

The impact of livelihood choices on deforestation in Kieni Sub Counties, Kenya

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Abstract: Poverty continues to cause livelihood challenges hence environmental problems among rural populations in semi and arid communities of developing countries. One of the understated impacts of livelihood activities on human wellbeing is their implication on deforestation. Nevertheless, most studies regarding poverty and the environment overlook implications of rural livelihood choices in marginal areas on the environment, and how organizations intervene to secure or enhance the problem. The purpose of this study is to investigate household livelihoods impact on deforestation in Kieni East and West sub counties of Nyeri County. This has become essential as rural populations are the hardest hit in terms of negative effects of livelihoods on the forests. The study adopted cross sectional research design, involving mixed method approaches to collect primary and secondary sources of data. The main source of quantitative data collection was household survey, while the qualitative aspect of data was gathered using semi structured interviews, participant observations, and desk reviews. An independent T-Test was carried out to test statistical significance at $p < 0.05$ at the two sites. Proportionate stratified random sampling technique was used to establish a 400 sample size in 10 sub locations. Hierarchical multiple regression analysis was applied in the determination of impact of livelihood choices on deforestation. Based on the analysis, the linkage between livelihoods and deforestation was significant. Overall results show that deforestation is mainly caused by crop activities [B=0.232], followed by forest activities [B=-.173], and off farm activities [B=-.103]. The results also demonstrate that household livelihood activities impact on deforestation in The Aberdare Ranges in Kieni West was more than in Mt. Kenya Forest in in Kieni East. The study concludes with some recommendations for policy consideration.

Keywords: Poverty, Livelihoods, Livelihood choices, Deforestation, Household, Forest, Mt. Kenya, The Aberdare Ranges, Sustainable livelihoods, Kenya.

I. INTRODUCTION

Generally poverty is associated with the rural populations because they are largely deprived of both basic and economic livelihood opportunities. Contemporary concerns about the level of poverty in rural areas have caused significant interests in research. In 2002, three out of four poor people in developing countries lived in rural areas, with the majority of them relying on agriculture for their livelihoods [1]. According to [2], agriculture was the main source of income for about 2.5 billion people in the developing world. In an effort to improve living standards of populations in developing countries, rural development objective over the last decades has been closely associated with the continuous evolution of development models. These models have been applied as strategies for poverty reduction with prominent examples like community development, integrated rural development, participatory development, sustainable livelihood approaches, poverty reduction strategies, food security programmes, sustainable agriculture and rural development, the Millennium Development Goals (MDGs) and from 2025, sustainable development goals [3]. Generally poverty remains a significant issue despite the rapid rate of urbanization. A study by [4] reported that there are millions of people worldwide who are still living in chronic poverty in spite of progress made in the achievement of MDGs, and that although poverty is declining overall, almost 800 million people are at risk of falling back into poverty if setbacks occur.

For decades now, promotion of rural livelihoods to enhance household welfare by rural development agents in developing countries has focused mostly on simplistic universal approaches of adopting sustainable livelihoods. Consequently, a lot has been learnt about poverty reduction and environmental conservation in the last decade (2008-2018), in terms of the relationship between poverty and environmental degradation and vice versa. Regardless of advances in the development and promotion of sustainable development, rural households' motivation to take up new sustainable livelihoods has remained minimal. This has led to the realization that livelihood adoption is not only a technical problem but also a socioeconomic problem, which in recent times, has directed attention to the influence of socioeconomic and behavioural factors in rural households' livelihood choices. Like in most contemporary developing countries, the fundamental characteristic of rural households in Kenya is the ability to adapt, through the rural livelihoods diversification. Rural livelihoods diversification is a survival strategy in which factors of both threat and opportunity cause the rural household to adapt intricate and diverse livelihood strategies in order to survive [5]. Although participation in multiple activities by rural households is not new, there was relative neglect of diverse dimensions of rural livelihoods other than access to farming until mid-1980s. The dominant strategy for improving rural welfare was therefore small farm output growth.

Previous studies [6],[7] show that poverty is the main obstacle to promoting environmental conservation and some of the environmental problems faced in developing countries are deforestation, land degradation, water shortage and contamination, air pollution and the loss of biodiversity. Over the last decades, interest in sustainable development [8] has been out of above concerns, and although current economic development may be leading to rapid accumulation of physical and human capital, it is at the expense of excessive depletion and degradation of natural capital. Human development and environmental issues have generally been articulated as separate issues [9]. A study on poverty and environmental links [10] reported that although many studies have focused on poverty as an impediment for economic development, the debates on poverty reduction often concentrate on the concept of poverty and its measurement.

