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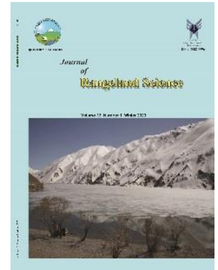

Research and Full Length Article:

Greenhouse Gas Emissions as Impacted by Topography and Vegetation Cover in Wooded Grasslands of Laikipia County, Kenya

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Received on: 24/12/2020
Accepted on: 01/12/2021
DOI: 10.30495/RS.2023.686655

Abstract: Global climate change has been linked to the increase in greenhouse gas (GHG) emissions. Wooded grasslands refer to an understudied landscape contributing an unknown quantity of GHGs to global climate change. The objective of this study was to determine the effects of topography and vegetation cover on carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) fluxes. The study was carried out in Ilmotiok community ranch, Laikipia County. An *in situ* experiment was done during the January, February, March and April of 2017. Randomized complete block design (RCBD) with split plot arrangement was used main plots topographical zones (TZ) (mid-slope (MS), foot slope (FS), and toe slope (TS)) and subplots vegetation cover (VC) (tree (T), grass (G) and bare (B)). Static chamber frames were installed for the three VC (T, G and B) in three TZ (MS, FS, and TS). GHGs were measured every 7-10 days from January, February, March and April between 8 and 12 hr local time. Sampling was done after fitting the lid at time zero (T0), 10 minutes (T1), 20 minutes (T2) and 30 minutes (T3). During the rainy season, CH_4N_2O and CO_2 fluxes were significantly higher than the dry season. Methane fluxes ranged from -0.32 to 0.24 $mg.m^{-2}.h^{-1}$ with the lowest (-0.32 $mg.m^{-2}.h^{-1}$) recorded under TS*T whereas CO_2 was highest under TS*G (47 $mg.m^{-2}.h^{-1}$) as compared to MS*G (19 $mg.m^{-2}.h^{-1}$). TZ*VC significantly influence N_2O with MS*B recording the lowest (0.008) as compared to TS*B (2.228 $mg.m^{-2}.h^{-1}$). CO_2, N_2O and CH_4 emissions were low in January and February and it increased in March and April in all the TZ*VC. From the study results, soil greenhouse gas emissions were significantly increased by topography and vegetation cover. Topography and vegetation cover primarily control the patterns of soil N_2O, CO_2 and CH_4 fluxes, therefore, topography and vegetation features must be explicitly included in the predictions of the responses of soil GHGs emissions.

Key words: Climate change, Greenhouse gas fluxes, Methane, Nitrous oxide, Topography, Vegetation cover

Introduction

Global warming is caused by increased atmospheric concentrations of the greenhouse gases (GHGs) carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4).Terrestrial ecosystems are important sources and sinks for these GHGs, produced and consumed through biological processes including photosynthesis, decomposition, nitrification, denitrification, methanogenesis, and CH_4 oxidation (IPCC, 2013). Soils are the dominating source of atmospheric CO_2 and N_2O (Butterbach-Bahl *et al*., 2013). Soil is a key producer of the atmospheric greenhouse gases (GHGs) carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4), as well as a sink in many circumstances (Oertel *et al*., 2016). However, livestock part contributes about 15% of worldwide greenhouse gas emissions (Gerber *et al*., 2013), and consequently escalates land degradation, environmental pollution, and decline in biodiversity (Bellarby *et al*., 2013). Studies in Kenya have revealed 115 significant differences in soil GHG emissions in diverse savanna ecosystems as a function of land-use (Ondier *et al*., 2019) and management activities (K'Otuto *et al*. 2013), emphasizing the relevance of savannas in the regional C balance. Therefore, there is challenge in maintaining a balance between productivity, household food security, and environmental preservation (Wright *et al*., 2012).

