Vol. 4 (Iss. 2) 2023, pp. 1157-1173 African Journal of Empirical Research https://ajernet.net ISSN 2709-2607

Adoption of Agroforestry as a Climate Smart Agriculture Practice among Smallholder Farmers in Kakamega County, Kenya

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ABSTRACT

Climate Smart Agriculture (CSA) technologies help guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security by increasing farmers' resilience to climate change. Agroforestry has been vouched for as one of the best CSAs because it provides ecosystem services such as water quality enhancement and prevents land degradation. This study sought to establish and document the adoption of agroforestry as a CSA practice among smallholder farmers in Kakamega County. Stratified sampling was used to select six sub-counties to represent the county's various agroecological zones and regions for the research sample. A combination of purposive and snowball sampling was used to select 428 smallholder CSA farmers, of whom 376 (87.9%) were practicing agroforestry. Primary data was collected using interview guides developed through the Kobo Collect application. Microsoft Excel and Statistical Package for Social Sciences (SPSS) statistical packages were used to process and analyze the data. This study found that wood fuel was the main source of energy for 73% of the smallholder agroforestry farmers, followed by solar energy devices (12%), charcoal (7%), electricity (6%), and kerosene (2%). Grevillea Robusta was the most widely preferred agroforestry tree variety, adopted by 91.8% of agroforestry smallholder farmers, followed by fruit trees (73.4%), blue gums (67.3%), Cyprus (34.0%), and Calliandra (37.5%). Fodder tree types such as Sesbania and Casuarina were adopted by 30.9% and 23.9% of the smallholder agroforestry farmers, respectively. This study recommends the integration of agroforestry into farming systems by incentivizing farmers through programs like tree planting, free seedlings, and farm competitions. School agricultural clubs, such as 4K clubs for primary schools and Young Farmers Clubs for secondary schools, could be motivated and supported to use school gardens for food and fruit tree production. This study also recommends the promotion of modern stoves (maendeleo jikos), which use less wood fuel, are more efficient in cooking, and also reduce GHG emissions.

Keywords: Agroforestry, Climate Smart Agriculture, CSA Adoption, Smallholder Agroforestry Farmers, Smallholder Farmers

I. INTRODUCTION

The global population is expected to hit nine billion by the year 2050. This implies that food demand will rise in the coming years and proper food production strategies need to be put in place to meet this demand. These food production systems and strategies, however, face myriad challenges ranging from land availability, technological incapacities, and negative effects of climate change. The Intergovernmental Panel on Climate Change (IPCC) reports indicate that negative effects of climate change is one of the most pressing global challenges facing agriculture and food production as it is associated with most catastrophic disasters occurring across the globe (IPCC, 2007). The IPCC (2007), further, associates the increase in the severity and frequency of extreme weather occurrences (such as storms, famine, floods, forest fires, rising sea levels, altered rainfall patterns) to climate change. These negative effects of climate change may hinder implementation of food and agricultural production systems, thereby increasing hunger and vulnerability of global population.

Climate change may not affect all global players in the same way as they are differently endowed. Developed economies with established food and agricultural production infrastructure such as irrigation systems and high-tech systems may not be affected in the same way as poor economies. The literature review suggests that a range of climate change scenarios will lead to a rise in the production gap between developed and developing nations, with developed nations will likely see productivity gains while developing nations are expected to experience yield reductions from climate change (Anderson et al., 2020). This will further increase the wealth gap between the rich and poor nations. In regions where productivity is already poor and there are few coping mechanisms, climate change is predicted to make agricultural production more irregular and drop it to far lower levels (IPCC, 2007). Other studies have reported that capacity for investments and remedial action to correct mistakes in developing countries is still low (Mertz et al., 2009). This makes them more vulnerable as they lack adequate resources to plan and adapt to climate change.

Smallholder farmers play a pivotal role in the food and agricultural production of many developing countries. Globally, smallholder farmers produce close to half of world's food (Network, 2018) and over 80 percent of the food produced in Africa (Mpandeli, 2020). In Kenya, available reports indicate that smallholder farmers account for more than 75 percent of total food production in the country (Kirimi et al., 2011). The contribution of smallholder farmers, therefore, cannot be overemphasized. Despite their major contribution to food security, smallholder farmers are the most impacted by the dangers and uncertainty related to climate change as they lack resources and abilities to adapt to climate change. Smallholder farmers must deal with land degradation issues brought on by ineffective soil fertility management and continual cropping. Additionally, recurrent droughts and floods have destroyed smallholders' crops and livestock systems, leading to their household food insecurity.

With the growing global population, more crops and livestock must be produced to meet the increasing demand for food, fiber, and energy. Adaptation to climate change has been widely acknowledged as one of the interventions to sustain food and agricultural production systems amidst a changing climate. Brooks (2003) defines adaptation as the behavioral and characteristic adjustment of a system to enhance the ability of that system to cope with external stress. According to IPCC (2007), climate change adaptation is the modification of natural or human systems in response to actual or anticipated climatic stimuli or their effects, which mitigates harm or takes advantage of beneficial opportunities. Adaptation activities have the potential to greatly reduce vulnerability by strengthening production systems, promote sustainable development, and have a positive impact on our environment provided they are properly implemented and maintained (Smit et al., 2002). Climate change adaptation interventions for smallholder farmers can, therefore, go a long way in meeting global food demands, increasing incomes and improving rural livelihoods.

Many climate change adaptation interventions have been developed geared towards helping smallholder farmers to cope with the changing climate. Agroforestry is one of the interventions, which could increase yields with minimal detrimental effects to the environment and less depletion of natural resource. Branca et al. (2011) defines Agroforestry as "the land use practices in which woody perennials are deliberately integrated with agricultural crops varying from simple and sparse to very complex and dense systems". Scholars consider Agroforestry as one of the best climate smart mitigation choices than other terrestrial options because it provides ecosystem services such as water quality enhancement and prevents land degradation (Yadava, 2010). Additionally, agroforestry is recommended by scholars as it produces a wide range of products, such as grain, fruits, cattle feed, timber, medicines and oils for food (Sharma et al., 2016). Other benefits of agroforestry among practicing farmers include creation of job opportunities, ensuring food security, tourism development and cultural preservations through local activities (Jemal et al., 2018b).

