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Evaluating Limitations of Agroecological Practices and Stakeholders' Response: A Case of Uluguru Mountains Landscape in Morogoro Municipality, Tanzania

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Abstract

In Sub-Saharan Africa, conventional farming is associated with intensive use of synthetic chemicals and inputs to maximize agricultural productivity. This is done at the expense of sustainable agroecologically based production systems. This objective was to describe limitations of agroecological practices and stakeholders' response along Mountain Uluguru. The area has been vulnerable to unregulated land degradation aggravated by soil erosion largely due to unsuitable agricultural practices. The data were collected through questionnaires and in-depth interviews from 72 respondents who were purposively selected. Both qualitative and quantitative data were analysed using content analysis and statistical software respectively. Farmers undertake agriculture to increase production so as to meet food needs (44.8%) and employment opportunities (55.2%). About 41.7% of farmers who had land with secure tenure grew fruit and non-fruit trees on their farms or homesteads, 11.7% rented the farming land temporarily from owners through informal arrangements and the rest squatted on public land for cultivation of vegetables. From SWOT analysis, agroforestry is threatened by unregulated agricultural activities (18.6%) and overuse of forest resources unsustainably (7.0%). The agroecology training is not coordinated and supported by government agencies, which have authority to inform the policy makers about insecure land tenure and unavailability of organic inputs that would increase farmers' livelihoods. Agro-soil erosion control and conservation agriculture measures are essential features of agroecology training, but some farmers were not aware of them and those who are aware do not adopt them effectively. The study concludes that, without the government acknowledgement of agro-ecology and its associated contributions there will always be weak institutional coordination among stakeholders required to regulate, promote and support agro-ecology practices to create a balance of conserved environment, protected ecology and enhanced farmers' livelihoods. This is because there is no clear national guidelines and support (financial and technical) addressing the challenges facing agro-ecology practice yet.

Keywords: *Agroecological Practices; Stakeholders; Uluguru Mountains; Agroecology in Tanzania*

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Introduction

The increasing population and demand for food in sub-Saharan Africa (SSA) has led to the adoption of conventional farming associated with the use of synthetic chemicals and other agricultural inputs to increase agricultural productivity (Emeana *et al.,* 2018). Despite the possibility of the use of synthetic agricultural inputs to increase food production per unit area, unregulated and uncontrolled farming activities associated with the practice lead to environmental degradation, ecological set-up depletion and output produced may impair public health (Emeana *et al.,* 2018; Marioara, 2019; Constantine *et al.,* 2021). After International Symposium on Agro-ecology held by FAO in 2014, governments, civil societies, the private sectors, academia, and research institutions in countries of the world were urged to come together to share experiences and points of view regarding the benefits and challenges of agro-ecology (Mitra *et al.,* 2020). Agroecology increases environmental sustainability, climate resilience, promotes agro-biodiversity, increases agriculture productivity, increases food security and improves the livelihoods of the farmers (Marioara, 2019). Agroecology is a pathway to reach agricultural sustainability and food security while promoting methods of agricultural production that conserve the environment (AdeOluwa, 2010; Reynaud *et al.,* 2019; Salazar *et al.,* 2020). Despite the contributions of agro-ecological practice to environmental conservation and farmers' livelihoods, the extent to which those contributions are dwindling is not clear (Tittonell *et al.,* 2012).

Agroecology is guided by sustainable agriculture practices, such as crop rotation, intercropping, agroforestry, and organic farming with no or less impact to the environment (Adidja *et al.,* 2019; Mitra *et al.,* 2020). Conservation agriculture as an agro-ecology component is recently emphasized by international agencies such as the World Bank, FAO and private agricultural organizations at national level to increase agriculture productivity while maintaining and restoring soil productivity, increasing water conservation and organic nutrient use efficiencies (Tittonell *et al.,* 2012; Paracchini *et al.,* 2020). Sustainable agriculture is a subset of agroecology practices that involve the use of organic manure, organic pest and disease control, adoption of agro-forestry, crop diversification and natural control measures for soil erosion (AdeOluwa, 2010; Emeana *et al.,* 2018; Constantine *et al.,* 2021). Agroecology neither emphasizes obsolete farming technologies nor disregard recent agricultural knowledge and innovation, but connect traditional and scientific knowledge in a way that food can be produced without jeopardizing the environment and ecological fragile areas (Adidja *et al.,* 2019; Cote *et al.,* 2019).

Conservation agriculture is considered good for agroecology practices. Kumawat *et al.* (2020) and Sahoo *et al.* (2017) suggest the use of cover crops, intercropping, contour strip cropping, crop rotation, mulching, conservation tillage, organic farming and agroforestry as soil and water conservation measures apply to sustainability of agroecological practices. Organic mulching is recommended in agroecology and soil conservation practices because it minimizes evaporation and the effect of heat on the plant, minimizes weed infestation, improves soil structure and adds soil organic matter when it decomposes (Dimelu *et al.,* 2013; Kumawat *et al.,* 2020). Under zero tillage, increased agricultural productivity can possibly minimize disturbance to soil microbial activities and environmental pollution (Hassan *et al.,* 2022). Wezel *et al.* (2013) noted that intercropping improves land productivity by complementing associated crops. Although agroecology practices increase income, diversify farm products and provide fodder for livestock, limited access to land and insecure land tenure hinder farmers to diversify crops and increase agriculture productivity (Sahoo *et al.,* 2017; Emeana *et al.,* 2018).

Strip cropping is one of the approaches that allow growing of crops along the contours' slope across the field to intercept the speed of water runoff and minimize the intensity of land degradation through soil erosion (Juventia *et al.,* 2022). Adopting strip cropping requires a balance of soil water conservation management and optimizing agro-ecological based benefits (Sahoo *et al.* 2017; Juventia *et al.,* 2022). Terrace farming partly converts a steep slope into a flat surface that minimizes intensity of water runoff and the formation of rill and gull erosion which

jeopardize soil conservation on the hilly farmland (Juventia *et al.,* 2022). Avoidance of water loss through an enhancement of temporary water percolation increases soil moisture and crop endurance to drought and consequently increase crop yield (Deng *et al.,* 2021; Juventia *et al.,* 2022). Climate change especially causing drought, construction costs of terraces and management skills hinder farmers from fully adopting terrace farming on the sloping land (Deng *et al.,* 2021).