The magnitude of soil N_2O and CO_2 emissions in these semi-arid rangelands vary considerably across spatial and temporal scales (Butterbach-Bahl *et al*., 2013). Soil CO_2, CH_4 and N_2O fluxes differ considerably as it is driven by biological processes, ecological conditions, non-uniformity of soil properties (Butterbach-Bahl *et al.*, 2013). Our understanding of GHG emissions from African soils is limited due to a lack of good soil GHG emission data from wild savanna and crops (Hickman *et al*., 2014; Valentini *et al*., 2014).

Although many studies have quantified the variability of CH_4 fluxes, they often covered large spatial extents which captured significant environmental gradients at those scales, but sampling locations were generally sparse (Teh *et al*., 2014). The smaller-scale patterns of CH_4 fluxes within these landscapes have not been investigated thoroughly at ecosystem scale gradients, which could be problematic if those patterns are important for estimating GHGs fluxes (Nicolini *et al*., 2013). Similarly, momentous effort on the study of carbon dioxide (CO_2) fluxes in a multiple of varied biomes using both chamber measurements and eddy covariance approaches has been done (Allaire *et al*., 2012) but there is a considerable uncertainty in the estimates of GHGs emissions from soils.

Therefore, practical methods are needed to quantify soil GHG fluxes in order to better understand magnitudes, spatial and temporal variability of soil-atmosphere trace-gas exchange (Allaire *et al*., 2012). Research studies integrating topographic inconsistency into ecological scale predictions of *in situ* chamber flux measurements of numerous GHGs are scarce (Merbold and Wohlfahrt 2012). Understanding topography and vegetation cover effects on soil GHG fluxes remains difficult due to the high spatial-temporal variations of fluxes in wooded grasslands. Therefore, a study was carried out to determine greenhouse gas (carbon dioxide, nitrous oxide and methane) fluxes as influenced by topography and vegetation cover types in wooded grasslands of Laikipia County, Kenya.

Materials and Methods

Study area

Laikipia County lies across the Equator between latitude (00°17′ S) and (00°45′ N) and longitude 36.015°E and 37.020° E (Fig.

1). Within an area of 9500 km^2 from the wider 56,000 Km^2 Ewaso Ecosystem extending from Mt. Kenya slopes of (5199 m) in the South East to the edge of the Great Rift Valley in the West. The study site Il Motiok Group Ranches (GR) is one of the 11 GRs in the region, lying in the northernmost part of the county. These covers approximately 3,651 ha west it boarders Mpala and Soita Nyiro private ranches, northward is Koija GR, eastward is Tie Mamut GR and southwards is Mukogodo private ranch (Ojwang *et al*., 2010).

The elevation ranges from 1,550 to 1,700 m, with gentle undulating terrain scarps (Lalampa *et al*., 2016). It lies between two major rivers, permanent river Ewaso Nyiro and seasonal river Losupukiai. The two largely impact ranch usefulness with wet season grazing taking place towards Losupukiai and dry season towards Ewaso Nyiro River due to access to permanent water.

Laikipia County experiences a weak bimodal rainfall pattern with the long rain expected in April– May while the short rains come in August and October (Lalampa *et al*., 2016) the study fell in the dry (January), intermediate (February) and rainy season (March and April). The rain is nevertheless extremely variable and might fall any other time within the year. The annual rainfall for the study site varies between 300 mm to 750 mm (Lalampa *et al*., 2016). Il motiok is within the Laikipia Plateau with imperfectly drained gray to black clay-vertisols and planosols and expanding into the lowland comprising of metamorphic rocks of gneisses.

