

# Assessing the impact of Farming Systems and Land use change on Dryland plant Biodiversity: A case study of Mwala and Yatta sub Counties in Machakos County, Kenya

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**Abstract**— The study focused on assessing the impact of farming systems and land use change on dryland biodiversity and documented the views, knowledge and practice of the farmers on the role of biodiversity in the semi-arid midlands of Eastern Kenya. A descriptive survey design was employed to collect data on farmers' views, knowledge and practices from 120 respondents from four locations in Mwala and Yatta Sub Counties in Machakos County. Nested Quadrat method was employed to determine levels of loss of plant live forms in the cultivated and uncultivated areas in the four locations. The collected data was then analyzed using simple descriptive statistical such as percentages, frequency and means. Other methods used in the analysis included Logistic regression, Pearson Chi-square and t-tests. The study established that Households in the study areas understand the benefits of non-crop tree species (100%) and therefore grow the tree species (72%) and also conserve the indigenous species (88%). Results from multivariate logistic regression analysis further showed that the age and level of education of the respondents were the strongest statistically significant factors affecting the farmers' knowledge on above ground biodiversity and its relevance to crop production ( $p < 0.005$ ). It was also established that mixed farming system was the main farming system practiced by 98% of the households in Mwala and Yatta sub counties, with crops and livestock on the same farm. It was established that average population of plant live forms (grass, shrubs and trees) in the study sites was found to be significantly different between cultivated and uncultivated zones in the four locations ( $p < 0.005$ ). It is concluded that human activities such as farming increases loss of plant live forms and interferes with above ground biodiversity and reduces the effectiveness of crop-livestock integration in the production systems due to reduced grazing areas.

**Keywords**— Biodiversity, Land use, Farming Systems.

## I. INTRODUCTION

According to the Convention on Biological Diversity (CBD) the most comprehensive global framework for conservation of biodiversity, the word "Biodiversity" was coined from the words 'biology' and 'diversity' and is defined as the totality of genes, species and ecosystems. It is thus distinguished into genetic diversity, species diversity and ecosystem diversity. At species level, it is construed to include plants, animals and micro-organisms that are and form the life support system of the earth. It can be measured by the types of different

species, or the genetic variations within and between them and how they interact with each other (Institute of Economic Affairs, 2011)

Globally, concerns about the changes in land use and ground cover emerged due to realization that land surface processes influence climate and that change in these processes impact on ecosystem goods and services (Lambin et al., 2003). The impacts that have been of primary concern are the effects of land use change on biological diversity, soil degradation and the ability of biological systems to support human needs.

Crop yields have declined, forcing people to cultivate more and more land to meet their needs (Kaihura and Stocking, 2003).

In the early 2000s, approximately 30% of Kenya was affected by very severe land degradation (UNEP, 2000) and an estimated 12 million people, or a third of the Kenya's population, depended directly on land that is being degraded (Bai, et al., 2008). The droughts of 1970-2000 accelerated soil degradation and reduced per-capita food production (GoK, 2002). According to Muchena (2008), land degradation estimate is increasing in severity and extent in many areas and that over 20% of all cultivated areas, 30 per cent of forests and 10% of grasslands are subject to degradation. The expansion of cropping into forested and water catchment zones accounts for much of this degradation. The damage to soil, loss of habitat, change of land use, water shortages and siltation leads to reduced ecosystem services. Since the 1972 United Nations Conference on Human Environment held at Stockholm, Sweden, the Government of Kenya has continued to reinforce formulation of policies and strategies that would address land degradation. As Murage, et al., (2000) noted, farmers' perceptions and experiences are paramount when planning to implement an enterprise counteracting the on-going land degradation. Moreover, recent diagnostic participatory approaches are increasingly showing that farmers clearly perceive and articulate differences in the levels of soil fertility on their farms.

According to Intergovernmental Panel on Climate Change (2001), in Africa agriculture has been the main contributor to current economy ranging from 10% to 70% of Gross Domestic Product (GDP) and is highly affected by land degradation leading to exploitation of natural resources like forests, settlement and cultivating of fragile land, like hills and sloppy areas. Due to the information gap among people in Africa on land conservation, this has led to mismanagement of natural resources causing land use change, although this has been highly challenged by global warming throughout the world. Biodiversity can contribute directly to food security, nutrition and the well-being of rural communities by providing a wide range of plant and animal food products from both domesticated and wild sources. It can also play a role in maintaining important ecosystem services while contributing to enhanced resilience and stability of rural social-ecological systems. Biodiversity can be viewed as a safety-net to vulnerable households experiencing shocks caused by droughts or market volatility (FAO, 2011). Biodiversity can be greatly affected, by

decisions made by various stakeholders about land-use and agricultural, livestock and natural resource management practices.

