REFOREST PROGRAMME POLICY BRIEFS – APRIL 2025

TANZANIA

Monitoring Miombo Phenology for effective climate change interventions

Background and Rationale

Miombo woodlands cover around 40% of Tanzania's land area. They are vital ecosystems that support community livelihoods, biodiversity and climate regulation. However, they are highly vulnerable to climate variability calling for empirical data on seasonal and species-specific phenology. In this context phenology refers to the timing of recurring biological events such as leafing, flowering and fruiting, and their relationship with climatic and anthropogenic drivers. Phenological events serve as bio-climatic indicators and are closely linked to drivers of climate change. Data on these patterns can inform the timing of critical actions for conservation thereby stemming biodiversity losses.

Research methods and results

Remote sensing data were used to quantify the phenology and seasonal variability of miombo tree species. Monitoring phenology with remote sensing offers the advantages of cost-effectiveness and consistent data acquisition over time. The research used drone imagery to identify and digitize dominant tree species and PlanetScope images to generate Normalized Difference Vegetation Index (NDVI) data from 2017 to 2024.

A drone collecting data in Katavi

Aerial photo collected by drone

NDVI data for the dominant tree species was extracted, and TIMESAT software used to measure the factors influencing the Start of Season (SoS), End of Season (EoS), and Length of Season (LoS). The results show that miombo tree species exhibit varied lengths of growing seasons, which shift seasonally in response to environmental changes. Start of Season (SoS) was primarily influenced by surface solar radiation and skin temperature, while End of Season (EoS) was effectively predicted based on the timing of Start of Season (SoS). The deeper understanding of miombo woodland phenology has enabled the development of models to predict shifts in tree species phenology under current climate change trends, suggesting the creation of more effective, climate-resilient policies. By leveraging these findings, policymakers can enhance biodiversity and ecosystem management in the face of climate change.

Policy Recommendations

Incorporate Phenological Data into resources assessment and conservation planning: collect and integrate species-specific phenology data into forest management planning in order to align interventions with critical growth phases. This will enhance resilience and biodiversity protection.

Support Climate-Responsive Management Practices: forest management practices should take into consideration seasonal phenology data, particularly the role of temperature and solar radiation, to mitigate the impacts of climate change on miombo ecosystems.

Invest in Phenology Monitoring Systems: promote the use of remote sensing and ground-based monitoring to continuously track miombo phenology and respond to shifting climate patterns, ensuring timely adjustments.

Collaborate with Climate Change Initiatives: support cross-sectoral initiatives to address the impact of rising temperature on phenology, aligning with broader climate adaptation and biodiversity goals.

Acknowledgements
This brief was developed by Siwa E. Nkya with guidance from Deo D. Shirima, Henrik Hedenas, and August B. Temu from the REFOREST Programme. We thank the Swedish International Development Cooperation Agency (Sida), under grant number 13394, through the REFOREST Programme for funding the research that led to the development of this policy brief.

Improving Forest Productivity by Managing Soil Quality: A Strategy for Sustainable Forest Ecosystems in Tanzania

Introduction

Forests are vital to the global ecosystems, as they play key roles in climate change mitigation, biodiversity, soil conservation, provision of forest products and contribution to livelihoods. Forest plantations are considered to be one of the important options for meeting global timber demand. This highlights the need to explore the interplay between soil quality and forest productivity, which varies within and across regions. Good soils are essential for enhancing forest productivity, ecosystem services including carbon sequestration (which is crucial for combating climate change), biodiversity conservation, soil nutrients and water conservation. Complex interactions among soil characteristics and external environmental factors shape the relationship between soil quality and forest productivity in terms of Mean Annual Increment (MAI). Despite the acknowledged significance of soil quality, a considerable knowledge gap persists regarding its influence on forest productivity, particularly within Tanzania's forest plantations. Recognizing soil quality as a complex measure including physical and chemical properties is crucial for understanding the ecological mechanisms that govern plant-soil interactions.