Agroforestry is primarily practised because trees are an essential component of the natural ecosystem, providing numerous benefits to the soil, other plant species, and overall biodiversity. In addition, practising farmers gain greatly from the fruits and medicines they produce, as well as the wood which they use for a variety of uses as well as increasing their resilience to unfavourable weather events like strong storms and droughts (McCabe, 2013). Another fundamental reason for agroforestry is to absorb carbon dioxide gas from the atmosphere, thereby regulating global warming (Montagnini & Nair, 2004). Lastly, according to Jemal et al. (2018a), agroforestry has numerous social benefits, including poverty and hunger eradication, improved living standards for practising farmers through job creation, food security, tourism development, and cultural preservation through local activities.

The United Nations Sustainable Development Goals (SDGS) Number 15 targets to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss" (SDGS, 2022). Agroforestry contributes to this and other SDGs by supporting the combination of crops, livestock, and trees in land management systems. Available reports indicate that conversion of forests to agricultural land is the major reason for loss of biodiversity and agroforestry, therefore, reverses this loss (Network, 2018).

Agroforestry is widespread in Kakamega County though there is scanty information on the actual number of smallholders farmers practicing it. Available reports, however, indicate that Grevillea robusta and Eucalyptus saligna are the two most popular tree species in Kakamega due to their quicker growth rates (Agevi et al., 2019). Other agroforestry trees adopted by smallholder farmers are Calliandra (Calliandra calothyrsus) and Sesbania (Sesbania sesban) which are also used as fodder crops for livestock (Gupta et al., 2023) This improves the farmers' livelihoods by providing them with a greater economic value. Other tree species are, however, adopted by smallholder farmers to meet their other needs. The International Tree Foundation (ITF) reports indicate that the Community Empowerment Initiative Network, has been involved in the planting of over 15,000 Moringa oleifera seedlings among smallholder farm families affected by Human immunodeficiency virus (HIV) and Acquired immunodeficiency syndrome (AIDS)(ITF, 2023).

1.1 Statement of the Problem

While agroforestry is widespread in Kakamega County there is scanty information on the actual number of smallholders farmers practicing it. The forms and types of agroforestry practiced by the smallholder farmers in Kakamega has not been documented. The study's objective, therefore, was to establish and document the adoption of Agroforestry as Climate Smart Agriculture Practice among smallholder farmers in Kakamega County.

II. LITERATURE REVIEW

The Government of Kenya (GOK) estimates that there are 4.5 million smallholder farmers in Kenya who account for more than 75% of the country's agricultural output (GOK, 2018; Kirimi et al., 2011). The contribution of smallholder farmers to Kenya's agricultural development, therefore, cannot be underestimated as they play a significant role in the food security of the country. Available reports indicate that smallholder farmers produce over 80% of the food produced in Africa (Mpandeli, 2020). In addition, they produce for their households thereby reducing the burden on the government to provide food for them. World Bank reports by Luc (2018) indicate that agriculture is two to three times more effective in eradicating poverty than other interventions.

Climate change studies have identified rising temperatures, more variable rainfall, and changes in the onset and offset of rainfall as some of the major challenges facing agriculture today (Harvey & Pilgrim, 2011). In addition, high temperatures and drought conditions have been reported to harm maize and bean production, flowering, and yields in many tropical countries (Eitzinger et al., 2013). In addition, climate change has been documented to have negative effects on tropical agricultural production, as a result of increased insect pests and crop disease incidences. Paudel et al. (2022), associates the invasion of fall armyworms (FAW) in Africa with climate change indicating that Eastern and Central Africa will have the optimal climate for FAW persistence. The foregoing notwithstanding, climate change has impacted negatively on smallholder agriculture through unpredictable weather and intensified drought cycles making farming unpredictable and reducing agricultural productivity (Ahmad et al., 2022). As a result, smallholder farmers must develop coping strategies such as sustainable agriculture, Climate-smart agriculture (CSA), precision agriculture, and other interventions.

Previous studies in indicate that the Kakamega county experiences unpredictable rainfall, with the planting seasons being marked by unusually early showers that are then followed by weeks of dry weather (Ochenje et al., 2016). According to Ochenje et al. (2016), smallholder farmers in Kakamega are becoming increasingly exposed to climate risk as a result of the increased rainfall intensity and delayed rainstorm onset, both of which tend to harm agricultural production. Comparable studies by Liru and Heinecken (2021) suggest that the main climate changes affecting the livelihoods of smallholder farmers in Kakamega County are changes in weather patterns, including temperature variations, variability in precipitation, and prolonged dry periods. The authors assert that these consequences are influenced by extreme climatic occurrences, such as floods, droughts, and the associated natural catastrophes that have an impact on cattle and crops.

Climate Smart Agriculture practices consider both resilience and adaptation to climate change. The Food and Agriculture Organization of the United Nations (FAO) defines CSA as an approach that aims to assist those who manage agricultural systems in responding effectively to climate change (FAO,2020). The triple wins of climate-smart agriculture are the sustainable increase in productivity and income, adaptation to climate change, and reduction in greenhouse gas emissions (FAO,2020). Thus, CSA helps guide actions to transform agrifood systems towards green and climate resilient practices.

The importance of agroforestry in the county cannot be overemphasized as 79.2% of the inhabitants use wood as their main source of energy (Chisika et al., 2022). Published literature, however, indicate that the shortage of wood fuel in the county has resulted to households adopting agroforestry and planting of trees to ease the problem (Sikei et al., 2009). Other arising needs for agroforestry include fodder for livestock, shade, medicinal and ornamental purposes and as a measure to conserve both water and the environment in the farms (Awazi & Tchamba, 2019).

The County Government of Kakamega (CGK) has an estimated 32,713 hectares of gazetted forests which influences biodiversity and farming practices among community members (CGK, 2018). Reviewed literature indicates that the local population perform important religious ceremonies and gather medicinal plants, grass for thatching, and fuel wood from the forest (Ondiba & Matsui, 2021). The restoration and conservation of Kakamega forest, Kenya's only tropical rain forest has attracted many partners thus promoting agroforestry in the county.

