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Community-based Knowledge of Indigenous Vegetation in Arid African Landscapes

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Abstract

This article is based on comparative research conducted in three African countries—Mali, Botswana and Kenya—between 2006 and 2007. The research focuses on local perceptions of biodiversity loss and land degradation in grazing pastures as a result of anthropogenic activities. We show that land degradation can be motivated by climate change, while local overuse of indigenous vegetation can lead to resource conflict. We then examine how changes in indigenous vegetation might influence the livelihood and security of local communities. In drawing key findings common to all three countries, we suggest that the sustainability of indigenous vegetation in dryland ecosystems can be maintained through seasonal mobility of herds, preservation of dry season grazing and improved livestock marketing, and that failure to do so can result in far-reaching consequences for rural communities.

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1. Introduction

In dryland ecosystems, the conservation of indigenous vegetation biodiversity poses major challenges (Lykke, 2000; Oba et al., 2000b; Sheuyange et al., 2005; López et al., 2006), and the effect of land degradation is diverse and complex (Behnke and Scoones, 1993; Oba et al., 2000b; Sullivan and Rhode, 2002; Walker and Sinclair, 1998). Anthropogenic factors and climate change can exacerbate the loss of native resources and vegetation and jeopardize the region's unique biodiversity. Further, many habitants of arid and semi-arid areas in Africa derive most of their incomes from extensive livestock production totally reliant on indigenous vegetation (Kamara et al., 2004), and may be hugely affected should these resources be allowed to degrade (Leakey, 2002). Thus, in order to effectively manage the biodiversity of indigenous vegetation in African drylands and ensure sustainability for the future generation, it is critical to gain a better understanding of how local communities adapt to changes in their environment (Berkes et al., 1998; Bolling and Schulte, 1999; Brown, 1971; Stringer et al., 2007).

In arid African landscapes, population growth, increasing demand for natural resources, and environmental degradation create environmental stresses that have considerable socio-economic and ecological consequences (Bolling and Schulte, 1999; Mouat et al., 1997; Sinclair and Fryxell, 1985; UNCCD, 2000; UNCED, 1992). These pressures have led to inappropriate systems of land use that can greatly contribute to the loss of indigenous vegetation (Angassa and Oba, 2008). According to Angassa and Oba (2008), land use changes linked to bush invasion in dryland ecosystems threaten both indigenous plants and animals and exacerbates soil erosion, with far-reaching implications for local communities. Oba et al. (2000) have reported that the grazing effectiveness of dryland ecosystems is completely eliminated if bush encroachment exceeds 90% of the vegetation cover. Generally, dryland ecosystems are subject to increasing land use changes as human need for food and natural resources rise, which eventually contributes to climate change (Grover et al., 2011). Shifts in rainfall patterns and frequent droughts, which are indicators of such climate change, cause massive loss of livestock in the region (Oba, 2001; Angassa and Oba, 2007). As a whole, widespread environmental degradation exacerbates the advancement of global climate change and furthers the reduction of ecosystem productivity (Berkes et al., 1998).

The challenges in finding environmentally sound and culturally acceptable natural resources management practices thus lead researchers to consider community-based-knowledge (Berkes et al., 1998; Bolling and Schulte, 1999; Fernandez-Gimenez, 2000; Mapinduzi et al., 2003; Oba, 2001; Oba and Kaitira, 2006; Angassa and Oba, 2008). In addition, there is little data on indigenous vegetation in arid African landscapes and its historical changes. Hence, the knowledge of local people becomes indispensable in order to fully understand long-term changes in indigenous vegetation. Local awareness of environmental issues is fairly comprehensive (Bolling and Schulte, 1999) and effective in sustainable development research and application (Bowman, 2002; Brown, 1971; Dale and Beyeler, 2001; Mouat et al., 1997; Romstad, 1999).

Indigenous vegetation resources may provide a range of ecosystem benefits apart from local livelihood security (Beer et al., 1998). In the case of African drylands, feed for livestock (Angassa and Oba, 2008), preservation of the natural landscape and its biodiversity (Menke and Bradford, 2001), carbon sequestration options (de Jong et al., 1995; Lal, 2001) and soil protection (Beer et al., 1998) are all major benefits of maintaining indigenous vegetation.

Local people often possess detailed knowledge of indigenous vegetation and the ecological value of individual plants (de Jong et al., 1995; Seely, 1998; Seely and Moser, 2004; Seely and Wöhl, 2004) that can assist policymakers in designing suitable land management policy (Brown, 1971; Mapinduzi et al., 2003). In general, they also acquire a comprehensive knowledge of how plants adapt to dryland environments (Ellis and Swift, 1988; Mapinduzi et al., 2003).