This comprehension is vital for fostering sustainable forest management and formulating specific practices that sustain soil productivity. To address this knowledge gap, a study was carried out from 2022 to 2024 focusing on *Pinus patula*, the most widely planted and utilized tree species in Tanzania. The research aimed to assess the impact of various soil quality indicators on productivity within the Sao Hill and Shume forest plantations. The research was conducted by categorizing the plantations into four site classes based on production potential as per management records. Site class in forest plantations is "site index" which refers to a measure used to determine the potential growth capacity of a forested area, specifically the average height that dominant and co-dominant trees will achieve at a certain age in fully stocked even-aged stands. It is commonly used in timber management to assess site quality and inform decisions regarding forest management practices. Data on tree growth were collected from quadrat plots in each site class, alongside soil samples taken from defined depths, to analyze the correlation between soil quality and forest productivity.

Photo: Pictorial description of methods applied in data collection

Why link soil quality and productivity in Tanzanian forest plantations?

By understanding the link between soil quality indicators and forest growth, forest managers can make informed decisions regarding species selection and silvicultural practices to optimize forest Mean Annual Increment and sustainability. This study's findings promise to revolutionize forest management in Tanzania, offering a brighter, more sustainable future for plantation forests.

Key Findings and Policy Implications:

- Soil quality indicators such as sand, clay, silt, organic carbon (OC), cation exchange capacity (CEC), Ca, Mg, and available P varied within the same forest and between site classes. By monitoring these indicators both within forests and across different site classes, forest managers can make informed decisions that promote healthy forests capable of providing ecological benefits and resources over time;

- Site classes I, II and III exhibited similar and higher forest productivity in terms of MAI than site IV. The observed difference or similarity for the site classes call for using different management strategies to improve productivity; and

- Soil quality indicators, including physical (porosity, clay and sand content) and chemical properties (K, Mg, avail P, soil pH, and OC), better predict productivity in Tanzanian forest plantations. By measuring these physical and chemical indicators, forest managers can better assess soil quality and predict the productivity potential of plantation sites. This information informs decisions on species selection, site preparation and management practices to optimize growth and sustainable yield.

Policy Recommendations

- *Promote sustainable soil management practices*: The variability of soil quality indicators among different site classes suggests the necessity of adaptive management practices tailored to specific soil conditions. Policymakers/technocrats should encourage practices that improve soil quality indicators such as organic matter addition through leftovers, which has been shown to positively impact on soil health;
- *Integrate soil health evaluations into forest policies*: Soil quality is an essential factor in enhancing forest productivity, but historically it has been overlooked in forest management policies, which hinders forest productivity. Integrating the relationship between soil health and forest productivity is essential for sustainable forest management, therefore there is a need to incorporate soil quality metrics into policies.

- *For sustainable use of soil resources there is a need to strengthen research and training programmes*: Sustainable utilization of soil resources involves enhancing capabilities by establishing funding avenues, such as the Tanzania Forest Fund (TaFF). This fund could support research and training projects aimed at assessing soil quality and forest health for the effective

implementation of soil management practices that enhance forest productivity in a sustainable manner.

Acknowledgement

I wish to express my sincere gratitude to the Swedish International Development Cooperation Agency (Sida) for generously funding the research conducted within the framework of the REFOREST Africa Programme, coordinated by Sokoine University of Agriculture (SUA).

This brief was drafted by Joshua Maguzu and reviewed by Salim S.M. Maliondo, Ulrik Ilstedt & Josiah Zephania Katani

Views expressed in this policy brief do not necessarily represent those of SUA, Partner Universities, the REFOREST Programme or Sida.