Agroecology challenges also are explored through examining the existing food production systems if they are fair to public health and environment (Place *et al.,* 2022). In practice, the adoption of organic and conservation agriculture depends on the level they are supported or hindered by institutional tools such as policy, laws and regulations (Emeana *et al.,* 2018; Tittonell *et al.,* 2012). The question whether or not the farmers receive institutional support related to agro-ecological practices cannot be understood without analyzing socio-economic dynamic factors and agricultural policies that underpin agro-ecological principles and practices (Emeana *et al.,* 2018; Marioara, 2019). Promoting and supporting agro-ecological practice cannot be effective without creating a good institutional environment and strengthening coordination between the government, private and community stakeholders (Le-Coq *et al.,* 2020). In line with this, Salazar *et al.* (2020) suggested areas for further research on technical, policy, legal and societal challenges in implementing agro-ecological systems in small and large scale farming.

International donor agencies and organizations are the sole funders of agroecology projects and research (Cote *et al.,* 2019). The possible rhetorical question is, if agroecology has substantial contributions to food security and environmental conservation, then why is it not supported legitimately by countries? Some countries with policy provisions on agro-ecology practices also enact related regulations to permit certain types of manure and agro-chemicals or completely prohibit the use of certain fertilizer, herbicides and insecticides that have adverse effects on the environment and public health (Essiedu *et al.,* 2020; Place *et al.,* 2022). Agroecology is acknowledged in some policy documents of Sub-saharan Africa countries but, its full adoption is not supported by government institutions and institutional frameworks (Cote *et al.,* 2019; Place *et al.,* 2022).

In Africa, the institutional structures related to agroecological framework offer little, and they are merely codifications of traditional farming practices (Mugwanya, 2019). In order to combat food insecurity in Africa, several countries have recently subsidized synthetic fertilizer and pesticides while there is a lack of formal codification and actions to support agroecology and organic farming (Mugwanya, 2019; Boillat *et al.,* 2021). Although in Nigeria agricultural policy states that food production should be done in a sustainable manner without jeopardizing the environment, extension officers provide agricultural advice and information related to conventional farming methods to farmers to increase agricultural production, even at the expense of environmental conservations so as to feed the rural and urban population (Emeana *et al.,* 2018). Senegal supports agroecology, but weak policies and institutions support have undermined agroecology practices adoption. In Kenya, agroecology is acknowledged by policy documents, but farmers have limited knowledge about it and no financial resource is directed to promote agroecology practices (Gatei, 2022). In the order of government priorities, particularly in SSA, food security issues precede environmental conservations, but food security is likely to be at risk when environmental degradation is rampant (Boillat *et al.,* 2021). Weak interactions among different stakeholders and limited knowledge of sustainable agriculture challenge agroecology, but this cannot be generalized to countries that operate using different institutional frameworks (Emeana *et al.,* 2018; Boillat *et al.,* 2021).

Dynamic challenges of agro-ecology practice in Tanzania

In Tanzania, agroecological practices cannot be sustainable if institutional barriers to it are not tackled by responsible stakeholders (Mdee *et al.,* 2018). Inaccessibility to micro-credits and markets for selling organic products de-motivated farmers in Mbalali District to adopt organic farming and agroecology practices (Msemo *et al.,* 2018). The way agricultural micro-

credits are regulated by the government in-favour of small-scale agroecology farmers is not specified in the formal government documents (Mwijage *et al.,* 2011). Some of the agroecological practices need intensive capital and labour at the initial stage than they can be afforded by indigent farmers (Constantine *et al.,* 2021). Limited knowledge about agro-ecology among rural farmers and insecure land tenure are among the factors hindering the adoption of agro-ecological practices (Constantine *et al.,* 2021; Mwijage *et al.,* 2011). Farmers and would-be farmers cannot adopt sustainable agro-ecological practices if they undertake agriculture on land which has insecure tenure (Mwijage *et al.,* 2011; Mbeyale & Mcharo, 2022). Farmers in Kilimanjaro region in Tanzania hesitate to plant trees on land that does not permanently belong to them because tree-planting is a long-term investment and before the trees mature, the owner might have taken over the land (Mbeyale & Mcharo, 2022).

The land suitable for agriculture may also be suitable for conservation to support other ecological creatures therefore raising conflicting interests in land use (Mkonda, 2021). Protection of environmentally-sensitive areas, such as riverbeds or riverbanks is affected by farmers who consider such areas fertile and supportive of farming activities without taking precautionary measures of conserving the environment (Msuya & Kideghesho, 2012). In the long run, unregulated farming activities cause soil erosion. The farming activities that degrade the environment or deplete microbial activities in the soil may include the use of synthetic fertilizers. This needs to be regulated by government organs or responsible stakeholders as prescribed in national policy and legal documents (Msuya & Kideghesho, 2012; Hong *et al,* 2018). If no specific policy exists, promotion of agroforestry and conservation agriculture becomes null and void (Msuya & Kideghesho, 2012; Jha *et al.,* 2021). In most of rural areas in Tanzania, traditional farming systems such as shifting cultivation and monoculture partly contribute to agricultural productivity, however they are not environmentally friendly (Mkonda, 2021; Mbeyale and Mcharo, 2022). Agricultural productivity, conservation of environment and agroecological system depend on farming technologies that are accessible and effective for farmers to minimize land degradation through soil erosion while increasing production (Hong *et al.,* 2018).

