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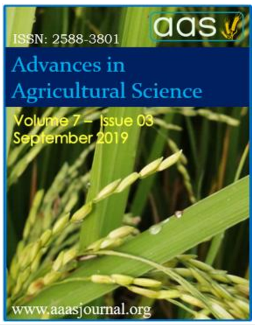

Research Article Open Access

Influence of Vegetation Cover and Topographic Position on Water Infiltration, Organic Matter Content and Aggregate Stability of Grassland Soils in Semi-Arid Kenya

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ABSTRACT

A study was conducted in Mpala and Ilmotiok ranches in Laikipia County, Kenya, to investigate the influence of vegetation cover and topographic position on soil organic matter, bulk density, aggregate stability and water infiltration rate. Three vegetation cover types; (Tree, Grass and Bare) and four topographic positions (Hillslope, Headwater, Riparian, and Plateau) were evaluated. Soil samples were collected along the topographic positions and within the vegetation cover types at five levels of depth; 0-10, 10-20, 20-30, 30-40, 40-50 cm during the dry season May to August 2016. The samples were analyzed for soil organic matter, bulk density and soil aggregate stability. Water infiltration rate was measured in situ on the soil surface using a mini-disk Infiltrometer. Soil aggregate stability varied significantly between topographic zones ($p=0.0124$) but not between the vegetation cover types and soil depth in Ilmotiok site. Mpala site showed a significant difference in aggregate stability between the topographic zones ($p=0.0152$). However, no significant difference was observed in variation of aggregate stability between the vegetation cover types and soil depth ($p=0.8998$; $p=0.8284$) respectively. In Ilmotiok site, the highest infiltration rate was recorded in the Tree covered fields (73.3 mm/hr) and decreased in Grass fields and Bare grounds at 25 and 17 mm/hr, respectively. The Headwater zones had the highest infiltration rates (73.3 mm/hr) while the lowest infiltration rates were (0 mm/hr) in the Hillslope zones. The infiltration rates in Mpala site were highest in Bare grounds (37.8 mm/hr) and lowest in Tree fields with 5.7 mm/hr. The Headwater zones had the highest infiltration rates followed by Hillslope zones with (8.9 mm/hr) while the Riparian zones had the lowest infiltration rates (0.00 mm/hr). Soil organic matter (SOM) differed significantly at P (<0.0001) among the vegetation cover types, topographic zones and soil depth for both sites. In Ilmotiok site, the mean soil organic matter was highest (1.96%) in Hillslopes zones and lowest in Grass covered fields (0.30%). In Mpala, SOM content was highest in Tree covered fields at 2.28%, and lowest in Grass covered fields at 0.38%, for RIP and PLA zones respectively. Topographic positions and grazing management influenced soil properties in the semi-arid grasslands, hence the need for strategies in grazing management that will promote restoration of these degraded areas.

Grazing, the most common use of grasslands, can influence ground cover, plant community structure, litter accumulation can negatively affect soil properties and nutrient cycling within the plant-soil system (Frank *et al.,* 1995). The most obvious change that occur due to uncontrolled grazing, especially on the topsoil, is an increase in soil compactio, a decrease in aggregate stability and infiltration rates, and a reduction in soil organic matter (SOM) and thus soil-inherent nutrient supply (Snyman and Du Preez, 2005). Two main mechanisms are responsible for this: firstly, trampling of the animals compact the soil and increase bulk density and secondly, grazing reduces and alters plant cover and botanical composition and therewith the biogeochemical cycling of nutrients. Animal grazing can also alter nutrient cycling within ecosystems by the interactions between plants and the soil (Wei *et al*., 2011). The long term effects of animal trampling on soil chemical, physical and microbiological properties, and the interaction between soil nutrients and vegetation are profound and need to be understood (Tessema *et al*., 2011).

The importance of soil organic matter on key soil functions is well known (Johnston *et al.*, 2009), and its correlated with productivity, and defines soil fertility and stability (Herrick and Wander, 1998). Consequently, loss of SOM is considered a major threat to sustained soil functions (Amundson *et al*., 2015). However, topographic-induced changes in the soil micro-environment often lead to changes in plant communities (Sebastia, 2004), which can determine organic matter quality and carbon cycling.

The functions of SOM relate to the soil structure and soil water content which is an important hydraulic property related to size and number of pore spaces (Tuller and Or, 2004). Therefore, these soil properties are interconnected, as emphasized by Meskini *et al*., (2014) who showed that the mineral composition and pore network geometry of many soils are different and that these can affect soil water retention.

Similarly, several authorities have proposed that soil stability (e.g., water-stable aggregates) is a critical indicator of grassland ecosystem processes (Six and Paustian, 2014). In addition, soil aggregation protects organic matter (Von Lutzow *et al*., 2006) and supports soil fertility since it reduces soil erosion and mediates soil aeration, water infiltration rates, and water holding capacity (Oades, 1984). Consequently, soils exposed to human impact or compacted by livestock are often stripped of organic-rich upper horizons, thereby increasing bulk density and reducing infiltration rates (Li and Shao, 2006). Few studies have investigated topographic and grazing management effects on soil properties especially in semi-arid grasslands in Kenya. This study was designed and conducted to investigate soil properties; soil organic matter, soil aggregate stability, bulk density and water infiltration rate in semi-arid grasslands as influenced by vegetation cover and topographic positions. The study was aimed at collecting data that would form a basis for best grazing land management strategies that would ensure conservation of grassland soils and improvement of livelihoods in Laikipia County, Kenya.

Methods

Description of the study sites

The study was carried out in Laikipia county, Kenya in two sites Mpala and Ilmotiok ranches which have varying grazing management systems. Mpala is a private commercial ranch which is fenced and protected and incorporates wildlife conservation with controlled livestock grazing. Ilmotiok is a group ranch occupied by pastoral communities who practice open uncontrolled grazing of livestock herds including cows, goats, sheep and camel. The two ranches in Laikipia county are located in agro-ecological zone (AEZ) IV with rainfall ranges of 400 mm to 800 mm annually (Sombrek *et al*., 1982). The rains are bimodal with long rains occurring between March to May while the short rains fall in October to November (Figure 1).

Mean monthly maximum temperature ranges from 23 to 28^{0}C, while minimum temperature ranges from 9 to 17^{0}C with July and August being the coldest and windiest months (Sombrek *et al*., 1982). Altitude range of the sampling sites in Mpala was between 1627to 1686 meters above sea level while in Ilmotiok the sampling ranged were located between altitude 1638 to 1661 meters above sea level.

