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Spatial Distribution in the Adoption of Agroforestry among Small-Scale Farmers in Tharaka Nithi County

Authors
Henry Murithi Mugambi[1]; Stephen K. Wambugu[2]; Paul Njue[3]
Main author email: henrymugambi73@yahoo.com
Other Email: stephen.wambugu@chuka.ac.ke; pnjue@chuka.ac.ke

(1.2.3) Chuka University, Kenya.

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ABSTRACT

The study investigated the spatial distribution in the adoption of agroforestry among small-scale farmers in Tharaka Nithi County, Kenya. Various efforts have been initiated to enhance the adoption of agroforestry. Despite the efforts made, farmers are yet to fully adopt agroforestry in Tharaka Nithi County. There is paucity of information regarding spatial variations in the adoption of agroforestry. The study was based on the Rogers Adoption-Diffusion Model. The study utilised a cross-sectional research design. The target population was 43,231 small-scale farmers in Tharaka Nithi County. Simple random sampling was employed to select 220 farmers to participate in the study. The data for the study was collected using questionnaires for farmers. Findings indicated spatial distribution in the adoption of agroforestry among small-scale farmers in the sub-counties in Tharaka Nithi County. Findings further showed that there were significant $\chi 2$ (chi-square) associations between soil fertility, topography, soil colour, soil depth, rainfall variability, flooding, temperatures and occupation in all the sites, showing that the agroforestry behaviour was associated with sites. Therefore, these factors accounted for spatial variations in agroforestry. Consequently, this study concludes that landscapes are important considerations for farmers who intend to adopt agroforestry. The findings of the study will be crucial in informing current agroforestry technology adoption decisions by the farmers within Tharaka Nithi County guided by the identification of constraints (socioeconomic, cultural and geophysical) that hinder wide adoption of agroforestry. The study recommends that the government introduce programs to sustain and continually improve agroforestry and reduce negative beliefs concerning agroforestry adoption.

Key terms: Adoption, agroforestry, geography, small-scale farmers, spatial distribution.

INTRODUCTION

More and more people are worried about the effects of climate change, which has rekindled interest in the idea of expanding tree-planting efforts to forested and otherwise degraded areas (Jerneck et al., 2019). Agroforestry allows rural residents to have access to wood while simultaneously improving food production. According to Harrington and Tow (2017), agroforestry is being seen more and more as a practical solution for improving carbon sequestration and bio-energy production while simultaneously benefiting local livelihoods, food security, and agro-ecological resilience. The management of watersheds, the prevention of erosion, the provision of food and herbal medicine, and the preservation of environmental quality are all vital products and services provided by forests (Nair et al., 2011). Woody perennials in agroforestry systems may influence several biophysical and biochemical processes that establish the soil substrate's health, as highlighted by the Food Agricultural Organization (FAO, 2011). The world is worried about the depletion of natural resources like trees. The loss in the tropics alone was anticipated by the Global Environment Facility (2015) to reach 15.2 million hectares in the year 2023. Economic growth and conservation goals often come into conflict due to the diversified usage of forest resources.

In Africa, the impact of loss of forest cover is being manifested through drought and increased environmental temperatures, making trees dry due to loss of water. This has made agroforestry to be introduced as an intervention measure. Despite this, the adoption of agroforestry by farmers in Africa is low (Kiptot et al., 2017). This low adoption of Agroforestry technologies has been influenced by a number of factors. Among the widely researched and documented include the economic value of trees (Ramphele, 2019), tree species available to the farmers for planting (Zhao et al., 2014), and availability of labour (Gabrielsson & Ramasar, 2012). Nevertheless, there is a dearth of ResearchResearch that attempts to explain the observed variance in the rate of agroforestry adoption by examining the impact of geographical variables in this practice. The factors that impact the adoption of agroforestry differ across different biophysical regions. To effectively promote and accelerate its uptake, it is crucial to further investigate the adoption process and identify the actual factors that influence agroforestry adoption. Villages and highland farmers continue to choose land for farming over forests, leading to severe deforestation in Kenya. Kenya has seen a rapid decline in forest cover and biodiversity due to factors such as population growth, ineffective government policies, and the displacement of indigenous peoples' long-established methods of land use management (Kio & Abu, 2016). Because of these and other causes, Kenya's forest cover is now lower than 1.7 per cent1.7 per cent. Worldwide, a minimum of 10 per cent coverage is considered optimal. Given this context, it is prudent to support initiatives aimed at enhancing agroforestry technology. In addition to helping people make a living, agroforestry methods may make local agricultural and subsistence systems more resilient and adaptable. Both the Kenyan government and non-governmental organisations (NGOs) have pushed for the widespread use of agroforestry practices in rural areas so that farmers there may reap the advantages of increased food production.

Seventy per cent of Tharaka Nithi County's residents call rural regions home, and most of those people make a living in agriculture (USAID, 2015). Low agricultural production, heavy reliance on rain-fed agriculture, traditional land tenure instability, and environmental deterioration as a result of unsustainable farming techniques are just a few of the numerous problems these people confront. Low productivity in smallholder agriculture is a direct outcome of these obstacles, which in turn contribute to the high poverty rate among smallholder farmers in rural areas (FAO, 2013). Although agroforestry technology might help improve land productivity, climate change mitigation, poverty reduction and is a wildlife habitat, there hasn't been enough study in this field. Understanding the geographical differences in Agroforestry adoption in Tharaka Nithi County was the primary motivation for this research. Sustainable land use relies heavily on agroforestry. Nevertheless, the influence and acceptance of agroforestry technologies in Tharaka Nithi County have been little and fragmented despite the great potential of these tools and the efforts made to promote them among smallholder farmers. Therefore, it is crucial to comprehend the causes of this geographical variance in agroforestry adoption in order to potentially alleviate the obstacles preventing the technology's widespread use. Agroforestry is vital for sustainable land use. However, despite all the potential of agroforestry technologies and the effort to promote them among smallholder farmers, their adoption and diffusion have remained low and segregated, and so has their impact in Tharaka Nithi County. Consequently, understanding the reasons behind this spatial variation in the adoption of agroforestry is important as this may help in mitigating the problems hindering full scale adoption of the technology. Therefore, this study sought to investigate spatial variations in the adoption of agroforestry by small-scale farmers in Tharaka Nithi County, Kenya.

LITERATURE REVIEW

Agroforestry is the growing of trees and crops on the same land. Agroforestry may be practised with or without animals. Agroforestry has been practised increasingly and widely in the developing world as an important land-use system (Nair, 2016). According to the International Centre for Research in Agroforestry (ICRAF) (2015), agroforestry is the technique of intentionally integrating woody perennials into an agro-ecosystem that also includes crops and/or animals on a single plot of land. Integrating agroforestry practices requires mixing them spatially or in time order. To be considered agroforestry, there must be interactions between the non-woody and woody parts that have an ecological and economic impact. Varieties of agricultural advances tend to spread and be adopted in various ways in different regions (Tafere & Nigussie, 2018). Research conducted by Ahmad and Ekanayake(2023) found that smallholder farmers who own less than 2 hectares of land make up 58 per cent of Pakistanis living in rural regions. Despite their significance to Pakistan's economy, they are particularly vulnerable to climate change since they depend on rain-fed agriculture in addition to subsistence farming. The region's agricultural land is vulnerable to environmental hazards, which reduces output and makes it difficult for farmers to acquire capital. In 2018, the Asian Development Bank (2018) found that 21.9 per cent of Pakistanis were living below the poverty level. Because of this, the local population relies heavily on wood for fuelwood and timber exploitation for subsistence. The environmental crisis in Pakistan has become even more dire due to the country's rapid population growth and rampant deforestation.