A World Bank report [1] shows that poverty reduction in sub-Saharan Africa may be achieved through livelihood diversification in rural areas. In line with this finding, rural households have four possible options to choose livelihoods for their wellbeing. They practice farming, raise livestock, and engage in small businesses. The last option is not appealing, at least for poor households, i.e. access to common forest resources when the need to survive arises. As an active social process, livelihood diversification involves the maintenance and continuous adaptation of diverse portfolio of activities over time in order to secure survival and improve living standards [11]. However, livelihood diversification has causes and consequences for the rural communities, and therefore the overall process of structural transformation impacts on the use of resources and the environment in general [12]. Since the environment is a critical input for rural households, environmental degradation in turn implies a shrinking input base for the poor households that increase severity of poverty. From this discourse, it has been argued that poor people are concentrated in fragile land [13], [6], in line with evidence that poverty has positive correlation with fragility of lands [14], and that the role of environmental resources in the share of aggregate income of the poor is strong [15], [16], [17], [18]. Although poor environmental condition is a determinant of poverty [19], environmental degradation such as deforestation, land degradation and limited water supply worsens the condition of the poor. One of the strategies employed by rural folk in quest to diversity from farming livelihood is dependence on forest resources, which in many ways results in biodiversity depletion. Forest as a resource becomes important as an additional natural resource to define household survival. According to [20], deforestation is the conversion of forest to an alternative permanent non-forested land use such as agriculture, grazing or urban development.

The battle against poverty remains an important priority on Kenya's development agenda as articulated in Vision 2030, the country's development blueprint for the period 2008 to 2030 [21]. The Vision aims to make Kenya a "middle" income country providing high quality life for Kenyans by the year 2030. However, the majority of the poor and food insecure groups continue to be concentrated in rural areas, where their livelihoods [22] depend on subsistence agriculture, making poor farmers encroach on forest resources leading to biodiversity loss. As a newly industrializing country, Kenya [21] therefore faces the challenge of improving its economic performance and the lives of its citizens without undermining the environment upon which its national earnings and individual people's livelihoods depend. The purpose of this study is to determine the impact of livelihood activities of rural households in Kieni East and West Sub counties on deforestation so that development programmes aim to reduce poverty and overcome environmental degradation can be achieved.

II. LITERATURE REVIEW

A. Fundamentals of Livelihood Approaches

Livelihood approaches recognise that resources are at the centre of livelihood choices. Resources are seen in terms of 'capitals' and which are viewed as accessible or inaccessible to people mainly on the basis of structural factors. Approaches like these focus on sustainable livelihoods and were largely developed by DFID in the 1990s [23], [24]. Livelihood studies have come to the fore in response to the limited success of poverty studies [25], [26]. Poverty studies have come to be seen as too engrossed on the powerlessness of poor people, and therefore livelihood approaches [27] enhance poverty studies by starting its analysis with the strategies and creative choices of people in making a living. The approach changes from a focus on what poor people lack to analyse how they manage to survive and thus emphasise the strengths of the poor rather than their weaknesses.

Livelihood approaches view resources as assets and categorise them into five categories: human, physical, financial, natural and social [28], [29], [30]. To investigate the behaviour of rural households in their attempt to improve their welfare, the rural household approach is most appropriate since it requires information on all household members. Definitional concepts of livelihoods vary among researchers. For example [31], define livelihood as 'comprising the capabilities, assets, and activities required for means of living' focusing directly to the links between assets and options households possess in pursuit of alternative activities that can generate the income level required for survival. On the part of [32] and [33], they define a livelihood as comprising the assets, the activities, and the access to these assets and activities as mediated by social capital which together determine the living gained by the rural individual or household. The authors identify assets, mediating processes, trends and shocks, and activities as the critical components and processes that jointly contribute to rural livelihood strategies. Therefore, the rural livelihoods approach is essentially a micro policy analysis framework in which the assets or resources are the activity components that improve livelihoods.

B. Rural Livelihoods and Deforestation

1. Rural Livelihood Activities

Rural households engage in a variety of activities to support their wellbeing. Various scholars have defined livelihood in different but related ways. Livelihood activities according to [34] are the activities, assets and the access that jointly determine the living gained by the rural households, but [35] simply identifies a livelihood activity as a means of gaining a living. Often household diversify livelihood activities to guarantee survival in case there is failure in one or the other. Here, again, meaning of livelihood diversification varies amongst scholars. It is defined as the course by which households establish progressively diverse livelihood portfolios [36]; adequate stocks and flows of cash to meet basic needs [37]; and it is a form of self-insurance [38]. [24] explains that a livelihood is sustainable when it has the capacity to meet the immediate needs of the people without jeopardizing its ability to meet future needs. Different scholars [39], [37], and [40] have identified several types of livelihood diversification activities adopted by rural households in developing countries. The authors content there are four distinct rural livelihood strategies, including: on-farm agricultural production, unskilled on-farm or off farm wage employment and non-farm earnings from trades, commerce and skilled employment and the fourth mixed strategy combines all the three strategies. The components of rural livelihood diversification are also classified by sector as farm or non-farm, by function as wage employment or self-employment or by location as on-farm or off-farm [41], [35].

In Kenya, [42] studied livelihood of arid and semi-arid lands (ASAL) communities in six districts and reported how rural households have a wide variety of activities. On average, the authors found that rural households are involved in 3.6 different livelihood activities. The main livelihood activities included livestock (livestock marketing, hides and skins, butchery, herding, sale of livestock products), fruit and vegetable, casual labour, firewood and charcoal, business, employment, kiosk and hotel, and handcraft manufacture. Based on these findings, two main categories of livelihoods relevant in the study area are discerned i.e. on farm and non-farm. On farm activities are largely crop and livestock activities; and non-farm as off farm and forest based activities.

