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Research Application Summary

Impacts of land cover changes on soil quality and the distribution/composition of pasture grasses species in Enkushin Micro Catchment, Kajiado County, Kenya

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Abstract

Land cover changes have profound effects on production systems in arid and semi-arid lands (ASALS). Often these changes results in land degradation in form of soil erosion and overgrazing of pastures. This study evaluated the impact of land cover changes in Enkushin micro-catchment in Kajiado for a period of 25 years (1993 to 2018) on soil quality indicators and the composition and distribution of pasture grasses species. A stratified random sampling was carried out using geographical information system (GIS) and remote sensing tools for different land cover classes of the area. Soil samples were collected at 0-25 cm, 25-50 cm and 50-75 cm depth from six land cover classes: wooded bushed grassland (WBG), riverine woodland (RW), bushed grassland (BG), wooded bush land (WB), wooded dense bush land (WDB) and bush land (B). These samples were analyzed for soil quality indicators; pH, bulk density (BD), saturated hydraulic conductivity (HC), total organic carbon (TOC), texture, cation exchange capacity (CEC), and for composition and distribution of grass species using soil seed bank germination method of soil samples at 0-5 cm depth. Data obtained were analyzed using XLSTAT 2018 version for ANOVA and frequency of occurrence in different land cover classes. Results showed significant difference in CEC, BD, increase in silt/clay ratio indicating soil erosion, reduction of soil organic carbon stocks and dominance of grasses associated with degraded pasture lands (Eragrostis Tremula and Sporoborus grasses spp.) in most of the land cover classes. We conclude that current pasture management and stocking density is not sustainable. And mitigation measures such as ex-closure and reseeding are needed to restore the degraded lands.

Key words; Kajaido County, Kenya, land degradation, land Use Land Cover, overgrazing, pasture grasses

Résumé

Les modifications du couvert végétal ont des effets remarquables sur les systèmes de production dans les terres arides et semi-arides (ASALS). Souvent, ces changements entraînent une dégradation des terres sous forme d'érosion des sols et de surpâturage. Cette étude a évalué l'impact des changements du couvert végétal dans le micro-bassin d'Enkushin à Kajiado couvrant une période de 25 ans (1993 à 2018) sur les indicateurs de la qualité des sols et la composition et distribution des espèces de graminées pâturées. Un échantillonnage aléatoire stratifié a été réalisé à l'aide d'un système d'information géographique (SIG) et des outils de télédétection pour différentes classes de couvert végétal de la zone. Des échantillons de sol ont été prélevés à 0-25 cm, 25-50 cm et 50-75 cm de profondeur dans six classes de couvert végétal : prairies buissonnantes boisées (WBG), forêts fluviales (RW), prairies buissonnantes (BG), savane boisées, les savanes denses boisées (WDB) et les savanes (B). Ces échantillons ont été analysés pour les indicateurs de qualité du sol ; pH, densité apparente (BD), conductivité hydraulique saturée (HC), carbone organique total (COT), texture, capacité d'échange cationique (CEC) et pour la composition et la distribution des espèces de graminées à l'aide de la méthode de germination de la banque de graines du sol contenue dans les échantillons de sol prélevés à 0 -5 cm de profondeur. Les données collectées ont fait l'objet de calcul de fréquence d'occurrence dans les différentes classes de couvert végétal et ont été soumises à une analyses de variance (ANOVA) dans le logiciel XLSTAT 2018. Les résultats ont montré une différence significative dans la CEC, la BD, une augmentation du rapport limon/argile indiquant l'érosion du sol, la réduction des stocks de carbone organique du sol et la dominance des graminées associées aux pâturages dégradés (Eragrostis Tremula et Sporoborus grasses spp.) dans la plupart des classes de couvert végétal. Nous pouvons donc conclure que la gestion actuelle des pâturages et la densité des peuplements ne sont pas durables. Et des mesures d'atténuation telles que la réalsiation des exclos et le resemis/reboisement sont nécessaires pour restaurer les terres dégradées.

