International Journal for Multidisciplinary Research (IJFMR)
E-ISSN: 2582-2160 ● Website: www.ijfmr.com ● Email: editor@ijfmr.com

Permaculture and Agroforestry as Sustainable Food Production and Climate Change Adaptation Approaches: A Case of Uwepo Farm, Jinja Uganda

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Abstract

Sustainable agriculture remains essential to addressing escalating food insecurity and climate risks in Sub-Saharan Africa. This study investigated the contribution of permaculture and agroforestry systems to food production and climate change adaptation using Uwepo Farm and its surrounding communities in Jinja, Uganda. A mixed-methods approach, including household surveys, key informant interviews, participatory observation, and focus group discussions, was conducted on a sample size of 40 smallholder farmers practicing permaculture and agroforestry at Uwepo main farm and within surrounding communities (n = 40). The results suggest that permaculture and agroforestry significantly enhance resilience to climate impacts, boost food security, and improve livelihoods. It was also evident that there is increased crop diversity, improved soil nutrient status, reduced vulnerability to drought, and enhanced livelihood resilience among smallholder farmers in communities around the Uwepo training hub engaged in permaculture and agroforestry, as well as at the Uwepo model farm, compared to the past 10 years. Statistical analysis revealed that 62.5% of farmers reported improved food availability, and 37.1% earned their primary income from permaculture and agroforestry products. Integration of trees, composting, water flow management, and Aquaponic systems significantly contributed to soil conservation and diversified yields. Despite notable adoption barriers, including limited irrigation access and insufficient financial support to farmers, the study concludes that permaculture and agroforestry offer scalable and climate-smart pathways for Uganda's agriculture. Strengthened extension services, youth engagement, and policy incentives are recommended to accelerate adoption.

Keywords: Agroforestry, Food Security, Permaculture, Sustainable Agriculture

1.0 Introduction

Agriculture sustains the livelihoods of over 70% of Sub-Saharan Africa's (SSA) population, yet its productivity is severely threatened by climate variability (IPCC, 2022; Serdeczny et al., 2017). Uganda's

agriculture remains predominantly rain-fed, exposing rural communities to heightened risks of drought, flooding, and declining soil fertility (NEMA, 2023). These climate-induced shocks exacerbate food insecurity, with an estimated 21.6 million Ugandans facing moderate to severe hunger in 2023 (FAO & WFP, 2024). Sub-Saharan Africa (SSA), with over 95% of its agricultural land being rain-fed, is highly vulnerable to climate change, which threatens agricultural productivity and food security. Climate change in this region is characterized by increased temperatures, aridity, and erratic rainfall patterns, exacerbating food insecurity and necessitating the adoption of sustainable agricultural practices like permaculture and agroforestry.

Conventional farming systems, often reliant on synthetic inputs and monoculture, have contributed to soil degradation, biodiversity loss, and greenhouse gas emissions (Ellison et al., 2017). Conversely, permaculture and agroforestry provide ecologically aligned frameworks that mimic natural ecosystem processes through integration of trees, crops, livestock, and soil biota to enhance resilience, biodiversity, and farm productivity (Leakey, 2023; Gliessman, 2022).

Recent studies reveal that agroforestry improves soil structure, carbon sequestration, microclimate regulation, and water retention, while expanding income streams from fruit trees, timber, fodder, and fuelwood (Li et al., 2021; ICRAF, 2024). Permaculture complements these benefits by promoting circular resource use, composting, mulching, rainwater harvesting, and diversified cropping (Holmgren, 2020). In Uganda, adoption of integrated systems is increasing, driven by community-based capacity building and environmental conservation efforts (Njeru & Kilawe, 2023). However, uptake remains limited due to constraints such as weak extension services, land tenure insecurity, and inadequate investment in smallholder training (MAAIF, 2022).

