University of Dar es Salaam

1ST KAGERA ANNUAL AGRICULTURAL CONFERENCE AND EXHIBITIONS (KAACE)

"Unlocking the potential for sustainable agricultural productivity, livelihood and inclusive development"

KAACE PROCEEDINGS 1

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Published by
Dar es Salaam University Press (DUP)
P. O. Box 35182
Dar es Salaam

ISBN: 978-9976-60-612-6

Foreword

It is quite rewarding to have this precious conference proceedings for the first Annual Agricultural Conference in Kagera (KAACE 1) published. Organised by the University of Dar es Salaam, KAACE 1 was held in Bukoba Municipality from 2nd to 3rd June 2022, with a theme: "*Unlocking the Potential for Sustainable Agricultural Productivity and Livelihood for Inclusive Development*".

Kagera was selected as the place for the conference due to its peculiar agricultural systems and economic challenges. Regardless of its significant potential, Kagera's per capita gross domestic product was by 2022 the 26th across the Tanzania mainland and its habitats – predominantly peasants had remained economically weak.

KAACE 1 brought together academicians, researchers, agricultural experts, financial institutions, government authorities, farmers, and other stakeholders in agriculture. Parallel to the conference, exhibitors were invited to showcase their agricultural produces, products, services and/or inputs. The objectives of the conference were to disseminate the researched proven best knowledge on good agricultural practices, expose the Kagera's farmers to agricultural marketing and agribusiness strategies, provide a platform for exchanging knowledge and challenges amongst the stakeholders, provide space for entrepreneurs in agriculture to exhibit their products and services and create visibility of Kagera's agricultural potential.

On behalf of the organising committee, I would like to thank our partners and sponsors of the Conference for funding the publicity of the conference (newspapers, radio, TV broadcast), funding participation of participants, production of conference proceedings and the upkeep of conference participants. The partners and sponsors of KAACE 1 include the Ministry of Agriculture, Kagera Regional Administration, University of Dar es Salaam, CRDB Bank, Kagera Sugar Company Limited, Air Tanzania Company Limited, Partnership for National Development of Tanzania and Radio FADECO.

Likewise, we thank all conference participants, the presenters and in particular the authors of the papers which appear in this work.

Much appreciation to unprecedented effort by the organising committee members: Principal and Dr. Mkabwa Manoko, Prof. Daniel Shilla, Dr. Frolence Rutechura, Dr. Lilian Kaale, Dr. Athuman Mahinda, Dr. Theresia Dominic, Dr. Winnie Nguni and Ms. Mary Chalamila.

Dr. George Leonard Kahangwa
KAACE Chairperson

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Opportunities for Using Agricultural Ashes as Binders in Blocks Production: A First Review for Kagera Region

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Abstract

Globally, affordability and carbon neutrality are among the most important aspects of sustainable building.In sub-Saharan Africa (SSA) and in places like Bukoba, the main sustainability issue with building is affordability. Due to long transport distances, cement prices are very high. Residential buildings are often constructed using block-based materials. These are increasingly produced using ordinary cement or Portland Cement (PC). In basic residential buildings, the cost of cement forms an important part of the total cost. If PC could be fully or at least partly substituted by locally made binders, this would reduce costs and improve affordability. Using local binders could also reduce the cement carbon footprint which is high. Globally, cement is responsible for some 8% of the manmade carbon emissions and typically one ton of cement generates some 600-900 kg of carbon dioxide emissions. For block production, the cement cost could be close to 50% of the variable costs. There is ample research on Supplementary Cementations Materials (SMC) that could be locally produced and that could contribute to cheaper binders with lower carbon emissions, the production of which could create employment. However, these studies are still often on a theoretical level and there are few examples from practice. Still, there should be good opportunities for putting this theory into practice. How this improvement opportunity for using alternative binders in block production looks, generally for SSA and specifically for Bukoba and Kagera Region is not clear. The purpose of this presentation is to highlight possible opportunities with using agricultural rest materials from Kagera Region that could be used as binders in producing cement based blocks. The present paper consists of: literature review of how agricultural rest products such as cassava peel ash, rice husk ash etc. can be used as binders in ordinary concrete; review of opportunities with cassava peel ash, bagash ash and coffee bean husk ash in

Kagera Region – quantities and total potential theoretical value; review of costs and carbon footprint in cement block production; challenges and opportunities with making use of the rest products; as well as research and development needed.

The purpose of this review is to make a first assessment of potential binders in Kagera Region. This includes a study of what information concerning amounts of ashes, their pozzolanic reactivity and costs for collection and processing, which is available and what still needs to be collected. We have carried out a first assessment based on the information found and highlighted some potential opportunities with the main focus on cassava peel ash and coffee husks.

1.1 Introduction

Combating extreme-poverty (SDG1) and mitigating climate (SDG 13) change could currently be considered as two of the most urgent challenges for global sustainable development. The population in sub-Saharan Africa (SSA) is rapidly growing which leads to an increasing need for housing. Affordable housing in SSA is already a huge challenge, especially for low-income households. Uganda, for example, has – according to Uganda Bureau of Statistics – a housing deficit of approximately 2.1 million housing units. The deficit is currently growing at an annual rate of 200,000 units. The development in most other countries in SSA such as Nigeria, Tanzania and Kenya follows similar patterns. As housing is a human right, providing shelter to the growing populations is a necessity and there is a need of stopping and reversing the current trend of increased scarcity of housing. It is important to find a way of securing access to affordable housing and simultaneously minimize the associated environmental impact. Globally, the building process, when described as the value chain that goes from cement and concrete raw materials over construction and use of buildings to demolition, is responsible for some 30-40% of global man-made carbon emissions. How we build and how we use buildings have significant impact on climate change. Globally, affordability and carbon neutrality are among the most important aspects of sustainable building. Focus in the developed world is on carbon emissions more than affordability where the opposite is valid for developing countries. In sub-Saharan Africa (SSA) and in places like Bukoba, the main sustainability issue with building is affordability. A significant part of building is residential building. For residential buildings, a common solution is a block-based material that enables intermittent small investments and incremental construction of residences over a long duration (Tusting *et al*., 2019). These could for example, be bricks or cement-based blocks. A cheaper block can speed up the process of completing the building process. Construction materials costs are currently increasing from already relatively high levels. Cement is currently the main driver of both price and CO2-emissions in building blocks. About 8% of CO2 global emissions in the world are assigned to cement production (Andrew, 2018). Current cement consumption in SSA is low. With increased economic development, housing construction activities will increase as it will demand for more construction materials. Current cement consumption per capita for SSA is estimated to about 130 kg per person and year, with a growth of 6-10% annually (World Cement, 2018). The 130 kg per year corresponds to about 20-25% of the global average per capita consumption. The current population of 1.2 billion in SSA is predicted to double until 2050. This will put enormous pressure on building.

In developing countries, the price of cement could be as little as 2% of the total building cost. In sub Saharan Africa when constructing a simple building without heating or cooling and for catering basic needs, the price of cement could be costing 10-20% of the building cost. The use of cement-based blocks is increasing; this is also observed in Bukoba. With long transport distances cement prices for the end consumer can be up to 2-3 times higher than in rich developed countries. When we compare how much work needs to be done for buying a bag of cement, this could be up to 40 times higher in Bukoba compared to a European country. A typical salary in Sweden before taxes is 3000 US$ per month which could be compared with a salary of 150 US$ in Bukoba. This implies a factor 20. However, cement prices in Sweden per ton would be about 50% of that in Bukoba. This makes the factor 40. In this, we have not included the fact that the Swedish cement would be considerably better with a one-day compressive strength of about 20 MPa, whereas the early strength of cements in Tanzania would be well below 10 MPa. This example serves to illustrate why it is particularly interesting in a place like Bukoba to find alternative to Portland Cement (ordinary cement). One specific area of interest is the use of cement in block production. These are increasingly produced using ordinary cement or Portland Cement (PC). Finding alternative binders to replace cement in concrete block production would therefore enhance the opportunity of reducing the dependence of expensive cement.

There should be alternatives in focus on local raw material and local competency in basic technology that reduces the dependency of PC that is produced in a few distant factories. Modern cement plants are needed, especially for demanding concrete constructions. In parallel, local binders, especially in regions far from the cement plants, could be developed to create/produce sustainable blocks that create employment andsupport local residential buildings.

There seems to be no agreed definitions on sustainable building. Based on a primary stakeholder needs focus, Isaksson and Rosvall (2020) propose that sustainable building should be at least affordable and carbon neutral. This provides a way to operationalise sustainability in the studied value chain going from raw materials to building blocks on the building site. Research on potential alternative binders has been going on for some decades, mainly with focus on reducing the clinker consumption in the cement production (Dhandapani *et al.,* 2018). Even if there is ample research on using alternative binders, this research is mainly on how to substitute parts of Portland Cement (PC) in ordinary concrete and not on how these alternative binders could be directly used in blocks as "block additives". The research done has been on concrete at higher levels of compressive strength, typically 25-40 MPa. The blocks are earth dry masses produced at strength levels of typically 1-7 MPa (Isaksson and Buregyeya, 2020). At these low strengths, the PC performance is poor using only about 15-30% of the inherent potential (Isaksson and Babatunde, 2019). Research for how alternative binders work in low strength block solutions seems to be missing. The driver for block costs and carbon footprint is the PC used. Using locally made alternative binders could possibly create labour opportunities (SDG 8) enabled by reduced or eliminated costs for PC.

How the improvement opportunity for using alternative binders in block production looks generally for SSA and specifically for Bukoba and Kagera Region is not clear. The purpose of this paper is to highlight opportunities with using agricultural rest materials from Kagera Region that could be used as binders in producing cement based blocks and how research for this could be conducted.The purpose of this review is to make a first assessment of potential binders in Kagera Region. We have studied how work could proceed with two potential alternative binders which are cassava peel ash and coffee bean husk ash.

2.0 Theory Background

Isaksson (2016) carried out an opportunity study for the global cement production concluding that it will be difficult for the cement industry to comply with requirements for reducing the carbon footprint. One proposal was to use cement for the high strength requirements where it is difficult to substitute and find alternative binders for low strength applications. The current situation for the value chain of providing cement-based blocks for residential building in SSA has not been established and could be seen to be in a pre-stage to understanding what sustainability means in the context. To do an opportunity study (Isaksson, 2015) for the studied value chain, it is necessary to understand the technical viability of the alternative binders for block production. Block sustainability could in simple terms be measured as kg CO_2 and price per m2 wall (Isaksson and Buregyeya, 2020).

The technology/innovation in focus is an optimised mix of binder + aggregates + water + additives substituting Portland Cement (PC) fully or partially in block production. The major portion of environmental footprints assigned with production of concrete blocks originates from cement. Limestone CaCO3 is the main raw material. The CO_2 from the raw material corresponds to about 60% of the total cement CO_2 emissions. A well-known solution to this problem is substitution of cement with supplementary cementitious materials (SCMs), producing the so called low CO_2 composite binders (Gartner, 2004).

The most explored and used SCMs in the past decades include coal combustion fly ash, ground granulated blast furnace slag, calcined clays as well as natural pozzolans. The pozzolanic activity is a term used to represent the reaction rate of a cement replacement material and calcium hydroxide, a hydration phase hydrated cementitious matrix, in the presence of water. Calcium hydroxide (CH) is one of the major phases produced in hydrated cement systems, exhibiting alkalinity in the system. Pozzolanicity indicates the rate in which the cement replacement material consumes the calcium hydroxide in excess to create further CSH and CASH phases, which are other main hydration phases in hydrated cementitious systems, providing the strength in the system. The hydration process of low CO_2 binders is illustrated in Figure 1:

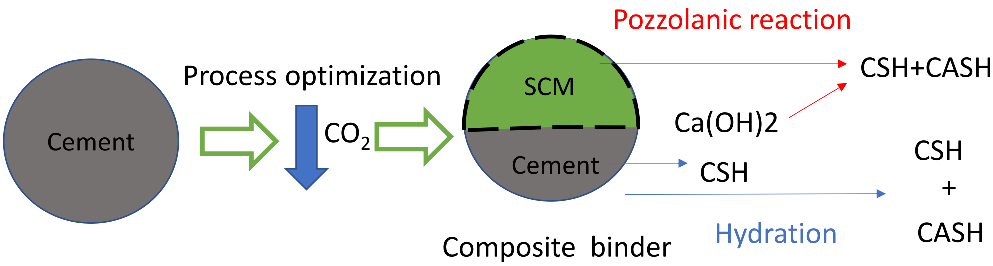

Figure 1: Hydration Process of Low CO_2 Composite Binders

The idea in the proposed research is to consider a larger proportion of SCM in the composite binder than in a standard based cement aiming for the complete elimination of PC and substituting this with slaked lime Ca (OH)2. This is an old solution dating back to the Roman times where slaked lime was mixed with volcanic ash and pottery rests to make Roman cement.

Earlier research on relevant and potential substitutes to Portland cement in SSA has shown several promising results. For instance, agricultural by-products combusted under certain conditions have shown not only to be a feasible substitute but also to affect some properties compared to a reference concrete based on Portland cement (Thomas *et al.,* 2021). Another potential pozzolanic material that can replace Portland cement is calcined clay of which Africa has abundant resources. Adding calcined clay, with or without limestone, is shown to be more durable and has increased resistance towards most of the potential aggressive actions of which concrete may be exposed, except carbonation (Jaskulski *et al*., 2020).

The scientific technological novelty of the proposed research is presenting the level of opportunity for building block production in SSA that could be realised using alternative binders to PC. One specific novelty is testing if PC can be substituted by locally produced lime Ca (OH)2 with a higher level of sustainability (affordability and carbon footprint) and possibly labour creating opportunities.

A major problem with using PC for producing blocks is that at the low levels of cement addition of about 5%, we only seem to be able to use some 15-30% of the cement building potential (Isacksson and Babatunde, 2019). The reason is that to compact the blocks, much more water is needed than the optimal water to cement ratio (w/c). In Figure 2, this is demonstrated with the "cement productivity" where the reference is presented as a mix with w/c = 0.5. Since compaction of sandcrete and other earth dry concrete mixes requires water at the levels of 7-10% by weight, the w/c ratio with 5% cement becomes in the range of 1.4-2. Based on Figure 2, this results in using only some 15-30% of the cement building capability.

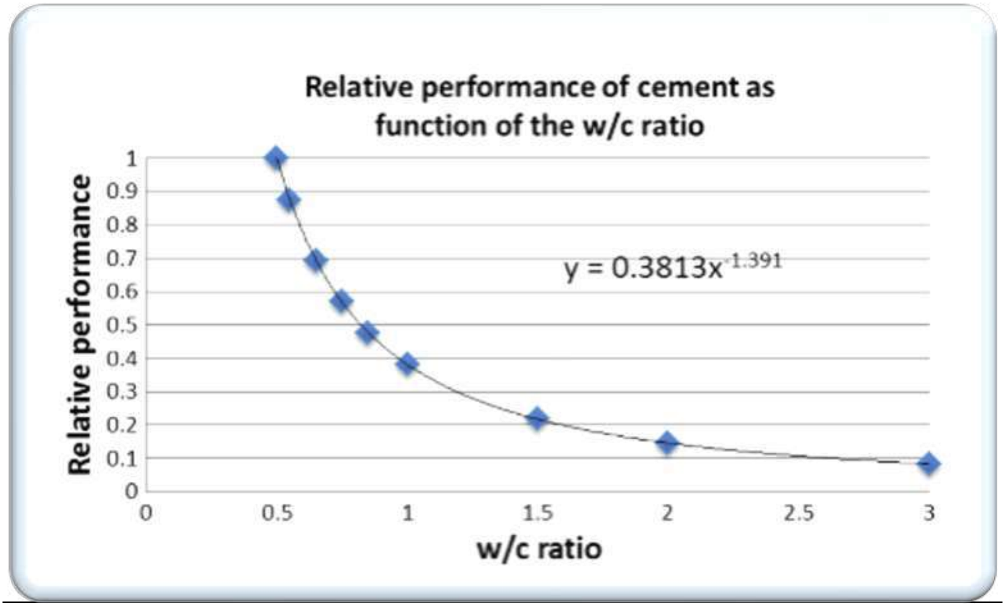

Figure 2: Cement Productivity as Function of w/c Ratio
Source: Isaksson and Babatunde (2019)

Method

Answering the research question of the viability of Cassa Peel Ash (CPA) and Coffee Bean Husk Ash (CBHA) as alternative binders in block production is divided in five parts as follows:

1. Yearly quantities of available material – tons of ash per year in Kagera Region;
2. Pozzolanic capability of CPA and CBHA at a chosen fineness (done in Chalmers, Sweden);
3. Preparing binders from local materials – calcining (700-800 C) and grinding (local equipment needs to be produced or alternative samples are prepared at the University of Dar es Salaam);

4. Pilot testing of binders in block production; and
5. The received results are used to assess the potential value of the agricultural ashes.

3.0 Preliminary Results for CPA and CBHA in Kagera Region: Coffee Bean Husk Ash (CBHA) Potential Building Value

The quantity of the CBHA yearly produced depends on the production of coffee beans and the quantity of husks generated. The husks then need to be burnt in a controlled process at about 700-800 C to produce an ash with pozzolanic properties. A pozzolanic material contains more than 75% of the sum of the oxides Al2O3, SiO2 and Fe2O3. When these are present as fine particles, they can in a water solution react with Ca(OH)2 from lime in CSA and CASH, see Figure 1. In the best of cases, the pozzolanic material can produce strength comparative to about 30% of Portland Cement strength. We can do a rough estimate of the best expected performance by attributing 30% to the ash. We can also attribute the best monetary value by comparing binders with cement price.

According to Tanzania Coffee Research Institute (TACRI)-Maruku Research Rreport on 5th May, 2021, coffee production in Kagera Region has increased from 12,500 metric tons in 1991 up to 43,680 metric tons. The main producers are Karagwe, Kyela, Missenyi, Muleba, Biharamulo and Ngara districts. The cooperative unions were vested with the big responsibility to buy, collect and sell coffee beans from farmers and other companies like KADERES, OLAM etc. The coffee husks produce last year were 10,920 metric tons. Husks are used as manure to fertilize soil and some are used as charcoal. If these husks instead are calcined to ash, we need to estimate how much ash is produced. We, here, assume 20% which will need to be tested. With 20% of ash, the amount of potential pozzolanic material is about 2000 tons per year. Would this have the best demonstrated performance of pozzolanic material, then this would correspond to 600 tons of cement. Using a cement price of 200 US$/ton, the total best possible value of the CBHA in Kagera Region would be 120 000 US$/year.This is not a huge sum and from this we will need to deduct all costs associated with processing of the material. However, where there is a concentration of unused husks, it could be of interest to conduct experiments.

3.1 Cassava Peel Ash (CPA)

The areas covered with cassava in Kagera Region makes 63.3% of the area planted with roots and tubers according to National Samples Census of Agriculture 2012/2013. The total area covered with plants and tubers was not available when writing this paper. We, therefore, can make only a very rough estimate of the potential amounts of CPA that could be produced. The entire Kagera Region is about 30 000 km2. Assuming that about 5% is cultivated land and 60% of this is cassava means 3% or 900 km2. This is only a guesstimate with the purpose of understanding the magnitude of the potential. One km2 is equal to 100 hectares (ha). This means that there could be 90 000 ha of cassava. An average yield is 15 tons per ha. Out of this, about 10 % could be the peels whose ash would be about 10%. This would result in 150 kg of CPA being produced per ha. The total potential CPA would be 0.15 ton/ha * 90 000 ha = 13 500 tons of CPA. With the best value as 30% of cement would correspond to about 4000 tons (of cement). With 200 US$/ton, the yearly potential value would be 800 000 US$. The challenge with CPA is that it is not concentrated in the way CBHA is. For CPA making economic sense, it probably would need a plant e.g., producing cassava flour. In such a plant, it would be of interest to take care of the peels and prepare them into a binder.

4.0 Conclusion

The significance of upcoming challenges in the construction industry in an economical, durable and sustainable manner while reducing environmental impacts is of paramount importance. This research was attempting to find ways for reducing environmental impacts in the area of construction materials and dependency on Portland cement as standalone binders. The research focused on development of low-carbon cementing binders systems that will use local available binders. The idea will not only avail opportunity for economic growth, address climate change but also it is a copying mechanism in agriculture and livelihood in Kagera Region.

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Improving Cassava Production and Community Livelihood through Using Improved Cassava Varieties

Petro G. Mwakamele

Abstract

Cassava is the world's fourth most important staple crop after rice, wheat and maize, and plays an essential role in food security. Due to cassava's growth characteristics and ability to grow in poor soils and regions prone to drought, it is preferred by poor farmers in many tropical countries (Mtunguja *et al*., 2019). While cassava plays an important role as a food security crop for subsistence farmers, it is prone to rapid postharvest deterioration. Processing cassava for starch is another strategy for overcoming post-harvest losses; the process can also add value to end products and has the potential to create additional employment opportunities along the supply chain (Mtunguja *et al*., 2019). Cassava starch is an important source of biomaterial for different food and non-food industrial applications. Moreover, farmers producing cassava can increase their income by finding alternative end uses to home consumption (Mtunguja *et al*., 2019). To meet the high demand for cassava in Kagera Region, varieties selection, production and processing need to be improved. The aim of this review is to explore the potential of improved cassava varieties for improving cassava production with respect to improving community livelihood in Kagera Region.

Keywords: *Cassava, Livelihood, Tanzania*

1. Introduction

Cassava (*Manihot esculenta Crantz*) is a perennial woody shrub with a starchy edible root. It grows in tropic and sub-tropic regions of the world. The most commonly used part of cassava is the starchy root, which is rich in carbohydrates; this is about 20-30% dry matter. Cassava leaves can also be consumed and they are rich in protein (14 - 40% dry matter), minerals, Vitamin B1, B2, C and carotenes (Mtunguja *et al*., 2019). Cassava's growth characteristics make it a suitable food security crop, particularly due to its resilience growing in conditions that become unfavourable for other crops, such as periods of erratic rainfall. Due to this resilience to adverse environmental conditions, cassava has been named as an ideal climate change crop (Mtunguja *et al*., 2019).

Cassava is adapted to growing on poor degraded soils and can tolerate low pH, high levels of exchangeable aluminum and low concentrations of phosphorus (Howeler, 2002), conditions that typically limit crop growth. Sandy soils have been also found to be suitable for cassava production because of easy root penetration and expansion of the growing root during carbohydrates partitioning. Sandy clay loam soils are also appropriate due to the high-water retention capacity which provides a good distribution of soil water for a long period even after the onset of dry season (Mtunguja *et al*., 2016b). However, adequate soil nutrient availability is very important for increasing cassava production and dramatic differences in cassava yield have been reported, with changes in soil nutrient supply (Mtunguja *et al*., 2016b). Cassava requires annual rainfall between 1000 and 3000 mm, but can tolerate low rainfall if the rainfall is well distributed throughout the growth period (Lebot, 2009). Significant water supply is required during the period of roots and shoots initiation (3-5 months after planting). Water deficit during this period severely affects cassava yield (Mtunguja *et al*., 2019. Several studies have demonstrated that if cassava experiences water deficit later than 5 months after planting, there is no significant yield reduction (Mtunguja *et al*., 2019).

In addition, cassava is also becoming an important raw material for industries around the world (Nassar and Ortiz, 2007; Mtunguja *et al*., 2014). Also, cassava is becoming an important crop for economic development in African countries. While corn starch has dominated the world starch production accounting for

80%, cassava accounts for 10%, wheat 7% and potato 3% (Mtunguja *et al*., 2019). Cassava starch production formerly done by small-scale farmers has now been transformed to be a large scale. This transition from small to large-scale production would be accomplished by using improved varieties with good agronomic practices (GAP).

Major food crops grown in Kagera Region are maize, banana, cassava, beans, sweet potatoes, groundnuts and paddy, grown mostly by smallholders. During the 2011 – 2015 period, Kagera Region had an average annual land area of 496,519.4 hectares planted with major food crops. Bananas were planted on an average annual land area of 143,233.0 hectares, accounting for 28.8 percent of the region's average annual land area planted with major food crops. Beans, which accounted for 26.9 percent of the average annual land area planted with major food crops, are normally intercropped with other crops. This was followed by cassava (13.1%), sweet potatoes (4.0%), paddy (1.3%) and groundnuts (0.9%). In 2015, the region cultivated the largest annual land area (541,949 hectares) under food crops. The year 2011 had the smallest annual land area (466,116.0 hectares) planted with food crops in the region.