The common vegetation comprises of drought tolerant trees and grass species largely classified as grassland, bushland, woodland and dry forest. The soils in the study area are generally classified as Ferric and Chromic Luvisols (red sandy loams) and Pellic Vertisols (black cotton soils), Sombrek *et al*., (1982).

Field Selection Methods

A reconnaissance field survey was carried out using transect walks and vegetation assessment to establish representative study sites on the basis of the level of vegetation cover and topographic position. Sampling fields were located on an area encompassing 4 km radius for each site whereby a topographic transect differentiated by the position in the grassland (Plateau, Hillslope, Headwater and Riparian) were identified. The level of vegetation cover was identified as Tree cover, Grass cover and Bare ground which are further described in Table 1.

The topographic setting of the study sites is described in Table 2. The upper zone comprising of the Hillslope and Headwater zones has moderate to high slope and is majorly covered by woody vegetation. The Plateau zones are located in the gentler slopes and are covered by grass and woody vegetation. The Riparian zones are depositional areas located at the lower plains consisting of tree and woody vegetation and wet soils.

In each topographic transect, three fields of size 200m x 150m were delineated based on vegetation cover: (1) Tree cover (fields with more than 50% trees or shrubs (2) Grass cover (fields with natural grass species and moderate grazing) and (3) Bare ground (fields with sparse grass vegetation or open grounds reflecting degradation after several years of intensive grazing). Similar vegetation cover types located within 50 m from each other in the same topographic transect were identified as replicates provided soil conditions were the same and the soil showed low heterogeneity.

Soil sampling was carried out in a 3 × 3 m subplot from the soil depths 0-10, 10-20, 20-30, 30-40, and 40-50 cm using a 5cm diameter soil auger. Water infiltration measurements were taken at two positions in each sampling field in the dry season of 2016. This resulted in two observations per replication, hence four measurements per sampling field. Bulk density and infiltration sample sites were selected to ensure that similar level of vegetation cover and uniformity of topographic positions were obtained. Undisturbed core ring samples were used for determination of bulk density based on methods described by Blake and Hartge (1986). Infiltration rate of soil was measured in situ, using a mini disk Infiltrometer as detailed by Zhang (1997). In brief, the starting water volume was recorded. At time zero, the Infiltrometer was placed on the surface,

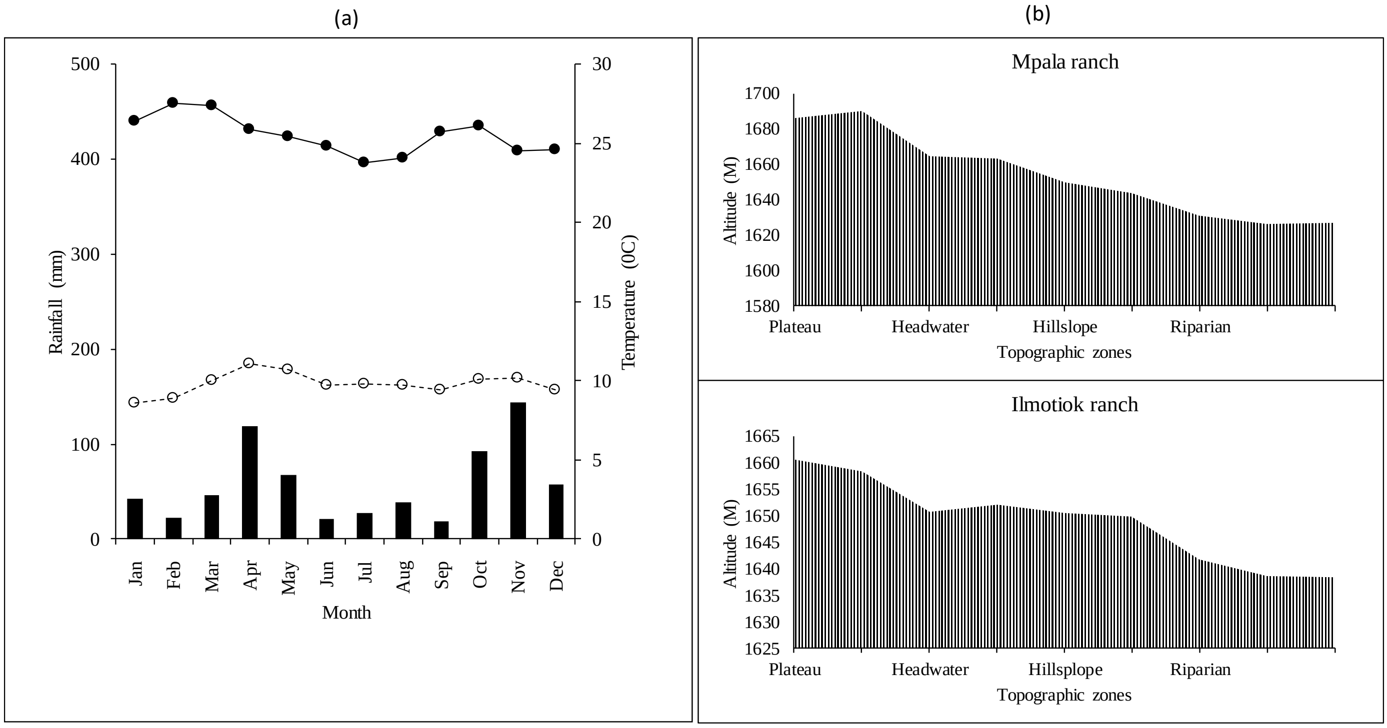

Figure 1. Map showing **(a)** Monthly rainfall (mm) shown as bars, minimum (O) and maximum (●) air temperature (^{0}C) for Laikipia County and (b) topographic orientation of the study sites. Rainfall and temperature data are based on 10-year average. Map adopted from Kibet *et al*., (2016)**;** sampling positions adopted with modifications from KEFRI- NASPEER project.