The promotion of agroforestry among smallholder farmers is mainly donor supported. Available literature suggests that bilateral and multilateral aids provide backing for African forestry (Blanchez & Dube, 1997). The World Agroforestry Centre (ICRAF) is one of the major supporters of agroforestry in Africa. Its' support is on scientific knowledge, germplasm, networking, capacity building, and operations funds while governments contribute infrastructure, executive power, personnel, and tax rebates. Other important donors in agroforestry include Canadian International Development Agency, IFAD, United Nations Development Program, European Development Fund, World Food Programme (WFP), Global Environmental Fund (GEF), World Bank, and the United Nations Environment Programme (UNEP) (Blanchez & Dube, 1997; Böhringer, 2001). There are many organizations promoting agroforestry at community levels in Kakamega. VI agroforestry, a Swedish NGO, promotes the integration of woody perennials in smallholder farming systems in Kakamega to improve soil fertility, reduce soil erosion and increase water infiltration (Hughes et al., 2020). Other programs that have promoted agroforestry include GIZ ProSoil Program, KCSAP and the Scaling up Sustainable Land Management and Agro-Biodiversity Conservation to Reduce Environmental Degradation in Small Scale Agriculture in Western Kenya project.

III. METHODOLOGY

3.1 The Study Area

This study was undertaken in Kakamega, one of the Forty-Seven Counties in Kenya. Kakamega County was purposely selected for it was one of the 24 implementing counties of Kenya Climate Smart Agriculture Project (KCSAP), which was funded by the World Bank and implemented under the National Climate Change Response Strategy and the Agriculture Sector Development Strategy (2010-2020). Moreover, Kakamega County has been implementing the the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, supported ProSoil project since 2015 and has been working with smallholder farmers to apply climate-smart, agroecological techniques to prevent soil erosion and preserve soil fertility. Lastly, Kakamega County is one of the three counties in Western Kenya that implemented the Scaling up Sustainable Land Management and Agro-Biodiversity Conservation to Reduce Environmental Degradation in Small Scale Agriculture in Western Kenya project.

3.1.1 Location and Size

As depicted in Figure 1, the county lies between longitudes 34 and 35 degrees East and Latitudes 0 and 1 degrees North (MoALF, 2017). The county covers an area of 3051.3 KM2 and borders Trans Nzoia and Bungoma counties to the North, Siaya and Vihiga counties to the South, Nandi and Uasin Gishu counties to the East, and Busia county to the West (CGK, 2018). The county is the fourth most populous in Kenya with a population of 1,867,759 persons comprising 897,133 males and 970,406 females (KNBS, 2019). It comprises of 12 Sub-counties and 60 wards. As shown in Table 1, the sub-counties are grouped to form the three regions of Southern, Central, and Northern. The Southern Region covers Matungu, Mumias West, Mumias East, Butere, and Khwisero sub-counties. While the Central Region covers the sub-counties of Navakholo, Ikolomani, Shinyalu, and Lurambi; the northern Region covers Malava, Lugari, and Likuyani sub-counties. Figure 1 below shows the location of the study area.

