all the informants

Species name	Family/subfamily	Ethnicity	Abundance
Acacia ataxacantha DC.	Fabaceae–Mimosoideae	F	2·00
Acacia dudgeoni Craib ex Hall.	Fabaceae–Mimosoideae	F, M	1·00
Acacia erythrocalyx Brenan (L.) Willd.	Fabaceae–Mimosoideae	F, M, S	2·60
Acacia laeta R. Br. ex Benth.	Fabaceae–Mimosoideae	F	1·00
Acacia macrostachya Rchb. ex DC.	Fabaceae–Mimosoideae	F, M, S	2·65
Acacia nilotica (L.) Willd. ex Del.	Fabaceae–Mimosoideae	F, M, S	2·87
Acacia senegal (L.) Willd.	Fabaceae–Mimosoideae	F, M, S	2·16
Acacia seyal Delile	Fabaceae–Mimosoideae	F, M, S	3·39
Acacia sieberiana DC.	Fabaceae–Mimosoideae	F, M, S	1·03
Acacia sp.	Fabaceae–Mimosoideae	M	3·00
Acacia tortilis (Forssk.) Hayne	Fabaceae–Mimosoideae	F	2·06
Adansonia digitata L.	Bombacaceae	F, M, S	1·56
Afzelia africana Smith ex Pers.	Fabaceae–Caesalpinioideae	F, M, S	0·88
Albizia chevalieri Harms.	Fabaceae–Mimosoideae	F, M	2·57
Annona senegalensis Pers.	Annonaceae	F, M, S	1·00
Anogeissus leiocarpa (DC.) Guill. et Perr.	Combretaceae	F, M, S	1·71
Azadirachta indica A. Juss.	Meliaceae	F, M, S	2·29
Balanites aegyptiaca (L.) Del.	Balanitaceae	F, M, S	2·54
Bauhinia rufescens Lam.	Fabaceae–Faboideae	F, M, S	3·44
Bombax costatum Pellegr. et Vuillet.	Bombacaceae	F, M, S	1·00
Borassus aethiopum Mart.	Arecaceae	F	0·84
Boscia angustifolia A. Rich.	Capparaceae	M, S	1·00
Boscia senegalensis (Pers.) Lam. ex Poir.	Capparaceae	F, M, S	2·00
Boswellia dalzielii Hutch	Burseraceae	F, M, S	0·78
Burkea africana Hook.	Fabaceae–Caesalpinioideae	S	0·76
Cadaba farinosa Forssk.	Capparaceae	M	1·00
Calotropis procera (Ait.) Ait. f.	Apocynaceae	F, M, S	2·00
Capparis sepiaria L.	Capparaceae	F, M, S	2·39
Cassia occidentalis L.	Fabaceae–Caesalpinioideae	F	1·77
Cassia siamea Lam.	Fabaceae–Caesalpinioideae	S	3·00
Cassia sieberiana DC.	Fabaceae–Caesalpinioideae	F, M, S	1·00
Ceiba pentandra (L.) Gaerth	Bombacaceae	M, S	1·80
Celtis toka (Forssk.) Hepper & Wood	Ulmaceae	F, M	1·00
Combretum aculeatum Vent.	Combretaceae	F, M, S	1·00
Combretum adenogonium Steud. ex A. Rich.	Combretaceae	S	2·20
Combretum glutinosum Perr. ex DC.	Combretaceae	F, M, S	2·00
Combretum micranthum G. Don	Combretaceae	F, M, S	1·79
Combretum nigricans Lepr. ex Guill. et Perr.	Combretaceae	F, M, S	2·37
Commiphora africana (A. Rich.) Engl.	Burseraceae	F, S	2·02
Crateva adansonii DC.	Capparaceae	F, M, S	1·00

(*Continues*)