Table 1. Description of the sampling units within the selected topographic positions in the study areas (Mpala and Ilmotiok)

Vegetation cover	Land use description	Land use history	Main vegetation type
Tree cover	Grassland vegetation moderately disturbed by grazing and human activity, with tree canopy coverage near 50%	No use during the past 10 years	Tree dominated by acacia species; *Acacia drepanolobium*
Grass cover	Grass vegetation grass with 40-70 % canopy cover	Moderate grazing during the past 10 years	Grass dominated by *Themeda triandra*, *C. dactylon*. *Cynodon*
Bare ground	Areas left to regenerate after extended period of grazing	Intensive grazing during the past 10 years	Few species of grass *Penisetum kikuyiensis*

assuring that it made solid contact with the soil surface. The volume was recorded at regular time intervals as the water infiltrated into the soil. The time interval was 30 minutes between readings for a cumulative period of 2.5 hours. The cumulative infiltration vs. time was measured and the results were fitted with the function:

$$I = C_1t + C_2\sqrt{t}$$

Where:

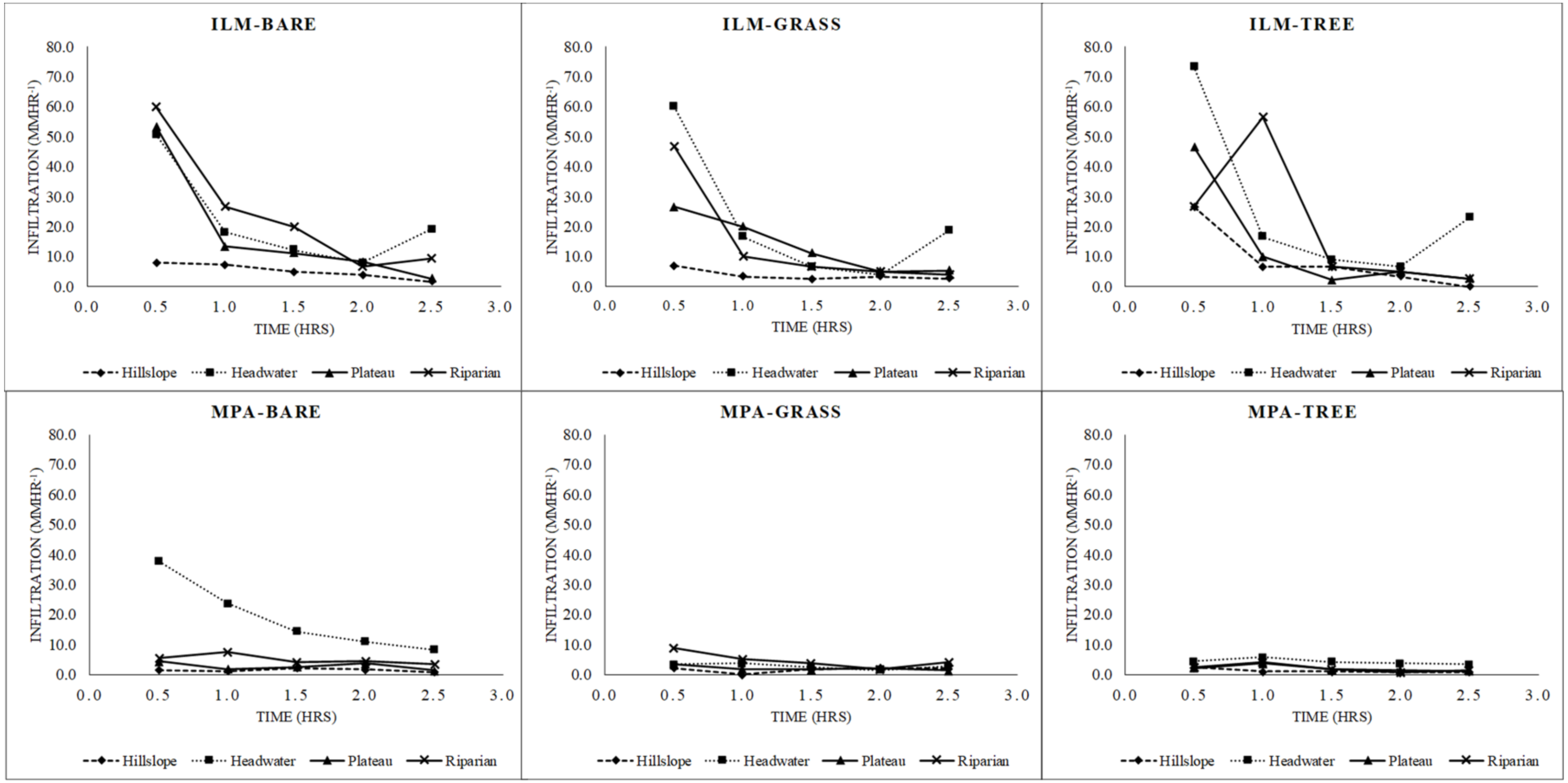

Figure 2. Effect of vegetation cover and topographic position on water infiltration rate in two semi-arid grasslands (Ilmotiok and Mpala) in Laikipia Kenya. Hillslope, Headwater, Plateau and Riparian refer to topographic positions of the sample point while Tree, Grass and Bare refer to vegetation cover types. MPA: Mpala ranch, ILM: Ilmotiok ranch