Research conducted by Bargali and Bargali (2020) over an elevation gradient in India's Central Himalayas found that home garden agroforestry systems might potentially increase agricultural yields and forest products all at once. The household's primary means of subsistence and economic production were the fruits of trees and herbaceous crops. The variety of plants in home garden systems varied over an elevation gradient. Sustainable land use and multi-purpose tree management on farms is the focus of agroforestry, a field within the forest sciences that emphasises an integrated, interdisciplinary approach. The importance of agroforestry was highlighted in Jamala and Oke's (2013) research on the topic, which showed that agroforestry technology promotion is crucial as it gives farmers the chance to increase their income and output. Achieving sustainable development via agroforestry requires a persistent and proactive strategy to engage farmers in tree-planting initiatives (Mercer, 2013). Research on and implementation of agroforestry technology among Nigeria's smallholder farmers has received substantial attention (Jamala & Oke, 2013). Beginning in 1980 at research stations and continuing in 1984 on farms in conjunction with farmers, agroforestry methods have been tested in Nigeria (Franzel et al., 2017). According to Franzel et al. (2017), agroforestry methods were widely used by farmers. Ajayi (2015) found that agroforestry technology adoption is low in Nigeria, according to different research. According to Jamala and Oke (2013), few farmers in Nigeria have used these technologies, even though there have been research and extension efforts made available to them.

Research on the topic of agroforestry adoption in Africa has mostly relied on official surveys of households and farms, as well as comparisons between adopters' and non-adopters' demographics (Adekunle, 2021). Future studies should focus on analysing the adoption of agroforestry at the village level and using spatial methods (Mercer, 2013). This research was motivated by this. Husselman and Zida (2018) said that families should be considered throughout several phases of adoption, including testers or experimenters, re-adopters, pseudo-adopters, and adopters, based on research on enhanced tree fallow adoption. One key point supporting this thesis is that different farmers have different reasons to keep doing agroforestry at different points in their careers.

Nzilu (2015) studied farmers' perceptions and their impacts on agroforestry adoption. The study presented a research gap that was subsequently addressed by the current study. The study only focused on the perceptions of farmers, while the current study investigated the geographical issues in the adoption of agroforestry. The study only focused on one form of agroforestry adoption, while the current study focused on all forms of agroforestry adoption. The study had methodological gaps also. It analysed data using frequencies and percentages, while the current study will employ data analysis methods such as choropleth maps, binary regression, chi-square and nearest neighbour index that allow for inferential interpretation of relationships between variables in the study.

Kabwe et al. (2016) studied the reasons why is adoption of agroforestry stymied in Zambia's perspectives from the farmers' ground up. The study was positive for this study in that it recommended geographical factors for agroforestry adoption that should be investigated. However, this study failed to investigate these factors empirically. The study was a review of the literature and, therefore, failed to analyse original findings from the respondents. The context of these studies was in Zambia focusing on one construct of agroforestry adoption. Research conducted by Wandahwa et al. (2023) in Kakamega County, Kenya, looked at the most common types of agroforestry practices among smallholder farmers. The agroforestry practices that were most often used were those involving compound trees, fence trees, and fruit trees. Some more examples of agroforestry practices are farm contour trees, timber lots, and intercropping with food crops. (Luvoni, 2021) also discovered that the most common types of agroforestry in Kakamega were woodlots, boundary trees, and dispersed trees. Therefore, the results of this study are consistent with theirs. Research in Bangladesh has shown that farmers there use a variety of agricultural practices, including mixed agroforestry with livestock kept under tree cover, tree crop association, border plantations, and woodlot agroforestry. According to these findings, smallholder farmers might practice many types of agroforestry on their properties. The survey also found that of the agroforestry tree kinds favoured by smallholder farmers in Kakamega County, the most popular one is Grevillea Robusta, which is chosen by 91.8 per cent of these farmers. The agroforestry program also included the planting of fruit trees, blue gums, Cyprus, and Calliandra. Only about a third of the farms that were tested had feed trees (such as Sesbania sesban and Casuarina). These results are in line with those of (Agevi et al., 2019), who also discovered that the fastest-growing tree species in Kakamega are Eucalyptus saligna and Grevillea robusta. Based on his research at the Nzoia site, Lugari district, Kenya, Wafuke (2012) found that the most popular agroforestry techniques used by farmers in the region include woodlots, home gardens, hedge planting, and boundary marking. The majority of farmers used boundary markers and hedges, whereas the minority farmed woodlots. The data also show that farmers use many Agroforestry technologies, which contributes to the high percentages for each method. Agroforestry technologies were also widely used in the area, according to the data.

Spatial Variations in the Adoption of Agroforestry

Jabro et al. (2017) found that soil structure and fertility, irrigation treatments, pests and diseases, plant genetics, and geographical and temporal fluctuations all contribute to tree planting spatial variability. The interplay between the many components that go into soil formation and the surrounding environment gives this natural resource, soil, its intrinsic diversity. Erosion, land usage, and farming are further potential causes of variations. According to Jara-Rojas et al. (2020), forest agroforestry is the most popular method in Colombia, with 50.9 per cent of farmers using it. The practice's advantages were cited as a basis for its acceptance. The forest provides fuel, is a building material for homes and cattle, generates income from wood sales, and helps keep watersheds and streams intact. The cheap cost of establishment and management associated with natural regeneration after human intervention is another element that encourages the broad acceptance of forests (Bottaro et al., 2018). That fits with what we know from research on the relationship between input intensity (labour and capital) and technology adoption in agricultural systems (Roco et al., 2016). Scattered trees, which are planted for various reasons like fruit, rubber, or wood production, as forage sources, and to shield cattle from the sun and high temperatures (particularly in hot regions where heat stress is more common), are the second most common agroforestry practice, with 22.6 per cent adoption. Forage from trees and shrubs and forestry plantations are two of the least popular agroforestry practices (18.4 per cent and 12 per cent, respectively). This is because getting these practices off the ground requires specific plant species, seeds, or plant material, and then there's a lot of extra work to keep the plants healthy until they're big enough to withstand cattle, which makes management more complicated and less appealing (Adesina et al., 2000).

The effect of agroforestry adoption on food security in Malawian households was investigated by Coulibaly et al. (2017). The idea of mixed agricultural behaviour served as the foundation for the investigation. The study employs an explanatory design. The data was examined using descriptive statistics derived from a questionnaire that was used to gather the data. The hypotheses that were generated were tested using multiple regressions and Pearson correlations. Although the study investigated variations in the adoption of agroforestry in two regions in Malawi, it failed to show the geographical variations in the adoption. The findings focused on only one construct of agroforestry adoption, which is climatic conditions, while the current filled this gap by testing spatial variations using inferential statistics that allow for relationships between factors to be established. In three catchments in Claveria, Philippines, Delgado et al. (2020) modelled how agroforestry systems affected soil erosion risk patterns in space. The study utilised both primary and secondary sources of information. The sample for selecting responders was created using the basic random sampling approach. The study found a strong positive correlation between the soil type and agroforestry adoption. The current study will investigate spatial variations and distribution in the adoption of agroforestry adoption in three sub counties that have different ecological zones. The study used only correlation analysis to analyse data, while the current study will use a mixed-method approach. The current studies also investigate the factors that account for spatial variations in the adoption of agroforestry.

The context of this study was in the Philippines, focusing on only one aspect of agroforestry adoption. Wang et al. (2013) report that spatial variability of soil properties plays an important role in crop growth and yield. There have been reports that spatial variability in soil, ecological zone and topography affects tree growth (Ziadat & Taimeh, 2013). However, studies documenting this in Kenya are inadequate. This study will, therefore, examine the spatial variations in the adoption of agroforestry among small-scale farmers in Tharaka Nithi County to fill this gap.