1.1. Objectives

This study aimed at improving cassava productivity in relation to increase food security and income of community in Kagera Region. The purpose of the research is to train farmers the importance of using improved cassava varieties and practicing good agriculture practices (GAP) to cassava production. This paper describes the difference of using local varieties and improved varieties in relation to cassava production and productivity.

2. Material and methods

2.1. General study and information

The study aimed at exploring the relationship between local varieties, improved varieties, and good agronomic practices (GAP) in relation to cassava productivity, food security and income generation to smallholder farmers (community) around Kagera Region.

2.2. Target areas

Scientists with long experience in cassava related research conducted the study between 2020 and 2021. It consisted of interviews with farmers and farm workers in rural areas in Kagera Region, where cassava is mostly cultivated using local cassava varieties. The sample of farmers from whom the information was collected comprised 15 small scale farmers selected from Muleba, Bukoba and Misenyi Districts.

2.3. Data collection

Data were collected in the form of questionnaires through the farm survey, face to face interviews with farmers/farm workers and field observation during farming activities. The questionnaire was designed in English and translated into Kiswahili, which is understandable by the majority of Tanzanians; it is the national language in Tanzania. The collected data included varieties used, agronomic practices used, yield (productivity) obtained and income generated. Computer data entry in Microsoft Access was done and analysis was conducted by using R Programming.

3. Results

3.1. Types of varieties used by farmers

The majority of farmers in Kagera Region (about 95%) use local varieties which are susceptible to cassava diseases such as Cassava Mossaic Disease (CMD) and Cassava Brown Streak Disease (CBSD) as well as susceptible to insect pests like whiteflies and cassava green mites. The local varieties used are *Katakya*, *Rushura*, *Mulinda*, *Bukarasa* and *Mazimolo*. As a result, farmers get low yield (about 40% low) comparing to the expected yield, if they were using improved varieties.

3.2. Agronomic Practices (GAP)

In spite of using local varieties, most of farmers in Kagera Region (90%) do not excercise agronomic practices such as application of fertilizer, using recommended spacing, mulching, control of pest and diseases as well as removing weeds at right time; hence, they get low yield.

3.3. Yield obtained

Farmers who use local varieties, typically have yields between 8-12 t/ha; that is about 60%-68% lower as compared with the average of 25-30 t/ha for improved varieties. The lower recorded yields in Kagera are attributable to the fact that cassava is grown on marginal lands with poor management practices. Input use in cassava production is also limited or absent. Productivity improvements will only occur if improved varieties and reliable markets are introduced, which could incentivise increased attention and resource allocation to cassava production. Table 1 shows the yield of cassava from local and improved varieties:

Table 1: Difference in Yields between Local and Improved Varieties of Cassava

S/N	Local Varieties	Yield/Ha	Improved Varieties	Yield/Ha
1	Katakya	8-12t	TARICASS(1-5)	15-50t
2	Rushula	10-15t	Kiroba	15-35t
3	Mulinda	6-10t	Kizimbani	15-25t
4	Bukaraza	8-12t	Mkumba	15-21t
5	Mazinilo	8-13t	Mkuranga1	15-30t

3.4. Income generated by farmers

Due to low yield, the income generated by farmers is low as we have seen in the previous section; cassava productivity can be increased if both suitable varieties and good management practices are adopted. The cassava industry can be used to produce native and modified starch, sweeteners and high quality cassava flour for baking industries (Mtunguja *et al*., 2019). In addition to facilitating product development, having an end use for cassava will spur increased market demand and industry attention to the problem of post-harvest loss. Increased demand for cassava can also facilitate a transition out of subsistence level production for market-oriented farmers who are able to create a business enterprise out of their agricultural production (Mtunguja *et al*., 2019). If there is a growing industrial demand for starch and cassava, it will help to meet demands and reduce supply pressure for other staple crops. Establishing and strengthening cassava processing industries in Kagera Region to replace imported starch will help to improve farmers' livelihoods. Cassava farmers will increase production to feed cassava processing industries. Thus, their income can increase when they sell fresh cassava to the cassava processing industries.

Developing processing industry will also help to tackle unemployment in Kagera Region. Youth will be attracted to take agriculture as a business due to availability of processing industries. Moreover, the market demand created by processing industries will likely attract youth to engage in agriculture. There is high labour availability and unused land; therefore, there is an opportunity for increased cassava production and processing which can lead to better income for farmers and employment for youth (Mtunguja *et al*., 2019). Cassava is a priority crop which can be used to reduce the rate of unemployment and thus attract youth to participate in agriculture (Mtunguja *et al*., 2019). Abbas *et al.* (2013) and James *et al.* (2013) estimate employment in the cassava flour industry to be around 53,124 people. Further development of this sector may lead to additional employment opportunities. This will reduce youth migration to urban areas and engagement in illegal activities. Policies should encourage the establishment of starch based industries such as those produced from cassava (Mtunguja *et al*., 2019). Cassava can play a big role in supporting development of the processing industry and reduce competition with other starch sources such as maize and potatoes (Mtunguja *et al*., 2019). Efforts to increase productivity through dissemination of good agronomic practices should be emphasised.

Cassava farmers would benefit from selling their cassava to processing industries. Another benefit of establishing cassava starch factories will be increased employment through the entire supply chain from breeding of new improved varieties to seed marketing processing and trade (Olukunle, 2013). Cassava value chain analyses have revealed that increased employment could be generated at the stages of production, processing and trade. Therefore, increased local demand for cassava-based products, especially starch, can foster the growth of cassava industry and subsequently generate employment opportunities (Olukunle, 2013).

3.5. Participation on cassava production

Almost 70% to 80% of the farmers involved in cassava production activities are women, whereby 20% to 30% are men. This happens due to a poor belief that cassava is a crop for women. Similarly, this belief makes the productivity of cassava in most areas in Kagera Region to be low and the participation of the women to be reduced to avoid conflicts in marriage. Hence, men should be educated to increase participation of both men and women in cassava production which will improve food security and living standard within households.

4. Discussion

Farmers in most African countries, including Tanzania, typically have yields between 8-12 t/ha (Mkamilo and Jeremiah, 2005) compared with the worldwide average of 25-30 t/ha (Lebot, 2009). The lower recorded yields in Tanzania and other sub-Saharan countries are attributable to the fact that cassava is grown on marginal lands with poor management practices. Input use in cassava production is also limited or absent. Apart from cassava's ability to tolerate low nutrients, its availability makes it a good staple crop for resource-poor farmers; however, it keeps yields low as compared with the global average and genetic potential. Productivity improvements will only occur if reliable markets are introduced (Lazaro *et al.*, 2007), which can increase attention and resource allocation to cassava. Development of the cassava market is anticipated to contribute to improved food security and contribute sustainably to poverty reduction in poor households (James *et al*., 2013).

Kagera Region has a mixed economy dominated by the agriculture sector, which employed about seventy-seven percent (77%) of regional population in 2012; both commercial and peasantry farming are practised. Agriculture contributes most of the region's cash income mainly from coffee, beans, tobacco, bananas, cotton, tea, fruits, and vanilla; also cassava production by small scale farmers or multi-cropping with other crops like banana. After the earthquake in 2016, cassava production in Kagera Region increased whereby about 5,000 households involved in cassava production from five district councils: Muleba, Kyerwa, Bukoba Rural, Missenyi and Bukoba Municipality. When market opportunities exist, farmers may prefer to grow cassava as it has been shown to have higher returns to production than other staple crops (Lazaro *et al*., 2007; Abbas *et al*., 2013; James *et al*., 2013). It is suggested here that the ability to capitalise on the increased cassava production depends primarily on improvements in processing outlets and access to viable markets (Abbas *et al*., 2013). Therefore, breeding programmes should ensure an increased productivity and profit for cassava farmers. Farmers need also to be sensitised on the benefit of using improved varieties, fertilisers and other agro-inputs for increased productivity for maximum income generation.

Different studies have found that productivity for local cassava varieties can be achieved through good agronomic practices. Also, development of high starch yielding varieties is important to maximise returns to investment. FAO argues that developing countries in Africa could start utilising cassava starch for different industrial applications. The growing industrial demand for starch and cassava can help to meet demand and reduce supply pressure for other staple crops (FAO Report, 2006). Establishing and strengthening starch industries in Tanzania to replace imported starch will help to improve farmers' livelihoods. Cassava farmers will increase production to feed starch industries. Thus, their income can increase when they sell fresh cassava to the cassava processing industries. Developing cassava processing industries will also help to tackle unemployment in Tanzania, which is estimated to be 10.3% (TNBS, 2016). Youth are not attracted to agriculture as a business because of low returns to labour and investments; which is mainly caused by market uncertainty. Therefore, the market demand created by starch industries will likely attract youth to engage in agriculture. There is high labour availability and unused land; therefore, it is an opportunity for increased cassava production and processing which can lead to better income for farmers and employment for youth. Cassava is a priority crop which can be used to reduce the rate of unemployment and thus attract youth to participate in agriculture. Abbas *et al.* (2013) and James *et al.* (2013) estimate employment in the cassava flour industry to be around 53,124 people. Further development of this sector will lead to additional employment opportunities. This will reduce youth migration to urban areas and engagement in illegal activities. Policies should encourage the establishment of starch based industries such as those engaging with cassava processing.

Cassava can play a big role in supporting development of the starch industry and reduce competition with other starch sources such as maize and potato. Efforts to increase productivity through dissemination of good agronomic practices should be emphasized and already established cassava improvement programmes should continue to be supported. Cassava farmers would benefit from selling their cassava to processing industries. Another benefit of establishing cassava starch factories will be increased employment through the entire supply chain from breeding of new improved varieties to seed marketing, processing and trade (Olukunle, 2013). Cassava value chain analyses revealed that increased employment can be generated at the stages of production, processing and trade. Therefore, the increased local demand for cassava-based products, especially starch, can foster the growth of cassava industry and subsequently generate employment opportunities (Olukunle, 2013).

5. Conclusion

This study provides valuable information on the tendency of smallholder farmers to use local varieties, gender participatory and agronomic practices in cassava production, in relation to income generation to community and improving cassava production. Findings from this study strongly indicate that cassava smallholder farmers lack appropriate knowledge on improved varieties like *Taricass4, Mkuranga1, Mkumba, Kiroba* and *Kizimbani* and good agronomic practices (GAP). This is attributed to almost absence of extension services and training. This information can be used to develop training programmes on improved varieties and use of good agronomic practices.

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The Spatial-temporal Trend Analysis of Rainfall in the Robusta Coffee Production Area in Kagera Region

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Abstract

Rainfall is an essential factor that influences Robusta coffee production. The analysis of the long-term history of rainfall is crucial for informing the planning for climate adaptation measures. The present study used high-resolution time-series gridded rainfall data from the Climate Hazard Infrared Group Precipitation Station (CHIRPS) to analyze the spatial-temporal trends of inter-annual and seasonal rainfall in Robusta coffee-producing areas of the Kagera Region. The analysis used a longitudinal climate period of 40 years (1981 to 2021). The non-parametric trend tests (Mann-Kendal and Sen's slope estimator) analyzed the trends and magnitude of the trend of spatial-temporal annual and seasonal rainfall at the district level using trend packages in R software v. 4.3.2. The results indicated uneven spatial-temporal distribution of annual and seasonal rainfall patterns in the Kagera Region, where more significant increasing rains ($p < 0.05$) occur in the northern and western parts of the region. The increasing rainfall trends range from 1.23 - 15.81mm/year (annual rainfall), 1.11 - 11.05mm/year (long rains), 0.16 - 3.93 mm/year (short rains) and 0.13 - 4.17 mm/year (Peak/April rains). The large parts of southern Kagera had a non-significant increase ($p > 0.05$) in annual and seasonal rains. Furthermore, annual and seasonal rains showed inter-and intra-district spatial-temporal variability. Generally, the robusta coffee-producing areas in Kagera Region have shown good rainfall patterns and distributions despite the presence of inter-annual and inter-seasonal variability. Yet, variability of annual and seasonal rainfall patterns could affect coffee growth stages, productivity, and quality of coffee beans. Therefore, it is crucial to enhance Robusta coffee

productivity and value chain resilience to the uncertainty of climate change by promoting innovative approaches for context-specific climate adaptation and mitigation measures.

Keywords: *Climate, Kagera, Robusta Coffee, Rainfall, Spatiotemporal, Trend Analysis*

1.0 Introduction

Robusta coffee is a historically critical crop for livelihoods and local economy in Kagera Region. The crop is climate-sensitive and adversely affected by climate patterns, and rainfall is an exceptionally significant factor influencing coffee production and the quality of coffee beans. Existing evidence suggests that climate change has significantly detrimental impacts on coffee production, including declining yield and shifts in coffee phenological stages (Kath *et al.,* 2021; Wagner *et al.,* 2021; Craparo *et al.,* 2015, 2020).

In many cases, past climate analyses applied the in-situ observation data. However, in many African countries, including Tanzania, the in-situ observational climate data are scarce due to the limited number of meteorological stations (Craparo *et al.,* 2015). Because of the missing well-established network of meteorological stations, researchers' interest in applying satellite-based rainfall data has increased. Spatial extrapolation techniques help to produce these satellite-based climate data to estimate climate phenomena in data-scarce areas. One commonly used rainfall data is the Climate Hazard Infrared Group Precipitation Station (CHIRPS). It is the high-resolution rainfall data with a spatial resolution of 0.05 arc degree or 5.5 km (Funk *et al.*, 2015). The study by Dinku *et al.* (2018) compared CHIRPS and other satellite-based climate data, and it found that CHIRPS data have high skills and low bias. Another study by Das *et al.,* (2022) found that the data was suitable for climate monitoring because of their long-term records. Several studies by Hordofa *et al.* (2021); Assowe-Dabar *et al.* (2021); Muthoni *et al.* (2019); Saeidizand *et al.* (2018); and Bai *et al.* (2018) have used CHIRPS rainfall data to analyze the long-term trends of rainfall patterns in different geographical regions.

Some studies like Gudoshava *et al. (*2020) and Muthoni *et al.* (2019) have assessed the historical trends of climate parameters such as temperature and rainfall in the eastern African region. However, they have differed in climate data, methodologies, and analytical approaches. For instance, some used high-resolution climate-gridded data such as version CHIRPS 2 (Muthoni *et al.,* 2019) and station-based meteorological data (Ojara *et al.,* 2021). The available study (Luhunga & Songoro, 2020) on assessing the long-term spatial-temporal rainfall trends at the district level in the Kagera Region uses low spatial resolution rainfall data (> 50 km). The low-spatial resolution climate data are insufficient to provide detailed spatial-temporal variations of rainfall trends and patterns on a large detailed scale, such as at the district level. Further, there is a limited study on Region about the inter- and intra-district level analysis on long-term rainfall trends and variability based on high-resolution gridded climate data. Hence, analyzing historical rainfall using high spatial resolution data is crucial for understanding climate change and planning climate adaptation measures for coffee production at the district level. Therefore, the present study aimed to fill these knowledge gaps by using recent high-resolution gridded rainfall data.

The objective of this study was to analyze the spatial-temporal trends of the annual, seasonal (MAM and OND), and peak rains in the Kagera Region by using the high-resolution time-series gridded rainfall data from Climate Hazard Infrared Group Precipitation Station (CHIRPS) for 40 years (1981 to 2021).

2.0 Methods and Materials

2.1 Study Area

The study area was Kagera Region, located in northwest Tanzania. The region has eight administrative districts, as shown in Figure 1. Kagera Region has an area size of 35686 km^2 (URT, 2019). It is located between 30.5^{0}E and 32^{0}E east of the prime meridian and between 1^{0}S and 3.5^{0}S south of the Equator. The region had a bimodal annual rainfall pattern (Luhunga & Songoro, 2020). The long rainy season is from March to May, and the short rainy season is from October to December (*Ibid*).

The region is predominantly known as the primary producer of Robusta coffee. The leading coffee-producing districts are Kyerwa and Karagwe, and other producing districts in the region include Misenyi, Bukoba DC, Muleba, Biharamulo, and Ngara. El Niño/Southern Oscillation (Otieno & Anyah, 2012) and sea-surface temperature variability over the Indian Ocean influence the region's climate (Gudoshava *et al.,* 2020).

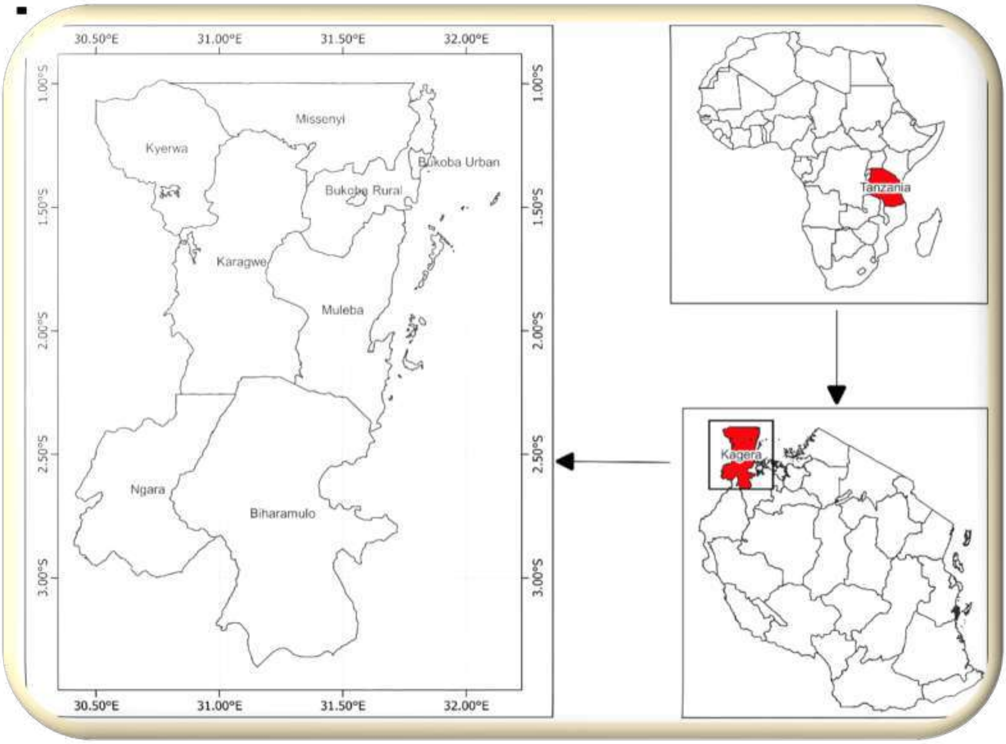


Figure 1: The Geographical Location of the Study Area

2.1 Historical Rainfall Data

We used gridded raster CHIRPS version 2; monthly rainfall data were acquired at ftp://ftp.chg.ucsb.edu/pub/org/chg/products/CHIRPS-2.0/. We used the CHIRPS rainfall data from January 1981 to December 2021. The data are freely available and can be downloaded in Geotif raster file format, which is compatible with GIS and Remote Sensing software.

2.2 Processing and Analysis of Historical Rainfall Data

We stacked individual monthly rasters to form a stacked raster. We applied the raster stack function in raster R software (R Core Team, 2022) to implement the raster stacking. Furthermore, we masked and cropped the stacked raster to fit the extent of the study areas using the Kagera Region boundary shapefile. We applied R software's raster mask and crop functions to implement the masking and cropping.

Moreover, we applied non-parametric statistical tests (Mann-Kendal and Sen's slope estimator) to determine the monotonic trend and magnitude of the season and annual rainfall trends. Several past studies widely used the Mann Kendal Test to detect monotonic trends of several parameters such as streamflow, temperature and rainfall using time-series datasets (da Silva *et al.,* 2015; Wang *et al.,* 2020). We also applied the trend R-package (Pohlert, 2020) and raster calculation function in R software version 4.3.2 to compute the spatial-temporal Mann-Kendal test and Sen's slope estimator statistics. We generated final maps of Mann-Kendall test statistics and Sen's coefficient using QGIS software version 3.22. The mathematical formula for the Mann-Kendal test (equations 1 – 3) is as follows (Gou *et al.,* 2020):

$$z = \begin{cases} \frac{S-1}{Var(s)} \;\; if\ S < 0 \\ 0,\ if\ S = 0 \\ \frac{S+1}{Var(s)} \;\; if\ S > 0 \end{cases} \tag{1}$$

Where Z is the transformation of the statistic S:

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n-1} sign(x_j - x_i) \tag{2}$$

$$sign(x_i - x_i) = \begin{cases} 1, & x_j - x_i > 1 \\ 0, & x_j - x_i = 0 \\ -1, & x_j - x_i < 1 \end{cases} \tag{3}$$

Furthermore, the Mann Kendall Test finds a trend in either a positive or negative direction (Marak *et al.,* 2020), and the strength of a trend is estimated using Sen's slope formula (equation 4) (Sen, 1968) as follows:

$$\beta = Median\left[\frac{Y_i - Y_j}{i-j}\right] for\ all\ j < 1 \tag{4}$$

Where Y_i and Y_j are data values at time steps i and j, respectively; the test statistic β denotes the median of all slope estimates. The positive value of β indicates an increasing trend, and the negative indicates a decreasing trend.

We also applied the zonal statistics tool in QGSIS version 3.22 to calculate several descriptive statistics such as min, max, and standard deviation of the trend analysis outputs for each district. To implement zonal statistics analysis, we treated each district as an individual zone and the unit of analysis. The results of zonal descriptive statistics were presented in the tables and helped compare the rainfall patterns among the districts. Figure 2 summarizes the overall methodological workflow applied in this study.

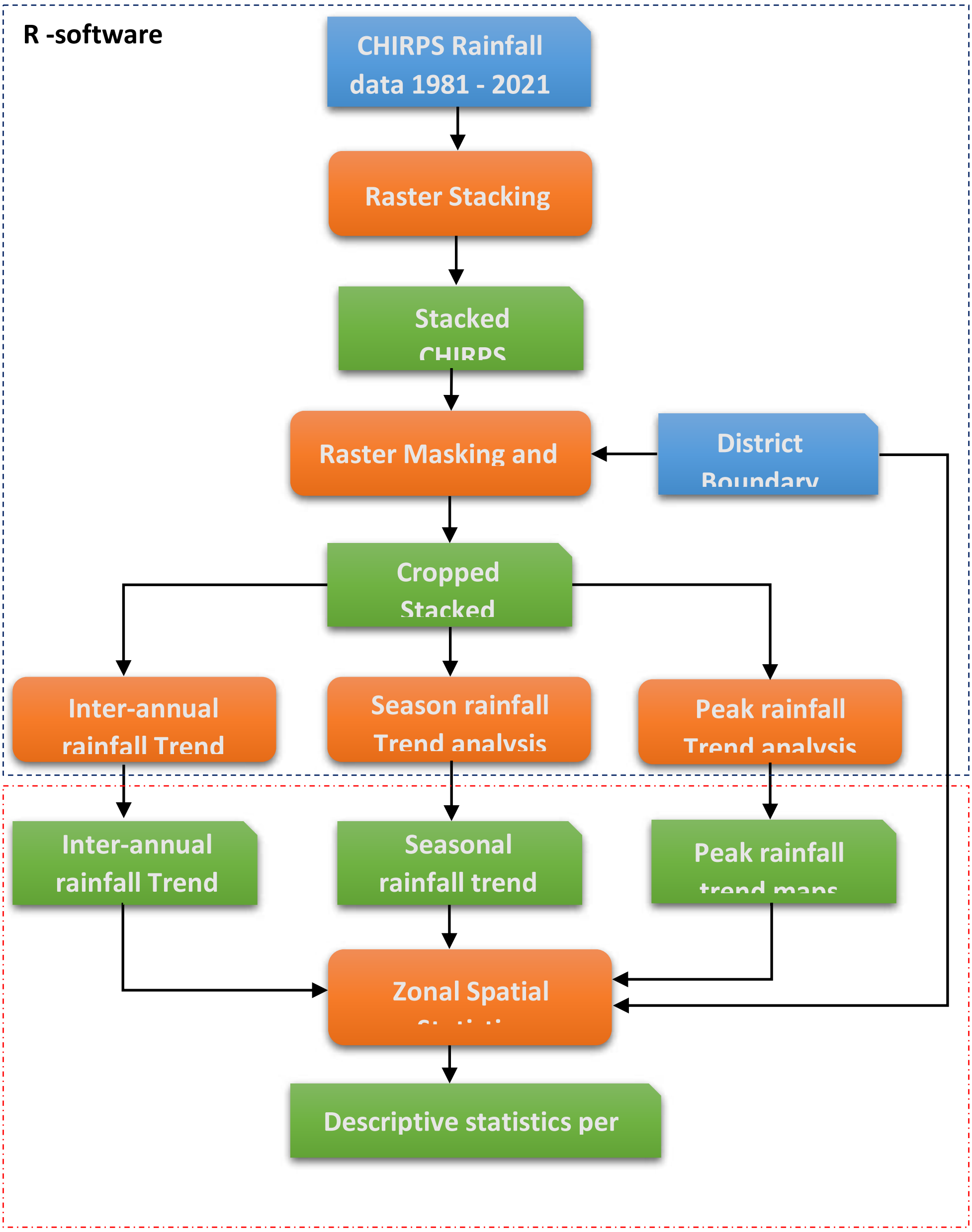


Figure 2: Methodological Workflow Adopted in the Study

3.0 Results

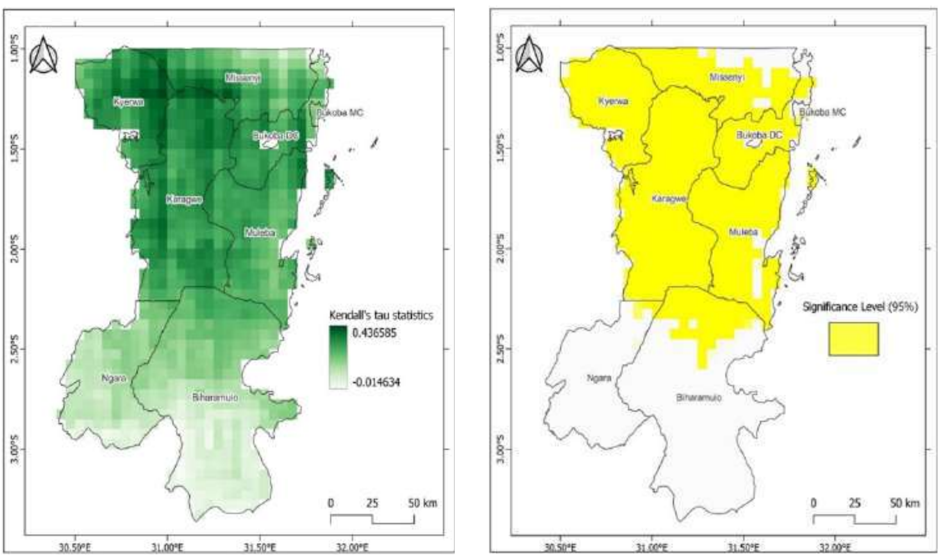
3.1 Spatial-Temporal Trends of Historical Inter-Annual Rainfall

The results (Figure 3a - b) indicate a significant increasing annual rainfall ($p < 0.05$) in the northern part of the region, including Bukoba, Misenyi, Kyerwa, Karagwe and Muleba districts. Similarly, minimal parts of Ngara and Biharamulo districts had significant increasing trends ($p < 0.05$). However, the southern part of the region, including Ngara and Biharamulo districts, had non-significant trends ($p > 0.05$).