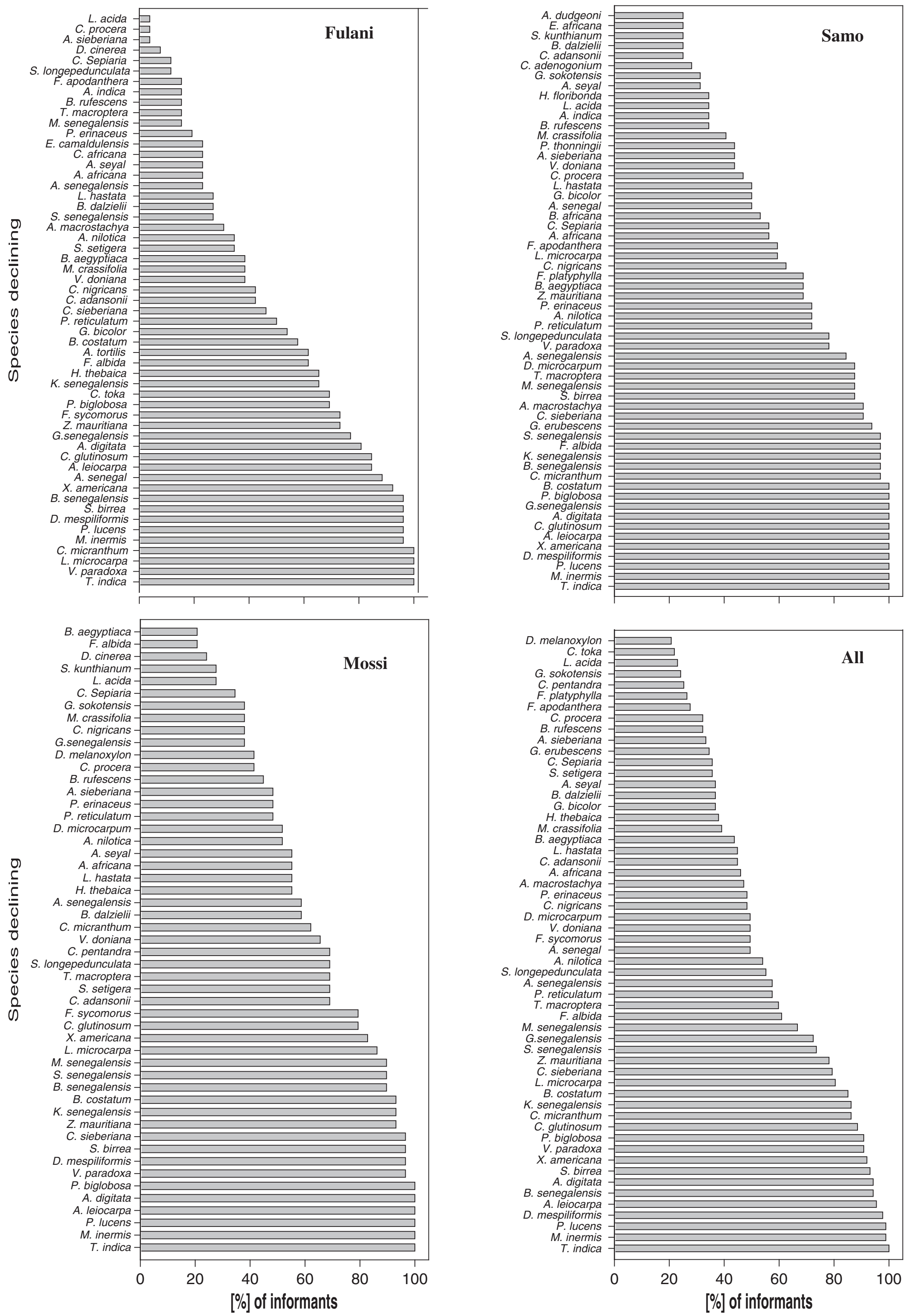
Table . (Continued)