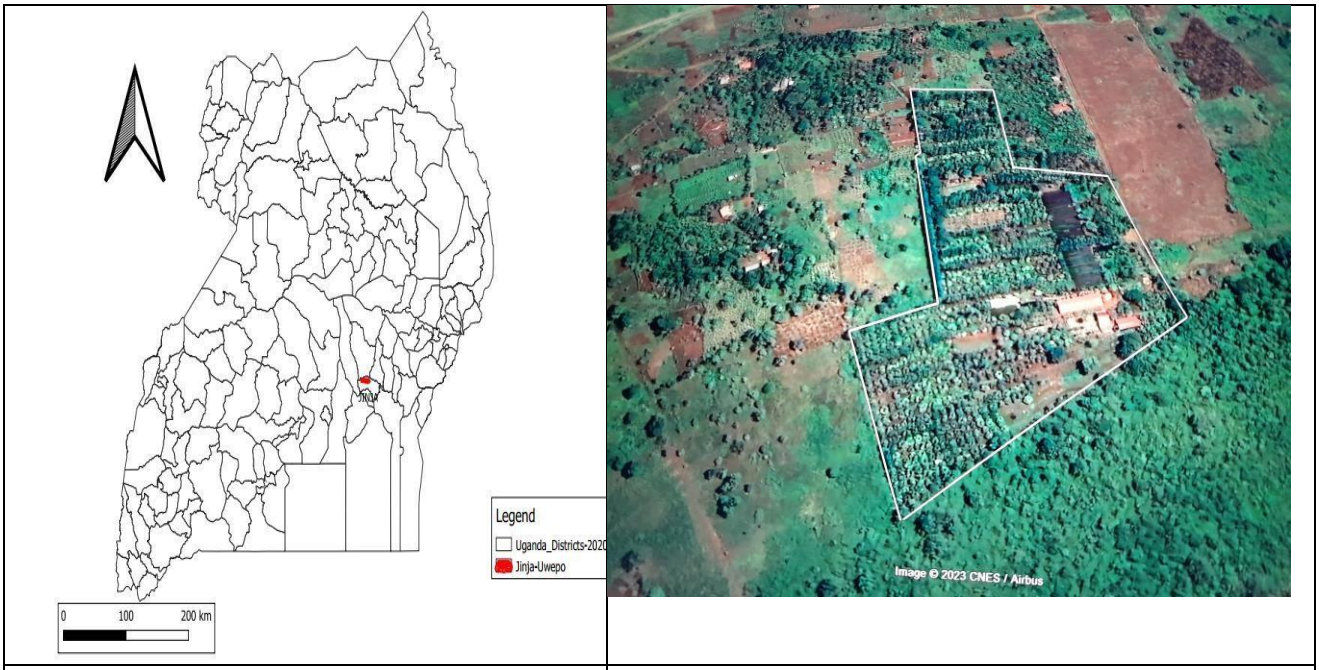
Therefore, this study evaluated how permaculture and agroforestry practices at Uwepo Farms enhance food production and climate resilience by impacting and training smallholder farmers. This research contributes to policy development, sustainable agricultural practices, community impact, and academic advancement by evaluating permaculture and agroforestry at UWEPO Farms. The study aims to provide practical knowledge for policymakers and development agencies and to promote sustainable practices among smallholder farmers in Uganda. This research provides evidence of Uganda's commitments under SDGs 1, 2, 13, and 15, and to national climate-smart agriculture programmes that promote resilient farming systems.

2.0 Materials and Methods

2.1 Study Area

The research was conducted at UWEPO Farms located in Nyenga Division, Njeru Municipality (Jinja and Buikwe Districts), and Eastern Uganda. The region lies within a tropical savannah climate, receiving mean annual rainfall ranging from 1,200–1,500 mm and temperatures between 20°C and 32°C. Farming in the area is predominantly subsistence-based and dependent on rain-fed systems.