Despite the recent emphasis on agroecological practices and sustainable agriculture in the Tanzania national policies, discourses on the use of industrial fertilizers and pesticides are still prominent in agricultural discussion (Mdee *et al,* 2018). Beyond Tanzania, Mugwanya (2019) questions the roles of SSA's governments in promoting agroecology, urging that most non-governmental organizations involved in promoting agroecology transformation in Africa are funded primarily by the western developed world donors. In Tanzania, awareness and training on agroecology are mostly provided by non-governmental agricultural research officers (Constantine *et al.,* 2021). Farmers in Mvomero and Masasi Districts in Tanzania received information and training on ecological practices from Non-Governmental Organizations (NGOs), such as Sustainable Agriculture in Tanzania (SAT) and SWISIS AID and from agricultural training institutions, such as Sokoine University of Agriculture (SUA), but not from the agricultural officers of local government authorities (Mdee *et al,* 2018; Constantine *et al.,* 2021). Recently, the status of agroecology remains unknown especially if donors will no longer fund agroecology research and projects. In practice, the promotion and support of agroecology in Tanzania should have been expressed in the relevant policies that guide its implementation and regulate its outcomes.

Tanzanian policies' provisions related to agroecology

Two policies reflecting provisions related to the debate on agriculture, environment and agro-ecology practices exist in Tanzania. Section 4.4 of Agriculture Policy of 2013 acknowledges the increased use of industrial fertilizers, agrochemicals and improved seeds for their contribution to agricultural productivity to meet economic development, food security and poverty reduction (URT, 2013). The need to increase food security and poverty reduction through agriculture is in-line with agro-ecology objectives, when agriculture is done in sustainable ways. Section 4.20 of the same policy outlines unsustainable farming methods and

systems, and weak enforcement of related laws and regulations of unsustainable agricultural practices as cross-cutting issues mainstreamed in conservation of natural resources, such as forests, land and water sources. Despite acknowledging unsustainable farming systems as antithetical to sustainable agricultural and agro-ecological practices, strategies for undertaking appropriate farming systems to achieve food security and environmental protection are not clear in the context of the Agricultural Policy. Section 46 (a) of the Environmental Policy of 1997 outlines the need of improving land husbandry through soil erosion control and natural soil fertility improvement. Section 46 (e) of the same policy acknowledges the need for controlling agricultural runoff of agrochemicals so as to minimize land pollution, surface and groundwater sources. Section 46 (f) recognizes the need for promotion of mixed farming, through multiple cropping, intercropping, crop rotation and agroforestry (URT, 1997).

The use of agrochemicals and agricultural inputs for improving agriculture productivity is not acknowledged by the Environmental Policy of 1997. Agricultural productivity can be achieved through the use of agrochemicals that increase food production and maintain the quality of the produce (Emeana *et al.,* 2018). Reflecting on the two policies, there is contrasting information between increased agricultural productivity and undertaking sustainable agriculture practices without risking the environment, which agro-ecology practice can ameliorate. It is from the dichotomy of policies' provisions related to agriculture, environment and agroecology, the roles played by institutions and stakeholders in managing agroecological practices are evaluated in the context of institutional frameworks. The manners through which the policy and legal provisions related to sustainability of agroecological systems are enforced and the manner in which they are adhered to, and the reasons they are not adhered to by farmers and other stakeholders are the issues debated and interpreted differently (Mdee *et al,* 2018). Regulations and bylaws related to environmental conservation should be enforced strictly in order to rescue forests and its related natural resources from being depleted (Adidja *et al.,* 2019). The bylaws that interrupt the way people meet their livelihoods from forest natural resources should be enforced collaboratively and proactively while suggesting solutions for sustaining the peoples' livelihoods and natural resources conservations (Emeana *et al.,* 2018; Mwamfupe, 2019; Jha *et al.,* 2021).

Analytical Outline

The analytical framework of this study is presented diagrammatically (Figure 1). The framework illustrates prerequisite components of stakeholders' responses emerging from literature review which apply to agroecological practices to enhance sustainable agroecological output. Agroecology practices cannot be sustainable without being supported by any policy's provisions, its related technology and support provided to farmers by responsible actors in a coordinated way. The components of agroecology practices should target the sustainability of agroecology output. The ways institutional tools and stakeholders respond to challenges of agroecological practice constitute the knowledge gap of the research.

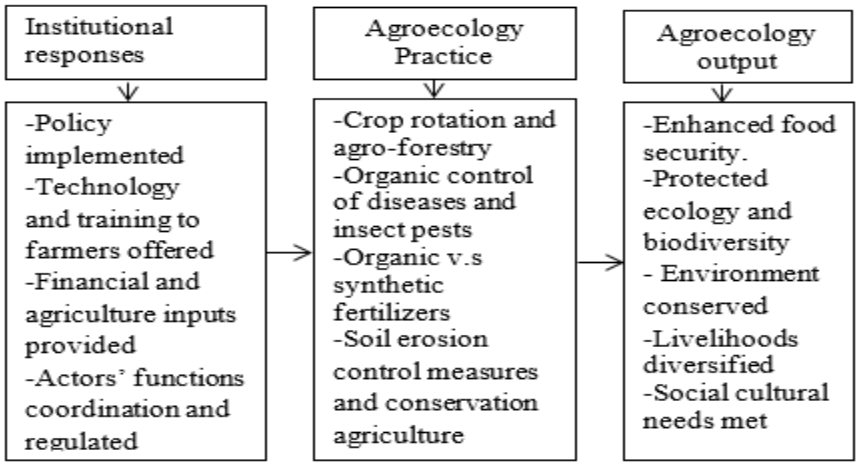

Figure 1. Analytical Framework

Materials and Methods

Materials and methods comprise description of the study area, research design, data collection and analysis protocol.

Study Area

The study was conducted in Mlimani, Boma, Bigwa, and Kilakala wards in Morogoro Municipality. These wards are mountainous, consisting of undulating terrain, steep and gentle slopes along the Uluguru Mountains base. Farmers in study areas grow crops on the land they reside and away from their residencies along the slopes of Uluguru Mountains. The study areas have fertile soil, forest and water streams. The areas had an average annual rainfall range of 550-1000 mm and annual average temperature, 26.7^{o} C (Morogoro Meteorological Station, 2022). The fertile soil and good climate along Uluguru Mountains are considered conducive for crop production under conservation agricultural practices (Kadigi, 2021). Majority of the natives (Waluguru) inhabiting the areas engage in agriculture, illegally extract forest natural resources for livelihoods as well as using water from catchment areas for irrigation and domestic utility. Deforestation, soil erosion and depletion of water catchment areas are the common problems contradicting regulation of agroecological practice (Mdee *et al.,* 2018). Thus, the study areas were considered relevant for the study.

