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Emerging Land Use Changes-Climatic Variability Nexus in Meru County, Kenya

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Abstract

The interplay between land use changes and climate variability are potential causes for the declining agricultural productivity in Meru County. Given that the agroecological disparities are attributable to the topography, a topo-sequence analysis of land use changes and climate variability was carried out in the major sub-agroecological zones of Meru County. Data on land use change and rainfall was triangulated with that of household survey, focused groups and in-depth interviews. Land use changes along the agroecological zones were consequently explained by various factors including climatic variability. There were marked land use changes in six of the seven major sub-Agro-ecological zones between 1976 and 2007. In low highland 1, upper midland 1, 2 and 3 and low midland 3, areas under agricultural land use increased while that under forest decreased further, in low midland 6 shrubs were replaced by rainfed crops (r^2 = 0.98) an indication that natural vegetation was being cleared for cultivation. Such practices constitute injurious land use and management tendencies. The upper midland zone described as coffee zone was converted into bananas as the main cotton zone (LM_3) evolved to irrigated crops. There was a detrimental land use trend where area under natural vegetation decreased as cultivated area increased therefore necessitating liberation of land under other uses for forest establishment. Mitigation of negative effects of climate variability on land use which focuses on seasonal land use patterns for enhanced land use performance or productivity are imperative. The agroecological differences in rainfall variability and land use changes call for tailored interventions that target specific sub-agro ecological zones.

Key terms: Topo-sequence analysis, seasonal rainfall variability

1. Introduction

The interest in land use and land cover results from their direct relationship to land productivity and hence ecosystem services necessary for human well-being (Remankutty and Foley, 1999). Systematic analysis of local land use changes over a given time frame helps to uncover general principles to provide an explanation of new land use changes and their implications in the development process (Lambin et al., 2003). Anthropogenic perturbations are increasingly causing changes in land use and land cover resulting in landscapes widely dominated by crop farming and urban development, which combined contribute to changes in climatic conditions through their effects on the hydrological cycle and forest cover (Stott el al., 2001). Balancing between changing landscapes, land quality and food security remains a pressing challenge in the development process everywhere in the world (Stott el al., 2001). However, Long term degradation of catchments, lakes and aquifers emanating from human activities renders Kenya vulnerable to perturbations in water supply (Mogaka et al., 2005). Climate variability leads to changes in precipitation and potential evapotranspiration (PET). Agriculture development strategy identifies irrigation as key to increased agricultural productivity (GOK, 2009). Several studies have associated trends of stream flow and discharge to climate variability (Jones et al., 2012; Yuting et al., 2011; Mogaka et al., 2005). This implies that stream flow is an indicator of climate variability. Other findings insinuated that land use changes as one of the human activities that affect the stream flow (Garbrecht et al., 2004; ZHAO et al., 2009).

In Kenya, the future of sustainable land management is anchored on the dynamics of smallholder farming. Meru County which is the focus of this study experienced decline in food production probably due to degraded soils and erratic rainfall (Jaetzold et al., 2007). Unsustainable land use practices are a major cause of land degradation (Lambin et al., 2003). The demand for food production by the growing population is further aggravated by climate variability under rainfed agriculture. Irrigation development remains a major strategy for boosting food security. Meru County targets a 30% growth in area under irrigation for the next 5 years from the current 13,000Ha, rivers and streams are expected to form major sources of irrigation water (GOK, 2013).

Since majority of the county residents are rural-based smallholder farmers, understanding reasons and effects of changes in their land use patterns are vital in informing decision-makers towards sustainable land management (use, care and improvement), hence the focus on the relationship between land use and climatic variability in this paper.

2. Methodology

The Meru County covers a wide range of agroecological zones (AEZs) ranging from tropical alpine cascading to semi-arid low midland six (LM_6). The study targeted the seven major sub-agro ecological zones of Meru, Kenya. These zones were LH_1 (Tea & dairy zone), UM_1 (Tea/coffee zone), UM_2 (main coffee zone), UM_3 (marginal coffee zone), LM_3 (Cotton zone), LM_4 (marginal cotton zone) and LM_6 the livestock zone (Fig 1). This area constitutes the four sub counties of Buuri, Imenti South, Central and North formerly known as Meru Central District. This area had an estimated population of 0.5 million (GOK, 2010). These people are primarily smallholder farmers dependent on land.