The results (Figure 3c & Table 2) show that the magnitude of rainfall trends varied among and within the districts. The Biharamulo district had both decreasing and increasing rainfall trends, while other districts only had increasing trends. A large part of the region had experienced increasing significant annual rains ranging from 1.28 to 15.81 mm/year.

Moreover, the results (Table 2) show that Muleba and Bukoba districts had the highest spatial variability in the inter-annual rainfall trends, with a standard deviation of 1.98 and 2.52 mm/year respectively. In contrast, Ngara and Kyerwa districts had the lowest spatial variability in the trends, with the standard deviation of 0.99 and 1.004 mm/year.

(a) (b)



(c)

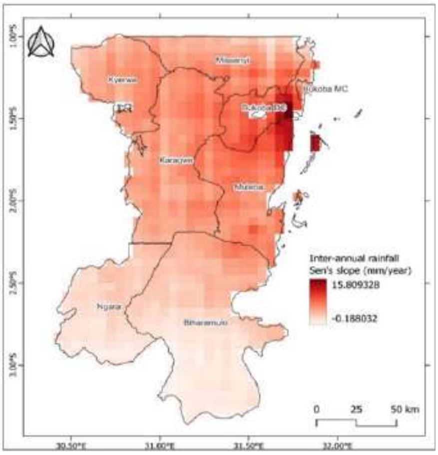


Figure 3:
(a) Mann Kendall's tau,
(b) Significance level (95%) of Sen's slope,
(c) Sen's slope.

Table 2: Descriptive Statistics of Sen's Slope and Mann Kendall's Tau for Annual Rains

	Sen's Slope			Mann Kendall's tau	
District Name	**SD**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Biharamulo	1.684	-0.188	7.651	0.173	0.220
Kyerwa	1.004	2.868	7.168	-0.015	0.298
Ngara	0.987	0.034	4.352	0.215	0.437
Muleba	1.979	4.845	13.701	0.002	0.271
Bukoba	2.519	2.573	15.809	0.188	0.385
Karagwe	1.019	3.835	8.466	0.122	0.380
Missenyi	1.569	1.281	9.592	0.222	0.422
Bukoba Urban	1.193	4.803	7.361	0.063	0.417

Note*: SD = Standard Deviation*

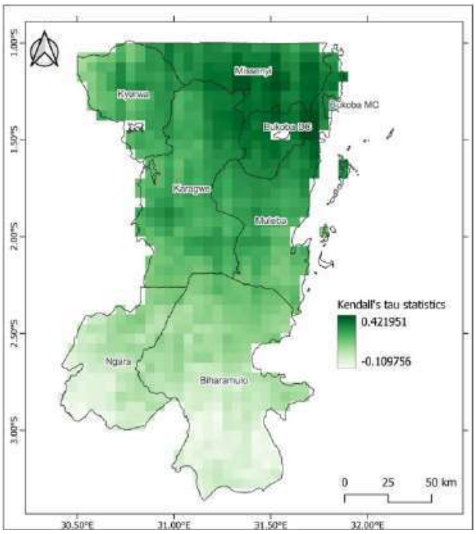
3.2 Spatial-Temporal Trends of the Historical Long Rainy Season (MAM)

The results (Figure 4a-b) indicate a significantly increasing rainfall in the long rainy season ($p < 0.05$) in the northern part of the region, including Bukoba, Misenyi, Kyerwa, Ngara, and Muleba districts. However, some small parts of Muleba, Kyerwa, and Karagwe had non-significant trends ($p > 0.05$). Furthermore, the whole southern part of the region, including Muleba and Ngara districts, had no significant trends ($p > 0.05$).

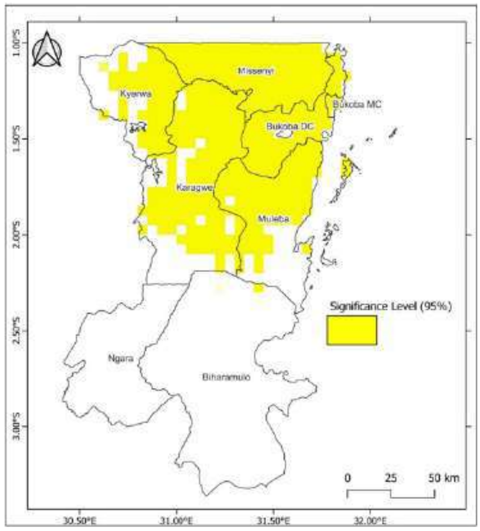
The results (Figure 4 (c) & Table 3) show that the magnitude of rainfall trends in the long rainy season varied among and within the districts. Biharamulo and Ngara districts had both decreasing and increasing rainfall trends, while others only had increasing trends. The significant increasing rains in the long rainy season ranged from 1.11 to 11.05 mm/year.

The results (Table 3) show that Muleba and Bukoba districts had the highest spatial variability in the long rainy season's trends, with a standard deviation of 1.298 and 1.498 mm/year respectively. In contrast, Ngara and Kyerwa districts had the lowest spatial variability in the trends, with a standard deviation of 0.521 and 0.679 mm/year.

(a)



(b)



(c)

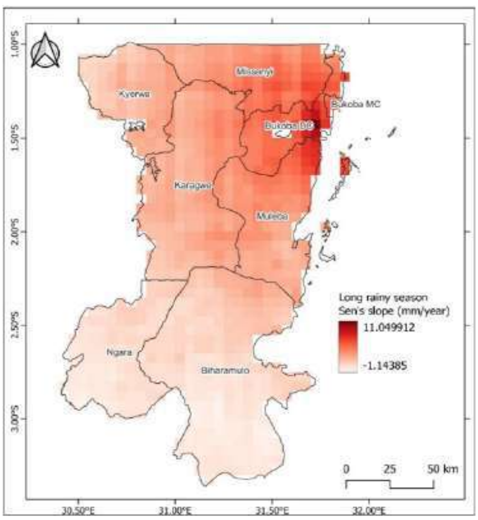


Figure 4:

(a) Mann Kendall's tau,

(b) Significance level (95%) of Sen's slope,

(c) Sen's slope.

Table 3: Descriptive Statistics of Sen's Slope and Mann Kendall's tau for Long Rains

	Sen's Slope			Mann Kendall's tau	
District Name	**SD**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Bukoba Urban	0.545	4.426	5.933	0.278	0.324
Biharamulo	0.841	-0.882	2.980	-0.102	0.224
Kyerwa	0.679	0.638	3.351	0.100	0.332
Ngara	0.521	-1.144	1.442	-0.110	0.173
Muleba	1.298	1.702	7.703	0.144	0.388
Bukoba	1.498	3.803	11.050	0.280	0.422
Karagwe	0.705	1.114	4.639	0.139	0.383
Missenyi	1.096	2.017	6.594	0.244	0.410

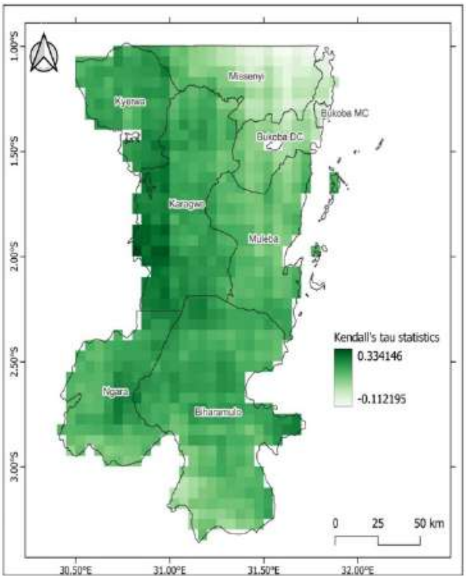
***Note:** SD = Standard Deviation*

3.3 The spatial-temporal trends of the historical short rainy season (OND)

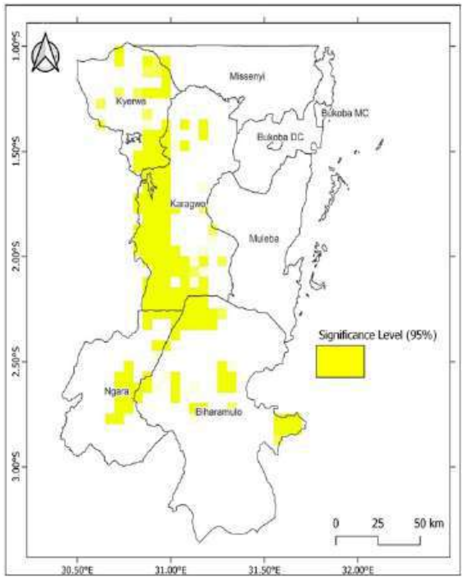
The results (Figure 5a-b) indicate a significantly increasing rainfall ($p < 0.05$) in the short rainy season in some areas of the western and southern parts of the region, including Kyerwa, Karagwe, Ngara, and Biharamulo districts. However, the entire eastern and northern parts of the region, including Misenyi, Muleba, and Bukoba DC, had non-significant rainfall trends ($p > 0.05$). The results (Figure 5 c & Table 4) show that magnitudes of rainfall trends in short rainy seasons varied between and within the districts. Bukoba and Misenyi districts experienced decreasing and increasing rainfall trends, while others only had increasing trends. In general, the rainfall trends in the short rainy season ranged from -1.594 to 3.929 mm/year across the region.

Furthermore, the results (Table 4) showed that the Misenyi and Bukoba districts had the highest spatial variability in short rainy season trends, with a standard deviation of 0.707 and 0.749 mm/year respectively. In contrast, Kyerwa and Karagwe districts had the lowest spatial variability in trends, with a standard deviation of 0.275 and 0.324 mm/year respectively.

(a)



(b)



(c)

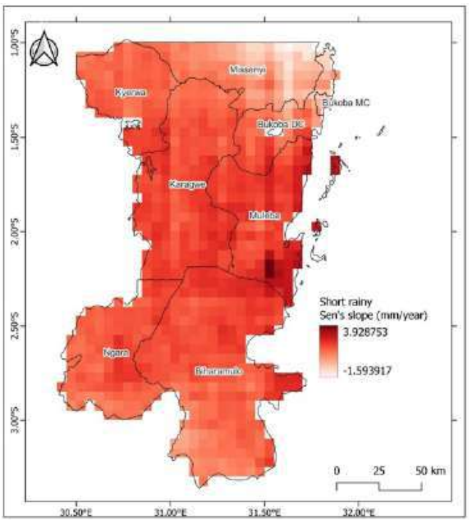


Figure 5:

(a) Mann Kendall's tau

(b) Significance level (95%) of Sen's slope

(c) Sen's slope

Table 4: Descriptive Statistics of Sen's Slope and Mann Kendall's tau Statistic for Short Rains

	Sen's Slope			Mann Kendall's tau	
District Name	**SD**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Bukoba Urban	0.290	-0.596	0.121	-0.054	0.007
Biharamulo	0.484	0.158	2.835	0.020	0.268
Kyerwa	0.275	0.899	2.213	0.124	0.273
Ngara	0.343	0.700	2.268	0.078	0.266
Muleba	0.520	1.042	3.929	0.046	0.207
Bukoba	0.749	-0.665	2.654	-0.056	0.171
Karagwe	0.324	0.802	2.410	0.090	0.334
Missenyi	0.707	-1.594	1.616	-0.112	0.232

***Note**: SD = Standard Deviation*

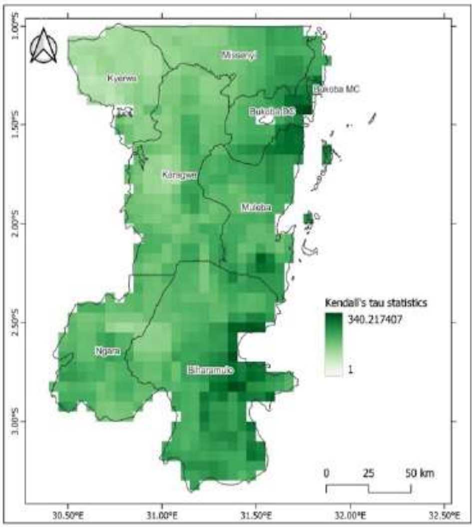
3.4. The Spatial-temporal Trends of the Historical Peak Rainfall (April)

The results (Figure 5 a - b) indicate a significant increasing peak rainfall ($p < 0.05$) in some areas of the northern part of the region, including Bukoba and Misenyi districts. Similarly, some parts of the northern Karagwe district had a significant increase in peak rainfall trends ($p < 0.05$). However, the rest of the region had non-significant trends in peak rainfall ($p > 0.05$).

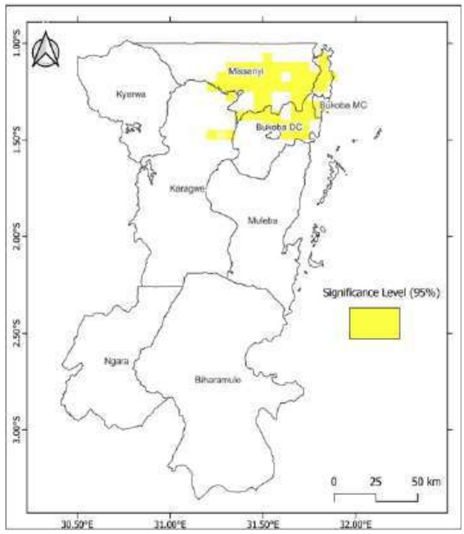
The results (Figure 5 c & Table 5) show that the spatial-temporal trends in peak rainfall varied among and within the districts. Specifically, Biharamulo, Ngara, and Kyerwa districts had experienced decreasing and increasing peak rainfall trends, while other districts only had increasing trends. The increasing peak rainfall trends ranged from 0.13 to 4.07 mm/year.

Furthermore, the results (Table 5) show that Misenyi and Bukoba districts had the highest spatial variability in peak rainfall trends, with the standard deviation of 0.493 and 0.727 mm/year. In contrast, Ngara and Kyerwa districts had the lowest spatial variability in the trends, with a standard deviation of 0.244 and 0.271 mm/year.

(a)



(b)



(c)

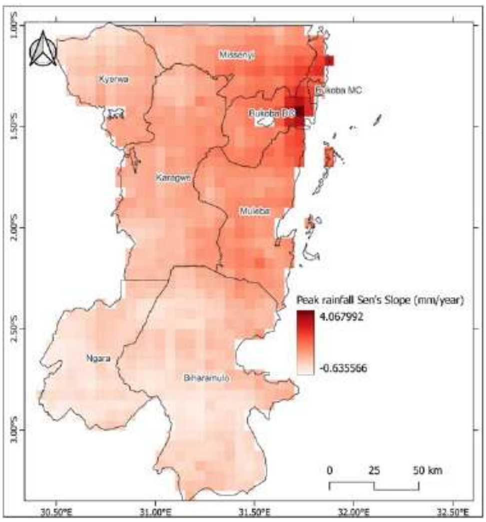


Figure 6:

(a) Mann Kendall's tau,

(b) Significance level, (95%) of Sen's slope

(c) Sen's slope.

Table 5: Descriptive statistics of Sen's slope and Mann Kendall's tau for peak rains

	Sen's Slope			Mann Kendall's tau	
District Name	**SD**	**Minimum**	**Maximum**	**Minimum**	**Maximum**
Biharamulo	0.317	-0.511	1.317	144.978	336.279
Kyerwa	0.316	-0.121	1.122	97.506	204.503
Ngara	0.244	-0.636	0.507	128.343	249.915
Muleba	0.329	0.531	2.268	175.620	321.613
Bukoba	0.727	0.958	4.068	185.588	340.217
Karagwe	0.271	0.130	1.399	111.080	245.957
Missenyi	0.493	0.242	2.371	137.232	272.808
Bukoba Urban	0.233	1.782	2.329	257.433	325.948

***Note**: SD = Standard Deviation*

4. Discussion

4.1 Spatial-temporal Trends and Variability of Annual and Seasonal Rains

The results have shown that the trends of inter-annual rainfall varied over space and time in Kagera Region. Large parts of the region generally had significantly increasing inter-annual rainfall trends from 1981 to 2021. Our results agree with the study by Muthoni *et al.* (2019) that found a significant increasing annual rainfall ranging from 1 to 8 mm/year in Kagera. However, our results have shown a slightly bigger range of significant annual rains, ranging from 1.28 to 15.81 mm/year in Kagera Region. The variations in the analysis period might cause variations in the results. In particular, the present study covered 40 years (1981 to 2021), while Muthoni *et al.* (2019) covered 37 years (1981 to 2017).

On the other hand, our results seem to differ from the study by Luhunga & Songoro (2020), which found that the trends of annual rains are decreasing but non-significant in many areas in Kagera Region. The variations in rainfall raster data resolutions might be a cause of the disagreement regarding the results. This is because the present study applied a high spatial resolution (5.5 km by 5.5 km), while Luhunga & Songoro (2020) applied regional climate model data with a low spatial resolution climate (55 km by 55 km). However, Regional Climate Model (RCM) data tend to have a higher spatial aggregation, which does not suitably represent climate phenomena (such as rainfall) in small geographical extents such as district level. In addition, the present study applied spatial-temporal statistical approaches to analyze trends of historical rainfall data by analyzing the trends at every single pixel in the time-series gridded climate data. This analysis differs from the analysis applied by the prior study.

Furthermore, the results have shown variations in spatial-temporal trends on seasonal rains. During long rains, the large area in northern Kagera had significantly increasing rains, particularly Misenyi, Bukoba, Karagwe, Kyerwa, and Muleba districts. However, the southern parts of the region had non-significant trends. In contrast, the region's western and some southern parts had significantly increasing rainfall during short rains, particularly in Kyerwa, Karagwe, Ngara, and Bihamulo districts. In general, seasonal rains had higher spatial-temporal variability than annual rains. Our results concur with the study by Muthoni *et al.* (2019), which found that the short rains significantly increased in the Lake Victoria basin, including in Kagera Region. However, in the present study, it was observed that the increasing short rains were only significant in limited areas as compared to the long rains.

Moreover, long rains had more trends than short rains in the region. However, this result differs from the study by Kizza *et al.* (2009), which established that short rains had more trends than long rains in the Lake Victoria basin. This disagreement arises because the prior study applied station data from only 20 meteorological stations in the Lake Victoria basin; information on non-sampled locations was not presented. In addition, our results show that the peak rains had significantly increased the trend in minimal areas in Kagera Region, particularly in the northern parts. These areas include parts of Bukoba and Misenyi districts. In contrast, the rest of the region had no significant trends. The spatial-temporal trends of peak rains were confined to small areas compared to the annual and seasonal rains.

Regarding the spatial-temporal variability, results indicated that annual and seasonal rains had uneven spatial distribution at the regional and district levels. However, annual rains had higher spatial-temporal variability than other seasonal rains. Furthermore, results indicated the presence of intra-district spatial-temporal variability of annual and seasonal rains. In particular, Bukoba, Muleba, and Misenyi districts exhibited the highest intra-district spatial-temporal variability, suggesting a more uneven spatial distribution of rainfall frequency and intensity. In contrast, Ngara and Kyerwa districts have experienced the lowest spatial-temporal variability of annual and seasonal rains, suggesting a more evenly spatial distribution of rainfall frequency and intensity.

4.2 Implications of Long-term Rainfall Patterns to Robusta Coffee Production

The long-term annual and seasonal rainfall trends analysis helps to shed light on soil moisture dynamics in the rainfed farming system (Guan *et al.,* 2014). These insights are also relevant to Robusta coffee, where large producers are smallholder coffee farmers who rely on a the rainfed system (Craparo *et al*., 2015). Also, it is relevant because the climate is a primary factor for successful coffee production (Kath *et al.,* 2021). Hence, results showed that the rainfall patterns and distributions are still good in many of Robusta coffee producing areas despite inter-seasonal and inter-annual rainfall variability. In general, Kagera Region still gets adequate rainfall amount and this provides a big opportunity to increase coffee productivity to boost coffee yields and increase the income and livelihoods of smallholder coffee farmers.

5. Conclusion

The study analyzed the spatial-temporal monotonic trend of annual and seasonal rainfall in Kagera Region from 1981 to 2021 using CHIRPS version 2 rainfall data. The results showed that annual and seasonal rains have significantly increased in specific areas in Kagera Region, and other areas have non-significant rainfall trends. The results also revealed that annual and seasonal rainfall trends had inter-and intra-district spatial-temporal variability. Furthermore, the results demonstrated that applying spatial-temporal analysis of the rainfall trends using satellite-based data in areas with insitu data-scarce like Tanzania provides better insights into the geographical distributions and patterns of annual and seasonal rainfall.

Moreover, the results exposed that rainfall patterns and amounts are crucial in understanding the impacts of climate change on Robusta coffee production and planning for adaptation measures. Despite Robusta coffee-producing areas having generally good rainfall patterns in Kagera Region, the variability in annual and seasonal rainfall patterns could affect crop growth stages, productivity, and the quality of coffee beans. Therefore, it is crucial to enhance Robusta coffee productivity and value chain resilience to the uncertainty of climate change by promoting innovative approaches for context-specific climate adaptation and mitigation measures through the collaboration of farmers and agricultural extension services backed with robust policy determination.