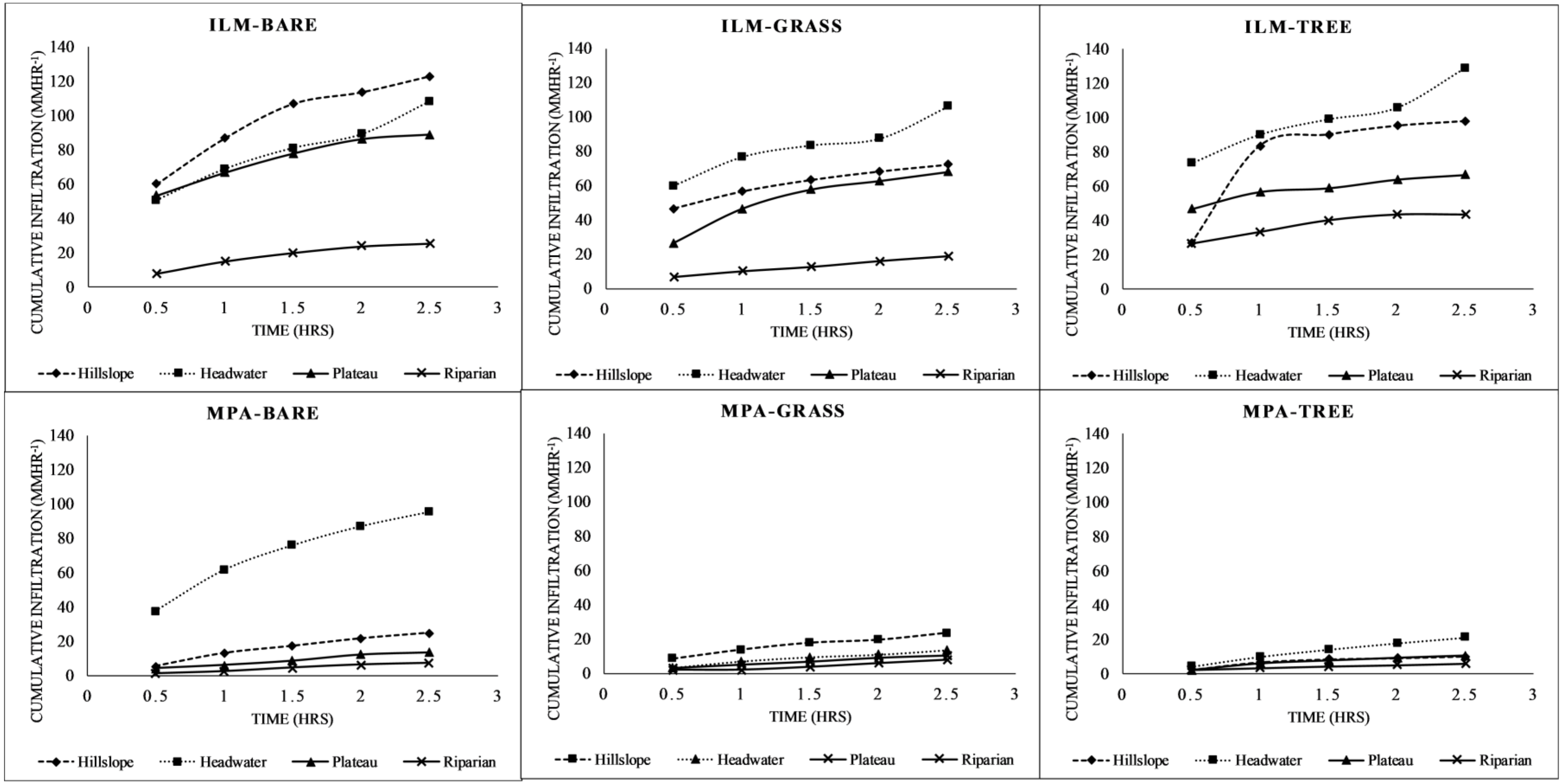

Figure 3. Cumulative infiltration rate as affected by vegetation cover types and topographic zones in Ilmotiok and Mpala sites, Laikipia county. Hillslope, Headwater, Plateau and Riparian refer to topographic positions of the sample point while Tree, Grass and Bare refer to the vegetation cover types. MPA: Mpala ranch, ILM: Ilmotiok ranch

I = infiltration rate,

C_1 (ms^{-1}) and C_2 ($ms^{-1/2}$) are soil parameters. C_1 is related to hydraulic conductivity, and C_2 is related to soil sorptivity.

Water infiltration data were used to assess the relative effects of vegetation cover on the soils ability to retain moisture.

Laboratory Methods

Disturbed soil samples were air-dried, ground and sieved to pass through a 2 mm sieve for subsequent analysis in the laboratory. Particle size distribution was determined by hydrometer method (Day,1965) after dispersing soil with sodium hexametaphosphate. Textural classes were determined using the USDA textural triangle (USDA, 1975). Organic carbon was determined by Walkley Black wet oxidation method (Nelson and Sommers, 1982) while soil organic matter (SOM) was calculated by multiplying soil organic carbon (SOC) with a factor of 1.724 according to Pribyl, (2010). Soil aggregate stability was determined by wet-sieving method as described by Six *et al*., (2002).

Statistical analysis

Data on soil parameters was subjected to two-way Anova separately for each site to test for significant differences in the variation of water infiltration rate, soil organic matter, bulk density and soil aggregate stability across the soil vegetation covers and topographic zones. A multiple comparison test was done to isolate the significant differences in water infiltration rates, organic matter, bulk density and soil aggregate stability between each of the vegetation cover types and topographic zones. Statistical tests were considered significant at the level of $P < 0.05$ unless otherwise stated.

Results

Soil texture variations were observed in the two study sites and across the topographic positions (Table 3). Mpala soils had a generally higher clay content than Ilmotiok soils. Grass covered fields in Ilmotiok site, had sandy clay loam soils across the topographic zones, while Bare grounds and Tree covered fields had sandy loam soils in the top 0-20 cm depth. In Mpala, Headwater and Plateau zones had similar textural classes across the three vegetation covers (sandy loam), while in Riparian zones, Grass and Tree cover fields had mostly clay soils, and Bare grounds had sandy loams.

Water infiltration rate as influenced by vegetation cover and topographic positions

Water infiltration rate differed significantly among the topographic zones ($P<0.05$) in the two study sites but there was no significant difference among the vegetation covers in Ilmotiok site (Table 4). In Ilmotiok site, the highest infiltration rate was recorded in the Tree covered fields (73.3 mm/hr) and decreased in Grass fields and Bare grounds at 25 and 17 mm/hr, respectively. The Headwater zones had the highest infiltration rates (73.3 mm/hr) followed by Riparian and Hillslope zones (60 mm/hr) while the lowest infiltration rate of (0 mm/hr) was recorded in the Tree covered fields in the Hillslope zones (Figure 2).

Mpala site had slightly lower infiltration rates across the vegetation cover types compared to Ilmotiok site. The infiltration rates ranged between 0.9-37.8 mm/hr in Bare ground; 0.0-8.9 and 0.7-5.7 mm/hr in Grass and Tree vegetation cover types respectively (Figure 2). The Headwater zones had the highest infiltration rates in Bare grounds (37.8 mm/hr) followed by Hillslope zones with (8.9 mm/hr) in Grass covered fields while the Riparian zones had the lowest infiltration rates in Grass fields (0.00 mm/hr).