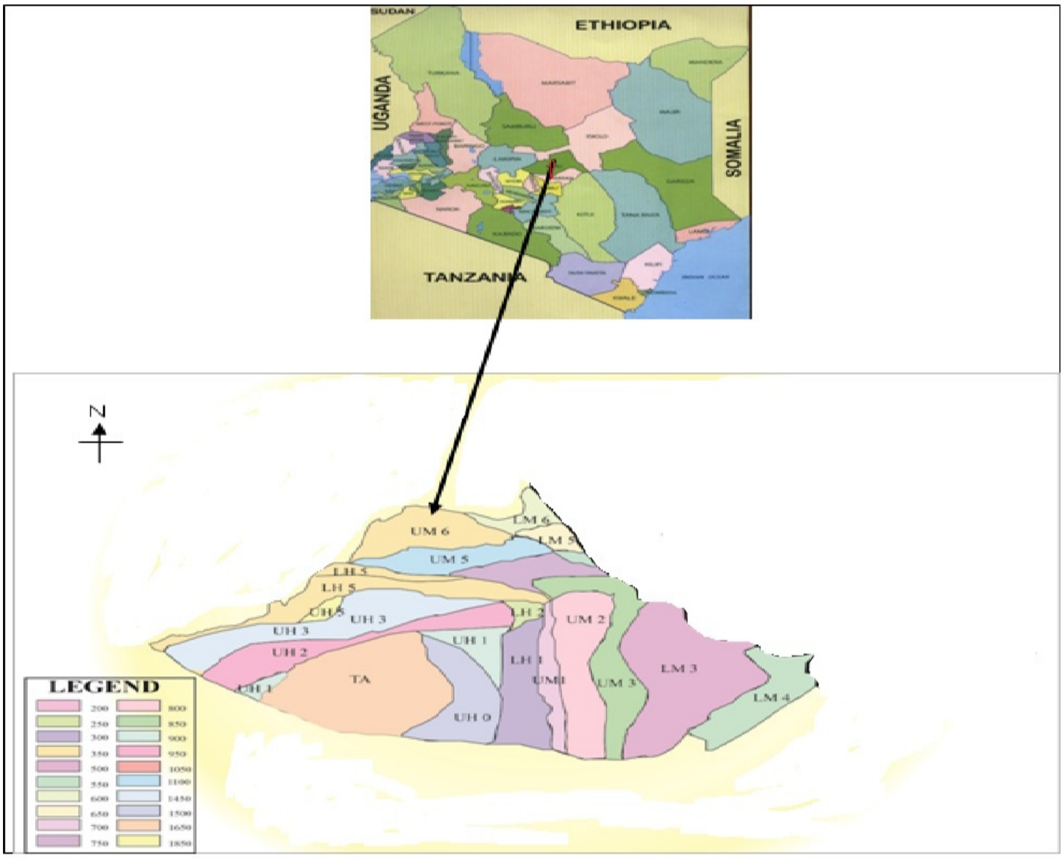

Figure 1: Location of study area

2.1 Data collection

The hydro-climatic data was obtained from the ministry of water, Githongo Tea Company, departments of forest and meteorological department. Rainfall figures ranging between 1976 and 2011 for both Meru forest station and Meru meteorological stations and from 1984 to 2011 for Githongo tea factory weather station were used.

Topographical maps at the scale of 1:50,000 of Isiolo, Marania, Meru, Mitunguu, Mount Kenya and Nkubu were used for reconnaissance and interpretation. Images for the years 1976, 1987, 2000 and 2007 of the scene of former Meru central district (P180R060) were employed to come up with a land use and cover analysis of 1976 to 2007. The raw bands P180R060_2M1976_Tiff, P168R060_02_1987_Tiff, P168R060_02_2000_Tiff and P168R060_02_2007 were used for image interpretation and analysis. The images were presented as bands 3, 2 and 1 with each band representing a particular feature in false colour composite.

A household survey was carried out where the study area was stratified according to sub-AEZ. Using a list of administrative units' as sampling frame one village per sub-AEZ was randomly selected as the target area. A sample of 280 smallholder household heads was randomly selected and semi-structured questionnaire administered to 275 respondents. To supplement the household survey data Focused Group Discussion (FGD) were undertaken. Each FGD consisted of 8-12 participants purposefully sampled within the socio-economic groups of interest. This was done with the assistance of village elder and frontline extension worker through homogeneous sampling of the most vulnerable/poor, the rich, elderly and key informants. The selection of 2 progressive and 2 vulnerable farmers in the three main study AEZs (LH, UM & LM) as participants In-depth interview was done during FGD. A transect walk from 00.0513'S 37.56193' E to 00.11349'S 037.788766 was carried out and observations were made on the type of vegetation cover, elevations, land use and its drivers.

2.2 Data analysis

This study applied a combination of qualitative and quantitative approaches. Remote sensing and GIS soft ware ERDAS, GEOVIS and ARCVIEW were used in analysing land use, land cover changes using 1976, 1987, 2000 and 2007 images to generate 15 land use classes. Trends of various land use types were correlated using scatter plot to determine their relationships. Significant differences (P=0) of an agro forestry land use type (rainfed crops and trees) was used for comparative analysis across sub- agroecological zones. This is because under the prevailing situation of decreasing vegetation cover coupled with increasing demand for food agro-forestry system remains a compromised alternative towards sustainable practices. The data emanating from transect walk was narrative. Analysis of variance (ANOVA) was used to generate seasonal rainfall mean ranging between 20 to 34 years for 3 weather stations. March, April and May (MAM) were picked for the first season rains while ONDJ - October, November, December and in addition January as 2nd season was considered since its inclusion was valued in previous studies (Shisanya, 1996; Recha, 2013; Muthee et al.,2015). The last day of 2nd season is considered January 31st, though most of the rains fall during months of October, November and December with an extension to the month of January included. The last day of 1stseason is 31st May. The mean significant difference at (P=0.05) of ONDJ and MAM seasons was tested using ANOVA. Rainfall variability expressed as a coefficient of variability (CV) was computed using mean and standard deviation derived from yearly seasonal average rainfall during first rainy season and the second rainy season using Excel. Household survey data was analysed using descriptive methods and expressed as mean and frequencies. This data was further triangulated with the results and narratives from FGD and in depth interviews.