Soil type, landscape location, soil physical and chemical characteristics, fertiliser availability, and other variables may all contribute to planting tree variability (Jabro et al., 2017). According to Glover and Lawrence (2017), the main reason why different communities and farmers embrace different technologies is because of socioeconomic issues. These factors include things like labour, gender, land tenure, and managerial expertise. Despite Glover and Lawrence's (2017) contribution to the current study, the study presented various research gaps; data was collected on 88 purposely selected respondents using questionnaires and analysed by frequencies and percentages. The current study used random sampling to collect data. Specifically, the study investigated factors that account for spatial variations in the adoption of agroforestry. The study introduced many factors but used only frequencies and percentages to analyse data. This did not allow for testing of relationships between variables; therefore failed to link this to the adoption of documented agroforestry. Smallholder farmers throughout the globe, especially in developing nations, are showing a growing interest in agroforestry practices and technology (Glover & Lawrence, 2017). There is a tangible world in which humans exist. The different rates of agroforestry adoption may be explained by physical characteristics such as soil type, vegetation, climate, and terrain. To begin, trees thrive in the climate that is associated with higher elevations. Second, there is a lot of room for tree growth in these soil types, particularly the deeper ones. Understanding the primary economic, social, and cultural elements that dictate the actual occurrence of agroforestry is crucial since these environmental preconditions govern its promotion. So, the purpose of this research was to look at how small-scale farmers in Tharaka Nithi County's adoption of agroforestry varied by location.

Theoretical Framework

The Rogers Adoption-Diffusion Model (2020) served as the foundation for the investigation. A model that aims to explain the how, why, and rate of transmission of innovations is the diffusion of innovations model proposed by Rogers (2020). According to Rogers, the final result of technology transfer is adoption, which is defined as the application of previously transmitted information about a technical breakthrough (Rogers, 2020). According to Rogers, a social system's members learn about a new invention via time as they interact with others as they pass through established routes. According to Rogers (2020), while making a choice on an innovation, people are driven to seek out and digest information in order to decrease ambiguity around the pros and cons of the innovation. "Any concept, practice, or object that is perceived as new by an individual or other unit of adoption, if an individual considers an idea new then it is an innovation," definitionalizes Rogers (2020). The rate and depth to which people use newly developed technologies are two indicators of how widely adopted such technologies will be. Conversely, diffusion refers to the gradual spread of an invention across a social system via predetermined routes. According to Rogers, there are five key factors that determine how far a fresh concept travels. First, being aware of the innovation; second, being persuaded to adopt it; third, deciding to adopt it or reject it; fourth, putting the innovation into action; and finally, confirmation, when the adopter assesses the innovation's impact.

According to Rogers (2020), there are five steps to the adoption process. In order for an innovation to be adopted, farmers must first become knowledgeable about it. Then, they must be convinced of its value. Then, they must decide whether to adopt it or not. The innovation must be implemented. Lastly, they must confirm or reject their decision. While other writers, like Luvoni (2021), use alternative terminology, the processes involved in the adoption process are still quite similar, with only slight variations, and are as follows: awareness, interest, assessment, trial, and adoption. Rogers (2020) proposes a theory that categorises individuals who embrace new technologies into three groups: innovators, early adopters (those in positions of leadership who encourage others to do the same), and the early majority (those who will embrace the technology just before half of their peers do the same). In his work, Rogers (2020) expanded the definition to include the concept of the "late majority," or members of society who hold off on making a choice to accept an innovation until the majority of their peers have done so. On the other side, those who lag behind are more likely to be cautious of new ideas and technologies, and they base their decisions on whether or not other people in the social system have successfully embraced similar advances in the past. The distribution of adopters follows a normal distribution, as seen in Figure 1.

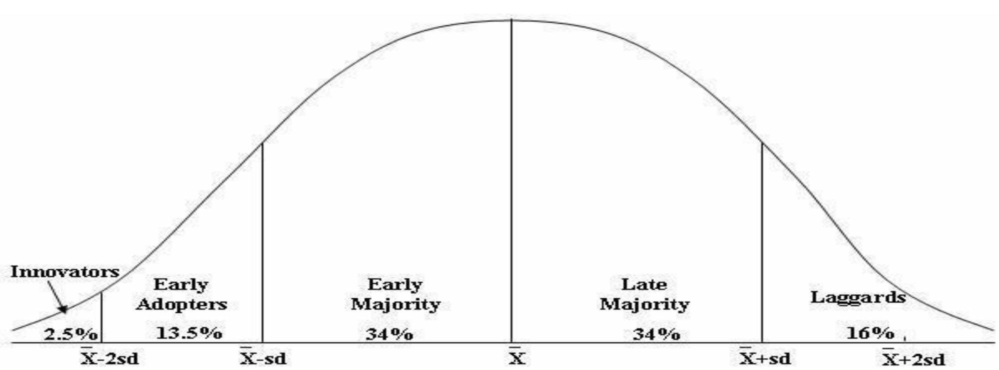

Figure 1: Adopter Categorization on the Basis of Innovation
Source: Rogers (2020)

When people fully embrace a new technology because they see it as the greatest way to solve a problem, that's when adoption happens (Rogers, 2020). The term describes the steps one takes when presented with, contemplating, and ultimately deciding whether to embrace and implement an invention. According to Rogers, capital requirements, agricultural policy, and farmers' socioeconomic characteristics are major factors in determining the pace of technology adoption, which in turn is affected by the technology's profitability and the level of risk and uncertainty linked with it. There are three tiers to the timing of adoption and diffusion: the rate of technology adoption in the system, the rate of innovation on the part of the farmer regarding when to adopt (or to abandon a technology once adopted), and the system as a whole. Cultivation intensity, as evaluated by factors like total area, area within farms, and number of farmers, might provide insight into the level of adoption (Rogers, 2020). Given that the emphasis is on the idea's perception, all that is required for an invention to be considered novel from a geographical perspective is that it be "new" to the prospective user. Adoption may be defined as the mental journey from learning about an invention to committing to fully use it (Adekunle, 2021). Improvements in social standing, ease, and efficiency are three of the most common motivations for innovations to be accepted by farmers. Several variables influence farmers' decisions to use agroforestry technology, as stated by Rogers (2020). Through extension, farmers learn about irrigation technologies and decide whether they are suitable for their needs based on a variety of criteria, including the size of their land, the crops they grow, their level of education and experience, the cost of inputs, the availability of credit, and the anticipated improvement in fertility. From the point of view of both the individual farmer and the global spread of new technology, the adoption process is inherently fluid. This means that the relative importance of the variables impacting adoption, the capacity to accept new technology, and the related support requirements may all evolve over time. For example, one's openness to adopting a child may evolve as they gain life experience. Individuals, groups, nations, and regions exhibit different degrees of adaptability due to a wide range of influences (Eriksen, 2011). Some examples of adaptive reactions include indigenous knowledge (IK) that is handed down through generations in a certain area (Ramphele, 2019; UNEP, 2017).