Forest based activities

Forests are an important resource where many people rely heavily on for their livelihoods. Some use it for subsistence i.e. timber, fuel wood, wild foods (animal and plants), medicinal plants, other non-timber forest products, grazing for animals, forest based agriculture, and nutrient supplements for agriculture. Others use forest for food, while, others use forest for

income generation i.e. sale of the above products, or sell of agricultural or livestock production dependent on forests. Lastly, some people dependent on forest for income from forest based labour by working in different forest based works. Previous studies [16] indicate that as much as 20-25% of people's rural income may be derived from environmental resources in developing countries. Poor people typically engage more in low return forest activities, but often fail to accumulate capital from such activities. [43] identified three broad type of people-forest relationships a) people who live inside the forests, who depend heavily on forests for their livelihoods primarily on a subsistence basis; b) people who live near the forest, who regularly use forest products (timber, fuel wood, bush foods, medicinal plants, etc.), and c) the last set of people, are engaged in such commercial activities like trapping, collecting minerals, or forest industries like logging. These relationships shape dependency of forest neighbouring communities.

Crop based activities

Crop expansion is one of the coping mechanisms for managing food security, production and market risks. For example, crop diversification was the single most important source of poverty reduction for small farmers in South and Southeast Asia [44]. In consistent with this finding, [45] identified three key factors that drive farmers' motivation for crop diversity: i) managing risk, ii) adapting to heterogeneous agro-ecological production conditions, and iii) meeting market demands and food security. [46] also confirmed that households in Central and Eastern highlands of Ethiopia would be able to improve their food security conditions by enhancing their crop diversification. With heterogeneity in agro-ecological, social and economic conditions, farmers' agriculture in Kenya is also highly diversified to meet own consumption and market needs, to withstand price fluctuation and to manage income risks. Crop diversification is therefore considered as an important step in the transition from subsistence to commercial agriculture. As [47] found out, a shift from food production for own consumption to a cash crop production contributes to improvement of income for smallholders.

Livestock based activities

In many developing countries as is the case in Kenya, rural households earn a living from livestock farming and consider keeping livestock as a store of wealth [48]. Livestock makes a multifaceted contribution to the social and economic development of the rural populations. Several factors have contributed both positively and negatively to changes in livestock numbers in developing countries. Some of these factors are economic growth and increased incomes [49]; increase in demand for livestock products arising from rapid growth in human population and urbanization [50], [51]; changing food preferences [52]; and changes in climatic conditions [53]. In West Africa, as in other developing countries, livestock plays an important role in the rural livelihoods by providing different functions, such as food, income, and other cultural and social functions. For the average rural farmer, livestock provides a buffer stock and an effective hedge against income fluctuations [54]. [55] adds that socio-economic and environmental factors such as population growth, urbanization and economic development, changing livestock market demands, impacts of climate variability and science and technology trends have contributed to the changes in livestock numbers in Kenya.

Off farm activities

There has been an increasing recognition that the rural economy is not confined to the agricultural sector alone [56], mainly because the number of poor people in rural areas exceeds the capacity of agriculture to provide sustainable livelihood opportunities in many parts of the developing world [57]. However, dependence upon subsistence farming confronts households with a precarious living, exposing them to adverse contingencies which make them 'risk overseers'. Consequently, the economic activity of poorer people seeks to spread risk among many sources of income and sustenance rather than depending upon a single occupation [58]. [59] found that rural non-farm economic activities may among other things; absorb surplus labour in rural areas, help farm-based households spread risks, offer more remunerative activities to supplement or replace agricultural income, offer income potential during the agricultural off-season, and provide a means to cope or survive when farming fails. Also in terms of employment, [60] show that the share of the non-farm sector in rural employment in developing countries varies from 20% to 50%. Further, in term of income, [61] demonstrates that rural non-farm income shares in Africa ranged from 22% to 93%, while [32] states that 30-50% is common in sub-Saharan Africa. The potential role of the rural non-farm sector in sustaining rural livelihood has attracted the attention of the Kenya government. Government policies and strategies are now focused on the development of the agricultural sector and the generation of non-farming opportunities in rural areas across the country [21]. In the face of acute weather variability, off-farm activities could become attractive adaptation options to agricultural activities. Although rural households tend to turn to off-farm activities to meet their needs and offset income shortfalls, participation appears to be

constrained by capital assets - human, social, financial, and physical. In their study of off-farm employment participation in Honduras, [62] show that educated and wealthier households take advantage of their human and physical capital by participating more in off-farm activities.

2. Rural Livelihoods Impact on Deforestation

Deforestation is a major concern in the developing countries [63] as it is shrinking areas of the tropical forests [64], causing loss of biodiversity and enhancing the greenhouse effect [65]. Therefore in order to save forests, we need to know why they are being destroyed. Distinguishing between the agents of deforestation and its causes is very important in order to understand the major determinants of deforestation. The agents of deforestation, [65] argues, are slash and burn farmers, commercial farmers, ranchers, loggers, firewood collectors, infrastructure developers and others who are cutting down the forests. Causes of deforestation are the forces that motivate the agents to clear the forests. However, most of the existing literature typically distinguishes between two levels of specific factors: direct and indirect causes of deforestation. Direct agents and causes of deforestation, also typically referred to as sources of deforestation, first level or proximate causes [66], [67], [68] are relatively easy to identify but the indirect causes which are usually the main drivers of deforestation are the ones that cause most disagreement and the ones that are hardest to quantify.