Research Design

The study deployed a descriptive survey research to gather qualitative and quantitative data from 72 respondents who were purposefully selected. The sampled respondents include 15 farmers from each of the four wards, 4 agricultural officers and 4 environmental officers from the wards, and 2 officials from Morogoro Municipal Council and 2 officials from SAT. The instruments of data collection were interviews and questionnaires. Qualitative data were analysed using content analysis. Regression analysis was used to reveal the relationship between the farming activities and agroecology sustainability, while SWOT analysis was used to analyse the strengths, weaknesses, opportunities and threats existing in agroecological practices and regulations. The frequency and percentages of quantifiable data were calculated by using Statistical Package for Social Science (SPSS).

Results

In the four wards, staple food and horticultural crops were grown by farmers interviewed. The crops grown include maize, upland rice, banana, yams, sweet potatoes, cassava, tomatoes, eggplants, onion, carrots, passion fruits, beans, legume, amaranth, mango, pawpaw, lemon and oranges. Fruit and non-fruit trees for wood and timber were also grown. The ways these crops are grown differ amongst farmers. There are farmers who intercropped their crops, adapted crop rotations and monoculture, and grew crops using organic manure and industrial fertilizers. Some other farmers kept livestock such as goats, cattle,

pigs, and chicken, but crop production was predominant. These forms of farming systems are associated with challenges that affect the contribution and sustainability of agro-ecological practices. The environment in general, and specifically water catchment areas, agroecology set-up along the mountain slopes were partly conserved, but largely degraded. Some residential houses were constructed within undulating slopes of Uluguru Mountains.

Crop rotation

The results showed that 13.3% of farmers were aware of crop rotation based on their long farming experience, 15% after training and 71.7 % were not aware of crop rotation (Table 1). Farmers who benefited from crop rotation kept on practicing it. Those who face challenges such as low productivity, perseverance of pests and disease and fail to manage them resort to abandon it. Farmers who reported to be aware of crop rotation were to some extent acquainted with the knowledge and principles of crop rotation. The farmers who were knowledgeable of heavy, medium and light feeders' crops or crop typology in the category of deep and shallow rooted, effectively practiced crop rotation.

Those who lacked the knowledge of crop rotation did not know which crops could be included in the rotation and how host pest crops could affect succeeding crops. These farmers lacked basic skills about which crops were to be planted in the rotation after the other and in which period of the year should be replanted. Furthermore, 65% of the farmers responded that following land for one season of the year was uneconomical due to climate change. The changes go hand in hand with rainfall and temperature fluctuation affecting crop cultivation and the price for agricultural produce. Agricultural land is also reported to be scarce to support land fallowing. Source of knowledge of crop rotation is indicated in Table 1.

Table 1:

Source of knowledge of crop rotation

Source of crop rotation knowledge	Farmers clear understanding of crop rotation principles (n=60)	
	Yes (%)	No (%)
Long farming experience	13.3	45.0
Agricultural training	15.0	26.7
Total	28.3	71.7

Agro-forestry

The study reveals that in 2005, residents in the study areas were encouraged by the Department of Environment and Natural Resources of Morogoro Municipality to plant trees, especially those which conserve the environment and could be grown together with crops. The farmers were promised that they would be paid some money after every 10 years, depending on the size and number of the trees planted. Ten years later, farmers who planted trees were not paid the money because the funder of the project was not available. All the effort made to contact the funder ended in failure. Eight farmers who were under the project were prohibited to cut down trees for whatever uses without seeking permission from the forest officers. This tendency discouraged farmers and non-farmers residents to trust the government led-programmes that promised to lessen their livelihoods difficulties, but in reality further complicated their lives.

Recently, farmers in study areas have been encouraged and few of them had started growing grafted fruit trees such as mango, avocado and oranges. However, insecure land tenure hindered farmers (43.3 %) from growing permanent fruit trees. Other factors reported to be challenging to agro-forestry include high price of grafted seedling (21.6%) and infestation of fruits by fruit flies (35.1%). One grafted fruit seedling costs TZS 3,000.00 at the Sokoine University of Agriculture, a price which was reported to be high by indigent farmers who wished to plant more trees, but had insufficient money to buy more seedlings. All farmers lacked grafting technology for fruit tree seedlings, but they wished to have it because they were aware that, unlike non-grafted trees, the

grafted trees bear first fruit not less than three years after being planted in the field. Only 41.7% of farmers who had land with secure tenure grew fruit and non-fruit trees on their farms or homesteads while 11.7% rent the farming land temporarily from owners through informal arrangements. The rest squatted on public land for cultivation of vegetables. Farmers who rent farming land enjoy the usufruct right of using the land by growing semi-annual crops and vegetables with short growing cycle, such as amaranth, carrots and spinach intercropped with trees or grown separately. Four extension officers reported that extension services provided to farmers in the study areas largely insist on farming activities intended to increase agricultural productivity and food security. All four environmental officers reported that agricultural related training and extension services are not specifically dedicated to the promotion of agro-forestry farming practices.

Some of the wood and timber trees grown on the farmers' field are left to grow freely and untrimmed, making perennial crops unable to grow well when intercropped by them. One of the respondents reported that the roots of large Neem tree-*Azadirachta indica* (Mwarobaini) dry up the soil around the trees hindering growth of other perennial crops. Forty-two per cent of the respondents mentioned that hill forests closer to their homestead provide habitable places for monkeys. The monkeys destroy premature crops such as maize, banana and mangoes; and it is difficult to control them. Four environmental officers, who were also ecology promoters, mentioned that wild animals, including monkeys should not be killed because they constitute both wildlife habitats and ecological balance respectively. One of the farmers reported that even in urban Agrovets, the type of poison for killing wild animals were illegal and their transactions were forbidden. However, the critical challenges here were making a comparative analysis of poisoning monkeys because they destroy food crops which matter most to people or tolerating them because they restore ecological balance and natural conservation. The victim reported that, since the area was not a forest reservation, the ideal to poison the monkey seemed relatively more grounded and justifiable.

