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A Diagnostic Study of Climate Change, Production, and Use of Organic Fertilizer in Regional Gambia

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ABSTRACT: The study was conducted to shed light on the current landscape of agroecology and organic fertilizer practices in the Gambia. Agriculture, a significant contributor to greenhouse gas emissions, faces challenges that agroecology seeks to address by integrating ecological principles into farming practices. This study aimed to enhance knowledge, promote research, and influence policy for promoting and implementing organic fertilizer practices crucial for sustainable agriculture and food security in The Gambia. A mixed method approach was employed to collect data through questionnaires from 1713 farmers from all five farming regions of the Gambia. Findings revealed a significant engagement in organic fertilizer production, despite challenges such as inadequate materials and inconsistent government support. There's a clear demand for better quality materials, consistent support, and comprehensive training programs to enhance organic fertilizer production. There's a call for more consistent and accessible support to promote the widespread adoption of organic fertilizers and sustainable agricultural practices. Overall, the study underscores the importance of addressing gaps in knowledge acquisition, tools, structures for the production of organic fertilizer, and policy awareness to foster sustainable agricultural practices in The Gambia.

Keywords – Agroecology, Organic Fertilizer, Rural Gambia, Farming systems, Production challenges

I. INTRODUCTION

Food production addresses one of the most fundamental human needs and has evolved in tandem with humanity to ensure consistent provision, food safety and variety, and improved nutritional composition [1], [2], [3]. Currently, food production meets a basic need as well as a variety of social, cultural, and even aesthetic needs and desires[3]. However, with the need to feed seven billion people, food production has a significant environmental cost[4], [5]. Farming practices have depleted the Earth's resources and contributed significantly to greenhouse gas emissions, low soil fertility and biodiversity loss, water scarcity, and the release of large amounts of nutrients and other pollutants that degrade ecosystem quality[6]. If nothing changes in the way we produce and consume food, and given the need to increase food production by more than 60% by 2050[7], [8], the environmental impacts of food production systems will worsen and increase across planetary boundaries[3]. Improving food production and consumption systems is central to all discussions about sustainable development, from both environmental and socioeconomic perspectives.

From a historical perspective, the Green Revolution has significantly increased global agricultural production, but at the expense of environmental and natural resource degradation[9], [10], [11]. Food production was restricted in many regions due to factors such as a lack of land, water, and access to capital[9]. Furthermore, studies show that, in general, technology bypasses the poor, who are unable to benefit from agricultural technologies due to poor land governance, difficulty obtaining inputs and credits, barriers that limit their access to the market and its opportunities, and unfavorable policies such as subsidies that discriminate against them[6], [9], [12]. Numerous studies suggest that small-scale farmers in developing countries play an important role in food security[13], [14], although they account for the vast majority of food-insecure people worldwide[9]. Many researchers, including [1], [13], [14], [15] have proposed organic farming as an environmentally friendly agricultural production system. Organic farming (using organic fertilizer) is thus a holistic production system that takes into account long-term environmental sustainability and primarily aims to produce food in an environmentally friendly manner[1], [15], [16], [17]. Organic fertilizer provides environmental benefits such as biodiversity conservation, improved soil quality, reduced evaporation and water harvesting, strengthened adaptation strategies, reduced greenhouse gas emissions, and increased energy efficiency. Using organic fertilizer aligns with the goals of environmentally friendly production, improving animal health and welfare, and promoting high-quality products[9]. The International Federation of Organic Agriculture Movements (IFOAM) defines organic farming as being based on four basic principles: health, ecology, fairness, and care for people and ecosystems.

1.1 Definition of Agroecology

Agroecology: In this study, agroecology is defined as agroecology is the integration of research, education, action, and change that brings sustainability to all parts of the food system: ecological, economic, and social.

Organic fertilizer: In this study, organic fertilizer is defined as materials primarily created by composting animal manure, or plant matter (such as straw and garden waste) with microorganisms that fermented at high temperatures with a specific chemical composition and high nutritional value that can provide sufficient nutrients for plant growth.

1.2 Purpose of Study

The overall objective of the study was to strengthen the capacities of small farmers in The Gambia to engage in policy dialogue at the national and regional levels, as well as in the implementation of ecological practices that include the production and use of organic fertilizer. Furthermore, the study aimed to strengthen the research, promotion, production, marketing, and use of organic fertilizers in the Gambia and to promote the consumption of diversified food items produced using organic fertilizers. Thus, the study is significant for pivoting farming systems and the use of organic fertilizer in the Gambia.

