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Land conversion is changing the landscape in the semi-arid Lokere and Lokok Catchments, northeastern Uganda

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ABSTRACT
The Lokere and Lokok Catchments, which form the main watershed in the semiarid Karamoja sub-region of Uganda, are experiencing land use and land cover (LULC) change from extensive livestock production to crop agriculture. This paper assessed the change in LULC in the Catchments during the period 1984-2013 through unsupervised and supervised classification of satellite images using Idrisi Selva and ArcGIS 9.3 tools and ground truthing. Qualitative information was used to obtain historical account of LULC in order to identify drivers of land use and land cover change. The classified LULC were cross-compared for change detection. Results showed change in LULC driven by sedentarisation and the quest for alternative livelihoods to mobile livestock herding, as government and non-state actors move to promote crop cultivation. Key changes include conversion of woodlands and bushlands into small-scale croplands, with degradation of woodland and bushlands increasing grassland area. Grasslands, which covered the largest land area, from 43.64 percent in 1984 to 60.05 percent in 2013, was the most dominant. Small-scale farming was steadily rising from 9.67 percent area coverage in 1984 to 15.69 percent in 2013. The annual rate of increase of farmland during this period was 2.1 percent, however the highest rate of the increase was experienced between 1994 and 2003 at 4.2 percent when 514.2 km^2 (37.53 percent) was converted to farmland. Loss of woodland, bushland, and degradation contributes significantly to the inherent water shortage in the Lokere and Lokok Catchments and Karamoja area in general. This has adverse impacts on communities' livelihoods. Central and local governments and non-state actors in the catchments should regulate LULC change through formulation of land use policies; participatory land use planning; and involvement of the communities in sustainable land management practices.

Key words: Karamoja, land use and land cover change, land degradation, livelihoods, small-scale farming, Uganda

RÉSUMÉ
Le bassin versants de Lokere et Lokok, qui constitue le principal bassin hydrographique dans la sous-région semi-aride de Karamoja en Ouganda, connaît actuellement une évolution de l'utilisation des terres et de la couverture végétale (UTCV), passant d'une production

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animale extensive à une agriculture de culture. Cet article a évalué le changement de l'UTCV dans le bassin versant au cours de la période 1984-2013 grâce à la classification non supervisée et supervisée d'images satellites utilisant les outils Idrisi Selva et ArcGIS 9.3 et la vérification au sol. Les informations qualitatives ont été utilisées pour obtenir un compte rendu historique de l'UTCV afin d'identifier les facteurs de changement et d'utilisation des terres. Les UTCV classées ont été comparées pour la détection de changement. Les résultats ont montré une évolution de l'UTCV due à la sédentarisation et à la recherche de moyens de subsistance alternatifs à l'élevage mobile, alors que les acteurs gouvernementaux et non-étatiques s'emploient à promouvoir la culture. Les changements clés incluent la conversion des terres boisées et des terres arbustives en terres cultivées à petite échelle, la dégradation des terres boisées et des terres arbustives augmentant la superficie des prairies. Les prairies, qui couvraient la plus grande superficie de terres, passant de 43,64% en 1984 à 60,05% en 2013, étaient les plus dominantes. La petite agriculture a régulièrement augmenté, passant de 9,67% de la superficie couverte en 1984 à 15,69% en 2013. Le taux d'accroissement annuel des terres agricoles a été de 2,1%, mais le taux de croissance le plus élevé a été enregistré entre 1994 et 2003, à 4,2% lorsque 514,2 km2 (37,53%) ont été convertis en terres agricoles. La perte de terres boisées, de broussailles et la dégradation contribuent de manière significative au manque d'eau inhérent au bassin versant de Akokorio et à la région de Karamoja en général. Ceci a des impacts négatifs sur les moyens de subsistance des communautés. Les gouvernements centraux et locaux ainsi que les acteurs non étatiques du bassin devraient réglementer le changement des UTCV en formulant des politiques d'utilisation des terres; planification participative de l'utilisation des terres; et implication des communautés dans les pratiques de gestion durable des terres.