If we want to know how farmers decide to try out and finally implement new agroforestry methods, we may utilise the Rogers Adoption-Diffusion Model (2020). The model was particularly useful for this study since it clarified for the researcher how two factors—farmers' relative innovativeness and their own personal attributes—influence the rate of adoption of agroforestry methods. As a result, researchers in this study were able to examine how small-scale farmers in Kenya's Tharaka Nithi County dealt with the impact of geographical variances on their adoption of agroforestry practices. Formal household/farm surveys and comparisons of adopters' and non-adopters characteristics have formed the backbone of most agroforestry adoption research. The significance of geographical analysis in determining the rate of agroforestry adoption was highlighted in this study. Therefore, the variance in the rate of agroforestry adoption may be largely explained by changes in the geophysical locations as well as the social, economic, and cultural features of individual farmers. Sustained increases in agricultural output, fuel wood supply, and revenue are impossible without adoption, which is the choice to fully use a concept and implement a new technique. An examination of previous research hypotheses, adoption, and the variables that impact adoption has been conducted. Although agroforestry-based production systems rely heavily on adoption, the utilisation of Agroforestry technology remains low. Adopting these Agroforestry technologies by small-scale farmers is crucial for ensuring the sustainability of commodities and services. However, many groups and areas have diverse socioeconomic and cultural aspects that impact the adoption of these technologies.

METHODOLOGY

The research adopted a cross-sectional survey design to sample 210 farmers from 3 sub-counties in Tharaka-Nithi County, Kenya. The research was conducted in the county of Tharaka Nithi. The three sub-counties that make up Tharaka Nithi County are Chuka/Igambang'ombe, Maara, and Tharaka. The target population was 43,231 small-scale farmers in Tharaka Nithi County (KNBS, 2021), including Maara, Tharaka and Chuka/Igambang'ombe County. The sample size was obtained using guidelines suggested by Nassiuma (2020) and adopted by Mutegi et al. (2023). The study used a coefficient variation of 21 per cent and a standard error of 0.02, obtaining a sample size of 220 households /farmers. Simple random sampling was employed to select 220 farmers to participate in the study. Data was collected using household questionnaires for farmers. The study employed inferential statistics to test the hypothesis. The collected data was coded and analysed with the aid of SPSS version 25. In order to analyse the spatial distribution of agroforestry adopters, the nearest neighbour index (NNI) was computed. The NNI was computed using the formula by Clark and Evans (1954). This formula is indicated below: $R = \bar{R}a / \bar{R}e$ Where R̄a=Mean Distance to nearest Neighbour, R̄e=Expected Distance to the nearest neighbour. The NNI was supplemented by the drawing of Choropleth maps and chi-square tests. As a kind of themed map, choropleth maps use shading to colour or pattern pre-defined regions in relation to a statistical variable that indicates an aggregate summary of a geographic feature within each area.

RESULTS AND DISCUSSION

Figure 2 shows the proportion of agroforestry adopters in percentages. The results indicated that there was a higher proportion of agroforestry adopters (57.3 per cent) in Maara subcounty than in Meru south subcounty (28.2 percent) and Tharaka subcounty (14.6 percent). This result can be explained by the geography of the areas and the main economic activities in the regions.

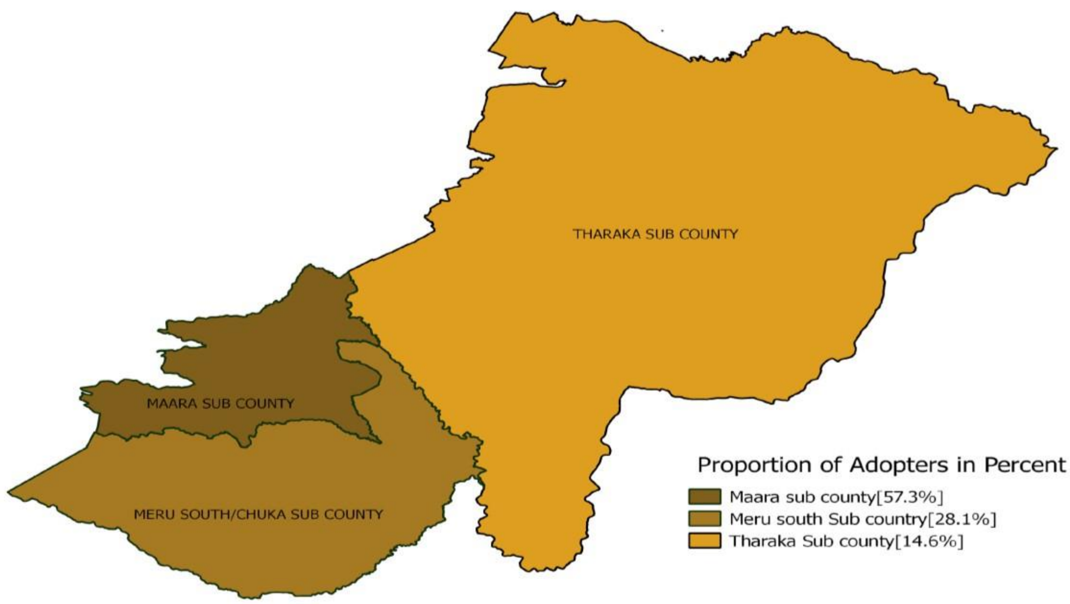

Figure 2: Spatial Variation in Agroforestry Adoption across the Sub Counties

Kaua *et al*. (2019) and Mung'athia (2021) showed that the three sub-counties greatly varied with the geography of the areas. Maara Sub County population are predominantly small-scale crop farmers, therefore the higher adoption of agroforestry. Maara and The Chuka people, who live in areas with sufficient precipitation for farming, use agroforestry more often. Tharaka is located in the semi-arid lower zone, which is ideal for raising cattle since it gets less rain. The ground is now barren and stony due to overgrazing, charcoal burning, inefficient agricultural practices, and lack of soil conservation. Deep gullies have formed over the terrain, particularly in Tharaka, as a consequence of unchecked soil erosion in the hilly regions.

Figure 3 showed that Tharaka Subcounty had poor fertile shallow depth soils. Meru South Subcounty had good fertile deep soils while Maara Subcounty had medium fertile moderate deep soils. The variations in soil properties in the three sub counties can be explained by the findings of Kaua *at al*., (2019) that

Tharaka Subcounty experiences changes in seasonal and annual rainfall patterns and hydrological regimes impact on soil properties.

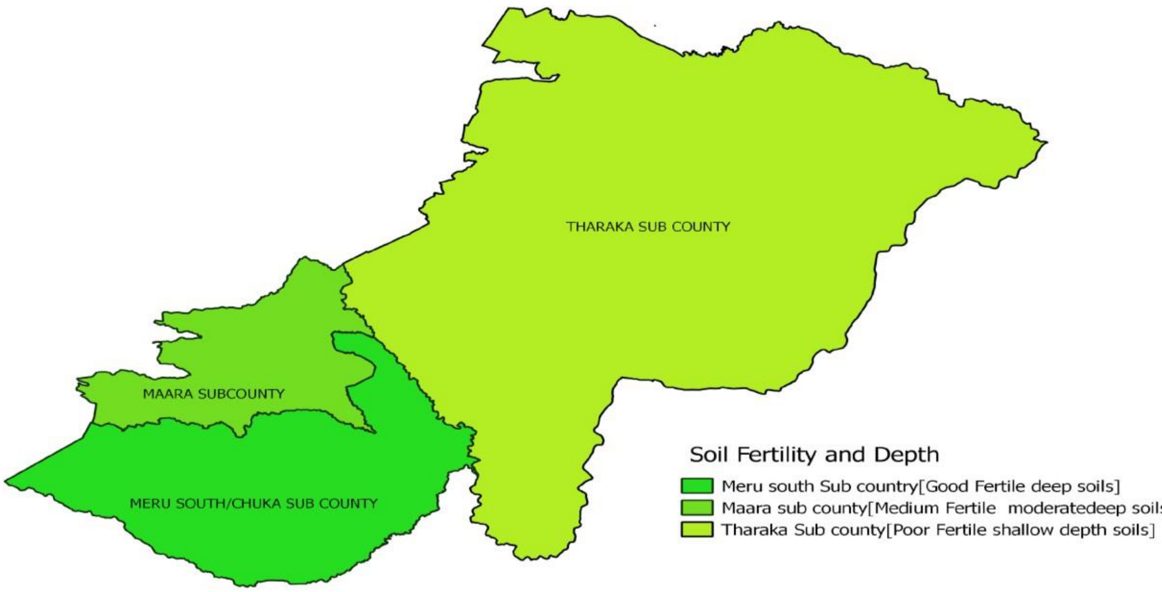

Figure 3: Soil Fertility and Depth Factors Influencing Adoption across the Sub Counties