The farm practices permaculture and agroforestry, which are climate change smart-agriculture adaptation approaches, host interns and run training programs annually for small-scale community farmers. UWEPO Farms operates as a social enterprise promoting agroecology, seedling distribution, farmer training, and youth agricultural innovation.



Location of UWEPO in Jinja Uganda (a)	UWEPO Farm satellite aerial view (b)

Fig. 1: Uwepo farm location (Dataset UG admin_2021 & Google earth pro, 2025)

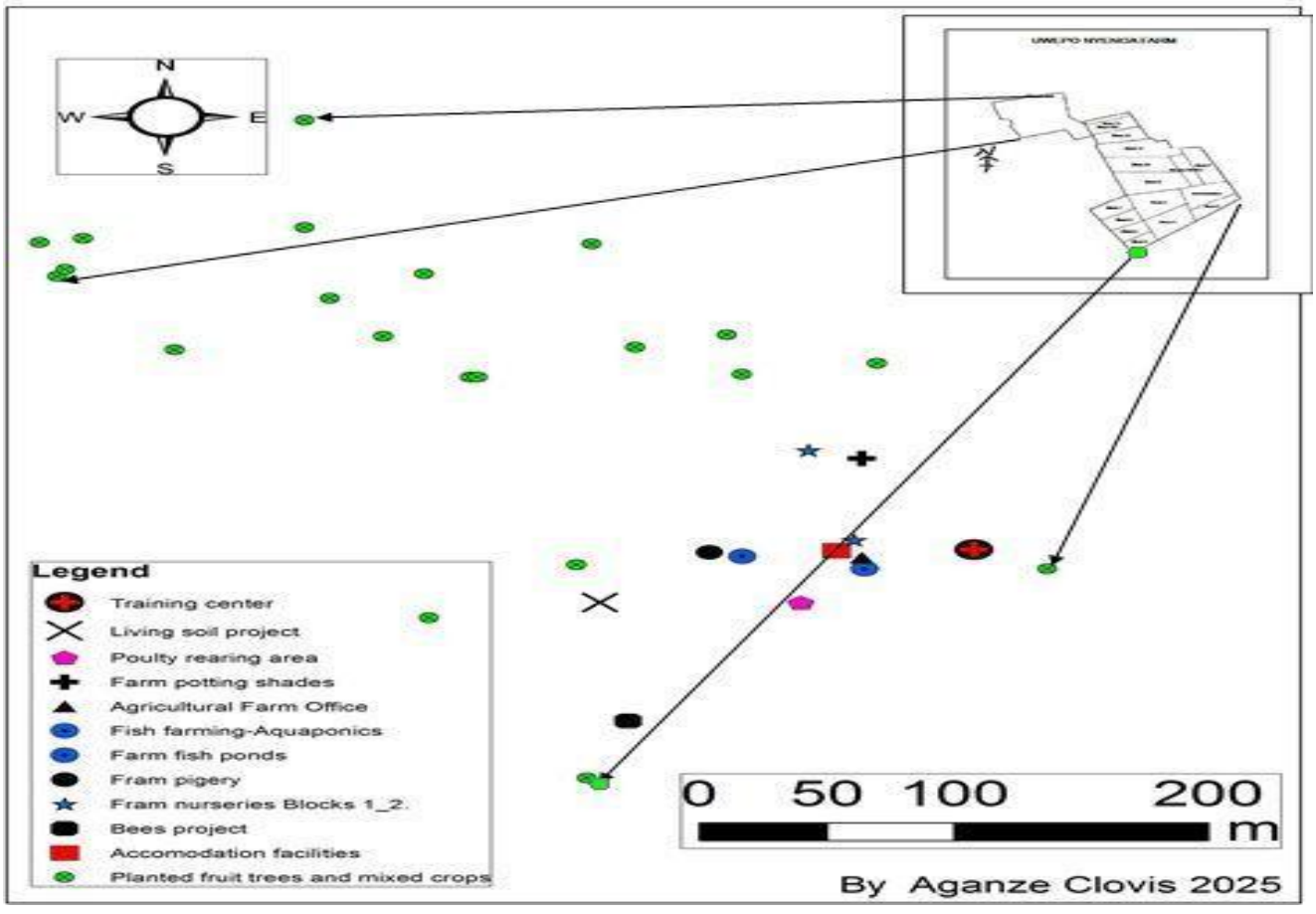


Fig. 2: Projects at UWEPO Farm in Jinja, (source: GPS waypoints drawn in ArcGIS Map 10.5)