1.3 Study Area

The present study areas were limited to the Gambia regions: North Bank Region (NBR), specifically Nuimi and Central River Region (CRR) North and South, Lower Fullado and Upper/Lower Saloum respectively, LRR and URR. The Gambia is the smallest country in mainland Africa, covering approximately 11,000 square kilometres and bordered by Senegal on all sides except the Atlantic coast. Administratively, the country is divided into five regions (West Coast, North Bank, Central River, Lower River, and Upper River) and two municipalities (Banjul and Kanifing)[18]. The Gambia is a low-income West African country where agriculture is practiced by two-thirds of the population. Peanuts are the primary export crop, while rice, millet, and sorghum are traditionally grown for food. Over the second half of the twentieth century, The Gambia became increasingly reliant on rice as a dietary staple, but the country's farmers were unable to increase their market share of the burgeoning urban rice demand[19]. Socioeconomically, the regions of The Gambia are not dissimilar. Thus, there are shared geographical and socio-economic characteristics among regions of The Gambia except for the West Coast Region (WCR) which is closer to the Atlantic Ocean and therefore has a different typological weather indicative of coastal regions. Generally, CRR is further east of the Gambia often referred to as rural Gambia. See fig. 1 for study area.

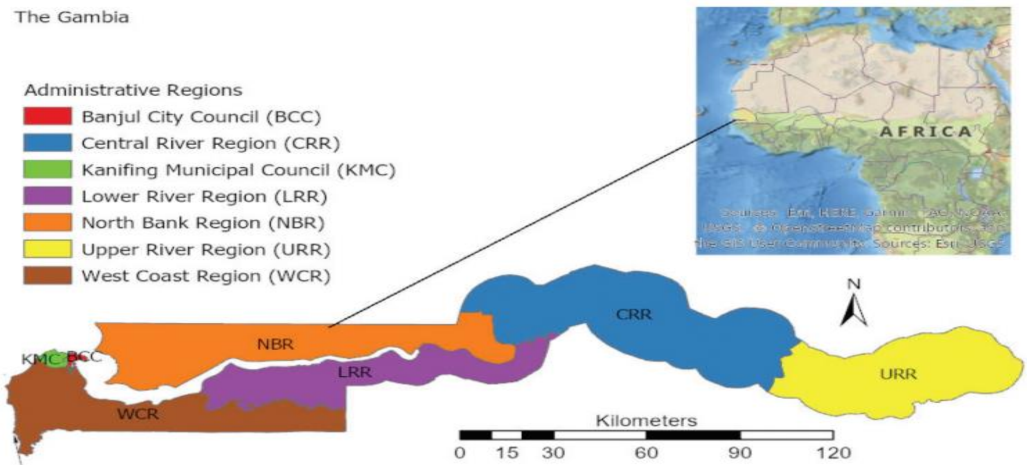


figure.1 Source: [20]

II. PROBLEM STATEMENT

Climate change and variability have had and will continue to have a significant economic impact in the Gambia. More than 98 percent of agricultural lands are rain-fed, making the agriculture sector extremely vulnerable to rainfall fluctuations. The yields of major crops fluctuate by up to 100% per year[21]. The productivity of these crops has decreased dramatically due to a lack of improved technology, declining soil fertility, and climate variability[22]. Crop productivity, such as maize, groundnut, and millet, is expected to suffer as the amount and distribution of rainfall decreases due to rising temperatures[22]. The Gambia's low-lying topography, combined with an overreliance on subsistence rainfed agriculture, inadequate drainage and storm management systems, and a high demand for rural-urban migration, has made it one of the most vulnerable countries to climate change. This vulnerability stems from widespread poverty and a lack of adaptive capacity to withstand the effects of such changes. Limited access to resources to cope with changing lifestyles, particularly during food supplies, and limited access to risk-spreading mechanisms make many households highly vulnerable to the vagaries of current and future climate change [23].

Environmental issues have also featured in The Gambia's Agriculture and Natural Resources (ANR) policies, starting with the (ANR) Policy (2009–2015), which identified the environment as one of the cross-cutting issues [18]. For this reason, the ANR Policy (2009 - 2015) identified several environmental policy objectives, including increasing nationwide awareness about environmental degradation, mainstreaming environmental considerations in the planning and implementation of all activities in the ANR sector, enforcing policies, guidelines, and legislation to ensure sustainable environmental management, and protecting the environment from agricultural and related land-use[18]. In the same vein, the ANR Policy (2017 – 2026) includes a number of environment-related policies such as mainstreaming climate change issues in policies, programs, and projects, creation of local conventions on NRM, and ensuring judicious and proper use of agricultural chemicals (fertilizers and pesticides)[18] Thus, Strengthening CSO Support and Advocacy for Sustainable Production and Use of Organic Fertilizer in The Gambia (SAPOF), is apt as one form of climate action as it relates to agroecological activity of the Gambian farmer who is encourage to engage in the production and use of organic fertilizers.

Small farms are estimated to feed roughly half of the world's hungry people[24]. To combat global food insecurity, it is imperative to prioritize the needs of small-scale farmers in developing countries[9]. Many developing countries, particularly those in Africa, face a slew of issues that must be addressed to improve the sustainability of food production. To address all of these issues, many researchers have identified low-external input sustainable agriculture as a preferred development strategy for the problem of food security[9]. Integrated farming, agroecological practices, pest management, and, in particular, organic farming are the most important sustainable agriculture systems introduced in recent years[9].