Mots clés: Karamoja, changement d'affectation des sols et d'utilisation des sols, dégradation des sols, moyens de subsistance, petite agriculture, Ouganda

INTRODUCTION

Globally, grasslands, forests, bushlands and woodlands are being converted in croplands (Tsegaye, 2010 and Baldi *et al.* 2013) as the demand for food to feed the ever-increasing human population rises. In East Africa, Oslon (2006) reported that the spatial pattern of land use change over the past 50 years had been characterized by increasingly intensively managed landscape except in protected areas or in extremely marginal environments. They highlighted that the most important land use conversions include, among others, the expansion of cropping into grazing areas, particularly in the semi-arid to sub-humid areas. In Uganda, Lokere and Lokok Catchments which is the main watershed in the semiarid Karamoja region is experiencing significant land use and land cover (LULC) change with reported shifting from extensive livestock production to crop agriculture and degazettement of protected areas (Majaliwa *et al.,* 2012). The change in LULC includes degradation of woodlands into bushlands and grasslands and conversion into cultivated land, driven by particularly the promotion of cropping and sedentarisation of pastoralists in efforts to address conflict among the Karimojong community in Uganda and the Pokot of Kenya (Stark, 2011; Vidal, 2011; Egeru, 2014). This change, presents unintended negative impacts on the landscape and its adapted uses such as grazing and water conservation and thus threatening livelihoods (Penning de Vries *et al.,* 2003). This trend is expected to continue given a wide range of efforts to popularize alternative livelihoods strategies to pastoralism such as poultry farming, aloe vera production, crop and vegetable production (ACTED, 2010).

Some studies on LULC have been undertaken in Karamoja region and the "Cattle corridor" that comprise Uganda's drylands area (Zziwa *et al*., 2010; Byenkya *et al.* 2014; Egeru *et al.,* 2014; Nakalembe *et al.* 2017). Nakalembe *et al.* (2017) reported 299% increment in cropland in Karamoja between 2000 and 2011. Egeru *et al.* (2014) and Byenkya *et al.*(2014) using Landsat imagery also observed an increase in small scale farming, and transitions in all land uses classified in the studies. Further, Zziwa *et al.* (2010) assessed land use changes in Nakasongola District and reported woody encroachment as the major change in the area. The present study qualitatively established existing land use and land cover types, identified factors that have influenced it, and determined land use and land cover change, and trend from 1984 to 2013.

MATERIALS AND METHODS

Lokere and Lokok Catchments are the main watershed in the Karamoja sub-region and connects downstream to part of Teso sub-region, in Uganda's dryland, known as the "Cattle Corridor". Karamoja sub-region is part of the Karamoja cluster (ACTED, 2016). The Catchments streams are important sources of water in the semi-arid area, especially during the dry season (Mbogga *et al.,* 2014).

To assess land use and land cover change in the Catchment, spatial and temporal trends of land use/cover change in the period 1984-2013 were determined basing on unsupervised and supervised classification of satellite images using Idrisi Selva and ArcGIS 9.3 tools and ground truthing. Qualitative accounts were used to obtain a historical account of land use change in order to aid ground truthing, and to identify drivers influencing land use changes. The classified land cover were cross-compared in ArcGIS 9.3 for change detection.

Perceptions of the community on land cover/ use change and its drivers. Experiences, perceived LULC, and its causes were obtained from the community and local government officers in charge of key departments through participatory mapping, focus group discussions (FGD), and key informant interviews. Participatory mapping was used to understand the land use/cover categories; and to establish historical land use/cover through participant recall of the land use/cover over the years. Participatory mapping was undertaken with five participants in eleven of the 45 sub-counties wholly or partly covered by the Catchment, following a modified approach described by Vajjhala (2005) and NOOA (2009).

The participants who were over 40 years of age were mobilized with the help of the local government administration, and were selected based on the researchers' perceived ability of a potential participant to comprehend and follow the exercise to the end. For the sub-counties in Karamoja sub-region where illiteracy is high, a local based timeline of historical events was developed with the participants to present the different years and periods under study.

Using the historical events corresponding to 1984, 1994, and 2003, FGD participants were then asked to map cultivation land, grassland (grazing land), bushland and woodland; and to show where shifts had occurred. During this process, participants were asked to explain the relationship between the identified LULC change drivers and LULC types. A walk or drive was then taken with some of the participants across representative areas of mapped LULC types. The coordinates for locations of the LULC types were taken using a hand-held GPS device and the corresponding LULC types over the four study periods recorded. For areas that could not be accessed, the LULC types were digitized on the image by visually relating information on the participatory map and topographic map as reference. These were used to digitize training sites during supervised image classification,

and for accuracy assessment of the preferred unsupervised land cover/use maps.