Farm Land Factors and Adoption of Agroforestry

This study aimed to investigate whether soil type, climatic conditions and landscape accounted for spatial variations in the adoption of agroforestry among small-scale farmers in Tharaka Nithi County. There was a significant linkage between soil fertility status and agroforestry adoption in all study counties. In the Maara sub-county, most of the farmers practised agroforestry on medium (43 per cent) and good fertility soils (28 per cent) (Table 13). In regards to the Tharaka sub-county, 41 per cent and 27 per cent planted agroforestry species in medium fertility and good fertility soil, respectively. In Chuka /Igambang'ombe, there were 44 per cent and 24 per cent of the farmers cultivated agroforestry species in medium fertility and good fertility soils (Table 1). According to Pinho et al. (2012), agroforestry systems, which make use of a variety of tree species, may provide viable alternatives to conventional methods of improving soil fertility and sustaining agricultural output; this research has significant implications for the long-term viability of tropical farming.

Table 1: Land Factors Influencing Adoption of Agroforestry (Soil Fertility)

Site	Agroforestry	poor	Medium	good	Total	χ^2
Maara	no	15(29.41)	0(0.00)	0(0.00)	15(29.41)	0.000
	yes	0(0.00)	22(43.14)	14(27.45)	36(70.59)	
	total	15(29.41)	22(43.14)	14(27.45)	51(100.00)	
Tharaka	no	30(30.93)	0(0.00)	0(0.00)	30(30.93)	0.000
	yes	0(0.00)	40(41.24)	27(27.84)	67(69.07)	
	total	30(30.93)	40(41.24)	27(27.84)	97(100.00)	
Chuka/igambang'ombe	no	20(32.26)	0(0.00)	0(0.00)	20(32.26)	0.000
	yes	0(0.00)	27(43.55)	15(24.19)	42(67.74)	
	total	20(32.26)	27(43.55)	15(24.19)	62(100.00)	

In relation to topography, most of the farmers in Maara (71 percent), Tharaka (69 percent) and Chuka/igambang'ombe (68 percent) cultivated agroforestry trees in slightly sloppy field (Table 13). There were significant χ^2 (chi-square) associations between site and topography in all the sites showing that the agroforestry behavior was associated with sites (Table 14).

Table 2: Land Factors Influencing Adoption of Agroforestry (Topography)

Site	Agroforestry	flat	slightly sloppy	Total	χ^2 sig.
Maara	no	15(29.41)	0(0.00)	15(29.41)	0.000
	yes	0(0.00)	36(70.59)	36(70.59)	
	Total	15(29.41)	36(70.59)	51(100.00)	
Tharaka	no	30(30.93)	0(0.00)	30(30.93)	0.000
	yes	0(0.00)	67(69.07)	67(69.07)	
	Total	30(30.93)	67(69.07)	97(100.00)	
Chuka/igambang'ombe	no	20(32.26)	0(0.00)	20(32.26)	0.000
	yes	0(0.00)	42(67.74)	42(67.74)	
	Total	20(32.26)	42(67.74)	62(100.00)	

In relation to topography, most of the farmers in Maara (71 per cent), Tharaka (69 per cent) and Chuka/igambang'ombe (68 per cent) cultivated agroforestry trees in slightly sloppy fields (Table 2). There were significant χ^2 (chi-square) associations between site and topography in all the sites, showing that the agroforestry behaviour was associated with sites. The Chi-square test at a 5 per cent significant level implied that topography is a significant factor in the adoption of agroforestry. This result can be explained by the fact that farmers in slightly sloppy topography may adopt agroforestry more in order to prevent soil erosion. This finding supports Jabro et al. (2017), who established that farmers in sloppy landscapes may embrace agroforestry in order to improve soil formation and prevent erosion.

Table 3: Land Factors Influencing Adoption of Agroforestry (Soil Colour)

Site		dark	brown	Total	χ^2 Sig.
Maara	No	0(0.00)	15(29.41)	15(29.41)	0.003
	Yes	14(27.45)	22(43.14)	36(70.59)	
	Total	14(27.45)	37(72.55)	51(100.00)	
Tharaka	No	0(0.00)	30(30.93)	30(30.93)	0.000
	Yes	27(27.84)	40(41.24)	67(69.07)	
	Total	27(27.84)	70(72.16)	97(100.00)	
Chuka/Igambang'ombe	No	0(0.00)	20(32.26)	20(32.26)	0.001
	Yes	15(24.19)	27(43.55)	42(67.74)	
	Total	15(24.19)	47(75.81)	62(100.00)	

In relation to soil colour, most of the farmers in Maara (73 per cent), Tharaka (72 per cent) and Chuka/igambang'ombe (76 per cent) cultivated agroforestry trees in brown soils while the rest cultivated them in dark soils (Table 3). There were significant χ^2 (chi-square) associations between site and topography in all the sites, showing that the agroforestry behaviour was associated with sites (Table 15). The Chi-square test at a 5 per cent significant level implied that topography is a significant factor in the adoption of agroforestry. This can be explained by the fact that Chuka Igambangombe and Maara Sub Counties are characterised by deep red loam. The areas experience more rainfall, hence finding it easier to adopt agroforestry. These soils are well drained and fairly fertile but require fertilisers to improve their fertility, as this has been lowered by continuous cultivation.

Table 4: Land Factors Influencing Adoption of Agroforestry (Soil Depth)

Site	Agroforestry	Shallow	medium depth	Deep	Total	χ^2
Maara	no	5(9.80)	0(0.00)	10(19.61)	15(29.41)	ns
	yes	8(15.69)	4(7.84)	24(47.06)	36(70.59)	
	Total	13(25.49)	4(7.84)	34(66.67)	51(100.00)	
Tharaka	no	0(0.00)	30(30.93)	0(0.00)	30(30.93)	0.000
	yes	28(28.87)	0(0.00)	39(40.21)	67(69.07)	
	Total	28(28.87)	30(30.93)	39(40.21)	97(100.00)	
Chuka/igambang'ombe	no	0(0.00)	7(11.29)	13(20.97)	20(32.26)	0.000
	yes	13(20.97)	0(0.00)	29(46.77)	42(67.74)	
	Total	13(20.97)	7(11.29)	42(67.74)	62(100.00)	

In the Maara sub-county, 47 per cent of the farmers planted agroforestry species in deep soils, while 16 per cent and 8 per cent planted them in shallow and medium-depth soils. In Tharaka, most farmers planted agroforestry species in deep (40 per cent) or shallow soils (29 per cent). While in Chuka/Igambang'ombe, agroforestry was mostly practised in deep soils (47 per cent) or shallow soils (21 per cent). There was a significant association between agroforestry adoption and soil depth in Tharaka (p=0.000) and Chuka/Igambang'ombe (p=0.000).

