Community Engagement in Agroforestry: Enhancing Climate Resilience and Environmental Sustainability, Iringa, Tanzania

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Abstract. Agroforestry has emerged as a vital strategy for environmental conservation and climate resilience, with trees playing a key role in carbon dioxide sequestration. However, community engagement in agroforestry and its impact on climate resilience in Tanzania remains underexplored. This study assessed community awareness and participation in agroforestry, tree species utilization, institutional support, and challenges faced in Kilolo District, Tanzania. Data were collected through semi-structured questionnaires, focus group discussions, and direct observations.

Results revealed significant variability in community engagement in agroforestry activities across the study area (χ^2 = 109.20, df = 2, $p < 0.001$). Non-governmental organizations were reported to be the primary motivators of participation (57.8%). Awareness of agroforestry as a climate resilience tool was significantly high (χ^2 = 33.80, df = 1, $p < 0.001$), varying by education and land ownership but not by age, gender, or occupation. The use of different tree species in agroforestry also differed significantly, with pine being the predominant species at 58%, primarily for commercial purposes. Challenges affecting reforestation efforts varied significantly (χ^2 = 240.836, df = 3, $p < 0.001$), with lack of financial support (94.4%) identified as the most pressing issues.

The findings highlight the importance of fostering collaboration among communities and stakeholders, including government officials, to enhance environmental sustainability and achieve climate resilience through agroforestry.

Keywords: Environmental sustainability, NGOs, Forest restoration, Climate change, Stakeholder collaboration

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1. Introduction

Climate change represents a global challenge, with rising temperatures, erratic precipitation, and extreme weather events threatening ecosystems and human livelihoods worldwide [1]. Agroforestry, the integration of trees with crops and livestock, has emerged as a critical strategy for climate resilience and sustainable land management. These systems demonstrate significant potential for carbon sequestration, with higher carbon storage capacity compared to traditional agricultural practices [2]. Agroforestry enhances soil health through improved fertility, nutrient cycling, and erosion control while supporting biodiversity conservation and ecosystem services [3,4]. The practice offers multiple climate adaptation benefits including enhanced agricultural productivity, improved water retention, and microclimate regulation [4]. Various systems such as agrosilviculture, silvopastoral, and agrosilvopastoral provide socioeconomic benefits and livelihood security for farming communities [3]. However, implementation faces challenges including policy gaps, land tenure insecurity, financial constraints, and limited technical knowledge, requiring interdisciplinary research and capacity-building for widespread adoption [5].

Agroforestry is increasingly recognized in Africa as a vital strategy for climate change adaptation, environmental sustainability, and rural livelihood improvement [6,7]. In Ethiopia, indigenous agroforestry practices help mitigate land degradation, enhance carbon sequestration, and support food security by integrating trees, crops, and livestock, while also providing ecosystem services such as soil and water conservation [7,8]. Despite these benefits, widespread adoption faces significant barriers, including limited financial resources, inadequate extension services, land tenure issues, and insufficient policy support [8,9]. Across Africa, additional constraints such as pests, lack of seeds, and insufficient knowledge further hinder agroforestry uptake [9]. Addressing these challenges through targeted policies, robust training, accessible financing, and context-specific interventions is essential to maximize agroforestry's potential for sustainable agriculture and climate resilience [6].

Research on agroforestry adoption in Tanzania reveals significant socio-economic and environmental benefits alongside persistent adoption challenges [10]. [11] emphasize that agroforestry can improve smallholder income, enhance food security, and provide ecosystem services through improved soil structure and carbon sequestration, though adoption remains limited due to insufficient policy recognition and comprehensive evidence. In Kilombero District, agrosilvopasture and agrosilviculture systems dominated, with home gardens and mixed intercropping reported as prevalent practices [12]. Key adoption factors included residence period, extension services availability, residence type, and gender, highlighting the importance of considering local socio-economic characteristics in system design. Despite positive farmer perceptions, adoption was constrained by local climate, socio-economic status, and institutional factors, demonstrating that favorable attitudes alone cannot ensure widespread implementation.