Interviews were undertaken with purposely-selected 11 key informants. They included one elder in each of the eleven sub-counties identified using snowballing technique; district local government officials in charge of agriculture, natural resource management, environment, land and community development who had worked in the district for at least five years. The districts were Moroto, Napak, Kaabong, Kotido, and Amuria. Focus group discussions were conducted in the sub-counties where participatory mapping was undertaken, with 10 to 12 local people selected as in participatory mapping, who provided their perceptions of land use change trends and drivers. Key informant interviews and focus group discussions were used to generate data on traditional land uses that have occurred in the periods dating 0-10 (2010-2013), 10-20 (1994-2003), and 20-50 (1970s-1890s) years back and internal and external reasons for the perceived land use/cover change.

To further describe how land use/cover patterns have evolved since the 1980s, historical timelines and seasonal calendars techniques were used, with a set of participants selected as for Participatory mapping. A combined historical timelines and seasonal calendars were used to establish a qualitative description of trends of LULC in the 1980s, 1990s, 2000s and 2010s (current) and periods, cycles and patterns of LULC change for each calendar month, based on a perceived average trend for a calendar month in each decade. These tools were implemented with participants as described for FDGs. The procedure followed was a modified a method for seasonal and historical timelines described by CARE International (2009).

Qualitative data obtained were analyzed by coding and content analysis to obtain and list stated factors and main thematic descriptions of land use/cover change.

Determining land use/cover change and trend. In addition to community assessment of land use/cover change, satellite imageries were used for land-use/cover change detection. Four series of landsat images covering the period of 1984, 1994, 2003 and 2013 were used. The images for the study area (Table 1), with less than 20 percent cloud cover, were downloaded through Earth Explorer (http://earthexplorer.usgs.gov/) and Global Visualization (GLOVIS) (http://glovis.usgs.gov/) websites. Blue, Red and Green (B,R,G) band combinations were used as they distinguish soil from vegetation and discriminate vegetation slopes (Barsi *et al.,* 2014).

Image classification. The acquired images were prepared and processed to meet the specific needs of the study using Idrisi Selva and ArcGIS 10.3 software. This included: image stacking; sub-setting using operations of Idrisi Selva and unsupervised classification using the ISOCLUST operation in Idrisi Selva was performed on the three of the single band mosaics for up to eight or more spectoral classes. Supervised classification was also undertaken by defining regions of interest around areas of reference training sites identified during fieldwork. The classes were cultivated, grassland, bush land and woodland as well as a classes for cloud cover and cloud shadow. The land cover/use categories were identified based on 1996 land use map for Uganda (NBS, 2002).

The two classifications were then loaded imported into ArcGIS 10.3 and compared. The unsupervised classification, because of having several spectoral classes, was able to provide a better quality classification. Thus eight separable classes (small scale farming, grassland, bushland, woodland, wetland, built up, cloud and cloud shadow) were identified.

The other spectoral classes were aggregated into these eight whereby associated spectoral class was identified based on its digital reflectance number (DN) relative to known class, and neighbouring classes (Richards and Jia, 2006). Cloud cover and cloud shadow at every location on the map were aggregated to classes that they were observed to obscure, by editing in ArcGIS 10.3.

Preliminary land-use/cover maps were validated using ground reference data (X, Y coordinate points collected using a Global Positioning System (GPS) device, from areas that were accessible. This was done for 2013 land use/cover. Corresponding detailed field notes and still photos (such as on Plates 1) were also taken. A total of 93 points was picked using a GPS device. Validation of land cover/use classes for 1984, 1994, and 2003 maps was based on ancillary data (pre-classified images, google earth, and topographic maps) and communities' participatory mapping. In addition, 238 random points were generated using ArcGIS.3.. A combination of visual interpretation of which were obtained from the Department of Land Surveys and the Uganda Bureau of Statistics (UBOS), was applied to identify the land use/cover classes represented by the random points. Thus, a total of 331 points were used for accuracy assessment. Triangulation approach of using interviews and focus group discussions further helped validation of historical land cover/use. For example, areas north of Kotido town were stated as perpetually cultivated areas, while the forest above Kalapata sub-county, in Kaabong District was stated to have since the 1970's been a woodland (described as forest by the residents). Furthermore, claims by the study participants were crosschecked on topographic maps, for known locations.