Mots clés: Comté de Kajaido, Kenya, dégradation des terres, utilisation et occupation des terres, surpâturage, herbes pâturées

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Background

Land use and land cover (LULC) changes are widespread and accelerate significant processes driven by human actions but also produce changes that impact humans. These changes alter the availability and quality of different biophysical resources and often lead to the deterioration of the rangeland (Macharia and Ekaya, 2005). In arid and semi-arid lands (ASALs), common LULC changes are caused by deforestation and overgrazing by livestock. These LULC changes have raised concerns about the environmental sustainability of feedstock in ASALs (Ashworth *et al*., 2015). Overgrazing often leads to soil compaction and loss of forage species resulting in lack of adequate ground cover. Also, overgrazing promotes the increase in undesirable herbaceous plant species and bush encroachment, which are all indicators of rangeland degradation (Katjiua and Ward, 2007). Grazing not only affects nutrient dynamics but also water fluxes and microbial diversity and population (Assmann *et al*., 2014). Soil organic carbon (SOC) quantity and quality are crucial to soil quality. Soil organic carbon (SOC) is one of the principal indicators of sustainability and soil quality, given its influence on many soil properties(Salvo *et al*., 2010). However, knowledge on the effects of land use change on soil carbon storage in ASALS is lacking (Gelaw *et al*., 2014) . Consequently, carbon comparisons of vegetation-land use effects on SOC reservoirs and their vertical distribution over depth, using paired situations under similar environmental conditions, are scarce (Berhongaray *et al*., 2013).

In Kenya, ASALs cover over 88% of the country's landmass. These areas are dominated by pastoralists where livestock production is the dominant production system. However, due to increasing human population in highlands, ASALs have experienced unplanned human settlements which often results in land degradation. Factors associated with this degradation include unsuitable farming practices for drylands, sedentary lifestyles that interfere with cultural practices of most pastoralists, overgrazing, and loss of biodiversity and soil erosion. Enkushin in Kajiado County in Kenya is a semi-arid area characterized by agro-pastoralist systems with key emphasis on livestock production. This land use system is suitable for such environment, however, the cultural belief of ‘the more cattle you have the more rich you are’ among the pastoral community has led to overstocking (Anderson and Grove, 1987). The high livestock density and increase in human settlement has led to soil erosion and deforestation of pasture land. Overgrazing is exacerbated by frequency and lengths of droughts in ASALs leading to livestock mortality (Manyeki *et al*., 2015). Hence, the current pastoral system in ASALs has failed to supply adequate quality grass for fodder and cover against soil erosion. Tanui *et al*. (2015), identified vegetation cover changes using GIS and remote sensing tools, however, these changes did not include measurements of changes in soil qualities, distribution and composition of pasture grasses. The objective of this study was to quantify the effects of LULC changes on the soil quality parameters, and distribution and composition of grasses over 25 year period under different LULC classes in Enkushin micro-catchment in Kajiado County, Kenya.

Methods

Study area description. The study was conducted in the rangelands of Kedong valley in Enkushin Sub-Location in Ngong Sub-County of Kajiado County covering an area of 58.87 square kilometers. The sub-location borders Mt. Suswa conservancy to the west and Nakuru County to the north. The sub-location covers an approximate area of 8,988.9 ha and is located between longitudes 36^o21’E and 36 32’E, latitudes 1 06’S and 1 11’S. The altitude ranges from 1,443 m.a.s.l. and increases westwards towards Mt. Suswa to 2,272 m.a.s.l.The area falls under agro-climatic zone V which is classified as semi-arid (Sombroek *et al*., 1982) and is characterized by a hot and dry climate. The average annual rainfall ranges from 450 mm to 660 mm. The area experiences a bimodal pattern of rainfall of which the “long rains” fall from March to May and the “short rains” from October to December. The “long rains” are more reliable and its failure greatly affects the rangeland’s productivity. The annual mean temperature in the area ranges from 15^0C in the Eastern Rift valley Escarpment to 21^o C in the Mt. Suswa area (Sombroek *et al*., 1982). Approximately 80 % of the soils are very shallow to moderately deep, friable, rocky and stony sandy clay loam while 20. % are moderately deep to deep, friable, gravelly sandy clay loam to gravelly clay/clay texture, and in places very shallow to shallow soils with rock outcrops (Kamoni *et al.*, 2015)