2.2 Research Design

A mixed-methods design combining cross-sectional and longitudinal approaches was used to assess the adoption of permaculture and agroforestry strategies, their socio-economic impacts, and adaptive capacity outcomes. Feasibility appraisals, field observations, community engagements, and iterative feedback strengthened validation of findings.

2.3 Sampling Procedure and Sample Size

A total of 40 respondents were selected through purposive and simple random sampling among farmers trained by UWEPO. Sample size was determined using Yamane's (1992) formula/ equation (1) below with 95% confidence level and 5% precision. The formula ensured an appropriate representation of the population for reliable data collection and analysis.

$$n = \frac{N}{1 + N(e)^2}$$

Where

n= required sample size, N = Target Population in the study area, e = Confidence Interval of 95%, (0.05), 1 = Constant.

(1)

2.4 Data Collection Tools

Primary data were collected using semi-structured questionnaires and focus group discussions (FGDs). The questionnaires were designed to elicit detailed responses from participants about the impacts of climate change and adaptation strategies. Face-to-face interviews were conducted, especially during FGDs, allowing respondents to provide firsthand information. Local languages (Lusoga and Luganda) were used where needed to ensure clarity and inclusiveness. The rest of the interviews were done in English. Secondary data were sourced from FAO, IPCC, ICRAF, and Ugandan energy and agricultural extension documentation.

2.5 Data Analysis

Quantitative data were coded and analyzed in SPSS IBM v21 using descriptive statistics (means, frequencies, percentages). Qualitative data were synthesized thematically. Data triangulation enhanced credibility.

3.0 Results

3.1 Demographic Characteristics

Ages 26–50 years constituted the largest age group (57.5%), representing the most economically active group. Secondary-level education dominated (52.1%), indicating literacy supportive of innovation adoption (Table 1).

Table 1. Demographic Characteristics of Respondents (n = 40)

Variable	Category	Frequency (n=40)	Percentage (%)
Age	15–25	2	5.0
	26–50	23	57.5
	≥50	15	37.5
Education	No formal education	3	7.5
	Primary	12	30.0
	Secondary	21	52.5
	Tertiary	4	10.0
Income Source	Agroforestry products	15	37.5
	Regular employment	12	30.0
	Permaculture	10	25.0
	Business	3	7.5

Source: Primary field data

3.2 Household Food, Income Improvements and soil ecosystem health

An estimated 62.5% of households reported increased food availability due to crop diversification (vegetables, fruits, herbs). Permaculture systems produced multiple yields (food, mulch, fuelwood, fodder) from single plots. Plates 1-4 below demonstrate different projects that are undertaken at Uwepo to enhance sustainable food production and improve livelihood incomes for the small-scale farmers.

Plate 1. Community engagement in vegetable production (onion plots)

Director Uwepo Mr. Nick (centre) discussing soil management with trainee Clovis and Staff (a)

Soil organic compositing pool (b)

Plate 2. Composting and organic matter recycling processes

Plate 3. Farmer trainees managing foliage-based agroforestry plots

Table 2: Main sources of household income

Occupation/income	Frequency	Percentage
Business	3	7.9
Permaculture	10	25
Regular employment	12	30
Agroforestry	15	37.1
Total	40	100.0

Source: Primary field data

Plate 4: Api-culture system at uwepo

Admin Offices at Uwepo (a)