3. Results and Discussion

3.1 Indicators and significance of climatic variability

Climate variability was manifested as stream flow variability and seasonal changes in rainfall.

3.1.1 Rainfall variability

Rainfall variability differed from one Sub-AEZ to another and from one season to another. The county receives a bimodal rainfall. The two seasonal rainfall accounts for over 85% of the annual rainfall and 2nd rainfall season receive more rain than the 1st season. Low highland one (LH_1) had CV of 0.43 in the first rainy season and CV of 0.26 in the second rainy season. The upper midland two ($UM_{2)}$ and upper midland two transition three (UM_{2-3}) had corresponding CV of 0.34 in the second rainy season due to their proximity. The first rainy season CV was 0.36 and 0.37 for UM_2 and UM_{2-3} respectively (Table1).

Table 1: The CV and P-value for Githongo, Meru Forest and Meru Met stations seasonal rainfall

STATION	Sub-AEZ	1stseason(mm)	p	CV	2ndseason (mm)	p	CV
Githongo T.F	LH_1	744.7	0.00	0.43	1329.9	0.00	0.26
Meru Forest	UM_{2-3}	478.1	0.00	0.37	811.2	0.00	0.34
Meru Met.	UM_2	466.2	0.00	0.36	789.5	0.00	0.34

Source: Muthee et al., 2015

The mean rainfall amount was higher in the second than first rainy season. From the computation, ($P<0.05$) therefore the difference in mean rainfall for the two seasons was significant in LH_1, UM_2 and UM_{2-3}. These findings concurred with other studies carried out in the adjoining Tharaka sub-counties (Recha, 2013). This implies that the first rainy season was more variable in LH_1 than in UM_2 and UM_{2-3}. There was an increasing rainfall variability moving towards the lower sub-AEZ during second rainy season, unlike in the first season where variability increased with altitude. Therefore, in such a bimodal rainfall, seasonality and elevation are potential determinants of rainfall variability. In LH_1 and UM_1 are predominately tea zones hence perennial crop, dairy therefore fodder and vegetables usually supplemented with irrigation. Rainfall variability affects marginal coffee zones and lower midlands leading to declining crop productivity but this would vary between varieties or one crop to another. Intergovernmental panel on climate change predicted increase in inter-seasonal and intraseasonal rainfall variability (IPCC, 2014). Seasonal and agroecological zone based information on rainfall trends would facilitate development of more focused strategies and interventions for sustainable agricultural land use.

3.1.2 Stream flow variability

The average monthly discharge from 1980-2011 and the coefficient of variation (CV) signified a high reduction in stream discharge in all the months over the years. The CV ranged between 0.40 to 0.22 with the highest variation recorded in the months of February and September and the lowest in April and December (Fig 2).September and February are generally the driest/hottest months with minimal precipitation but with reported increased fluctuation in rainfall in January and August/ September coupled with land use land cover changes may be the cause for relatively high variability during these months. Clearing of vegetation cover also aggravates surface runoff leading to flooding and sedimentation.

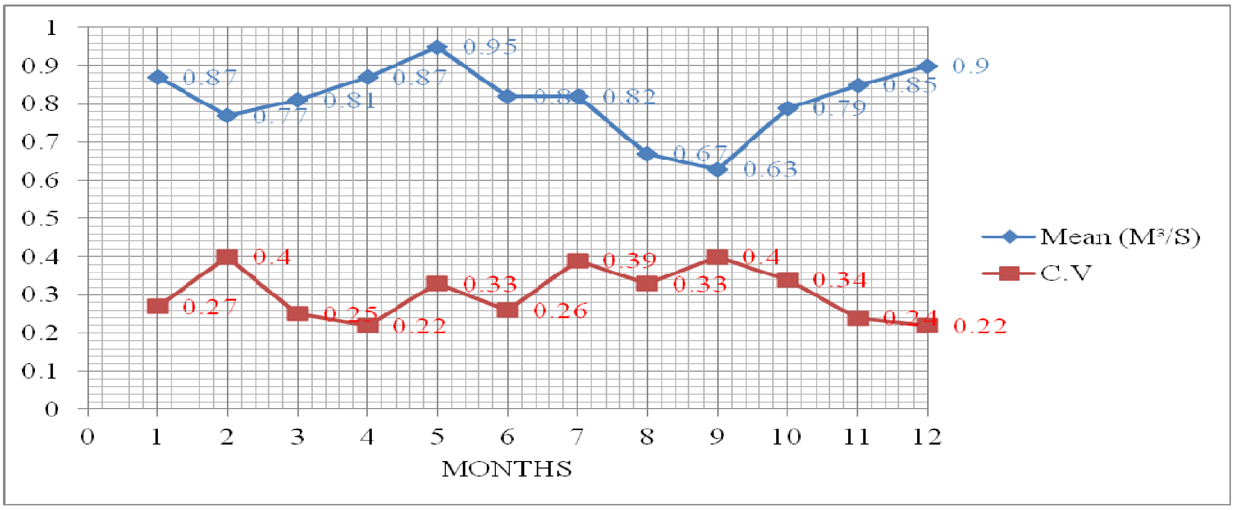

Figure 2: Trends of Mean discharge and CV among the months

These results signified a trend which was general reduction in stream flow over years and in all months. This could be attributed to over exploitation of water resources upstream and changes in ground water level. The month of September had an average volume of 0.809 for mu1 which was far below mu2. September is generally a dry month with minimal precipitation (Fig 3). Chawdhury and Ward (2004) postulated some relationship between increases in heavy precipitation and changes in high stream flow. Dettinger and Diaz (2000) found a direct correlation between increasing heavy precipitation and stream flow. The stream discharge was decreasing. The decrease in September water volumes would be explained by exploitation due to increased irrigation demands. In the drier months the demand supersedes the available water, while in wet seasons the river discharge is enhanced by surface runoff, raised water table, precipitation and reduced evaporation. These fluctuations affect hydrological cycle.