Research design. Stratified sampling was conducted in six major LULC classes of the area (Table 1) as identified by Tanui *et al*. (2015). The six LULC were identified to have undergone changes from 1993-2015 using satellite imagery analysis and GIS tools with most changes induced by human settlement and introduction of agro-pastoral production system in the area.

Table 1. Land cover/land change (LULC) classification

Land cover classes	Description
Wooded bushed grassland (WBG)	These are areas with grasses (>50%), trees (<20% cover) and shrubs (<20%).
Riverine woodland (RW)	Areas along the river valleys covered by trees and shrubs.
Bushed grassland (BG)	These are areas dominated by grasses and herbs (>60%) and some shrubs (<30% cover).
Wooded bushland (WB)	These are areas dominated by shrubs with a tree cover of <20%.
Wooded dense bushland (WDB)	Areas dominated by shrubs (less than 70% and more than 50%) with some trees less than 20%.
Bushland (B)	Areas characterized by woody vegetation generally less than 6m tall

Source: Tanui *et al*. (2015)

Soil sampling and analysis. Random cluster points in each LULC class were generated using geographical information system (GIS) and the generated points loaded to Garmin, Geographical position system (GPS). Using the GPS, selected random points were tracked in the field and located. At each point, soil was sampled from 0-5 cm and 5-25 cm using soil auger, core rings and shovel. Samples for laboratory analysis were air dried and sieved using 2mm gauge sieve. Soil pH in 1:2.5 soil /water mixture was determine using pH Meter and CEC, exchangeable cations were extracted using 0.001M ammonia acetate and thereafter analyzed using atomic absorption spectrophotometer. Total organic carbon (TOC) was analyzed using Walkely Black method while bulk dencity (BD) and HC were analysed using standard laboratory methods. Soil texture was analyzed using hydrometer method. In summary, soils were analyzed for texture, silt/clay ratio, pH, CEC, TOC, BD and N .To determine composition and distribution of grass species, soil samples collected from 0-5 cm depth were transferred to 5 litres plastic plant pots in a green house and arranged according to respective LULC class. These plant pots were then supplied with same amount of water (300 ml) every three days for germination of seeds. The germinated plants were then allowed to grow and mature for 45 days for identification purpose. The different grass types were identified, counted and composition recorded per plant pot and LULC class. To determine the contribution of LULC on soil organic carbon storage in active rhizosphere zones, samples collected at 25-50 cm and 50-75 cm depth soil samples were also analyzed for TOC measurements.

Identification of grass species and composition. After 45 days, all germinated grasses in each plant pots were Identified, counted and frequency of occurrence of each grass specie in plant pot and LULC determined using Equation 1, where
Equation 1: frequency = (total number of identified grass specie/ total number of all grass species) in specific LULC * 100%

Distribution of each identified grass specie in the six LULC was measured by the number of counts of stands in each LULC and the dominant grass species selected using frequency of occurrence and simple comparison made in all LULC classes. Statistical analysis using analysis of variance at 95% confidence level and means separated using least significant difference (LSD) for soil parameters. Livestock characteristics of the area was collected using a structured questionnaire.

Results

Total organic carbon, silt, sand, silt/clay ratio, CEC, exchangeable calcium and exchangeable sodium percentage were found to be significantly different in the land cover classes of the area (Table 2).