There is compelling evidence to support the claim that organic farming can contribute to food security[14], particularly in certain regions such as Africa. On the other hand, in developing countries where the majority of farmers are small-scale, the conventional agricultural system fails to meet the basic needs of resource-poor farmers[9]. This is due to their inability to afford costly synthetic inputs, demonstrating how poverty and food insecurity frequently coexist[9]. As about three-fourths (70%) of the poor in the world are living in sub-Saharan Africa and Asia, investing in agriculture is an effective strategy to improve their livelihood[5,9]

This study is critically important as organic fertilizer production has received much attention in the literature. Organic amendments' impact on crop yield and soil fertility has been studied extensively around the world, and it has been identified as critical for sustainable agroecosystem management[25]. For example, Kwesiga et al. (2020)[26] investigated the effects of repeated applications of green and farmyard manures on rain-fed rice performance in East African rural floodplain environments and discovered that both amendments resulted in a significant increase in grain yield (18-62%), with a positive residual effect on non-amended rice yield in the third year, as well as increased soil fertility. Thus, there is enough evidence available even though researchers have paid little attention to these systems – to suggest that agroecological technologies promise to contribute to food security on many levels[27]. This is particularly important for The Gambia as an agriculture-based economy. The use of organic manure and compost has been shown to improve the soil organic matter content, water infiltration and retention, and the available water content of soils by 58–86%[28].

III. LITERATURE REVIEW

The Gambia has an agrarian economy, with more than half of the total arable land area (558,000 ha) dedicated to some form of annual agricultural production.[29] The country is divided into three distinct agroecological zones (AEZs): AEZ1, AEZ2, and AEZ3, all of which suffer from widespread land degradation caused by deforestation, desertification, and biodiversity loss. These zones run along the River Gambia, cutting through the administrative regions. These agroecological zones support agricultural crop and livestock production. The following table shows the country's AEZs.

Table 1: Broad characteristics of the three agroecological zones in The Gambia

AEZ	Name	Average Rainfall (mm}	Length of growing period (days)	Vegetation
1.	Sahelian	< 600	< 79	Open savannah
2.	Sudano-Sahelian	600-1100	70-139	Savannah Woodlands
3.	Sudano-Guinean	< 1200	140-150	Woodlands

Source:[29] Adapted from the Report on consulting services for Gambia agriculture transformation program (2020-2030)

AEZ 1 is the smallest of the three AEZs, located in the far north of Central River Region (CRR North).[29] [18] The zone consists of the following districts:

1) Upper Saloum,
2) Lower Saloum, and
3) Nianija

The districts have a total land area of approximately 568 km2 and a sparse human population of 43,995 people (2013 Population and Housing Census)[29], who live in a few large settlements. The zone's population density was estimated to be 77 people per square kilometer. The zone's topography is generally flat, with soil types ranging from non-saline colluvial and alluvial (in wetlands and swamps) to sandy loam soils in the uplands. The climate is Sahelian Woodland Savannah, with a short rainy season from July to October and a long dry season from November to June.

The average annual temperature in the zone is 290 degrees Celsius, the average annual rainfall is less than 600 millimeters, and the cropping season lasts less than 79 days.[29] This makes the area prone to drought and water stress. Its vegetation is primarily open savannah, with shrubs and grasses dominating. The zone's forest resources supply domestic energy (fuel wood), timber (poles, posts, and other building materials), utility requirements, and resources for local medicinal treatments and wild fruits. Non-wood forest products also provide honey to the local population, which serves as a source of income and a food reserve, helping to ensure food security, particularly during the hungry season. The presence of large cattle herds in the zone may also contribute to the overgrazing of the available natural vegetation cover. The majority of the remaining forests in the zone are open forest types, growing on shallow soils with underlying hardpans. The forests that once existed on the deep soils have been lost due to farming encroachment, leaving only a few economically important tree species, such as the bush mango (Cordyla Africana, a food source) and nitrogen-fixing trees.[29]

The farming system commonly practiced in this zone is traditional mixed farming, in which smallholder resource-poor farmers produce crops and livestock side by side. Crop production is primarily carried out on arable land, which is characterized by soils with a low water-holding capacity and thus prone to erosion. Most farm activities are limited to rain-fed agriculture (some farmers use animal traction), and the main food crops grown are cereals (maize, early and late millets, sorghum, and rice); cash crops are groundnut and sesame. Early millet and groundnuts are the most important crops grown in the zone, with low production and productivity owing to the limited use of chemical fertilizers and their high cost, low rainfall of less than 600 mm, and a short growing season of less than 79 days. Crop varieties with a growing period greater than 79 days will not thrive in this agro-ecological zone.[29]