Kilolo District in Iringa Region exemplifies Tanzania's commitment to agroforestry, with its diverse topography and reliance on agriculture (81% of GDP) creating a conducive environment for tree-based systems [13,14]. The district have embraced agroforestry to address local challenges such as soil degradation and water scarcity, for commercial and environmental purposes [15,16]. However, the extent of community awareness, participation, and the influence of institutional support in these villages remain underexplored. This study aims to assess community engagement in agroforestry in Kilolo District, focusing on awareness levels, participation rates, tree species utilization, institutional roles, and challenges faced. By providing insights into these dynamics, the research seeks to inform strategies for enhancing climate resilience and environmental sustainability in Tanzania's rural landscapes.

2. Materials and methods

2.1 Study Area

The study was conducted in Kilolo District, Iringa Region, Tanzania, located in the southern highlands between latitudes 7°20'–8°00'S and longitudes 35°30'–36°30'E. Covering approximately 7,882 km², the district features a tropical climate with a wet season (November–April) and a dry season (May–October), receiving 800–1,600 mm of annual rainfall and temperatures ranging from 8°C to 27°C, depending on altitude (900–2,700 m above sea level) [14]. The topography includes highlands and lowlands, supporting diverse vegetation, including natural thickets, woodlands, and grasslands, as well as artificial plantations of pine, eucalyptus, and cypress [14]. The district's socio-economic reliance on agriculture (81% of GDP) and forestry activities.

2.2 Sampling and data collection technique

Data were collected using a mixed-methods approach, integrating quantitative and qualitative techniques to assess community awareness, participation, and challenges in afforestation and agroforestry. As recommended by [17] at least 5% of households per village were randomly selected for interviews. Semi structured questionnaires were administered to 180 respondents (60 per village) from Kimala, Magome, and Ndengisivili, ensuring representation across gender, age (18 years and above), education, occupation, and land ownership. The information collected involved awareness of afforestation as a climate resilience tool, participation in afforestation activities, and challenges. The questionnaires included closed-ended questions (Likert-scale rankings) and open-ended questions to capture different perspectives. Questionnaire pre-testing was conducted with 15 respondents in a neighboring village to refine clarity and validity. Three focus group discussions (FGDs) (one per village, with 8 to12 participants each) were conducted with diverse participants (based on gender, age, and occupation) to explore qualitative insights on community motivations, institutional channels support (e.g., NGOs, village leaders), and barriers to afforestation. Field observations were carried out to validate reported afforestation practices, including plantation types (e.g., forest plantations, agroforestry, home grounds), and evidence of institutional support (e.g., nurseries).

2.3 Data Analysis

Quantitative data from questionnaires were analyzed using SPSS (Version 26). Descriptive statistics (frequencies, percentages) summarized demographic characteristics, awareness levels, participation rates, and challenges. Chi-square goodness-of-fit tests were used to evaluate significant differences in awareness, participation, and challenges across villages and demographic groups, with a significance threshold of $p < 0.05$. Ranking data for challenges were analyzed for deviations from uniform distributions using chi-square tests. Qualitative data from FGDs were summarised to identify key themes related to community motivations, institutional roles, and barriers. Observational data were cross-referenced with questionnaire and FGD findings to ensure consistency and reliability of results.

3. Results

3.1 Community Involvement in Agroforestry in Kilolo District

The results revealed a significant difference in community involvement in agroforestry activities ($\chi^2 = 109.20$, df = 2, $p < 0.0001$), with 71% of respondents involved and 29% not involved. Variations were also observed across villages, with Kimala and Magome showing higher participation rates (73.3% each) compared to Ndengisivili (66.7%) (Fig. 1). Feedback from the FGD indicated high level of community involvement in agroforestry practices. *"In our village, we've been planting trees alongside our crops for years now. It's not just about farming; it's a way for the whole community to come together and protect our land from erosion and droughts."* (Male farmer, Kimala village).