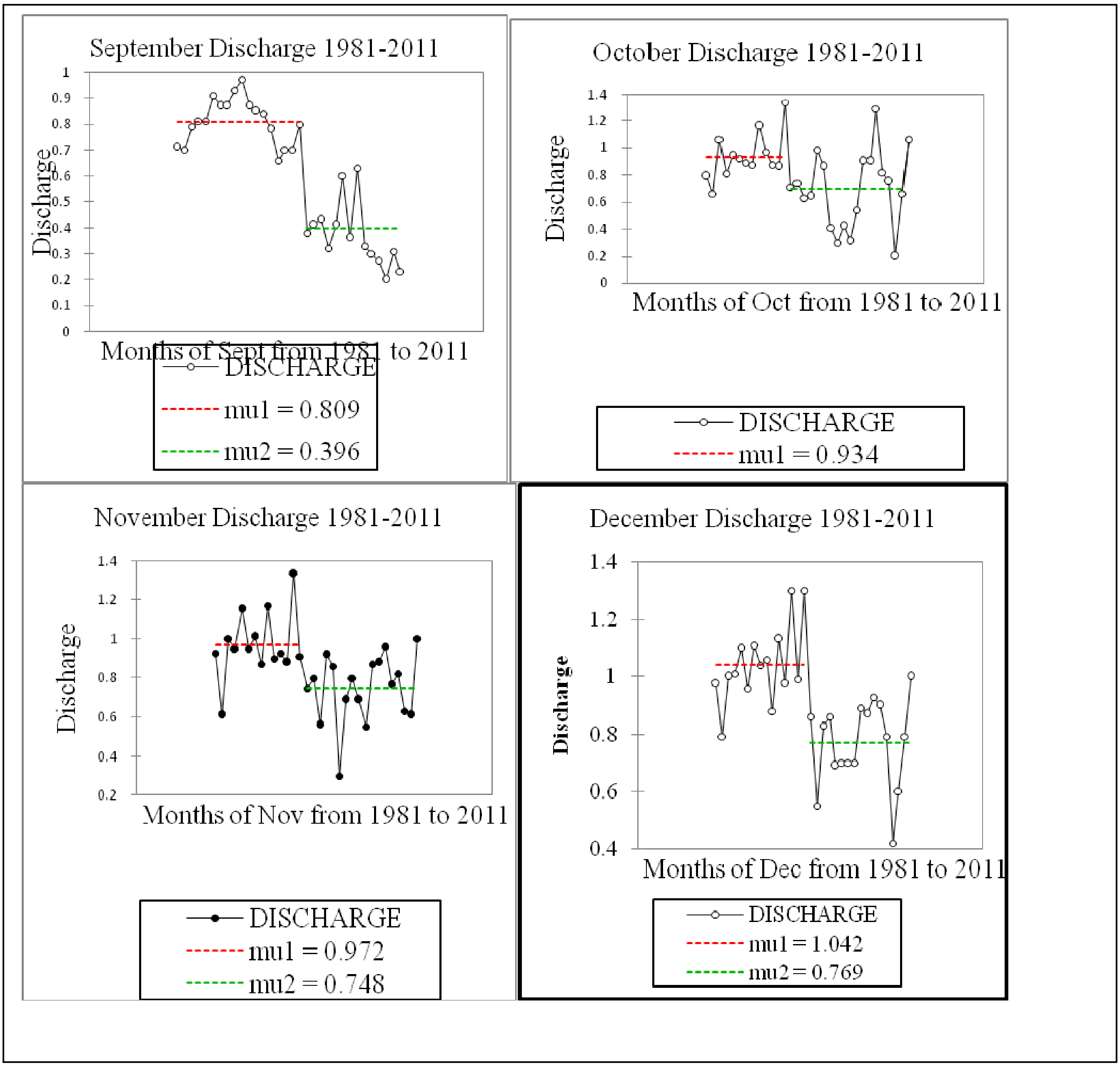

Figure 3: Plot of 30 years trend, mu1 represents means of the first set of 15 years while with mu2 represents the last set of 15 years

There was exponential increment of irrigated crop from 2007 to 2011. The increase in irrigated area signified a shift from rain dependant to irrigated agriculture. The steep increase in 2007 to 2011 was due to inauguration of more irrigation projects (Fig 4).