AEZ 2 is classified as Sudano-Sahelian vegetation, with a growing season ranging from 70 to 139 days and a rainfall range of 600 to 1100 mm.[29] The zone's total land area is 418,742 hectares, with a population density of 156/km2 in 2012.[29] AEZ2's landscape is characterized by rolling plateaus interspersed with gallery forest or swampland basins. Except for the extreme north of CRR, the easternmost part of URR South, and the westernmost parts of NBR and WCR, the AEZ 2 encompasses the entire country's agricultural region. Notably, the Central River Region (CRR) and Lower River Region (LRR), which contain extensive areas of swampland, mangroves, rice fields, barren flats, and water surface, account for approximately 79% of the zone's lowland ecosystems.[29] “The rice ecologies are threatened by salinization caused by shortfalls in rain, resulting in salt-water intrusion upstream into the river and its tributaries, as well as by the emergence of potential acid sulphate soils.”[29] (p.28)

In contrast, the uplands have sandy-loam to silt-clay-loam soils that are low in nutrients.Upland soils, particularly in the NBR, LRR, and CRR, are typically less than one metre deep and consist of a layer of lateritic hardpans. Furthermore, the high sand content of these soils, combined with their shallowness, makes them highly susceptible to erosion and leaching. Although soils in WCR are typically deeper than those in other parts of the zones, they are still fragile and vulnerable to erosion and nutrient depletion. The vegetation is fairly open. Forest with scattered trees (usually under 15 meters tall), grasslands, and farmlands. Common trees belong to the *combretaceae* family and exist in this zone, indicating the presence of impoverished soils caused by the destruction of the original valuable vegetation cover or soil shallowness.[29] Parts of AEZ 2 in the West Coast Region (WCR) and Lower River Region (LRR) are characterized by the presence of tall Andropogon grass, while the remainder is covered in Meriscus grass. The abundance of grass in the zone makes it vulnerable to frequent severe fires, which have a negative impact on the soils and woody vegetation cover.

AEZ 3 is in the Sudano-Guinean Zone and has an agricultural population of 163,727 (out of a total population of 587,393), making it less agrarian than AEZ 2.[29] The zone falls within the 900 to 1200 mm rainfall isohyets, has a 140-150 day growing season, and receives roughly 80% of its total rainfall between late July and early to mid-September.[29] Maximum daily temperatures range from 280 to 290 degrees Celsius. It takes up the entire West Coast Region, including much of the western third of the country and the southeastern portion of the Upper River Region. Its topography is distinguished by relatively rich and dense vegetation (now less densely vegetated) comprising more than 50 tree species**.**[29]

The soil texture in this zone varies from clay to clay-loam, loam, and sandy loam. Soils along riverbanks become hardpan, friable, and tillable in moist lowland ecosystems, and sandy and poorly structured in upper plateau areas. Nonetheless, some lowland ecosystems that experience extreme weather conditions during the long dry season cause increased salinization of the River Gambia in its lower reaches, west of Carrol's Wharf and beyond, up to Tankular in the Kiang district.[29] The vegetation is savannah woodland, which is gradually turning into woodland in some areas, with *Acacia spp*., *Cordia spp*., and oil palm trees dotting the lowland ecologies, where rice cultivation is predominant.[29] The zone resembles humid tropical forest vegetation in parts of the Lower Nuimi and Kombo South Districts. Horticulture production (fruits and vegetables) is popular in this region due to its favorable climate. Horticultural production has the highest potential for providing additional food sources, on-farm income, and export earnings in the zone.[29]

The main upland crops grown in this agro-ecology are early millet, groundnut, rain-fed upland and lowland rice, maize, vegetables, cowpea, cassava, sesame, and fruit trees (mango, citrus, etc.). This zone is most important for horticultural production, which includes small-scale backyard and private gardens, medium to large commercial farms, and communal village garden projects. These crops are grown in smallholder plots on an individual basis. Women grow mixed vegetables in small plots near underground water sources that can be tapped for vegetable irrigation.[29]

IV. METHODOLOGY

The present diagnostic study adopted a mixed-methods approach, combining both quantitative and qualitative methods to gather a holistic understanding of agroecology and organic fertilizer practices in The Gambia, and drawing data from horticultural marketing federations in NBR and CRR (North and South). Studies of farming systems with similar objectives to the current study are typological mixed methods analyses to classify prevailing practices among farmers and identify farmer characteristics that determine their proclivity to engage in those sets of practices[30]. Such analyses typically use multivariate statistical approaches with a variety of techniques[31]. The most commonly used techniques in this regard are factor analysis (FA), principal component analysis, and cluster analysis[32]. The usefulness of each of these techniques is situation-dependent. From the literature, we identified a universal set of observable organic fertilizer use decisions to support possible sub-sets of decisions by farmers in the study area. Since there is no prior information about how farmers make organic fertilizer decisions, we could not assume any number or nature of expected factors. Hence, the present study applied exploratory factor analysis on observed decisions/actions of farmers to identify common factors/challenges and opportunities engaging in agroecological and organic fertilizer practices. Thus, based on the objectives of the study, the nature of the study was exploratory. Hence the study adopted an exploratory research design using a micro survey (questionnaire and focus group discussions). The study was conducted in three main phases: preparatory phase (1), data collection phase (2), and data analysis phase.