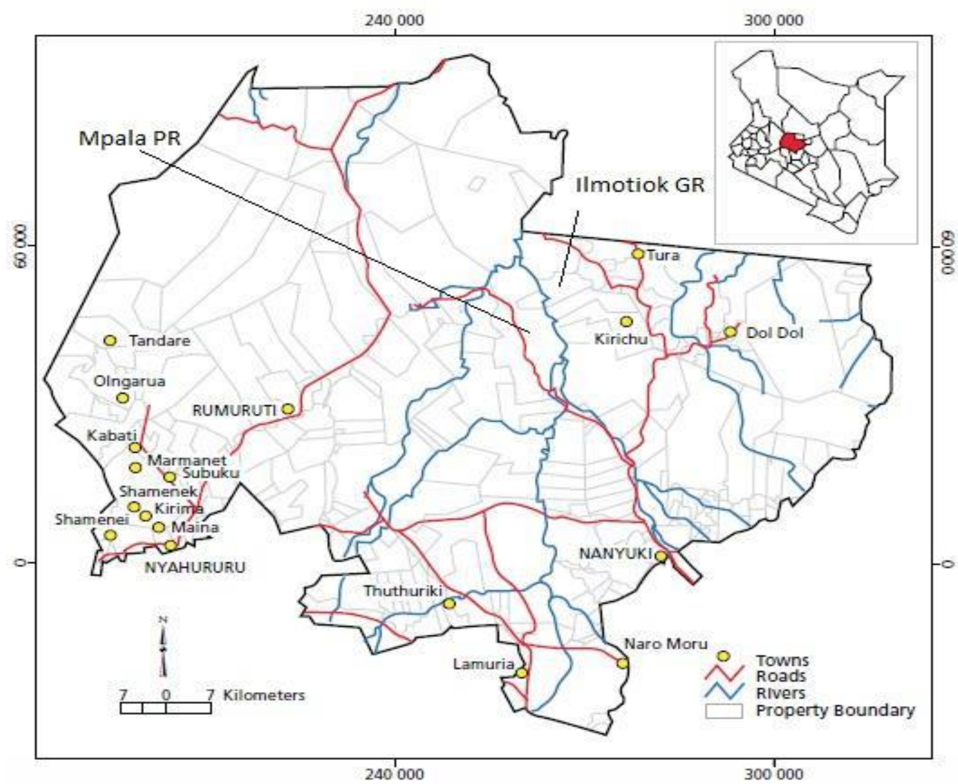

Fig.1. Map of Kenya showing position of Laikipia County (inset) County map showing land properties and position of study site Il Motiok GR. Source (Ojwang *et al*., 2010).

Research Method

A split plot design based on Randomized Complete Block Design (RCBD) was used; the main plot had three topographical zones; mid slope (MS), foot slope (FS) and toe slope (TS) and the subplots were the vegetation cover Tree (T), Grass (G) and Bare (B) as the control. A total three transect lines measuring 150m long were drawn for each topographical zone as replicates. Blocking was done along the transect line after every 50m. Measurements of GHGs were done from January to April 2017. The vegetation cover types were determined as the percentage of the selected area through visual estimation based on the (20 x20 m) subplot area.

Static chamber installation

Static chamber frames were installed (two weeks to the first sampling date to prevent disruption of the soils that could affect greenhouse gas emissions) for the three-vegetation cover in each of the three topographical zones. The chamber anchor was inserted 10 cm into the soil, allowing for 15 cm of chamber space above the soil surface (Fig 2).