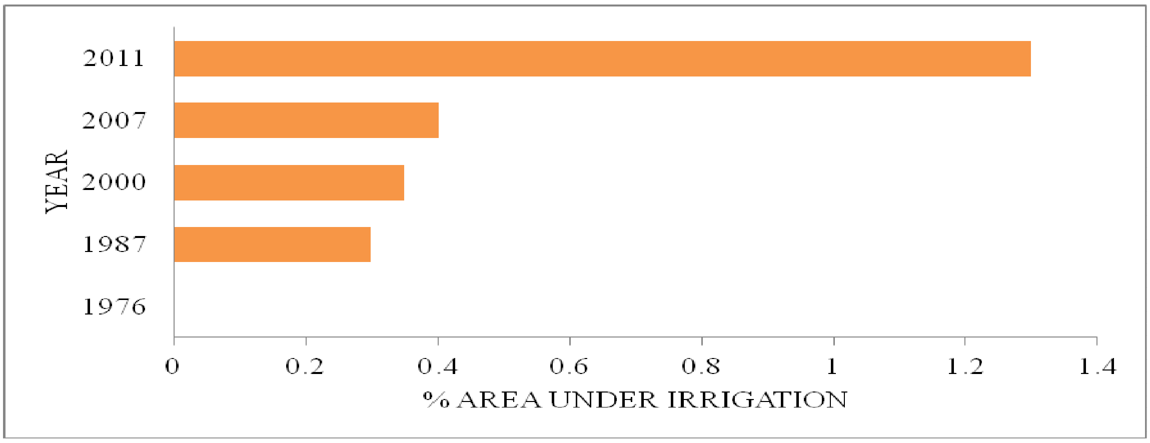

Figure 4: Trend of area under irrigated crop in Meru central region (Source: Afri cover FAO statistics)

For instance (Giaki- Kioru (LM_3) irrigation project commenced operation in 2009 and Nkabune (UM_2) irrigation project in 2010 among others). According to the ministry of water 72.6% of the licensed water projects were for irrigation purpose. This study also revealed that 34.3% of respondents practiced irrigation. Those who were practising irrigation (87%) indicated that unreliability of rainfall was the main reason for venturing into irrigation. Other reasons were; demand for constant market supply and maximizing returns per unit land. However, stream flow dynamics and seasonal climatic variations are intertwined and both drive irrigation among other factors.

3.2 Land use change

Comparative analysis of land use changes between sub-agroecological zones

There was a statistically significant difference between the average land use through rain fed crops and trees in the five sub-ecological zones (Table 3).

Table 3: Multiple Comparisons (Variable: rainfed crops and trees (Tukey HSD)

(I)	(J)	(I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
LH_1	UM1	-57.9500(*)	1.51844	.000	-62.6388	-53.2612
	UM3	-79.4000(*)	1.51844	.000	-84.0888	-74.7112
	LM3	-33.1500(*)	1.51844	.000	-37.8388	-28.4612
UM_1	LH1	57.9500(*)	1.51844	.000	53.2612	62.6388
	UM3	-21.4500(*)	1.51844	.000	-26.1388	-16.7612
	LM3	24.8000(*)	1.51844	.000	20.1112	29.4888
UM_3	LH1	79.4000(*)	1.51844	.000	74.7112	84.0888
	UM1	21.4500(*)	1.51844	.000	16.7612	26.1388
	LM3	46.2500(*)	1.51844	.000	41.5612	50.9388
LM_3	LH1	33.1500(*)	1.51844	.000	28.4612	37.8388
	UM1	-24.8000(*)	1.51844	.000	-29.4888	-20.1112
	UM3	-46.2500(*)	1.51844	.000	-50.9388	-41.5612

Where: The mean difference is significant at the .05 level. (I) land use through rainfed crops& trees; (J) Land use through rainfed crops and trees; (I-J) Mean Difference.

This signified existence of variations across sub-Agro-ecological zones, hence the need to understand the land use changes in each of the sub-agro-ecological zones.

Low highland one

On average substantial area (60.3%) of sub-zone (LH_1) was under forest cover while 32.2% was under tea as rainfed crop and trees occupied 4.4%. The area under open and natural forest decreased from 66% in 1976 to 56.5% by 2000 as area under tea, rainfed crops and trees and cleared forest increased (Table 4). The decrease in area under natural forest arose from curving of 100M (width) along Mt Kenya forest edge for tea production in late 1980s by Nyayo Tea Zones Development Corporation. This was established by Act of Parliament in 1988. There were efforts as from 2004 to include local neighbouring communities' in the use of the forest reserve through smallholder agro-forestry interventions such as shamba system. In 2009 the forest user associations, pro shamba system organizations and Kenya forest service revised the policy and initiated a livelihood improvement program targeting neighbouring farming communities (KFWG, 2001; Gachanja, 2003). Information from Kenya forest service's regional office indicated that 1037Ha of forest land was under this system by April 2012. Annual crops such as potatoes, peas, cabbage spinach, maize, beans, were also grown in the midst of existing trees throughout the year supplemented with irrigation especially in June to October and January to March. Therefore, conversion of forest area into agriculture remained unchecked leading to reduced vegetation cover, loss of biodiversity and increased desertification. Tea was predominately rainfed, however, the increased rainfall variability in the first rainy season coupled with the dry spell in February, August and September curtail proliferation of tea leaves. This necessitates management of soil moisture to minimize yield decrease. Extreme temperatures reduce tea production with low temperatures resulting to frost burns and high temperatures leading to reduced vegetation. Temperatures are predicted to increase by 2020 and continue to increase progressively by 2050 limiting tea production from current altitude of between 1500 and 2100M ASL to an altitude of between 2000 and 2300M ASL (Laderach and Eitzinger, 2011). This would reduce potential tea zone since LH_1 occupies the area between 1830 and 2200M above sea level rendering conversion of forest area into tea zone counterproductive. However, dominance of tea, a perennial crop (35%) moderates the effects of seasonal rainfall variability as compared to annual crops which occupied less than 4.5% of the area under this sub-zone. Stream flow variability leveraged on the small proportion of area under annuals enhancing production through irrigation for all year round production.