4.1 Population

The population of the present diagnostic study represents the households in the respective districts of the 5 rural regions in the Gambia (NBR, CRR-North &South, LRR, and URR); the largely farming communities in the Gambia. Therefore, the study targeted households in the farming communities in the districts of the regions mentioned above. The population (No. of households) for the study consists of 31 districts with 99549 households. See Table 6 for the number of districts and households in the study area.

4.2 Sampling

The population of this study was stratified first by regional population, followed by farming districts, followed by farming households, and finally active farmers male or female. The respondents were randomly selected in their respective districts. Stratification of the population was necessary to achieve the aim of the study's participant representation. Farming communities are found in all five regions of the Gambia. However, this diagnostic study requires that participants are sourced from specific farming communities. Thus, stratification of the population started with: strata (1) identifying the communities of interest regionally; strata (2) as per the scope of the study, regions LRR, CRR-North & South, and URR were selected; strata (3) identifying farming districts in the selected regions; strata (4) identifying farming households in the community, and lastly strata (5) identified farmers (Male and Female) for participation in the study. Furthermore, the difficulty in accessing all rural households of the regions warranted the use of stratified sampling. Therefore, stratified sampling was appropriately used to ensure that the study obtained an accurate representation of the Gambian population of which a significant number (approximately 70% of the population earn their living through agricultural engagement). Moreover, samples obtained from the stratification of the farming regions were sufficiently representative of the farming households in the specific geographical locations (scope). Moreover, stratified sampling approach was the most appropriate for the present diagnostic study because of the availability of information (list of households in the regions/districts provided by Gambia Bureau of Statistics(GBoS)[33]. The present study was only able to access the list of farming households in the Gambia using GboS data. Thus, the present study determined 50110 farming households (krejcie and Morgan formula to determine the sample size of the study-1713). Questionnaire distribution by district in a region was calculated based on the proportionate-to-size method: (district household size/region household size x sample size).

4.3 Findings

4.3.1 Engagement in Organic Fertilizer Production

Engage in organic fertilizer production (overall)

Figure 2 shows the level of engagement of the respondents on organic fertilizer production for the implementation of agroecology in five (5) rural farming regions of CRR-North, CRR-South, LRR, NBR, and URR. The overall results revealed that 64% of the respondents are not engaged in organic fertilizer production in their communities, while 36% said they are engaged in organic fertilizer production for the implementation of agroecology in their communities. These findings imply that the amount of organic fertilizer being produced locally by farmers is significantly small to be able to solve the problem of low soil fertility and reduce the usage of chemical fertilizer in the country.

Regional Comparative Analysis on the Organic Fertilizer Production

The regional comparative analysis of the respondents' engagement in organic fertilizer production is shown in Figure 3. The results reveal that the highest percentage of the respondents who practice organic fertilizer production are found in CRRN (87%) followed by URR (76%), CRRS (75%) and LRR (50%). The NBR had the lowest percentage of respondents (29%) who are engaged in organic fertiliser production to implement agroecology in their communities. Therefore, the result of the findings implies that the level of organic fertilizer production and usage for implementing agroecology in NBR and URR is significantly lower than in the rest of the regions in the country.