Forest activities and deforestation

According to [69] logging can seriously degrade forests. In Southeast Asia logging is more intensive and can be quite destructive. Previous studies [70], [71], [72] found that fuelwood gathering is prevalent in tropical dry forests and degraded forest areas. Fuelwood gathering was considered to be the main cause of deforestation and forest degradation in El Salvador [71]. Therefore, the rising demand for fuel wood and charcoal is also a major cause of deforestation and land degradation in regions where biomass is the main source of energy for domestic uses [73]. [74], [75] have argued that environmental resources provide a variety of life supporting ecosystem services to rural households in developing countries such as timber, non-timber forest products and fish. The extraction of environmental resources in rural areas is often considered an important source of income and a means of livelihoods for low income rural households [76], [77], which results in the degradation of forests [78], [79].

Cropping activities and deforestation

In view of [80], Africa has among the fastest rates of deforestation in the world associated with competing land uses which are mainly agriculture and human settlements. About 60 per cent of the clearing of tropical moist forests is for agricultural settlement [63] with logging and other reasons like roads, urbanization and fuelwood accounting for the rest. Shifting agriculture also called slash and burn agriculture is the clearing of forested land for growing crops until the soil is exhausted of nutrients and then moving on to clear more forest. Previous studies have shown that smallholder production in deforestation and the growing number of such producers notably shifting cultivators were the main cause of deforestation [81], [82]. Most of these studies indicate shifting agriculture as responsible for about one half of tropical deforestation and some put it up to two-thirds.

Livestock activities and deforestation

Livestock has been shown to be one of the major drivers of global habitat change today. The two main habitat changes are degradation of pasture already in use and the clearing of forests for new pasture [83]. Forests are also increasingly being cleared to grow crops such as soya beans and cereals to feed livestock. Deforestation in these areas is predominately caused by livestock farming by small-scale traditional ranchers and by large-scale commercial intensive systems [83]. The role of cattle in deforestation varies, depending upon the type of production system. Previous studies [84] and [85] have identified primary factors of cattle that causes deforestation including: favourable markets for livestock products; government subsidies for livestock credit and road construction; land tenure policies that promote deforestation to establish property rights; slow technological development that favours extensive systems; and policies which depress timber prices and make logging a poor alternative investment.

Off farm activities and deforestation

Expanding cities and towns require land to establish the infrastructures necessary to support growing population engage in off farm activities, which is done by clearing the forests [86]. Tropical forests are a major target of infrastructure developments for oil exploitation, logging concessions or hydropower dam construction which inevitably conveys the

expansion of the road network and the construction of roads in virgin areas [87]. The construction of roads, railways, bridges, and airports opens up the land to development and brings increasing numbers of people to the forest frontier. Whether supported or not by the governmental programmes, these settlers have usually colonized the forest by using logging trails or new roads to access the forest for subsistence land [88]. The development of these infrastructure projects are of worldwide concern, since tropical forest clearing accounts for roughly 20 per cent of anthropogenic carbon emissions destroying globally significant carbon sinks and around 21 per cent of tropical forests have been lost worldwide since 1980 [89]. Also, although national parks and sanctuaries protect the forests, if uncontrolled can lead to improper opening of these areas to the public for off farm activities like tourism that is damaging. Unfortunately, the national governments of tropical and sub-tropical countries adopt tourism for easy way of making money sacrificing the stringent management strategies. Further, many companies and resorts who advertise themselves as eco-tourist establishments are in fact exploiting the forests for profit. In Cape Tribulation, Australia, for example, the rain forest is being threatened by excessive tourism [90].

III. METHODOLOGY

Research design

In order to understand fully the phenomenon of this study, a mix of quantitative and qualitative approaches was used because from past studies [91], [92] the approach is effective for livelihood investigations. The quantitative component of the study was used to collect quantitative data to understand household behaviour through household survey. The qualitative component of the survey measured variables that generally are inappropriate to determine using quantitative techniques [93] and [94]. Additional techniques were used to collect qualitative data in form of focus group discussions, key informant interviews and participant observation.