The driving forces behind land degradation in dryland ecosystems, however, can be complex. Thus, local ecological knowledge of climate change must be integrated with the scientific approach in order to understand the causes and consequences of land degradation. Such an approach, which involves the participation of the local community, has proven to be effective in devising proper management system for the sustainable use of arid landscapes (Grice and Hodgkinson, 2002).

Based on research in these three African countries, this article focuses on the value of indigenous ecological knowledge in future development endeavors for the sustainable usage of indigenous vegetation in the region. In particular, we consider communities' experiences in managing indigenous vegetation and common strategies adopted by the local community for sustainable use of drylands. We also attempt to determine whether local communities use key environmental indicators in describing their local situations.

Our main interest is to know how local herders may respond to environmental challenges with regard to natural resource management and livelihood strategies. We are further interested in whether local decisions regarding indigenous vegetation have exacerbated threats to biodiversity. Overall, our study reports on the role of indigenous knowledge regarding environmental changes, perception of indigenous vegetation, land use practices, effects of water points on vegetation, land degradation, local indicators of degradation and the consequences of these factors on local livelihood conditions. Regarding local ecological knowledge, we focus on three aspects: (a) knowledge and experiences of local people in the management and conservation of indigenous vegetation resources; (b) dependency of local livelihood systems on indigenous vegetation and socio-economic status, and (c) local perception of land degradation.

We first briefly describe the nature of African arid landscapes and their management.

1.1 African Arid Landscapes

Arid landscapes are defined as ecosystems and landforms that are not suited for intensive types of land use due to limitations imposed by the physical environment (climate, soil) and other natural forces (Arnalds and Archer, 2002; Stoddart et al., 1975). Extensive livestock production is the primary contribution of such habitats in Africa (Homewood and Rodgers, 1991). There is also a growing recognition of the importance of these landscapes for other uses, including wildlife habitation, hydrology and tourism (Homewood and Rodgers, 1991). The drylands of Africa comprise 60% of the continent and a major part of Botswana (80%), Kenya (80%) and Mali (70%) (CEES, 2007). They support more than 70% of the livestock population and 90% of the wildlife in Botswana, 50% of the livestock and 75% of the wildlife in Kenya, and 60% of the national livestock herd in Mali (CEES, 2007). The result is a great diversity of cultures and human-environment interactions across these three countries (CEES, 2007), which provide a number of opportunities for improving our understanding of environmental processes. The greatest strengths of such African arid landscapes are their ability to support diverse indigenous vegetation resources (woody and herbaceous layers) and their resilience to natural calamities and climate change.

1.2 Sustainable Management of Arid Landscapes

Sustainable management of arid landscapes in Africa requires an understanding of interactions among environmental processes, socio-cultural components and local livelihood systems across both temporal and spatial scales (Behnke and Scoones, 1993; Ellis and Swift, 1988; Fernandez-Gimenez, 2000). Progress towards environmental resiliency will originate from basic adjustments in local people's beliefs about their environment (Salem, 2007). Furthermore, establishing sound natural resource management will necessitate the participation of local users, due to their experience and intimate knowledge of their local environment passed on through generations (Bolling and Schulte, 1999; Fernandez-Gimenez, 2000). It is also widely recognized that local knowledge systems have been largely overlooked by researchers until very recently (Salem, 2007). Novel management approaches to the sustainable use of arid landscapes in Africa can also provide opportunities for local people to explore feasible and alternative livelihoods while maintaining the diversity and social values of their culture and landscape. Overall, the effective rehabilitation of African arid landscapes must entail a novel combination of policies and technologies that draw from both the scientific approach and the participation of local people in research and development activities.