Promoting Integrated Harvesting for Efficient Wood Utilization and Product Diversification in Tanzania

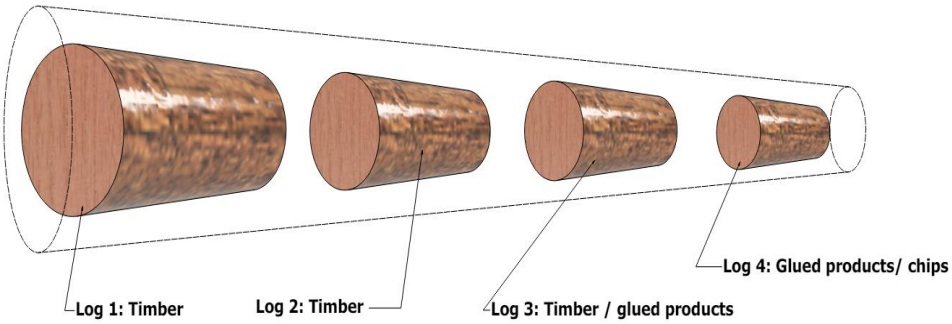
Prepared by Scolastica Ntalikwa

Introduction, Rationale and Methodology

The forestry sector in Tanzania is a vital component of the national economy, contributing significantly to employment, income generation and environmental sustainability. Forests cover approximately 48.1 million hectares, accounting for over 55% of the country's land area. These forests provide a range of ecosystem services, while also supplying raw materials for the wood industry. The conversion of a standing tree into usable products is an important activity and is considered as part of a management regime. With the current high demand of wood products and industrial requirements, plantation owners need to re-think how forest harvesting is carried out and identify the most efficient system.

Despite the sector's importance, Tanzania's forestry industry faces several challenges that threaten the sustainable provision of forest resources; including traditional harvesting methods characterized by high amount of residues, underutilization of small size logs and high timber demand. Furthermore, the processing small size logs is marked by inefficient practices, leading to suboptimal utilization of wood resources. My research aimed to address these challenges by developing a comprehensive framework that integrates harvesting and processing activities to enhance efficiency and profitability. This can be achieved by exploring the development of harvesting and wood products processing systems in an integrated production approach, with the goal to enhance efficiency and profitability.

This study compared two harvesting systems: (i) Conventional Harvesting (CH) which does not necessarily align with the log dimensional requirements of the customer and only recover logs with big diameters, and (ii) Integrated Harvesting (IH) which is based on harvesting and sorting logs according to need in a single operation to achieve higher recovery in terms of volume and value.



Proposed integration approach

Key Findings

- Integrated production approach significantly enhanced efficiency and profitability.
- The current conventional harvesting and wood processing systems in Tanzania are characterized by significant inefficiencies, coupled with high levels of waste.
- The inefficiencies experienced reduce the economic potential of the sector and underutilization of the resource material. Results showed low cutting productivity with IH (14 m^3/h) compared to CH which was 16 m^3/h, and low skidding productivity with IH (15.3 m^3/h) as compared to CH (24.9 m^3/h) respectively.
- CH had stem recovery of 60% compared to that of IH which had 75%. This was due to IH utilizing raw materials that was previously discarded by CH. Meaning, IH resulted to high tree utilization and bigger volume harvested.
- Integrated processing enabled utilization of small diameter logs. Through Integrated processing, 98% of the log was utilized: lumber with 50% large size, 26% small-lumber size, 18% briquettes and 4% into planks, while with CS, only 41% was recovered as lumber and 24% which was considered as waste.
- An integrated harvesting approach has shown to deliver economic benefits, whereby it increased industry profits, and it promotes sustainable forest management, to carter for the high demand of wood.
- The final financial result shows higher total costs with IH ($2379) than CH ($1544), but also IH had low costs per cubic meter ($84.37/$m^3$) than CH ($100.3/m^3) of final produced volume. The costs were topped by higher revenues generated by IH ($177.222/$m^3$) compared to CH ($128.3/m^3), resulting in greater benefits for IH
- Generally, the study builds a case for the adoption of Integrated Harvesting over Conventional Harvesting in Tanzania, demonstrating the financial advantages, sustainability, higher recovery rate and productivity of the IH system.