Study area location

Two sites were used in this study – Kieni East and Kieni West sub counties, in Nyeri County in Kenya. The two sites depict similar farming systems and socio-cultural settings. The study area comprises of four wards in each sub county i.e. Mweiga, Mwiyo/Endarasha, Mugunda and Gatarakwa wards of Kieni West; and Naromoru/Kiamathaga, Thegu River, Kabaruru, and Gakawa wards of Kieni East Sub County. The area of study lies within the longitudes of 36°40" East to 37°20" East. The northernmost point of Kieni just touches the Equator (0°) and then extends to 0°30" South. The area is sandwiched between two major water towers in Kenya i.e. Mt. Kenya and The Aberdares Ranges in Kieni East and Kieni West sub counties respectively. The area is characterized by high temperatures in low altitude areas and low temperatures for areas adjustment to the two water towers. Kiganjo (1830m) is the lowest area, from where the land rises northwards to the Equator at Nanyuki (2300m), eastwards to Mt. Kenya (>4000m) and westwards to Nyandarua (>3000m) above sea level. These altitudes [95] are believed to affect the amounts of rainfall received in the locality, for example Kiganjo receives about 850mm per annum. This rises eastwards to 2300mm at Kabaruru on the slopes of Mt. Kenya and westwards to 3100mm in the Abadare National Park. Therefore, the driest areas are Kiganjo and Narumoru that are within Agroclimatic zones (V) and (VI) respectively. Conversely the mountains (Kenya and The Aberdare Ranges) within zone (I) are the wettest.

Population

According to the 2009 population census [96], the population of Kieni was estimated at 175,812 (51,304 households) over an area of 1,321Km². Populations are mainly immigrants from the higher potential areas of Nyeri County and surrounding counties in the Mt. Kenya region and The Aberdare Ranges. The study populations were all the 51,304 households. Ten sub locations for this study were randomly selected from a total 59 sub locations (clusters) in the eight wards (strata). The individual farm household was used as the unit of analysis.

Sample size

The sample size for the study was determined using this formula as proposed by [97] at 95% confidence level and P=0.5, i.e. $n = N/[1 + N(e)^2]$; where: n = the desired sample size; N = population of study (51,304); and e = level of precision (sampling error), the range in which the true value of the population is estimated. In this study, the range was $\pm 5\%$. Based on these values set for alpha, desired statistical power level, effect size, and anticipated number of predictors, a sample size (n) of 396 (≈ 400) households (200 households for each of the two sites) of study site was considered

adequate to balance required level of reliability and cost. The number of ten sub locations was also considered to be sufficiently large for drawing valid statistical inferences and was also manageable to be surveyed with the available resources of finance and time.

Sampling Techniques

In order to represent the population with sufficient accuracy and to infer the sample results to the population, the target sample households were selected in a random two stage sampling process. In the first stage, the study sub locations were randomly selected using proportionate stratified random sampling technique (PSRST) to determine the number of sample sub locations relative to sizes of each stratum(ward) in the population. This resulted in the selection of 10 sub locations; see Table I., each with 40 households according to their respective population strengths. Accordingly, the probability of selecting each of the ten selected sub locations based on population size was determined and varied between 11.1% for Gakanga sub location, and 56.8% for Kamatongu sub location, see Table I. The probability of selecting each household in the selected sub locations based on the population was also determined, and varied from 1.4% for Kamatongu to 10.9% in Bondeni sub location (Table I.). The constant overall weight of 1.3 (see Table I) demonstrated that each household in the population had an equal chance of being selected for the household survey interview. In the second stage, using random sampling techniques, individual households units in the selected sub locations were randomly selected in relation to population. Household lists provided by the local administrators (area Assistant Chiefs) of the sampled sub locations were used as sampling frame for selecting households. Accordingly, 400 households (40 households for each of the ten sub locations) were randomly selected for the study (Table I).

Instruments and Data Collection Procedures

A survey using structured questionnaire was the primary method of investigation employed for this study. However, focus group interviews, key informant interviews, and direct personal observations were also used in order to enrich the investigation with relevant qualitative information. A common questionnaire was developed for both study sites. The questionnaire [98], was found to be ideal instrument because it helped to gather descriptive information from a large sample in a fairly short time. The questionnaire was administered in Kikuyu, the local language which households of both sites speak between April and July, 2017. A team of 5 enumerators was recruited and trained for each study site to collect the data from the sampled households. Two separate focus group discussions were conducted for each study site, with male and female household members. The focus group discussions were conducted in June 2017 after some preliminary findings from the questionnaire survey data were investigated. The focus groups composed of between 6 and 9 members of households in both sites. The participants were identified in purposeful selection among the survey samples that were thought to express their views actively in consultation with the enumerators. Village and major town markets in the area were visited to gather information on prices of major traded agricultural, livestock and forest products, including off farm activities. Farm field observation was conducted on some household farms to observe livelihood activities, management practices, and spatial locations in the farmers' land holding.

Data organisation and analysis

The data was coded and entered into SPSS in three separate data files; one for Kieni East, the second for Kieni West, and the third for pooled data. To estimate impact of livelihood activities on deforestation, multiple regression analysis technique was used to predict the unknown values of deforestation variables from the known values of the four livelihood activity variables, also called the predictors (see Table II). Multiple regressions as a technique had an advantage of enabling the researcher to study the individual livelihood activity variable influence on deforestation. As shown in Table II, independent sub variable for forest activities(FA) included household annual income from forest activities and proportion (%) that depends on forest for a livelihood. The second category of crop activities(CA) with sub variables that consisted of average household annual crop income, and average number of crop varieties per household. Household livestock activities(LA), annual income from livestock sales and livestock numbers in tropical livestock unit (TLU) variables were studied as the third category, while the fourth category of variables related to off farm (OA) sub variables including annual average income from off farm activities and proportion of households who engage in off farm activities. Dependent variables related to deforestation (D) which comprised of the following sub variables i.e. proportion of households who felt forest tree cover has reduced over the last 5 years; household proportion that belief tree cutting is prevalent in the area, and household proportion that belief timber extraction from forest is by villagers.