Many smallholder farmers focus on increasing land productivity and crop yields without paying much attention on what happens to biodiversity. The farmers have little or no information on the relevance of non-crop species and the surrounding biodiversity on sustainable and increased crop production. In the efforts of encouraging sustainable dryland biodiversity, use of local knowledge and practices is a key element for success. Land ownership and changes in land uses may affect the distribution of non-crop tree species and general biodiversity. The choices people make in terms of what they plant influences the diversity and abundance of crop and non-crop trees. Population growth has led to land fragmentation in the study area leading to opening up of uncultivated land for crop production. Farming clears plants, interferes with biodiversity and reduces the effectiveness of crop-livestock interactions due to reduced grazing areas. Cultivation also enhances decomposition of organic matter indirectly affecting above ground biodiversity. Farming systems introduced to small holder farmers like mono-cropping and use of inorganic fertilizers can significantly reduce agrobiodiversity by affecting above ground biodiversity. So far, there are very limited studies done on dryland areas, and particularly in the proposed study area focusing on the relationship between biodiversity and land use change and farming systems, and their relevance to improved crop yields for small scale farmers. Therefore, the purpose of this study was to establish the relationship between different farming systems, land use change and the dryland biodiversity in the study area and recommend the appropriate way forward. Specifically, the study sought to: assess the effect of farming systems and land use change on above ground dryland biodiversity for cultivated and uncultivated areas of Mwala and Yatta Districts; and document the views, knowledge and practice of farmers regarding the status and role of dryland biodiversity in crop production.

## II. MATERIALS AND METHODS

### 2.1 Description of the study area

This study was carried out in Agro-ecological zone (AEZ) Low Midland (LM) 4 and 5 in Mwala and Yatta Sub Counties respectively in Machakos County. The study was executed in two locations in each of the two Sub Counties. These are Kavumbu and Kyawango Locations in Mwala Sub County, and Katangi and Ndalani Locations in Yatta Sub

County. Population density in the study area varies with the agro-ecological zones, and ranges from 40 to 100 person/km<sup>2</sup> (Jaetzold et al, 2006).

## 2.2 Data collection and analysis

Semi-structured questionnaires were used to gather information on the level of understanding of the farmers on dryland plant biodiversity and its relevance to crop production. Respondents were identified using simple random sampling method. Information on farmers' understanding on biodiversity and its link to crop production was recorded during the interviews. The different farming systems practiced by the farmers and their effects on above ground plant biodiversity were also recorded. A total of 120 respondents were interviewed in the two Sub Counties with 30 in each location. To determine the level of reduction in plant diversity, the dead stumps and the living trees were compared at the sampling points. All the farms which were sampled during the transect walk were geo-referenced. The method was pre-tested before the actual field work started to minimize errors during the actual work.

Data was analyzed using the Statistical Package for Social Sciences (SPSS) where Simple descriptive statistical such as percentage, frequency, mean, mode and median were generated and presented in form of tables and graphs. Descriptive statistics were used in report presentation to bring out the dominant knowledge, attitude (feelings or perceptions) and practice of the farmers regarding the status and role of dryland plant biodiversity on crop production. Logistic regression was also used to determine the effects of social-economic factors on the farmers' knowledge on above ground biodiversity and Pearson Chi-square analysis for the association between socio-economic factors and farming activities. Data on plant live forms between the cultivated and uncultivated lands was subjected to t-tests and analysis of variance (ANOVA) using mixed model in Statistical Package for Social Sciences (SPSS 20). Differences between variable means in the cultivated and uncultivated lands was examined using least significant difference (LSD) at the 5% level of significance.

## III. RESULTS AND DISCUSSIONS

### 3.1 Households' information and demographic characteristics

Findings from the study showed that 82% of the households in the study areas were male headed while 18% were female headed households. The average age of the respondents was 51 years and thus respondents were mature enough to share quality knowledge and experiences on different aspects of

plant biodiversity. Most of the respondents had primary (54%) and secondary (29%) as their highest levels of education. 86% of the respondents practiced farming as the main household occupation while the others were employed (7%) and traders (7%) as shown in Table 1.