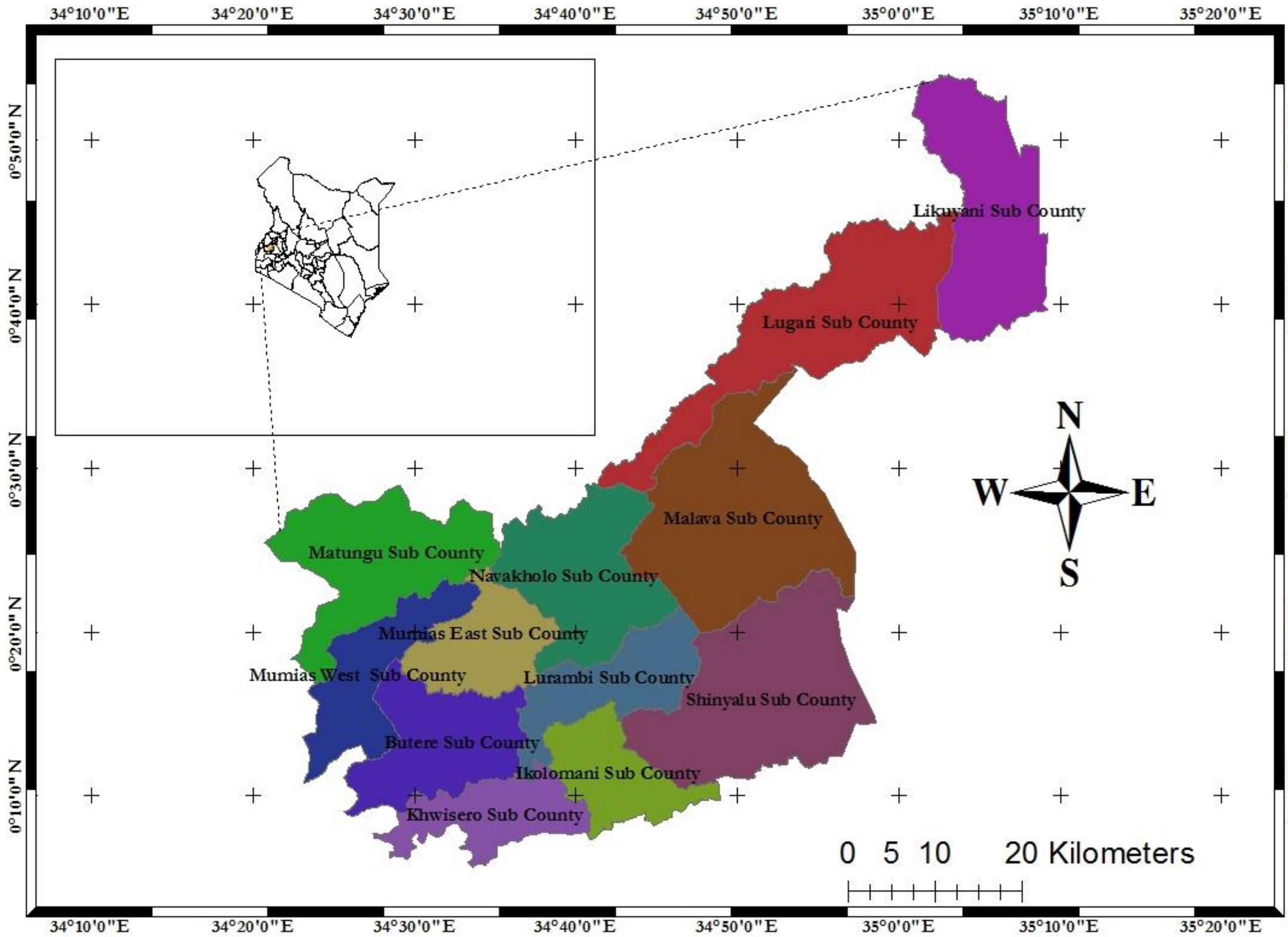

Figure 1
Map of Kakamega County, the study area

Table 1
Kakamega County Wards and Population per sub-counties

Region	**Sub County**	**No. of Wards**	**Population**
Central	Lurambi	6	188,212
	Shinyalu	6	167,641
	Ikolomani	4	111,743
	Navakholo	5	153,977
Southern	Butere	5	154,100
	Matungu	5	166,940
	Mumias East	3	116,851
	Mumias West	4	115,354
	Khwisero	4	113,476
Northern	Malava	7	238,330
	Lugari	6	188,900
	Likuyani	5	152,055
County		**60**	**1,867,579**

3.1.2 Major Livelihood Sources

It is estimated that over 80 per cent of the working population in the county is employed in agriculture, and is mainly in rural areas (CGK, 2018). The main crops grown in the county include sugarcane, tea, coffee, maize, beans, sweet potatoes, bananas, upland rice, cassava, sorghum, finger millet, local vegetables, and other horticultural crops. Reports by the County Government of Kakamega indicate that the county has a total of 255,483.30 hectares under food and cash crop production. Table 3.2 below shows the production of the major crops in the county.

Table 1

Major Crop Production in the County

Crop	Production (Tons)
Dry Maize	168,256.71
Beans	25, 353.45
Tea	2,797
Sweet Potatoes	32,370

Source: CGK (2018)

Apart from crop production, the county also produces various livestock. Reports from the County Government of Kakamega indicate that cattle, poultry, pigs, goats, sheep, rabbits, and bees are the main livestock reared in the County. Table 3 shows the major livestock population in the county.

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Kakamega County Livestock Population

Product	Population (Numbers)
Cattle	377,910
Sheep	88790
Goats	74,405
Pigs	24,604
Chicken	1,033,622

Source: CGK (2018)

3.1.3 Climate Information

The county's climate is classified as tropical and is characterized by heavy, reliable, and well-distributed rainfall throughout the year. The rainfall pattern in the county is bimodal with two peaks. The long rains season peaks during May while the short rains season peaks during September. The annual rainfall in the county ranges from 1280 mm to 2214 mm per year with the average annual rainfall being 1971mm (CGK, 2018, 2023). Other reports by the County Government of Kakamega (2018) indicate that January is the driest month with an average rainfall of 61mm while May is the wettest month with an average precipitation of 273mm. The rainfall distribution, however, is different in various parts of the County. The Southern Region of the County receives more rainfall than the Central and Northern Regions.

The temperatures range from 18 degrees Celsius to 29 degrees Celsius with the annual mean temperatures being 24 degrees Celsius (Climate-Data, 2020). Climate-Data (2020) reports indicate that February is the hottest month in the County with a mean temperature of 22.5 degrees Celsius while July is the coolest month with a mean temperature of 19.7 degrees Celsius. In addition, the county has an average humidity of 67 per cent (Climate-Data, 2020).

Figure 2 depicts the mean annual rainfall in the various parts of the county.

