East African Journal of Forestry & Agroforestry
eajfa.eanso.org
Volume 7, Issue 1, 2024
Print ISSN: 2707-4315 | Online ISSN: 2707-4323
Title DOI: https://doi.org/10.37284/2707-4323

EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Distribution, Diversity and Role of the Trees outside Forest in the Mount Kenya East Region

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Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

Date Published:

30 June 2024

Keywords:

Ecosystem Services, Trees Outside Forest, Indigenous Species, Climate Change, Tree Diversity.

ABSTRACT

Globally, Trees outside the Forests (TOF) are essential for providing a range of ecosystem services, which lessens the demand placed on protected forests. However, the majority of native tree species outside the forests are in danger of destruction because of the effects of climate change and the increased human population in the Sahel Africa. One of the ecosystems with TOF that has experienced extensive changes due to anthropogenic disturbance is Mount Kenya East Region. The objectives of this study were to establish: The diversity and distribution of native TOF, the drivers of change in TOF cover and the role of TOF in supporting the local livelihoods. This study used a mixed technique approach that included questionnaires, interviews, PGIS, and ecological surveys. SPSS was used to analyse the data. A total of 2145 individual trees distributed in 102 species were identified in the study area with 36% of the individuals being native while 64% were exotic. Additionally, 16 of the native tree species including *Pachystela brevipes*, *Carissa spinarum L.*, *Faurea saligna*, *Delonix electa* and *Vitex doneana* among others, previously known to the area, had disappeared, resulting in a broad loss of ecosystem functions. Across the altitudinal gradient, the perceptions of the respondents on the loss of ecosystem services were variable. Herbicide use on farms, industrial firewood, agricultural diversification, and shifting cultural values were cited as the primary causes of the change in TOF cover in the study area. The surviving native TOF were found in public institutions, road reserves, riverine and protected places and on farms. In conclusion, there is an urgent need to continually protect the remnants of indigenous TOF because the region will lose some ecosystem services exclusively obtained from native species if the business as usual is continued.

APA CITATION

Mwenda, N. D., Lukhoba, C. & Ouma, G. (2024). Distribution, Diversity and Role of the Trees outside Forest in the Mount Kenya East Region *East African Journal of Forestry and Agroforestry*, *7*(1), 252-267. https://doi.org/10.37284/eajfa.7.1.2010

CHICAGO CITATION

Mwenda, Nyaga David, Catherine Lukhoba and Gilbert Ouma. 2024. "Distribution, Diversity and Role of the Trees outside Forest in the Mount Kenya East Region" *East African Journal of Forestry and Agroforestry* 7 (1), 252-267. https://doi.org/10.37284/eajfa.7.1.2010.

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Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

HARVARD CITATION

Mwenda, N. D., Lukhoba, C. & Ouma, G. (2024), "Distribution, Diversity and Role of the Trees outside Forest in the Mount Kenya East Region", *East African Journal of Forestry and Agroforestry*, 7(1), pp. 252-267. doi: 10.37284/eajfa.7.1.2010.

IEEE CITATION

N. D., Mwenda, C., Lukhoba & G., Ouma "Distribution, Diversity and Role of the Trees outside Forest in the Mount Kenya East Region", *EAJFA*, vol. 7, no. 1, pp. 252-267, Jun. 2024.

MLA CITATION

Mwenda, Nyaga David, Catherine Lukhoba & Gilbert Ouma. "Distribution, Diversity and Role of the Trees outside Forest in the Mount Kenya East Region". *East African Journal of Forestry and Agroforestry*, Vol. 7, no. 1, Jun. 2024, pp. 252-267, doi:10.37284/eajfa.7.1.2010

INTRODUCTION

Tree outside forests (TOF) are delineated as "trees growing on lands that are not defined as forests or other wooded lands". Such include trees growing in association with agricultural crops and in pasture fields, as well as in riverine areas, in towns, gardens and parks (Malkoç et al., 2021; Rossi et al., 2016). The definition is ambiguous since it is only limited to what FAO defines as a forest or other wooded lands (Rossi et al., 2016; Thomas et al., 2021). This limitation is further recognized by: (Lund, 2002; Peluso & Vandergeest, 2011) who pointed out that existence of wide variations between a country and another in the criteria of description between a "forest and non-forest land (other land –uses)".

Thus, according to (Liu et al., 2023), Trees outside the forest (TOF) may be considered to be all the trees that exist beyond the legal borders of a forest and also include fruit tree orchards and agroforestry systems. The considerations for delimitation are usually enshrined into legal, policy and institutional frameworks for their formalization (Lund, 2002; Mansourian, 2021). Such formalizations have however, resulted in the division and institutionalization of land uses into forestry and non-forestry related institutions for resources management (Fay & Michon, 2005). The rise and grouping of these institutions have left the attention of forest trees, their products and services under the stewardship of forestry institutions, while the other institutions focusses on crops and livestock production since their mandate is agriculture and rural-urban planning (Liu et al., 2023). Native forest trees found outside the forest boundaries have thus been left without any governing body despite their critical importance to the sustainability of local, regional, and global livelihoods (Liu et al., 2023; Reiner et al., 2023). Since around 40% of all agricultural lands worldwide have up to and beyond 10% tree cover, TOF which have the potential to considerably contribute to biomass stocks are an underappreciated, neglected and fast disappearing resources (Thomas et al., 2021).

Globally, TOF are viewed as surrogates of forest reserves because they readily supply almost all the ecosystem products and services obtainable from any natural forest, thereby reducing pressure that would have been exerted onto the protected forests by the rural communities (Reiner et al., 2023). The rural communities obtain and perceive ecosystem services under categories namely:- provisioning of materials including fodder, food (in form of fruits, vegetables, honey and bush meat), water, medicinal herbs, and firewood among others; regulating of climate, water quality, air quality, soil fertility and pests and diseases insurgence among others); supporting biodiversity and cultural– religious services such as ecotourism and spiritual values (Ottaviano & Marchetti, 2023). In this regard, there has been increased dependence on the TOF for income, food, firewood and timber particularly by the communities living in the rural areas in the recent past (Islam, 2004). Furthermore, (Salam et al., 2000; Thomas et al., 2021), recognizes TOF as an essential resource in safeguarding ecological diversity and richness as well as acting as wind breakers when grown to sufficient heights in Bangladesh. Konijnendijk (2011), revealed that within the urban centres, TOF appears to be planted along the streets, as city parks and in private or

Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

public gardens where they provide important aesthetic (ornamental), economic and social benefits.