During data collection, the researchers noted fodder grasses cultivated along the base-slopes of Uluguru Mountains within the study areas. The respondents reported that some grasses such as Vetiver grow naturally. Other grass types are intentionally planted by farmers as fodder, and used to intercept rainwater runoff that could otherwise cause soil erosion. The study reveals that only farmers and community residents who own land and who were aware that grass control soil erosion grew them. However, farmers in town, who keep livestock under indoor-system, buy extra fodder during the dry season, but farmers in the study areas had poor knowledge of how to make hay. Besides that, the undulating terrains along the slopes of Uluguru Mountains do not facilitate the mechanized process of grass mowing for hay making.

The strengths, weaknesses, threats and opportunities of agroforestry systems are indicated in Table 2. SWOT result shows that a reason for farmers to engage in agriculture is linked more to food and income than conservation of environment protection through agro-forestry, but balancing the two is accompanied by serious threats.

Table 2

SWOT's results of the normal agricultural practice versus agroforestry systems

	Normal agricultural practice	**(%) Multiple response (n = 189)**	**Agroforestry system**	**% Multiple response (n = 128)**
Strengths	Provide food for subsistence	14.8	Provide environment and ecosystem services	8.0

	Provide employment opportunities and income	21.7	Help community members to meet their livelihoods	18.0
Weakness	Excessive use of synthetic pesticides and fertilizers may impair human health, degrade soils and pollute the environment	10.1	Land degradation and deforestation is due to uncontrolled agricultural activities	8.6
	Lack of coordination among actors to manage agricultural practices	9.0	Lack of actors' collaboration in the management to agro-forestry systems	16.4
Opportunities	Availability of agricultural research, agricultural officers and supportive policies	5.8	Restoration of fauna and flora species, and conserved environment are supported by relevant policies	10.2
	There is a possibility of farming techniques to improve agricultural productivity without degrading the environment	6.9	Use and conservation of natural agro-forestry resources are strictly regulated by bylaws	13.3
Threats	Severe crop destruction by wild animals	20.6	Increasing demand of the food associated with uncontrolled agriculture affect agroforestry activities	18.6
	Limited access to agricultural land and unregulated land use competition for residential and conservation activities affect agriculture	11.1	Over harvesting of forest for charcoal, timber and firewood risk sustainability of agro-forestry	7.0

Non-chemical control of diseases and insect pests

Farmers (23.3%) reported that despite growing diverse crops in alternating periods, still their crops are infested with insect pests and diseases which are only controllable or treated using specified synthetic chemicals. However, synthetic chemicals are effective as they target specific pests; their applications contravene organic farming principles. The study revealed that some of the crop pests and disease were hardly controlled or treated by using organic chemicals. All the farmers had limited knowledge about crops that are resistant to insect pests or plant extracts that are effective in controlling targeted pests, such as aphids. The farmers who grow crops in the rotation reported that some of the crops are also affected by insect pests which can be treated using specific synthetic chemicals. Organically grown leafy vegetables when infested with insect pests and diseases, farmers opt to use synthetic chemicals because they are available and effective. Organic chemicals are not adopted because they are not available. All sixty (farmers) respondents reported that adopting crop rotation does not mean that all insect-pests are naturally and permanently controlled. All farmers reported

that they did not know a place in Morogoro Municipality where organic chemicals were being manufactured or sold. Apart from that, the farmers questioned the efficacy of organic chemicals which are not thoroughly researched. All four agricultural officers from four wards reported that currently organic chemicals are not subsidized by the government and no monetary or facilitation incentives promised or provided to the existing manufacturers.

Organic manure versus inorganic manure

The use of agrochemicals adversely affects the environment, but about 65.0% of farmers reported that when they grow crops without applying industrial fertilizers or chemicals, the production decreases which is contrary to when they use them. These farmers also reported that they never got health problems or received complaints from the customers to whom they sell agricultural crops grown using industrial fertilizers. One of the farmers reported that from January to March, 2023, the government provided a TZS 52,000.00 as a subsidy to every 50kg bag of all category of inorganic fertilizers such as NPK, CAN, DAP and Urea. This was an indication of official recognition of farmers in the whole country, including interested farmers in the study areas. But, the farmers were not aware of subsidy of organic manure and its related inputs.

On the contrary, the respondents further reported that organic manure such as compost was labour intensive both in terms of production and application, very bulky and used in large quantities. It is also difficult to be transported from where they are available, especially from a farmers' homestead to farms and garden locations especially in the sloping terrain where roads are in bad conditions. This in turn increases agricultural production cost. The agricultural officers from SAT reported that conversions of organic inputs into a form of manure, which can easily be soluble and used as nutrient by the plant in less amount involve chemical processes, which may amount to inorganic compounds. In the study areas, organic manure is made through composting technology or obtained from livestock keepers. Yet manure such as farm yard and chicken manure from livestock depends on the number of livestock kept under the indoor system by residents. Livestock keepers in this category were reported by respondents to be limited in numbers. The number of farmers adopting organic and inorganic farming is indicated in Table 3.

Table 3

Adoption of different farming practices

Farming practice	Mlimani (n=15)	Bigwa (n=15)	Kilakala (n=15)	Boma (n=15)
Organic farming	0.0%	0.0%	0.0%	0.0%
Inorganic farming	66.7%	60.0%	63.3%	53.3%
Both	33.3%	40.0%	36.7%	46.7%

The results showed that despite the ongoing awareness creation on agro-ecological practices, especially by donor funded organizations and research institutions, inorganic fertilizers and synthetic pesticides are still used by farmers in the study area, either independently or complimenting with organic practices. For example, 36.0% of all farmers used farm-yard and chicken manures as basal dressing in growing horticultural crops and CAN as a top dressing. Some leafy vegetables, such as amaranth, collard greens and spinach grown using farmyard manure are sprayed with booster containing inorganic compounds. One agricultural officer from SAT said that carrots are top-dressed with potassium and phosphate fertilizers to promote tuber growth, but this may challenge organic certification procedures when tracing the last time when the synthetic fertilizer was applied to the plant.