Policy Implications

The study underscores the need for policy makers and practitioners to promote the adoption of IH for its potential to improve processing, logs utilization, efficiency and profitability of wood industries. This is particularly relevant as Tanzania adopts the development of engineered wood products.

Policy recommendations

i. Promote IH system as a management practice to ensure maximum utilization of the raw materials, improved efficiency and reduced wood wastes;
ii. Enhance awareness on value addition in integrated wood processing. This can be achieved by diversifying and integrating the production lines with other wood products e.g. pulp, Medium-Density Fibreboard (MDF) and Cross Laminated Timber (CLT); and
iii. Put in place regulatory frameworks to promote and support the integration of harvesting and processing activities.

Acknowledgment

Grateful to the Swedish International Development Cooperation Agency (Sida) through the REFOREST Program at the Sokoine University of Agriculture for funding this work.

Enhancing Pollination Services to Increase Crop Yields through Agroforestry in Tanzania

Prepared by Nanyika Kingazi

Introduction, rationale, and methodology

Insect-mediated pollination is essential for global food security and ecosystem stability, playing a critical role in crop production and the maintenance of wild plant populations. However, declining population of insect pollinators, driven mainly by agricultural expansion and climate change, pose a significant threat to sustainable agriculture and biodiversity. In response to the growing demand for increased crop yields, agroforestry offers a promising solution that balances productive agriculture with ecosystem services such as pollination. By integrating woody plants with crops, agroforestry has the potential to create environments conducive to support insect pollinator populations.

Agroforestry systems, especially in tropical regions like Tanzania, have not been adequately studied to uncover their impact on pollinators. Given the decline in forest cover and the resulting habitat loss for insect pollinators in Tanzania, it is critical to explore agricultural practices that can mitigate these effects while improving crop yields. This policy brief draws from a study conducted on agroforestry and non-agroforestry plots to assess the effectiveness of agroforestry practices in promoting insect pollinator abundance, species richness, and pollination services, while also investigating farmers' awareness of pollinators and their conservation.

This study compared 16 agroforestry plots with 16 non-agroforestry plots, documenting insect pollinator communities, visitation rates on bean flowers, and their impact on crop (bean) yield. Additionally, interviews with 101 smallholder agroforestry farmers were conducted to assess their knowledge on pollination services. In addition, farm surveys were conducted to identify forage plants for pollinators.

Figure 1: Example of an agroforestry plot (left) and a non-agroforestry plot (right).

Key Findings

- ❖ Agroforestry plots had nearly twice as many the insect pollinator abundance, three times the species richness, and higher visitation rates than non-agroforestry plots (Figure 2), resulting in significantly increased bean yields (Figure 3). This indicates that agroforestry can improve agricultural productivity while fostering biodiversity.
- ❖ Agroforestry plots maintained higher pollinator abundance and species richness during both wet and dry seasons, demonstrating their role in providing year-round forage for pollinators.

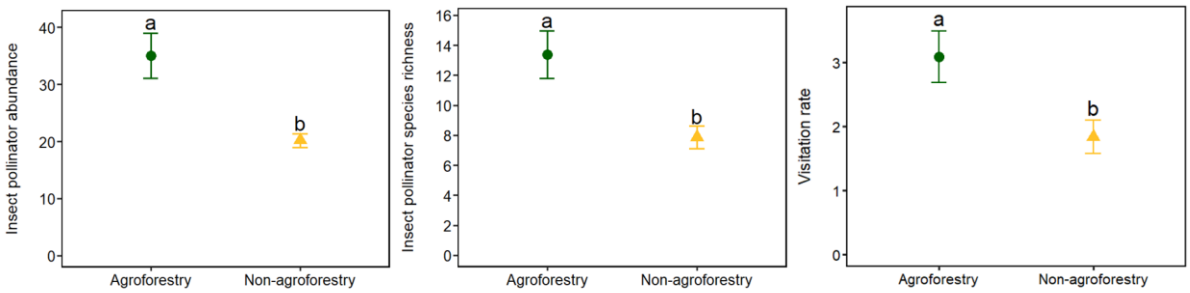


Figure 2: Mean (a) abundance, b) species richness and c) visitation rates of insect pollinators that were recorded visiting bean flowers in agroforestry and non-agroforestry plots