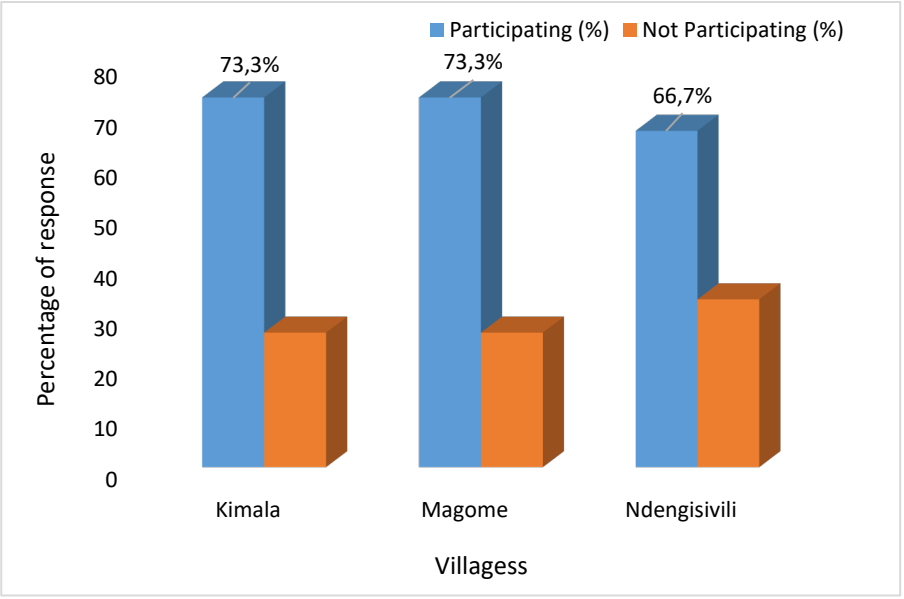

Figure 1: Community Involvement in Agroforestry in Kilolo District

3.2 Respondents' awareness of tree planting and agroforestry as a tool for climate resilience

The results indicated that respondents were significantly aware of tree planting and agroforestry as a tool for climate resilience ($\chi^2 = 33.80$, df = 1, $p < 0.001$), with 71.7% aware and 28.3% not aware. Awareness also varied significantly across study villages ($\chi^2 = 10.80$, df = 2, $p < 0.01$), with Kimala showing the highest level at 80.0%, followed by Magome at 75.0%, and Ndengisivili at the lowest (60.0%) (Fig. 2). The results from the focus group discussion indicated that the majority of the community were aware that agroforestry has a major role of maintaining climate resilience. During the FGD, everyone agreed that planting more trees means better rains and less flooding for our farms. *"We know that trees help stabilize the weather patterns here."* (Female elder, Magome village).

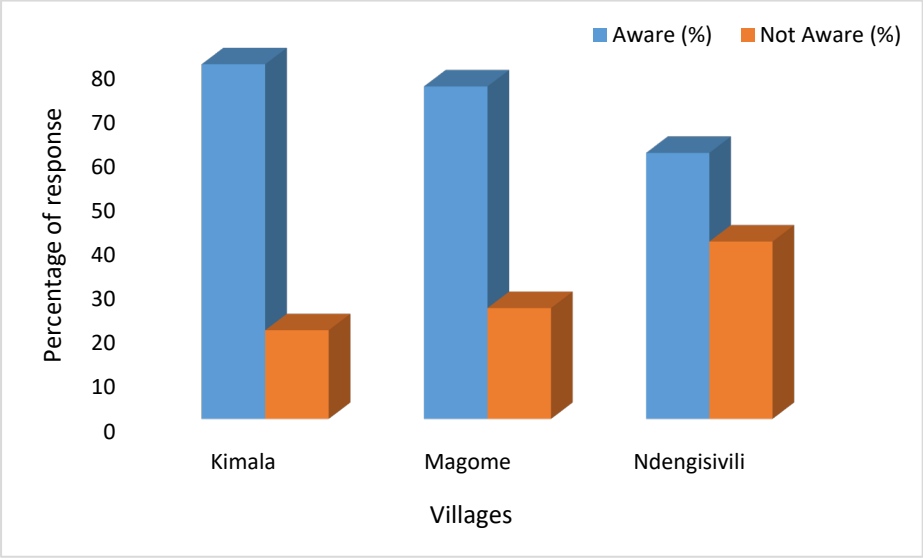

Figure 2: Respondents awareness on tree planting and agroforestry as a tool for climate resilience