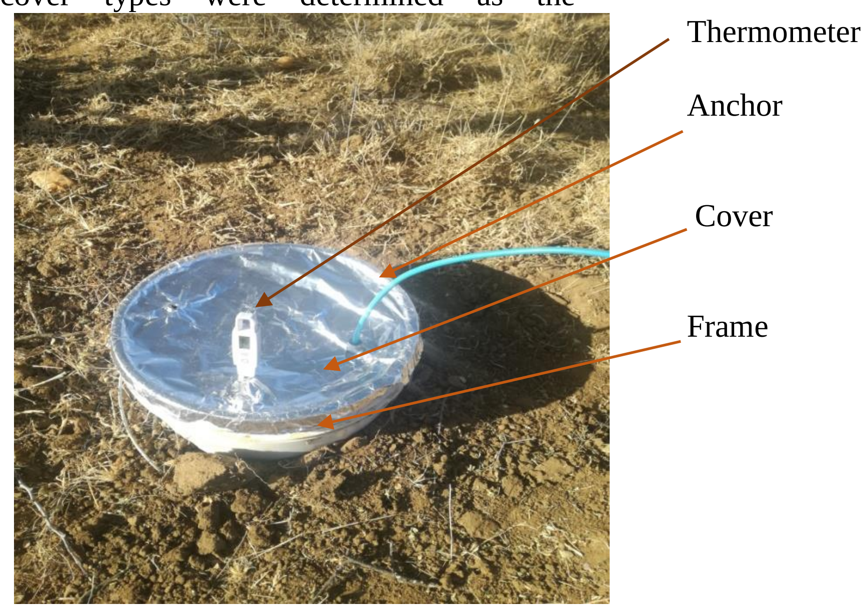

Fig. 2. Static GHG chamber

To capture observed temporal variability of greenhouse gas emissions, sampling was done for four months (January to April) in 2016, dry month (January), intermediate (February and March) and rainy season (March/April) of 2016. Gas samples were collected between 0800hrs and 1200hr local time. Gas sampling was done immediately after fitting the lid at time zero (T0), after 10 minutes (T1), 20 minutes (T2) and lastly after 30 minutes (T3). Other measurements taken included soil moisture, soil temperature, air temperature and chamber temperature, air pressure and chamber height from the soil surface. Above ground air temperatures at 1.5 m and inside the base chamber were measured concurrently in each gas sampling event using an Einstich—TFA digital probe thermometer. Soil temperature (°C) and soil moisture content (SM, %v/v) were measured at 5 cm surface soil depth using a probe sensor model 5MT, Decagon Devices Inc. which measured both soil moisture and temperature. Once the systems were operational and set, i.e., thermometers and chamber lids, gases were collected using

Luer-Lok syringe and stored in 20ml evacuated vials which were later transported to mazingira Laparotomy, International livestock research institute LRI, Kenya for CO_2, N_2O, and CH_4 analysis using an Agilent 6890 Gas chromatograph (Lutes *et al*., 2016).

Linear regression of standard concentrations as described by Lutes *et al*. (2016) was used to calculate CH_4, CO_2 and N_2O fluxes versus chamber closure time and corrected for soil moisture and temperature using equation 1 below (computerized).

$$F = (P/Po) \times (M/Vo) \times (dc/dt) \times (To/T) \times H \quad \text{(Equation 1)}$$

Where:

F= (for) CO_2 - C Linear flux ($mg.m^{-2}.h^{-1}$), CH_4-C Linear flux ($mg.m^{-2}.h^{-1}$) and N_2O- N Linear flux ($\mu g.m^{-2}.h^{-1}$),

P= atmospheric pressure of study site (Pa),

P_o= atmospheric pressure (Pa),

M= gas mass (g/mol),

V_o= molar volume (ml),

dc/dt = rate of change in concentrate,

T_o = absolute chamber temperature (°C),

T= absolute chamber temperature at time of sampling (°C),

H= height of static chamber at the time of sampling.

Statistical analysis

Analysis of variances (ANOVA) was performed to determine if Methane (CH_4), Carbon dioxide (CO_2) and Nitrous Oxide (N_2O) determined were significantly different among the topography and vegetation cover. A Fisher's least significant difference (LSD) test was performed to test the significance of differences $p<0.05$ in the Methane (CH_4), Carbon dioxide (CO_2) and Nitrous Oxide (N_2O) among treatments, using the GENSTAT 14th edition.

Results

Rainfall and temperature data

Rainfall and air temperature over the four months study period ranged from 7 mm to 400 mm per month), which was closely similar to the long-term average annual rainfall (560 mm) of the study site (Lalampaa *et al*. 2016). Mean annual air temperature ranged from 19-29°C, whereas minimum and maximum ranged from (9-15°C) and 24-32 °C, respectively (Table 1).