In order to improve the classification accuracy and specificity of the land use/cover classification of the images, a post classification refinement was undertaken (Harris and Ventura, 1995). This involved visual analysis and comparison with topographic maps, data from participatory mapping, google earth and local knowledge of the catchment.

Change in land use/cover was established by cross comparing pairs of land use/cover maps for each of the periods of 1984-1994, 1994-2004; 2003-2013 and 1984-2013 using ArcGIS 10.3 Spatial analyst tool > Zonal, tabulate area, to generate land use change matrices for the pairs.

RESULTS AND DISCUSSION

The communities identified four traditional land uses in the catchment. These are grazing, cultivation, hunting, and settlement. The findings indicate that the four land use types still exist but with a shift towards crop cultivation more than in the past. The communities perceived settlements to have increased, hunting has reduced and a sedentary lifestyle now overrides the nomadism. The study participants identified seven causes of LULC change that included increase in rainfall, soil fertility, new agricultural technology, promotion of crop cultivation by government and Non-profit organisations, increase in agribusiness, rise in population, and return of peace in the sub-region.

There were six major land uses/cover in Lokere and Lokok Catchments over the 1984 to 2013 period: built-up areas, bushland, grassland, small scale farming (cropland), wetland and woodlands (Figure 1, Table 1). These are consistent with uses and land cover identified by similar studies carried out in the subregion (NBS, 2002; Egeru, 2014) and rangelands in eastern Africa (Tsegaye, *et al.,* 2010). Grassland, which covered the largest land area, from 43.64 percent in 1984 to 60.05 percent in 2013, was the most dominant land cover. Dominance of grassland in the Catchments are expected, as water shortage limits plants (woody and bush) growth in grassland rangelands (Balks and Zabowski, 2016).