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Assessment of the Measures of Agricultural Productivity in Mbozi District, Tanzania

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Abstract

This article assesses the measures of Agricultural Productivity in Mbozi District, Songwe Region, Tanzania. It has not been well known to what extent the measures of agricultural productivity have been fully utilised for bringing about high productivity. Following changes in land tenure system measures of productivity should also be implemented based on land tenure changes which have implications on agricultural productivity. More specifically, the study evaluated the intervention measures of land tenure in Mbozi District by being guided by the Diffusion Theory. Triangulation research design was used in which both quantitative and qualitative methods were used to collect and analyse data. A total of 300 respondents (individual peasants) were involved to respond to the structured interviews and 30 responded the unstructured interviews of which observation supported these two methods to answer the study objectives. In selecting these 330 respondents from 90,000 peasants, various characteristics, namely sex, residence, age, education level, marital status, status of land occupancy, family size, status in the household, levels of wealth, and size of land occupied or rented by a peasant were used. The study evaluated intervention measures for land tenure such as multi-national companies, experienced stakeholders like TaCRI, restitution, structural transformation and application of new technology. It was found that land tenure is the primary factor that influences agricultural productivity but its influence depends on other factors like migration, cultivation systems, and application of chemical fertilizers, technologies and labour. The study recommends that factors which limit land occupancy such as cultural settings that exclude females from full participation in land tenure and production should be changed or phased out to allow both men and women to have equal land occupancy and equal rights of participation in agricultural production which increases productivity. It is further recommended that the Land Policy of 1995 and the Agricultural Policy of 2013 should be amended by updating land and agricultural laws which guide stakeholders to implement and put such policies into practice among the peasants.

Keywords: Agriculture, productivity, measures, land tenure, Mbozi.

1.0 Introduction

Productivity is a ratio of a volume measure of output to a volume measure of input use (OECD, 2001b). At its most fundamental level, productivity measures the amount produced by a country, industry, sector, farm or almost any target group given a set of resources and inputs. Productivity can measure a single entity (farm, commodity) or a group of farms, at any geographical scale. It should be noted that the measure should reflect the ultimate purpose for the inquiry. If, for example, the purpose is to compare productivity among farms, then measures that are micro-based are required. If the need is to evaluate the national agricultural policy at the country level, then macro-measures are required. Farm-level productivity measurement for one commodity and one input (for example, labour productivity of maize farms) may only require basic information on output quantities and input use, whereas producing aggregated measures generally requires pricing outputs and inputs.

Globally, different measures have been undertaken here and there to ensure that the highest agricultural productivity meets the demand of the growing population. The study by Ludena (2010) on growth rates and levels indicates that completing traditional productivity growth measures with information on levels may be relevant for several reasons which have also been briefed by Radel (2005). Firstly, it would be for international comparability purposes because countries that have already reached high levels of productivity have a less room for additional substantial productivity improvements, contrary to countries where agriculture is less capitalized and subsistence-oriented as the productivity gap is wide. Comparing the productivity growth of these two groups of countries makes little sense without additional information on the levels of measures of agricultural productivity. Secondly, levels are more intuitive for single-input (or partial) productivity measures. For example, labour productivity can easily be measured in levels, such as output per number of hours or days of work. Levels can be easily compared across sub-sectors, regions and countries to provide evidence of differences in input productivity. Some elements on productivity levels and growth rates can be constructed at different levels of aggregation that involve on-farm processing, and any output generated by off-farm processing.

In America, measures of agricultural productivity have brought greatest transformation of food (maize) industry which is happening now in some countries like fruits in Italy, sugarcane in Cuba and bananas in Jamaica. Following the growing population, agricultural sector is undergoing systematic transformation from one place and time to another. With the technological transformation, food systems are being reimagined and shaped by a focus on consumer, planet and market connections (Pohamba, 2002). There have been different efforts in America that have led to the current transformation. For example, in 1996, the Federal Agricultural Improvement and Reform Act (FAIR) was signed by President Bill Clinton. FAIR is the most ambitious federal farm programme that has influenced the domestic and export markets rather than only depending on local government to determine crop production. The programme has built a good agricultural foundation up to the year 2021 because it intends to bring about rural economic development and encourages farmers to practise conservation methods through incentives from public and private stakeholders (*ibid*).

There is low productivity in developing countries compared to developed countries because farming systems in the former tend to be fairly diversified. Often, they combine crops, livestock activities and cash crops with subsistence activities that involve many localised measures such as depending only on manure without industrial fertilizers, use of hand hoe together with mechanization. Proper accounting of the output of the farm, including secondary crops, by-products and unsold produce, is a prerequisite for obtaining an adequate measurement of productivity. The common practice of mixed cropping in developing countries where several crops are simultaneously grown on the same parcel of land adds complexity to the measurement of output. Kelly *et al.* (2016) maintains that the most noted problem associated with the measurement of productivity in developing countries, particularly in sub-Saharan Africa, is the underestimation of output and yields. Indeed secondary crops and by-products are not properly estimated due to lack of effectiveness of different measures like land restitution and structural transformation (Lyne and Darroch, 2003).

In East Africa, different historical data from 1965 to 2020s show that average productivity has been less than 2t/ha over the whole period due to lack of proper measures of agricultural productivity that fit the changing climate and the nature of the soil. Average agricultural productivity has ranged from 1t/ha from 1965 to 1970 and 1.5t/ha from 1990 to 2010. The regional long-term average crop productivity (1965-2010) stood at about 1.3t/ha. During the same period, the average productivity stood at 1.1t/ha, 1.2t/ha, 1.2t/ha, 1.4t/ha, and 1.5t/ha in Rwanda, Burundi, Tanzania, Uganda and Kenya respectively. There was a gradual increase in productivity in all East African countries for the period between 1960 and late 1980s. It was then followed by a drop in Burundi, Kenya and Rwanda till early 2020. In the period from 1965-1975, Tanzania crop productivity was trailing behind the other countries with 0.7t/ha and 0.8t/ha in periods of 1965-1970 and 1970-1975 respectively. This was below the 1t/ha, a level that all other four countries had achieved and below the average regional productivity. Over the period from 1965 to 2010, crop productivity in Tanzania had been declining at a rate of 6.6% per annum. However, over time Tanzania's crop productivity has been gradually increasing from 0.8t/ha in the period from 2010 to 2015 up to a high of 1.6t/ha in 2015-2020, eventually overtaking Rwanda and Burundi that reached 1.36t/ha in 2010-2015 and 1.38t/ha in 2015-2020 respectively (Thorbecke, 1964; Folkers, 2010; Karugia *et al*., 2013).

1.1 Theoretical Framework

This paper employed Diffusion Theory on its empirical observation on land, labour and productivity which are among the key factors of agricultural development. Diffusion Theory on agricultural productivity rests on the substantial differentials in land, labour, and productivity among farmers and regions. The route to agricultural productivity, in this view, is through more effective dissemination of technical knowledge and a narrowing of the differences in agricultural productivity by balancing land tenure systems among female and male peasants or farmers and across regions (Udemezue & Osegbue, 2018). With regard to this theory, there is a need for more research in the field of measures of agricultural productivity in Mbozi District due to the fact that the district practises different measures, but its productivity is low regardless of being one of the agricultural zones in the southern highland of Tanzania.

1.2 Statement of the Problem

Agricultural productivity depends on the quality of the inputs and how well those inputs are integrated with production processes. The inputs have often been associated with measures of agricultural productivity. In Tanzania, particularly in Mbozi District, there is a lack of better options in implementing measures of agricultural productivity. Peasants have been partially implementing the macro and micro measures of agricultural productivity which by the end of the season yield low productivity regardless of more efforts being taken at the local and national level. Thus, this study intended to evaluate the measures of agricultural productivity in Mbozi District, located in Songwe Region. It is an important study because it provides areas of weakness and suggestions which the government, through the ministry, can take to increase productivity in Tanzania by providing awareness on issues like the way land productivity highly depends on location of the land and its physical characteristics which in most cases peasants and farmers fail to note before selecting the crop to be cultivated.

So far, there is a limited understanding of the measures of agricultural productivity in relation to the increased urban population in centres like Vwawa, Mlowo, Itaka and Ihanda in Mbozi District. These seem to change the systems of land tenure in the district by turning formal food crops like finger millets to cash crops. Thus, the rate of land selling, even in the rural area, to accommodate urban settlements and urban agricultural population has increased which requires more studies to bring way forward.

The study presents an evaluation of measures of agricultural productivity of some of the key food and cash staples in Mbozi District. Data were analysed based on different crops such as maize, coffee, beans and avocadoes. The rest of the paper is organised as follows: section two summarises data sources and methodology for the analysis, while section three presents findings and discussion of key findings. These sections form the basis for the conclusion and recommendations which are made in section four.

2.0 Materials and Methods

The study was conducted in Mbozi District (Figure 1). It was the best case study because it is one of the agricultural zones whose land is fertile; hence suitable for agricultural productivity although its productivity is still low. Based on the economy, the agricultural sector was studied because agriculture plays a crucial role within the critical triangle of the district and national development goals. It plays an essential role in individual livelihood at the district and national levels. Fortunately, Mbozi is one of the Southern Growth Corridor of Tanzania. Therefore, it is obvious that the trend of statutory land tenure system especially in the urban areas is increasing with time and place. These changes have significant influences on agricultural productivity as it was also observed by Baron (1978) in sub Saharan Africa that there is an ample evidence that the incidence of land disputes and land grabbing by larger or more powerful farmers are increasing as the potential return to land rises. Thus, the understanding of existing systems of land tenure is essential for better planning and sustainable agricultural productivity in Mbozi District.

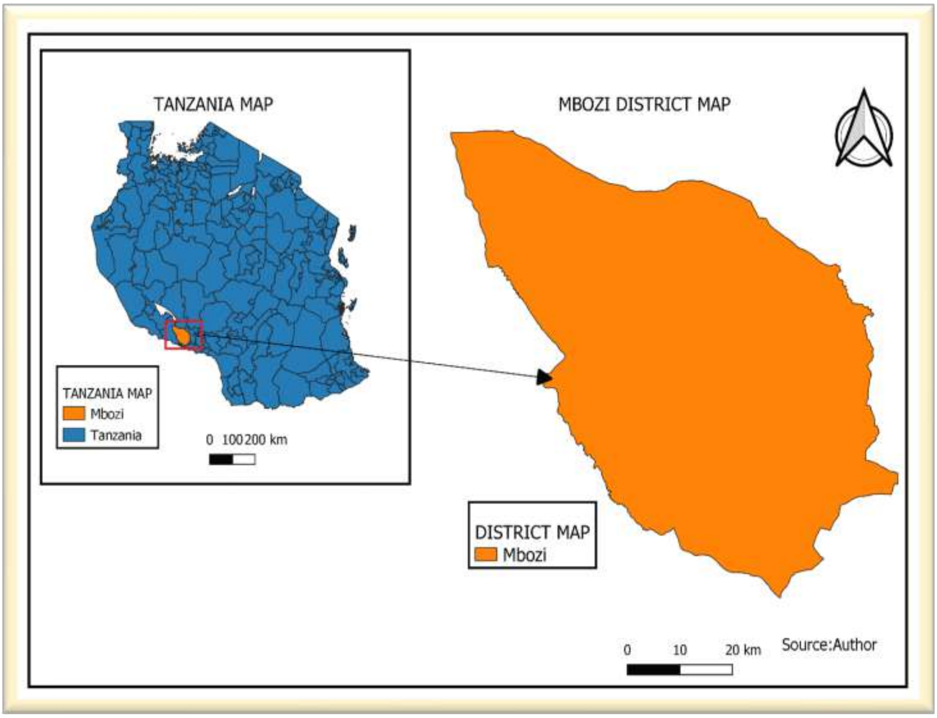

Figure 1: Location of Mbozi District
Source: GIS Software (2022)

Both qualitative and quantitative methods were used to complement the gaps of each other. It involved secondary and primary data through literature reviews and fieldwork because it was a case study. Data were collected from peasants through questionnaires, interviews and observation in Mbozi District; particularly in Mponela, Ndolezi, and Matula villages in the rural, and Mlowo, Vwawa and Ihanda urban centres. Data were collected from March to June 2021. An individual farmer/peasant based on different sex, residence, education level, and age was taken as a unit of analysis. Besides, primary data were supported by the findings from the reviewed related literature. The data were collected by administering questionnaires to 300 (200 males and 100 females) participants. As adopted from Cohen (1988), studies that involve quantitative approaches should have a larger sample size to provide satisfactory data. The respondents were randomly selected to avoid biases in the findings responded within 30 to 60 minutes for each participant. Before their selection, the researchers introduced themselves by releasing the research permits and stating the significance of this study to individuals and nation as well until the respondents reached the stage of accepting and being able to provide the data. To enrich the data from questionnaires, observation (participatory and non-participatory) was also involved in which the study observed various land tenure and agricultural issues; some of them were the size of land, boundary identification and inputs involved in agricultural production. Furthermore, in-depth interviews with seven key informants who were selected by snowballing technique, each lasting for 60 to 90 minutes, were conducted. Interviews which included experienced villagers and street leaders as well as one extension officer from the district council and TaCRI were conducted through Nyiha or Swahili languages which were later translated to English language. Data collection took place at three levels, namely, peasants, stakeholders like TaCRI, and District Council levels. Individuals were selected from these levels to prove the validity and reliability of findings about measures of agricultural productivity. The collected data were analysed by descriptive and content analysis methods. Quantitative data from the questionnaires were analysed through descriptive statistics of which the Statistical Package for Social Sciences Version 20 was used to analyse the data from the field. Frequencies were determined to observe the occurrence of the responses from interviewed peasants.

Qualitative data from reviewed literature, interviews and field observation were analyzed by content analysis which allowed the researchers to identify various recorded data during field communication between the researchers and respondents. This was adopted from Downe-Wamboldt (1992). In this study, the unit of analysis was an individual peasant. Since the study based on measures of agricultural productivity in Tanzania, it used accounting technique and econometric estimation models to measure productivity per farm size based on the perceptions from peasants who were involved in questionnaires. Both participatory and non-participatory observations were also used to justify the results from questionnaires and interviews.

Ethical consideration was insured through requesting the permit from the district administration during data collection. Pilot study and the use of triangulation during data collection and analysis were employed to ensure validity and reliability of findings.

3.0 Results and Discussion

The article assessed five measures of agricultural productivity as follows:

i. Presence of multinational companies which guide peasants on land tenure system

Different companies including TaCRI, ADP and NFRA were assessed. Results indicated that various stakeholders were formed to support the agricultural economy. During the time of this study, respondents commented on the presence and role played by TaCRI that it enabled peasants to get new agricultural skills through researches, training and consultancies of which the arguments accounted for 154 (51.3%) respondents. TaCRI as one of agro-dealers in Mbozi District conducts various trainings to ensure capacity building for peasants and agricultural extension service providers or extension officers. The agency provides training to peasants of Mbozi District and other parts of Southern Highlands.

However, some weaknesses from some companies including TaCRI were observed. Measures taken by TaCRI (in Mbozi District) were found to be ineffective and not implemented in time in some areas due to few permanent workers who are employed in the institute to the extent that some peasants, especially in remote/rural areas, were not aware of the presence of the institute. So far, the carrying capacity and its scope is very broad in such a way that there could be the possibility of partial implementation of peasants' technical support. For example, TaCRI was operating in four regions with eleven districts. In Songwe Region, it was operating in Mbozi and Ileje districts; in Mbeya Region, it was operating in Mbeya Municipal, Mbeya Rural, and Rungwe and Busokelo districts; in Rukwa Region, it was operating in Kalambo, Sumbawanga Municipal, Sumbawanga Rural and Nkansi District; while in Katavi Region, it was operating in Tanganyika District. The performance might be substandard due to a few TaCRI workers whereby during this study, there were only three researchers of which all were men; throughout the country, there were 80 TaCRI workers. This policy of employing few workers was said to be influenced by the European Union (EU) which is one of their donors. EU applies the policy that there must be few workers based on the principle that "*Lean but Efficiency*" which seems to be like a colonial and capitalist slogan that limits the number of workers by expecting high performance.

In solving the burden of few workers at TaCRI, the institute was using one of the alternatives of hiring casual workers which was costly. The institute was hiring casual workers by season. For example, during high season, they could hire 25 workers and during low season, they could hire 15 workers. So far, for research and consultancies, TaCRI was incurring the costs for calling and integrating extension officers from each district council or municipal which was difficult during the time they had no fund. Moreover, such a gap could not suffice the demand of all peasants in Mbozi District, for in some areas and periods the institute was unable to control coffee leaf rust, berry and wilt diseases on time and to all peasants. Due to the fluctuation of price of coffee at the local and national markets, some peasants in Mbozi District were not dealing with coffee plantations which disqualified them to benefit from TaCRI. Hence, it is suggested to add more staff and other related agro-dealers.

Moreover, 129 (43%) respondents said that the Actions for Development Programmes-Mbozi (ADP) has been playing various roles by insisting peasants to use the land effectively for the production of crops to increase agricultural productivity. The insistence was being done through visiting and talking to peasants about agricultural skills, doing researches and consultancies related to land use, agricultural production and productivity. Before those roles, there were various land tenure and agricultural associated factors that forced the establishment of ADP-Mbozi. For example, in 1985, there occurred a serious famine in many parts of southern Tanzania including Mbozi District. As a result, the Mbozi District Council contracted a consultant to find out what was the cause and how best to deal with the problem. The survey findings highlighted low utilization of agricultural technology, inadequate extension staff, and inadequate supply of agricultural inputs as the main causes. Thus, the findings forced the government to register ADP-Mbozi on 10th October 2005 as an NGO with registration number 1639 that could intervene the systems of land tenure and agricultural production based on the law governing the establishment of Non-Governmental Organizations in Tanzania {Section 11 (3) of Non-Governmental Act No. 24, of 2002}.

The coverage of ADP on land tenure system and agriculture among peasants was not enough due to various challenges. The study found various challenges that limited the effective performance of ADP. There was a limited number of ADP staff of which the study found 37 females and 21 males. Likewise, land tenure and agricultural productivity were not core activities of ADP. Apart from that, transportation was too expensive not only because of poor infrastructures, but also Mbozi District is large and has many peasants. There was also unreliable supply of inputs in such a way that in some growing seasons, fertilizers are brought during the end of the season. Thus, even their training and consultations could not work for some growing seasons. Worse enough, the agency has low capital to enable timely visitation to all parts of Mbozi District and also low knowledge of entrepreneurship among peasants. For example, some peasants are still conservative in such a way that they could not adopt to multi-cropping.

Generally, the study found National Food Reserve Agency (NFRA) to be another donor which indirectly contributed to the improvement of land tenure system and agricultural production which raised productivity. The findings show that 17 (5.7%) respondents said the National Food Reserve Agency (NFRA) helps peasants by influencing effective land use for agriculture due to provision of market for crops. There was low proportion of responses from respondents because NFRA had no direct effects on peasants as it was the case of TaCRI and ADP. NFRA was directly linked to crop traders who were acting as middlemen between the named agency and peasants. Critical observation point of view shows that the agency had no direct contribution on land tenure, as one of the key informants commented as follows:

> Actually the agency has not persisted for a long time that is why many peasants are not aware of its existence but also the agency is not directly affecting the peasants' demands rather it is connected to middlemen who buy crops from the rural and urban peasants.

On the same issue, the agencies were working seasonally as in some seasons their offices were not opened and working (they were not buying crops) until further order or notice from the responsible ministry. Therefore, lack of frequent purchase of crops was one of the major causes of price decline. For example, the price of maize was very poor during the time of this study.

ii. Learning lessons from experienced stakeholders

The findings about the lessons from experienced stakeholders were studied based on different variables, namely material support from TaCRI, role of institutes like Uyole and Walter Reed, and contribution from the American Embassy. Respondents provided different opinions about the lessons from experienced stakeholders in Mbozi District. In this measure, 216 (72%) respondents said material support, consultancies and training from TaCRI, ADP and village land committees or council direct peasants on better land tenure system and production. On the same, 42 (14%) respondents viewed that the American Embassy encourages peasants on effective land use for agriculture; 27 (9%) respondents said through the district council authority, Uyole Institute through Tanzania Research Institute (TARI) and Walter Reed program insists on proper land use for agriculture by supplying some seeds like avocadoes; and the remaining 15 (5%) respondents said the presence of third party or witness when buying and selling land adds verification of boundaries which control land conflicts that might lead to ineffective land use, hence slowing productivity.

In the interview conducted at Vwawa City Center, one of the key informants who was a peasant but also a government employee said:

> We get lessons from both local and international stakeholders. For example, on 5th April 2021 when Honourable Miss Imni Patterson, the Deputy Ambassador (Germany-Tanzania Embassy), came during the anniversary of food in Songwe Region which was held from 5th to 10th October 2018, she insisted on various projects including the improvement of agriculture to ensure food security and availability. It is not only international donors but also our political leaders are insisting on the same thing. For example, the one who was the minister of Agriculture before former minister Hon. Japhet Ngailonga Hasunga (MP) becoming a Minister of Agriculture on November 13th, 2018, Eng. Dr. Charles John Tizeba (MP.) insisted on the logistics of providing loans to peasants in Bukoba on 6th October, 2018 which should be done in Mbozi District as well… (Key Informant/Vwawa City Center/ April, 2021).

The data from observation also indicated the presence of various trainings to take place in the studied area which in most cases were provided by TaCRI and extension officers in the urban and rural areas through normal sessions (Figure 2 B) and farm field school or "shamba darasa" (Figure 2 A). Actually, such trainings had led to effective use of arable land to some peasants, hence increased agricultural productivity in Mbozi District.

Figure 2: Extension officer (left) and peasants at tacri (right)

Generally, these findings are similar to Pohamba (2002) who observes that strong capacity building is needed to properly implement programmes which are dealing with market networks among peasants. Such programmes are also ensuring smooth land tenure among peasants and farmers. For instance, where land is first acquired by the state and subsequently transferred to beneficiaries, as it is done in Namibian Model; government agencies need land valuation and other skills for peasants to be able to negotiate a fair land and crop market price with the willing seller. In Namibia, the prices asked by landowners are often inflated, and the government lacks qualified land valuers to assist in land acquisition; thus, donors and other agents are required to smoothen the situation to affect land use and raise agricultural productivity.

Some stakeholders were lacking operational definition during the time of this study because they were working in some phases. For example, the American Embassy, Uyole Institute and Walter Reed Program influenced land tenure and agricultural production and productivity in some phases and had no direct integration with peasants and the district authority. Thus, they were not being implemented throughout the time and throughout the district. These were observed to lack effectiveness since some stakeholders like Uyole Institute, Water Reed and the American Embassy had not yet opened their offices in the studied district. The offices for Uyole Institute and Water Reed were situated in Mbeya City whereas that of the American Embassy was only in Dar es Salaam in such a way that they were not effective and sharp. Thus, timely measures that could benefit peasants throughout the time could not be ran. It was also observed that much efforts provided by Water Reed were based on HIV/ AIDs, which is an indirect measure on land tenure system and agricultural productivity because during this study its primary role was to control HIV/ AIDs among peasants in rural areas. The study found a few trainers at TaCRI and ADP. For example, during this study, there were three researchers, two drivers and one accountant at TaCRI and 21 male and 37 female workers at ADP. Therefore, the human resource was not enough because Mbozi District is big and has many peasants whose number was approximated to be 60,000 males and 30,000 females making a total of 90,000 peasants (Mbozi District Council, 2021). Generally, the area is large compared to the capacity building provided by agro-stakeholders in terms of human resources in such a way that the measure was not well implemented and operated in the studied area; hence, there is a need to improve the aspect of learning lessons from experienced stakeholders in order to ensure effective land tenure and raise agricultural productivity.

iii. Land restitution

This study evaluated issues of land restitution in Mbozi District and the results are presented in Figure 3. Data indicate that 265 (88.3%) respondents commented on the presence of land to land or land to money compensation, 15 (5.0%) respondents said restitution is done only to peasants who have a formal land lease, and 20 (6.7%) respondents viewed that land restitution at family level resolves land conflicts, especially during inheritance, hence raises productivity due to harmonious land use. These results concur to Lyne and Darroch (2003) who observe the pace of restitution that led to better land tenure in South Africa remarked around 2000s increased agricultural productivity among local people.