Cumulative infiltration in Ilmotiok site ranged from 26.7-128.7 mm/hr; 7.9-122.7 mm/hr and 6.9-106.2 mm/hr in Tree fields, Bare grounds and Grass fields

Table 2. Description of the Topographical positions in the two study sites (Mpala and Ilmotiok)

Topographic Zones	Slope (%)	Dominant soil texture	Vegetation cover	Surface characteristics
Hillslope (HS)	>10	Sandy-silt loams, gravel and stones	High coverage of bare grounds	Gravel and stones, erosion features, removal of top soil
Headwater (HW)	5-10	Sandy clay soils,	High grass vegetation cover and medium tree/woody vegetation cover	Medium bare ground areas
Plateau (PLA),	<5	Sandy Loam soils.	Medium grass and tree/woody vegetation cover	Medium bare ground areas
Riparian (RIP)	<2	Sandy clay, Wet soils,	High coverage by tree/woody vegetation, high canopy shade cover	Deposited soil materials from upstream

Table 3. Particle size distribution and soil textural classes of the surface horizon in Ilmotiok and Mpala study sites

			Particle size			
			Sand (%)	Clay(%)	Silt (%)	Textural class (0-20cm depth)
Ilmotiok	Hillslope	Bare	82	10	8	Loamy sand
		Grass	59	28	13	Sandy clay loam
		Tree	73	17	10	Sandy loam
	Headwater	Bare	72	21	8	Sandy clay loam
		Grass	69	23	8	Sandy clay loam
		Tree	70	18	12	Sandy loam
	Riparian	Bare	79	16	5	Sandy loam
		Grass	63	28	10	Sandy clay loam
		Tree	80	14	6	Sandy loam
	Plateau	Bare	80	10	8	Sandy loam
		Grass	69	23	8	Sandy clay loam
		Tree	69	19	13	Sandy loam
Mpala	Hillslope	Bare	69	20	11	Sandy clay loam
		Grass	81	12	6	Sandy loam
		Tree	79	12	10	Sandy loam
	Headwater	Bare	78	11	11	Sandy loam
		Grass	77	13	10	Sandy loam
		Tree	69	14	17	Sandy loam
	Riparian	Bare	76	16	8	Sandy loam
		Grass	13	76	11	Clay
		Tree	38	43	18	Clay
	Plateau	Bare	80	10	8	Sandy loam
		Grass	67	14	17	Sandy loam
		Tree	79	12	10	Sandy loam

Table 4. Anova table showing the significant differences for mean soil organic matter, aggregate stability and water infiltration rate and Bulk density between topographic zones, vegetation cover types and soil depth.

		Ilmotiok ranch			Mpala ranch		
Soil parameter	F value	TZ	VC	Soil depth	TZ	VC	Soil depth
Soil organic matter	F Value	*17.51*	17.77	115.60	22.62	17.13	133.12
	Pr > F	*<.0001*	<.0001	<.0001	<.0001	0.0031	<.0001
Aggregate stability	F Value	4.01	1.33	0.99	3.83	0.11	0.37
	Pr>F	*0.0124*	*0.2726*	*0.4227*	*0.0152*	*0.8998*	*0.8284*
Infiltration rate	F Value	*7.45*	*0.87*	*23.02*	*7.25*	*6.20*	*1.51*
	Pr>F	*0.0003*	*0.4260*	<.0001	*0.0004*	*0.0039*	*0.2147*
Bulk density	F Value	*20.85*	*1.44*	*18.57*	*11.32*	*1.77*	*11.64*
	Pr>F	<.0001	*0.2472*	<.0001	<.0001	*0.1816*	<.0001

Legend: TZ: Topographical zones (Hillslope, Headwater, Riparian, and Plateau); VC: Vegetation cover types (Grass, Tree and Bare covered fields). Soil depth: 0-10, 10-20, 20-30, 30-40, 40-50 cm.

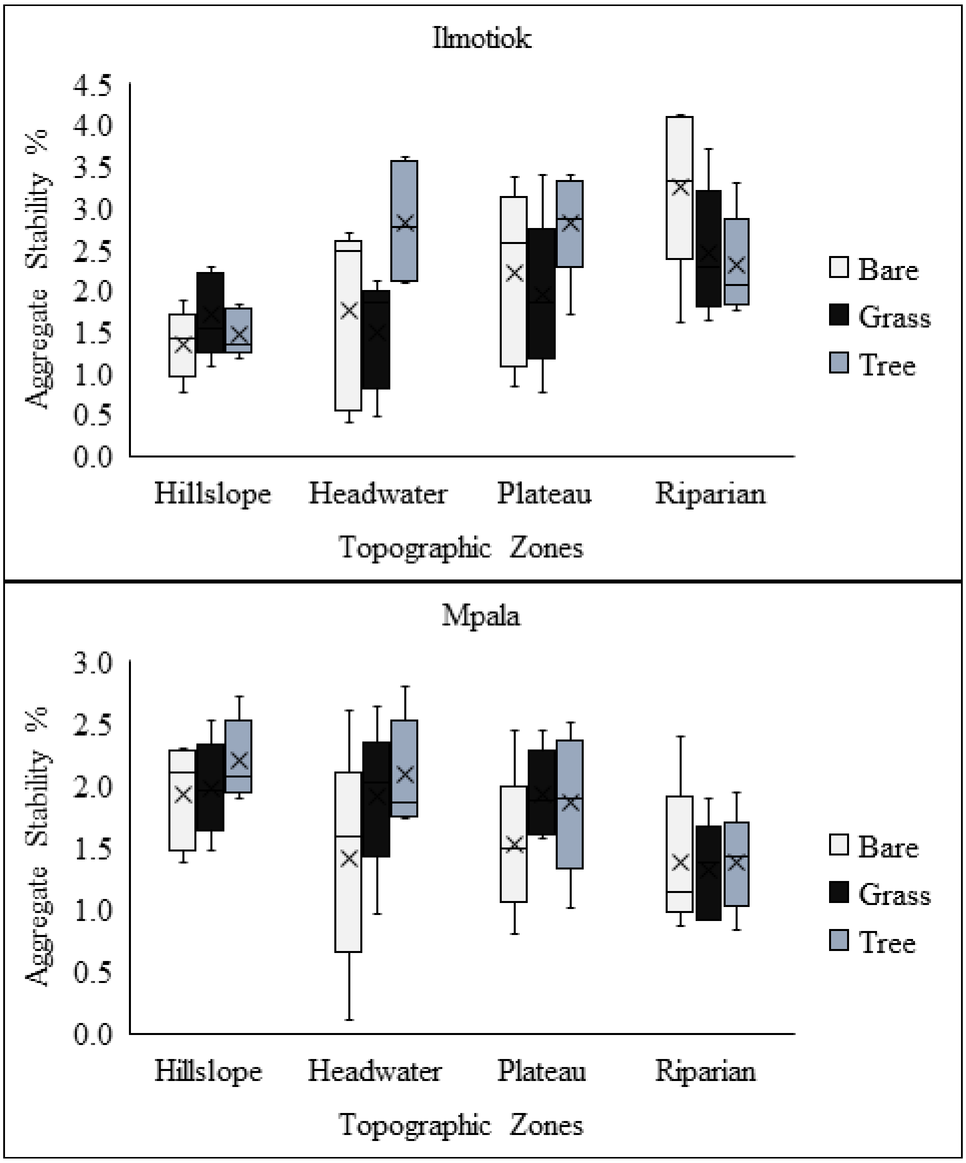

Figure 4. Ranges of soil aggregate stability for Ilmotiok and Mpala study sites as influenced by vegetation cover, topographic positions and soil depth. The box and whisker diagrams include the range of the samples (the upper and lower quantile), the median (cross bar) and the minimum and maximum values (extreme of the lines).