Species name	Family/subfamily	Ethnicity	Abundance
Dalbergia melanoxylon Guill. et Perr.	Fabaceae–Faboideae	M, S	1·04
Detarium microcarpum Guill. et Perr.	Fabaceae–Caesalpinioideae	M, S	1·33
Dichrostachys cinerea (L.) Wight et Arn.	Fabaceae–Mimosoideae	F, M	1·65
Diospyros mespiliformis Hochst ex A. DC.	Ebenaceae	F, M, S	2·00
Entada africana Guill. et Perr.	Fabaceae–Mimosoideae	M, S	2·13
Eucalyptus camaldulensis Dehnh.	Myrtaceae	F, M	1·50
Faidherbia albida (Del.) A. Chev.	Fabaceae–Mimosoideae	F, M, S	2·75
Feretia apodanthera Del.	Rubiaceae	F, M, S	2·31
Ficus ingens (Miq.) Miq.	Moraceae	M	2·00
Ficus platyphylla Delile	Moraceae	M, S	2·00
Ficus sp.	Moraceae	S	1·87
Ficus sycomorus L.	Moraceae	F, M, S	1·00
Gardenia erubescens Stapf et Hutch	Rubiaceae	S	2·14
Gardenia sokotensis Hutch.	Rubiaceae	M, S	2·30
Grewia bicolor Juss.	Tiliaceae	F, M, S	2·00
Guiera senegalensis J. F. Gmel.	Combretaceae	F, M, S	2·09
Gymnosporia senegalensis (Lam.) Loes	Capparaceae	M, S	2·58
Holarrhena floribunda (G. Don) Dur et Schinz	Apocynaceae	F, M	2·00
Hyphaene thebaica (L.) Mart.	Arecaceae	F, M, S	1·03
Khaya senegalensis (Desr.) A. Juss.	Meliaceae	F, M, S	1·05
Lannea acida A. Rich	Anacardiaceae	F, M, S	1·10
*Lannea microcarp*a Engel. et K. Krause	Anacardiaceae	S	2·47
Lannea velutina A. Rich	Anacardiaceae	F, M, S	1·00
Leptadenia hastata (Pers.) Decne.	Apocynaceae	F, M, S	2·62
Maerua crassifolia Forssk.	Capparaceae	F, M, S	1·74
Mitragyna inermis (Willd.) Kuntze	Rubiaceae	F, M, S	1·45
Moringa oleifera L.	Moringaceae	F, S	1·90
Ozoroa obovata (Oliv.) R. Fern. & A. Fern.	Anacardiaceae	S	2·91
Parkia biglobosa Jacq. R. Br. ex G. Don	Fabaceae–Mimosoideae	F, M, S	1·00
Piliostigma reticulatum (DC.) Hochst.	Fabaceae–Caesalpinioideae	F, M, S	0·68
Piliostigma thonningii (Schumach.) Milne-Redh.	Fabaceae–Caesalpinioideae	S	2·57
Prosopis africana (Guill. & Perr.) Taub.	Fabaceae–Mimosoideae	M	1·00
Pteleopsis suberosa Engl. et Diels	Combretaceae	S	1·00
Pterocarpus erinaceus Poir.	Fabaceae–Faboideae	F, M, S	2·00
Pterocarpus lucens Lepr. ex Guill. & Perr.	Fabaceae–Faboideae	F, M, S	1·00
Saba senegalensis (A. DC.) Ait. f.	Apocynaceae	F, M, S	1·85
Sclerocarya birrea (A. Rich.) Hochst	Anacardiaceae	F, M, S	1·88
Securidaca longepedunculata Fres.	Polygalaceae	F, M, S	2·52
Sterculia setigera Del.	Sterculiaceae	F, M, S	0·67
Stereospermum kunthianum Cham.	Bignoniaceae	M, S	1·22
Strychnos spinosa Lam	Strychnaceae	F, M	2·62
Tamarindus indica L.	Fabaceae–Caesalpinioideae	F, M, S	0·00
Agelanthus dodoneifolius (DC.) Polhill & Wiens	Loranthaceae	M, S	1·72
Terminalia macroptera Guill. et Perr.	Combretaceae	F, M, S	1·62
Vernonia colorata (Willd.) Drake	Asteraceae	M	2·00
Vitellaria paradoxa C.F. Gaertn.	Sapotaceae	F, M, S	2·48
Vitex doniana Sweet	Verbenaceae	F, M, S	0·98
Ximenia americana L.	Olacaceae	F, M, S	1·36
Ziziphus mauritiana Lam.	Rhamnaceae	F, M, S	2·48
Ziziphus mucronata Willd.	Rhamnaceae	M	1·00