Table 1: Rainfall, maximum, average and minimum temperature

Annual data		**Jan**	**Feb**	**Mar**	**April**
Rainfall (mm)		17	7	250	400
Temperatures (°C)	Min	9	10	12	15
	Mean	19	20	19	19
	Max	28	32	28	24

Effects of soil moisture on CO2, CH4 and N2O fluxes

Soil moisture conditions had a significantly ($p<0.05$) increased GHGs emission (CO_2, CH_4 and N_2O). CO_2 was significantly ($p<0.05$) higher (79.39 $mg.m^{-2}.h^{-1}$) for the wet soil as compared to dry soil (12.79 $mg.m^{-2}.h^{-1}$). Wet soil had (-0.00662 $mg.m^{-2}.h^{-1}$) CH_4

whereas dry soil had (-0.01742a mg.m^{-2}.h^{-1}) (Table 2). Measurements were done during the dry and rainy months for determine dry and wet soil condition, respectively.

Table 2: Effects of soil moisture condition on CO_2, CH_4 and N_2O fluxes

Soil condition	CO_2 - C (mg.m^{-2}.h^{-1})	CH_4-C (mg.m^{-2}.h^{-1})	N_2O- N (µg.m^{-2}.h^{-1})
Dry	12.79^a	-0.01742^a	0.822^a
Wet	79.39^b	-0.00662^a	18.543^b

Means of column followed by the same letter are not significantly different ($p<0.05$) by Fisher's LSD test.

Effects of topographical zones and vegetation cover type on Methane (CH4) fluxes

Topography and vegetation significantly ($P<0.05$) increased CH4 emissions. Methane fluxes ranged from -0.021 to 0.026 mg.m^{-2}.h^{-1} with the lowest (-0.021 mg.m^{-2}.h^{-1}) recorded in bare foot slope. The bare area in all slopes had negative values for all the months (January-April) with April recording more negative values but not significantly different with March values. Methane (CH4) emissions were low in January and February and it increased in March and April in all the all slops (Table 3). The positive values for methane were recorded in grass cover in all slops. The highest and lowest, amount of methane was observed in Toe slope (0.026 mg.m^{-2}.h^{-1}) and Foot slope (0.003 mg.m^{-2}.h^{-1}) in the month of April and Februarys respectively, as compared to other zones.

Table 3: Effects of topographical zones and vegetation cover type on Methane (CH4) emissions

Topographical zones	Vegetation cover	JAN	FEB	MAR	APR
Foot slope	Bare	-0.006c	-0.020b	-0.009c	-0.021b
	Grass	0.003e	0.007fg	0.009fgh	0.013j
	Tree	0.003e	-0.001d	-0.002d	-0.020b
Mid slope	Bare	-0.003d	-0.010c	-0.090a	-0.017b
	Grass	0.005f	0.011hi	0.011hi	0.022l
	Tree	0.001d	0.003e	0.005f	0.007fg
Toe slope	Bare	-0.001d	-0.08a	-0.070a	-0.013c
	Grass	0.007fg	0.014j	0.016k	0.026l
	Tree	0.006f	0.008fg	0.009fgh	0.011hi

Means of column followed by the different letter are significantly different ($p<0.05$) by Fisher's LSD test.

Effects of topography and vegetation cover on CO_2 emission

Topography and vegetation significantly ($P<0.05$) increased carbon dioxide emission. The toe slope had the highest soil CO_2 fluxes than the other slopes. Average CO_2 fluxes in all topographical zones ranged from 2.8 to 48 mg.m^{-2}.h^{-1} (Table 4). The highest emissions were recorded for grass vegetation cover as compared to other vegetation cover throughout the seasons. The highest and lowest emissions were observed in mid slope in the month of April (48.56 mg.m^{-2}.h^{-1}) and the bare areas of mid slope in February (2.88 mg.m^{-2}.h^{-1}), respectively. CO_2 emissions were low in January and February and it increased in March and April.