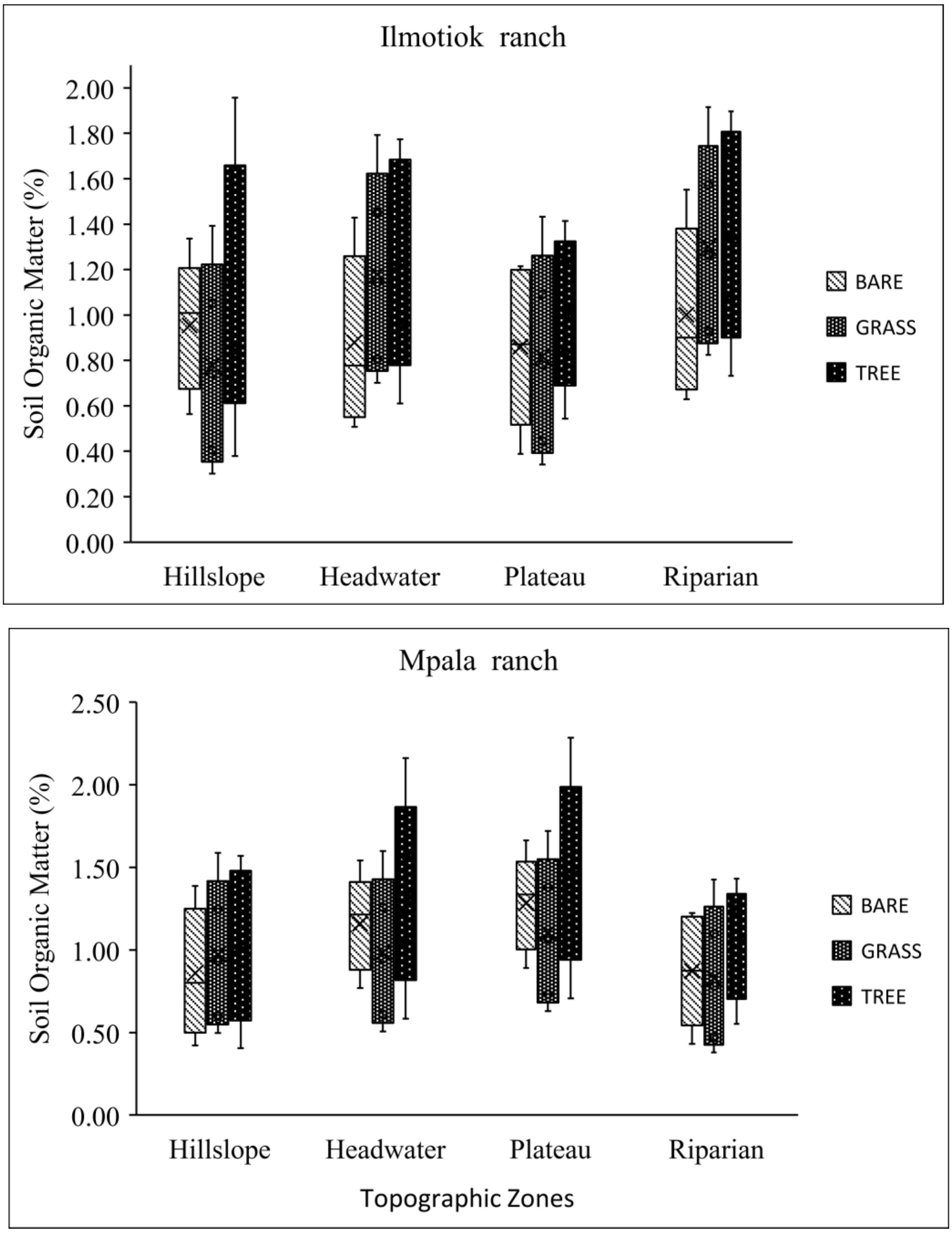

Figure 5. Ranges of soil organic matter for Ilmotiok and Mpala study sites as influenced by vegetation cover, topographic positions and soil depth. The box and whisker diagrams include the range of the samples (the upper and lower quantile), the median (cross bar) and the minimum and maximum values (extreme of the lines).

respectively. The highest (128.7 mm/hr) and lowest cumulative infiltration (6.9 m/hr) occurred in Headwater zones after 2.5 hours. In Mpala ranch, Bare grounds recorded a cumulative infiltration of 1.5-95.5 mm/hr; Grass fields 2.2-23.7mm/hr and Tree fields 2.2-21.3 mm/hr. Headwater zones had the highest cumulative infiltration (95.5 mm/hr) while Riparian zones recorded the lowest rates (1.5 mm/hr) in Mpala site (Figure 3).

Soil aggregate stability as influenced by vegetation cover, topographic positions and soil depth

Soil aggregate stability varied significantly (P<0.05) between topographic zones in the two study areas (Table 4). Soil aggregate stability in Ilmotiok site was significantly higher and ranged from 0.4-4.1%, 0.5-3.7% and 1.2-3.6% in Bare grounds, Grass and Tree vegetation covers respectively across the topographic zones. Mpala site had lower aggregate stability which ranged between 0.1-3.7-%, 0.9-2.6% and 0.8-2.8% for Bare grounds, Grass and Tree covered fields across the topographic zones (Figure 4).

Riparian zones showed high aggregate stability while Hillslope and Headwater zones recorded low aggregate stability across the vegetation cover types, in Ilmotiok site. The trend was different for Mpala site with Hillslope zones recording the highest aggregate stability and Riparian zones the lowest in Bare grounds, Grass and Tree covered fields respectively (Figure 4).

Soil aggregate stability fluctuated with soil depth, whereby 0-10 cm depth had the lowest aggregate stability across the vegetation covers in the study sites. In Ilmotiok site, aggregate stability for 0-10 cm depth in Bare grounds ranged from 1.4-2.7 % while Grass and Tree covered fields had 0.8-2.7 % and 1.2-2.5 % respectively. In this site, Riparian and Headwater zones had the highest aggregate stability of 2.7 % in Bare grounds and Grass fields while Plateau zones had the lowest at 0.8 % respectively.