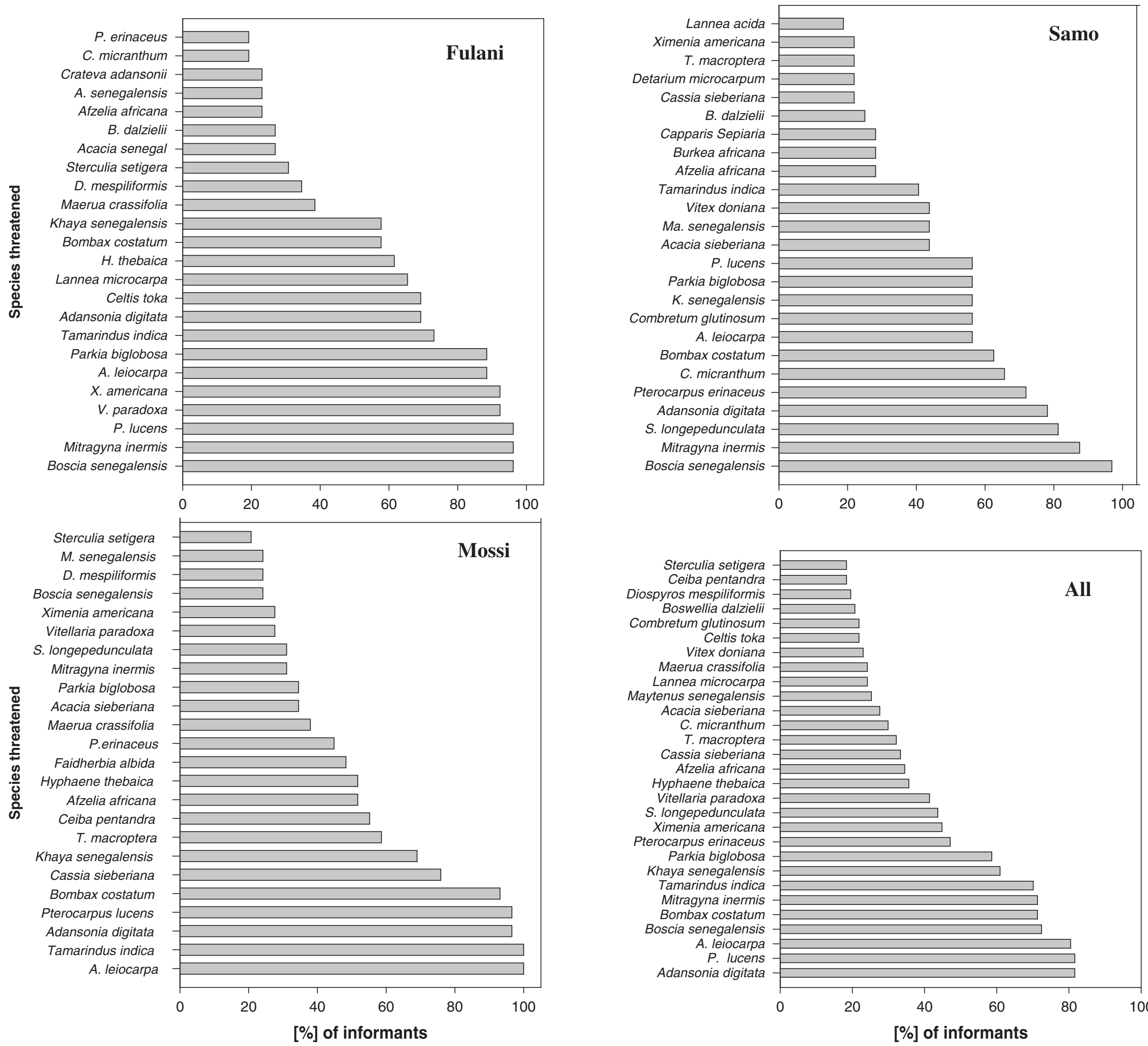
F, Fulani; M, Mossi; S, Samo.