3.3 The influence of demographic characteristics on community awareness of tree planting and agroforestry as a climate resilience strategy

Respondents revealed significant variations in awareness of tree planting and agroforestry as a climate resilience strategy across demographic characteristics. Awareness varied significantly by education level ($\chi^2 = 22.283$, df = 3, $p < 0.001$), with respondents holding tertiary education exhibiting the highest awareness (93.3%), followed by those with secondary (88.9%), primary

(60.0%), and informal education (55.6%). Similarly, land ownership significantly influenced awareness ($\chi^2 = 9.930$, df = 1, $p < 0.002$), with 77.8% of landowners aware compared to 53.3% of non-landowners. In contrast, awareness showed no significant differences across age groups ($\chi^2 = 3.118$, df = 2, $p = 0.210$), with 75.0% of those aged 18–30, 76.7% of those aged 31–50, and 63.3% of those aged 51 and older being aware. Gender also showed no significant difference ($\chi^2 = 1.34$, df = 1, $p = 0.247$), with 75.6% of males and 67.8% of females aware. Likewise, occupational differences were not significant ($\chi^2 = 1.970$, df = 1, $p = 0.161$), with 75.0% of agricultural workers and 65.0% of employed respondents aware (Table 1). FGD participants agreed on the potential role of education and land ownership in boosting agroforestry practices across study area. For instance, one educated landowner from Ndengisivili village stated that *"Those of us who went to school understand how agroforestry fights climate change, like reducing heat and improving soil. But without land, it's hard to put that knowledge into practice.*"

Table 1: The Influence of Demographic Characteristics on Community Awareness of Tree Planting and Agroforestry as a Climate Resilience Strategy

Demographic Feature	Aware (%)	Not Aware (%)	Chi-Square (χ^2)	df	p-value
Education					
Informal	55.6 (25/45)	44.4 (20/45)	22.283	3	< 0.001*
Primary	60.0 (36/60)	40.0 (24/60)			
Secondary	88.9 (40/45)	11.1 (5/45)			
Tertiary	93.3 (28/30)	6.7 (2/30)			
Age					
18–30	75.0 (45/60)	25.0 (15/60)	3.118	2	0.21
31–50	76.7 (46/60)	23.3 (14/60)			
51+	63.3 (38/60)	36.7 (22/60)			
Gender					
Male	75.6 (68/90)	24.4 (22/90)	1.34	1	0.247

Female	67.8 (61/90)	32.2 (29/90)			
Occupation					
Agriculture	75.0 (90/120)	25.0 (30/120)	1.97	1	0.161
Employed	65.0 (39/60)	35.0 (21/60)			
Land Ownership					
Landowners	77.8 (105/135)	22.2 (30/135)	9.93	1	< 0.002*
Non-landowners	53.3 (24/45)	46.7 (21/45)			

3.4 Channels motivating communities to participate in agroforestry

The involvement of four channels (Village Meetings, Mass Media, Government Officials, and NGOs) in motivating community participation in agroforestry activities varied significantly (χ^2= 186.142, df = 3, p < .001, N=180). NGOs were the most prominent channel in creating awareness, with 57.8% of respondents followed by village meetings at 33.3%. In contrast, Mass Media and government officials had minimal involvement, with 2.2% and 1.1%, respectively (Fig. 3). One participant from the FGD pointed out that *"The NGO in our village shows us how to integrate trees with our maize fields. Without their workshops, we wouldn't have started agroforestry on such a scale."* (Village leader, Kimala village).