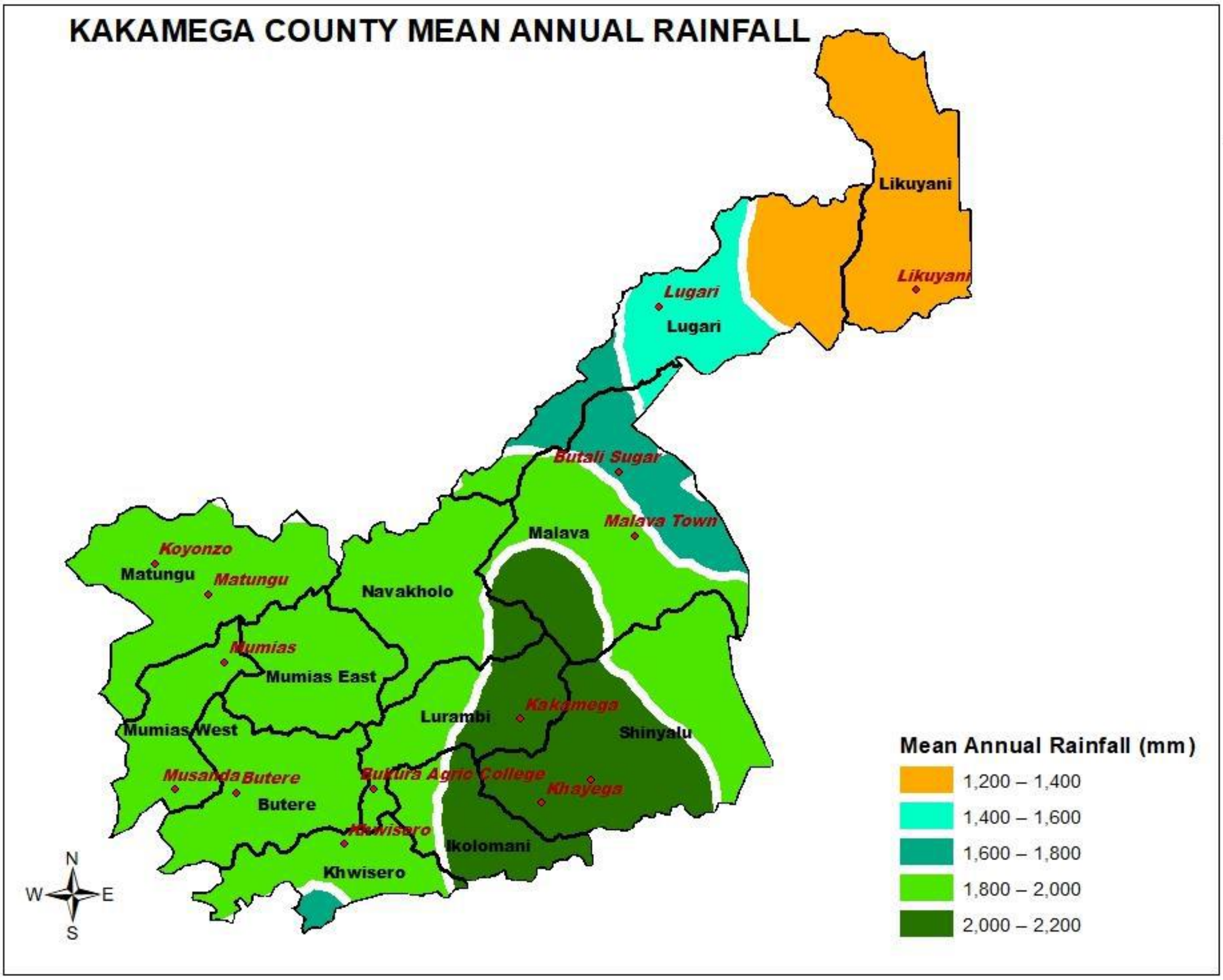

Figure 2
Kakamega County Mean Annual Rainfall (Source: CGK (2018)

3.1.5 Agroecological Zones and Landforms

Ministry of Agriculture, Livestock, Fisheries and Co-operatives (MOALFC) reports indicate that the county has two main agroecological zones namely, the Upper Midland (UM) and the Lower Midland (LM). The UM Zone which covers the Central and Northern regions of the county is suitable for forestry, dairying and the production of maize, beans, tea, coffee, sunflower, bananas, grain amaranth, sugarcane, and Horticulture (MOALFC, 2018). The LM Zone which covers the Southern region of the County is suitable to produce sweet potatoes, cassava, sugarcane, maize, groundnuts, oil palm, dairy, horticulture, and pineapples (MOALFC, 2018).

The county lies between 1,240 metres to 2,000 metres above sea level. The southern part is hilly and made up of rugged granites rising in places to 1,950 metres above sea level. The county has several hills including Eregi, Butieri, Eshikhokhochole, Misango, Imanga, Lirhanda, Kiming'ini and Mawe Tatu hills (CGK, 2023). The county landform is also characterized by the Nandi escarpment to the North. This escarpment, which rises over one kilometre above the general elevation, forms a prominent boundary feature of the county and is the source of several streams that flow into the main rivers (Chepkosgei, 2016).

3.2 Sampling

3.2.1 Target Population

The target population for data collection included smallholder farmers who had received training from various CSA promotion programs. Among the trained smallholder farmers, this study sought to identify both the adopters and the dis-adopters of agroforestry and other CSA technologies. Table 4 indicates the CSA beneficiaries trained by different CSA promoting organizations in Kakamega County by December 2021.

Table 4
CSA Beneficiaries as of December 2021

S/No	Organization	Beneficiaries as of December 2021
1	KCSAP	18,900
2	GIZ ProSoil Project (Welthungerhilfe)	8,263
3	GIZ ProSoil Project (GOPA Consulting Group)	7,500
4	GIZ ProSoil Project (GFA Consulting Group)	3,334
5	MOALFC/Anglican Development Services/Kenya Agricultural and Livestock Research Organization	30,765
	Total (N)	68,762

3.2.2 Sampling Strategy

For the research sample, six sub-counties were chosen using stratified sampling to represent the County's various agroecological zones and regions. By doing this, it was ensured that each sub-county in each region had an equal chance of being selected and that half of the sub-counties in Kakamega would take part in the study. Lurambi and Navakholo were chosen to represent the Central Region, while Matungu and Mumias West were chosen to represent the Southern Region. Malava and Lugari acted as the Northern region's representatives. Finally, the identification of specific farmers and farmer groups using Agroforestry and other CSA technologies was done through purposeful sampling.

3.2.3 Sample Size Calculation

The sample size calculation and the methodology of this study based on Ndung'u et al. (2023) on factors influencing the adoption of Climate smart agriculture practices among smallholder farmers in Kakamega county. Data collection focused on smallholder farmers who have received training from several CSA promotion programs. The major CSA-promoting organizations in Kakamega County had offered support on CSA practices to 68,762 smallholder farmers by December 2021. As a result, 68,762 was the study population.

Yamane's (1967)'s formula was used to calculate the study sample size, lowest number of responses to maintain a 95 per cent confidence level. The formula is given as follows:

$n = N/1 + N(e)^2$

Where:

n is the required minimum sample size from the population under study
N is the whole population that is under study
e is the precision or sampling error (0.05 for this study)

Thus:

$n= 68{,}762/1+68762(0.05)^2$

$n = 397.68$

The minimum sample size calculation gave a sample size of 398 respondents. A cluster sampling technique was used to select six sub-counties to represent the County's various agroecological zones and regions for the research sample. This ensured that each sub-county in each region had an equal chance of being chosen and that half of the Kakamega sub-counties would participate in the study. The stratified Random Sampling technique was used to identify smallholder farmers who were trained on different CSA practices including agroforestry. This data collection process reached 428 respondents.

3.3 Primary Data Collection

Primary data was collected using online-created mobile phone questionnaires. The study made use of the Kobo Collect software. A personal account was created on the publicly accessible instance of Researchers, Aid Workers, and Everyone Else. Using the Toolbox form creator feature of Kobo Collect, an interview guide was created from scratch. The questionnaire was assessed several times using the Kobo Collect App, and feedback was used to improve the questionnaire before collecting field data. Data collection targeted smallholder farmers who were utilizing CSA technologies and those who had given up and abandoned the CSA technologies.

3.4 Data Processing

The collected data were downloaded into MS Excel. Both descriptive and inferential statistics were used to analyze the data. The data was processed and analyzed using SPSS statistical software and Ms. Excel. In order to write a report that included discussions and conclusions, the findings were eventually incorporated into interpretations based on the reviewed literature. Descriptive statistics, such as frequencies, percentages, and means, were used to sum up how the sample's relevant variables were distributed. Tables, charts, diagrams, and discussions were used to present the analysis' findings. The various situations that were observed were given possible explanations using descriptive statistics.

IV. RESULTS & DISCUSSIONS

4.1 CSA Technologies Trained, Adopted, and Abandoned by Smallholder Farmers

This study found that smallholder farmers in Kakamega County were trained in a variety of CSA technologies and implemented what they could. As shown in Table 5 below, out of the 428 smallholder farmers interviewed 376 (87.9%) practiced agroforestry as a CSA. Other CSA technologies practised include composting (82.0%), soil and water conservation (72.2) and conservation agriculture (44.4%). These results indicate that agroforestry was the most adopted CSA practice among the trained CSA farmers in Kakamega county.