Crop diversifications for climate resilience (b)

Plate 5 (a & b): Multiple income and crop diversification climate resilient permaculture projects

Fish farming ponds (a)

Fish tank (b)

Plate 6: Aquaponics (fish farming) at Uwepo farms

Potting of seeds into plastic containers (a)

Trees and crop nurseries at Uwepo farm (b)

Plate 7 (a & b): Preparation and rising nursery beds

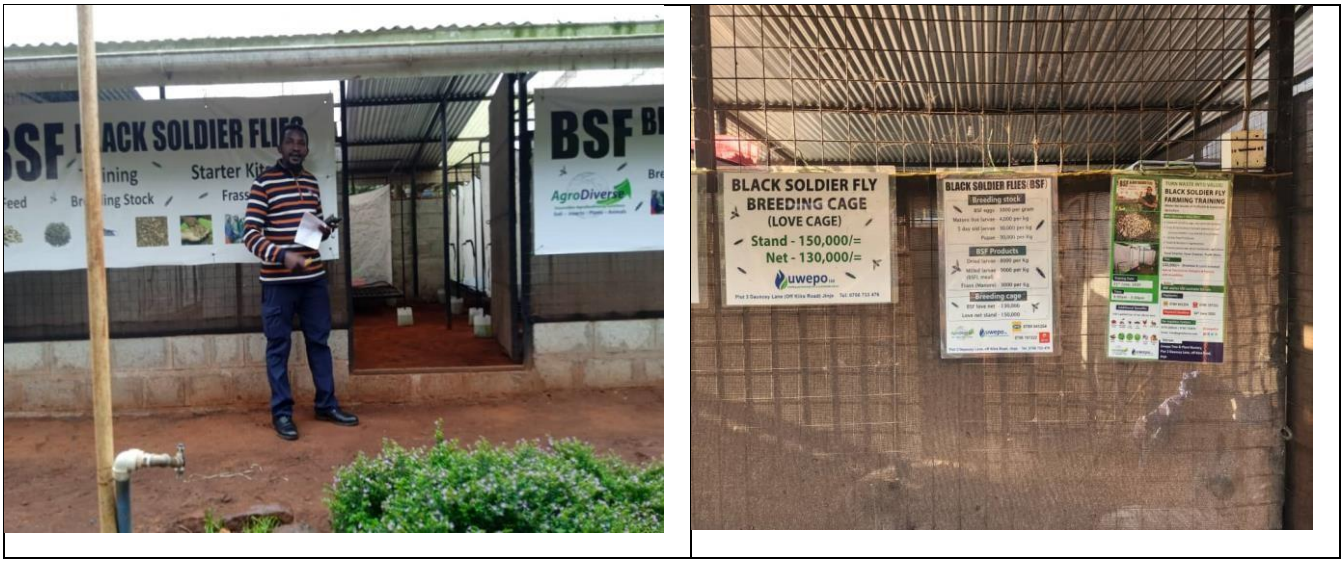


Plate 8: Production and training in FSB Black soldier Flies

Plate 9: Poultry farming project

3.3 Climate Adaptation Measures

Table 3: Preferred Adaptation Responses under ideal conditions

Adaptation Option	Current (%)	Desired (%)
Improved access to irrigation	5.6	28.1
Planting fast-maturing crops	2.1	27.0
Increased tree planting	7.0	11.7

Source: Primary field data


Plate 10: Agroforestry for improvement of Microclimate and adaptation inset is Researcher Clovis

Technician in carbon measurements Joshua (a)

Director Uwepo Mr. Nick & Researcher Clovis at tree plantation area (b)

Plate 11: Silviculture in agroforestry for climate adaptation and resilience

4.0 Discussions

The results in Table 1 demonstrate that permaculture and agroforestry practices at UWEPO Farms provide substantial livelihood and ecological benefits to smallholder farmers in Jinja. Engagement was strongest among individuals aged 26–50, consistent with findings that innovation adoption is driven by economically active groups with greater risk-taking capacity (Asfaw et al., 2017). Moderate literacy rates further supported knowledge acquisition and adoption processes.