Results indicated that the majority of the farmers that had adopted agroforestry also cultivated them on medium soil fertility soils (Table 4). This indicates that soil fertility level influenced the adoption of agroforestry among farmers. The Chi-square test at a 5 per cent significant level implied that soil fertility is a significant factor in the adoption of agroforestry. This result can be explained by the fact that farmers who feel that the fertility of their land is low may seek alternative sources of income rather than invest in their lands by adopting agroforestry practices. To make sure farmers understand the importance of agroforestry in increasing soil fertility, however, training is necessary. Agroforestry systems, according to Pinho et al. (2012), can increase soil fertility and sustain agricultural production through the use of diverse tree species and other practices. This has significant practical implications for the long-term viability of tropical agriculture. Results in Table 4 indicated that the majority of farmers' agroforestry was in a slightly sloppy topography. This indicates that topography influenced the adoption of agroforestry among farmers. The Chi-square test at a 5 per cent significant level implied that topography is a significant factor in the adoption of agroforestry. This result can be explained by the fact that farmers in slightly sloppy topography may adopt agroforestry more in order to prevent soil erosion. This finding supports Jabro et al. (2017), who established that farmers in sloppy landscapes may embrace agroforestry in order to improve soil formation and prevent erosion. Results in Table 16 indicated that the majority of farmers adopted agroforestry and also indicated their soil colour was brown. The Chi-square test at a 5 per cent significant level implied that topography was a significant factor in the adoption of agroforestry. This can be explained by the fact that Chuka Igambangombe and Maara Sub Counties are characterised by deep red loam soils (Nitisols). The areas experience more rainfall and hence find it easier to adopt agroforestry. These soils are well drained and fairly fertile but require fertilisers and improved soil management, such as agroforestry practices, to improve their fertility.

Economic Factors and Adoption of Agroforestry

In relation to occupation and adoption of agroforestry in different sites, there was a significant association between occupation and adoption in Maara, but this was not significant in all the other sites. In Maara, business persons recorded 100 per cent agroforestry rates, followed by 96 per cent (farmers) and 85 per cent (civil servants). In Tharaka, 71.4 per cent, 70.8 per cent and 62.2 per cent of the business persons, civil servants, and farmers cultivated agroforestry species, respectively. In Chuka/Igambang'ombe, 71.4 per cent, 29.2 per cent and 64.4 per cent of businessmen, farmers, and civil servants adopted agroforestry (Table 5).

Table 5: Occupation and Adoption of Agroforestry in Different Sites

Site	Adoption	Farmer	Civil Servants/Teacher	Business Person	Other	Total	χ2
Maara	No	1(4.5)	2(15.4)	0(0.0)	12(100.0)	15(29.4)	0.000
	Yes	21(95.5)	11(84.6)	4(100.0)	0(0.0)	36(70.6)	
	Total	22(100.0)	13(100.0)	4(100.0)	12(100.0)	51(100.0)	
Tharaka	No	17(37.8)	7(29.2)	2(28.6)	4(19.0)	30(30.9)	Ns
	Yes	28(62.2)	17(70.8)	5(71.4)	17(81.0)	67(69.1)	
	Total	45(100.0)	24(100.0)	7(100.0)	21(100.0)	97(100.0)	
Chuka/Igambang'ombe	No	12(29.3)	3(30.0)	5(50.0)	0(0.0)	20(32.3)	Ns
	Yes	29(64.4)	7(29.2)	5(71.4)	1(4.8)	42(43.3)	
	Total	41(91.1)	10(41.7)	10(142.9)	1(4.8)	62(63.9)	

The association between education and sites did not show a significant association in Maara and Tharaka, but this was detected in Chuka/igambang'ombe (χ^2 significance =0.05). In Maara, all farmers were below primary school graduates who adopted agroforestry, while farmers with more than primary education adopted the practice (69 per cent). In Tharaka Nithi, 100 per cent and 68 per cent of farmers with below primary and above primary education adopted agroforestry, while this was 100 per cent and 64 per cent for farmers with below primary and above primary in Chuka/igambang'ombe (Table 6).

Table 6: Education Level of the Respondent and Adoption of Agroforestry in Different Sites

Site	Agroforestry Adoption	below primary	above primary	Total	χ2
Maara	No	0(0.0)	15(31.3)	15(29.4)	ns
	Yes	3(100.0)	33(68.8)	36(70.6)	
	Total	3(100.0)	48(100.0)	51(100.0)	
Tharaka	No	0(0.0)	30(32.3)	30(30.9)	Ns
	Yes	4(100.0)	63(67.7)	67(69.1)	
	Total	4(100.0)	93(100.0)	97(100.0)	
Chuka/igambang'ombe	No	0(0.0)	20(36.4)	20(32.3)	0.05
	Yes	7(175.0)	35(37.6)	42(43.3)	
	Total	7(175.0)	55(59.1)	62(63.9)	

In relation to farm size, 68.2 per cent (0-5 acres), 55.6 per cent (6-10 acres) and 100 per cent (> 11 acres) of farmers in Maara adopted agroforestry practices. In Tharaka, this was 62 per cent (0-5 acres), while all farmers with more than 5 acres adopted agroforestry. In Chuka/igambang'ombe, the adoption was as follows: 83 per cent (0-5 acres), 48 per cent (6-20 acres) and 78 per cent (> 11 acres) (Table 19). In relation to farm size, 68.2 per cent (0-5 acres), 55.6 per cent (6-10 acres) and 100 per cent (> 11 acres) of farmers in Maara adopted agroforestry practices. In Tharaka, this was 62 per cent (0-5 acres), while all farmers with more than 5 acres adopted agroforestry. In Chuka/igambang'ombe, the adoption was as follows: 83 per cent (0-5 acres), 48 per cent (6-20 acres) and 78 per cent (> 11 acres).

Table 7: Farm Size and Adoption of Agroforestry in Different Sites

Site	Adoption	0-5 Acres	6-10acres	11 Acres And Above	Total	χ2
Maara	No	7(31.8)	8(44.4)	0(0.0)	15(29.4)	0.037
	Yes	15(68.2)	10(55.6)	11(100.0)	36(70.6)	
	Total	22(100.0)	18(100.0)	11(100.0)	51(100.0)	
Tharaka	No	16(38.1)	10(29.4)	4(19.0)	30(30.9)	ns
	Yes	26(61.9)	24(70.6)	17(81.0)	67(69.1)	
	Total	42(100.0)	34(100.0)	21(100.0)	97(100.0)	
Chuka/Igambang'ombe	No	4(17.4)	13(52.0)	3(21.4)	20(32.3)	0.023
	Yes	19(82.6)	12(48.0)	11(78.6)	42(67.7)	
	Total	23(100.0)	25(100.0)	14(100.0)	62(100.0)	

Social Factors and Adoption of Agroforestry

In relation to gender, 73 per cent of females and 70 per cent of males in Maara adopted agroforestry systems. In Tharaka, 73.7 percent of females and 68 percent of males adopted agroforestry while 92 percent and 61 percent of female and male heads in Chuka/igambang'ombe adopted agroforestry respectively. There was a significant linkage between site and gender in Chuka/igambang'ombe (sig = 0.030) (Table 8).