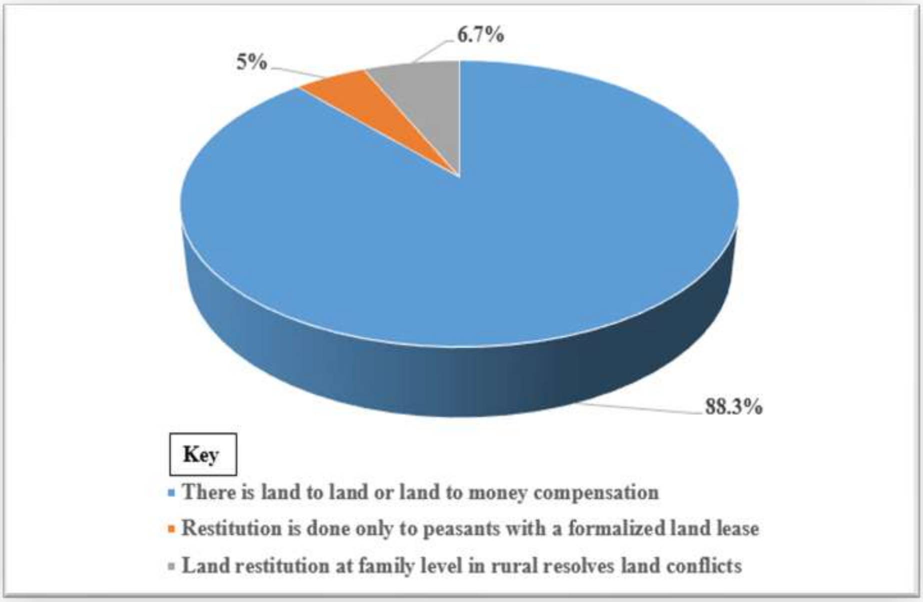

Figure 3: perceptions about land restitution in mbozi district (N = 300)

In some areas, the restitution was achieved since the views provided by peasants about 'the presence of restitution as one of the measures for land tenure system and agricultural productivity' were observed to be applicable; it was achieved in four areas. The first area was Ilembo Village at Vwawa Town where the Songwe Regional Hospital was about to be constructed. The second was Iboya Village near Ihanda semi-urban centre area where the government planned to construct the international weighing. The third area was known as the New Itaka Military Camp, while the fourth one was Mlowo at Ilonga Stone Mining Centre for Mbeya Cement Industry. In both categories of restitution, the land to land and land to monetary compensation were done to ensure sustainable land occupancy among peasants whose arable land were dispossessed. The measure was found not to be applicable along the basins which the government dispossessed peasants. They were denied to practise agriculture under irrigation to conserve the environment as well as reserve and protect water catchment areas. The dispossessed land where peasants were cultivating under irrigation is Mwenge (Figure 4 A) and Mtoka Basin (Figure 4 B). Others were Mantengu, Kilimampimbi and Masaki basins. It was recommended by the authority but also in environmental laws that the basin should be reserved from its bank up to 120 meters on either side as a part of wetland resource. These basins were reserved carefully to conserve Ikomela and Momba rivers which pour water in Lake Rukwa. Land compensation to peasants who were cultivating along these basins was not done. Thus, the measure reduced the size of arable land to peasants in these basins, hence reducing agricultural productivity especially maize which the indigenous Nyiha were cultivating. Additionally, the land to monetary restitution was not effective to some peasants who after being given money, they ended up buying other commodities instead of farms. Such situation reduced farm size to individuals, hence reduced productivity. On that stand, the measure focused much on peasants with formalized land lease but majority of peasants were occupying land traditionally, that means without any documentation, and others inherited land from their fore bearers whose occupancy was informal. Hence, it was easy for these groups not to be compensated even a small piece of land.

Figure 4: Reserved mwenge and mtoka basins

iv. Structural transformation as a measure on land tenure system

The structural transformation on land was among the measures for land tenure system and agricultural productivity in Mbozi District which were evaluated by this study. Different views from respondents were provided and the results are presented in Figure 5:

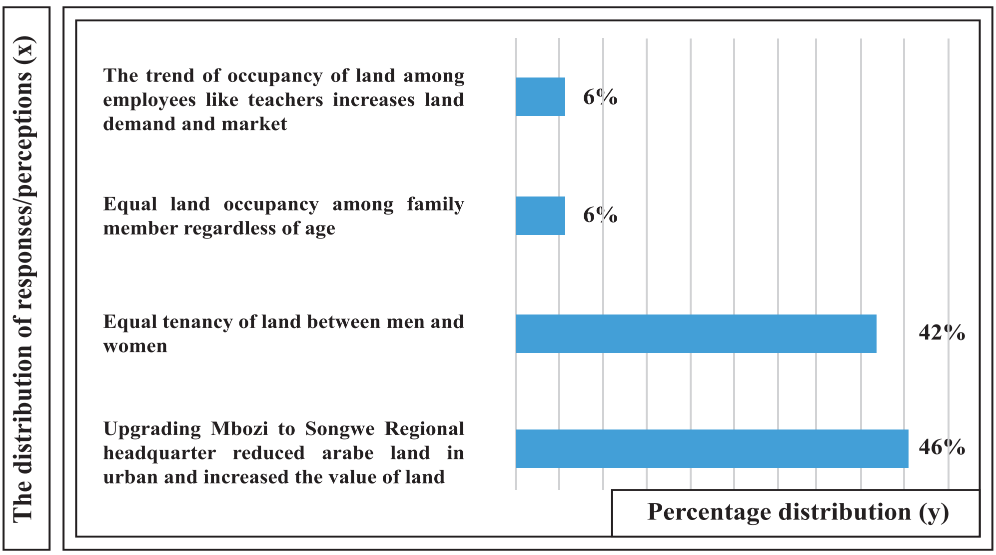

Figure 5: Perceptions on structural transformation on land tenure system

Figure 5 shows the results based on the perceptions of respondents on the structural transformation. From the results, 126 (42%) peasants said social transformation of providing room for women to occupy land increased more equality of land tenure between men and women though there was a slight persistence of patriarchal system which favoured men the most. On the same issue, 138 (46%) peasants said the changes of Mbozi District status to become the headquarters of Songwe Region on 29th January 2016 reduced arable land in town centres like Vwawa and Mlowo due to population increase through in-migration though such changes increased its value in both urban and rural areas. For example, areas like Masaki Basin and water reserve were used for agriculture under irrigation, but during this study the area was full of people's residence. Similarly, the trend of urbanisation in urban centres of Mbozi District, namely Vwawa and Mlowo was increasing on either side, hence reducing arable land and agricultural productivity in urban areas. Moreover, 18 (6%) respondents said equal land occupancy among family members regardless of age (social transformation of land occupancy regardless of age) influenced productivity because at least all family members are involved in agricultural production rather than just being a family labour power. Then, 18 (6%) respondents responded that the trend of occupancy of land among employees like teachers increased land demand and market. This has been the case in the studied area due to human behaviour and recent economic situation which forces some government servants, teachers inclusive, to create more than one source of income. Such diversification of economic sectors has increased land demand and its market has risen in both rural and urban areas. Similarly, Thorbecke (1964) and others observe the recognition of structural changes as preconditioning factors in the process of effective land use and agricultural growth.

Observations show that there were financial transformations in which peasants were being assisted and financed by banks like CRDB through AMCOS. This made some peasants who had qualifications for loans and grants to adopt new and modern farming technologies. There were also social transformations in which peasants were being insisted about land occupancy regardless of sex and age, whereby previously the aged and men were considered as occupiers of land while women were considered as housewives and helpmates as it was also observed by Radel (2005). In the study area, there were also political transformations as one of the ways to bring development including agricultural transformation in Tanzania. During the time of this study, the district had upgraded from being a council within Mbeya Region to headquarters of the new Songwe Region since 29th January 2016 in which agriculture was among the economic activities which were being improved in different initiatives. In other ways, this measure of political changes was found to cause the scarcity of arable land especially in urban areas because some arable lands were used for urbanization (Figure 6 A).

In technological transformations, peasants were insisted to use chemical fertilizers (especially in areas whose arable land had been exhausted), chemicals for killing weeds, herbicides for inset and pest sides and the use of modern, treated and hybridized seeds (Figure 6 B). This measure was also difficult to peasants whose economic situation was poor. Moreover, the adoption was limited by the price of some crops like maize. It was quite poor in such a way that a peasant was supposed to sell more than one bag of maize to get 50 kilograms of chemical fertilizers.

On top of that, technological transformation on agricultural productivity was done in the context of boundary verification between peasants' farms. It was observed that through the advancement of boundary verification, peasants were in the harmonious state that prevented land conflicts among neighbor landholders. Previously and during this study, some peasants were using canals, crops like bananas and trees (Figure 6 C) as limits between one farm holder and another. However, during the time of this study, some peasants who were well aware of the value of land and the trend of population increase started using more formalized benchmark or rods that identify the occupancy and boundary verification (Figure 6 D). On the same, this measure item was more applicable in urban and areas near the urban areas rather than rural areas. The rural peasants were not much familiar with the formalized boundary verification in such a way that there was a need to disseminate the skills. There were changes in tillage systems. Peasants shifted from the cultivation system by using farm fields (Figure 7 A) to the use of "sensa", which meant a cultivation without construction of farm fields (Figure 7 B) of which the interview findings indicated that there was the possibility of planting many crops in a small piece of land; hence, high productivity compared to the use of field which leave large useless spaces between one field and another.

Figure 6: Various ways of technological transformation on land occupancy

Figure 7: Tillage systems {farm fields (a) and "sensa" (b)}

Moreover, the measure was applicable because it has transformed various aspects of life including political and socio-economic aspects which have brought major changes on agricultural production and productivity. For example, many head offices before political transformation of Mbozi District were situated in Mbeya Region in such a way that it was difficult for timely consultation and sharing of capacity building among extension officers, donors, other agro-dealers and peasants. During the time of this study, major agricultural offices were nearby peasants which simplified capacity building on agricultural production and productivity. This measure was limited by the small number of experts from agricultural departments and other agro-dealers like ADP and TaCRI which could not suffice the large number of peasants and large size of Mbozi District. Hence, there is a need for the authority in the studied area to consider this limitation in order to insure effective land use and raise agricultural productivity.

Finally, relatively to Mulungu and Myeya (2018), there is demographic transformation which has transformed systems of single crop cultivation to multi cropping by adopting new crops, example in-migrants from Ileje (the Ndali) has changed patterns of cultivation systems among indigenous Nyiha from relying on food crop to multi cropping of food and cash crops. This initiative was also limited to financial and cultural issues. For example, some peasants could not afford cultivating coffee because it is too financially demanding and it needs close supervision with application of more technical skills. On the same issue, the measure was limited by cultural and spiritual issues. For example, at Mponela Village, peasants were not allowed by their Chief Kayombo to adopt and cultivate new crops before sending them to Hayombo Forest for spiritual issues such as requesting a permit from gods. Without spiritual prayers (snares/*matambiko*), such adopted crop could yield low productivity.

v. Application of new technology as a measure of agricultural productivity

This study evaluated the application of agro-technologies as a measure to ensure high productivity. The identification focused on the use of various agricultural inputs related to modern and traditional technologies. Different views from respondents about agro-technologies were obtained. 120 (40%) respondents had the view that the use of inputs like modern seeds, chemical fertilizers, forecasting technology and herbicides increases effective use of arable land which facilitates high agricultural productivity. On the same response, related agro-technologies about the application of local processing machines (local machine for curing groundnuts as shown in Figure 8) helped peasants to minimize processing costs of which such amounts which could be used to for processing in modern industries were then used to develop their arable land (Figure 8). Moreover, 164 (54.7%) respondents said the use of organic manure increases the value of arable land, hence leads to high productivity. The remaining 16 (5.3%) respondents claimed that expansion of land for cultivation and boundary verification due to population increase reduces conflicts on arable land and increases productivity. Such observation was similar to the principles of Rev. Thomas Malthus (1798) who theorizes that when population grows, resources like land become scarce in such a way that people start to compete. This eventually leads to conflicts. Thus, to solve such conflicts, the village councils and village land committees were using various mechanisms of land distributions to the increased population to insure land occupancy to all and thereof increase agricultural productivity.

Figure 8: Local Machines Used for Curing Groundnuts in Mbozi District

The interviews about agro-technologies as a measure of agricultural productivity indicated the importance of technology in agriculture to raise productivity. One of the key informants said that peasants who do not follow local and modern forecasting information about growing seasons grow their crops like beans out of proper season; thus without using more chemicals to kill insecticides, they yield low productivity. For example, cultivation of beans in the early rain season, say November, especially in areas or farms located in the southern parts of Vwawa Urban like Shanko, Mbozi, Matula, Igamba and Itaka Village, cannot give high yield without using pesticides to control pests and diseases unlike the northern, western and eastern parts of Vwawa Urban.

Moreover, peasants in the studied area were observed to adopt agroforestry technologies (Figure 9 C) as a mechanism of effective use of land. This was used mostly in areas whose land had been exhausted. Therefore, the solution was to grow trees as an alternative use of the exhausted land since trees were well growing even in soils with poor fertility. Similarly, trees did not demand chemical fertilizers or any other inputs rather than weeding and creating fire breaks along the farm especially during dry seasons. Thus, such technology was helpful for minimizing some costs of buying agricultural inputs and it was a profitable and sustainable agricultural project; hence, the probability of getting high profit in agroforestry technology was larger than growing maize whose risk factors are many.

On the other side, application of technologies was found to face various challenges during this study. First, peasants had no enough knowledge over the use of new and modern seeds in relation to climatic condition of Mbozi District. For example, not all "SEED.CO" maize seeds were suitable in the climate of Mbozi. Other SEED CO. species were being misplaced, that is Mbozi was not a right place for planting some kind of SEED.CO maize species. In the studied area, various kinds of SEED.CO maize seeds were being sold. Different varieties of SEED CO. species were observed. There were the so called Pundamilia, Tembo, Tumbili and Simba (Figure 9 A). In relation to the climatic condition, *Tembo seed.co* was suitable in cold climate only, like Tukuyu and Makambako. Pundamilia and Tumbili were only suitable in hot climatic condition like Chunya, Mbarali in Usangu Basin and Momba District along the Msangano Basin, whereas Simba *seed.co* was suitable in cold and hot regions Mbozi District inclusive. However, peasants were just buying any kind of those seeds in turn some were yielding low productivity regardless of fertile and large size arable land they were occupying. Other kinds of maize which peasants adopted and were suitable for the soils and climate of Mbozi District were *Pannar* (Figure 9 B).

Secondly, some advanced technologies related to boundary verification such as the GPS phone had not yet been introduced in the studied district. Peasants who were aware of the important boundary verification along the arable land used Global Positioning System (GPS), which involved the costs of hiring land surveyors from the district council or companies; while others were using local technology as it is indicated in Figure 9 B, which was temporary and vulnerable to land dispossession due to land conflicts.

Thirdly, there was a challenge related to the price of chemical fertilizers, insecticides, herbicides and pesticides which many peasants during the time of this study in the growing season 2020/2021 could not afford to buy. This is because they expected to buy fertilizers after selling some crops like maize whose price was poor. This limited the effectiveness of application of new technology; also some peasants opted for other businesses rather than farming.

Lastly, some technologies like agro-forestry (Figure 9 C), cultivation of avocadoes and coffee needed permanent land occupancy and large size of land because the life span of these crops up to harvesting stage was found to be not less than seven years. As a result, even peasants with small size of land but occupying it permanently could not afford these crops due to the reason that they could limit them to grow some compulsory crops, including food crops like maize, beans, sweet potatoes and groundnuts. Moreover, the technology was not friendly for peasants who were depending on renting arable land because many renters were renting land for a short period of time, mostly one year or one growing season.

A

B D

Figure 9: Agro-Forestry (C), Modern Seeds for Maize (A) and Maize Farm (B)

4.0 Conclusion and Recommendations

It should be noted that the persistence of traditional farming practices were the results of poor implementation of measures of agricultural productivity which include the presence of multinational companies guiding peasants on land tenure system, learning lessons from experienced stakeholders, land restitution, structural transformation as a measure on land tenure system and application of new technology as a measure of agricultural productivity. Measures like involvement of companies, TaCRI in particular, attempted to transform peasants in some urban areas unlike rural areas where experts were not going for farm trainings. This might be due to poor infrastructure in the rural areas. Based on the findings, the study recommends that:

a. Measures like social structural transformation on agricultural productivity should be of gender inclusive to effectively implement the land policies including the Land Policy of 1995 which insists equality on land use between men and women. The ministries dealing with land and agriculture should enact laws which implement the land policy, act and legislation by intervening the attitudes of the population and their cultural settings.

b. Since measures studied highlighted issues of land tenure which are among the primary variables that affect agricultural productivity, then Land Acts number four of 1999 and Village Land Acts number five of 1999 should be refined to fit the Agricultural Policy of 2013. It is almost 20 years since these land laws were made. Thus, many changes related to land tenure system and production are not addressed in those laws, which can lead to poor land tenure and agricultural production and hence low productivity. Moreover, some regional acts should be re-checked in relation to climate change and digested by being sharpened from the national to local act.

c. This study focused on measures of agricultural productivity for all crops. Thus, other studies may investigate the measures that explain a single crop like maize to find more scientific alternatives of increasing productivity.

d. Financial assistance institutions like Tanzania Agricultural Development Bank should be closer to peasants and ensure general (all peasants) and scientific (support based on peasants' performance) financial support.

e. Further studies should be conducted in Mbozi District by focusing on the reasons and implications to why cultural settings ignore measures like cultural transformation by intimidating the rights of women from occupying land and its implications on agricultural productivity.

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Supporting Rain-fed Agricultural Water Supply and Demand Decisions under Climate Change in Kagera River Sub-catchment, Tanzania

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Abstract

Rainfall is the primary source of water supply for agricultural activities in the developing world. Agricultural drought is linked to a shortage of water supply needed to support crops. Climate change can influence rainfall patterns and shortage in an area, with effects to all sectors of the economy and ecosystem. This study aimed at applying water supply and demand indices to support decision making in a timely manner in a changing climate. This included the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI). These were evaluated in relation to the maize crop in the *Masika* season, which is the main staple food in sub-Saharan Africa. The case study is the Kagera River Sub-catchment in Tanzania. The long-term climate change and its effect on the maize crop's water supply and demand in 1980s (baseline) as well as 2050s and 2090s (future) was estimated. Rainfall data of 30 years (1971-2000) were analyzed by using non-parametric Mann Kendall test and generally results indicated a non-significant increasing trend. Indices applications using observed data during 1971-2000 indicated contrasting and complementary results. Generally, the southern part of the study area (Biharamulo, Ngara and Rulenge) was wetter than the other areas. The Kayanga area was relatively at moderately dry to very wet conditions. The northwestern area of Kaisho was frequently dry. Global Climate Models (GCMs) data were evaluated and selected for suitability and used for projection of future climates and application of the indices spatially in the

sub-catchment. Climate change impacts were obtained by comparing the baseline and future periods. This study helped extension services to identify and use suitable spatially distributed adaptation measures or coping mechanisms in the case of projected water stresses for informed rain-fed agriculture decision-making in future.

Key words: Climate change, decision-making, rain-fed agriculture, water supply and demand Indices, Kagera River Sub-catchment area

1. Introduction

Climate change affects global water resources in multiple ways, with complex spatiotemporal patterns, feedback effects, and interactions between physical and human processes (Bates *et al*., 2008). The effects of climate change can be highly distinctive at the local scale (IPCC, 2019), current trends and future projections indicate major shifts in climate and more extreme weather events in many parts of the world (IPCC, 2014). Climate change is likely to cause shifts in seasonal water availability throughout the year in several places (IPCC, 2014; Gulacha and Mulungu, 2017), which could impact agricultural water supply and production. Rainfall deficiency is of concern because most agricultural activities that support over 80% of livelihoods across the African continent are rain-fed or regulated solely by weather and climate. Thus, climate change can influence rainfall patterns and shortage in an area, with effects to all sectors of the economy and ecosystem. It is therefore paramount to consider the potential impacts of a changing climate when managing water resources, which are fundamental to sustainable development (Abdelfattah, 2021). Once the impacts are understood, suitable or appropriate adaptation measures can be applied in strategic planning. Adaptation options exist in all water-related sectors and should be investigated and applied where possible (Rotich and Mulungu, 2017; Abdelfattah, 2021; Dismas *et al*., 2018).

Kahimba *et al.* (2015) indicate that agriculture practices in Tanzania are highly vulnerable to climate variability and change due to poor adaptation capacity and limited community resilience to cope with climate variability and change. They call for research on adaptation against the impacts of climate change to ensure food security. Importantly, they recommend improvement of climate change research by analyzing observed meteorological data and by using the best available GCMs and downscaling techniques for Tanzania. Climate information including location-specific, timely and easier to interpret is important for decision making in an area or specific agro-ecological zones (Tumbo *et al*., 2010; Kijazi and Reason, 2009; Arndt *et al*., 2012). In this case, indices are more relevant and usually used by managers and decision makers. In Tanzania, only this study applied indices for supporting rain-fed agriculture and observed historical data analyzed before looking into the future. Also, little has been done for maize under climate change on the Tanzania side of the Kagera Basin than other areas of Tanzania (Batho *et al*., 2019; Luhanga, 2017; Volk *et al*., 2021). Currently, the Ministry of Agriculture (MoA) has an Agenda 10/30 and this study will contribute to meet the target for growth of agricultural sector in Tanzania by 2030.

Water stress or shock is mainly caused by too much or insufficient rainfall water supply and sharp lowering or rise in temperature. Therefore, water stress in water supply or water demand for rain-fed agriculture was evaluated using rainfall and temperature. Accordingly, the objective of the study was to support rain-fed agriculture decision making in a timely manner by applying water supply and demand indices in a changing climate. The indices applied were the Standardized Precipitation Index (SPI) and the Standardized Precipitation Evapotranspiration Index (SPEI). Specifically, it aimed to:

a) Assess historical and projected climate from selected scenarios by suitable climate model(s);
b) Determine historical and future water supply and demand indices; and
c) Evaluate climate change impacts through water supply and demand indices so as to support adaptation decision making in rain-fed agriculture.

Accordingly, this study will help extension services to identify and use suitable spatially distributed adaptation measures or coping mechanisms in the case of projected water stresses for informed rain-fed agriculture decision-making in future.

2. Methodology

2.1 Description of the Study Area

The Kagera River Basin is located in Africa's Great Lakes Region, between the massive lakes of Victoria, Tanganyika and Kivu. The Kagera River drains a basin area of 59,800 square kilometers (Figure 1), which is divided among the countries of Burundi (22%), Rwanda (33%), Tanzania (35%) and Uganda (10%) (Nzeyimana, 2003). With an altitude range of 1129–4480 m, the landscape is dominated by mountains and hills. The average annual temperature in the higher reaches is 18°C, whereas it is 21°C in the lower reaches. The average annual rainfall in the upper and lower portions of the basin varies substantially, ranging from 800 mm to 2000 mm, respectively (Li *et al.*, 2021).