Table 4: Area in percentage under various uses in LH_1, UM_1, UM_2, UM_3 year1976, 1987, 2000 and 2007

	LULC Type	1976	1987	2000	2007
LH1	Cleared Forest	1.3	0	1.2	1.4
	Open Forest	0	3.2	2.6	2.6
	Natural Forest	66	62.3	56.5	56.5
	Sub Total (Forest)	67.3	65.5	60.3	60.5
	Rainfed Crops & Trees	4.2	4.3	4.7	4.5
	Tea Zone	28.5	30.2	35	35
	Sub Total(Agriculture)	32.7	34.5	39.7	39.5

Upper Midland

In Upper Midland One (UM_1) referred to as the tea-coffee zone, Area under tea increased while that under rainfed crop with trees, natural and cleared forest decreased. In the Upper Midland Two (UM_2) - main coffee zone an estimated 84.2% of the area was under agricultural land uses, 14.8% under forest, while, 2.2% was under urban settlement by the year 2007. Over the years total area under forest dropped but stabilized from 2000 to 2007 at 13.2% as that under agriculture increased but slightly declined by 1% by 2007. Area under irrigated crops, tea zone and urban settlement was gradually expanding. Between 1976 and 1987, 4% of the cleared forest was mainly replaced by rainfed crops while between 1987 and 2000, 0.8% of area under natural forest and 1.3% of rainfed crops was converted into irrigated crops, Tea zone and urban settlement further gained another 10.9% between 2000 and 2007 from area under rainfed crops and rainfed crops with trees. In upper midland three (marginal coffee zone) on average 86.8% of the land was under agricultural land uses and 12.8% under forest, with 0.4% under urban settlement throughout the period. Total area under forest dipped between 2000 and 2007 at 6.4 % when 4% was cleared as that under agriculture kept on fluctuating. As from 1987 area under rainfed crops and shrubs was fully transformed into rainfed crops and trees (Table 5).

Table 5: Area in percentage under various uses in LH_1, UM_1, UM_2 & UM_3 year 1976, 1987, 2000 & 2007

	LULC Type	1976	1987	2000	2007
UM_1	Cleared Forest	1	0	0	0
	Open Forest	0	0.5	0.5	0
	Natural Forest	8.2	8.2	7.3	7.3
	Total Forest	9.2	8.7	7.8	7.3
	Rainfed Crops & Trees	26.8	27	27.5	23.7
	Tea Zone	64	64.3	64.7	69
	Total Agriculture	90.8	91.3	92.2	92.7
UM_2	Cleared Forest	4.1	0.00	0.00	0.00
	Natural Forest	14.8	14	13.2	13.2
	Total Forest	18.9	14	13.2	13.2
	Rainfed Crops	15.3	18.5	17.2	13.8
	Rainfed Crops & Trees	65	64	64	56.5
	Irrigated crop	0	1.2	2.9	11.6
	Tea Zone	1.1	1.4	1.5	2.7
	Total Agriculture	81.4	85.1	85.6	84.6
	Urban Settlement	0.7	0.9	1.2	2.2
UM_3	Natural Forest	13.5	13.5	6.4	13.6
	Cleared Forest	0	0	4.0	0
	Total Forest	13.5	13.5	10.4	13.6
	Rainfed Crops & Shrubs	0	2.6	0	0
	Rainfed Crops	1.8	2.9	2.9	1.8
	Rainfed Crops & Trees	84.2	80.6	86.3	84.2
	Total Agriculture	86	86.1	89.2	86
	Urban Settlement	0.4	0.4	0.4	0.4