Training of farmers

Respondents in Kilakala and Mlimani reported that in 2014 farmers who were interested and others nominated by ward agricultural officers participated in a six-day workshop training about

organic farming. The training was organized by SAT and 34.0% of the respondents participated in the training. In 2022, farmers in Morogoro Municipality and Morogoro Rural District, including 16.0% of farmers from Mlimani and Bigwa attended a three days training about agro-ecological farming (Figure 2).

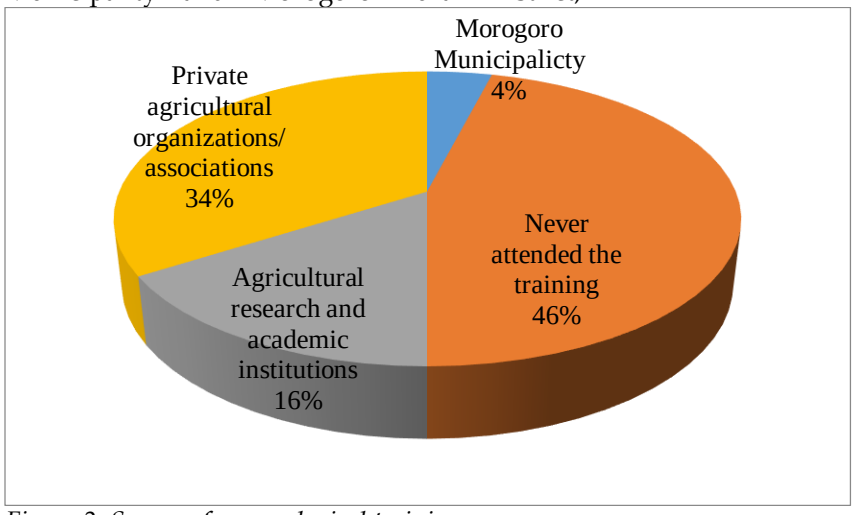

Figure 2. Source of agroecological training

The training was done by Sokoine University of Agriculture researchers under the support of Agroecological Methodology in Vegetable Crops (AGROVEG) project. The participants were trained on how to produce crops without causing health problems to farmers and consumers and affecting the environment. The two trainings were relevant to agro-ecological practice, but they were not succeeded by evaluation on how farmers were capable of applying the knowledge gained from the training into practice. The issues related to irrigation water, land scarcity, inadequate capital, availability of good natural seeds and organic inputs were not envisioned in the training objective. Apart from agro-ecology and organic farming training done by non-government bodies, 4.0% of the respondents had participated in training on conservation agriculture organized by Morogoro Municipality while 46.0% reported that they had not attend any agricultural related training.

The results showed that some farmers attend agricultural training with some incentives such as per-diem to the trainees even if they are not interested in the knowledge to be gained. The agricultural training run by the government that was unlikely to include per-diem hence was rarely attended by many participants. The farmers who also attended training but who did not own land and lacked capital to rent it and buy farm inputs could not practice the knowledge gained from the training anywhere. The training provided by government institutions still has a gap indicating responsiveness and support to agroecology sustainability. Government oriented agricultural training mostly focuses on creating awareness and support for increasing agriculture production to meet the food demand, but not to address fundamental and specific challenges of agroecology. The study shows that on average, farmers who use inorganic manure are 56.9% compared to 43.1% of farmers who used both organic and inorganic manure. This is opposed to the emphasis by experts from Sustainable Agriculture in Tanzania (SAT) who insist training in organic food farming. In turn, this limits harmonization of decisions targeting sustainability of agro-ecology practices.

Soil erosion control measures and conservation agriculture

Soil erosion was reported by 38.0% of the farmers interviewed that it contributes to low harvest of horticultural crops because most of the topsoil eroded contains organic matter. About 34.0% of farmers were trained by SAT experts about conservation tillage in 2016. Some horticultural crops, such as leafy cabbage and carrot were reported to grow better in a semi-tilled land along the hill slopes, but when the land is left without being mulched, the topsoil is eroded. Nineteen percent of farmers who adopted zero tillage reported that the practice somehow minimizes

soil erosion, but under this practice resists root development and tuber formation of some crops, such as carrots and beets.

Mechanical weeding was reported by the respondents to be laborious when farming is done on a no-till large farm while the use of herbicides were against the long-run quality of the soil. In order to support zero-tillage farming, farmers were advised to use cover crops and mulches to minimize the incidence of weeds, but mulches are not easily available in large quantities. Planting shrubbery wood trees and fodder grass minimize the intensity of soil erosion, but they are grown in a small quantity because they cannot be directly consumed or sold for cash.

The multiple responses of farmers regarding soil erosion control measures and conservation agriculture are shown in Table 4. The result shows that 40.1% and 31% of the farmers were not aware of soil control measures and conservation agriculture respectively. Hence, the government's efforts to create awareness to improve agricultural technology and adopt the same for increasing agriculture productivity and environmental conservation is minimal. However, 25.2% and 32.7 % of the farmers were aware of the roles of mulching/cover crops and agrofestry in agroecology respectively.

Table 4

Agro-soil erosion control measures versus conservation agriculture

Agro-soil erosion control measures (n=63)	%	**Conservation agriculture (n=60)**	%
Strip cropping	11.5	Mulching/cover crops	32.7
Bench terraces	23.2	Zero tillage	19.3
Agroforestry	25.2	Intercropping	16.0
Not aware	40.1	Not aware	31.0

Source: Survey, 2023

Institutional issues and agroecology practice

The Environmental and Natural Resources Conservation Bylaws of 2014 in Morogoro Municipal Council prohibit and penalty for environmental degradation and unauthorized extraction of forest resources. The bylaws were weakly adhered to by community members because they imposed control rather than promoting livelihood-based activities which are compatible and complement conservation initiatives. The study revealed that there were farming and charcoal making activities along the slopes of Uluguru Mountains which support farmers' livelihoods, but they were associated with soil erosion and deforestation. The members of ward environmental committees exist, but were not motivated to patrol the areas damaged by uncontrolled livelihood activities. There were also perceptions among community members that environmental sensitive areas are encroached upon for farming to meet the livelihoods needs. In this regard, they consider bylaws that hinder their ways of surviving as restrictive and unfriendly rather than supportive to their livelihoods.