Table 5
Adoption of Various Field CSA Technologies by Smallholder CSA Farmers

CSA Practice	**No of Respondents (No)**		**Proportion (%) of practicing respondents to total respondents**
	Trained	*Practicing*	
Composting	413	351	82.0
SWC	398	309	72.2
Agroforestry	398	376	87.9
CA	386	190	44.4

4.2 Energy Sources Adoption as a CSA Practice

Traditional energy sources like wood fuel, charcoal, and kerosene significantly contribute to GHG emissions. As seen on Figure 3, wood fuel was the main source of energy for 73 per cent of the respondents. On the other hand, charcoal, solar energy devices, electricity, and kerosene were the main energy sources for 12 per cent, seven per cent, six per cent, and two per cent of the respondents, respectively. Only a small proportion (0.02 per cent) of the respondents used Liquified Petroleum Gas (LPG) as their main source of energy in their households. These findings show imply low levels of clean energy adoption among the farming communities. These findings are similar to those of Hassan et al. (2013) who found that wood fuel was the most commonly used biomass fuel in Bangladesh. The high number of households using wood fuel as their main source of energy points to a dire need to promote more agroforestry solutions to the farmers.

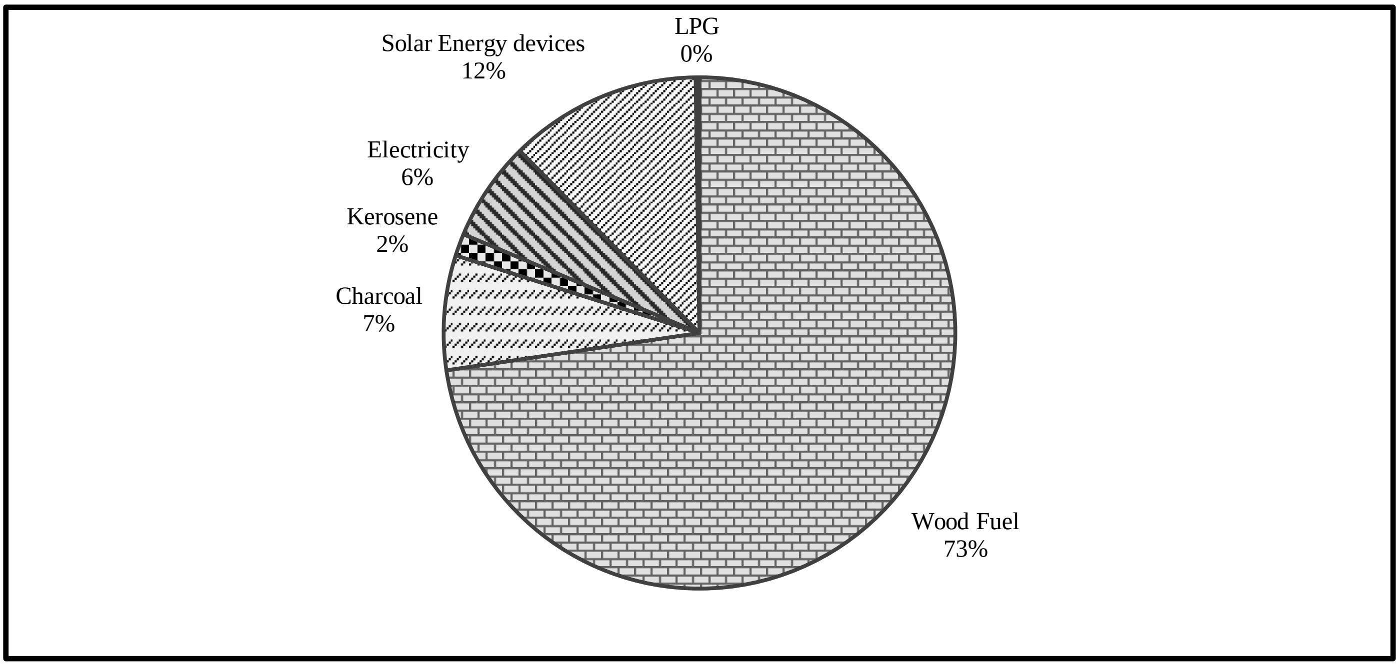

Figure 3
Major Sources of energy for Smallholder CSA Farmers

4.3 CSA Farmers' Adoption of Energy-Saving Devices

Energy-saving devices make a significant contribution to reducing GHG emissions. Solar lighting systems were identified as the most widely used energy-saving devices by 84.1 per cent of the respondents. As shown in Table 6, solar radios had been adopted by less than half (49.1 per cent) of the farmers, while modern wood fuel stoves (maendeleo jikos) had been adopted by slightly more than a third (36.2 per cent) of the respondents. These results are similar to those of Githiomi et al (2012) who found less than 29 per cent adoption of modern stoves in Kiambu, Thika and Maragwa.

Table 6
Smallholder CSA Farmers' Adoption of Energy-Saving Devices

Variable	**Respondents**	
Energy Saving Device	**Frequencies**	**Proportion of Response**
Maendeleo Jikos	155	36.2
Solar Lighting	360	84.1
Fireless Cookers	16	3.7
Energy Saving Bulbs	65	15.2
Solar TVs	137	32.0
Solar Radios	210	49.1

4.4 Forms of Agroforestry as Practiced by Smallholder Farmers in Kakamega County

The study investigated the major forms of agroforestry by the smallholder farmers in Kakamega county. As shown in Table 7 compound trees, fence trees, and fruit trees were the most widely adopted forms of agroforestry, by for 92.0 per cent, 77.4 per cent, and 65.7 per cent of the respondents, respectively. Other forms of agroforestry identified include wood lots (64.1 per cent), intercropping with food crops (45.7 per cent), and farm contour trees (39.9 per cent). These findings are comparable to those of Luvoni (2021) who found woodlots, boundary trees, and scattered trees as the main forms of agroforestry in Kakamega. Other studies conducted in Bangladesh showed that the farmers engaged in border plantations, woodlot agroforestry, tree crop association, and mixed agroforestry with livestock under tree cover all around their homesteads. These results indicate that it was possible for smallholder farmers to have more than one form of agroforestry in their farms.