Appendix 2 Perception of the dynamics of woody species by the informants of Fulani, Mossi and Samo ethnic groups.

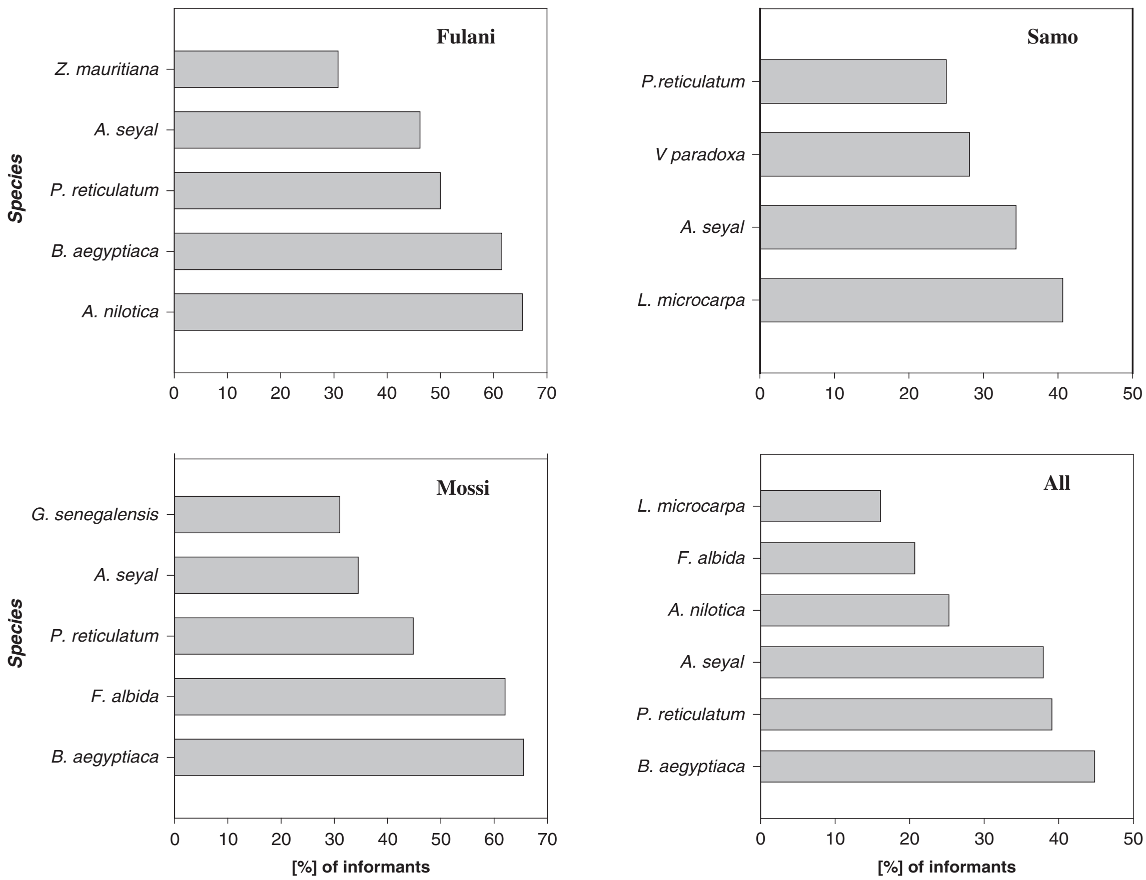
Appendix 2a Declining species mentioned in the three ethnic groups.