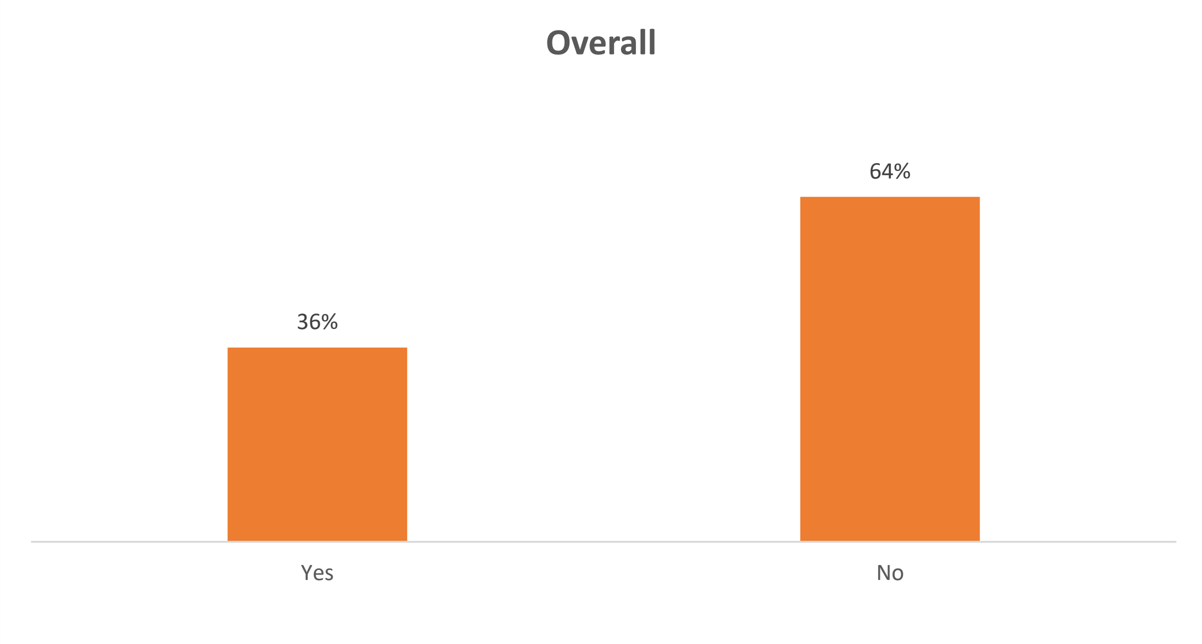


Figure 2. Metrix

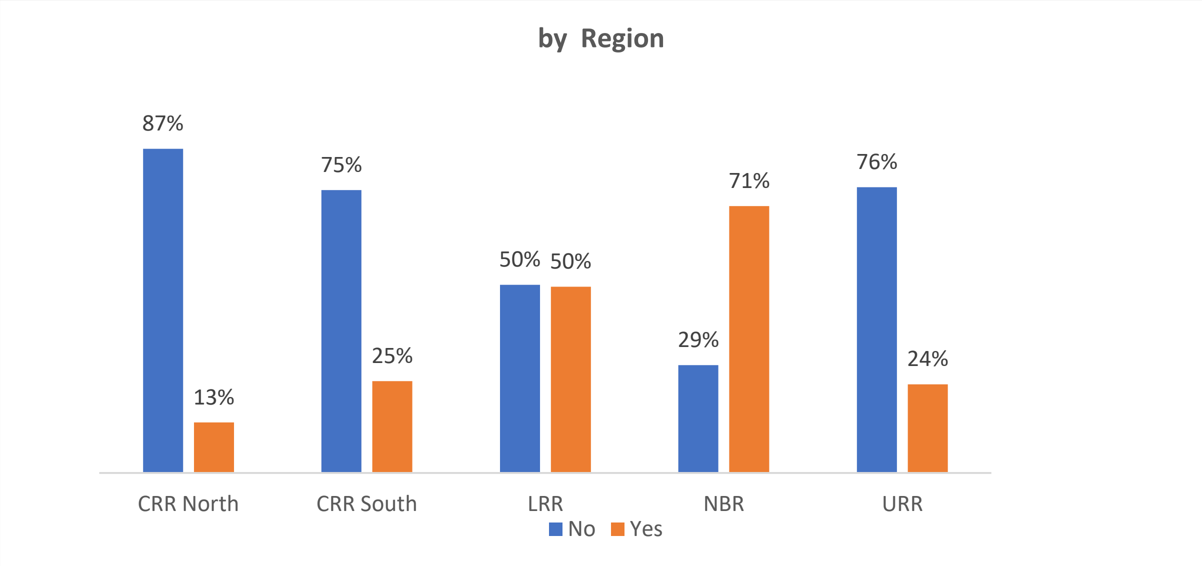


Figure 3. Regional Comparison

4.3.2 Structures for the production of organic fertilizers

Regional Comparative Analysis on the structures for the production of organic fertilizers

Figures 4 & 5 below report diagnostic study results on the Regional Comparative Analysis of structures for the production of organic fertilizers in each of the five (5) rural farming regions of CRR-North, CRR-South, LRR, NBR, and URR. Most of the respondents in all the regions stated the use of no structures for the production of organic fertilizers. The CRRN had the highest percentage (88%) of respondents who mentioned the use of no structures for the production of organic fertilizers, followed by URR (78%) and CRRS (68%). On the other hand, NBR recorded the highest percentage (37%) of the respondents with the use of compost pit as their structures for the production of organic fertilizers, followed by LRR (35%) and CRRS (26%). All the regions indicated a very low percentage (not more than 5%) of respondents with the use of biogas plants. The use of drums for organic fish fertilizer production was only observed in NBR (5%) and not practised in other regions.