For rural communities in emerging nations, particularly those in Asia and Sahel Africa, forests and TOF are essential to their subsistence cultivation (Skole et al., 2021). Agroforestry, hedgerows, agri-silvipasture, silvipasture, and small areas of woodlots and urban parks are among the widely used approaches in these areas. Trees that are included into farming systems are typically important because they produce significant services and products that are necessary for improving soil fertility, controlling soil erosion, regulating pests and diseases and regulating microclimate, among other things that are critical for agricultural output (Bowler et al., 2010; Manning et al., 2009). According to (Asbjornsen et al., 2011; Bayala et al., 2008) in Sahel Africa where environmental constraints like dry climate and irregular annual rainfall are frequent and common phenomena, trees have been found to play more specific roles such as enhancing accessibility of the underground water resources to the crops. Further, in the views of Di Cristofaro et al (2020), TOF have been found to be easily reachable to the farmers for provision of goods and services like fruits, fodder, shade, erosion control, soil fertility maintenance and boundary delimitations among others since trees in the protected forests may not be accessible.

According to (Zhu & Waller, 2003) TOF occur when forested lands are converted into production systems such as agroforestry, agrosilvipastrolism, silvopastrolism, apiculture and commercial timber logging to which trees are an integral part. In Kenya, despite the existence of hefty penalties and strict regulations on illegal forest access, which is enshrined in the Kenya forest Act 385 and the presidential ban on indigenous trees harvesting in 1986, illegal timber logging and massive encroachment of Mount Kenya forest reserve by the communities in search of various ecosystem services has remained high (Nyongesa & Vacik, 2019). As a result, there has been extensive forest degradation and increased cases of human- wildlife conflicts especially in the eastern parts of Mt. Kenya Forest. According to (Klopp, 2012), this prompted the government of Kenya to carry out forest Act reforms between 1990s and early 2000’s that culminated into a repeal Forest Act 385 and enactment of Kenya Forest Policy of 2005 to allow community involvement in the management. However, the achievements of these policy reforms have still ranked low especially in the aspects like human-wildlife conflicts and controlling illegal access to the forest resources hence the interventions provided by conservation and charitable organizations like Greenbelt movement, Rhino Charge and many others through promotion tree planting outside the forest and electric fence installation in 2015 (Mbuba, 2019; Nyongesa & Vacik, 2019). Due to this extensive protection and lack of access to forests in the region, TOF have thus remained to be the only source of various ecosystem services required by the community. However, in the face of climate change, population growth and shrinking number of indigenous trees in the farmlands among other pressures, the knowledge of the diversity, distribution and specific contributions of TOF in the MKER remains scanty and unevaluated. Hence, it is against the situational backdrop that this study was conducted to with the following three specific objectives: 1. Evaluate the diversity and distribution of TOF in MKER. 2. Find out the drivers influencing change of TOF cover within the MKER, and 3. Determine the role played by TOF in supporting the local livelihoods of communities in MKER.

MATERIALS AND METHODS

Study Area

Mount Kenya East Region lies between (37º 10’E and 38º24’E) and (0º91’S and 0º82’N) and an approximate elevation of between 600M above mean sea level (AMSL) in the dryland grasslands and 5199M (AMSL) at the mountaintop. This area has three administrative counties namely: Embu,

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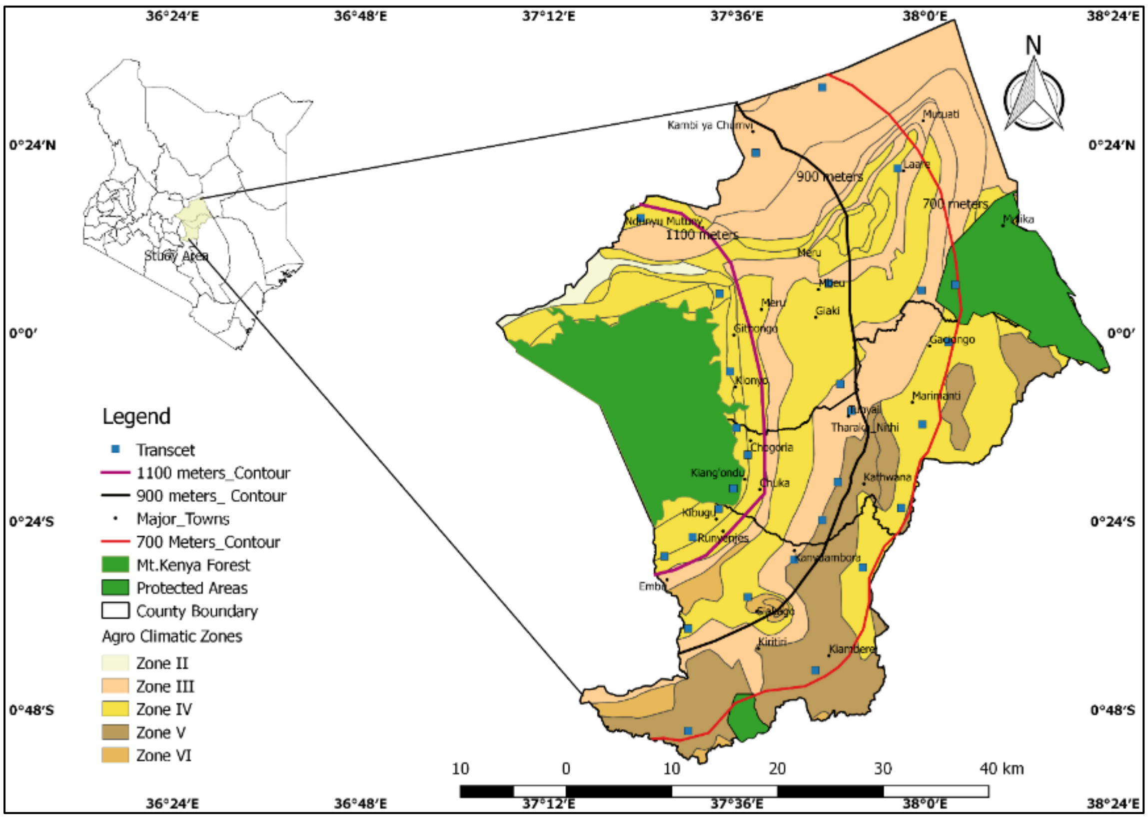
Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

Tharaka-Nithi and Meru Counties which cover an approximated area of 12,391 KM^2 whereby, according to Kenya Population and Housing Census (*KPHC*, 2019) 2564.4 Km^2, 2820.7 Km^2 and 7006.3 Km^2 are in Tharaka-Nithi, Embu and Meru Counties respectively.

The region receives a bi-modal rainfall pattern with the long rains beginning in March and end in May, while the short rains fall from October to December and intermittent periods of dry-humid, cool-humid and hot-dry weather in between the rainy seasons. This region is fairly cool, and the temperatures ranges between 13^0C and 28^0C, with a monthly mean of 18^0C. Due to the existence of these climatic conditions, the region is characterized by a wide range of plant and animal diversity. According to (Camberlin & Okoola, 2003; Smucker & Wisner, 2008), the region's climatic conditions favour a broad spectrum of economic activities involving combined agricultural production systems like mixed farming, agroforestry, agrisilvipasture, apiculture and silvipasture in the high, mid and low altitude areas respectively.