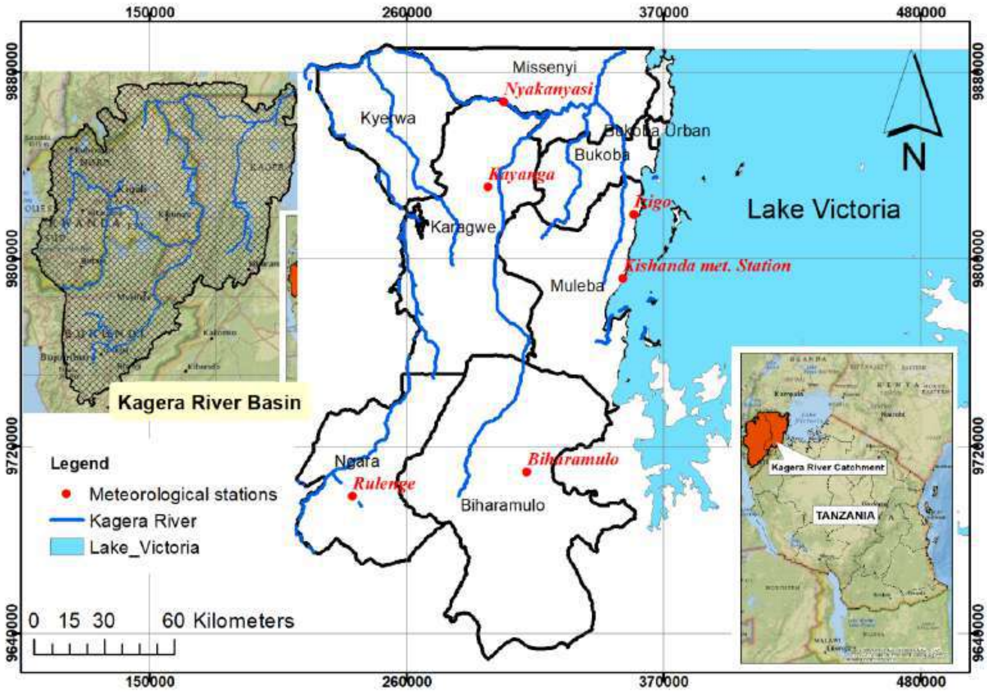


Figure 1: A Location Map of Kagera River Sub-catchment in Tanzania

2.2 Research Conceptual Framework

The methods of data collection for this study were categorized into three major components considering baseline and future periods: assessment of the climatic conditions; determination of water supply and demand indices; as well as evaluation of climate change impacts on water supply and demand indices. In this case, climatic data (temperature and rainfall) and maize crop agronomic data for the Kagera River Sub-catchment were collected and analyzed to achieve the objectives of the study. Future climatic data were obtained from the selected Global Climate Models (GCMs) and climate predictions were obtained from the best performing GCM for the selected climate change scenario after downscaling using Long Ashton Research Station Weather Generator (LARS-

WG) model. The methodology for the study is summarized by the research conceptual framework in Figure 2:

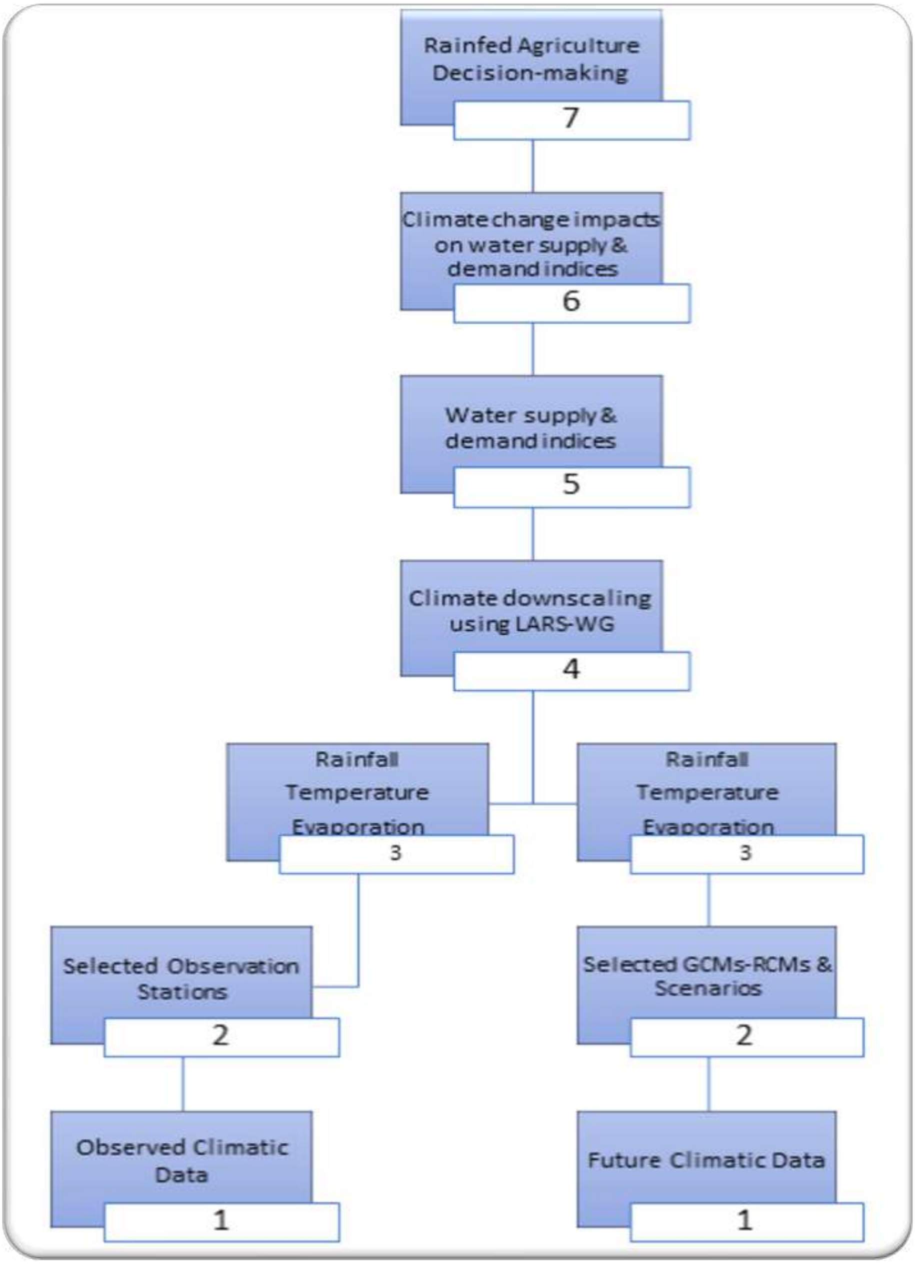


Figure 2: The Research Design Framework for the Study (Numbers Show the Order of Flow of Activities)

Due to data quality and continuity issues, data quality analysis and selection for use in the study was done. Figure 3 presents the data availability spread from 1939-2021 and gaps:

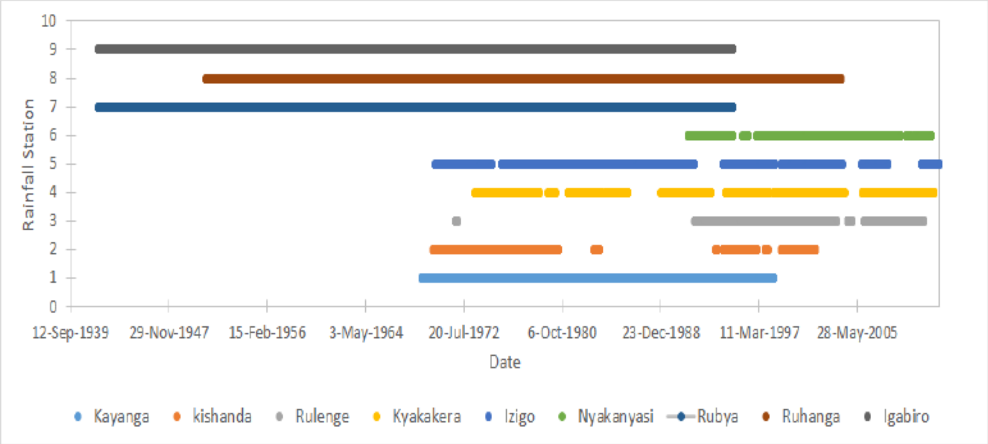


Figure 3: Rainfall Data Availability for the Observation Stations

2.3 Assessment of Climatic Conditions in Kagera River Sub-catchment under Baseline and Future Conditions

2.3.1 Baseline Climatic Conditions

Trends of rainfall and temperature data were analyzed to assess climate patterns. Climate patterns on the data were detected from the trend and significance of the trend in time series. A non-parametric Mann-Kendall (MK) method was used for the trend analysis. However, the Autocorrelation Function (ACF) and Partial Autocorrelations Functions (PACF) were firstly examined before carrying out MK test. This is because the MK test can potentially give false trend if the data are serially corrected. Other tests such as the Spearman's Rank Correlation Coefficient test, or Spearman's rho test are among the trend analysis methods used. These trend tests were carried out using R software. The output of Mann-Kendall test was examined by using the tau value (i.e., Kendall's tau statistic) and the 2-sided p-value in which the null hypothesis (H_o) was "H_o: no trend" versus alternative hypothesis (H_a) "H_a: monotonic trend (upward or downward)".

To select the baseline period, a step change analysis was done on the rainfall and temperature data. In this case, the Buishand test, Non-parametric Petit test, Hubert's Segmentation method, and Lee and Heghinian's Bayesian methods were performed for step change analysis in the time series data. The Khronostat software was used to conduct these tests. The null hypothesis (H_o) was that 'H_o: no break in rainfall series' versus alternative hypothesis (H_a) 'H_a: break exists in rainfall series', this hypothesis was tested at 0.05 significant level.

2.3.2 Future Climatic Conditions

In this study, the future climatic conditions were projected by using Global Circulation Models (GCMs). Previous studies identified and selected the following best performing GCMs or GCM/RCMs combinations in different areas of Tanzania as indicated in Table 1:

Table 1: Sampled best GCM-RCM used in Previous Studies in Tanzania

S/N	Selected GCM/RCM	Scenario	Study Area	Reference
1	• GFDL • HadCM3 • CMCM3	CMIP3	Kikafu Catchment in the Pangani River Basin	Rotich and Mulungu (2017)
2	• HadCM3	CMIP3	Ngerengere Catchment in the Wami Ruvu Basin	Shagega *et al.* (2018)
3	• CanESM2/CanRCM4_r2 • CanESM2/RCA4_v1 • CNRM-CM5/CCLM4-8-17_v1 • EC-EARTH/CCLM4-8-17_v1 • EC-EARTH/RCA4_v1 • MIROC5/RCA4_v1	CMIP5	Kilombero Catchment in the Rufiji River Basin	Näschen *et al.* (2019)
4	• ACCESS1-3 • Bcc-csm1-1 • CanESM2 • IPSL-CM5A-MR • HadGEM2-ES • MIROC5	CMIP5	Upper Ruvu River Catchment in the Wami Ruvu Basin	Tibangayuka *et al.* (2022)

S/N	Selected GCM/RCM	Scenario	Study Area	Reference
5	• CNRM-CM6-1-HR • INM-CM4-8 • INM-CM5-0 • AWI-CM-1-1-MR • EC-Earth3 • EC-Earth3-Veg • MRI-ESM2-0	CMIP6	Bahi (Manyoni) Catchment in the Internal Drainage Basin	Hersi *et al.* (2022)
6	• MPI-M-MPI-ESM-LR/RCA4 • ICHEC-EC-EARTH/RCA4 • CNRM-CERFACS-CNRM/CM5 • ICHEC-EC-EARTH/RACMO22T • ICHEC-EC-EARTH/HIRHAM5	CMIP5	Southern & Western Highlands (Rukwa, Mbeya, Iringa, Njombe & Ruvuma regions)	Luhunga (2017)
7	• ICHEC-EC-EARTH/HIRHAM5 • ICHEC-EC-EARTH/RACMO22T • MPI-M-MPI-ESM-LR/RCA4 • ICHEC-EC-EARTH/RCA4 • CNRM-CERFACS-CNRM/CM5	CMIP5	Lake Victoria Region (Kagera & Geita regions)	Luhunga and Songoro (2020)
	• ICHEC-EC-EARTH/RACMO22T • ICHEC-EC-EARTH/RCA4 • CNRM-CERFACS-CNRM/RCA4 • CNRM-CERFACS-CNRM/CCLM4	CMIP5	Kagera Sub-Catchment in the Lake Victoria Basin	Mulungu *et al* (2018)

Note: *Bolded Ones are for Rainfall Data*

Source: Authors in This Study (2022)

This indicated that various GCMs and GCMs/RCMs combinations may be suitable for different locations in Tanzania. Also, some studies used bias correction only while others used bias correction together with a dedicated downscaling model. Therefore, it is important to evaluate the GCMs or GCMs/RCMs data for suitability at a location before using them in agricultural applications. This study used the new CMIP6 GCMs data with a combination of Shared Socio-economic Pathways (SSPs) and Representative Concentration Pathways (RCPs) scenarios. Accordingly, this study provided new insight of future climate based on these new climate scenarios. The Long Ashton Research Station Weather Generator (LARS-WG) was employed in this study for climate downscaling to the rainfall and temperature station. In this case, the LARS-WG was calibrated and validated by comparing observed and simulated rainfall and temperature data against the performance metrics.

2.4 Determination of Water Supply and Demand Indices under Baseline and Future Conditions for Maize Crop Grown in the Sub-catchment

2.4.1 Water Supply Index under Baseline and Future Climatic Conditions

The SPI is a valuable tool for all water resource management for either short- or long-term moisture supplies (Hayes *et al*., 1999), and choice of crops and management decisions to conserve water in rain-fed systems (Yamoah *et al.*, 2000). Accordingly, the SPI was selected and used in this study. To obtain SPI, the rainfall data values during the period of interest (e.g., 1, 2, 3, 6, 9, 12, 24 or 48 month) are fitted to a Gamma distribution. A Gamma distribution is transformed into normal distribution (with mean zero and variance of one), which represents the SPI value for the time scale selected. The SPI is the number of standard deviations that the monthly rainfall data would deviate from the long-term mean (Eq. 1).

$$SPI = \frac{(X_i - X_m)}{\sigma} \quad (1)$$

Where, Xi is monthly rainfall record of station, Xm is rainfall mean and σ is the standard deviation. The categories of SPI levels as classified by McKee et al. (1993) are as follows:

Table 2: SPI and SPEI Categories

S/N	SPI/SPEI Value	Category or Severity
1	2.00 or more	*Extremely wet*
2	1.50 to 1.99	*Very wet*
3	1.00 to 1.49	*Moderately wet*
4	-0.99 to 0.99	*Near normal*
5	-1.00 to -1.49	*Moderately dry (MD)*
6	-1.50 to -1.99	*Severely dry (SD)*
7	-2.00 to less	*Extremely dry (ED)*

Source: McKee *et al.* (1993)

In this study, SPI and SPEI (Eq. 2) were computed for the 3-month interval (i.e., SPI-3 and SPEI-3) with a focus on the heavy rainfall (*Masika*) season during March-April-May (MAM), which is very important for crop growth in rain-fed agriculture. The 3- and 6-month or shorter time scale SPIs are more useful for crops, highlighting available moisture conditions for crops growth. Rouault and Richard (2003) indicate that the 3-to 6-month timescales of SPI are commonly used for agricultural droughts that can result in damage to crops. Also, the 3-month period is used in regional seasonal forecast (Verdin *et al.*, 2005). In this study, the severely dry and extremely dry were considered to be water deficiencies, which cause crop failure (Bänzinger *et al*., 2000). In this case, time series and maps of the index and their frequencies were obtained.

2.4.2 Water Demand Index under Baseline and Future Climatic Conditions

The standardized precipitation evapotranspiration index (Vicente-Serrano *et al*., 2010) is improved from the SPI. The procedure for calculating the standardized precipitation evapotranspiration index (SPEI) is similar to that for the SPI. However, SPEI considers the effect of reference evapotranspiration, which is directly related to crop water demand and therefore more useful for climate change studies. It captures the main impact of increased temperature under climate change on water demand.

Since there is no soil water-balance component, thus no consideration of evapotranspiration/potential evapotranspiration (ET/PET) can be calculated with SPI. Therefore, the SPEI attempts to address the PET issue by including a temperature component in the calculation of the index. The inputs required to run the SPEI program are precipitation, mean temperature and latitude of the site(s). It uses the difference between rainfall, X_i and PET (Eq. 2), representing a simple climatic water balance, which is calculated at different time scales to obtain SPEI.

$$D_i = X_i - PET_i \quad (2)$$

Therefore, D_i values provide a simple measure of water surplus or deficit for the analyzed month or season. These values are aggregated at different time scales following the same procedure as for the SPI (i.e., standardized). Accordingly, the same categories or severity levels are used for SPEI.

2.5 Evaluation of Climate Change Impacts on Maize Crop Water Supply and Water Demand Indices in the Sub-catchment

Climate change impacts were obtained by comparing indices for the future and baseline periods. This was done on monthly basis, which is suitable for agricultural production. The severity categories were monitored for changes in future. Spatial distribution maps were used to capture the extreme or the spread of severity of the indices categories.

3. Results and Discussions

3.1 Climatic Conditions in Kagera River Sub-catchment under Baseline and Future Conditions

3.1.1 Baseline Climatic Conditions

The observed time series were applied for the MK test and the results are given in Table 3:

Table 3: Trends from Observed Rainfall Data

S/N	Station	Mann Kendall Test Z	p-value	Trend Significance
1	Kayanga	0.437	0.74811	+ non-significant
2	Kishanda	0.113	0.39179	+ non-significant
3	Rulenge	-0.113	0.39179	- non-significant
4	Izigo	0.113	0.39179	+ non-significant
5	Bukoba	-0.103	0.43245	- non-significant
6	Ngara	-0.0253	0.8584	- non-significant
7	Biharamulo	-0.262	0.043763	- significant
8	Kaisho	0.0253	0.8584	+ non-significant

Source: Authors in this study (2022)

Results in Table 3 show that the p-value associated with the Mann-Kendall test is statistically non-significant increasing trend for Kayanga, Kishanda, Izigo and Kaisho, while for Rulenge, Bukoba and Ngara it is non-significant decreasing trend and for Biharamulo trend is significantly decreasing in the annual precipitation time series at a significance level of 0.05. This indicated that the trend for the observed rainfall data in Kagera Catchment vary from one station to another.

3.1.2 Future Climatic Conditions

Prediction of future climate was done using the Coupled Model Intercomparison Project Phase 6 (CMIP6) scenarios in particular, a combination of Shared Socio-economic Pathways (SSPs) and Representative Concentration Pathways (RCPs) scenarios, which not only incorporate greenhouse gas concentration but also socio-economic advances were used. Specifically, SSP2-4.5 and SSP5-8.5 scenarios are commonly used in climate change studies. However, only SSP2-4.5 was presented in this paper. Monthly rainfall and temperature from Global Climate Models (GCMs) for 2050s (2041 - 2060) and 2090s (2081 - 2100) were used. Table 3 shows the CMIP6 GCMs data correlations with the observed monthly rainfall data at Rulenge station. As a result, the best performing GCM (IPSL) was used for the projection of the future climate.

Table 4: Correlations of CMIP6 GCMs Data and Observed Monthly Rainfall Data at Rulenge Station

S/N	GCM	Correlation Coefficient, r (-)
1	IPSL	0.68
2	MIROC	0.52
3	ACCESS	0.50
4	CNRM	0.49
5	INM	0.15
6	MIROC	0.52

Source: Authors in this study (2022)

3.2 Water Supply and Demand Indices under Baseline and Future Conditions for Maize Crop Grown in the Sub-catchment

3.2.1 Water Supply and Demand Index under Baseline Climatic Conditions

Figure 3-6 present the water supply and demand index (WSI & WDI) during MAM for 1971-2000 period. The threshold levels EW, MW, MD and ED means extreme wet, moderately wet, moderately dry and extremely dry respectively.

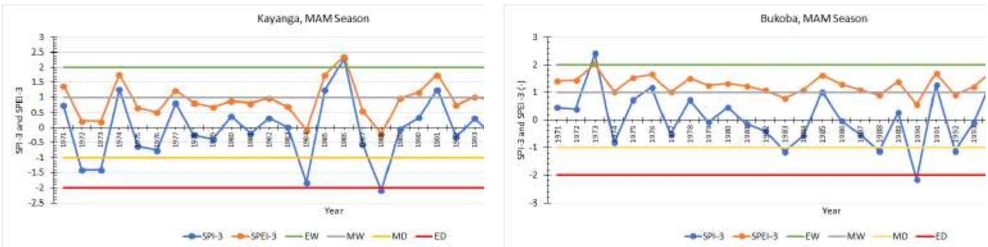


Figure 3: WSI & WDI during MAM Season for 1971-2000 at Kayanga and Bukoba

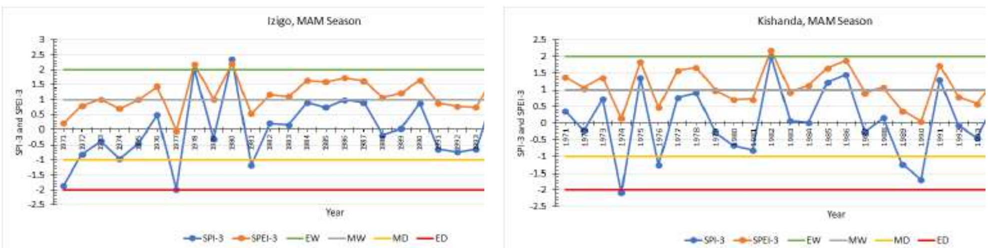


Figure 4: WSI & WDI during MAM Season for 1971-2000 at Izigo and Kishanda

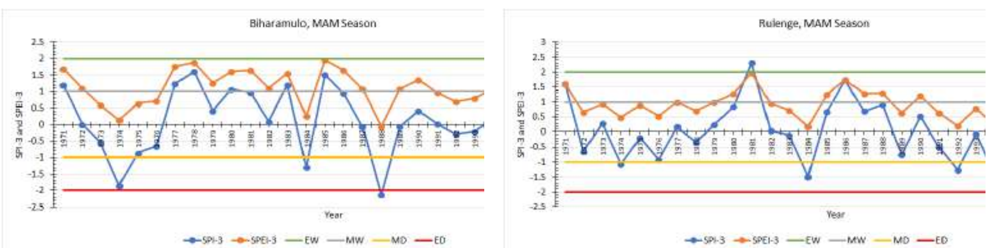


Figure 5: WSI & WDI during MAM Season for 1971-2000 at Biharamulo and Rulenge

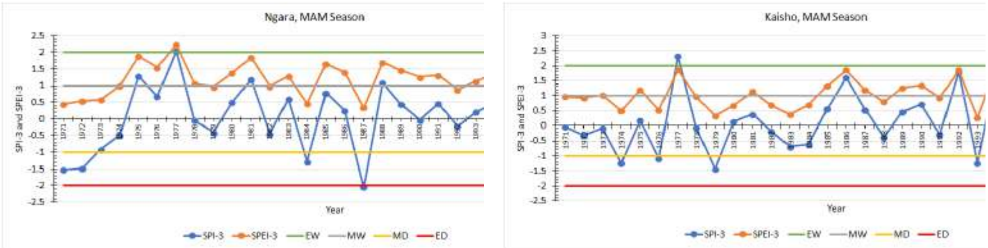


Figure 6: WSI & WDI during MAM Season for 1971-2000 at Ngara and Kaisho

The results from observed data showed that the pattern of SPI and SPEI matched well. However, the values of the SPEI were lower than SPI, which was not expected. With a component of water demand (loss) as PET values in SPEI (Eq. 2) unlike SPI (Eq. 1), more effects or severity levels are expected. Considering the severe or extremely dry events by SPI, we expected more impacts (values) with SPEI. Our results indicated a contradiction, which is tied to the PET calculation equation within SPEI. The original SPEI uses the empirical Thornwaite equation, which may not be applicable to other places than its original parameter sets for the USA. It is therefore recommended to work with SPEI that can represent well the PET in our area. One of the recommended, robust and physically based PET equations is the Penman-Monteith equation.

Previous studies (e.g., Stagge *et al*., 2014; Liu *et al*., 2021) indicate SPEI sensitivity to PET and parameters, which makes it discernible difference in index values for SPEI. Other studies (Stagge *et al*., 2014) could not recommend the Thornwaite equation in SPEI software, which provides significant differences in the results compared to other consistent methods such as temperature-proxy or radiation-based methods.

Comparing SPEI-3 and SPI-3 results, more differences were in the dry condition (negative values) unlike the wet condition, indicating the influence of PET in the water balance. Considering SPEI-3 results, with exception to Biharamulo (1988), Izigo (1977), Kayanga (1984 & 1988) and Kishanda (1996) stations all with normal conditions of negative values, all SPE-3 results are positive on the wet conditions. This indicated near normal to wet conditions during 1971-2000 at all station locations. On the wetness side, extremely wet (EW) conditions were in Bukoba (1973), Izigo (1978 & 1980), Kayanga (1986), Kishanda (1982) and Ngara (1977 & 1997). Very wet (VW) conditions were in Biharamulo (1971, 1977, 1978, 1980, 1981, 1983, 1985, 1986 & 1997), Bukoba (1975, 1976, 1978, 1985, 1991 & 1995), Izigo (1984, 1985, 1986, 1987, 1990, 1994 & 1997), Kaisho (1977, 1986, 1992 & 1994), Kayanga (1974, 1985 & 1997), Kishanda (1975, 1977, 1978, 1986, 1991 & 1997), Ngara (1975, 1976, 1981, 1985 & 1988) and Rulenge (1971, 1981 & 1986). Very wet conditions were more frequent than extremely wet conditions for the stations. This indicated generally wetter conditions during 1971-2000 at all station locations in the indicated years. Otherwise, in other years the stations indicated between moderately wet and moderately dry conditions during 1971-2000 for the MAM season. Generally, the southern part of the study area (Biharamulo and Ngara) and the central eastern part near the Lake Victoria (Bukoba, Izigo and Kishanda) were wetter than the other areas. Also, this is supported by SPI results (Fig. 7). The Kaisho, Kayanga and Rulenge areas were relatively at normal to very wet conditions. The northwestern area of Kaisho and Kishanda had relatively high frequency of dryness. Figure 6 shows the spatial patterns of the SD and ED frequencies relative to the whole index events in the study area.

Table 5 summarizes the SPI results on the SD and ED levels while in SPEI there were none. It is worth noting that the water supply deficit detected by SPI at SD and ED conditions for all stations were translated by SPEI to moderate and normal conditions. Since SPEI-3 could not detect severely dry and extremely dry conditions to all stations unlike SPI-3 (Table 5), this matter needs to be investigated further with replacement of the PET equation in SPEI software, as indicated above.