Table 1: Households' general and demographic characteristics

Variable	Statistics	Percentage (%)	Mean
Age (Yrs)			51
Household head	Male	82	
	Female	18	
Marital status of household head	Married	84	
	Unmarried	6	
	Separated/divorced	3	
	Windowed	8	
	Never married	0	
Education level of household head	None	13	
	Primary	54	
	Secondary	29	
	Above secondary	4	
Occupation of household head	Employed	7	
	Farmer	86	
	Trader	7	

Results from multivariate logistic regression analysis further showed that the age and level of education of the respondents were the strongest statistically significant factors affecting the farmers' knowledge on above ground biodiversity and its relevance to crop production ( $p < 0.005$ ). Respondents' knowledge on above ground biodiversity and its relevance to crop production was found to increase with increasing age and levels of education ( $p < 0.005$ ). Other demographic factors such as gender, marital status and occupation were found to insignificantly effect on the knowledge on above ground biodiversity and its relevance to crop production ( $p > 0.005$ ) (Table 2).

Table 2: Multivariate logistic regression analysis for the association between socio-demographic factors and knowledge on above ground biodiversity and its relevance to crop production

Variable	B	S.E.	Wald	df	p value
Age	.059	.025	5.581	1	.018
Gender	1.179	1.066	1.222	1	.269
Marital status	19.302	13397.664	.000	1	.999
Education	.940	.449	4.377	1	.036
Occupation	.763	.628	1.477	1	.224
Constant	-47.446	46730.118	.000	1	.999
Variable(s): Age, Gender, Marital status, Education, Occupation					

### 3.2 Farmers' knowledge on importance of non-crop tree species

Most HH (88%) understand the benefits of non-crop tree species and therefore grow them and also conserve the indigenous species. In the study area, Mwala Sub County practiced higher levels of diversity in terms of growing of non-crop tree species and conservation of indigenous species an indication that farmers in that area are more resilient and providing for in-situ conservation. Farmers understand the importance of biodiversity as most of them reported benefits such as environmental conservation, soil conservation and soil fertility improvements, medicinal and nutritional purposes, beauty and ornamental purposes, provision of firewood, fencing posts, timber and other building materials (Table 3). According to Rerkasem et al., (2009), in many traditional agricultural landscapes, the wild and cultivated areas are integrated under a management system to complement each other. Various forms of forests and individual trees are cared for, managed and used for food, fuel, medicine, timber and various other necessities.

Table 3: Purposes of non-crop tree species in the farm

Purposes of non-crop species	Frequency	Percentage (%)
Firewood	41	24.8
Timber/building materials	41	24.8
Shade	25	15.2
Environmental conservation	14	8.5
Fencing	12	7.3
Wind brake	10	6.1
Soil conservation	6	3.6
Charcoal	5	3.0
beauty/amenity/Ornamental	3	1.8

Income	2	1.2
Draw rainfall	2	1.2
Nutritional value	2	1.2
Medicine	1	0.6
Nitrogen fixation/soil fertility	1	0.6

#### 3.2.1 Land ownership and utilization

Land ownership in the study areas was found to be evenly distributed among HH with majority of HHs owning 2-5 acres of land. However, majority of the HHs cultivated 2-3 acres of their land. This is an indication that some of the land might have been put under non-crop tree species for the purpose of diversification. It was also established that the amount of land cultivated significantly depends on the size of land owned by the household ( $p < .005$ ). Crops grown by farmers include maize, green grams, beans, sorghum, millet, tomatoes, cassava and pigeon peas. The crops were intercropped with fruit trees such as mangoes and oranges tree as reported by 93.2% the respondents. Land utilization is significantly associated with the respondents' occupation and land owned ( $p < 0.005$ ) as shown in Table 4. Other studies conducted elsewhere in tropical regions have shown, for instance, that farmers with larger farms are willing to manage trees for timber production (Sebastian et al. 2014). More timber trees can be retained or planted in pastures, especially in linear plantings such as living fences, farm boundaries and along internal roads and paddock divisions (Plath et al. 2010; Esquivel et al. 2014). Farmers produce timber even in small-scale fallows (Marquardt et al. 2013; Robiglio et al. 2013)

Table 4: Pearson chi-square analysis for the association between crops growing and other socio-economic factors

Variable	Chi-square	df	p value
Occupation of respondent	25.697	15	.041*
Education level of respondent	15.332	15	.428
Amount of land owned by household	35.582	15	.002*
Land ownership status	5.715	5	.335

\*. The Chi-square statistic is significant at the .05 level.