Figure 1: Map of the study area.



Data Collection

A mix of field surveys, Participatory GIS (PGIS), Questionnaires and Key Informant Interviews (KII) was employed in the collection of various type of data required to achieve the objectives of this study. Due to the vastness of the study area, the data for current tree-diversity was obtained by conducting field surveys on 27 quadrates of 200M by 200M established in three belt transects laid in the three altitudinal gradients (< 700 M ASL, between 700-1400 M ASL and >1400M ASL) of the study area, using similar principles illustrated by (Kehlenbeck et al., 2011). In order to achieve consistency, the quadrates were distributed so that three quadrates were equally spaced out in each of the three transects in each of the altitudinal parts of the study area counties. Every single tree in the plot that is taller than five meters and has girths larger than ten

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Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

centimetres or a thickness of 3.18 centimetres at Diameter Breast Height (DBH) was recorded by local or common names and later transliterated into scientific names using available literature such as (Carsan & Holding, 2006; Mori et al., 2013). For scientific identification and future reference, voucher specimens of the trees that could not be reliably identified in the field were gathered, pressed, and placed at the University of Nairobi (*Index herbariorum NAI*) and the National Museums of Kenya (*Index herbariorum EA*) herbaria, Nairobi. (Kehlenbeck et al., 2011). Through the use of questionnaires, interviews, and Key Informant interviews, data regarding the contribution of TOF to the local livelihoods as well as the factors driving change in TOF cover within MKER were established. Purposive sampling was used to administer the questionnaire, focusing on 54 respondents (two from each quadrate) who had owned and controlled land resources for at least 30 years. Officers from the Kenya Wildlife Service (KWS), Kenya Forest Service (KFS), village head men, and chiefs of the administrative units where the quadrates occurred were interviewed as key informants.

Data Analysis

The Statistical Package for Social Sciences (SPSS) and Ms. Excel's spreadsheet functions were utilized to analyse the data gathered. The primary results of descriptive statistics were frequencies and percentages, which were displayed using tables and several graphical techniques.

RESULTS

Demographic and Socio-Economic Characteristics of the Respondents

Approximately 48% of the respondents were male while the remaining 52% were female. Similarly, 89% of the respondents were natives while the remaining 11% was represented by the immigrants who had either bought land and settled in it or were in the study area by having been married from other places. The results further revealed that approximately 13%, 52% and 35% of the total respondents were in the age brackets of between 51 to 60, 61 to 70 and beyond 70 years respectively. Additionally, 66%, 22% and 11% of the respondents had owned and controlled the land and its resources for periods between 31 -40, 41-50 and beyond 50 years respectively.

Table 1: Respondent's Demographic Characteristics

Characteristic	Category	Frequency	Percentage
Age in years	51- 60	7	12.96
	61-70	28	51.85
	More than 70	19	35.18
Gender	Male	26	48.15
	Female	28	51.85
Nativity	Born and raised in the community	48	88.88
	Immigrant	6	11.11
Period of land ownership	31-40 years	36	66.67
	41-50 years	12	22.22
	Above 50 years	6	11.01

Diversity and Distribution of TOF in MKER

Diversity of TOF in MKER

A total of 2145 individual trees distributed across 102 species were recorded within the 27 quadrates studied; 36% of these individuals were native trees distributed across 87 species, while the exotic species were represented by the remaining 64% of the total count of individuals distributed into only 15 species. The most abundant indigenous species in the region were *Commiphora eminii*, *Euphorbia*

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Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

tiriucali, Terminalia brownii, Prunus africana and *Vachellia seyal*, with relative abundances of 5.36%, 3.03%, 2.33%, 1.72%, and 1.59%, respectively, while the most dominant exotic species were *Grevillea robusta*, *Eucalptus* spp., *Acacia mearnsii*, *Mangifera indica*, and *Cassia siamea* represented by relative frequency of 31.61%, 11.98%, 4.48%, 4.20% and 3.54% correspondingly.

Rather than being used for their economic benefits, *Euphorbia tirucalli* and *Commiphora eminii* were abundant in the area because they were used for designating land boundaries. The species *Senegalia ataxacantha* and *Piliostigma thonningii*, which had relative frequencies of 1.54% and 1.49% respectively, were among the most prevalent native species in the area which may be attributed to both ecological and economic factors. However available literature (Carsan et al., 2013) had previously listed *Vitex keniensis*, *Cordia africana* and *Croton macrostychyus* as the top ten indigenous tree species in the region. Due to their multipurpose uses, the farmers were however deliberately establishing on-farm *Eucalyptus* Spp. and *Grevillea robusta*, which is why they are so abundant.

It was noted that sixteen common native forest tree species previously recorded from the area were not recorded to be growing outside the forest area and are probably lost. They include *Pachystela brevipes* (Baker), *Carissa spinarum L.*, *Faurea saligna, Delonix electa, Vitex doneana, Sclerocarya birrea*, *Boscia augustifolia*, *Dombeya torrida, Thespesia garckeana, Bridelia taitensis, Berchemia discolor, Harrisonia abyssinica, Balanites aegyptiaca, Zizyphus mucronata*, and *Fagaropsis angolensis*. This observation was collaborated by the findings from PGIS, Focus Group Discussions, and available literature (Carsan et al., 2013; Kehlenbeck et al., 2011; Simons & Leakey, 2004). Additionally, the following rare indigenous species were also missing from the field resource mapping (PGIS): *Lowfia swynertonii, Grewia villosa, Combretum molle, Zanthylum chalybeum* and *Dovyalis abyssinica*. Similarly, despite reports of their presence in earlier study periods among members of some FDGs and the literature of earlier studies like Mburu et al (2016), three exotic species like *Citrinus limon, Citrinus sinensis*, and *Jacaranda mimosifolia* were not encountered during the field work.

The second category of indigenous species rarity was represented by: - *Dovyalis abyssinica, Combretum molle, Zanthylum chalybeum, Lowfia swynertonii*, *Albizia anthelmintica* and *Grewia villosa*. These registered 0% in their relative frequencies but were generously abundant in the checklist generated from previous studies (Simons & Leakey, 2004), but absence from field resource mapping exercises (PGIS) or on the farms. Similarly, three exotic species namely; *Citrinus limon, Citrinus sinensis* and *Jacaranda mimosifolia* were also not encountered in the field work despite the reports of their presence in earlier periods of study period among the members of some FDGs as well as in literature of previous studies such as (Mburu et al., 2016).