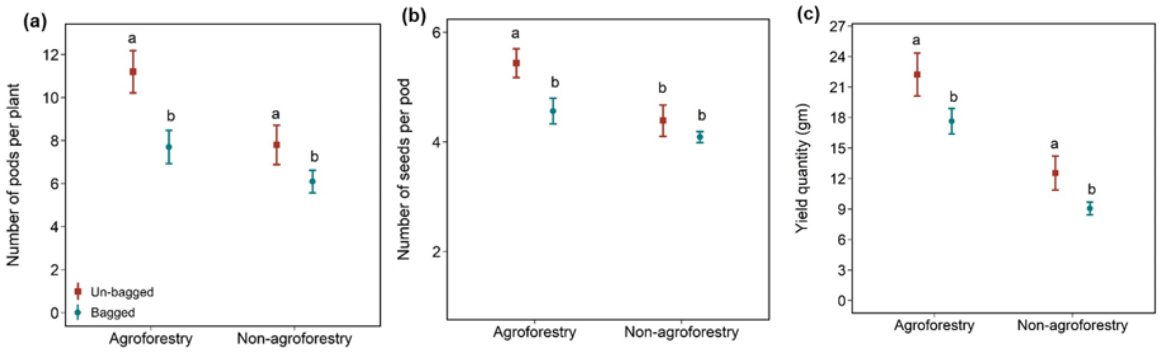


Figure 3: Yield parameters: number of pods per plant (a), the number of seeds per pod (b), and yield quantity (c) between un-bagged and bagged beans in agroforestry and non-agroforestry plots.

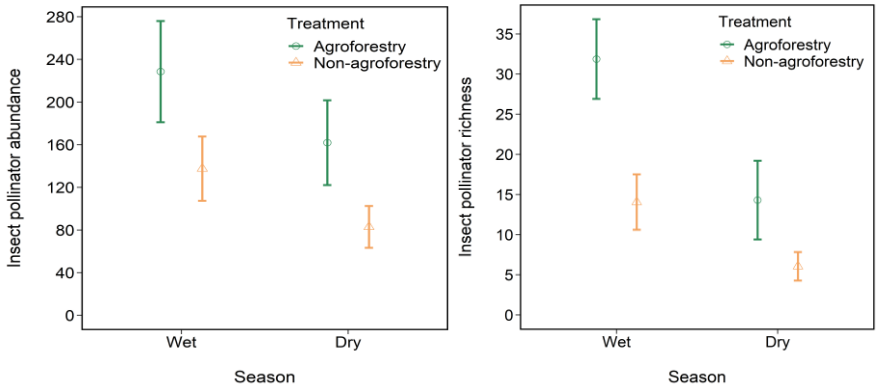


Figure 4: a) Estimated mean abundance and b) species richness of insect pollinators that were captured in agroforestry and non-agroforestry plots during wet and dry seasons

- ❖ Agroforestry plots had higher plant richness, flower abundance and landscape level woody cover and this positively influenced pollinator communities, suggesting that

agroforestry is likely to be helpful for pollinators when it increases flower abundance and plant richness and if it is coordinated so that woody cover also increases at the landscape scale. This highlights the importance of local (farm) level and landscape-level approaches in agricultural planning.

- Most farmers (89%) lacked awareness of pollination services, although they recognized some insect species, especially honeybees. This knowledge gap indicates a need for education and outreach programs to enhance pollinator conservation efforts.

- 293 woody plant species (152 natives and 141 exotic) from 62 families in the 101 studied agroforestry farms, provided insect pollinator forage. The pollinator-forage plants in agroforestry farms flower intermittently throughout the year, ensuring a continuous supply of forage resources to insect pollinators.