The demographic patterns reveal that the 26–50 year age group represents the bulk of practitioners (57.5%) and stands as the most economically productive segment in the farming chain (Table 1). Their dominance confirms that adoption of innovative practices such as agroforestry and permaculture is driven by individuals with the strength, time horizon, and motivation required to trial new technologies. The 37.5% participation of individuals aged 50 years and above reinforces how long-term farming experience anchors soil stewardship practices and ecological understanding. In contrast, the minimal 5% representation of youth aged 15–25 signifies a worrying demographic shift toward declining youth engagement in agriculture — an urgent sustainability concern.

Education levels equally show a system primed for innovation uptake, with 52.5% having reached secondary education and 30% primary (Table 1). This literacy distribution correlates with the adoption of more knowledge-driven practices like soil improvement, tree-crop integration, and sustainable water management. The presence of only 10% tertiary-trained practitioners suggests that practical sustainability is locally embedded rather than academically driven. However, this implies a missed opportunity for scientific extension to strengthen outcomes further.

The family income, as indicated by the number of household heads who are employed for salary, those who practice agro crops, agroforestry tree products, and those who do business (Table 2). The results in Table 4 show that the farmers who depend on agroforestry tree products are the majority, 37.1%, followed by those who depend on agro crops, whereas there is no respondent who depends on regular employment or business for livelihood. Therefore, this shows that the farmers are really interested in Agroforestry tree products and permaculture, other than any other source of income.

Economically, agroforestry is the leading livelihood option, supporting 37.1% of respondents (Table 2), followed by permaculture at 25%, proving strong confidence in tree-based, diversified land-use systems as viable income generators. Regular employment (30%) and business (7.9%) play limited roles, demonstrating that natural-capital-based livelihoods dominate household economic security at UWEPO farms.

Agroforestry's ecological contributions, including enhanced soil health, microclimate regulation, and carbon sequestration, have been reported across similar tropical smallholder systems (ICRAF, 2024; Li et al., 2021). Compost use at UWEPO enabled nutrient recycling, minimizing greenhouse gas emissions associated with synthetic fertilizer use (IPCC, 2022).

Crop diversification enhanced dietary quality and food availability, with 62.5% of households acknowledging improved household nutrition. These outcomes align with earlier studies confirming that integrated agroecosystems contribute to food security through increased productivity, stabilized yields, and reduced expenditure on external inputs (Leakey, 2023; Njeru & Kilawe, 2023).

The Plate series (1–11 above) provides visual and practical validation of how diversified, regenerative systems directly translate into food availability, income improvements, and ecosystem regeneration:

Table 4: Various permaculture and agroforestry activities

Evidence Source	Demonstrated Contributions
Plate 1	Household vegetable consumption and micronutrient supply
Plate 2	Soil carbon recovery, nutrient cycling, fertilizer substitution
Plate 3	Tree-crop synergy improving biomass and soil protection
Plate 4	Honey and pollination services contributing to food chains
Plate 5 a-b	Fisheries and aquaponics → dietary protein + household revenue
Plate 6 a-b	Seedling propagation ensuring system expansion and scalability
Plate 7 (a & b):	Preparation and rising nursery beds
Plate 8	Black Soldier Fly biowaste conversion → low-cost animal feed
Plate 9	Poultry manure input completing circular nutrient flows
Plate 10 & 11	Climate-buffering canopy + carbon sequestration stewardship

Together, these plates form a closed-loop ecological economy, where nothing leaves the system without value addition, and every biological process plays multiple roles the pure definition of permaculture efficiency (as demonstrated in Table 4 above).