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Table 2: Diversity of trees outside forest in Mount Kenya East Region

Tree Species	f	%
Commiphora eminii	115	5.36
Erythrina abyssinica	25	1.17
Afrocarpus falcatus	3	0.14
Ehretia cymosa	5	0.23
Ficus thonningii	16	0.75
Anthocleista grandifolia	15	0.70
Sparrea gomphopyhylla	4	0.19
Markhamia lutea	7	0.33
Neutonia buchananii	2	0.09
Prunus Africana	37	1.72
Spathodea campanulata	4	0.19
Senegalia ataxacantha	32	1.49
Milleta dura	5	0.23
Lachocarpus eriocalyx	9	0.42
Doryalis abyssinica	1	0.05
Rhus nataheusis	19	0.89
Senegalia mellitera	24	1.12
Terminalia brownie	50	2.33
Melia volkensii Gürke	9	0.42
Combretum collinum	14	0.65
Podocarpus latifolius	3	0.14
Synsepalum breripes	0	0.00
Monanthotaxis schweinfurthii	9	0.42
Senegalia brevispica	6	0.28
Vachellia drepanolobium	6	0.28
Vachellia seyal	34	1.59
Barleria mirabilis	3	0.14
Grewia rothii	4	0.19
Senegalia polyacantha	3	0.14
Albizia amara	2	0.09
Senegalia mellifera	12	0.56
Bridelia micrantha	11	0.51
Delonix elata	5	0.23
Zanthoxylum chalybeum	2	0.09
Euphorbia tirucalli L.	65	3.03
Tamarindus indica L.	8	0.37
Vachellia nilotica (L.)	21	0.98
Carissa spinarum L.	0	0.00
Vachellia hockii	10	0.47
Euclea acutifolia	1	0.05
Vachellia gerardi	3	0.14
Grewia similis	2	0.09
Senegalia Senegal	13	0.61
Piliostigma thonningii	33	1.54
Adausonia digitate L.	2	0.09
Lannea schweinfurthii	18	0.84
Combretum molle	1	0.05
Croton megalocarpus	3	0.14
Zanthoxylum chaffanjonii	1	0.05
Faurea saligna	0	0.00
Delonix electa	0	0.00
Acokanthera shimperii	2	0.09
Boslia coriacea	6	0.28
Gynosporia senegalensis	8	0.37
Euphorbia murielii	8	0.37
Euphorbia inaguaensis	8	0.37
Vitex doniana Sweet	0	0.00
Lovoa swynnertonii	1	0.05
Dicliptera zambeziensis	3	0.14
Diospyros abyssinica	1	0.05
Vachellia tortillis	6	0.28
Euclea divinorum	0	0.00
Sclerocarya birrea	0	0.00
Boscia integrifolia	0	0.00
Commiphora Africana	9	0.42
Commiphora schimperi	8	0.37
Lannea triphylla	5	0.23
Melia volkensii Gürke	2	0.09
Dombeya torrida	0	0.00
Thespesia garckeana	0	0.00
Grewia tembensis	3	0.14
Grewia villosa	1	0.05
Euphorbia ingens	2	0.09
Bridelia taitensis	0	0.00
Berchemia discolour	0	0.00
Harrisonia abyssinica	0	0.00
Ficus sycomorus	5	0.23
Terminalia pranioides	2	0.09
Cambretum aculeatum	8	0.37
Albizia anthelmintica	1	0.05
Balanites aegyptiaca	0	0.00
Ziziphus mucronata	0	0.00
Fagaropsis angolensis	0	0.00
Grevilea robusta	678	31.61
Euculyptus spp	257	11.98
Acacia mearnsii	96	4.48
Eriobotrya japonica	7	0.33
Jaranda mimosifolia	0	0.00
Casuarina equisetifolia	32	1.49
Calliandra calothysus	54	2.52
Acrocarpus fraxinifilous	5	0.23
Psidium guajava	4	0.19
Citrus sinensis	0	0.00
Citrus limon	0	0.00
Macadamia spp.	49	2.28
Mangifera indica	90	4.20
Azadirachta indica	15	0.70
Casia siamea	76	3.54
Olea europaea	7	0.33
Ficus natalensis	3	0.14
Croton microstachyus	4	0.19
Cordia Africana	2	0.09
Total	2145	100.01

NB: 0 frequency means that the species was not observed in the current fieldwork but was previously present in the study area as revealed by respondents and available literature

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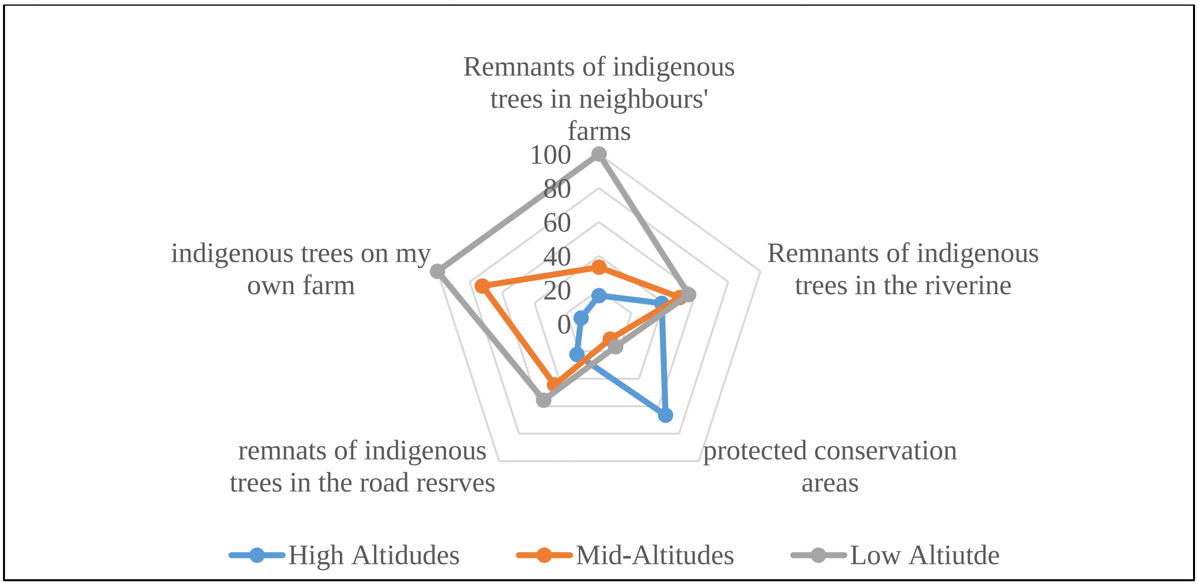
Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

Perceived Location and Distribution of TOF in MKER

Perceived locations of indigenous tree species in the study area was established by assessing the respondents' knowledge of the possible location of mother trees for the indigenous seedlings observed in their farms. This was further corroborated by resources mapping (PGIS) and five sources of propagules were identified and perceived by the residents as follows:-

In the high-altitude areas 67% of the respondents linked protected areas and public lands mainly Mount Kenya and school lands with indigenous seedlings observed in their farms. The riverine forests, road reserves, neighbours' farms and own farm were also thought to be a source of propagules by 39%, 22%, 17% and 11% for respectively. In the Mid-altitudes 72% and 50% of the respondents regarded trees on the own farm and the riverine as main sources of propagules respectively, while protected areas, road reserves and trees on neighbours' farm were identified by 44%, 33% and 11% respectively. In the low altitude areas, all the identified sources of propagules were acknowledged by more than 55% of the respondents as follows; trees on own farm (100%), trees on neighbours' farm (100%), road reserves (56%) and Riverine (56%), except trees on protected areas which was regarded by 17% of the respondents.