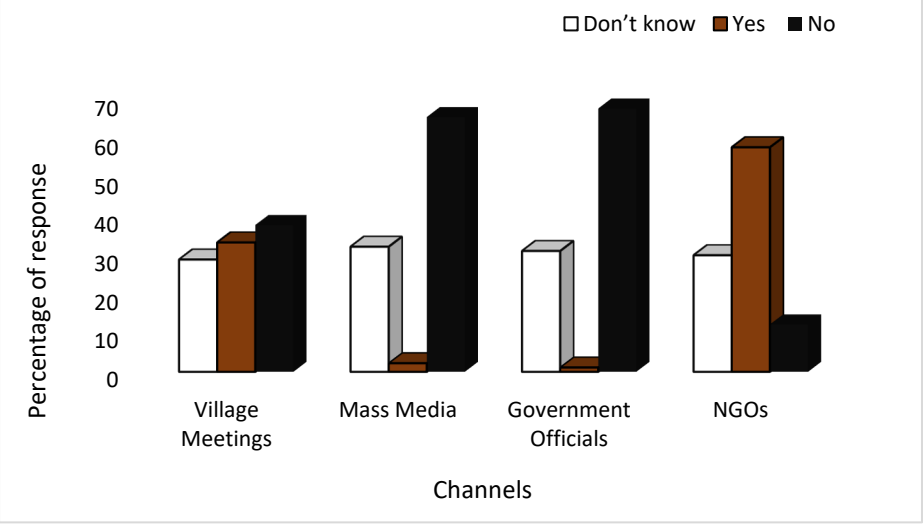

Figure 3 Channels motivating communities to participate in agroforestry

3.5 Major challenges facing communities in involvement in agroforestry activities

Respondents ranks revealed significant differences in the distributions of the four major challenges facing communities in involvement in agroforestry activities ($\chi^2 = 240.836$, df = 3, $p < .001$, N = 178). In terms of prevalence, the most commonly reported challenge was lack of financial support (94.4%), followed by no land for agroforestry (74.2%), lack of awareness (37.1%), and lack of interest (15.7%) (Fig. 4). To illustrate the prevalent challenges like lack of financial support and land availability, during FGD one young farmer, from Magome village insisted that*: "The biggest problem is money, we need funds for seedlings and other tools. And with no extra land, how can we expand? That's why many hesitate to get involved."*

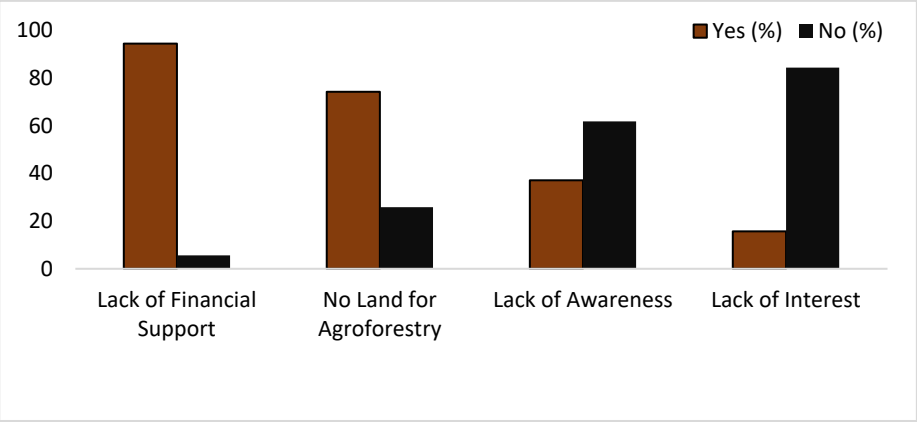

Figure 4. Major challenges facing communities in involvement in agroforestry activities

4. Discussion

4.1 Overview of Community Engagement in Agroforestry

The findings indicate robust community engagement in agroforestry within Kilolo District, with notable variations in participation and awareness across villages. The high level of involvement, particularly in Kimala and Magome, reflects the success of localized efforts in promoting agroforestry as a strategy for environmental sustainability and climate resilience. These results align with previous studies in Tanzania, which emphasize that community-driven forestry initiatives thrive when supported by strong local leadership and external organizations [18]. However, the lower engagement in Ndengisivili suggests disparities in resource access and outreach, highlighting the need for inclusive strategies to ensure equitable participation across all

communities. The integration of agroforestry into local agricultural systems demonstrates its potential to address both socio-economic and environmental challenges, as supported by [2].