Table 8: Gender and Adoption of Agroforestry in Different Sites

Site	Agroforestry adoption	female	male	Total	χ2
Maara	No	3(27.3)	12(30.0)	15(29.4)	ns
	Yes	8(72.7)	28(70.0)	36(70.6)	
	Total	11(100.0)	40(100.0)	51(100.0)	
Tharaka	No	5(26.3)	25(32.1)	30(30.9)	ns
	Yes	14(73.7)	53(67.9)	67(69.1)	
	Total	19(100.0)	78(100.0)	97(100.0)	
Chuka/igambang'ombe	No	1(7.7)	19(38.8)	20(32.3)	0.030
	Yes	12(92.3)	30(61.2)	42(67.7)	
	Total	13(100.0)	49(100.0)	62(100.0)	

In relation to group membership, 59.4 per cent (No) and 89.5 per cent (Yes) adopted agroforestry practices. In Tharaka, this was 70.6 per cent (No) and 65.5 per cent (Yes). In Chuka/igambang'ombe, the adoption was as follows: 62.2 per cent (No), 48 per cent and 82.4 per cent. There was a significant association between group membership and agroforestry adoption in Maara. This shows that farmers who were group members tended to have a higher propensity to adopt agroforestry practices in most of the sites (Table 8). A higher proportion of group members adopted agroforestry practices.

Table 9: Group Membership and Adoption of Agroforestry in Different Sites

Site	Agroforestry adoption	Group membership			χ2
		No	Yes	Total	
Maara	No	13(40.6)	2(10.5)	15(29.4)	0.022
	Yes	19(59.4)	17(89.5)	36(70.6)	
	Total	32(100.0)	19(100.0)	51(100.0)	
Tharaka	No	20(29.4)	10(34.5)	30(30.9)	ns
	Yes	48(70.6)	19(65.5)	67(69.1)	
	Total	68(100.0)	29(100.0)	97(100.0)	
Chuka/igambang'ombe	No	17(37.8)	3(17.6)	20(32.3)	ns
	Yes	28(62.2)	14(82.4)	42(67.7)	
	Total	45(100.0)	17(100.0)	62(100.0)	

Cultural Factors and Adoption of Agroforestry

Beliefs regarding land ownership were linked to agroforestry in all sites. In Maara, farmers 56.7 per cent of farmers believed that women should not own land adopted agroforestry, while this was 53.4 per cent in Tharaka and 55.3 per cent in Chuka/igambang'ombe.

There was a site association between land use beliefs and agroforestry adoption in all sites (Table 10).

Table 10: Agroforestry Adoption and Beliefs around Land Ownership in Different Sites

Site	Agroforestry adoption	Women, not own land		Total	X^2 significance
		Yes	No		
Maara	no	13(43.3)	2(9.5)	15(29.4)	0.009
	yes	17(56.7)	19(90.5)	36(70.6)	
	Total	30(100.0)	21(100.0)	51(100.0)	
Tharaka	no	27(46.6)	3(7.7)	30(30.9)	0.000
	yes	31(53.4)	36(92.3)	67(69.1)	
	Total	58(100.0)	39(100.0)	97(100.0)	
Chuka/igambang'ombe	no	17(44.7)	3(12.5)	20(32.3)	0.007
	yes	21(55.3)	21(87.5)	42(67.7)	
	Total	38(100.0)	24(100.0)	62(100.0)	

Beliefs regarding women not planting trees were linked to agroforestry adoption in all sites. In Maara, farmers 13.3 per cent of farmers believed that women should not plant trees adopted agroforestry, while this was 10 per cent in Tharaka and 15.0 per cent in Chuka/igambang'ombe. There was a site association between land use beliefs and agroforestry adoption in all sites (Table 11).

Table 11: Agroforestry Adoption and Beliefs around Land Ownership in Different sites

Site	Agroforestry adoption	Women should not plant trees		Total
		Yes	no	
Maara	no	13(86.7)	2(5.6)	15(29.4)
	yes	2(13.3)	34(94.4)	36(70.6)
	Total	15(100.0)	36(100.0)	51(100.0)

Tharaka	no	27(90.0)	3(4.5)	30(30.9)
	yes	3(10.0)	64(95.5)	67(69.1)
	Total	30(100.0)	67(100.0)	97(100.0)
Chuka/igambang'ombe	no	17(85.0)	3(7.1)	20(32.3)
	yes	3(15.0)	39(92.9)	42(67.7)
	Total	20(100.0)	42(100.0)	62(100.0)

CONCLUSION AND RECOMMENDATION

Conclusion: Based on the findings, the conclusion of this study from the results is that soil type/fertility, topography, soil colour, and soil depth are important considerations for a farmer who intends to adopt agroforestry; therefore, sustainable agroforestry can be achieved by farmers actively checking their soil type, topography and colour. The study also concluded that landscapes, whether flat landscapes or mountain landscapes, significantly predict the probability of adoption of agroforestry. Therefore, this study concludes that landscapes are important considerations for farmers who intend to adopt agroforestry. The study also concludes that climatic conditions and occupation are important considerations for the adoption of agroforestry, while the education level of the farmer and farm size did not account for spatial variability in the adoption of agroforestry, while the main occupation of the respondent accounted for spatial variation in agroforestry. The study concludes that cultural factors such as gender and membership in farmers' groups have had a negative relationship with the adoption of agroforestry.

Recommendations: The study recommends that training should be conducted on the significance of agroforestry to soil fertility and farming. The government to introduce programs to sustain and continually improve agroforestry and reduce negative beliefs concerning agroforestry adoption. This will create a positive culture for agroforestry adoption. This study focused on spatial variations in farmland factors and social economics. A similar study should be conducted on other factors that enhance agroforestry adoption, such as location, enterprise decision aids and agricultural innovations.

REFERENCES

Adekunle, S. K. (2021). *Some Tenural and Legal Aspects of Agroforestry in Socio Economic and Institutional Aspects of Agroforestry*. United Nations University, Japan.

Adesina, A. & Chianu, J. (2000). Determinants of farmers' adoption and adaptation of alley farming technology in Nigeria. *Agroforestry systems, 55,* 99–112.

Agevi, H., Tsingalia, H., Muyekho, F., Obiri, J., Mukoya, W., & Onwonga, R. (2019). *On-farm tree abundance and biomass carbon stocks of Grevillea robusta and Eucalyptus saligna on farms around Kakamega Forest.*

Ahmad, S., Xu, H., & Ekanayake, E. M. B. P. (2023). Socioeconomic determinants and perceptions of smallholder farmers towards agroforestry adoption in northern irrigated plain, Pakistan. *Land, 12*(4), 813.

Ajayi, O. C., (2015). Policy support for large-scale adoption of agroforestry practices: Experience from Africa and Asia. *Agroforestry-The Future of Global Land Use*. 175–201.

Asian Development Bank. (2018). Local population reliance on woods for fuel wood and timber exploitation. Environments in Pakistani. *Agricultural Economics 30*, 215–228.

Bargali, K., & Bargali, S. S. (2020). Effect of size and altitude on soil organic carbon stock in home garden agroforestry system in Central Himalaya, India. *Acta Ecologica Sinica, 40*(6), 483-491.

Bottaro, G., Roco, L., Pettenella, D., Micheletti, S., & Vanhulst, J. (2018). Forest plantations' externalities: An application of the analytic hierarchy process to non-industrial forest owners in central Chile. *Forests,* 9(3), 141.

Clark, P. J., & Evans, F. C. (1954). Distance to nearest neighbour as a measure of spatial relationships in populations. *Ecology*, *35*(4), 445–453.

Coulibaly, J. Y., Chiputwa, B., Nakelse, T., & Kundhlande, G. (2017). Adoption of agroforestry and the impact on household food security among farmers in Malawi. *Agricultural systems, 155,* 52-69.