In the climate adaptation dimension, Table 3 shows that farmers' preferred adaptation strategies are highly rational under climate stress:

- 28.1% would adopt irrigation if access was available (current: 5.6%) → Demand for water security is urgent.
- 27% would prioritize fast-maturing crops (current: 2.1%) → Farmers already experience unreliable rainfall.
- 11.7% would escalate tree planting (current: 7%) → Trees are proven buffers against climatic extremes.

Plates 10 and 11 empirically document tree-based microclimate modification and carbon monitoring, confirming that agroforestry activities already deliver measurable climate mitigation outcomes.

Altogether, UWEPO Farms represents an active climate-smart laboratory, where diversified production reduces vulnerability, increases food system stability, and enhances economic sovereignty for resource-poor households

Major climate adaptation measures identified tree planting, irrigation, and drought-tolerant crop selection reflect wider adaptation patterns in SSA (Rahaman et al., 2020; Rose et al., 2024). However, gaps remain in access to irrigation infrastructure, climate advisory services, and financial capital, limiting optimal adoption. These barriers are consistent with national challenges affecting transformative adaptation (FAO & WFP, 2024; MAAIF, 2022).

Scaling integrated farming therefore requires strengthening agricultural extension systems, youth engagement initiatives, and supportive financing models that value the ecosystem services of multifunctional farms.

5.0 Conclusion

The findings decisively confirm that permaculture and agroforestry are not theoretical alternatives but operational realities driving:

- Food security via reliable yield diversity (vegetables, fruits, livestock products, fish)
- Income elevation through tree-based and circular-economy enterprises
- Environmental rehabilitation through composting, soil life restoration, and canopy improvement
- Climate change resilience by buffering weather extremes and ensuring continuity of livelihoods

UWEPO Farms in Jinja stands as a working model capable of supporting Uganda's national climate-smart agriculture agenda and the global sustainability framework (SDGs 1, 2, 12, 13, 15). Thus, scaling these methods across Uganda is not optional it is a strategic imperative for future national food sovereignty.

Permaculture and agroforestry at UWEPO Farms significantly contribute to sustainable food production and climate resilience in Jinja. By enhancing soil health, diversifying yields, and expanding income opportunities, these systems enable households to withstand climate variability more effectively than conventional farming approaches. The study supports the integration of agroforestry and permaculture into Uganda's climate-smart agriculture plans and demonstrates their relevance to SDGs 1, 2, 13, and 15. Wider adoption will require targeted capacity-building, improved access to agricultural resources, and enabling policy interventions.

6.0 Recommendations

The study suggests the following crucial recommendations:

- Strengthen Extension Services: Increase farmer training in sustainable practices and water management technologies.
- Enhance Policy Incentives: Subsidies, carbon-credit schemes, and land tenure security to accelerate adoption.
- Youth Inclusion: Tailored programs to attract young people into sustainable agriculture.
- Community Knowledge Platforms: Farmer-to-farmer exchanges to reinforce local innovation.
- Affordable Water Security Infrastructure-Subsidized small-scale irrigation technologies must be prioritized to match farmers' expressed needs (28.1% demand).
- Climate-Finance Inclusion- Tree-based farmers should be registered for carbon-credit access, enabling recognition and payment for environmental services.
- Farmer-to-Farmer Scaling Pathways- Knowledge demonstration farms like UWEPO should be upgraded into regional learning centers.

- Circular Bioeconomy Regulation Support- Sanitary and commercial certification for products like BSF feeds, compost, and honey must be streamlined to unlock market value.

7.0 Conflict of Interest

The authors declare no conflicts of interest.

8.0 Acknowledgements

The authors acknowledge Uwepo farm Ltd for making it possible for me to study at their farm despite the busy work schedules and in particular, Nick Deckoning, training personnel Mr. Joshua Semuwemba, and community farmers around Uwepo for their participation and cooperation. Friend and mentor Alexander Siegfried Krabbe, M.D Layne Hartsell, Mr. Ryan Coleman who have always encouraged me to continue working hard.

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