Table 2. Variation of soil quality parameters across the different land cover/land use classes

LULC Type	*CEC (me %)	*BD (g/cm^3)	*Sand (%)	*Silt/Clay ratio	% N	pH
Bush grassland (BG)	13.20	1.12	64.57	1.95	0.11	6.99
Bush land (B)	17.52	1.19	58.40	1.11	0.10	6.62
Riverine woodland (RW)	13.53	1.20	67.33	0.92	0.12	6.85
Wooded bush grassland (WBG)	22.27	1.14	58.00	2.72	0.09	8.03
Wooded bush land (WB)	12.34	0.92	51.33	0.76	0.10	6.61
Wooded dense bush land (WDB)	10.00	1.36	69.27	1.20	0.11	7.10

CEC= cation exchange capacity; BD= bulk dencity

Stability of soil aggregates. The silt/clay ratio between the different LULC were found to be significantly different (p=0.045). The results showed that BG, WBG and WDB to have a positive silt/clay ratio indicating stability of the soil structure in relation to soil erosion (Table 2). Negative correlation of silt/clay ratio was observed in B, RW and WB LULC indicating low soil aggregate stability and proneness to soil erosion. Field observation in B, RW and WB LULC showed presence of human settlement, grazing fields, surface sealing and evidence of sheet and gully erosion.

Total organic carbon and nitrogen. All the LULC had low TOC (Table 3) and were composed of sandy/clay texture. The difference in TOC was not significant in all the soil depth measured. However, there were observed differences between different LULC. The RW LULC had the highest 50-75 cm TOC. This level of TOC in RW in relation to other LULC indicates accumulation of eroded soil and organic matter over time. Limitation of soil depth was observed in elevated LULC such as WBG and WDB as these landscapes are dominated by shallow soils with >20% rock outcrops. In all the LULC, nitrogen was low with most soils having total nitrogen of < 0.1 % (Table 2).

Table 3. Mean percentage of total organic carbon of each land use land cover at different soil depth

	% TOC		
LULC type	**0-25 cm**	**25-50 cm**	**50-75 cm**
BG	0.77	0.84	0.53
B	0.97	0.79	0.82
RW	0.69	0.73	0.89
WBG	0.73	0.70	0.70
WB	0.80	0.65	Limited*
WDB	1.04	Limited*	Limited*

*Limited soil depth. No observed significant difference in all LULC.

Composition and distribution of grasses in the different land use land cover frequency. Eight grass species were found to dominate the area (Table 4). The frequency of occurrence and composition of grass types, was in the following order; *Sporoborus* spp> *Scirpus* spp> *Chloris pycnothrix* spp > *Eragrostis* spp (Table 4). The rest of the germinated grasses such *Tragus Berteronianus, Paspalidium germinatum, Panicum* spp and *Dactylotenium aegyptium* were limited to a few LULC. These grasses were distributed in an area whose livestock characteristics are as indicated in Table 5. The results showed that most of the cattle were grazed in RW, BG and WB while shoats (goats and sheep) prefer B, WBG and WDG LULC areas for browsing and grazing.

Discussion

Pastures are associated with environmental sustainability and productivity because they present a significant potential to mitigate soil degradation processes and to recover its productive capacity (Salvo *et al*., 2010). It is well documented that conversion of grassland to cropland or the reverse generally causes a loss or gain of soil C (Mudge *et al*., 2011). Loss of SOC shown in Table 2 in all the LULC implies reduction of soil nutrients reserves, decline in cation exchange capacity, and hindering formation of well-aggregated soil structural elements and consequently reduction of soil water holding capacity (De Ridder and van Keulen, 1990). These results further indicate that recovery of degraded landscape would need to incorporate readily available organic fertilizer source such as farm yard manure available in cattle Bomas (kraals) and appropriate grasses that are tolerant to low fertility. The selected grasses should be able to improve TOC from root activity, develop bio pores, improve aggregate stability and greater carbon sequestration and enhance wetting–drying cycles though controlled extraction of water by perennial grasses (Schwartz *et al*., 2003) . The observed TOC values could form a basis of designing best bet rehabilitation strategy that improve SOC stocks.