2. Methodological Approach

This article synthesizes findings of a study based on the MSc education and training (see for details CEES[1], 2007) funded by the Global Environmental Facility-Indigenous Vegetation Project (GEF-IVP), which was conducted in three African countries focusing on Botswana, Kenya and Mali. Biophysical, socio-economic and cultural approaches were analyzed to investigate the role of local knowledge and indigenous institutions in the management and maintenance of indigenous vegetation, contribution of natural resources in supporting local livelihood systems. Data were collected by 12 MSc students (4 MSc students from each of the three countries, i.e., Botswana, Kenya and Mali) between October 2006 and January 2007. The different studies employed local knowledge and ecological methods in assessing socio-economic and cultural information, as well as evaluating the status of indigenous vegetation and conservation of biodiversity at landscape level. The following methods were employed to collect information: (1) Local perception on indigenous vegetation resources were collected using household interviews, through a semi-structured questionnaire, group discussion and key informant interview; (2) Information related to impacts of traditionally managed water wells along radial distances on indigenous vegetation resources was evaluated with the participation of local community members along a transect walk. Locally managed traditional wells aged between 150 and 350 years were considered to assess effects of water points on indigenous vegetation resources. Such information is believed to provide a chronological time scale and an appropriate method of evaluating the effect of grazing intensity on indigenous vegetation resources when using radial distance as a proxy indicator (Angassa, 2012), since grazing intensity was heavier nearer to well points; (3) perceptions of local indicators such as lack of rain, lowered water flows, dried out wells, reduced vegetation cover and soil exposure to erosion were used to collect information on the impact of climate change; (4) local perception of degradation was assessed in terms of decline in biomass (productivity) and species richness, reduced herbaceous coverage, abundance of exotic species and disappearance of indigenous plant species. The productivity indicators were related to vegetation status and livestock performance in terms of milk production, calving rates, mating frequencies and livestock body conditions, which local people used to assess environmental changes (Dembele, 2006). Ecological indicators like natural disturbances, vegetation changes, reduced water source and decline in wildlife number might only inform a fraction of the story about an environmental problem, while production indicators, which ecologists seldom consider, remain a key element for influencing indigenous systems of land management.

3. Results and Discussions

3.1. Local Perception on Indigenous Vegetation Resources

This article adapted a participatory research approach (i.e., integrated indigenous knowledge and ecological methods) in understanding how different forms of land use and management practices of grazing lands influenced the status of indigenous vegetation and conservation of biodiversity (Table 1). The present results showed that local perceptions of biodiversity conservation were based on the connection between people, environmental conditions and ecosystem productivity. It has been shown that local knowledge of vegetation monitoring and conservation of biodiversity involved an evaluation of the status of indigenous vegetation, soil types and access to water as proxy indicators of land productivity (Oba and Kotile 2001). For example, in the Malian case studies, we observed a negative correlation between grazing pressure (as evaluated by herders) and herbaceous cover (as evaluated by ecologists) ($r = -0.96$, $P < 0.001$). Generally, grazing pressure was positively correlated with tree cover but there was no significant relationship between grazing pressure and tree cover. By comparison, grazing pressure was negatively correlated with the cover of shrubs ($r = -0.91$, $P < 0.001$). We realized that local people's knowledge in terms of assessing the status of indigenous vegetation using environmental indicators might be relevant in conducting integrated assessments that could help to set research and development priorities (Table 1). Based on our results, we were able to establish that local people have a detailed knowledge of environmental indicators that are effective in evaluating the status of indigenous vegetation and changes in biodiversity at the landscape level (Table 1). Herders in the three African countries emphasized that environmental factors such as soil type, topographic variation and grazing pressure were important factors to map the spatial variability of indigenous vegetation. Overall, it was stated that variation in grazing pressure resulted in greater species richness in the open grazed areas than protected sites. Such findings might be contrary to the expectation that grazing contributes to the loss of plant species biodiversity. Our hypothesis suggested that such findings would confirm the role played by grazing animals as part of an ecosystem service in contributing to the conservation of biodiversity, as long as the ecosystem is not misused. On the contrary, the result indicated that protected areas were dominated by few species, probably through the process of ecological succession. However, the protected pastures showed greater accumulation of biomass than the adjacent continuously grazed areas.

It was interesting to note that herders used both ecological and anthropogenic indicators in assessing the abundance of indigenous vegetation at the landscape level (Table, 1). This may be related to three key factors: different grazing landscapes might disclose differences in performance with respect to the unique feature of an individual landscape that would enable it to support different levels of grazing pressure. Secondly, a landscape with low grazing potential may be vulnerable to degradation and loss of biodiversity, while landscapes with higher potential could be resistant to grazing pressure and more resilient in terms of recovery after the removal of grazing stress. Thirdly, in the herders' experience, all landscapes may be varied in terms of utility and suitability for livestock use (Table 1). Some landscapes may be preferred for grazing and/or browsing by a given species of livestock (e.g., cattle, sheep and goats or camels) and their utilities might also be diverse according to seasons. Using such comprehensive knowledge systems, herders in the three countries had no difficulties in adjusting livestock grazing according to the suitability and potential of each landscape (Oba et al., 2000a). Overall, indigenous landscape classification and land use practices by the local people greatly reflected herders' detailed knowledge of ecosystem variability (Table 1).