Policy Implications

The findings from this study underscore the significant role of agroforestry in enhancing insect pollinator communities and improving pollination services, which are essential for increasing crop yields and ensuring food security. The clear difference in pollinator abundance, species richness, and pollination services between agroforestry and non-agroforestry farms highlights the need for agricultural policies to recognise and promote agroforestry. Furthermore, the study illustrates that agroforestry systems provide continuous forage resources for pollinators throughout the year, which is critical in maintaining pollinator populations year around. Importantly, the limited awareness of pollination services among farmers confirms the needs for awareness raising to increase farmers' knowledge on pollinators' conservation. Additionally, the study points to the importance of maintaining and enhancing plant richness and flower abundance at the farm level as well as woody cover at the landscape scale, indicating that policies should integrate both farm-level and broader landscape-level approaches to support pollinators.

Policy Recommendations

- *Promote Agroforestry Practices in Agricultural Policies*: Agricultural policies should encourage the adoption of agroforestry systems, as they significantly enhance pollination services and contribute to increased crop yields among other benefits;
- *Enhance Farmer Awareness and Extension Education Programs*: Extension services and training programs focused on pollinator conservation and pollination services should be integrated into agricultural policies;
- *Support Landscape-Level Agroforestry Initiatives*: Agricultural policies should promote the implementation of agroforestry practices in a coordinated way so as to ensure woody cover at the landscape scale.

Acknowledgment

I am grateful to the Swedish International Development Cooperation Agency (Sida) through the REFOREST Program at the Sokoine University of Agriculture for funding this work.

Enhancing Spice Farmers' Livelihoods and Sustainability in Tanzania

Introduction and Rationale

Spice farming is vital to the livelihoods of rural communities in Tanzania and contributes significantly to the national economy. The Eastern Arc Mountains, especially Uluguru and Usambara ranges, offer ideal conditions for growing key spices such as cloves, black pepper, cardamom, and cinnamon which are vital income sources for communities. However, farmers face several challenges including market instability, low productivity, environmental conservation pressures, vulnerability to climate variability, and economic shocks, making it difficult to balance conservation efforts with their livelihood needs.

Farmers' capacity to secure fair prices and grow their businesses is restricted by market limitations, such as inadequate infrastructure, restricted access to market information, and weak value chains. Farmers may turn to unsustainable land use in an effort to maximize short-term profits, which not only affects their incomes but also discourages sustainable farming practices. As farmers struggle to meet their immediate needs for a living, there is a delicate risk of environmental degradation.

Considering the abundance of biodiversity in the area and the local communities' reliance on the production of spices, finding a balance between enhancing farmers' livelihoods and safeguarding the environment is crucial. Without timely and targeted interventions, farmers will remain highly vulnerable to the increasing impacts of climate change, price volatility in local markets, and limited access to fair and consistent market opportunities, further exacerbating the economic instability of farming households.

This policy brief highlights the urgent need for strategic interventions to strengthen the livelihood strategies of spice farmers in the Uluguru and East Usambara mountains. Support for capacity-building initiatives, improved infrastructure, market development, and the adoption of agro ecological practices can protect both the economic stability of farming communities and the ecological integrity. Without these interventions, the vulnerability of spice farmers will continue to threaten the EAM's biodiversity and hinder long-term conservation efforts.

Methodology

This Policy Brief is based on my PhD study entitled *Spices and Agroforestry System in the East Usambara and Uluguru Mountains: Value Chains analysis* conducted for four years. The PhD study used 542 household samples randomly drawn from Muheza and Morogoro districts. Key methods applied were household surveys, key informants' interviews, and focus group discussions. Five distinct livelihood strategies of spice farmers were identified through cluster analysis, and multinomial logistic regression was used to assess the determining factors through a sustainable livelihood framework.