Figure 2: Perceived Sources of Indigenous Tree Species Seedlings in MKER



Drivers of Change in TOF Cover in MKER

The top drivers of TOF cover loss in MKER were: - Increased demand for industrial firewood, increased use of herbicides on the farms and social cultural erosion as regarded by 98%, 80% and 63% of the total respondents in each of the case respectively. Additionally, approximately 41% and 30% of the total respondents in each case also linked loss of TOF cover in the region to the onslaught of climate change and diversification of agricultural activities correspondingly.

The respondents revealed that the declining TOF cover in the region was associated with the rising demand for industrial firewood as a result of increase in boarding basic and secondary learning institutions, hospitals and tea processing factories in the region. This agrees with views by Suryani et al (2022), who showed that high demand for fuelwood by rural communities and industry led to deforestation and the depletion of trees in Kenya. The respondents were fully acquainted with the effects of herbicide use on their farms and beyond. However, in their opinion, they were being compelled to employ them by circumstances like, increased cost labour, shortage of labour, nuisance of perennial weeds, climate variability and increased commercialization of cereal crops. Increased cost and shortage of labour were attributed to inflation

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Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

in the country and shift of livelihood activities by the energetic population from farming to motorcycle riding respectively. This is supported by studies like (Saina et al., 2023) who have revealed that motorcycle riding business can significantly income the income of those who own or operate them. In regard to climate variability the respondents revealed that unpredictable on set and off sets and shortening of rainy seasons in the study area. This forced the farmers to employ use of herbicides to catch up with the seasons.

According to the respondents, rainfall was becoming increasingly erratic while temperature was steadily rising over the region. As a result, the respondents associated such changes with disappearance of some tree species in the region. Additionally, tree species like *Podocarpus spp.*, *Ficus natalensis* and *Croton macrostachyus* as well as sacred grooves were associated with some cultural religious believes among the residents of the study area and it was a taboo to cut or use any part of them or even do farming them. Erosion of beliefs and taboos was hence associated with loss of tree diversity in this region. For example, "*The current generation is longer careful about these taboos. They even carelessly destroy our longtime preserved heritage by cutting down these tree species and nothing is in them about the fate of tomorrow*". Reported a respondent. In the study area, the respondents revealed that advent of western education together with demise of elderly members of the community were the main factors that could be attributed to erosion of culture in the region.

Table 3: Drivers of TOF Cover Loss in MKER

Causes of tree cover loss	Frequency	Percent
Climate change	22	40.74
Socio-cultural erosion	34	62.96
Increased use of herbicides on farms	43	79.63
Agricultural intensification	16	29.63
Industrial demand by tea factories	53	98.15

NB: This is a Multiple Response Frequency Table

The Role of TOF in supporting local livelihoods in MKER

The role of TOF in the MKER was variable across the three altitudinal sections in supporting local livelihoods. The respondents in each of the three altitudinal sections associated loss of TOF in the region with decline in the availability of nine commonly used ecosystem services as follows.

Loss of wildlife habitat was reported by 89%, 61% and 33% of the total respondents in the upper, mid and lower altitudes respectively. Similarly, loss of soil fertility, moderation of climate and loss of landscape aesthetics were perceived by 39%, 33% and 72% of the respondents in the upper altitudes, 83%, 56% and 50% in the mid-altitudes and 67%, 78% and 17% in the lower altitudes respectively. Loss of other ecosystem services namely, medicinal trees and herbs, cultural-religious beliefs, construction materials, firewood and water were reported by 11%, 44% ,78%, 89% and 11% in the upper altitudes, 50%, 33%, 28%, 44% and 50% in the mid- altitudes and 67%,56%, 33%, 22% and 94% of the respondents in the lower altitudes respectively.

Concerning loss of wildlife habitats in the region, the respondents reported reduced frequency of seeing or hearing sounds made by organisms like African honeybees, chameleons, some bird species and butterflies. For instance, according to the residents, the frequency of observing migrating swarms of bees had reduced from at least 7 times to only 2 times in every season. This was attributed to reduced number of farmers practicing apiculture which was further linked to loss of certain indigenous TOF species in which the traditional hives were being hoisted. Similarly, the respondents further reported that animals like chameleons, butterflies and sparrows were previously common to encounter in the farms, but they were becoming increasingly difficult to find over time. On the other hand, due to decline in TOF within the region, the respondents also

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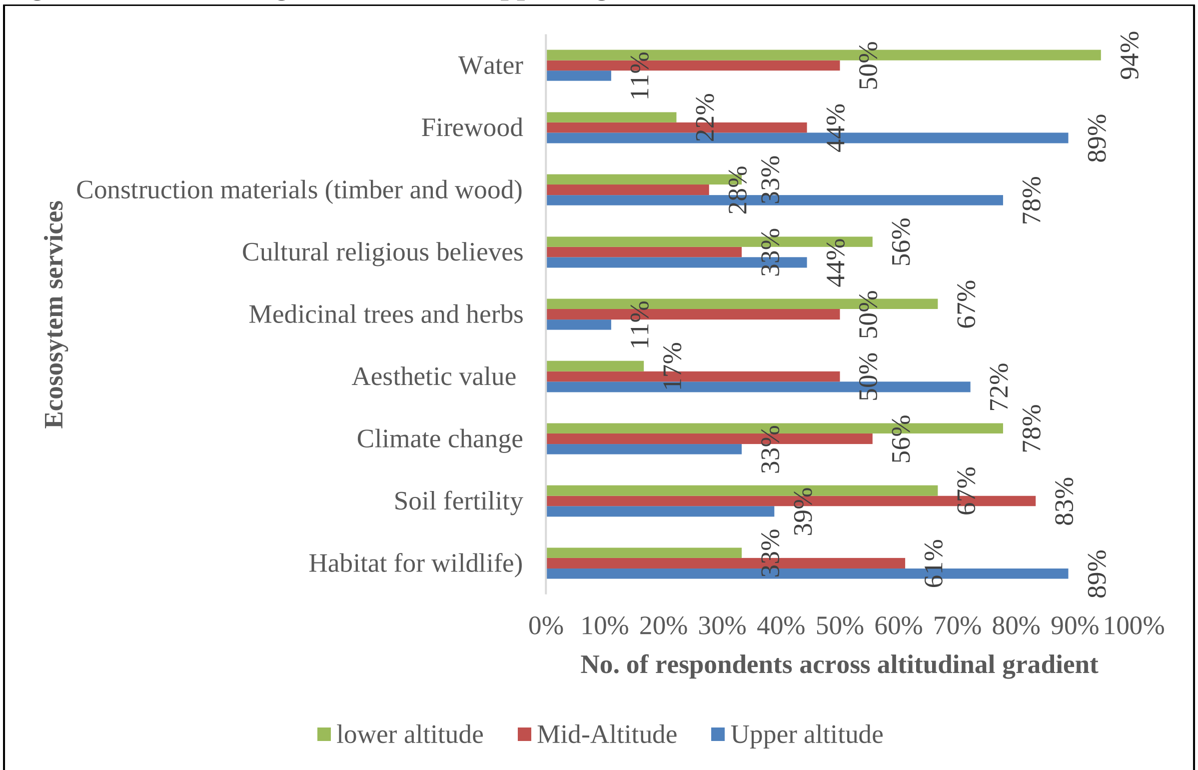
acknowledged difficulty in finding fodder for livestock. In regard to soil fertility and climate moderation, the respondents argued that earlier years of the study period corresponding to early 1990's to mid-2000's were better in terms of crop productivity than they were towards the mid and end of the study period. For instance,