Table 5: The Years with Insufficient Water Supply (SD and ED) Associated with Crop Failure by SPI

WSI/Station	Biharamulo	Bukoba	Izigo	Kaisho	Kayanga	Kishanda	Ngara	Rulenge
SD	74	00	71 & 77	96 & 00	84	90	71 & 72	99
ED	88	90	-	-	88	74	87	-
Percentile (%)	21.28	26.92	24.00	23.53	26.42	23.08	18.00	18.00

Note: Rank percentile are for SPI < -1.5 considering all index events in 1971-2000

Source: Authors in this study (2022)

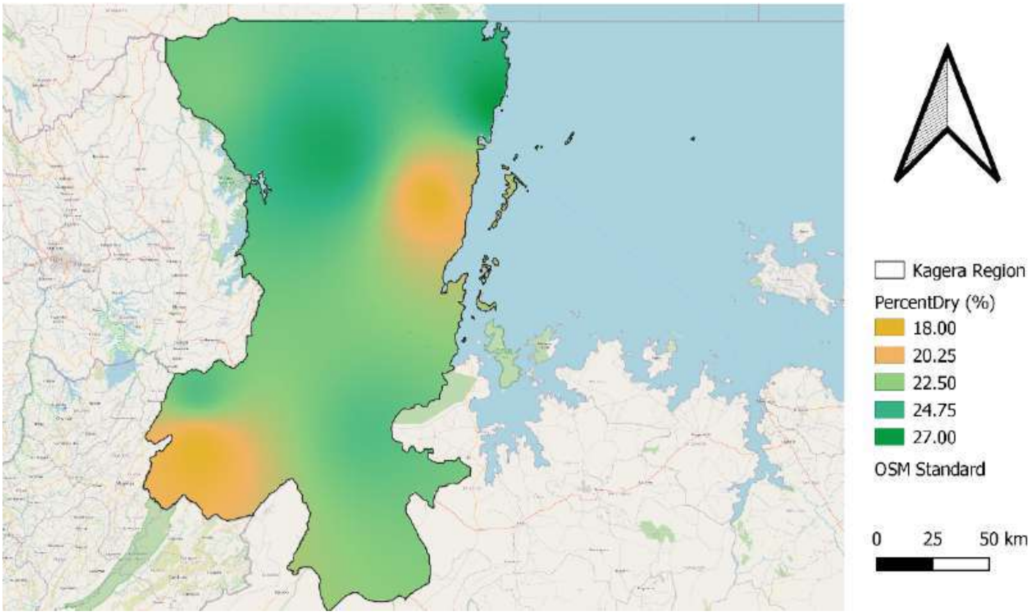


Figure 7: Distribution of Percentile Frequency of Deficient Water Supply in Kagera Area by SPI

3.2.2 Water Supply and Demand Index under Future Climatic Conditions

(a) Rainfall Change

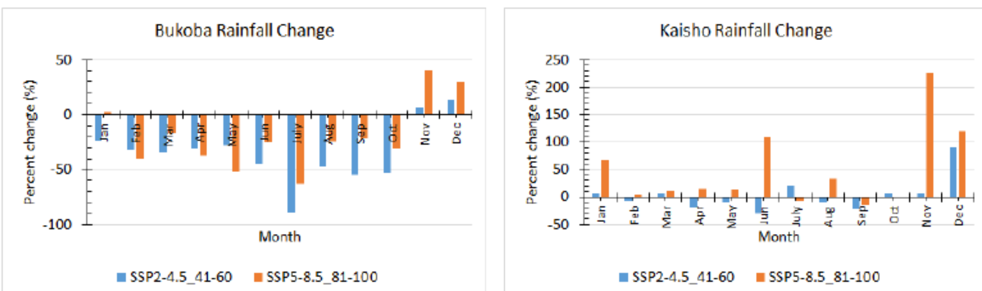


Figure 8: Future Rainfall Change at Bukoba and Kaisho Stations

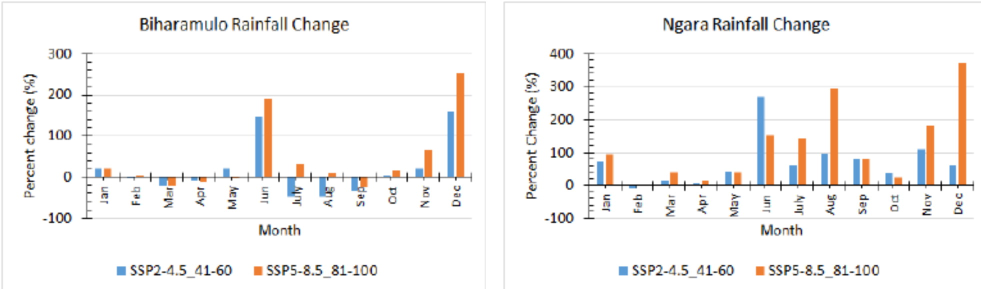


Figure 9: Future Rainfall Change at Biharamulo and Ngara Stations

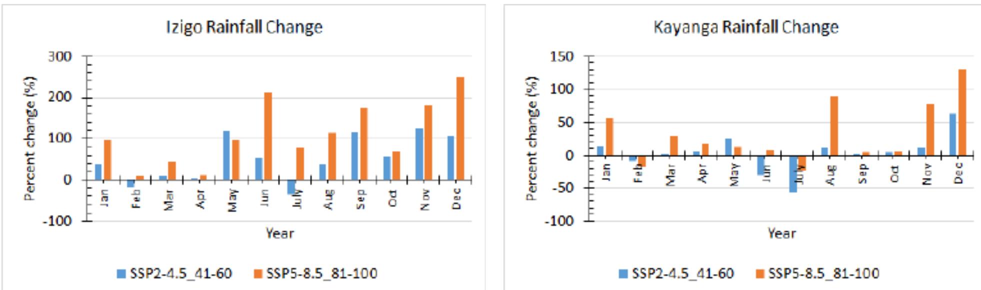


Figure 10: Future Rainfall Change at Izigo and Kayanga Stations

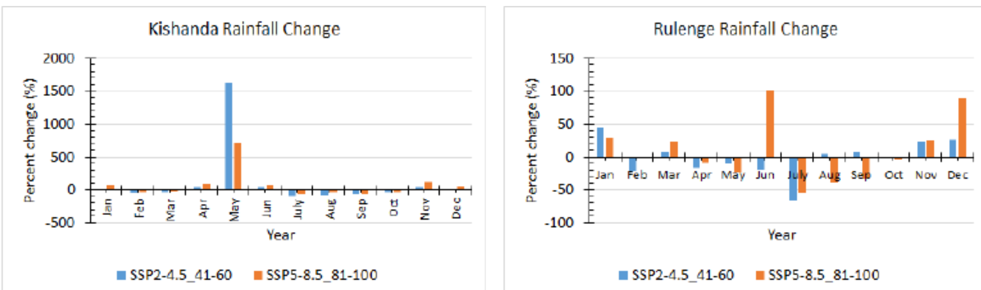


Figure 11: Future Rainfall Change at Kishanda and Rulenge Stations

As indicated above, different station locations have different and varied changes of the rainfall amount. The highest and lowest monthly change was observed at Kishanda in May and March respectively. The rainfall changes during the MAM season for the SSP2-4.5 scenario for the stations are as shown in Table 6:

Table 6: Future Percentage Change of Rainfall during MAM Season for SSP2-4.5 Scenario

S/N	Rainfall Station	2041-2060 Rainfall Percent Change (%)	2081-2100 Rainfall Percent Change (%)	2041-2100 Rainfall Percent Change (%)
1	Biharamulo	-21% - 21%	-21% - -4%	-4% - 21%
2	Bukoba	-34% - -28%	-52% - -17%	-52% - -17%
3	Kaisho	-18% - 7%	10% - 16%	-18% - 16%
4	Ngara	5% - 44%	14% - 38%	5% - 44%
5	Izigo	4% - 120%	10% - 96%	4% - 120%
6	Kayanga	1% - 25%	12% - 29%	1% - 29%
7	Kishanda	-33% - 1613%	-17% - 719%	-33% - 1613%
8	Rulenge	-16% - 9%	-22% - 24%	-22% - 24%

Source: Authors in this study (2022)

(b) Temperature Change

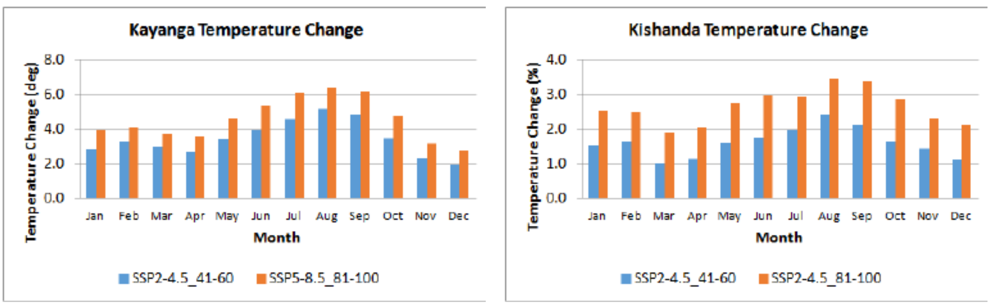


Figure 12: Future Temperature Change at Kayanga and Kishanda Stations

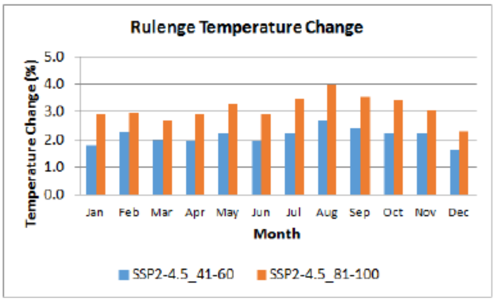
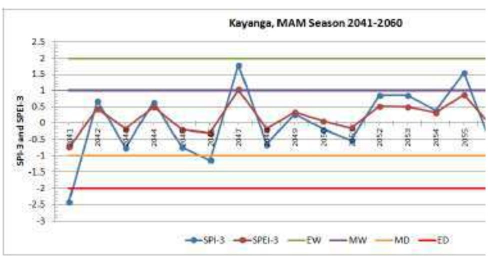


Figure 13: Future Temperature Change at Rulenge Station

As indicated above, different station locations have different and varied change of the temperature. The highest change of temperature was during 2081-2100. The highest monthly change was observed at Kayanga station. The high rise in temperature of 5.2 and 6.4, 2.4 and 3.4, and 2.7 as well as 4.0 during 2041-2060 and 2081-2100 respectively was in August for all stations. The lowest monthly change was observed at Kishanda station. The low rise in temperature of 1.9 and 2.7 in December, 1.0 and 1.9 in March, and 1.6 and 2.3 during 2041-2060 and 2081-2100 respectively was observed for Kayanga, Kishanda and Rulenge stations. The temperature changes during the MAM season for the SSP2-4.5 and SSP5-8.5 scenarios for Kayanga, Kishanda and Rulenge stations will range from 2.7-3.4, 1.0-1.6 and 1.9-2.2 during 2041-2060 as well as 3.5-4.6, 1.9-2.8 and 2.7-3.3 during 2081-2100 respectively.

(c) Time Series of WSI and WDI during MAM Season

Figure 14-17 present the future water supply and demand index (WSI & WDI) during MAM for SSP2-4.5 scenario.



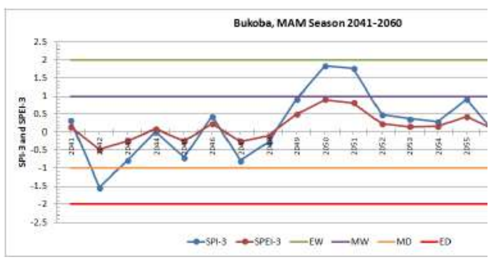


Figure 14: Future WSI & WDI during MAM Season at Kayanga and Bukoba

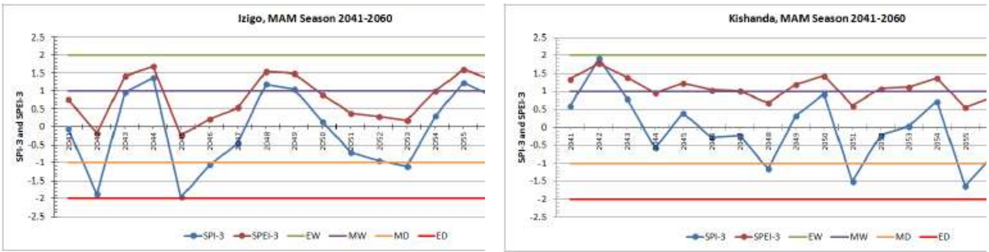


Figure 15: Future WSI & WDI during MAM Season Izigo and Kishanda

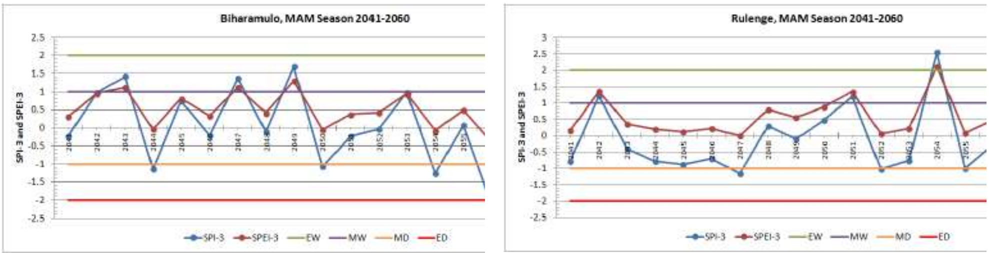


Figure 16: Future WSI & WDI during MAM Season at Biharamulo and Rulenge

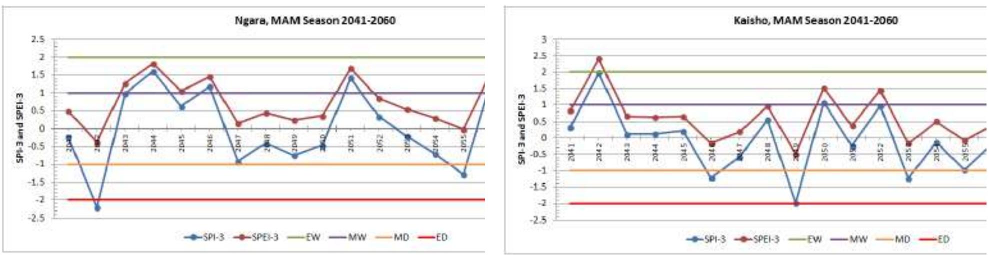


Figure 17: Future WSI & WDI during MAM Season at Ngara and Kaisho

From the above, the SPI-3 showed erratic pattern than SPEI-3 though they were in phase.

Figure 18 shows water supply indices tracking both the SD and ED categories in the sub-catchment for the future, which can be used to indicate climate change impacts on the maize crop production.

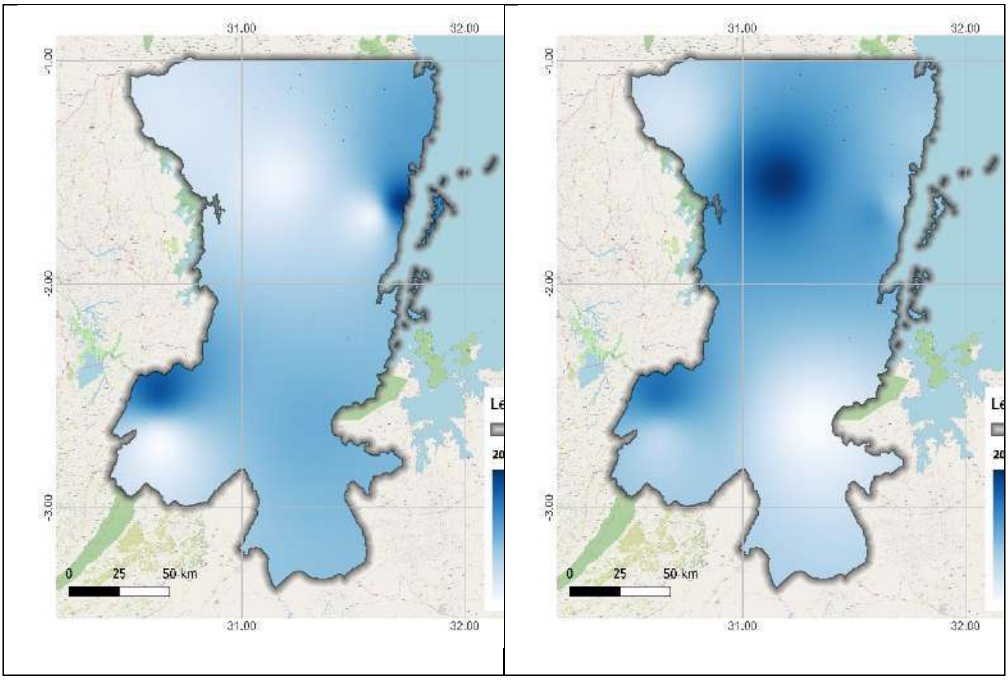


Figure 18: Future (a: 2041-2060; b: 2081-2100) Distribution of Percentile Frequency of Deficient Water Supply in Kagera Area by SPI

Comparing Figure 7 and 18, it showed that the distribution of areas under high dry conditions was reduced in 2041-2060 but increased towards the central areas in 2081-2100. Generally, the northern and southern areas may experience relatively low degree of dryness, hence favourable for rain-fed agriculture in future.

The findings of this study will be useful to the Ministry of Agriculture. In terms of organization arrangement, the Ministry has two divisions that may use climate change information for decision making related to rain-fed agriculture:

(a) National food security division, with the functions, among others, of carrying out overall monitoring of food crops performance at all stages for early warning on impending food situation. It has a crop monitoring and early warning section which, among others, provides advice on farm operations in accordance to weather changes information data.

(b) Crop development division, with the functions, among others, of promoting sustainable agriculture. It has a plant health services section which, among others, provides advice on production of crops based on agro-ecological zones.

4. Conclusion and Recommendations

From the historical data use in the indices, the pattern of SPI and SPEI matched well. However, with severe or extremely dry by SPI we expected more impacts with SPEI. The same applied to the future conditions, where there is a potential of temperature rise. This indicated a contradiction of results where SPI showed more intense dryness than SPEI. This was tied to the PET calculation equation within SPEI. The original SPEI uses the empirical Thornwaite equation, which may not be applicable to other places than the point of its development (i.e., USA). It is therefore recommended to work with PET equation in SPEI (or other versions of SPEI) that can represent well the PET values in our area. One of the robust and physically based PET equations is the Penman-Monteith equation.

Generally, from observation data, many stations indicated between moderately wet and moderately dry conditions during 1971-2000. Also, the southern part of the study area (Biharamulo, Ngara and Rulenge) was wetter than the other areas. Kayanga area was relatively at moderately dry to very wet conditions. The northwestern area of Kaisho was frequently dry. However, the SPEI-3 could not detect severely dry and extremely dry conditions in many stations unlike SPI-3. One best performing GCM (IPSL) was used for projection of future climate and for impact analysis. In future, it is recommended to use more scenarios from one or more GCMs with one scenario and obtain an ensemble data for the same. Future prediction during 2041-2100 years indicated high varying change of rainfall in the study area, which could impact rain-fed water supply and crop production. As a point for decision making, analysis of observed data showed intermittent nature and lack of continuous patterns of water stress across the study area. The same applies to the future following change and varying rainfall patterns. Therefore, precautionary agricultural planning for adaptation measures is required unlike reactive planning.

Acknowledgement

This study is building from the previous work and financial support from the Nile Basin Capacity Building Network (NBCBN) foundation for the water scarcity study on the trans-boundary Kagera River Basin.

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Decline of Traditional Cattle Keeping in Kagera Region and Its Impact on Soil Fertility, Crop Production and Environmental Change of Natural Vegetation

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and
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Abstract

For many years, people from Kagera Region, particularly the Haya and other related tribes, have been practising farming traditions which used to not only support their livelihood but also sustain the environment. There was interrelationship between farming practices and environmental conservation. The practices included keeping cattle herds and therefore collecting cow dungs for fertilising the soil. This study was undertaken to investigate the decline of traditional cattle keeping in Kagera Region and its impact on soil fertility, crop production and change of natural vegetation in the region. The study specifically focused on changes on soil fertility, cropping and natural vegetation in relation to the decline of traditional cattle keeping in the area. The study used Bubuya Hamlet, located at Ijumbi Village in Ijumbi Ward from Muleba District in Kagera Region. The hamlet was purposely selected due to its uniqueness in the decline of semi-sedentary small scale farming, keeping from more than 500 cows to zero currently. All 63 Bubuya households were included in sample and questionnaires were administered to heads of the households. Questionnaires were used as the main method of data collection as well as interviews which were administered to 14 most aged members of the sampled population. It was found out that agricultural land use in Kagera had, for many years, sustained a twofold arrangement. Semi-sedentary farming sustained soil fertility in permanent farms owned by households as well as communal land whereby the cow dung from the cattle fertilised the soils in both sides of the farming areas. Permanent farms are predominantly used for

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cultivating traditional banana, coffee and cassava. Communal land was used in a sharing manner; for pastures and cultivation of cassava, sweet potatoes, groundnuts and red millet. It was further revealed that the decline of cattle keeping has brought negative impact on soil fertility, crop production as well as the change in a pattern of grasses and other natural vegetation which has in turn affected cereals and cassava growth. The paper, therefore, suggests the need to increase soil fertility, regain production of traditional food and cash crops as well as improve soil fertility through investing on cattle keeping to bring back into health the traditional cattle keeping (semi sedentary) farming.

Key words: Cattle keeping, crop production, Kagera, soil fertility

1.0 Introduction

In Kagera Region of Northwest Tanzania, smallholder banana-coffee-based farming systems developed over hundreds of years. To this day, they traditionally consist of four components: the older and younger home gardens (*kibanja* and *kikamba* in the local Bantu language), woodland (*kibira*), and grassland (*rweya*). The management of organic farm waste has played an essential role in maintaining soil fertility, diversity and agricultural productivity in these agro forestry systems. However, rapid population growth since Tanzania's independence in the 1960s, an influx of refugees in the 1990s, and accompanying environmental degradation have shaped large parts of the study region. As a result, farm sizes, crop yields and food security have declined, soils and farming systems have degraded, and impoverishment has increased. The overall objective of this study was to investigate whether degraded home gardens can be transformed back into multifunctional, sustainable, and fertile agroforestry systems through sustainable organic farm waste management. Organic farm waste embraced crop and tree residues, kitchen and food waste including cooking ash (as inorganic residue), livestock manure and urine, animal bones as well as human faces and urine (Reetsch, 2022).

Traditional breeds and processes dominate the livestock sector in Tanzania. Short Horn Zebu is the most widespread cattle breed in the nation. Agro-pastoralists households account for 80% of livestock production, pastoral communities 14% and the remaining 6% comes from the commercial ranches and dairy sector. Sheep and goats are widely distributed and adapted to many agro-ecological zones. Production coefficients are low. In indigenous cattle, the calving rate is 40 – 50%, calving interval 18 – 24 months, pre-weaning mortality 30– 40%, adult mortality 8 –10%, mature weight 200 – 350 kg, off take rate 8 –10% per annum, milk yield 400 liters per lactation and carcass weight 100 – 175 kg. For small ruminants, the off take rate is 25-15% per annum, lamb/kid mortality 20– 40%, adult mortality 8 – 15%, and average carcass weight of 12 – 15 kg.

During the early 1960s to 1980s, field services were directly under NAIC with support from Regional Development Directors and Regional Livestock Development Officers. Between 1980s and 2000s, the support of these services shifted from state support to stakeholders mainly by development partners under dairy development programmes which were mainly operating in Southern Highlands supported by the Swiss Government; Kagera Region by KALIDEP and Tanga Region by TDPP supported by the Dutch and the Austrian Government under Austro project which was supporting Mara and Coastal regions. Under dairy development programmes, most of the semen use was being imported from abroad, mainly from the Netherlands and the USA from progeny tested sires and was basically used in inseminating cows (Zebu and Boran) for the purpose of crossbreeding to get F1 heifers for distribution to aspiring dairy farmers in the project areas (Ministry of Livestock and Fisheries, 2018).

The political system and economy of Tanzania have been transformed since late 1980s and the country is acknowledged among the leaders in sub-Saharan Africa for its economic reforms and social equity (Potts, 2008). Since 1996, growth in real GDP has averaged over 4%, but GDP per head remains at around USD 250 and basic needs poverty still affects 36% of the population. The predominantly subsistence-based agriculture sector has grown at 3% per year, though it employs 80% of the workforce and accounts for around 50% of both GDP and all exports. The planning of KAEMP coincided with decentralisation under the Local Government Reform Programme. In 2001/2002, the development policy framework was further enhanced by adoption of the Poverty Reduction Strategy Paper (PRSP); Agricultural Sector Development

Strategy (ASDS); Rural Development Strategy (RDS); and the new Agricultural Sector Development Programme (ASDP) (IFAD, 2021).