Key Findings and Policy Implications

There are five distinct livelihood strategies among households in spice-producing regions. Fully Spice Dependent households (25%) rely almost exclusively on spice cultivation, making them highly vulnerable to price fluctuations, yield variability, and climate change impacts, despite the potential for high incomes. Business Dependent households (14%) focus on off-farm income sources such as small-scale businesses, but face challenges related to market access and financing. Spice and Non-Spice Crop Dependent households (29%) combine spice cultivation with other crops, improving food security but remaining vulnerable to climate and market shocks. Spice and Business Dependent households (12%) balance spice farming with business activities, leading to the highest per capita income and greater resilience due to diversified income streams. Finally, Diversified households (20%) engage in a range of activities including spices, crops, livestock, and casual labor. Although this group earns the lowest income per capita, their diverse approach provides resilience against shocks, highlighting the need for better market access and improved productivity to boost incomes.

Key Determinants of Livelihood Strategies

Several factors influence livelihood strategies. Land ownership plays a crucial role, with households possessing more land typically specializing in spice farming, while those with less land often diversify into other income sources such as business or casual labor. Education also affects livelihood strategies; higher education levels are linked to a greater likelihood of engaging in off-farm enterprises, which generally increases household income. Additionally, access to extension services and NGO (non-government organization) support enables households to engage in business activities, enhancing income diversification and resilience. Geographical factors further affect livelihoods, with households in higher altitudes or remote areas more likely to focus solely on spice production due to limited alternative opportunities.

Policy Implications

To mitigate these vulnerabilities, supporting income diversification is crucial. This involves providing farmers with access to off-farm income opportunities and microfinance. By fostering small businesses and offering financial services, we can enhance household resilience and income stability. In addition to market and income diversification strategies, improving productivity is vital. The adoption of modern agricultural techniques and inputs can significantly increase spice yields. This not only makes farming more attractive, particularly to younger farmers but also helps to ensure long-term economic stability and sustainability in spice farming. By addressing these key areas; market stability, income diversification, and productivity enhancement stakeholders can better improve the economic stability and resilience of spice farming households while also addressing the need for environmental conservation

Policy Recommendations

- *Develop reliable markets*: Develop cooperatives or private partnerships to improve market access and negotiation power. Implementation steps include the formation of spice cooperatives that directly link farmers with buyers, allowing for more equitable

trade terms and reducing reliance on intermediaries. Additionally, establishing digital platforms to offer real-time price information and market access can help farmers make informed decisions and respond promptly to market changes;

- *Infrastructure investment*: Improve roads and storage facilities to reduce post-harvest losses and transportation costs, ultimately making spice farming more profitable and sustainable;
- *Promoting entrepreneurship and off-farm business development*. This is crucial in enhancing the economic resilience of spice farmers. Encouraging business diversification can help farmers reduce their dependence on spice cultivation and improve their financial stability. Implementation steps should include introducing comprehensive training programmes, low-interest loans can enable farmers to launch and sustain off-farm businesses and strengthening partnerships with microfinance institutions is also essential to expand access to credit, helping farmers overcome financial barriers and invest in diverse income-generating activities;

- *To boost the productivity and income of spice farmers*: It is essential to enhance agricultural practices through innovation and support. Access to modern farming technologies can significantly increase spice yields and improve overall profitability. Implementation steps should include expanding extension services to focus on sustainable farming practices and modern techniques such as agroforestry and subsidizing the cost of improved seeds, tools and other essential inputs making them more affordable for smallholder spice farmers to adopt advanced technologies and improve their yields; and
- *Enhance the resilience of spice farmers*: developing crop insurance schemes is essential for protecting against climate and market-related shocks. Implementation steps should include partnering with insurance companies to design affordable and accessible crop insurance explicitly tailored for spice farmers.

The brief was developed by J.G. Kajembe and reviewed by B. Göran, Y.M. Ngaga and J. M. Abdallah

Acknowledgment
I am grateful to the Swedish International Development Cooperation Agency (Sida) through the REFOREST Program at the Sokoine University of Agriculture for funding this work.