> *"The colour of the soils is becoming lighter and lighter as the days go by. In addition, if you plant crops without the input of chemical fertilizers as we used to do in 1980's, you will leap nothing because the rains have also become very erratic, and the soils do not hold enough moisture for more than 3 days after a rainy day".* Explained a respondent.

Additionally, though reported the loss of medicinal trees and herbs, cultural religious beliefs, construction materials and firewood were not perceived with sufficient weight among the respondents because of their close association with changes in lifestyles due to modernity and availability of their alternatives. For instance, the respondents reminisced how they used to treat livestock and some human diseases like malaria with concoctions made by boiling barks and leaves of trees like *Newtonia buchananii*,, *Erythrina abyssinica* and *Rauvolfia caffra* for livestock and *Ximenia caffra*, *Citrinus limon* and *Azadirachta indica* for human respectively. However, according to the respondents, treatment of diseases using these species was no longer tenable because drugs for all types of diseases were available in pharmacies and agrovets. As for construction materials and firewood, the respondents revealed that construction of houses using rafters, grass and poles was outdated in the region and materials such as stones and ballast were being obtained from as far as Thika, while other materials like cement, roofing sheets and nails were readily available in hardware. On the other hand, use of Liquefied Petroleum Gas (LPG) and biogas was becoming a popular trend in the region, thereby making the residents less perceptive of decreasing availability of firewood sources. Lastly, loss of land aesthetics was linked with expansion of monoculture farming where the farmers in the region were deliberate in planting exotic trees due to their multi-purpose functions.

Figure 3: Role of Indigenous TOF in Supporting Livelihoods in MKER



Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

DISCUSSION

According to the findings, there is enough flexibility for both genders to use the land and its resources as indicated by the non-significant gender difference among research participants. Nonetheless, among the respondents, with the exception of a few instances in which the respondent was a window, the male gender was the custodian of data pertaining to land sizes and ownership certificates. This may be explained by the region's predominately male social structures and inheritance culture, which completely barred women from inheriting land prior to the adoption of Kenya's 2010 constitution. Likewise, earlier research conducted in sub-Saharan Africa demonstrated that, under customary land tenure, only household men were eligible to transmit their legal rights to land ownership (Doss et al., 2014; Villamor et al., 2014). Conversely, women possessed extensive knowledge of the different land use and land cover changes that had taken place on different areas of the farm.

Furthermore, the documented extinction of sixteen native species and the low percentage of native tree species distributed in 87 species, compared to the high percentage of exotic species distributed in only 15 species are clear indicators that the ecosystem is experiencing an unnatural shift that is detrimental to the existence of native species. This is corroborated by Backes (2001), who noted that while undisturbed ecosystems can readily return to their native state, high rates of anthropogenic disturbance can result in the wide-ranging extinction of uncommon species. The reasons for the shifts in tree diversity in MKER were rooted in a number of human actions. These include; intentional planting of exotic tree species on farms because of their multiple uses, logging, and the selective exploitation of species good for producing charcoal and fuel (Carsan & Holding, 2006; Kaburi & Medley, 2011). Other factors that worsen this include the introduction of modern education, which caused people to lose their traditional beliefs about the preservation of trees, the widespread use of herbicides, the diversification of agriculture, which resulted in constant tillage and uprooting of seedlings prior to their establishment on farms, and climate change. This is in agreement Kathambi et al (2020) who have established significant declines in cultural value of plant resources in Tharaka-Nithi. In the similar way, Huang et al (2020) have shown a strong link between culture and conservation of certain species of trees. Hence, as a result the indigenous TOF in the MKER are reduced to small remnants in protected areas, on public lands such as schools, hospitals, and other government institutions, along rivers, and on road reserves. However, there was a significant representation of indigenous TOF in the farms within the low-altitude areas. This could be attributed to the availability of extensive uncultivated lands in these zones. In this regard, maintaining business as usual in MKER poses a risk since it will result in the monoculture of exotic trees and a loss of ecosystem services, like cultural values, habitat and water catchment among others, which are only available from native trees. This is consistent with the findings of Himes et al (2020), who found that the greatest range of value categories is supported by tree species diversity at high levels. Similarly, according to (Liu et al., 2018) mixed-species plantations with two, three, or four species can outperform monocultures in terms of productivity and offer more benefits in terms of biodiversity, economy, and forest health when designed carefully and managed appropriately.

Another major finding of this study revealed that there was a significant loss of ecosystem services throughout the study area because of decline in native tree species. This was evaluated differently by the locals throughout the altitudinal gradient. For example, the habitat of wildlife, the supply of building materials, and the availability of firewood were all severely impacted among the population of higher altitudes. This can be supported by studies like Sagwa (2021), who reported 16.76% reduction of bee colonies in Kenya. Similarly, according to the residents of mid altitudes, soil fertility and habitat for wildlife were the most perceived, while in the low altitudes, loss of water availability and soil fertility were the most felt. In the similar way, declines in crop yield and soil fertility in Mount

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Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

Kenya have also been reported because of changes in fallow and nutrient cycles (Wawire et al., 2021). Accordingly, the least valued ecosystem services in the upper, mid, and low altitudes, respectively, were the disappearance of construction materials, medicinal plants, and trees, and the loss of land's aesthetic value.