Classification of landscape level grazing suitability as adopted by the local herders was based on soil types, grass species composition and shrub and tree densities. Furthermore, the relative abundance of species (i.e., the number of individual species per unit area) was used to classify the various landscapes according to their suitability. From the results of this study, we confirmed herders' knowledge of landscape classification with respect to the landscape's grazing potential and degradation status (degraded and less degraded). Generally, herders' perspectives of a degraded versus less degraded landscape inferred from vegetation status and soil types in response to grazing pressure (Oba and Kotile, 2001). According to the results of this study, landscapes highly sensitive to grazing were often grazed for shorter periods during the wet season as opposed to being considered as key resources. This might imply that contrary to the perception of environmental degradation, herders do not continue to degrade their environment; they rather rotate their land use based on seasons. However, degraded lands could be inevitable around settlements where grazing pressure is expected to be high year round. In

Northern Kenya for instance, grazing pressure was seasonally avoided through livestock mobility by sending excess herds elsewhere. On the contrary, in the other two countries (i.e., Botswana and Mali) livestock mobility as a strategy in reducing pressure on grazing lands was not an option.

Herders in the three countries used the abundance of palatable species as indicators for assessing range condition. Based on the current grazing condition of each landscape, herders could show landscape preferences by livestock where they often referred to the abundance and palatability of herbaceous species. The herders' observations suggested that the dominance of unpalatable grass species and forbs are indicators of poor range condition. Similarly, previous studies (e.g., Oba, 2001; Oba and Kaitira, 2006; Oba and Kotile, 2001; Oba et al., 2000a) have confirmed herders' knowledge of foraging species as an indicator of the status of rangeland condition. Many herders claimed that some foraging species not recorded during the vegetation sampling in the field were species that are disappearing from their grazing lands. Therefore, the incorporation of local knowledge into the scientific approach may improve our understanding of environmental changes affecting indigenous vegetation. The value of such information cannot be disregarded, considering that field vegetation surveys usually lack long-term experimental monitoring and as a result, there is little history of vegetation change other than from local communities' knowledge or other more sophisticated but generalizing methods (e.g., satellite imagery).

3.2. Effects of Water Points on Vegetation Composition

The evidence suggests that an increased number of artificial water points in a communal land use system leads to the degradation and loss of indigenous vegetation resources. Due to increased grazing pressure nearby the water points, the cover of indigenous vegetation correspondingly decreases, as seen in Mali. What we also confirmed from the results of this study was that sites associated with the younger age of well points (3 to 45 years old) had a higher grass cover than sites nearby the older wells (150 to 350 years old). Nevertheless, sites associated with the older water points had superior grass species diversity. Overall, even though vegetation cover increases in relation to increased distance from water points, this does not indicate species richness. Our analysis indicates that plant cover and species richness was higher at intermediate distances from water points in accordance with the intermediate disturbance hypothesis (Connell, 1987). This hypothesis suggests that older wells in communally managed rangelands might enhance species richness but reduce plant cover. These results might be a surprising departure from conventional ecological expectations that older and heavily used wells would be associated with poorer range condition and lower plant species richness and diversity than younger and lightly utilized range sites. Generally, such conclusions may undermine systems of indigenous range management, which were highly efficient in terms of regulating livestock density and setting time of use in the wells zone. Quite often, the well rangelands are rested from any form of use during the wet season when rain pools are available, and the livestock return to them during the dry season when plants are in dormancy (Oba, 1998). We did not however compare these wells with the more modern boreholes developed by states or aid agencies where traditional systems of land management might have broken down. According to herders' observations, the impact of climate change and frequent drought remain the most critical risks to the management of grazing lands and consequently, the exploitations of indigenous vegetation by humans. Accordingly, we also emphasized the role of climate change and the impact of recurrent drought on local livelihood security in Botswana and Kenya (Table 2).