Multiple Regression Models

Based on general regression model, regression of livelihood activities on deforestation is written as follows (Eq. 1):

$$Y_D = B_0 + B_{FA} X_{FA} + B_{CA} X_{CA} + B_{LA} X_{LA} + B_{OA} X_{OA} \dots \dots \dots 1$$

where: Y_D = Deforestation; B_0 = Regression intercept coefficient ; B_{FA} = Forest activity regression coefficient ; X_{FA} = Forest activity variable; B_{CA} = Crop activity regression coefficient; X_{CA} = Crop activity variable; B_{LA} = Livestock activity regression coefficient; X_{LA} = Livestock activity variable; and X_{OA} = off farm activity variable.

Considering deforestation factors identified in this study, regression coefficients for four livelihood activity variables may be computed as shown below in the regression models (2, 3, & 4) for the deforestation variables in Kieni East, Kieni West, and overall study area. It is therefore a 3-step hierarchical regression, which involves the interaction between four continuous scores. In this case, deforestation variables for Kieni East were entered at Step 1 (Model 1). In the second model, deforestation variables for Kieni West entered (Model 2), while pooled data for the first two models (Model 3) was for the overall deforestation in the study area.

$$\text{Model 1: } Y_{dke} = B_0 + B_{FA} X_{FA} + B_{CA} X_{CA} + B_{LA} X_{LA} + B_{OA} X_{OA} \dots \dots \dots 2$$

$$\text{Model 2: } Y_{dkw} = B_0 + B_{FA} X_{FA} + B_{CA} X_{CA} + B_{LA} X_{LA} + B_{OA} X_{OA} \dots \dots \dots 3$$

$$\text{Model 3: } Y_D = B_0 + B_{FA} X_{FA} + B_{CA} X_{CA} + B_{LA} X_{LA} + B_{OA} X_{OA} \dots \dots \dots 4$$

where: Y_{dke} = deforestation variable in Kieni East; Y_{dkw} = deforestation variables in Kieni West ; and Y_D = overall deforestation

The data obtained from all respondents (200 from each site including their livelihood activities and deforestation) were considered in the models. The explanatory variables (X_i) included in the model were household: forest activities (FA), crop activities (CA), livestock activities (LA), and off farm activities (OA). FA, CA, LA, and OA are categorical variables. The dependent variable used in this multiple regression analysis was deforestation experienced by households. Like explanatory variable, dependent variables are also categorical. In Table III regression analysis results are shown of livelihood activities on deforestation.

IV. RESULTS AND DISCUSSION

Regression results (Table III) indicate that the main causes of deforestation in the study area are crop, forest, and off farm activities practiced by households in the area. Results show that livestock activities had insignificant effect on deforestation.

Crop activities (CA)

In Table II, it is shown that 76.5% of the respondents engage in cropping activities. Common crops grown in the area include: maize, beans, potatoes, cassava, and vegetables, amongst others. Regression results in Table III show that engaging in crop activities leads to deforestation [$B=0.232$, $t\text{-values}=3.931$, $p<0.05$]. It is also shown that the effect of crop activities on deforestation in both sites was significant (Kieni East [$B=.149$, $t\text{-values}=2.182$, $p<0.05$], Kieni West [$B=.236$, $t\text{-values}=3.593$, $p<0.05$]). Results show the impact of cropping activities is almost half [$B=.149$] in Kieni East (Mt. Kenya) compared to Kieni West [$B=0.2329$] in Kieni West (The Aberdare Ranges). These findings are in conformity with previous studies of similar nature. [101] found that a third to fifth of deforestation is caused by subsistence activities by people who simply use the forest's resources for their survival. The results are also in consistent with [63] findings that about 60 per cent of the clearing of tropical moist forests is for agricultural settlement. After cutting trees for building material, people in the area use the slash-and-burn technique to clear the surrounding forest for short-term agriculture. Also as people who engage in agricultural activities in the forest areas continue with their activities, the land becomes degraded and people are forced to move to new forest frontiers thus increasing deforestation [98]. In defence of this finding, it has been argued [81], [82] that smallholder production in the forest and the growing number of such producers like shifting cultivators will remain the main cause of deforestation for generations to come.

Forest activities (FA)

Results in Table II it is shown that 45.8% households in the study area engage in the following forest activities i.e. grazing of livestock, farming, fuel wood collection, charcoal burning, and collection of non-timber products. Regression results in Table III show that overall engaging in forest activities leads to deforestation ($B=0.192$, $t\text{-values}=4.132$, $p<0.05$). However, the impact of forest activities on deforestation was insignificant in Kieni East ($B=.110$, $t\text{-values}=1.369$, $p>0.05$), but significant in Kieni West ($B=.173$, $t\text{-values}=2.335$, $p<0.05$). These findings are in concurrence with previous studies indicating that households cut down trees in forest to harvest timber for wood, products or fuel, as one of the primary drivers of deforestation [100]. The other practice that drives deforestation is farming in forested area. Key informant interviews and focused group discussions in both sites reported that through the *shamba* system (slash-and-burn technique), households in the study area are allowed to clear the land for crops or for cattle. Also, grazing of livestock in the forest removes the vegetation cover over the soil and the exposed soil gets compacted due to which the operative soil depth declines. So the roots of trees cannot go much deep into the soil and adequate soil moisture is not available for vegetation cover. According to previous studies [84], [85], among other factors cash flow, risk reduction (through diversification), and use of cattle as a production input for other farming activities (manure for fertilization, provision of draft power) are the main factors that motivate households to overgraze, leading to deforestation in the long run.