In Mpala site, the soil aggregate stability of the top soil depth (0-10 cm) ranged between 0.8-1.6 %; 1.9-2.1 %; 1.9-2.8 % in Bare grounds, Grass and Tree covered fields respectively, with the highest aggregate stability recorded in Headwater zones and the lowest in Plateau zones.

Soil organic matter as influenced by soil vegetation cover and topographic positions

The mean soil organic matter (SOM) differed significantly at P (<0.05) among the vegetation cover types, topographic zones and soil depth for both Ilmotiok and Mpala sites (Table 4). In Ilmotiok site, the mean SOM was highest (1.96%) in Hillslope zones and lowest in Grass covered fields (0.30%). In Mpala, SOM content was highest in Tree covered fields at 2.28%, and lowest in Grass covered fields at 0.38%, for Riparian and Plateau zones respectively (Figure 5). Tree covered fields had the highest organic matter at the top 0-10cm soil depth of 1.96 %, Grass covered fields had intermediate levels of 1.92 % while Bare grounds had the lowest organic matter of 1.55 %, in Hillslope and Riparian zones in Ilmotiok site respectively. A similar trend was observed in Mpala ranch, with Tree fields recording the highest SOM content of 2.28 %, Grass fields had 1.72 % and Bare grounds 1.66 % in Riparian zones respectively.

Soil bulk density as influenced by vegetation covers and topographic positions

Soil bulk density varied significantly across the topographic zones and soil depth (P<0.05) in Mpala and Ilmotiok sites (Table 4). However, no significant differences were observed across the vegetation covers *P=0.2472* and *P=0.01816* in Ilmotiok and Mpala respectively. Soil bulk density (BD) in Ilmotiok site was highest in Grass cover fields with 1.02 g/cm^3 and lowest in Bare grounds with 0.76g/cm^3 in Hillslope and Riparian zones respectively. In Mpala, the highest bulk density was in Bare grounds with 1.07 g/cm^3, and the lowest in Grass covered fields with 0.73 g/cm^3 in Headwater and Plateau zones respectively (Figure 6).

Discussion

Water infiltration rate as influenced by vegetation covers and topographic positioning

As has been largely documented in grassland ecosystems, the type and spatial distribution of vegetation influence the soil surface characteristics and infiltration (Van Schaik, 2009; Castellano and Valone 2007). This is evidenced by the findings from this study where Bare grounds recorded lower

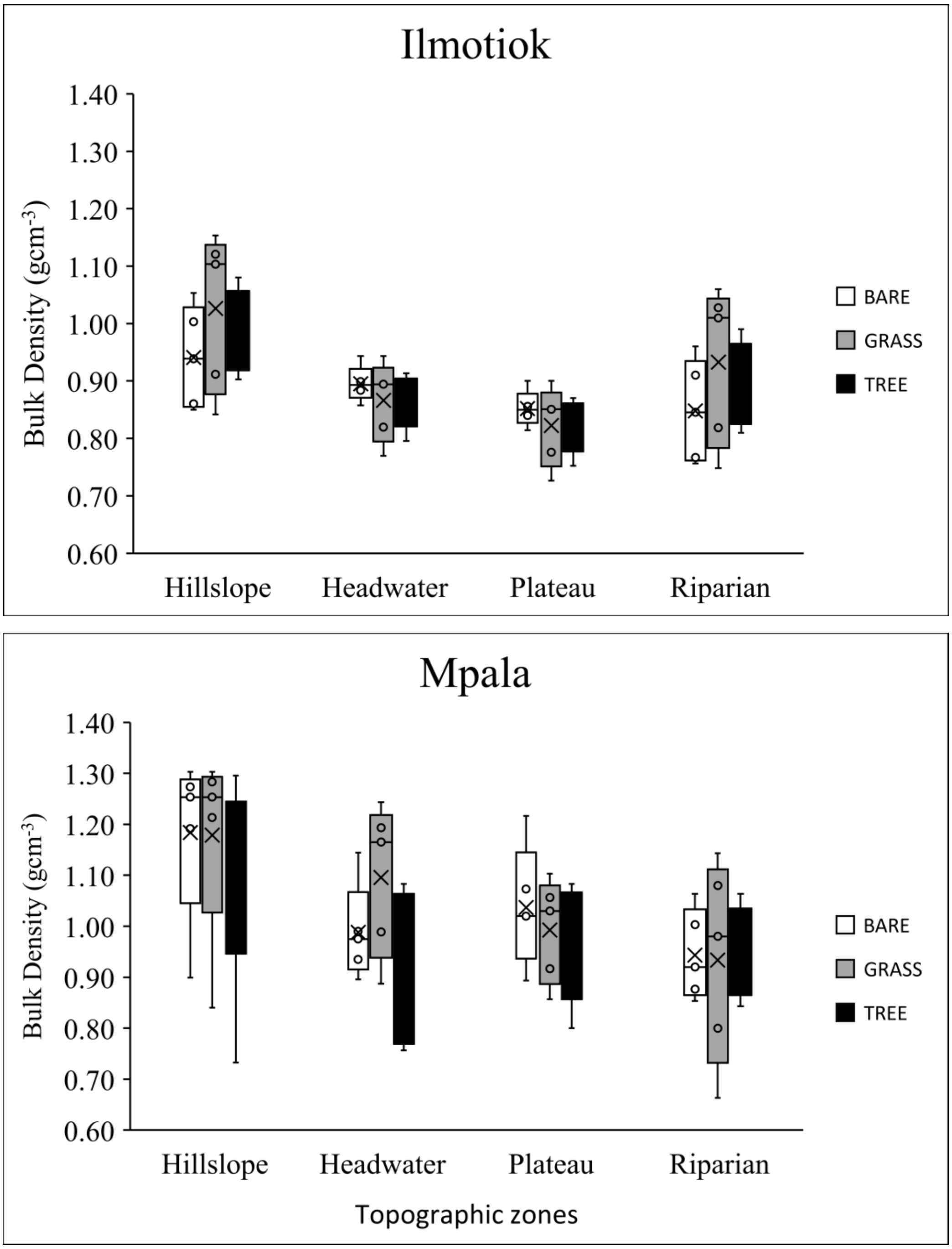

Figure 6. Ranges of soil Bulk density for Ilmotiok and Mpala study sites as influenced by vegetation cover, topographic positions and soil depth. The box and whisker diagrams include the range of the samples (the upper and lower quantile), the median (cross bar) and the minimum and maximum values (extreme of the lines).

infiltration rates compared to vegetated areas (Tree and Grass fields) (Figure 2). Our findings revealed differences in infiltration rates partly due to loss of vegetation attributed to land use practices such as grazing which resulted to progressively lower levels of soil infiltration. This is in agreement with several researchers (Huang *et al*., 2010; Zehetner and Miller, 2006; Pirastru *et al*., 2013) who reported stable infiltration rates in grass covered fields which was higher compare to bare soil. They further noted that changes in land use affects the structural and hydro physical properties of soil.