3.3. Impacts of Climate Change

The findings from Botswana and Kenya pointed out that multiple droughts had substantially reduced livestock resources and threatened the livelihood security of pastoral communities (Table 2). Similar evidence (e.g., Berge, 1999) has shown that the impact of climate change on livestock population is critical because of its direct implication for local livelihood systems (Table 2). The evidence implied that slow herd recovery following droughts would increase the impoverishment risk of the local pastoral households. In general, the present study provided a wealth of knowledge on drought coping strategies and methods for early warning systems based on those practiced by the herders. The present results suggest the importance of linking indigenous early warning systems with modern drought management strategies in order to achieve effective drought management in arid regions of Africa. Previous studies (Ellis and Galvin, 1994; Angassa and Oba, 2007) have shown that rainfall is a dominant driver of ecosystem dynamics in the drylands of Africa. In such environments, livestock responses to climate variability would demand opportunistic herd management and flexibility (Ellis and Swift, 1988; Oba et al., 2000b) such as through increased herd mobility in response to effects of multiple droughts (Angassa and Oba, 2007) and the scarcity of resources (McCabe, 2004). Based on the Botswanan case study we could summarize the relationship between global climate change indices (e.g., North Atlantic Oscilation-NAO and El Niń o Southern Oscillation-ENSO) and patterns of livestock species (Table 2). The results of the study from Botswana showed that the more variable climate has strongly influenced livestock population dynamics and suggest that more frequent drought will cause substantial reductions in herd numbers (Table 2). Conversely, a fixed time lag after average rainfall years reflected an increase in livestock populations. Overall, there was a strong relationship between rainfall variability and livestock performance indicators, suggesting that management needs to be improved in order to protect the loss of livestock during drought periods. The current study therefore suggests that drought management strategies must be improved to minimize the negative impact of variable environmental conditions on livestock population. It also recommends that the link between indigenous drought management strategies and modern systems of early warning should be further explored and integrated. Based on herder knowledge, the most problematic deduction is the link between the drivers of drought and land degradation. We suggest, however, that the impact of rainfall alone might not be a problem; rather the interactions between rainfall variability and increased population pressure that cause greater demands on the local environment might explain the links.

3.4. Perceived Drivers of Land Degradation

Local herders would argue that the impoverished situation associated with rainfall variability and greater demands on the local environment might exacerbate the process of land degradation. Generally, our synthesized results suggest that seasonal mobility, preservation of dry season feed and improved livestock marketing are methods to be explored in order to cope with environmental risk. We concluded that both anthropogenic and natural events contributed to land degradation and the livelihood insecurity of households. When comparing herders' knowledge of land degradation to an ecologist's, herders combine the same indicators as those used by ecologists with production indicators. They determine the impact of land degradation on the basis of rangeland condition indicators and livestock performance rather than ecological indicators alone.

3.5. Local Indicators of Land Degradation

An important aspect of indigenous ecological knowledge could be the application of complex indicators (i.e., the link between rainfall, fodder availability, livestock productivity and household food security) in order to show that processes involved in land degradation are not simple and straightforward. Indigenous knowledge can also explain the close connection among rainfall, primary production and secondary productivity (Hiernaux et al., 1990; Ellis and Swift, 1988). For instance, the view that milk production is directly related to the availability of fodder, while forage productivity is dependent entirely on rainfall has been confirmed (Berge, 1999). The complexity of separating cause-effect relationships in driving land degradation and loss of biodiversity might be above the informal reasoning used by herders, while ecologists can combine many varieties of environmental and socio-economic indices to come up with more cohesive conclusions.

3.6. Consequences of land degradation

According to herders' observations, one of the many consequences of land degradation is the severity of famine associated with the occurrence of droughts. The probable reason is that, in degraded environments, additional stress will simply exacerbate the problem of food production. The impact of environmental variability may lead to a decline in crop and animal production performances, threatening livelihood security. Generally, with failure of rain and prolonged drought, households may be threatened with lack of sufficient milk to feed family members when feed resources for animal maintenance are in short supply. In reality where famine and poverty prevail, "communities' health conditions have become endangered by malnutrition, followed by infant death," as stated in the MSc studies used as primary literature in this study. In arid regions of Africa, livestock is part of the local communities' culture and hence an important asset. However, many sedentary households have lost large numbers of their animals due to recurrent drought and inadequate feed supply. In general, our analysis suggests that loss of livestock is linked to drought, and the problem of land degradation can cause severe poverty for inhabitants of arid environments. What emerges from the present analysis across the three countries of Africa is that management of indigenous vegetation resources cannot be separated from a community's development endeavors. Proper management and sustainable use of indigenous vegetation resources can be achieved successfully by bringing in conservation education through community participation. Consequently, conservation education would enhance local ecological knowledge and therefore help local communities realize their capacity to respond to environmental challenges. We suggest that this could be achieved through a proper extension of public education (Oettlé et al. 2004; Chanda 1996).