CONCLUSION

The primary finding of this study is that the MKER is undergoing rapid transformations in terms of tree diversity. This is being driven by a number of human activities including logging, agricultural intensification, increased herbicide use and selective harvesting of tree suitable for industrial firewood and charcoal production among others. In this regard, the native tree species are being replaced by exotic species because the exotic species are able to offer multiple benefits from an economic standpoint.

Therefore, in conclusion, while it is fashionable for the inhabitants of MKER to plant exotic trees on their farms and accrue the associated economic benefits, it's equally critical that they exercise adequate prudence. This is because numerous ecosystem functions, such as habitat for wildlife, water catchment, and sociocultural activities that are only supported by native tree species, will be lost if this environment is converted to a pure exotic. Finally, preservation of already existing pockets of native species in the riverbanks, along the roads and also within the public land should be further encouraged. Local farmers can also be urged to preserve and allow growth to maturity any native tree seedlings they come across in their farms. This will have far reaching benefits in fostering biodiversity and ecosystem health in the region and beyond.

REFERENCES

Asbjornsen, H., Goldsmith, G. R., Alvarado-Barrientos, M. S., Rebel, K., Van Osch, F. P., Rietkerk, M., Chen, J., Gotsch, S., Tobon, C., Geissert, D. R., Gomez-Tagle, A., Vache, K., & Dawson, T. E. (2011). Ecohydrological advances and applications in plant-water relations research: A review. *Journal of Plant Ecology*, *4*(1– 2), 3– 22. https://doi.org/10.1093/jpe/rtr005

Backes, M. M. (2001). [No title found]. *Agroforestry Systems*, *52*(2), 119–132. https://doi.org/10.1023/A:1010685317405

Bayala, J., Heng, L. K., Van Noordwijk, M., & Ouedraogo, S. J. (2008). Hydraulic redistribution study in two native tree species of agroforestry parklands of West African dry savanna. *Acta Oecologica*, *34*(3), 370–378. https://doi.org/10.1016/j.actao.2008.06.010

Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: A systematic review of the empirical evidence. *Landscape and Urban Planning*, *97*(3), 147– 155. https://doi.org/10.1016/j.landurbplan.2010.05.006

Camberlin, P., & Okoola, R. E. (2003). The onset and cessation of the “long rains” in eastern Africa and their interannual variability. *Theoretical and Applied Climatology*, *75*(1), 43–54. https://doi.org/10.1007/s00704-002-0721-5

Carsan, S., & Holding, C. (2006). *Growing farm timber: Practices, markets, and policies: the Meru timber marketing pilot programme case studies and reviews*. World Agroforestry Centre.

Carsan, S., Stroebel, A., Dawson, I., Kindt, R., Swanepoel, F., & Jamnadass, R. (2013). Implications of shifts in coffee production on tree species richness, composition and structure on small farms around Mount Kenya. *Biodiversity and Conservation*, *22*(12), 2919–2936. https://doi.org/10.1007/s10531-013-0563-8

David Mbuba, M. (2019). Fencing and Forest Conservation: Attitudes of Local People Living Adjacent to Eastern Slopes of Mount Kenya. *International Journal of Natural Resource Ecology and Management*, *4*(1), 1. https://doi.org/10.11648/j.ijnrem.20190401.11

Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

Di Cristofaro, M., Sallustio, L., Sitzia, T., Marchetti, M., & Lasserre, B. (2020). Landscape Preference for Trees Outside Forests along an Urban–Rural–Natural Gradient. *Forests*, *11*(7), 728. https://doi.org/10.3390/f11070728

Doss, C., Meinzen-Dick, R., & Bomuhangi, A. (2014). Who Owns the Land? Perspectives from Rural Ugandans and Implications for Large-Scale Land Acquisitions. *Feminist Economics*, *20*(1), 76– 100 https://doi.org/10 .1080/13545701.2013.855320

Fay, C., & Michon, G. (2005). Redressing Forestry Hegemony When a Forestry Regulatory Framework Is Best Replaced by An Agrarian One. *Forests, Trees and Livelihoods*, *15*(2), 193– 209. https://doi.org/ 10.1080/14728028.2005.9752520

Himes, A., Puettmann, K., & Muraca, B. (2020). Trade-offs between ecosystem services along gradients of tree species diversity and values. *Ecosystem Services*, *44*, 101133. https://doi.org/10.1016/j.ecoser.2020.101133

Huang, L., Tian, L., Zhou, L., Jin, C., Qian, S., Jim, C. Y., Lin, D., Zhao, L., Minor, J., Coggins, C., & Yang, Y. (2020). Local cultural beliefs and practices promote conservation of large old trees in an ethnic minority region in southwestern China. *Urban Forestry & Urban Greening*, *49*, 126584. https://doi.org/10.1016/j.ufug.2020. 126584

Islam, S. S. (2004). Stratified two-stage sampling (self-weighted) for assessment of village forest resources. *Journal of Tropical Forest Science*, *16*(1), 9–16. JSTOR.

Kaburi, S. M., & Medley, K. E. (2011). Community Perspectives on Fuelwood Resources in East Africa: Enrichment and Extraction Along the Eastern Slopes of Mount Kenya. *Mountain Research and Development*, *31*(4), 315–324. https://doi.org/10.1659/MRD-JOURNAL-D-10-00121.1

Kathambi, V., Mutie, F. M., Rono, P. C., Wei, N., Munyao, J. N., Kamau, P., Gituru, R. W., Hu, G.-W., & Wang, Q.-F. (2020). Traditional knowledge, use and conservation of plants by the communities of Tharaka-Nithi County, Kenya. *Plant Diversity*, *42*(6), 479–487. https://doi.org/10.1016/j.pld.2020.12.004

Kehlenbeck, K., Kindt, R., Sinclair, F. L., Simons, A. J., & Jamnadass, R. (2011). Exotic tree species displace indigenous ones on farms at intermediate altitudes around Mount Kenya. *Agroforestry Systems*, *83*(2), 133–147. https://doi.org/10.1007/s10457-011-9413-4

Klopp, J. M. (2012). Deforestation and democratization: Patronage, politics and forests in Kenya. *Journal of Eastern African Studies*, *6*(2), 351– 370. https://doi.org/10.10 80/17531055.2012.669577

Konijnendijk, C. C. (Ed.). (2011). *Urban forests and trees: A reference book; with 31 tables* (Nachdr.). Springer.

Kenya population and housing census. (2019). Kenya National Bureau of Statistics.