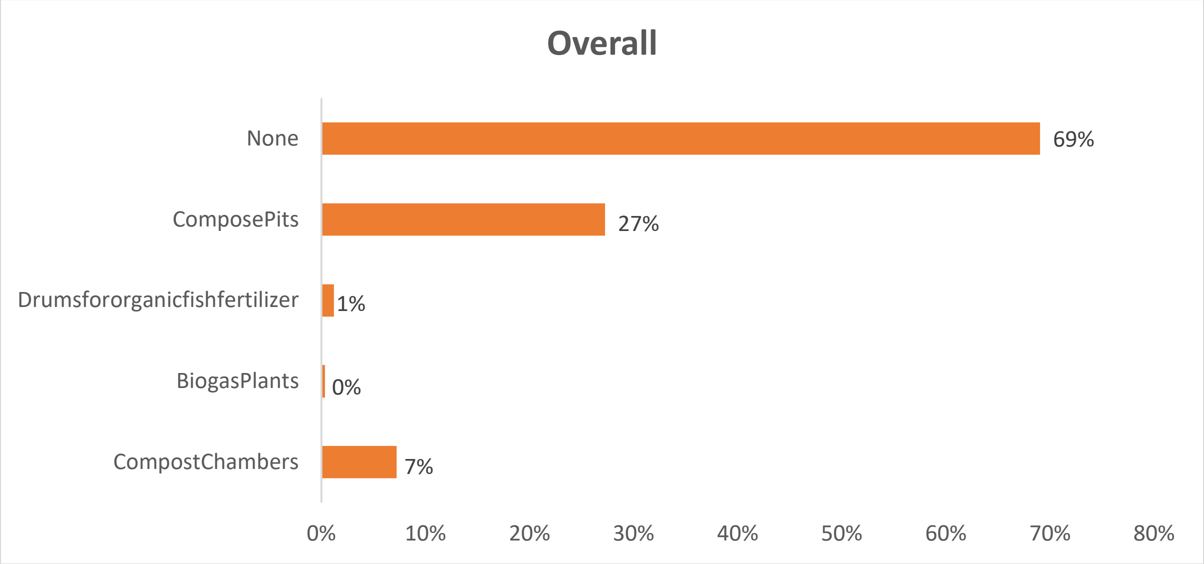


Figure 4. Regional Comparative Analysis

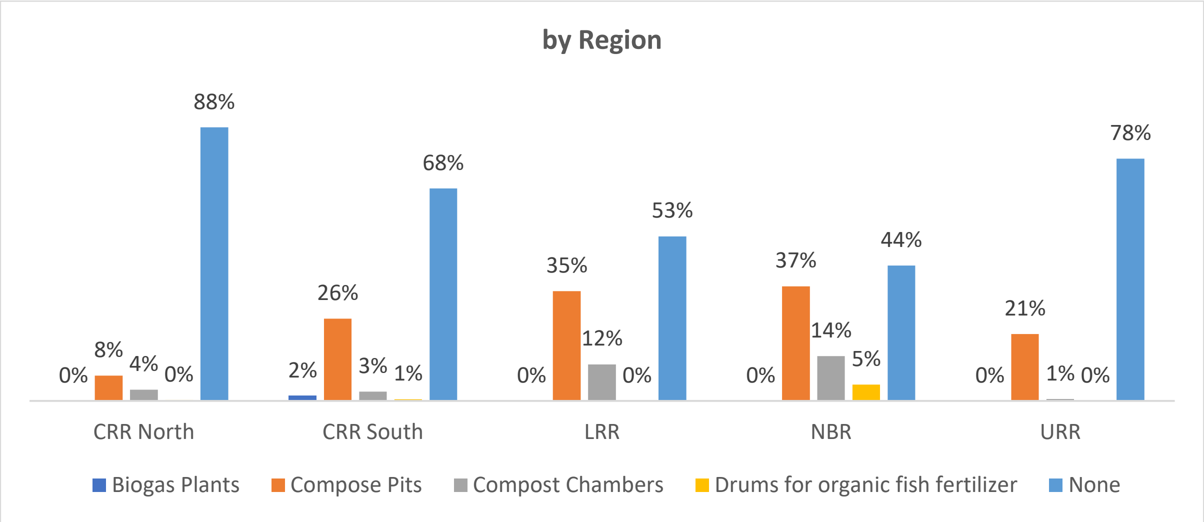
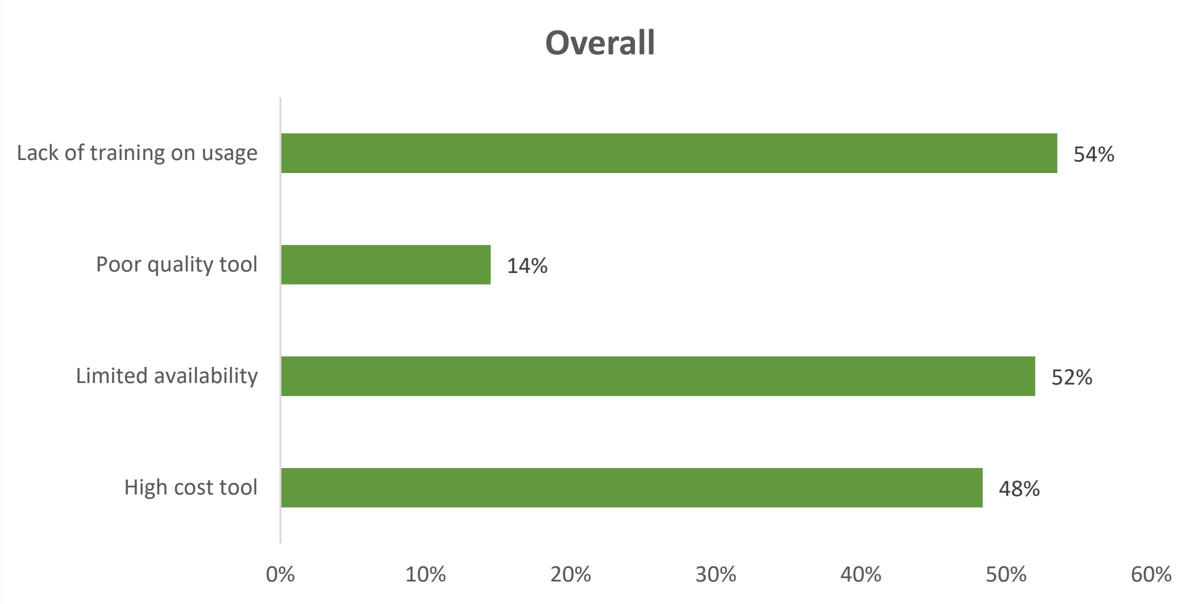