4. Conclusion

This study provides insight for more effective strategies of resource utilization and management, drought coping mechanisms and adaptation to local circumstances under changing climate. From the findings, several issues have emerged: (1) the use of local ecological knowledge indeed might be a key element for sustainable management and preservation of indigenous vegetation in the arid landscapes of Africa; (2) Traditional management systems have important contributions to be made for conservation of the biodiversity of indigenous vegetation; (3) Community-based knowledge is crucial in strengthening local institutions for sustainable use of indigenous vegetation and conservation; (4) This article may also contribute to current knowledge of sustainable farming systems that aim at improving food security and risk minimization. This article has been presented with the hope that it might contribute to an exchange of knowledge and experiences among the various stakeholders in developing models that could be adopted in other arid zones of Africa. We suggest that indigenous ecological knowledge needs to be promoted, as well as supported by scientific-based methods of resource management and conservation of natural landscapes. The implication of this synthesis article is that the maintenance and proper use of African arid landscapes will require integration of local ecological knowledge with the scientific approach that can be achieved through a participatory research approach within local communities.

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Tables

Landscape types	Species list	Local name	Authority	Life form	Indicator	Frequency (%)
Niesokema landscape	*Cenchrus biflorus*	Kekene	Hort.Bengal	Herb	increaser	30
	Borreria sp	Koutoukoumbe	G.Mey	Herb	decreaser	24
	Schoenefeldia gracilis	Sokekulé	Kunth.	Herb	decreaser	18
	Zornia glochidiata	Kosossafune	Reichb.DC	Herb	decreaser	12
	Mitracarpus villosus	Layik	(S.W) D.C	Herb	decreaser	9
	Digitaria sanguinalis	Diadie	Bol.Soc.	Herb	increaser	4
	Digitaria ciliaris	Narakata	Koeler	Grass	stable	3
	Combretum nigricans	Tiagran	Leprieur	Shrub	decreaser	54
	Guiera senegalensis	Camou	J.F.GMEL	Shrub	stable	46
	Acacia tortilis	Bague	Hayne.	Tree	increaser	77
	Balanites aegyptiaca	Zekene	Var.	Tree	increaser	23
Mari landscape	*Cenchrus biflorus*	Kekene	Hort.	Herb	increaser	62
	Schoenefeldia gracilis	Sokekule	Kunth.	Herb	decreaser	38
	Combretum nigricans	Tiangran	Leprieur	Shrub	decreaser	3
	Guiera senegalensis	Camou	J.F.GMEL	Shrub	stable	30
	Combretum nioroense	Gore	Aubrev	Shrub	decreaser	19
	Leptadenia hastata	Saharate	Decne.	Shrub	decreaser	13
	Calotropis procera	Popopokolo	Aiton.	Shrub	decreaser	3
	Acacia tortilis	Bague	Hayne	Tree	increaser	95
	Ziziphus mauritiana	Fah	Lam.	Tree	increaser	5
Seguendi landscape	*Schoenefeldia gracilis*	Sokekule	Kunth.	Herb	decreaser	45
	Zornia glochidiata	Kosossafune	Rchb.	Herb	decreaser	31
	Mitracarpus villosus	Layik	(SW) D.C	Herb	decreaser	24
	Combretum nigricans	Tiagran	Leprieur	Shrub	decreaser	74
	Leptadenia hastata	Saharahate	Decne.	Shrub	increaser	26
	Acacia tortilis	Bague	Kast.	Tree	increaser	71
	Balanites ayegyptiaca	Zekene	Var.	Tree	increaser	21
	Acacia senegalensis	Dibe	Hout.	Tree	increaser	4
	Ziziphus mauritiana	Fah	Lam.	Tree	increaser	4

Table 1. Indigenous plant species identified based on indigenous ecological knowledge from three arid landscapes of Africa in Mali

Livestock species	NAO (t – 1)	ENSO (t– 1)	SST (t – 1) (Feb)	SST (t – 1) (May)	SST (t – 1) (July)	SST (t – 1) (September)	SST (t – 1) (November)
Cattle	0.015	0.002	0.111	0.009	0.009	0.008	0.016
Goat	0.010	0.044	0.004	0.004	0.051	0.048	0.071
Sheep	0.026	0.033	0.044	0.144	0.176	0.192	0.172

Table 2. Coefficient of determination (R^2) for the relationship between livestock population dynamics and global climate indices in Kgalagadi district