Table 4: Grass species identified in green house plant pots

Grass Specie Type	Total no. of stands	Frequency of Occurrence (%)	Distribution in LULC class
Tragus Berteronianus	8	2.53	WB,B,RW,WBG
Sporoborus Cordofanus	105	33.23	WB, RW, B,BG
Scirpus spp	73	23.10	WB, WBG, RW,B, BG
Paspalidium germinatum	1	<0.1	WDB
Panicum spp	7	2.22	WB, WBG
Eragrostis Tremula	41	12.97	WB, WBG, RW,B, BG
Eragrostis Tenuifolia	10	3.16	B, WB
Dactylotenicon Aegytium	7	2.22	WB, WBG
Chloris pycnothrix spp	64	20.25	WB, WBG, RW,B, BG

Table 5: Mean Livestock characteristics in sampled land use land cover types

LULC Type	Land size (ha)	Cattle size	Cattle/ha	Shoats size	Shoats/ha
BG	179.9	240	1.33	299	1.66
B	226.7	170	0.75	460	2.03
RW	321.2	375	1.17	567	1.77
WBG	20.2	27	1.34	77	3.81
WB	274.1	248	0.90	447	1.63
WDB	24.3	20	0.82	80	3.29

The occurrence of low soil fertility in most LULC imply that the current efforts to increase more arable land for crop production may not be feasible without adequate soil fertility management and are likely to result in more land degradation. Intensification of crop production in fragile ecosystem such as Enkushin could displace large numbers of smallholders and pastoralists to remote drier areas where they could exacerbate existing land degradation through over grazing (Grainger, 2014). Results in Table 5 show a higher stocking rate of 1 to 1.34/ha than the long-term estimated carrying capacity of agro-climatic zones V and VI of Kajiado district, that ranges from 3 and 7 ha per 250 kg TLU (Manyeki *et al*., 2015). New groundbreaking research shows that cattle numbers are stagnating and that flocks (shoats) are expandind at an unprecedented scale. It is argued that the risks posed by increased numbers of sheep and goats have not been adequately recognized, since sheep and goat management bypasses the traditional approaches to thinking and governing land (Løvschal *et al*., 2018). This implies that current stocking rate of livestock need to be reduced to cope with the land use changes occurring in the area. Rotational grazing together with reduced stocking rates should be part of the efforts towards restoration of degraded lands.

Savanna grasslands are characterized by high spatial heterogeneity in vegetation structure, aboveground biomass and nutritional quality, with high quality short-grass grazing lawns forming mosaics with patches of tall bunch grasses of lower quality (Veldhuis *et al*., 2016). However, diversity and distribution of important palatable grass species have been lost due to excess grazing and aridity of the area. As such the observed dominant grass species (Table 3) have been associated with degraded pasture land. Therefore, efforts for recovery should include reseeding with lost grass species that have economic value in terms of outputs, costs of production and profit to attract wide farmers' adoption (Manyeki *et al*., 2015). In elevated areas, vegetative measures involving hedgerows and grasses could be included as they are cost-effective, durable and find people's acceptance since they offer multiple benefits such as providing fodder and fuel wood and thus, reducing deforestation in woodland (Lenka *et al*., 2012).

Conclusion and recommendations

The results of this study showed that there exist land degradation in form of soil quality and grass species degradation and that the current management practices of intensive grazing has led to land degradation. Appropriate conservation practices such as rotational grazing, reseeding with known pasture grasses of economic value to livestock keeper and erosion control using hedge rows, tree planting and ex-closure of severe degraded LULC such as B, BG and WBG can reverse land degradation in Enkushin. We recommend the use of known grasses such as *Cenchrus ciliaris, Chloris roxbohurghiana, Enteropogon macrostachyus* and *Eragrostis superba* that have shown promising results in ASALs in Kenya.

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