Liu, C. L. C., Kuchma, O., & Krutovsky, K. V. (2018). Mixed species versus monocultures in plantation forestry: Development, benefits, ecosystem services and perspectives for the future. *Global Ecology and Conservation*, *15*, e00419. https://doi.org/10.1016/j.gecco.2018.e00419

Liu, S., Brandt, M., Nord-Larsen, T., Chave, J., Reiner, F., Lang, N., Tong, X., Ciais, P., Igel, C., Pascual, A., Guerra-Hernandez, J., Li, S., Mugabowindekwe, M., Saatchi, S., Yue, Y., Chen, Z., & Fensholt, R. (2023). The overlooked contribution of trees outside forests to tree cover and woody biomass across Europe. *Science Advances*, *9*(37), eadh4097. https://doi.org/10.1126/sciadv.adh4097

Lund, H. G. (2002). When Is a Forest Not a Forest? *Journal of Forestry*, *100*(8), 21–28. https://doi.org/10.1093/jof/100.8.21

Malkoç, E., Rüetschi, M., Ginzler, C., & Waser, L. T. (2021). Countrywide mapping of trees outside forests based on remote sensing data in Switzerland. *International Journal of Applied Earth Observation and Geoinformation*, *100*, 102336. https://doi.org/10.1016/j.jag.2021.102336

Manning, A. D., Gibbons, P., & Lindenmayer, D. B. (2009). Scattered trees: A complementary strategy for facilitating adaptive responses to climate change in modified landscapes? *Journal of Applied Ecology*, *46*(4), 915–919. https://doi.org/10.1111/j.1365-2664.2009.01657.x

Mansourian, S. (2021). From landscape ecology to forest landscape restoration. *Landscape Ecology*, *36*(8), 2443–2452. https://doi.org/10.1007/s10980-020-01175-6

Mburu, S. W., Koskey, G., Kimiti, J. M., Ombori, O., Maingi, J. M., & Njeru, E. M. (2016). Agrobiodiversity conservation enhances food security in subsistence-based farming systems of Eastern Kenya. *Agriculture & Food Security*, *5*(1), 19. https://doi.org/10.1186/s40066-016-0068-2

Mori, A. S., Shiono, T., Koide, D., Kitagawa, R., Ota, A. T., & Mizumachi, E. (2013). Community assembly processes shape an altitudinal gradient of forest biodiversity. *Global Ecology and Biogeography*, *22*(7), 878–888. https://doi.org/10.1111/geb.12058

Nyongesa, K. W., & Vacik, H. (2019). Evaluating Management Strategies for Mount Kenya Forest Reserve and National Park to Reduce Fire Danger and Address Interests of Various Stakeholders. *Forests*, *10*(5), 426. https://doi.org/10.3390/f10050426

Ottaviano, M., & Marchetti, M. (2023). Census and Dynamics of Trees Outside Forests in Central Italy: Changes, Net Balance and Implications on the Landscape. *Land*, *12*(5), 1013. https://doi.org/10.3390/land12051013

Peluso, N. L., & Vandergeest, P. (2011). Political Ecologies of War and Forests: Counterinsurgencies and the Making of National Natures. *Annals of the Association of American Geographers*, *101*(3), 587–608. https://doi.org/10.1080/00045608.2011.560064

Reiner, F., Brandt, M., Tong, X., Skole, D., Kariryaa, A., Ciais, P., Davies, A., Hiernaux, P., Chave, J., Mugabowindekwe, M., Igel, C., Oehmcke, S., Gieseke, F., Li, S., Liu, S., Saatchi, S., Boucher, P., Singh, J., Taugourdeau, S., … Fensholt, R. (2023). More than one quarter of Africa's tree cover is found outside areas previously classified as forest. *Nature Communications*, *14*(1), 2258. https://doi.org/10.1038/s41467-023-37880-4

Rossi, J.-P., Garcia, J., Roques, A., & Rousselet, J. (2016). Trees outside forests in agricultural landscapes: Spatial distribution and impact on habitat connectivity for forest organisms. *Landscape Ecology*, *31*(2), 243–254. https://doi.org/10.1007/s10980-015-0239-8

Sagwa, C. B. (2021). Bee populations, genetic diversity, conservation, marketing and contribution to rural households in Kenya: A review. *International Journal of Tropical Insect Science*, *41*(2), 933–943. https://doi.org/10.1007/s42690-020-00389-0

Saina, E., Ronald, K., & Veronica Wawira, G. (2023). Factors Affecting Household Income Among Motorcycle Operators. A Case of Embu County Residence, Kenya. *Journal of Business Management and Economic Research*, *5*(2), 48–56. https://doi.org/10.29226/TR1001.2021.259

Salam, M. A., Noguchi, T., & Koike, M. (2000). [No title found]. *Agroforestry Systems*, *50*(1), 77– 93. https://doi.org/10.1023/A:1006403101782

Simons, A. J., & Leakey, R. R. B. (2004). Tree domestication in tropical agroforestry. In P. K. R. Nair, M. R. Rao, & L. E. Buck (Eds.), *New Vistas in Agroforestry* (Vol. 1, pp. 167–181). Springer Netherlands. https://doi.org/10.1007/978-94-017-2424-1_12

Article DOI: https://doi.org/10.37284/eajfa.7.1.2010

Skole, D. L., Samek, J. H., Dieng, M., & Mbow, C. (2021). The Contribution of Trees Outside of Forests to Landscape Carbon and Climate Change Mitigation in West Africa. *Forests*, *12*(12), 1652. https://doi.org/10.3390/f12121652

Smucker, T. A., & Wisner, B. (2008). Changing household responses to drought in Tharaka, Kenya: Vulnerability, persistence and challenge. *Disasters*, *32*(2), 190–215. https://doi.org/10.1111/j.1467-7717.2007.01035.x

Suryani, A., Bezama, A., Mair-Bauernfeind, C., Makenzi, M., & Thrän, D. (2022). Drivers and Barriers to Substituting Firewood with Biomass Briquettes in the Kenyan Tea Industry. *Sustainability*, *14*(9), 5611. https://doi.org/10.3390/su14095611

Thomas, N., Baltezar, P., Lagomasino, D., Stovall, A., Iqbal, Z., & Fatoyinbo, L. (2021). Trees outside forests are an underestimated resource in a country with low forest cover. *Scientific Reports*, *11*(1), 7919. https://doi.org/10.1038/s41598-021-86944-2

Villamor, G. B., Van Noordwijk, M., Djanibekov, U., Chiong-Javier, M. E., & Catacutan, D. (2014). Gender differences in land-use decisions: Shaping multifunctional landscapes? *Current Opinion in Environmental Sustainability*, *6*, 128–133. https://doi.org/10.1016/j.cosust.2013.11.015

Wawire, A. W., Csorba, Á., Tóth, J. A., Michéli, E., Szalai, M., Mutuma, E., & Kovács, E. (2021). Soil fertility management among smallholder farmers in Mount Kenya East region. *Heliyon*, *7*(3), e06488. https://doi.org/10.1016/j.heliyon.2021.e06488

Zhu, Z., & Waller, E. (2003). Global Forest Cover Mapping for the United Nations Food and Agriculture Organization Forest Resources Assessment 2000 Program. *Forest Science*, *49*(3), 369– 380. https://doi.org/10.1093/forestscience/49.3.369

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