There was a tendency to abandon, replace or intercrop coffee with the seasonal crops in UM_1. Coffee was being abandoned or replaced with other crops. Coffee was ranked last in order of importance while tea was first (Jaetzold et al., 2007). Laderach and Eitzinger (2011) postulated that coffee farming was losing most of its suitability but pea, passion-fruit and banana performed quite well on predicted changes in tea- coffee areas. Other findings indicted that coffee farming was replaced by more profitable land uses (Jaramillo et al., 2013). Other findings have indicated possible replacement of coffee due to environment changes (Schepp, 2010 and Laderach et al., 2010). In UM_2 there was a strong correlation between the change in total area under agricultural use and that under forest ($r^2 = 0.936$) in that area under forest was converted to agriculture. Encroachment of upper Imenti forest for food production and excursion for physical development in 1980s reduced area under natural forest. Further, changes in the area under rainfed crops alone and that of rainfed crops-trees were strongly correlated to changes in area under irrigated crops ($r^2 = 0.902$) area under tea ($r^2 = 0.8697$) and area under urban settlement ($r^2 = 0.8533$). This implies that area under rainfed crops- tree intercrop was replaced by irrigated crops, tea and urban settlement. For instance tree crop such as coffee was uprooted when the price drastically dropped (Karanja and Nyoro, 2002). This Paved way for expansion of banana orchards. Over years, new varieties of more marketable bananas were introduced and adopted, thus changing the area once known as coffee belt into a banana zone. Biotechnology led to rapid increase of area under bananas from late 1990s due to increased accessibility of tissue culture materials. The banana plant has a sparse, shallow root system with its most feeding roots spread laterally near the surface, a 35 percent depletion of the total available soil water should not be exceeded ($p = 0.35$) the reason for irrigating banana orchards for meaningful economic gains (Berntsson and Winberg, 2013). Introduction of some drought tolerate tea clones led to extension of tea growing zone beyond UM_1 to transition UM_1-UM_2. The road network in UM_2 and existence of bitumen road to the city of Nairobi since 1985 facilitated expansion of urban areas and hosting of county administration centres in towns of Meru, Nkubu, Kariene, Kanyakine, and Igoji. This led to conversion of agricultural land (area under rainfed crops and trees) to urban settlement and irrigated crops. However, are these land use changes sustainable and in consistent with Bruntland commission (WCED, 1987)? Where, vegetation cover has reduced; in a country classified as water deficient riding on an epoch of global warming? Such a scenario is bound to aggravate the environmental degradation through reduced tree cover and increased water use (Hulme et al., 2001; Mogaka et al., 2005).Therefore the need to consider appropriate ways of managing the emerging land use such as irrigated crop.

In UM_3 as forest decreased the area under agriculture increased ($r^2 = 0.999$). This zone harboured a portion of the lower Imenti natural forest, by year 2000 an estimated 30% of the natural forest was cleared for cultivation of rainfed crops. This was because prior to 1997 elections neighbouring farmers were allocated parcels of land, however, by 2007 corrective measures had been taken and initial area under forest restored. The area was a marginal coffee zone that experiences high evapotranspiration coupled with low precipitation and therefore climate modification through enhanced vegetation cover is imperative. Like other AEZ in this study area most of respondents (97.4%) majored on food crop production. Whereby 92.4% of respondents intercropped pulses with maize in both seasons. Intercropping was believed to lessen the risks associated with unreliable rainfall. During the second season maize was the main crop while drought tolerant pulses such as dryland beans, cowpeas, and pigeon peas were the major crops in the relatively more variable first rainfall season. Planting of tree crops like bananas, coffee, fruit trees and afforestation took place in the less variable second rainy season. Seasonal rainfall variability was an important factor in seasonal agricultural productivity and land use and of this sub-AEZ Other recent studies done in the region concur with this phenomenon (Herrero et al., 2010; Jaetzold et al., 2007 and Olson et al., 2004). Hence the need for appropriate seasonal cropping pattern for sustainable land management practices.

Lower Midland

In LM_3 96.8% of the area was under agricultural use, while 2.97% was under forest and grassland. During the period 1976-2007 total area under forest remained stable with sharp decline between 1987 and 2000 at 0.5 % when close to 3% was converted to rainfed crops and trees. However, the area under grassland remained unchanged for the entire period. Except for irrigated crop that gradually increased, area under other land uses were relatively stable.

In the LM_6 area under grassland remained unaffected for the entire period. Between 1976 and 1987 area under rainfed crop and shrubs evolved to rainfed crops an indication that shrubs were cleared for rainfed cropping. Further, between 1987 and 2000 area under woodland was cleared to pave way for rainfed crops, and by 2007, 93.06% of the total area was eventually under rainfed crops. However no change was detected in LM_4 during the 31 year period. This would therefore stand out as one of the most stable ecosystems. To a large extent LM_4 had 91.1% of the area under agricultural (crops) uses and the remaining under other natural vegetation comprising of forest and grassland (Table 6). LM_3 was dominated by crop based agricultural systems which evolved from rainfed crops and shrubs to agro-forestry and crops.

In LM_3 changes in area under forest and grassland were strongly correlated to area under agricultural ($r^2 = 0.9673$). Area under agricultural use increased as that under forest and grassland decreased. Reasons for decline in natural forest was as a result of encroachment of section of lower Imenti forest for food crop production as depicted in the rise of area under rainfed crops with tree cover. Between 1987 and 2000, 87.7% of area under natural forest was converted into rainfed crops and trees. Such changes are known to exacerbate land degradation leading to loss of soil fertility amidst unreliable rainfall leading to low agricultural productivity. For instance, maize yields decreased from 3320 kg/ha in 1978 to 695 kg/ha in 2004 during first season in low midland three (LM_3) and from 3,378kg/ha to 887 kg/ha in second season (Jaetzold et al., 2007).