Table 4: Effects of topographical zones and vegetation cover type on carbon dioxide (CO2) mg.m-2.h-1

Topographical zones	Vegetation cover	JAN	FEB	MAR	APR
Mid slope	Bare	4.41a	4.63a	13.79cde	21.89efg
	Grass	5.77a	11.97bcd	24.49efg	36.70k
	Tree	7.73ab	13.73cde	11.38bc	28.32ghi
Foot slope	Bare	5.98ab	2.88a	8.21bc	9.94bc
	Grass	12.08cde	11.70bc	68.56m	69.94mn
	Tree	25.05fgh	7.64ab	55.64l	63.18m
Toe slope	Bare	7.27ab	6.24ab	16.50def	25.51fgh
	Grass	8.78bc	7.34ab	31.47j	80.29o
	Tree	9.83bc	7.87ab	23.42efg	24.88efg

Means of colomn followed by the different letter are significantly different ($p < 0.05$) by Fisher's LSD test.

Effects of topographical and vegetation cover on Nitrous oxide (N2O)

The results showed that topography and vegetation cover had a positive influence on N_2O fluxes. The mean N_2O emission for toe slope ranged from 0.475 to 43.026 $ug.m^{-2}.h^{-1}$, these values were significantly higher than at the mid slope (-2.63-15.02 $ug.m^{-2}.h^{-1}$) and foot slope (-1.31-10.75 $ug.m^{-2}.h^{-1}$) ($P<0.05$) (Table 5). Bare soil had the lowest average fluxes than both vegetation cover types in all topographical zones. The highest emissions Nitrous oxide (N_2O) was observed in March as compared to other months in all the topographical zones and vegetation cover types.

Table 5: Effects of topographical zones and vegetation cover type on Nitrous oxide (N2O)

Topographical zones	Vegetation cover	JAN	FEB	MAR	APR
Foot slope	Bare	-0.578b	-1.311a	-0.378bc	1.088de
	Grass	1.377fg	1.117def	0.673de	9.224jk
	Tree	0.835de	1.305def	0.802de	10.759jk
Mid slope	Bare	-1.053b	-1.321a	-2.630a	-0.712de
	Grass	1.311def	1.583fg	5.426j	15.016l
	Tree	1.300def	1.181def	5.557j	8.629jk
Toe slope	Bare	0.475d	1.004de	0.489d	6.946j
	Grass	1.098de	2.156h	22.155m	43.026n
	Tree	3.432hi	0.032d	2.596h	28.477m

Means followed by the same letter at different months are not significantly different ($p < 0.001$) by Fisher's LSD

Discussion

Soil CO_2 fluxes substantially increases when the soil became wet. Soil temperature and moisture content immediately affect production and intake of CO_2 through their effects on microbial activity and plants, soil aeration, substrate availability, and redistribution. Soil moisture plays a major role for the soil CO_2 fluxes, wetter soils emitted extra CO_2 because of better conditions for microbial respiration (Zhou *et al*., 2013). Dry soils have both methanogenesis and methanotrophy which increase emissions from the soil to the environment without coming in touch with the oxidizing soil environment, increased methanogenesis will have the higher effect and the net result could be a increased CH_4 emissions. These findings validate that CH_4 emission is switched on and off in incredibly dry soils, as has been formerly suggested by (Angel *et al*., 2012). With increasing soil moisture in the previously dry soils, populations of methanogenic organisms' increases and methanogenesis are introduced because methanogenesis increases under anaerobic situations (Le Mer and Roger, 2001). But, if soils are wet, the methanogenic activity is decreased (Inubushi *et al*., 2003). The temporal and spatial variant of CH_4 fluxes in the course of the study duration turned into low and changed into independent of adjustments in soil temperature and moisture. This is consistent with the ones researched by Zhu *et al*. (2013).

Consequently, moisture results on soil nitrous oxide fluxes are a result of the limitations of O_2 diffusion into the soil and increases soil anaerobiosis, which promotes reductive microbial strategies together with denitrification. Soil water is a critical using factor for N_2O capture as stated by (Christiansen *et al*., 2012). Soil moisture is a major factor in N_2O emissions because it regulates the oxygen availability to soil microbes. Better N_2O fluxes at high soil moisture contents have been suggested (Pennock and Corre, 2001) and were associated to growing denitrifying bacteria because of reduced O_2 diffusion into the soil (Yanai *et al*., 2007). Wet condition promote the soil microbial population and inorganic N for that reason causing increased N_2O emission at some stage in the wet periods. N_2O emissions from soils, in particular, derive from microbial nitrification and denitrification, even when the soil is wet (Katayanagi and Hatano, 2012). In soils, moisture and temperature are the key controllers on nitrous oxide and methane fluxes. Study by Wu *et al*., (2010) discovered that temporal patterns in nitrous oxide and methane fluxes correspond closely with seasonal adjustments in soil moisture and temperature.