#### 3.2.2 Farming systems

Mixed farming systems is the main farming system practiced by Households in the study areas, with crops and livestock on the same farm. Households grow and keep a variety of

crops and animals. The main cropping systems identified during the study included agroforestry, intercropping, mono-cropping and livestock keeping. Intercropping fruit trees and other farm crops encouraged planting of non-crop trees and therefore increasing plant biodiversity. 94% of farmers in the study areas had maintained the same trend of intercropping trees and crops for the last five years (Table 5). According to Selvaraju et al., (2006), many communities harvest wild vegetables, fruits, tubers and other edibles from the forest during the year, especially during the season of greatest food scarcity and use them as food. The establishment of more trees in different land uses can also increase the fuel-wood supply and avoid the extraction of wood from forests (Ndayambaje et al. 2013). Most on-farm production of fruits is lost due to poor market development (Almendarez et al. 2013); home consumption of fruits and other edible products from woody species is critical for food security, as has been shown in many agro-ecological zones e.g. in dryland Africa (Kehlenbeck and McMullin 2015). Despite the demonstrated contributions of non-crop tree species to domestic consumption, modest income generation, reduction of vulnerability to contingencies, conservation of tree biodiversity and carbon sequestration, more efforts are needed to promote the establishment of trees at the farm level (Lovell et al. 2010). The potential role of incentives such as payments for ecosystem services (Rudel et al. 2016), and the creation of conditions to increase the net incomes and cash in smallholder farm economies need to be assessed and promoted (Etongo et al. 2015). Providing farmers with sound technical advice on non-crop tree species and farmer managed regeneration may also increase the role of trees on farmers' livelihoods (Regmi and Garforth 2010; Oeba et al. 2012; Iiyama et al. 2017). Econometric studies show that the decision to grow trees is not necessarily the same as deciding the number of trees grown. Land certification, as an indicator of tenure security, increases the likelihood that households will grow trees, but is not a significant determinant of the number of trees grown. Other variables, such as risk aversion, land size, adult labor availability, and education of household head, also influence the number of trees grown (Mekonnen and Damte 2011).

Table 5: Main farming systems in each location

Farming system	Kyawango (%)	Katangi (%)	Ndalani (%)	Masii (%)
Intercropping	0	52	57	47
Shifting cultivation	0	0	0	0
Mono-cropping	71	22	11	20

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Strip cropping	0	0	4	0
Livestock keeping	11	67	39	50
Agro-forestry	93	33	43	37
Mixed cropping	7	44	68	3

The main livestock kept include cattle and goats (ranging from 1-10) compared to sheep, pigs and donkeys. About 88% of the HHs interviewed kept over 5 chicken. The farmers practice intensive livestock production on cattle, goats, sheep, donkey and poultry. The number of livestock kept was significantly associated with the farming system used ( $p < .005$ ) as shown in Table 6.

Table 6: Number of livestock kept

Livestock	None	1 - 4	5 - 10	10 - 14	15 and above
Cattle	23%	60%	15%	0%	2%
Goats	8%	33%	31%	11%	17%
Sheep	74%	16%	6%	3%	1%
Poultry	7%	5%	28%	30%	30%
Pigs	100%	0%	0%	0%	0%
Donkeys	67%	32%	2%	0%	0%

Different farming systems contribute differently in the efforts of maintaining above ground biodiversity in the study area. According to Maitima, et al, (2004), in forest and communal grazing areas, adjacent to mixed farming areas, plant and animal biodiversity may decrease because of over-grazing. According to FAO (2011)<sup>[30]</sup>, Biodiversity can contribute directly to food security, nutrition and the well-being of rural communities by providing a wide range of plant and animal food products from both domesticated and wild sources. It can also play a role in maintaining important ecosystem services while contributing to enhanced resilience and stability of rural social-ecological systems.