Table 7
Forms of Agroforestry as practiced by smallholder farmers in Kakamega County

Form of Agroforestry	*Respondents*	*Proportion*
Wood lot	241	64.1
Compound Trees	346	92.0
Fruit Trees	247	65.7
Trees planted along the fence	291	77.4
Trees planted along farm contours	150	39.9
Trees intercropped with food crops	172	45.7

4.5 Land Size under Agroforestry

This study sought to establish the smallholder farmer land size under agroforestry. It was found that agroforestry was practised on small pieces of land, with a substantial number of farmers (85.9 per cent) having less than 0.9 acres of land under the practice, and 10.9 per cent having the practice on land sizes ranging from 1 to 1.9 acres (see Table 8).

Table 8
Land Size under Agroforestry practice

Variable	**Responses**	
Land Size (Acres)	**Respondents (No.)**	**Proportion (%)**
0 - 0.4	156	41.5
0.5 - 0.9	167	44.4
1.0 - 1.9	41	10.9
2.0 - 2.9	9	2.4
≥ 3	3	0.8

4.6 Agroforestry Tree Types.

This study identified the major agroforestry tree varieties that are preferred by smallholder farmers in Kakamega county. As shown in Table 9 below, Grevillea Robusta was the most widely preferred agroforestry tree variety by 91.8 per cent agroforestry smallholder farmers. Other agroforestry trees planted were fruit trees (73.4 per cent), blue gums (67.3 per cent), Cyprus (34.0 per cent) and Calliandra (37.5 per cent). Fodder tree types (Sesbania sesban and Casuarina) were found in less than a third (30.9 per cent and 23.9 respectively) of the sampled farms. These findings are similar to those of Agevi et al. (2019) who found that Grevillea robusta and Eucalyptus saligna are the two most popular tree species in Kakamega due to their quicker growth rates.

Table 9
Major types of Agroforestry Trees

Agroforestry Trees	**Respondents**	**Proportion (%)**
Grevillea Robusta	345	91.8
Blue Gum/Eucalyptus	253	67.3
Cyprus	128	34.0
Casuarina	90	23.9
Sesbania Sesban	116	30.9
Calliandra	141	37.5
Fruit Trees	276	73.4

4.7 Main uses of agroforestry

This study sought to establish the major uses of agroforestry trees by the smallholder farmers. Table 10 summarizes the main uses of agroforestry by smallholder agroforestry farmers in Kakamega. A significant number (87.0 per cent and 84.8 per cent) of the respondents utilized their agroforestry on timber, poles, and posts, and wood fuel, respectively. This could be due to agroforestry farmers' preference for Grevillea Robusta and Eucalyptus tree varieties. Other uses of agroforestry as identified by this study include provision of shade in homesteads (78.2 per cent), fruits (65.2 per cent), fodder for livestock (39.6 per cent), and ornamental uses (25.8 per cent). These findings are similar to those of De Giusti et al. (2019) who found smallholder farmers uses of agroforestry as poles, timber, trunks, fuelwood, charcoal and fruits. These results indicate that agroforestry can be practiced for different uses thus explaining the high level of its adoption.

Table 10

Main uses of Agroforestry

Agroforestry Use	Respondents	Proportion (%)
Wood Fuel	319	84.8
Fodder	149	39.6
Timber, poles, and posts	327	87.0
Ornamental	97	25.8
Shade	294	78.2
Fruits	245	65.2

4.8 Biophysical and Socio-economic factors considered in Agroforestry.

This study investigated the smallholder farmers major motivation for adopting agroforestry in their farms. As shown in Table 11, the need for wood fuel motivated a big number (79.8 per cent) of smallholder farmers to adopt agroforestry. This could be explained by the many farming households whose main source of energy is wood fuel. Other major considerations include topography (55.6 per cent) and climatic conditions (46.5 per cent). Without much thought, 11.7 per cent of farmers adopted agroforestry. These findings contradict those of Buyinza (2020) who found that smallholder farmers' adoption behaviour is mostly influenced by social norms and beliefs that are already present in the community and tend to foster knowledge interchange. Other contradicting studies conducted in Europe indicate that the primary drivers behind the adoption of agroforestry systems by European farmers were their desire to receive direct payments, prevent the funded area from being reduced, preserve family or regional traditions, learn from one another, and diversify their product offerings (Rois-Díaz et al., 2018).

Table 11

Biophysical and Socio-economic factors considered in Agroforestry

Characteristic	*Responses*	*Proportion (%)*
Topography	209	55.6
Soil type	127	33.8
Climatic Conditions	175	46.5
Need for wood fuel	300	79.8
Other (Specify)	1	0.3

4.9 Main crop Grown Under Agroforestry Plots by the Smallholder Farmers

The smallholder farmers that were interviewed are mixed farmers who rear livestock and grow many types of crops. This study investigated the major crops that smallholder farmers grew in the agroforestry plots. These results are presented in Table 12. Close to half (47.3 per cent) of agroforestry farmers grew maize as their main crop under agroforestry. Banana was the next main crop, accounting for 24.2 per cent, followed by fruit trees (14.6 per cent) and sugarcane (8.0 per cent). Similar studies by Nyaga et al. (2015) indicate that maize was the main crop under agroforestry practice by the farmers in the Rift Valley region of Kenya.

Table 12

Main Crops grown under Agroforestry practice by smallholder farmers in Kakamega County

Variable	**Total**	
Crop	Responses	Proportion (%)
Bananas	91	24.2
Cassava	1	0.3
Exotic Vegetables	13	3.5
Fruit Trees	55	14.6
Local Vegetables	3	0.8
Maize	178	47.3
Other (Specify)	1	0.3
Sugarcane	30	8.0
Sweet Potatoes	3	0.8
Tomatoes	1	0.3

4.10 Other Crops Grown by Smallholder Farmers Under Agroforestry Plots

Other crops grown using agroforestry CSA technology were investigated and summarized in Table 13. The other crops grown in agroforestry include beans (41 per cent), fruit trees (39.6 per cent), local vegetables (36.2 per cent), bananas (30.9 per cent), and fodder crops (27.9 per cent), and exotic vegetables (27.9 per cent). These findings indicate that different food crops could be grown in association with agroforestry.