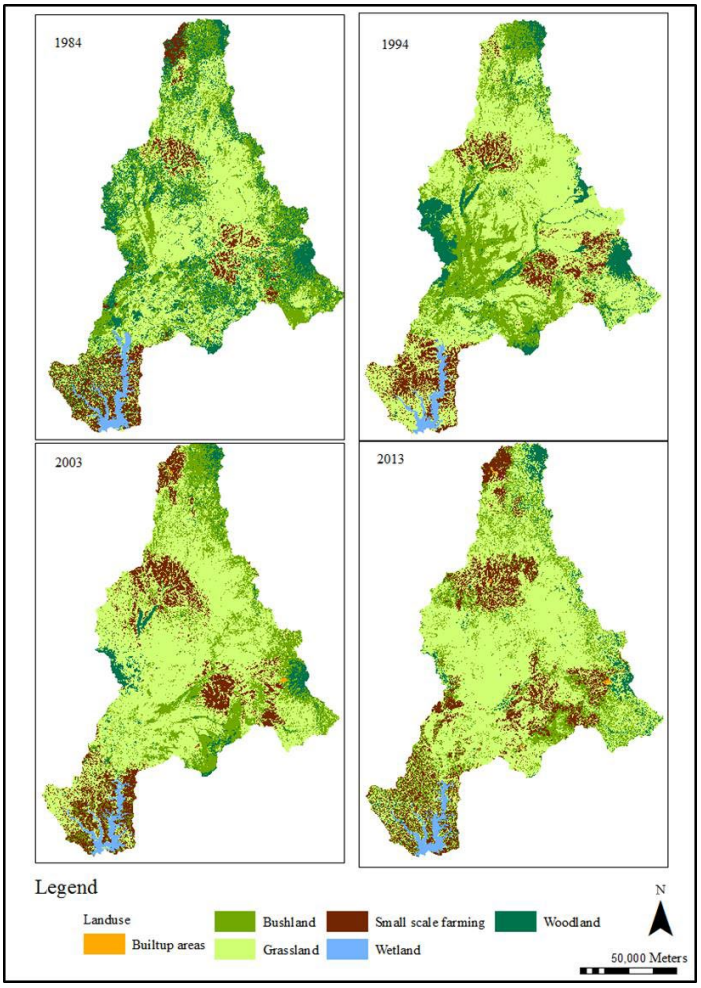

Figure 1. Land cover/use maps for the study areas of 1984, 1994, 2003 and 2013

Table 1. Areas under the different land cover/use during the study period

	1984		1994		2003		2013	
	Area	Percentage of total area	Area	Percentage of total area	Area	Percentage of total area	Area	Percentage of total area
Built-up areas	5.1	0.04	7.0	0.05	16.6	0.12	27.4	0.20
Bushland	3343.3	24.39	3053.7	22.28	2937.4	21.43	2414.1	17.59
Grassland	5981.3	43.64	7614.6	55.56	7962.1	58.10	8241.5	60.05
Small scale farming	1325.4	9.67	1370.1	10.00	1884.2	13.75	2153.0	15.69
Wetland	328.2	2.39	260.5	1.90	266.1	1.94	272.1	1.98
Woodland	2722.6	19.86	1398.1	10.20	637.9	4.65	616.4	4.49
Total	13705.8	100.00	13704.1	100.00	13704.2	100.00	13724.5	100.00

Table 2. Dynamics of land cover and use change from 1984 to 2013

Land use/ cover types 1984	Land use/cover types in 2013						
Land types	Built-up	Bushland	Grassland	Small scale farming	Wetland	Woodland	Total
Built-up areas	86.2	1.6	6.0	5.4	0.0	0.9	100
Bushland	0.1	22.3	58.3	12.8	0.4	6.0	100
Grassland	0.1	15.0	70.4	12.6	0.2	1.7	100
Small scale farming	0.5	13.8	34.6	47.4	2.2	1.4	100
Wetland	0.0	7.3	20.4	5.5	64.6	2.1	100
Woodland	0.2	20.7	56.5	11.9	0.2	10.5	100

The overall annual rate of increase of grassland from 1984 to 2013 was 2.1 percent, while the overall annual rate of loss of woodland between 1984 and 2013 was 2.6 percent, as 77.3 percent of woodland was lost (Table 2). Reduction in woodland in rangelands has been widespread in recent years. Baldi *et al.* (2013) found a declining trend of woody cover accompanied by lower and less stable productivity in the tropics and subtropics of in regions of Asia, Africa, Australia, and America. Tsegaye *et al.* (2010) reported a rapid reduction in woodland from 8.35% to 0.28% cover in the Northern Afar rangelands of Ethiopia between 1972 and 2007. Unlike in the present study, grassland also declined from 7.75% to 0.91% (Tsegaye *et al.,* 2010). Tsegaye *et al.* (2010) also reported that the proportion of bushland trebled, while the area of cultivated land increased eightfold (Tsegaye *et al.,* 2010). In the present study, bushland continually declined.

Built-up areas increased at a rate 14.7 percent over the 1984-2013 period but most of this increase occurred in the 1994 to 2003 period when it was at 15.1 per annum, probably because of the disarmament exercise between 2001 and 2002 (OPM, 2007) that forced pastoralists to move to settlement concentration areas. Nonetheless, the rates of growth of built-up areas established by this study are within the range of growth at the national level. From 1980 to 2015, Uganda's national urban population grew at an annual rate of between 2.56 percent in 1980 to 17.8 percent in 2006 (Nyakana *et al.,* 2007).

Small scale farming steadily rose from 9.67 percent area coverage in 1984 to 15.69 percent in 2013. The annual rate of increase during this period was 2.1 percent, however the highest rate of increase was experienced between 1994 and 2003 at 4.2 percent when 514.2 km^2 (37.53 percent) of the total area was converted to farm land. Increase in cropping in rangelands is now a widespread phenomenon. As reported by Rufino *et al.* (2013) a number of households in agro-pastoral systems of east Africa, particularly in locations with annual rainfall higher than 800 mm, were increasing their crop and diet diversity. This subsequently contributes to increased area of land under cultivation.

Woodland which retained 10.5 percent of its 1984 area, lost 56.5 percent to grassland in 2013, but only gained 1.7 percent of grassland. In the 1984 to 1994 period, much of the 48.65 percent decline in woodland was transformed into small scale farming land as 44.7 percent of 1984 woodland became small scale farming land in 1994, 27.3 percent became bushland, while 23.9 percent remained as woodland. Alongside cropping, felling of trees to burn charcoal is driving woodland loss (Egeru, 2014). The practice of charcoal burning has

a potential to degrade the catchments and threatens eastern Africa's rangelands. For example, Tsegaye *et al.* (2010), reported that charcoal and firewood commercialization was said to have been responsible for reduction in woodland in Ethiopian rangeland. The sale of firewood served as a major source of income for the rural households as way of coping with the effects of drought.