Off farm activities (OA)

Table II shows 60.5 per cent of respondents reported to engage in off farm activities in the study area. Regression results in Table III. show that engaging in off farm activities leads to deforestation ($B=0.103$, $t\text{-values}=2.139$, $p<0.05$). Also, results show the effect of off farm activities on deforestation in both sites was varied. Like for forest activities, it was significant in Kieni West [$B=.274$, $t\text{-values}=3.799$, $p<0.05$] and insignificant in Kieni East [$B=.123$, $t\text{-values}=1.599$, $p>0.05$]. Households in the study area engage in various off farm activities as a strategy of livelihood diversification. These include: casual and formal employment, trade/business (self-employment), selling forest products, and food for work programs. These results are in consistent with previous studies [100] that have shown that human activities, including off farm activities, are the primary contributors to forest degradation. The authors argue that peasant farmers with few alternative economic opportunities tend to drive deforestation, noting that low skills or weak off-farm labour markets may lead poor households to undertake activities with low returns, which might lead the poor to deforest more. Following the introduction of new governance structures in Kenya (Constitution of Kenya, 2010), rural urbanization has been on the increase. In the study area, there has been emergence of new market centres and expansion of old ones over the last five years. These have resulted into deforestation in the area, consistent with reports by [102] and [103] who found that expanding cities and towns require land to establish the infrastructures necessary to support growing population engage in off farm activities, which is done by clearing the forests. Moreover, [87] argued that the construction of infrastructure like roads which are determinants of non-farm activities lead to opening up of forest thus increasing numbers of people to the forest frontier.

V. CONCLUSION

The research findings revealed that most of the livelihood activities of the locals to some extent cause deforestation but some are more serious than others. Cropping, forest, and off farm activities were perceived as the main livelihood activities that have an immense impact on forest ecosystem. We found the strongest association between crop activities and deforestation while the weakest link was between off farm activities and deforestation. The results demonstrate the impact of livelihood activities on deforestation in the study area. First, crop activities were found to play a significant role in leading to deforestation as was demonstrated by [101] and [63] who found that about 60% of deforestation in tropical forest is caused by subsistence farming and agricultural settlement respectively. It was thus realized that farm expansion leads to clearing virgin lands for crop production. Secondly, we conclude activities like grazing, fuel wood collection, charcoal burning, and other forest activities were also associated with the deforestation outcome. The results are in consistent with studies by [84] and [85] who pointed out risk reduction as one of the factors that motivate households to overgraze in the forest. Furthermore demand for charcoal in the sub counties and other parts of the country encourages charcoal producers to expand their activities hence worsening deforestation rate in the area. It was also realized that high and ready market for wood log promotes the activities of chainsaw operators which end up degrading the forest. Thirdly, we conclude that off farm activities carried in the area contribute to deforestation, in coherent with findings of [87], who

argued that the construction of infrastructure like roads which are determinants of non-farm activities lead to opening up of forest and increase numbers of people to the forest frontier.

Therefore, policy recommendations for sustainable use of forest resources should be developed based on evidence from deforestation founded on livelihood activities. The National and County governments must continue to show political will to regulate and monitor the forestry situation with strong measures, allowing the balance of local community interests, state interests, business interests and with a master plan for appropriate, sustainable and equitable development. Improved management of timber concessions will not alone solve deforestation. Centrally imposed concessions should be abandoned in favour of a process favouring local level consultation and participation. The right of communities to manage forest should not be seen as a privilege to be granted by the state, but rather as an essential step to enable local people to provide a service for the present and future economic wellbeing of the area. Local communities need input and access to concession areas, and local alternatives to concessions should be considered. Therefore incorporating views and decisions of local people in government environmental policies to formulate good policies can address challenges of forest communities. This would encourage community participation in an environmental protection as well as forest management. Rigorous enforcement of environmental bye laws at both national and county/community level to apprehend and punish those who engage in activities such as illegal wood logging and charcoal production would serve as deterrent. Both the Ministry of Agriculture and the Ministry of Environment have taken an interest in community forestry initiatives by creating community forestry associations. Capacity building of local communities through such groups should be considered to increase their resilience to environmental degradation. Government interventions through the provision of alternative livelihoods like improvement of livelihoods for the sustainable use of forests and forest products through the cultivation of drought resistance crops and medicines should be encouraged. Moreover, nature based enterprises such as beekeeping and other skill training that could empower the local people to gain self-employment as well as income would serve as alternative to activities with negative effects to forest resources in the area.