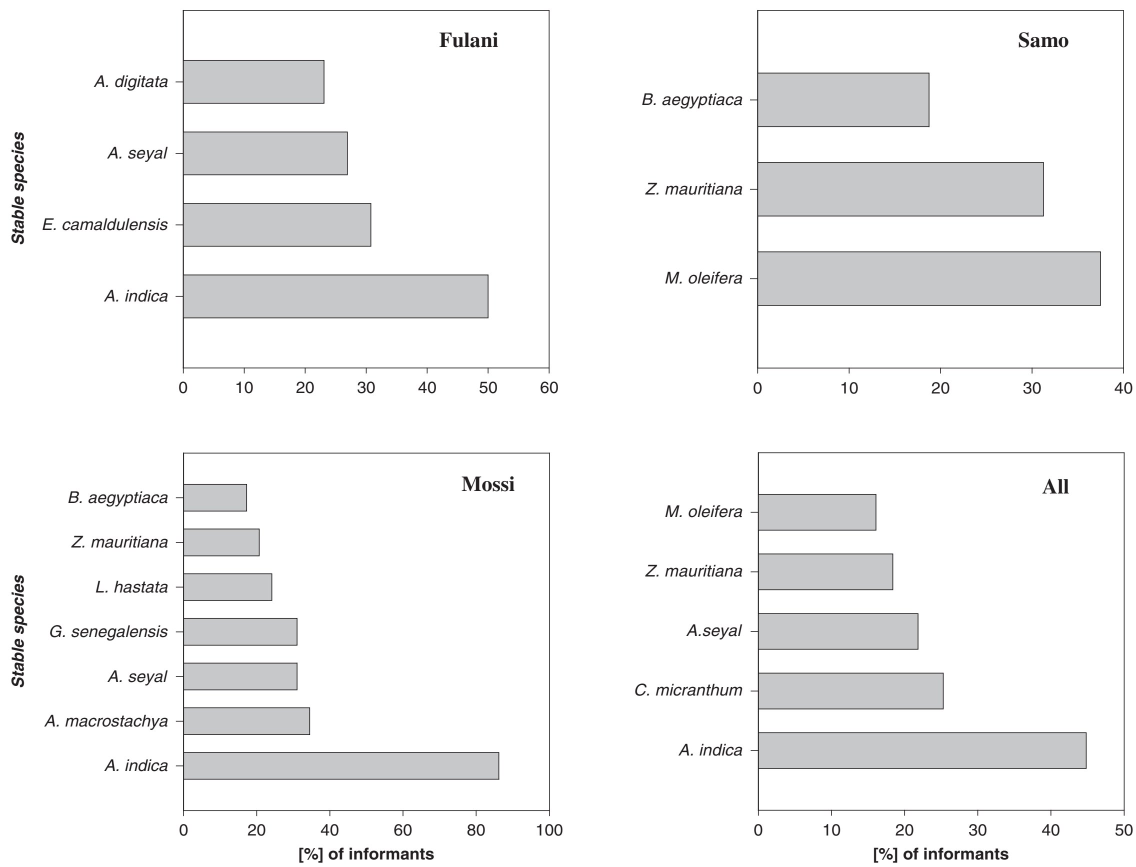
Appendix 2b Species listed as threatened in all ethnic groups and in the whole study area.