The low infiltration rates in Bare grounds can further be explained by soil compaction caused by animal trampling and movement as indicated by Thurow *et al*., (1988) that animals compress the soil with their hooves hence reduce infiltration rate. This has been reiterated by Castellano *et al*., (2007) in their studies, which showed that low water infiltration rates in degraded grasslands relative to enclosed/protected sites were due to the high soil compaction induced by the grazing livestock. Soil compaction is related to changes in soil bulk density, which has been linked to alter soil infiltration rate (USDA-NRCS, 2001). Therefore, the changes in bulk density may have contributed to the differences in infiltration rates.

Soil texture variability resulting from different topographic positioning of the sampling sites was associated with different infiltration rates (Table 4), which can be related to the particle size distribution of the soil. For instance, the highest infiltration rate in Hillslope zones might be associated to the high sand content while lower infiltration rates in the Riparian zones can be attributed to the high clay content. The fact is, coarse textured soils have higher macro pores than fine textured soil thereby increasing infiltration rate (Clemmens,1983) while soils enriched in clay content (Bouza *et al*., 2007) are associated with lower soil infiltration rate.

Soil aggregate stability as influenced by vegetation covers and topographic positioning

The root system of grasses is more intense and dense thus holds the soil aggregates together, through exertion of drying effect on soil particles, and excretion of organic substances that act as binding glue. Perennial grasses are generally associated with high microbial biomass and carbohydrate production which also stimulates micro aggregation (Gale *et al*., 2000). However, this was not the case in our findings. Instead, Grass and Tree cover fields showed lower levels of water-stable aggregates compared to Bare grounds. This phenomenon can be explained by Peres *et al*., (2013) and Ayoubi *et al*., (2012) who noted that plant species may affect aggregate stability and binding agents, such as fungal hyphae and plant roots stabilize large aggregates but are temporary and unstable. The Tree cover fields had slightly more stable aggregates than Grass fields, which can be associated to the quantity of plant litter fall and its subsequent decomposition found which are vital factors in the formation and stabilization of aggregates (Blanco-Canqui and Lal, 2004). Also, Chaudhary *et al*., (2009) identified positive relationships between measures of soil stability and plant cover which could explain the stable aggregates in Tree cover fields.

Influence of vegetation cover and topographic position on soil organic matter

The study findings revealed that Grass and Tree covered fields stored more soil organic matter than Bare grounds in both sites probably because Grass and Tree covered areas generated more plant litter than Bare grounds, and a larger proportion of it was returned to the soil through litter fall. Further, vegetation plays a significant role in controlling the soil physical and chemical properties, which in turn determine the plant composition (Dunkerley, 2002; Ludwig *et al*., 2005). The Bare grounds may have resulted from prolonged heavy continuous grazing and increased soil erosion that reduces productivity of the semi-arid lands by depleting most of the vegetation cover and soil organic pools (Ritchie *et al*., 2012). Therefore, the low SOM content observed in Bare grounds and in Ilmotiok ranch compared to Mpala ranch can be attributed to continuous heavy grazing which changes both the above-ground litter deposition and below-ground carbon allocation (Derner *et al.*, 2006). Accordingly, Sanjari *et al*., (2008) pointed out that a relative increase in soil organic matter under time-controlled grazing as opposed to continuous grazing was attributed to higher rates of grass growth and rest periods that led to an increase in litter accumulation and subsequent increase of extra 1.37 ton/ha carbon in the top 10 cm of the soil under time rotational grazing compared with the continuous grazing.

Riparian zones recorded the highest SOM content compared to Hillslope, Plateau and Headwater zones. This relates to the study by Wiaux *et al*., (2014) who showed that organic carbon stocks on the foot slope were 2.5 times higher than other slope positions along an eroding hill slope situated on cropland in Belgium. Hancock *et al*., (2010) found similar results in an undisturbed environment in Australia. These authors noted that higher SOC content is likely to relate to a higher above-ground biomass on the lower slope positions. This has been emphasized by Berhe *et al*., (2008) who determined that at erosional positions along the hill slope, soil organic carbon and nutrient content are typically lower and soil thickness is reduced compared to depositional positions. Further, fine soil particle proportions of silt and clay in the Riparian zones may have contributed to the high SOM contents. This is in agreement with Yang *et al*., (2008) who showed that SOC density increases significantly with clay and silt content. Thus particles tend to stabilize and retain more organic matter than coarser particle (Gregorich *et al*., 1994).

Mpala ranch had higher SOM contents than Ilmotiok ranch which is can be associated with the minimum livestock impact and grazing disturbance (Tuffour *et al.*, 2014) and loafing (Wang and Batkhishig, 2014) due to short duration grazing that gives maximum rest to the grazed area. Also, the high soil bulk densities in Ilmotiok ranch conditioned by lower SOM contents could probably be a result of soil compaction due to continuous grazing (Wolf, 2011). Accordingly, Igwe, (2005) found that continuously grazed areas exhibited higher bulk density than areas under moderate grazing in south eastern Nigeria.

Finally, several researchers have modeled the relationship between organic matter and bulk density of soils and showed a strong correlation between them. For instance, Sakin *et al*., (2011) determined the strongest correlation between bulk densities and organic matter among the data attained from the analysis results.

Conclusion

It is evident from the study that vegetation and topography influence soil physical, chemical and biological properties. The relationship between SOM, aggregate stability, bulk density and infiltration rates with one other might influence the general functioning of the soil to support plant productivity. In addition, uncontrolled grazing regimes and topography of the landscape contribute to soil degradation processes such as erosion and runoff, leading to decline in soil fertility and grassland productivity. However, the study recommends further research on the dynamics of soil water movement in degraded soils in the semi-arid regions, to inform on the soil water requirements of such areas. Grassland soils have the potential to store more organic matter content and release nutrients that will promote rejuvenation of grassland vegetation for biodiversity conservation and improvement of livelihoods.

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