The reduction of vegetation cover increased CH_4 emissions, Sturtevant and Oechel (2013) suggested that CH_4 emissions have been extensively correlated with plant biomass and stem density. The same was reported by Vieira *et al*. (2012) that methane emissions were affected collectively by vegetation type. This study additionally indicated that vegetation cover, soil characteristics, and climate situations affected CH_4 emissions, which is an illustration that vegetation cover is a vital thing affecting methane emission. Increased CH_4 emissions were associated with improved root biomass production and with warm conditions resulted in to increase decomposition of plant material through aerobic soil conditions as reported by (Yun *et al*. 2012).

The toe slope, showed increasing CH_4 fluxes than that in the mid-slope and foot slope in all vegetation cover types. The assumption is that topography controls soil, water redistribution, which affects soil aeration and thus soil microbial activities. Yvon-Durocher *et al*. (2014) also found out zones containing soils that aid microbial activities and the net CH_4 flux at the soil surface. The soil in the toe slope area is saturated, and the hydrologic flow from the foot slope provides a downslope movement of dissolved organic carbon. The low CH_4 fluxes are consistent with observations from different studies, where lots of the CH_4 produced deeper in the soil is oxidized earlier than reaching the subsurface (Vidon *et al*., 2015). Toe slope and mid slopes of the watershed have slower drainage, developing a soil environment that may be extra conducive to CH_4 production, or may also have a better stability between methanogenic and methanotrophic methods. Soil CH_4 flux results from energetic methanogenic and methanotrophic bacteria relying on the extent of oxygen in soil (Kim, 2015).

Methane fluxes ranged from net uptake to net emission, demonstrating that both methanotrophs (CH_4-oxidizing bacteria) and methanogens (CH_4-producing) were present in the soil microbial ecosystem. CH_4 flux is notably variable both spatially and temporally, especially due to the fact, microbial production and consumption of CH_4 can occur simultaneously within the soil. Typically, CH_4 absorption decreases with an increase in soil moisture because of alterations in gas transport and decreases in aerobic zones in the soil. This is driven via the renewed mineralization and the availability of without problems decomposable organic matter for the metabolism of reactivated microbes (Borken and Matzner, 2009). The Birch impact decreases with better frequencies of wet-dry cycles (Borken and Matzner, 2009). Then again, the absorption of CH_4 using soil became enhanced using rainfall due to CH_4 flux response to increases in soil moisture. CH_4 fluxes shifted from uptake during dryer conditions to slight emissions under wet conditions (Teh *et al*., 2014).

Topography influences soil CO_2 fluxes by way of influencing the soil moisture condition. Inclined soils are normally properly aerated and properly drained, for this reason, providing conditions favorable for aerobic heterotrophic. Previous research discovered better soil CO_2 fluxes in toe slope positions compared to foot slopes or mid-slope positions, because of better soil moisture and better carbon and nutrient depositions (Arias-Navarro *et al*. 2017).

Vegetation has impacts on CO_2 emissions and undoubtedly correlates with net ecosystem production. Metcalfe *et al*., (2007) demonstrated that decrease root density or litter content material corresponds with decreased CO2 fluxes. Increased CO_2 concentrations in soils can also be because of better root mass because of elevated atmospheric CO_2 concentrations. Increase in ground cover also can impact C and nutrient cycling approaches and regulate the ecosystem-environment exchange of CO_2 (Buckeridge *et al*., 2010). Despite the fact that growth in leaf area with more vegetation cover increases gross ecosystem production and uptake of CO_2 (Shaver *et al* 2000).