Delgado, M. E. M., & Canters, F. (2020). Modelling the impacts of agroforestry systems on the spatial patterns of soil erosion risk in three catchments of Claveria, the Philippines. *Agroforestry Systems, 85*(3), 411-423.
Eriksen, S. (2011). The Role of Indigenous Plants in Household Adaptation to Climate Change: The Kenyan Experience. In Climate Change and Africa, ed. P.S. Low, Cambridge University Press, 248–259.
FAO, (2011). Bagar Farming. (Baluwakhati) in riverbanks of Nepal. Retrieved from teca.fao.org/es/read/7376.
Food and Agriculture Organisation (FAO). (2013). Advancing Agroforestry on the Policy Agenda: A guide for decision-makers. Agroforestry Working Paper no. 1 – G. Buttoud, in collaboration with O. Ajayi, G. Detlefsen, F. Place & E. Torquebiau. FAO.
Franzel S., Phiri D. and Kwesiga F. (2017). Assessing the adoption potential of improved fallows in eastern Zambia. In Franzel S. and Scherr S.J. (eds.), Trees on the Farm: Assessing the Adoption Potential of Agroforestry Practices in Africa. CAB International, 37–64.
Gabrielsson, S., & Ramasar, V. (2013). Widows: Agents of change in a climate of water uncertainty. *Journal of Cleaner Production, 60*, 34-42.
Global Environment Facility. (2015). *What Kind of World? The Challenge of Land Degradation.*
Glover, E. K. & Lawrence, Y. M. (2017). *Agroforestry Practices among Smallholder Farmers of Southern Sudan: Sustainable Land-use, Agrobiodiversity and Food* Security. VDM Verlag.
Harrington, L., & Tow, P. (2017). Types of rainfed farming systems around the world. *Rainfed farming systems,* 45–74.
Husselman, M., & Zida, M. (2018). Opportunities for enhancing poor women's socioeconomic empowerment in the value chains of three African non-timber forest products (NTFPs). *International Forestry Review, 13*(2), 136-151.
ICRAF-International Centre for Research in Agroforestry. (2015). *A Selection of Useful Trees and Shrubs for Kenya*. ICRAF.
Jabro, J. D., Iversen, W. M., Stevens, W. B., Allen, B. L., & Sainju, U. M. (2017). A new automated passive capillary lysimeter for logging real-time drainage water fluxes. *Applied Engineering in Agriculture, 33*(6), 849-857.
Jamala, G. Y., & Oke, D. O. (2013). Soil organic carbon fractions as affected by land use in the Southern Guinea Savanna ecosystem of Adamawa State, Nigeria. *Journal of Soil Science and Environmental Management, 4*(6), 116-122.
Jara-Rojas, R., Russy, S., Roco, L., Fleming-Muñoz, D., & Engler, A. (2020). Factors affecting the adoption of agroforestry practices: insights from silvopastoral systems of Colombia. *Forests, 11*(6), 648.
Jerneck, A., Olsson, L., Ness, B., Anderberg, S., Baier, M., Clark, E. & Persson, J. (2019). Structuring sustainability science. *Sustainability science, 6*(1), 69-82.
Kabwe, G., Bigsby, H. R., & Cullen, R. (2016). *Why is the adoption of agroforestry stymied in Zambia? Perspectives from the ground-up.*
Kaua, C. G., Mutheu, J. M., & Thenya, T. (2019). Contextualizing climate variability in Tharaka South Sub-county, Tharaka Nithi County, Kenya. *Journal of Environmental Science, Toxicology and Food Technology, 13*(12).
Kio, P. R., & Abu, J. E. (2016). Updated environmental accounting and mechanism for reconciling land use pressure on forests. *Malaysia Forester Journal. 1994.57* (1-4) 40 – 52.
Kiptot E, Hebinck P, Franzel S, Richards P (2012). Adopters, testers or pseudo-adopters? Dynamics of the use of improved tree fallows by farmers in western Kenya. *Agric. Syst. 94*(2), 509-519.
KNBS, M. I. (2021). *Kenya Demographic and Health Survey 2018.* Kenya National Bureau of Statistics.
Luvoni, T. K. (2021). *Social determinants of adoption of on-farm tree planting and its contribution to household income in Shinyalu, Kakamega, Kenya.*
Mercer, D. E. (2013). Adoption of agroforestry innovations in the tropics: a review. *Agroforestry systems, 61*, 311-328.
Mung'athia, M. K. (2021). *Production and Consumption of African Indigenous Vegetables in Meru and Tharaka Nithi counties (Upper Eastern Kenya).* Doctoral dissertation, JKUAT-COHRED.
Mutegi, T. M., Joshua, P. M., & Kinyua, J. M. (2023). Workplace safety and employee productivity of manufacturing firms in Kenya. *Cogent Business & Management*, *10*(2), 2215569.

Nair, H., Brooks, W. A., Katz, M., Roca, A., Berkley, J. A., Madhi, S. A. & Campbell, H. (2011). Global burden of respiratory infections due to seasonal influenza in young children: a systematic review and meta-analysis. *The Lancet, 378*(9807), 1917-1930.

Nair, P. K. R. (2016). Agroforestry systems in the tropics. *Kluwer*. Academic, Dordrecht.

Nassiuma, D. K. (2020). Survey sampling. *Theory and methods, 14*. Ebenergy Enterprises Limited.

Nzilu, W. B. (2015). *Farmers' Perception and Its Impacts on Adoption of Agroforestry*. Doctoral dissertation, Kenyatta University.

Pinho, R. C., Miller, R. P., & Alfaia, S. S. (2012). Agroforestry and the improvement of soil fertility: a view from Amazonia. *Applied and environmental soil science,* 2012.

Ramphele, M. (2019). Women's Indigenous Knowledge: Building Bridges Between the Indigenous and the Modern. In: Indigenous Knowledge; Local Pathways to Development. World Bank.

Roco, L., Poblete, D., Meza, F., & Kerrigan, G. (2016). Farmers' options to address water scarcity in a changing climate: Case studies from two basins in Mediterranean Chile. *Environmental management, 58*, 958-971.

Rogers, E. M. (2020). Diffusion of Innovations (5th Ed.). The Free Press. Production in Kenya: A review. *International Journal of Poultry Science, 9*(4), 309–316.

Tafere, S. M., & Nigussie, Z. A. (2018). The adoption of introduced agroforestry innovations: Determinants of a high adoption rate–a case-study from Ethiopia. *Forests, Trees and Livelihoods, 27*(3), 175-194.

UNEP. (2017). Global Environmental Outlook 4: Flagship Report.

USAID (2015). Agroforestry adoption decision in green growth initiative programs: Key lessons from the Billion Trees Afforestation Project (BTAP). *Environmental Management, 71*, 950–964. https://doi.org/10.1007/s00267-023-01797-x

Wafuke, S. (2012). *Adoption of agroforestry technologies among small-scale farmers in Nzoia location, Lugari district, Kenya.* Doctoral dissertation, Egerton University.

Wandahwa, P. (2023). Adoption of agroforestry as a climate smart agriculture practice among smallholder farmers in Kakamega County, Kenya. *African Journal of Empirical Research, 4*(2), 1157–1173.

Wang, J., Ren, C., Cheng, H., Zou, Y., Bughio, M.A. & Li, Q. (2013). Conversion of rainforest into agroforestry and monoculture plantation in China: Consequences for soil phosphorus forms and microbial community. *Science of the Total Environment, 595*, 769–778.

Zhao, Y., Sun, Y., Lu, X., Zhao, X., Yang, L., Sun, Z., & Bai, Y. (2014). Hyperspectral retrieval of leaf physiological traits and their links to ecosystem productivity in grassland monocultures. *Ecological Indicators, 122*, 107267.

Ziadat, F. M., & Taimeh, A. Y. (2013). Effect of rainfall intensity, slope, land use and antecedent soil moisture on soil erosion in an arid environment. *Land Degradation & Development*, *24*(6), 582-590.