Figure 5. Structures for the production of organic fertilizers

4.3.2 Challenges in accessing tools and equipment for organic fertilizer production

Figures 5 & 6 shows diagnostic study results on the Regional Comparative Analysis of the challenges in accessing tools and equipment for organic fertilizer production in five (5) rural farming regions of CRR-North, CRR-South, LRR, NBR, and URR. The CRRN had the highest percentage (54%) of respondents who mentioned a lack of training in accessing organic fertilizer production tools and equipment followed by CRRS (38%) and NBR & URR (26%). On the other hand, NBR recorded the highest percentage (47%) of the respondents with limited availability of tools and equipment for the production of organic fertilizer followed by URR (35%) and CRRS (32%). Most of the respondents in LRR (40%) complained of the high cost of organic fertilizer production tools and equipment as their major limitation. All the regions indicated a very low percentage (not more than 15%) of respondents with poor quality of tools and equipment for the production of organic fertilizer.



Figures 5

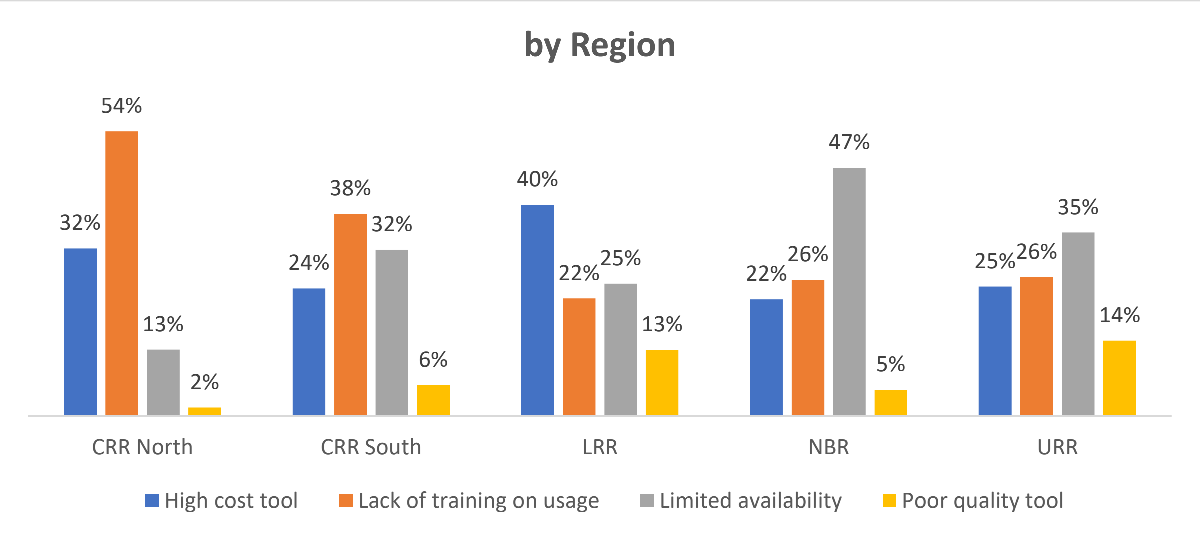


figure 6. Challenges in accessing tools and equipment for organic fertilizer production

V. CONCLUSION

The diagnostic study on agroecology and organic fertilizer production across key farming regions in The Gambia highlights several critical challenges and opportunities. There is a strong community engagement in agroecology, particularly among youth and women, but their efforts are hindered by a lack of resources, such as access to tools, raw materials, and necessary infrastructure. The study reveals that despite their willingness to adopt sustainable farming practices, many farmers lack the requisite skills and support, limiting the scalability of agroecological initiatives.

Climate change has significantly impacted agricultural productivity in these regions. Challenges such as flooding, rising temperatures, soil degradation, and increased pest and disease outbreaks have affected both agroecology and organic fertilizer production. In regions like CRR North and URR, the absence of adequate infrastructure and tools has further compounded these challenges, making it difficult for communities to cope with the effects of climate change.

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