The existing policies and bylaws lack clear provisions to guide on the way agro-ecological activities could be regulated and supported collaboratively. The study shows that there were no groups of organic food producers and government agencies specifically concerned with agro-ecology issues. The agricultural extension and institutions mostly target, increasing food production to meet increasing food demand. The farmers opined that organic farming produced less amount of food compared to crops grown using synthetic fertilizers and pesticides. Notably, the farmers were not aware of reliable markets where organically grown food through agroecology practice could be sold at a premium price. The results showed that there was no government commitment and budget for promoting agroecology practice. The local government authorities have power to regulate agricultural activities that contravene environmental conservation, but the implementation of regulatory measures that do not recognize farmers' and community members'

livelihoods or involve communities never succeed.

Discussion

The discussion of the results focus on the key attributes which the study was confined to.

The number of farmers who have no knowledge of crop rotation exceeded those who claimed to have the knowledge through long farming experience and attending agricultural training (Table 1). This implies that the agricultural training has not transformed fully the farmers' way of farming through crop rotation. However, since the farmers who were not aware of the crop rotation live in the same community with those who were aware of it, they can easily learn from their fellow farmers, but this was not the case in the study areas. The farmers who could not adopt crop rotation disregarded its contribution to agricultural productivity. This was due to the fact that even farmers who had knowledge of crop rotation do not adopt it persistently when they do not realize its positive effects on agriculture productivity or interruption of survival of insect pests. This is consistent with the research work by Constantine *et al.* (2020) who reported that farmers may wish to adopt a certain technology if they are likely to benefit from it.

Insecure land tenures and unfavorable climate limit the fallowing of land in successive growing seasons. This also implies that knowledge of climate change is inseparable from the aspects of crop rotation and agroecology practice. Undeniably, the issue of access to land and secured land tenure for agricultural activities constitutes the success of crop rotation and its related principles. The actual adoption of crop rotation is slow because some of its critical challenges are not addressed; hence lowering its anticipated benefits. This implies that immediate and long-run benefits of crop rotation cannot be realized amidst unsolved challenges. Consistent with the results, Kumawat *et al.* (2022) have noted that apart from farmers being trained on crop rotation, the challenges of good seed availability, severity of pest and disease attacking crops and the impact of climate change on the rotations limit the fully adoption and success of crop rotation.

Agroecology practices were not adopted by all farmers, ostensibly from the indirect benefits the farmers get, lack of knowledge and the challenges they face. Ordering farmers to get permits in order to harvest their trees grown in their farm discouraged them because the essence of integrating trees in a crop land was to meet livelihoods. Majority of farmer respondents wished to plant fruit trees, but they had no land with secure tenure and the price of grafted seedling was considered high and the government (Morogoro Municipality) still closes an eye on the matter. The tendency of the government leaving farmers to take their own initiatives to undertake agro-forestry without supporting them implies that the activity is neglected or less important. Failing to address insecure land tenure also hindered farmers to grow permanent trees in the farm land. Farmers whose land occupancy rights are not secure cannot undertake agroecology practice because assurance of reaping the long-term benefits is not guaranteed (Jha *et al.,* 2021).

Growing some tree species which were not compatible with crops adversely affected the crops. This was an indication of limited knowledge of agroecology despite the presence of government agricultural officers at Morogoro Municipal Council who could educate the farmers. The essence of agroecology is to increase agriculture yield while minimizing adverse effects to environment and ecology. But in the study areas, crops were being destroyed by wild animals, especially monkeys without any intervention by the municipal authorities. Regulating agroecology practice should be accompanied by analyses of how different components of agro-ecosystems are interacting (Marioara, 2019). From an ecological point of view, wild animals have to live, because they are part of the ecology set-up. Nevertheless, wild animals destroying crops cannot be tolerated while making farmers starve. The results imply that there are no coordinated ways among responsible stakeholders toward balancing ecology in the purview of wildlife conservation and food production needs. Their results corroborate those by Kadigi (2021) who

established that agroforestry farming cannot fully support livelihoods of the farmers and lead to conserved ecology dimensions when the challenges related to its practices are not regulated or managed collectively by responsible stakeholders.

Through SWOT analysis (Table 2), the results indicate that strengths of normal agricultural practices outweigh strengths of agroforestry farming. The strengths of agroforestry exist when it's related agro-forestry farming activities contribute to the livelihoods of the farmers rather than just protection of ecosystem services and environment. This implies that; agroforestry farming can be sustainable when its contribution is linked to farmers' livelihoods in terms of food and income. The weakness of conservation agriculture is attributed to excessive use of industrial fertilizers and chemicals, which increase agriculture production. This implies that unregulated and uncontrolled detrimental agricultural activities weaken the initiatives of conservation agriculture and sustainable agroecological practices. Mechanisms for regulating farming activities which are detrimental to soil and environment hardly succeed when they undermine stakeholders' livelihood interests (Dimelu *et al.,* 2013).

The results show that farmers could never let crops grown organically be infested with insect pests and disease while they could be treated using specific synthetic chemicals. The use of non-synthetic chemicals in controlling pests and disease could be an alternative to synthetic pesticides, but the latter are not readily available. Yet, their efficacy in controlling specific pests was questioned by farmers because the pest may remain alive even after application of the pesticides. These results are similar to that of Essiedu *et al.* (2020) who report that the use of bio-pesticides is challenged by limited lifespan and inconstancy in-field performance on the targeted pest or disease. The result implies that used organic pesticides could not be effective if not preceded by scientific investigations aimed to determine their effects in controlling pests or treating disease. Likewise, Emeana *et al.* (2018) noted that the effectiveness of organic treatments cannot be generalized to insect pests or disease because each of these has its perseverance level against the treatment applied or crop management practices adopted.