VI. APPENDICES

List of table:

Table I. Sub locations and number of Households randomly selected for questionnaire survey

A	B	C	D	E	F	G	H	
Strata/Ward	Cluster/ Sub location	Sub Location Size	Cumulative Sum(a)	Clusters sampled	Probability 1	Household per Sub Location	Probability 2	Overall weight
Naromoru/ Kiamathiga	Naromoru	1161	1661	1200	32.4%	40	2.4%	1.3
	Ndiriti	1094	2755					
	Gaturiri	1063	3818					
	Rongai	989	4807					
	Kamburaini	1813	6620	6330	35.3%	40	2.2%	1.3
	Thigithi	666	7286					
	Murichu	762	8048					
	Gikamba	1098	9146					
Kabendera	830	9976						
Kabaru	Kirima	1505	11481	11460	29.3%	40	2.7%	1.3
	Ndaathi	1719	13200					
	Kimahuri	1961	15161					
	Munyu	1020	16181					
Thegu	Thungari	1811	17992	16590	35.3%	40	2.2%	1.3
	Lusoi	605	18597					
	Thirigitu	1446	20043					
	Maragima	872	20915					
Gakawa	Gathiuru	1609	22524	21720	31.4%	40	2.5%	1.3
	Githima	1363	23887					
	Kahurura	5125	29012					
Mweiga/Mweiga	Bonden	367	29379	26850	7.2%	40	10.9%	1.3
	Amboni	1194	30573					
	Njengu	784	31351					
	Kamatongu	2915	34272	31980	56.8%	40	1.4%	1.3

Gatarakwa	Watuka	1126	35398					
	Lamuria	1366	36764					
	Embaringo	1217	37981	37110	23.7%	40	3.3%	1.3
	Kamariki	1809	39790					
Endarasha/ Mwiyogo	Mitero	901	40691					
	Charity	1456	42147					
	Gakanga	569	42716	42240	11.1%	40	7.0%	1.3
	Endarasha	1907	44623					
	Kabati	701	45324					
	Muthuini	571	45895					
	Labura	1494	47389	47370	29.1%	40	2.7%	1.3
	Mwiyogo	471	47860					
Mugunda	Karemeno	538	48398					
	Ruirii	993	49391					
	Kamiruri	722	50113					
	Nairutia	1191	51304(b)					
TOTAL	10					400		

Table II. Descriptive statistics of Kieni East, Kieni West, and Pooled Data (all surveyed households)

Variable Description	Kieni East (N= 200)		Kieni West (N= 200)		Pooled Data (N= 400)	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
Household activities						
% household who engage in forest activities[FA]	39.2		52.2		45.8	
% household who engage in crop activities[CA]	64.5		88.5		76.5	
% household who engage in livestock activities[LA]	47.0		32.5		39.8	
% household who engage in off farm activities[OA]	55.0		66.5		60.5	
Independent variables(livelihood activities)						
[FA]Annual Household income from forest activities (KShs) **	10,459.55	11,653.17	20,995.45	37383.35	31,455.20	21,554.19
[FA]% of household who depend on forest for a livelihood***	96.2		100.0		98.4	
[CA]Annual household income from agriculture (KShs) ***	23,056.62	52,615.09	81,033.08	175,790.46	34,430.73	63,077.08
[CA]Average number of crop varieties grown per household	4.8		3.8		4.3	
[LA]Annual Household income from livestock (KShs) **	29,064.89	37,175.48	37,783.08	46,821.33	32,628.93	41,472.23
[LA]Average household livestock number in TLU***	12.48		7.97		10.23	
[OA]Average annual household income from off farm activities (KShs) **	63,672.73	70,353.60	68,490.91	142,522.19	66,300.83	115,263.53
[OA]% of households who engage in off farm activities **	55.0		66.0		60.5	
Dependent variables(deforestation)						
% household who felt forest tree cover has been depleted over the last 5 years**	26.6		18.9		22.8	
% of households who belief tree cutting is prevalent in the area **	56.3		51.7		54	
% of households who belief timber extraction from forests is by villagers	29.1		32.5		30.9	

Variables in which sample households of Kieni East have significant differences from those of Kieni West: *** = at 0.01 level of significance ** = at 0.05 level of significance.

Table III. Hierarchical regression analysis coefficients of livelihood activities predicting deforestation for Kieni East and West and pooled data

Variables	Kieni East			Kieni West			Pooled Data		
	Model 1: Deforestation			Model 2: Deforestation			Model 3: Deforestation		
	B	t	Sign.	B	t	Sign.	B	t	Sign.
Const.		-6.817	.000		-3.256	.001	-.336	-7.166	.000
Forestacktivities[FA]	.110	1.369	.172	.173	2.335	.021	.103	2.139	.033
Cropsactivities[CA]	.149	2.182	.030	.236	3.593	.000	.232	3.931	.000
Livestockactivities[LA]	.118	1.476	.142	-.023	-.305	.761	.056	1.181	.238
Offfarmactivities[OA]	.123	1.599	.111	.274	3.799	.000	.192	4.132	.000
F		4.984			13.314			16.358	
Adjusted R ²		.074			.198			.133	

Dependent Variables: Deforestation.

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