4.2 Respondents' Awareness of Tree Planting and Agroforestry as a Tool for Climate Resilience

The high level of awareness of agroforestry as a climate resilience strategy, particularly in Kimala and Magome, reflects the effectiveness of educational outreach by NGOs and village leaders. This aligns with [19], who found that awareness campaigns significantly enhance community understanding of forestry's role in mitigating climate change. However, the lower awareness in Ndengisivili indicates uneven dissemination of knowledge, possibly due to limited access to educational programs or weaker institutional presence. This gap underscores the need for culturally tailored outreach to ensure all communities recognize agroforestry's benefits, as emphasized by [10]. Addressing misconceptions and highlighting tangible benefits, such as income generation and environmental stability, could further boost awareness across the district.

4.3 The Influence of Demographic Characteristics on Community Awareness

Awareness of agroforestry as a climate resilience strategy was significantly influenced by education and land ownership, but not by age, gender, or occupation. Higher awareness among respondents with tertiary and secondary education aligns with [8,19], who noted that education enhances understanding of environmental practices. Similarly, landowners' greater awareness reflects their direct stake in land-based activities, as supported by [2,3]. The lack of variation across age, gender, and occupation suggests that awareness is broadly accessible but constrained by structural factors like education access and land tenure. Contrary to these findings, the study in Uganda, reported young generation to involve more in agroforestry practices compared to older ones [19]. These findings highlight the need for inclusive policies to address barriers faced by less-educated individuals and non-landowners, ensuring equitable knowledge dissemination.

4.4 Channels Motivating Communities to Participate in Agroforestry

The dominant role of NGOs in motivating agroforestry participation, followed by village meetings, highlights the effectiveness of community-based and external support systems. From FGD a female farmer, Kimala village explained that: *"The New Forest Organization brought trainers to our village meetings, teaching us how to plant trees that improve our soil and crops. They even gave us seedlings to start. But we rarely hear from government officials, and the radio doesn't talk much about agroforestry, so many of us rely on these meetings to learn and act."* NGOs' provision of technical expertise and resources, as seen with the New Forest Organization, aligns with [11,20], who emphasized NGOs' critical role in forestry initiatives. The limited involvement of government officials and mass media suggests a gap in top-down and broad-reach communication strategies. Strengthening government support and leveraging media campaigns could amplify agroforestry adoption, ensuring broader community engagement and long-term sustainability.

4.5 Major Challenges Facing Communities in Agroforestry Activities

The primary challenges reported included; lack of financial support, land scarcity, limited awareness, and lack of interest highlight systemic barriers to agroforestry adoption. Other studies reported financial constraints to limit access to inputs like seedlings and tools, particularly for resource-poor households [8,9,21]. Land scarcity, driven by competing agricultural demands, also found to limit fully engagement to agroforestry practices. During the focus group discussion, one respondent explained that; *"I know agroforestry supports climate resilience, and I would love to participate. However, with my small plot of land, I must prioritize intensive mixed annual cropping to feed my family".* Low interest, is also linked to the long maturation period of trees, could be addressed by promoting fast-yielding species or non-timber products like fruits and medicinal plants, and integrating with other agricultural crops [5].

5. Conclusion and Recommendation

This study underscores the crucial role of community engagement in agroforestry as a multidimensional strategy for boosting climate resilience and environmental sustainability in Kilolo District, Tanzania. High awareness and participation levels, driven primarily by NGOs and influenced by education and land ownership. However, persistent challenges such as financial constraints, land scarcity, and uneven awareness highlight the need for integrated interventions to ensure equitable and scalable implementation. To maximize agroforestry's potential in mitigating climate change impacts, we recommend: strengthening multi-stakeholder collaborations between governments, NGOs, and local communities. This can be achieved through targeted policy reforms that provide accessible funding mechanisms, promote diversified native tree species to enhance ecological resilience, and expand tailored educational programs to bridge demographic gaps. Ultimately fostering sustainable land management practices that align with global goals like the UN Sustainable Development Goals and IPCC recommendations for carbon sequestration in vulnerable African landscapes.

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