The information from ward agricultural officers revealed that the effect of organic manure in terms of increasing agricultural productivity is not questionable, but its frequency and improper uses impair the quality of soil and environment. In Table 4, the results show that the majority of farmers used inorganic manure independently and few of them complimented it with organic manure. The results indicate that organic and inorganic manure complement each other, but they do not substitute each other. Top-dressing of vegetable crops which initially were basal dressed with organic manure was adopted by farmers, but this weakens the quality of organically produced products. The use of organic manure amends the soil quality such as texture, water holding capacity and soil microbial activities that might be impaired by excessive use of inorganic manure. The results imply that the use of organic manure should exceed the use of inorganic ones. However, leaving farmers to fend organic manure and other organic pesticides while the government is subsidizing fertilizers alone implies that the government is either less concerned with organic manure or its use does not contribute substantially to the crop yield. The results corroborated with that of Constantine *et al.* (2021) who observed that the use of organic manure is narrowly adopted by farmers because its production is not directly supported and its use is not promoted by the government.

The results (Figure 2) show that training farmers about the aspect of organic farming and agro-ecology was rarely being provided by government agricultural officers. Instead, such training was provided by private agricultural organizations, associations and research institutions which were funded by the donor. The trainees sometimes are interested in the allowance paid by training sponsors. This has an implication that without donors' hands on the agroecology training, the agroecology training is not among the government priorities. The agriculture training done by government officials is done on important or crosscutting issues such as food security, increasing agricultural productivity and agricultural pest and diseases control as if agroecology is not part of them.

Agroecology training is regarded as less important partly because it is weakly supported in existing policy provisions and there is no government fund allocated to it. The government cannot promote and support the implementation of agroecological practice sustainability if its socio-economic and environmental incentive is not well articulated in the existing institutional structures (Mwamfupe, 2019).

Farmers' awareness of soil erosion control and conservation agriculture was emphasized by environmental officers, agricultural officers and experts from SAT. Sustainable agriculture and soil erosion control are among concerns of SAT. In general, the results indicate that the majority of the farmers were somehow aware of the soil erosion control measures and conservation agriculture. But being aware does not mean that they had the willingness and capacity to adopt them. The adoption of soil erosion control measures were tried by farmers, but not fully operationalized because limited access to land and insecure land tenure, availability of organic manure and local seeds adoptable to local climate and environment were left unsolved by government authorities. The results imply that awareness creation was not succeeded by identification of possible drawbacks to agroecology practice as well as suggesting the possible solutions. Awareness of soil erosion conservation provided to farmers cannot be put into effect if the actual knowledge is not supported by the government to make farmers realize the actual contributions of the knowledge to their livelihoods, beyond rhetorical awareness creation on soil and environmental conservation (Adidja *et al.,* 2019).

The results imply that existing bylaws that regulate uncontrolled farming practices cannot be effective while farmers and other community members are vulnerable to life-hardships due to food security or income instability. In practice, well managed agroecological practice can address the problems associated with food insecurity and environmental degradation due to unregulated farming activities. Synergistic decisions on promoting and regulating agroecology practice cannot lead to balanced agricultural productivity and minimized environmental degradation where there is weak cooperation and coordination among stakeholders operating under institutional frameworks. Synergistic decision making is likely to be successful when there is a common goal collectively and intuitively established, and supported by the policies 'provisions that outline the principles of actions to be implemented by stakeholders with different roles and harmonized powers (Place *et al.,* 2022).

Conclusions

The study concludes that despite the benefits of practicing crop rotation aimed at soil conservation, controlling pest and disease risk and enhancing crop production, the complete knowledge of agroecology is not fully adopted by the majority of farmers. Agroforestry practices is one of the aspects of agroecology challenged by insecure land tenure; a problem which is not addressed in collaboration with officials from land sector, agriculture sector and environmental sector and other agro-ecology promoters or supporters. Unsolved challenges of destruction of farmers' crops by wild animals also suggest the presence of little coordination between environmental officers, agricultural officers and farmers. Farmers somehow sensitized about the importance of agroforestry in terms of ecological and environmental conservations, but the direct benefits of agroforestry to their livelihoods is not fully met and appreciated.

The use of non-synthetic pesticides and chemicals cannot solely complement synthetic ones because their availability is limited and their efficacy is not guaranteed. The use of non-synthetic pesticides is not well researched and their application and management knowledge are not well communicated to interested farmers. In so far use of inorganic manure to increase agriculture produces matter most to farmers than having just protected environment or organically produced crops which do not guarantee them a premium price. The promotion, production of organic manure and subsidization of the same are ill-equipped by government institutions and agencies.

The agroecology training is not coordinated by government agencies, which have authority to inform the policy makers about agroecology

practices and issues of insecure tenure and limited access to land that hinder production of perennial crops and undertaking long-term agroforestry practice. Agro-soil erosion control and conservation agriculture measures are essential features of agroecology training, but some farmers were not aware of them and those who are aware do not adopt them effectively. Inadequate stakeholders' participation and coordination to regulate, promote and support agroecology practices weaken institutional interventions to support and make farmers realize the livelihood benefits linked to agroecology practices while protecting the environment.

Recommendations

The study recommends that stakeholders and institutions related to sustainability of agroecological practices from departments of agriculture, forest, environment and land should be identified and their duties toward sustainability of agroecology become more obligatory. Existing institution frameworks such as policy and regulations relating to agriculture, forest, environment and land issues should not only recognize agroecology but also identify its key challenges and suggest tentative solutions. The government and community stakeholders should collaboratively find possible solutions of agroecology while exploring more opportunities for its sustainability. The activities related to agroecology in terms of training, excursion, making and distribution of organic inputs and implements, promotion of agroforestry and soil conservation should be clarified in the sections of relevant policies. There should be a government oriented mechanism to set a budget and evaluate its implementation in supporting financial and technical issues of agroecology sustainability. Agroecology and its related concepts and components should be introduced in the curriculum of ordinary and tertiary education. This in turn will create awareness of the benefits and challenges of agroecology to agricultural officers in government and private institutions.

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