### 3.3 Effect of cultivation on above ground biodiversity

The rapid loss of species due to human activities and its important implications for ecosystem functioning, services and human well-being have prompted biodiversity research to grow into one of the most active fields in ecological research during the last 20 years (Loreau et al. 2001,2002; Hooper et al.2005). The dominant grass species identified in the study areas were *Dactyloctenium*spp and *Acanthospermum* spp. The most dominant shrub species in the study sites included *Indigoferaspicata*, *Gnidialatifolia* and *Orthosiphon* spp. The dominant tree species were *Acacia* spp, *Combretum*spp and *Terminalia* spp. Generally, the



study established that the population of plant live forms in the study sites was higher in the un-cultivated areas than in the cultivated areas (Table 7)

Table 7: Population of plant live forms in the study sites

Study site	Plant live forms	Cultivated	Un-cultivated
Masii	Grass per M <sup>2</sup>	4.33	14.67
	Shrubs per Ha	833.33	2083.33
	trees per Ha	200.00	466.67
Kyawango	Grass/ herbs per M <sup>2</sup>	3.67	10.33
	Shrubs per Ha	1875.00	2291.67
	trees per Ha	300.00	600.00
Katangi	grass herbs per M <sup>2</sup>	6.33	10.00
	Shrubs per Ha	625.00	3750.00
	trees per Ha	100.00	300.00
Ndalani	grass herbs per M <sup>2</sup>	7.67	13.00
	Shrubs per Ha	625.00	2916.67
	trees per Ha	150.00	533.33

The average population of plant live forms (grass, shrubs and trees) in the study sites was found to be significantly different between cultivated and uncultivated zones ( $p < 0.005$ ) in the four locations (Table 8).

Table 8: T-test results comparing plant population in cultivated and uncultivated zones

Plant live forms	t	D f.	Mean Difference	Std. Error Difference	p-value
Grass per M <sup>2</sup>	-5.849	2	-6.5	1.111	0.000
Shrubs per Ha	-3.466	2	-1697.917	489.866	0.002
Trees per Ha	-3.742	1	-286.111	76.469	0.001

Aboveground and below ground compartments of terrestrial ecosystems have traditionally been studied in isolation from one another (Wardle et al. 2004<sup>[36]</sup>), hampering a holistic understanding of ecosystem functioning. The interactions between human activities and agricultural production influence plant community dynamics and composition (Klironomos 2002; Wurst et al. 2008<sup>[34]</sup>; Bardgett and Wardle 2010).

#### IV. CONCLUSIONS

HHs in the study areas demonstrated to have knowledge on the importance non-crop tree species and majority practiced high levels of diversity. The HHs grow dryland crop species and conserved indigenous trees/non-crop species in their farms and therefore are more resilient and providing for in-situ conservation. Maintenance of high levels of inter- and intra-species diversity is a strategy to decrease vulnerability and enhance resilience to climate change and associated stresses. Adaptation activities include the maintenance and reintroduction of traditional varieties, the adoption of new species and varieties to meet newly developed production niches, and the development of ways of ensuring that materials remain available and adapted. In the efforts of encouraging sustainable dryland biodiversity, use of local knowledge and practices is a key element for success. It is concluded that farmers understand the importance of biodiversity conservation and are keen to ensure that natural vegetation is conserved for it benefits such as environmental conservation, soil conservation and soil fertility improvements, medicinal and nutritional purposes, beauty and ornamental purposes, provision of firewood, fencing posts, timber and other building materials.

Land ownership and changes in land uses in the study areas affected the distribution of non-crop tree species and general biodiversity. Findings showed that households owned 2-5 acres of land and utilized about 2-3 acres of their land in cultivation. There was a significant variance in the average population of plant live forms (grass, shrubs and trees) between cultivated and uncultivated zones in the four locations. The rates of reduction in plant diversity in the study area was also found to differ significantly between the cultivated and uncultivated areas. Results from the analysis of the data collected showed that cultivation has reduced above ground plant biodiversity of grass and herbs, shrubs, and tree saplings significantly. Degradation of habitats due to changes in land use is the immediate most serious threat to dryland biodiversity. This is further exacerbated by climatic factors at both local and global scales. The choices people make in terms of the production system influences the diversity and abundance of crop and non-crop trees. Therefore, it is concluded that cultivation significantly reduces above ground plant diversity. Loss of plant diversity in the study areas was highly characterized by reduced biodiversity where this has been majorly contributed by human and animal activities.

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