Higher soil CO_2 concentrations were recorded in moist periods of March and April; our results correspond that excessive $C0_2$ emission throughout wet durations was due to $C0_2$ displacement in the soil due to increased rainwater. Increase in CO_2 flux during the wet season are most probably due to an aggregate of factors occurring simultaneously – will increase in soil temperature and soil moisture that can additionally induce higher carbon (C) availability as reported by (Hubbard *et al*., 2006). In addition, at some point of the observation period of this study, the large quantity of litter that had gathered all through the dry period became intensively decomposed with the onset of rainfall. Soil water content also can impacts rates of CO_2 by diffusing soluble C substrates in thin water as suggested by Davidson *et al*. (2006). Addition of water to the soils as precipitation through infiltration can elicit vast increases in total respiratory reflecting greater decomposition of the organic layer and growth in substrate availability. Increased precipitation is likely to decrease rates of O_2 diffusion into the soil (Liptzin *et al*., 2011) thus decreasing carbon oxidation. Precipitation variability is a famous essential driving force of the seasonal variability of soil CO_2 flux in many environment kinds (Stielstra *et al*., 2015, Vargas *et al*., 2012). In rainy season respiration is likely to increase with increased vegetation covers because of the increased insulating ability of the plants-trapped snow developing warmer soil surroundings (Sturm *et al* 2015).

The bare soil had N_2O accumulated emissions near zero this due to reduced soil moisture content, soil temperature and soil aeration, therefore, affecting the emissions. Soil moisture will increase as a result of stomata starting as a consequence growing situation for N_2O emissions through denitrification force (Ding *et al*., 2003). Van der Nat and Middelburg (2000) observed that N2O emissions have been affected collectively by vegetation cover percentage. Soil N_2O emissions are increased in the toe-slope than in foot slope or mid-slope positions this is because of moisture content between the different positions along the slope commonly explaining well the located variability in N_2O fluxes. The differences in moisture content material among the different topographic positions explaining well the determined variability in N_2O fluxes with the highest soil N2O fluxes at the toe slope intently correlated with the highest soil moisture in these positions (Negassa *et al*., 2015). Extensive consequences of topographic position on a couple of components of the N cycle were proven by Weintraub *et al*. (2014), indicating lower N availability and a less open N cycle in toe-slopes. Increased N_2O fluxes occur in the soil with a high moisture content that is because patterns of N_2O flux is controlled via soil moisture variability. Soil moisture affects earthworm casts that produce nitrous oxide. Geng *et al* (2017) in his study in tropical soils reported that N_2O emissions can be sporadic and brief, for example, after heavy rains and are characterized via short pulses of emissions related to better nitrogen inputs or excessive precipitation occasions. As an example, an increase in soil temperature can directly stimulate nitrifies and denitrifies that produce N_2O, however greater fast soil drying (Bijoor *et al*. 2008). Temperature increases could also stimulate plant boom and N uptake, thereby decreasing the effect of N being lost as N_2O. However, warming boost N_2O emissions due to increased microbial activity and N deliver via accelerated N mineralization (Dieleman *et al*. 2012).

Conclusion

Soil moisture plays a major role for the soil GHGs fluxes, wetter soils emitted extra GHGs because of better conditions for microbial respiration. Topography influences soil GHGs fluxes by way of influencing the soil moisture condition. GHGs emissions are increased in the toe-slope than in foot slope or mid-slope positions, this is because of moisture content between the different positions along the slope. From this study additionally indicated that vegetation cover affected GHGs emissions, which is an illustration that vegetation cover is a vital thing affecting GHGs emissions due to improved root biomass production and warm conditions results in increased decomposition of plant material.

Acknowledgement

The study was financed by SLEEK 'System for Land-based Emission Estimation in Kenya' http://www.sleek.**environment**.go.ke/ Enumerators are highly acknowledged for their assistance in data Collection and labelling. The authors would like to acknowledge Ilmotiok community ranch who allow their ranch for the experiment. Finally, we acknowledge Kabete soil laboratory technician (University of Nairobi) for their assistance and provision of the required equipment.

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