Since LM_3 was comparatively the largest in size (occupy 30% of the total study area) and therefore significant in making the county food secure. Though, LM_3 was a cotton zone not a single farm was observed to have the crop along the transect path. This was because the cotton industry underwent difficulties rendering close down of the two local ginneries. The former cotton belt was replaced by maize, sorghum, pulses, mangoes and pawpaw. Other studies concur with these findings that cotton was conspicuously missing in LM_3 (Jaetzold et al., 2007). A similar trend was also observed in the cotton zones of Uganda (Ebanyat et al., 2010). Majority (91.6%) of respondents reported increased frequency of drought necessitating irrigation as an alternative way of soil moisture enhancement to sustain crop production. Forthwith, area under irrigated crops was slowly upcoming ($r^2 = 0.0108$). In presence of irrigation facility banana production formed a substitute cash crop as evidenced in Mitunguu irrigation scheme where over 85% of the total area was under bananas. Area under river line vegetation was cleared from year 2000. This was associated to expansion of area under crops such as arrow roots, sweet potato, banana and dry season vegetable along the riverline. Farmers tended to cultivate valley bottoms whenever there was drought exacerbating siltation. In tandem with this study, other studies noted poor land use along riverline activities as a major cause of environmental degradation due to increased overexploitation of the surface and ground water within this area (Agwata, 2006).

Table 6: Area in percentage under various uses in LM_3, LM_4 & LM_6, year 1976, 1987, 2000 & 2007

	LULC Type	1976	1987	2000	2007
LM_3	Grassland	0.4	0.39	0.39	0.39
	River line vegetation	0.001	0.00	0.00	0.00
	Natural Forest	3.5	3.3	0.5	3
	Total Forest& grassland	3.9	3.69	0.89	3.39
	Rainfed Crops	47.5	47.6	47.97	47.67
	Rainfed Crops & Shrubs	12	11.35	11.35	11.35
	Irrigated Crops	0.0	0.05	0.08	0.1
	Rainfed Crops & Trees	36.7	37	39.5	37
	Total Agriculture	96.2	96	98.9	96.1
LM_4	Grassland	1.4	1.4	1.4	1.4
	Natural Forest	7.5	7.5	7.5	7.5
	Open Forest	0.002	0.002	0.002	0.002
	Rainfed Crops	80	80	80	80
	Rainfed Crops & Shrubs	0.1	0.1	0.1	0.1
	Rainfed Crops & Trees	11	11	11	11
LM_6	Grassland	6.94	6.94	6.94	6.94
	Rainfed crop	30.097	83.97	93.063	93.063
	Rainfed crop and shrub	53.88	0	0	0
	Woodland	9.089	9.089	0	0

The LM_4 constituted 1.8% of the study area and it was the smallest in size. The area has been under cultivation of traditional food crops since time in memorial. The traditional crops include sorghum, pigeon peas, cowpeas, dryland beans and maize varieties, and pearl millet which are adaptable to the area and have drought tolerance traits. The sub zone was also faced with a myriad of constraints including impassable roads during wet seasons and incomplete land adjudication hampering meaningful development to cause land use changes. Prospectors from the upper zones hoard substantial hectarage under absentee land lords; therefore such land is left under natural vegetation cover.

In LM_6 area under rainfed crops with shrubs correlated with area under rainfed crops ($r^2 = 0.772$) while, changes in area under woodland strongly correlated with that of rainfed crops ($r^2 = 0.826$). This implies that over time, rainfed crop were replacing shrubs and woodland. Shortage of good farmland on the highlands caused migration to the LM_6, which received less than 400mm of rain annually. Beans and maize were major crops grown by 92.3% of the respondents in both seasons but further inquiries indicated that economic yields were only tenable after a span of 5 to 7 years during intense. Though LM_6 was part of the northern grazing area political manoeuvres led to reallocation of land to the landless people. The migrants came from the highlands. Unable to adapt to pastoralism, they migrated with what they knew most such as midland maize varieties (5 series), beans and even Irish potatoes instead of drought tolerant crops, therefore rendering crop production an uneconomical practice. Persistence to this culture consequently translates often to a bare land for eight months in a year. Residents seek alternative livelihoods such as sale of gravel, ballast and charcoal. Findings of a study on status of indigenous and exotic tree species in a wide range of agro-ecological zones east of Mount Kenya postulated destruction of trees which was evidenced by the declining tree cover intensity towards the lowerlands (Oginosako et al., 2006). Such practices constitute injurious land use and management tendencies, a thrust for land degradation and eventual desertification. However, in future due to its proximity to the planned Isiolo resort city as stipulated in Kenya National vision 2030, the economic prospects of LM_6 are bound to improve.

4. Conclusion

Seasonal changes in rainfall remains the single most important indicator of climatic variability in Meru. Land use changes along the AEZ are consequently explained by various factors with climatic variability being among the most important. Increasing investment in irrigated agriculture and use of drought tolerant varieties is a direct respond to climatic variability. Land use changes were certainly being caused by other factors such as population growth and government policy, whose relative importance calls for further studies. Development of good roads led to urbanization in upper midland 2, whereas irrigation development drove changes in upper midland 1 and 2; low highland 1 and low midland 3. Land use changes in low midland sub-zone 6 and upper midland sub zone 3 were driven by drought and in addition aggravated by climate variability. Increasing conversion of land to agricultural was associated with decline in forest cover and stream volumes, hence their services to communities. Replacement of some of predominate crops such as coffee and cotton with crops such as bananas are likely to cause significant demand for water use. Mitigation of negative effects of climate variability on land use which focuses on seasonal land use patterns for enhanced land use performance or productivity are imperative. The agroecological differences in rainfall variability and land use changes call for tailored interventions that are agro ecological zone specific. This would require farmers' empowerment and increased inputs access for irrigation and soil fertility improvement. In addition there is need to put in place policy enforcement and legislation measures for safety and expansion of forest resource.

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