Table 13

Other Crops grown under Agroforestry

Variable	Total	
Other crops grown	***Responses***	***Proportion (%)***
Maize	103	27.4
Beans	154	41.0
Sugarcane	71	18.9
Bananas	116	30.9
Cassava	81	21.5
Soybeans	26	6.9
Ground Nuts	21	5.6
Tea	1	0.3
Tomatoes	2	0.5
Fruit Trees	149	39.6
Finger Millet	1	0.3
Sorghum	1	0.3
Sweet Potatoes	72	19.1
Bambara Nuts	1	0.3
Exotic Vegetables	105	27.9
Local vegetables	136	36.2
Fodder Crops	105	27.9
Other	3	0.8

4.11 Benefits that smallholder farmers derive from agroforestry practice.

Agroforestry has numerous advantages for the farming community. Table 14 summarizes the main benefits as perceived by smallholder agroforestry farmers. A significant number (87.0 per cent) of the respondents cited agroforestry as a source of various products such as wood fuel, timber posts, and poles. Other advantages cited by smallholder agroforestry farmers include providing shade (80.5 per cent), acting as a windbreak (80.3 per cent), and increasing soil fertility (54.0 per cent). Studies conducted in Ethiopia found that farmers engage in agroforestry for such reasons as economic value, ecosystem services, and the survival of visually appealing and economically significant birds (Amare et al., 2019). Studies by Jahan et al. (2022) found that in addition to growing fruit for food and sale, Bangladeshi farmers also engage in agroforestry to sell their wood, to get fuel, and medicinal purposes.

Table 14

Benefits that Smallholder Farmers Derive from Agroforestry Practice

Benefit	Responses	Proportion
Increased soil fertility	203	54.0
Provision of shade	303	80.5
Source of diverse products such as wood fuel, timber, posts, and poles	327	87.0
Serves as a wind break	302	80.3
Other (Specify)	3	0.8

4.12 Challenges facing smallholder farmers in agroforestry practice

Table 15 summarizes the major challenges faced by study respondents in agroforestry practice. The low survival rate of certain tree species, the long time it takes to realize the benefits of agroforestry, and a lack of necessary seeds and seedlings are some of the main challenges faced by agroforestry farmers, as identified by 57.7 per cent, 57.4 per cent, and 50 per cent of respondents, respectively. About a third (33.8 per cent, 32.2 per cent, and 31.9 per cent) of the respondents reported a lack of resources to implement the technology, tree theft, and the shade effect of some agroforestry trees on crops. Other challenges identified include the project's completion (26.3 per cent), lack of support from the technology-promoting NGO (24.5 per cent), and lack of knowledge and information on how to implement (20.5 per cent). Similar studies by Jahan et al. (2022) showed that agroforestry farmers in Bangladesh had to grapple with long waiting times before getting benefits of agroforestry, high investment costs and limited advisory services.

Table 15
Challenges of Agroforestry

Challenge	Responses	Proportion
The lengthy period of waiting before reaping the benefits	217	57.7
Lack of knowledge and information to implement	77	20.5
Lack of resources to implement	127	33.8
Lack of requisite seeds and seedlings	188	50.
Effect of tree shade on crops	120	31.9
Coming to the end of the technology-promoting Project	99	26.3
Lack of support from the technology-promoting NGO	92	24.5
The low survival rate of certain tree species	216	57.4
Theft	121	32.2

4.13 Smallholder Farmers Intention to Increase Land Size Under Agroforestry

Respondents were asked on their intention to increase the land under agroforestry and the feedback captured in Table 16. To have more trees for sale were the reason by slightly more than two-thirds (67.5 per cent) of those who intended to expand their land size through agroforestry. Other major reasons for expanding agroforestry land size included wood fuel (19.3 per cent), increased tree coverage (15.6 per cent), and construction purposes (11.9 per cent). 61.7 per cent of respondents who had no intention of increasing their land size under agroforestry cited limited land size, while 14.8 per cent were content with their current level of adoption. Other factors included a lack of capital (4.9 per cent), as well as the negative effect of shade on crops (6.2 per cent).

Table 16
Reasons for intention to increase or not increase land size under agroforestry

Main Reasons given for their response	No of Respondents	Proportion (%)
For those intending to increase land under agroforestry		
For Sale	199	67.5
For Soil & Environment Conservation	30	10.2
For Construction	35	11.9
To increase tree coverage	46	15.6
Wind Breaker	17	5.8
To have trees as boundary markers	18	6.1
For wood fuel	57	19.3
Other Reasons	24	8.1
For shade around the homestead	11	3.7
For those who did not intend to increase land under agroforestry		
Limited land size to expand	50	61.7
Lack of requisite capital	4	4.9
I have enough	12	14.8
Negative effect of shade on Crops	5	6.2
Other Reasons	12	14.8

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusions

The study's objective was to establish and document the adoption of Agroforestry as Climate Smart Agriculture Practice among smallholder farmers in Kakamega County. In a changing climate environment, this study found that wood fuel was the main source of energy for smallholder agroforestry farmers followed by charcoal, solar energy devices, electricity, and kerosene. It has been established that CSA practices, among them agroforestry has been promoted among smallholder farmers in Kakamega County by the government and different development partners. Results indicate that 87.9 per cent of the trained farmers practiced agroforestry as a CSA practice. Grevillea Robusta was the most widely preferred agroforestry tree variety by agroforestry smallholder farmers followed by fruit trees, blue gums, Cyprus and Calliandra Fodder tree types such as Sesbania and Casuarina were adopted by a smaller number of farmers. It was further established that the main uses of agroforestry were timber, poles and posts, and wood fuel. Other uses of agroforestry as identified by this study include provision of shade in homesteads, fruits, fodder for livestock and for ornamental uses.

5.2 Recommendations

This study recommends integration of agroforestry in farming systems of Kakamega county. This can be done by incentivizing farmers through programs like tree planting, free seedlings and farm competitions around agroforestry. Tree planting initiatives could be started in schools through 4K clubs, young farmers clubs and initiation of environmental clubs. This study also recommends the promotion of modern stoves (*maendeleo jikos*) which use less wood fuel, are more efficient in cooking and also reduce emission of GHGs.

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