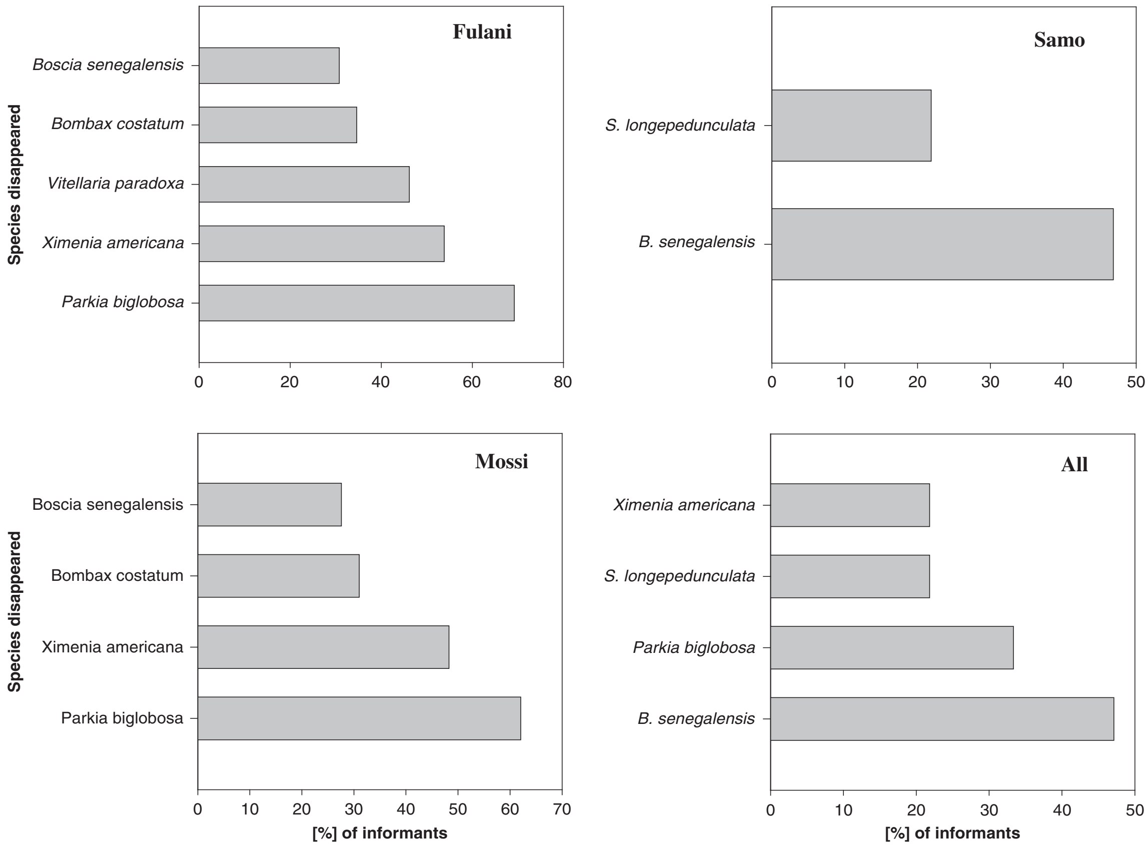
Appendix 2c Increasing species mentioned in each ethnic group and across the study area.



Appendix 2d Stable species mentioned in each ethnic group and across the study area.



Appendix 2e Species disappeared mentioned in each ethnic group and across the study area.



Appendix 3 Sampled villages in the Sub-Sahel and their geographical coordinates (latitude and longitude).

Ethnicity	Village name	Longitude_WGS84	Latitude_WGS84
Fulani	Ngountouré	0·465300	13·385000
Fulani	Helga	0·618622	13·497247
Fulani	Takoungonadié	0·740297	13·735297
Fulani	Titabé	0·391970	13·759728
Fulani	Sampelga	0·230014	13·745020
Fulani	Mamangue	0·245006	13·658058
Mossi	Moèmè-Barsalogho	−1·068350	13·404725
Mossi	Kora-Kongoussi	−1·508622	13·374470
Mossi	Kornean	−0·983892	13·100278
Mossi	Koulou	−1·603367	12·995006
Mossi	Sim-Thiou	−2·579728	13·793911
Mossi	Tougou	−2·251689	13·686128
Mossi	Kasseba-Samo	−2·433892	13·170017
Samo	Dounkou	−3·200308	13·301672
Samo	Djimbara	−3·149186	12·888345
Samo	Da	−2·913622	12·985297
Samo	Koin	−2·838889	12·715578
Samo	Bangassogo	−2·912244	13·314739
Samo	Ouellé	−2·696392	13·370578
Samo	Koui	−3·190847	13·192803