Bushlands and woodlands often retained the least area under the land uses, losing principally to grassland. Small scale farming gains from woodlands and bushlands was often lost to grassland. Clearance of woodlands and bushlands for cultivation appears to facilitate transitions to grassland, however, these areas are later re-cultivated for small scale farming. It is thus observed that, woodland, followed by bushland continually transformed into grassland, and small scale farming land, with reverse conversions only occurring minimally. Nakalembe *et al.* (2017) noted that in Karamoja (upstream of the catchment), over 55% of once cultivated land is left fallow due to lack of resources for agricultural inputs. It's therefore likely that woodland, bushlands or even grasslands when left for long periods may begin to regenerate.

The decline of wetlands from 1984 to 1994 is consistent with reports that wetlands in Uganda continued to decline from the colonial times, while the stability in wetland area in 2003 may have been due the government campaigns to conserve wetlands, with Government working closely with the local leaders and communities, in 2001, on the process of physical restoration of critical wetlands in the country (Aryamanya-Mugisha, 2011). Awoja wetland in Teso subregion where the Lokere and Lokok Catchments discharges into, was one of the beneficiaries of the physical restoration.

The progressive engagement of pastoralists in cropping is globally acknowledged as agriculture continues to expand into arid and semiarid environments (Rufino *et al.* 2013). This trend is indeed a result of several but similar factors. The communities indicated that sedentarisation policy following disarmament and protected kraals introduction is driving cropping. Sedentarisation has been seen as an approach adopted by policy makers to transform the mobile herders of Karamoja to "modern farmers" (Vidal, 2011). Elsewhere, Tsegaye *et al.* (2010) reported that increased sedentarization of pastoralists in Afar region and a high influx of migrants resulted in an expansion of cultivation in the alluvial plains.

McCabe *et al* (2010) found that, among the Maasai, the integration of agriculture into traditional partoralism was by some a move to reduce risk, while for others it was a reflection of changing cultural and social norms as influenced by power differentials among Maasai age sets and by government policies. This is consistent with the findings from the current study that NGO and government promotion, education and promotion of crop diversification by government and NGOs were promoting increasing small scale farm holding.

The view that sedenterisation of pastoralists would increase their productivity is not only held in Uganda. Blench (2001) reported that some interest groups, which included the official view in Nigeria, argued, "Pastoralists are inherently inefficient and self-destructive, and should be settled…" Such a policy, especially when it is spontaneous must be approached with caution as sedentarisation does not necessarily result in increased productivity and food security. The role of pastoralism as a livelihood strategy where the potential for crop cultivation is limited due to low and highly variable rainfall conditions, or extreme temperatures is well documented (Rota and Sperandini, 2009, Oxfam, 2008), and should be considered when

promoting livelihood diversification. However, upholding the view that pastoralism is a strategy sustainable production system is a challenge, given that many pastoralist communities are amongst the poorest in Africa (Oxfam, 2008). Oxfam (2008) explains that direct economic value (such as meat and milk) generated by pastoralists is not retained in their communities, and the indirect value (such as wildlife conservation and tourism) is un-rewarded and even unacknowledged by decision-makers. While there is need for pastoralists to adapt to the global and changing trends such as technologies, the skills pastoralists have learned over centuries of adapting to their harsh environments could be of huge value in the face of climate change. A means to enhance the direct and indirect benefits of pastoralism, often through enhancing household and community resilience, and increasing livelihood capacity and human capital ought to build on these skills.

CONCLUSION

There is substantial change in land use and cover in the Lokere and Lokok Catchments, driven by sedentarisation and the quest for alternative livelihoods rather than mobile herding, as government and non-state actors promote crop cultivation in the rangelands. Key changes include woodlands and bushlands conversion into small scale farmlands, with degradation of woodland and bushlands increasing grassland areas. Small scale farming could also be facilitating degradation of woodlands and bushlands. Land use and land cover changes are likely to continue as population and settlement increases, a trend that has been illustrated by increase in the built-up areas. Loss of woodland area, bushland, and degradation of land has the potential to make worse the inherent water shortage in the Lokere and Lokok Catchments and Karamoja in general, with likely adverse impacts on livelihoods. There is therefore need for the Central and local governments, as well as non-state actors in the catchments' areas to regulate land use and land cover LULC change through formulation of land use policies, participatory land use planning and involvement of the communities in sustainable land management practices.

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STATEMENT OF NO-CONFLICT OF INTEREST

The authors declare that there is no conflict of interest in this paper.

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