The total number of cattle in the region was 886,474. Cattle rearing was the dominant livestock type in the region followed by goats, sheep and pigs. The region had 5.3% of the total cattle population on the Tanzanian Mainland. The number of indigenous cattle was 869,424 head (98.1% of the total number of cattle in the region) and 17,050 (1.9%) were dairy breeds. There were no small holder beef cattle in the region (Chuwa, 2003).

Study Problem

Hitherto, there is scanty information on the current fertility status of the soils in Kagera Region. It is for this reason that a study was conducted for the purpose of assessing the fertility status of some selected fields as proxy to the soil fertility status of Bukoba, Missenyi and Biharamulo districts. This led to the formulation of recommendations on appropriate soil fertility management strategies to improve crop productivity at farm level and the region as whole, thereby improving household food security and income production. However, there is scanty information on the current fertility status of the soils in Kagera Region. It is for this reason that this study was conducted for the purpose of assessing the fertility status of some selected fields as proxy to the soil fertility status of Bukoba, Missenyi and Biharamulo districts. This led to formulation of recommendations on appropriate soil fertility management strategies to improve crop productivity at farm level and the region as a whole, thereby improving household food security and income (Msanya, 2020).

The extensive loss of nutrients through leaching especially in high rainfall zone (above 1800 mm), extensive weathering of the soils, low soil organic matter content and continuous crop removal of the nutrients from the soils without replenishment. This suggests the need to use fertilizers in the soils to improve the soil fertility status for optimum and sustainable crop yields. However, before deciding to use fertilizer, farmers need to understand the inherent soil fertility status of their farms (Msanya, 2020). There was an obvious need for conducting an investigation from the observable evidences of traditional cattle keeping decline in Kagera Region particularly in the studied area of Bubuya

Hamlet. This area shows the uniqueness of cattle decline, cropping and soil fertility.

Objectives of the Study

Generally, this study intended to assess the decline of traditional cattle keeping in Kagera Region and its impacts on soil fertility, crop production and environmental change of natural vegetation. The study specifically intended to:

i. investigate the decline of traditional cattle keeping in Kagera Region and its impacts on soil fertility;
ii. investigate the decline of traditional cattle keeping in Kagera Region and its impacts on crop production; and
iii. investigate the decline of traditional cattle keeping in Kagera Region and its impacts on environmental change of natural vegetation.

Significance of the Study

There is no way we can ignore the traditional livestock keeping without adopting the modern ones. The study saw the need for discovering the relationship of former farming systems with high yields than the current ones. Thus, the findings aimed at improving the soil fertility by showing the contribution of semi-sedentary cattle farming at the permanent home place and around the pasture areas. The study also showed the value of cattle in terms of making high value and quality of crops production especially food crops, and particularly banana; there was good production as a result of maturing added willingly or none willingly. The change of cropping systems obviously shows that something went wrong. The changing natural vegetation, particularly the variety of species of big steam (andropogon) commonly known as *'omushanje'* show currently the negative impacts on soil as well as the environment. So, the study intended to show the relationship between cattle decline and change of environment.

Theoretical and Empirical Literature Arguments

According to the bacterial theory of soil fertility, the fertility of a soil depends largely on its bacterial population; the enemies of which are destroyed by partial sterilisation, which the bacterial spores survive (Fletcher, 1913). Microbes in the soil are directly tied to nutrients recycling especially carbon, nitrogen, phosphorus and sulfur. Bacteria are a major class of microorganisms that keep soils healthy and productive (Hoorman, 2016).

Traditional Cattle Keeping

Traditional pastoralism is the main sheep production system of the semi-arid rangelands, where there is unpredictable climate and economic dependence on livestock increases as rainfall decreases. Traditional pastoralism can be categorised by the degree of movement of animals from highly nomadic through transhumance to agropastoral. Pastoralists by their nature are flexible and opportunistic and can swap between systems; likewise, they have multiple systems in one overall productive enterprise. Nomadic systems are highly flexible with seasonal migration of livestock and normally have no home base. Transhumance is the regular movement of flocks among fixed points to exploit the seasonal availability of pastures. In mountainous regions, the movement is usually vertical between established points and the routes are often very ancient. Horizontal transhumance is perhaps more opportunistic with movement between fixed sites developing over a few years and are often disrupted by climatic, political or economic changes. Recently, transhumance has been transformed with the introduction of modern transport in many regions of the world and trucks are often used to transfer sheep from lowland to highland areas for summer grazing in the United Kingdom. Agro-pastoralism can be described as settled pastoralists who cultivate sufficient areas to feed their families from their own crop production and keep animals only enough to ensure they can graze them close to their home base or village. These farmers often own larger flocks that are sent away to nomadic shepherds in rangelands who look after the sheep for the owners (FAO, 2001).

The main risk to traditional systems is the unpredictability of the climate. This has an impact on the growing season of plants and hence the forage that is available to sheep. The risks are particularly acute mid-winter when sheep are in their poorest condition and least likely to be able to withstand any other challenges, and during the spring lambing season. High losses of newborn lambs can be especially damaging as it limits the supply of new females to enable flock rebuilding, and hence slow recovery from a catastrophic climate event (Kilgour *et al*., 2008). In traditional systems in arid regions, lack of drinking water for sheep, attack from predators and disease can be a barrier for production and good animal welfare standards (Nadia, 2022).

Decline of Traditional Cattle Keeping

The agro-ecosystems in the region are facing increasing pressures as a result of rapid population growth, agricultural and livestock intensification characterised by progressive reduction in farm sizes as well as unsustainable land use and management practices. The basin's land and freshwater resource base, associated biodiversity and populations whose livelihoods and food security depend on those resources, are threatened by land degradation, declining productive capacity of croplands and rangelands, deforestation and encroachment of agriculture into wetlands. Climate change and variability aggravate these threats. To address these problems, it is necessary to work with all actors at all levels because the adoption of improved practices for the management of soil, water, vegetation and diverse ecosystems cannot be made without putting in place a suitable institutional and policy framework, including processes for planning, organisation and decision making at community, district/provincial and regional/trans-boundary levels (FAO, 2022).

Environmental Change of Natural Vegetation

The area of grasslands was shown to have decreased over 50 years by 40% whereas the area of annual crop fields increased by 225%. Encroaching on grassland reduced the ability of farmers to restore the fertility of their soils as possibilities to keep livestock, thus the supply of manure diminished. This had a consequence on nutrient balances whereby the home gardens receiving manure had positive balances of N, P and K whereas the home gardens receiving no manure had negative nutrient balances. Nutrient balances of annual crops were negative particularly with maize, indicating that they are vulnerable to impoverishment (Baijukya, 2004).

In general, in the K*ibanja*, most parts of the farm waste usually return to the crop fields, except human excreta, which is gathered in pit latrines on the K*ibanja* land and it is not reused. To fertilise the *Kikamba* land and protect its topsoil against erosion, farmers remove organic materials originating from the *Kibanja* and add them to the soils of the *Kikamba* land. From the R*weya*, grass and firewood are imported to the *Kibanja*. The grass is either used as fodder or as mulch. Leftovers of the burnt firewood usually stay in the *Kibanja*. Wooden biomass is imported from the *Kabira* into the *Kibanja a*nd leftovers of the use of wooden biomass usually stay in the K*ibanja* (Baijukya, 2004).

2.0 Research Methodology

The study employed a case study research design. The design was chosen due to the fact that the area given though aimed at representing Kagera Region based on inductive research approach, it has very unique variables of the study. The area has dropped from more than 500 traditional cows owned before to zero currently. This rose up the need for investigation to make fair conclusions to other areas.

Description of the Study Area and Justification

The study used Bubuya Hamlet found in Ijumbi Village and Ward of Muleba District in Kagera Region. It was purposely selected due to its uniqueness of declining of semi-sedentary small scale farming from more than 500 cows to 0 recently. The observed abrupt change of nature vegetation, soil fertility and cropping style also made the area suitable for the study. This area was suitable to represent the whole region due to the fact that most of the villages were homogenous in terms of the study issues.

Sampling Procedures and Sample Size

Likewise, 63 households were included in sample. This made an option for a purposive sampling as the available household fitted the sample size for this study.

Data Collection Methods and Instruments

Questionnaires were used, as the main method of data collection, as well as interviews in some areas. Interviews were administered to 14 most aged people in the area as they had a lot of experience on faming activities, soil fertility as well as vegetation change in the area.

Data Processing and Analysis

Data collected was analysed both quantitatively (as a main method), and qualitatively. Quantitative data was analysed by using the Statistical Package and Service Solution (SPSS) version 20.0 to derive frequencies and percentages using tables. Descriptive statistics were also used to give a summary of distribution of responses to be able to classify and explain the association among and between the variables. Inferential statistical analysis was undertaken through cross-tabulation of dependent variables with independent variables. This helped to assess if the associations were statistically significant. Qualitative data from face to face interviews and observations were labeled and transcribed.

3.0 Study Results

Decline of Traditional Cattle Keeping in Kagera Region

Tanzania accounts for about 1.4% of the global cattle population and 11% of African cattle population (FAO 2014). Tanzania has about 30.5 million cattle, 18.8 million goats and 5.3 million sheep. Other livestock include; 1.9 million pigs, 38.2 million local chickens and 36.6 million improved chickens. The livestock sector employs about 50% of her population, which is equivalent to 4.6 million households who their income depends on livestock (Mpina, 2022).

The study investigated the decline of traditional cattle keeping in Kagera Region and its impacts on soil fertility. Cattle in Kagera Region have been declining from time to time apart from having a lot of positive outcome on soil, cropping and health of vegetation. For example, according to Baijukya (2004), cattle in Kyamtwara Division, cattle holding per household declined from 51 in year 1961 to 8 by 1999. This situation can be observed in almost all places in the region. According to the National Bureau of Statistics (2010) livestock population distribution in Kagera Region in 2009/2010 was as follows: Cattle 1,012,798, goats 893,671, sheep 240,031 and poultry 938,170.

Impact of Cattle Keeping on Soil Fertility

Tanzania has about 30.5 million cattle, 18.8 million goats and 5.3 million sheep. Other livestock include 1.9 million pigs, 38.2 million local chickens and 36.6 million improved chickens. The livestock sector employs about 50% of her population, which is equivalent to 4.6 million households, whose income depends on livestock. Livestock sector plays an important role in building a strong national economy by increasing household food security, income, animal draught power, manure, foreign currency and employment opportunities while nurturing the livestock resources. This contributes to increased economic growth and government revenue. The findings through the respondents for both questionnaires and interviews revealed that the relationship of negative impacts resulted from the decline of soil fertility in relation to decline of traditional cattle keeping in the region. On this area, the study investigated if semi-sedentary added values to soil fertility at shed farms and grazing areas. About 58.7% strongly agreed with the response being the largest group of respondents on this option. On the other hand, 34.9% opted for agree while 3.2% for neutral as well as disagree with 3.2%. There were no respondents who opted for strongly disagree.

The other variable on this area questioned if semi-sedentary farming made no need of using artificial fertilisers. Among the total study respondents, 23.8% opted for strongly agree. 50.8% of the respondents opted for agree. The category of neutral was opted by 4.8% of the respondents. Moreover, 14.8% opted for disagree while 4.8% opted for strongly disagree. The last area was examining if loss of fertility has accelerated soil erosion. 41.3% of the respondents strongly agreed, while 30.2% simply agreed. On the other hand, 25.4% opted for neutral and 3.2% chose to disagree and no respondent opted for strongly disagree.

From the analysis, it is obviously indicating that the decline of traditional cattle keeping in Kagera Region has brought impacts on soil fertility. Majority of respondents strongly agreed and agreed that the deterioration of traditional cattle keeping in the selected area had some impacts on soil fertility.

Table 4.1: Decline of Traditional Cattle Keeping in Kagera Region and its Impacts on Soil Fertility

SN	Factor	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total	
		R	%	R	%	R	%	R	%	R	%	R	%
1	Semi-sedentary added values to soil fertility at shed farms and grazed areas	37	58.7	22	34.9	2	3.2	2	3.2	-	-	63	100
2	Semi-sedentary made no need of using artificial fertilisers	15	23.8	32	50.8	3	4.8	9	14.8	3	4.8	62	98.4
3	Loss of fertility has accelerated soil erosion	26	41.3	19	30.2	11	17.5	5	7.9	2	3.2	63	100

NB: 'R' represents respondents

Source: Field Data (2022)

The interviewed respondents were asked to explain the way semi-sedentary farming added values to soil fertility at shed farms and grazed areas. They pointed out that at the shade areas, manure could be used as an organic fertiliser, hence making soil more fertile. Also, semi-sedentary farming made no need of using artificial fertilisers as the cow dung was good for soil health. Loss of fertility has accelerated soil erosion too. One male respondent who introduced himself as Ta Angelo aged about 100 years said:

> I and my brother, Aloys, had more than 80 cows without counting goats, sheep and other animals. We used to share grazing routine. At this moment, I don't own even a chicken; the same applies to Aloys' family.

A photograph below shows the banana farm owned by two different peasants. From the right hand side of the photograph is the farm which was not enriched with organic manure; hence the plants are very weak. On the left hand side, the farm was provided with manure and has a good yield of bananas; it can be seen that the tall and big banana are supported by posts. It was also, observed that the idea for mixing cultivation was performing better on a farm with organic manure in the west; than in the east. The two farms are separated by the footpath.

Impact of Cattle Keeping Decline on Crop Production

The decline of traditional cattle keeping in Kagera Region was investigated in relation to how it related to the impacts on crop production. The study investigated several areas on this objective including focusing on if there was a change of cropping systems in the selected area. On this, 55.6 % strongly agreed while 38.1% agreed. There was no respondent who opted for neutral. 4.8% of the respondents opted for disagree and there were no respondents who opted for strongly disagree.

The investigation was made to test if there was introduction of new crops with fewer values. The ‘strongly agree’ was opted by 31.7% while ‘agree’ was opted by 34.9%. The neutral option was opted by only 6.3%. The ‘disagree’ and ‘strongly disagree’ options were opted by 20.6% and 6.3% respectively.

There was also a need to examine if there was less production in the yields as a result of decline of traditional livestock keeping. Respondents who opted for strongly agree and agree were 41.3% and 12.7% respectively. Neutral was opted by 9.5% of the total respondents. The respondents who opted for disagree were 28.6%, while strongly disagree was opted by 7.9% of the total respondents.

Furthermore, the study tested if the traditional crops were declining in the area. The respondents who strongly agreed were 47.6% and those who agreed were 41.3%. Neutral was opted by 6.3% while 4.8% opted for disagree and no respondent opted for strongly disagree. Table 4.2 b summarises data for explanations above:

Table 4.2: Decline of Traditional Cattle Keeping in Kagera Region and its Impacts on Crop Production

SN	Factor	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total	
		R	%	R	%	R	%	R	%	R	%	R	%
1	There is a change of cropping systems in areas	35	55.6	24	38.1	-	-	3	4.8	-	-	62	100
2	There is introduction of new crops with fewer values	20	31.7	22	34.9	4	6.3	13	20.6	4	6.3	63	98.4
3	There is less production in the yields	26	41.3	8	12.7	6	9.5	18	28.6	5	7.9	63	100
4	The traditional crops are declining	30	47.6	26	41.3	4	6.3	3	4.8	-	-	63	100

NB: ‘R’ represents respondents

Source: Field Data (2022)

The interviewed respondents did not differ much from questionnaire findings. They indicated that there were changes of cropping systems in area. They pointed out, for example, the presence of giant banana (*fia*) cultivation. They said that the crops introduced had fewer values compared to traditional ones, hence low yields. Also, they claimed that traditional crops are declining due to the invasive crops introduced and luck of fertility. One of the old men who introduced himself as *Ta* Marco said:

> We had varieties of food (food crops). For example, some vegetables such as small tomatoes can no longer grow naturally. These were available due to organic fertilisers we got from cattle shades.

The photo below was taken by the researcher to show a part of Ta Marco’s farm. It can be observed that the idea of mixed cultivation being practised, which is the best tradition of *Kibanja* farming practice. Apart from mixed farming (cattle and plants), the mixed cultivation (several crops) is the commonest method in Kagera Region.

This part of Marco's farm is showing the real picture of decline of vegetation due to lack of soil nutrients resulting from monoculture. The region's indigenous people are permanently planting bananas and coffee mostly mixed with other crops such as cassava, beans, yams and so many others.

On this photo, the vegetation is very weak with yellowish colour indicating lack of nutrients in the soil as a result of lack of cow dang to fertilise the soil. The photo shows several weak plants like coffee trees, banana, cassava, yams and other plants.

Impact of Cattle Keeping Decline on Environmental Change of Natural Vegetation

There is an observable indicator on the decline of traditional cattle keeping in Kagera Region and its impacts on environmental change and natural vegetation. The study examined if there was disappearance of some natural species of vegetation. It was found out that the respondents who strongly agreed were 25.4% while who agreed were 47.6%. Neutral response was opted by 3.2% while those who disagreed were 14.3% of the respondents. The strongly disagree response was opted by 7.9% of the participants in the study.

The study further examined if natural vegetation had positive outcome on food and cash crop production. Among the respondents, 41.3% opted for strongly agree while 20.6% opted for agree. The neutral response was opted by 23.8%. The respondents who opted for disagree were 9.5% and 4.8% opted for strongly disagree.

On the other hand, the study investigated if semi-sedentary farming decline was observed on the strengths of available vegetation cover. The respondents who strongly agreed were 17.5% while those who agreed were 22.2% of the total respondents. The neutral response was opted by the majority of respondents reaching about 41.3%. The disagree and strongly disagree responses were opted by 9.5% and 9.5% respectively.

There was a question targeted to know if the decline of vegetation caused change of weather in the selected area. Respondents who opted for strongly agree were 55.6%, followed by 31.7% of those who agreed, while the neutral response was opted by 6.3% of the total respondents.. Disagree and strongly disagree were opted by 4.8% and 1.6% respectively.

Lastly, the study investigated if there was new species of natural vegetations observed in the area. On this category, the respondents who strongly agreed were 4.8% and who agreed were 25.4%. The neutral response was opted by 36.5% while strongly disagree was opted by 17.5% of the respondents. Table 4.4 summarises the data described above:

Table 4.4: Decline of Traditional Cattle Keeping in Kagera Region and its Impacts on Environmental Change of Natural Vegetation

SN	Factor	Strongly Agree		Agree		Neutral		Disagree		Strongly Disagree		Total	
		R	%	R	%	R	%	R	%	R	%	R	%
1	There is a disappearance of some natural species of vegetation	16	25.4	30	47.6	2	3.2	9	14.3	5	7.9	63	100
2	The natural vegetation had positive outcome on food and cash crop production	26	41.3	13	20.6	15	23.8	6	9.5	3	4.8	63	98.4
3	Semi-sedentary declined is observed on strengths of a1vailable vegetation cover	11	17.5	14	22.2	26	41.3	6	9.5	6	9.5	63	100
4	Decline of vegetation caused change on weather of the area	35	55.6	20	31.7	4	6.3	3	4.8	1	1.6	63	100
5	There is new species of natural vegetations observed in the area.	3	4.8	16	25.4	23	36.5	10	15.9	11	17.5	63	100

NB: ‘R’ represents respondents
Source: Field Data (2022)

The findings indicate the decline of traditional cattle keeping in Kagera Region and its impacts on environmental change of natural vegetation. As it has been found in this study, livestock keeping had strong impacts on vegetation cover. For example, natural vegetation grown after harvest away from permanent home farms has disappeared. The highly declining natural vegetation pointed by the interviewees was the species of blue steam (*Omushanje* /andropogon).

On the other hand, the interviewed respondents pointed out that there was a disappearance of some natural species of vegetation, for example, some species of andropogons were disappearing in the area. These were used as pastures for cows and were covered by soil for tubers (cassava and sweet potatoes) as a positive outcome on food and cash crop production. Respondents showed that the grass cover and other vegetation supported moistures, hence rain formation in a predictive way.

4.0 Conclusion

The findings indicated the decline of traditional cattle keeping in Kagera Region and its impacts on soil fertility. Semi-sedentary farming was found to be potential on both the shade farms and grazing areas. The manure obtained from the cattle was fertilising the soil around the places of home kraals and grazing area, hence supporting natural ecosystem. Crops need a fertile soil. It was found out that cattle had a lot of contribution on organic farming. The decline of traditional cattle keeping in Kagera Region brought negative impacts on crop production. Some impacts include low yield and disappearing of some species.

The decline of traditional cattle keeping in Kagera Region brought a lot of impacts on environmental change of natural vegetation such as the presence of new species and disappearance of some old species. Vegetation also was found to affect soil fertility and cropping system in Kagera Region and Bubuya Hamlet in particular.

Recommendations

Since it was found that the decline of traditional cattle keeping in Kagera Region has significant impacts on soil fertility, there is a need to find the new ways of adopting cattle keeping especially sedentary farming. The sedentary farming can be adopted on the same species of animals (traditional cattle) to improve soil fertility and reduce the running coast which could be incurred due to the introduction of new and more modern species. Moreover, there is a need to increase production of food and cash crops through investing on cattle keeping to bring back into health the traditional banana and coffee farming. This will enhance the agricultural system which is organic as cattle, crops and vegetation are interdependent; thus it will consequently reduce or culminate the use of chemicals. Lastly, the study investigated on the decline of traditional cattle keeping in Kagera Region and its impacts on environmental change of natural vegetation. It was discovered that the vegetation was affected to the large extent. Therefore, this raises the need for modern cattle keeping to reach to fair ecology for plants and animals.

The two photographs show a farm with modern cattle. The researcher interviewed the farmer on the benefit obtained from the cattle. Apart from milk, meat and sells, the farmer said he was valuing the cow dung as his best product. Apart from having three cows and the possibility of selling each one for Tsh 2,000,000 (for a matured one) and Tsh 600,000 for a young one. He said he wanted more cows mainly because of the cow dung.

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BOOK REVIEW

Marketing of Agricultural Products

By Elias E. Sanga & Legnard N. Ngailo,

First Edition, 2014. ISBN: 978-9987-9646-1-1, 393PP

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Abstract

Agricultural marketing plays a crucial role in fostering and improving the economy of the country. As a discipline, it needs to be integrated on most of the business courses to equip students to know the basics of the marketing of agricultural products in Tanzania. This book is very conversant and detailed that it contributes to the knowledge and understanding of the important aspects and issues in managing the marketing of agricultural products and produces. It managed to connect the marketing principles and methods in the success of the flow of agricultural inputs and outputs and narrated associated risks and solutions to the identified risks and problems. The main weaknesses of the book include failure to openly show the sequence of flow in terms of agricultural products supply chain and the channels, risks associated with international agricultural marketing, skills and application of ICT in agricultural marketing and balance of trade in international business as well as the role of regional integration in the flow of agricultural products. Therefore, there is a room for more discussions on the international business arena and the issues of consumer behavior and how a customer's buying behavior affects the rational decision making process of farmers and how it affects the strategies posed by marketing institutions and the government. Nevertheless, the book is very resourceful to university educators, researchers and students, especially those pursuing

business studies. It is also a useful instrument to policy makers at both local and international levels and agricultural business practitioners. This book review is very important as it helps readers understand what is missing and resources to fill the trench. It presents the synopsis of the book and a critical evaluation of the content and then offers an endorsement, weakness and strength of the book.

Key words: Agricultural marketing, trade liberalization, co-operatives, and marketing costs

1.0 Synopsis and Reflections

Agriculture plays a significant role in the economies of most developing countries. Agricultural activities being one of the important economic activities in Tanzania need a kin eye in terms of perfection and capture crucial elements in marketing of the agricultural produces. Applying marketing strategies and methods in the distribution of agricultural produces plays a crucial role in ensuring better processes on the same and also on making the produces available in places that they are not produced or processed. In the marketing of the agricultural products, it is important to understand the forces of demand and supply and how to deal with the issues pertaining to the bigger pictures of supply chain. This will pave ways in ensuring smooth coordination, physical distribution and storage of the agricultural products. This book has been instrumental because it captures all these aspects in marketing of agricultural products.

This book has been prepared by authors with strong experiences in marketing and entrepreneurship as researchers, consultants and facilitators; being also reflected from field works they have done for long in the United Republic of Tanzania. The book is tailored to equip students and practitioners with the marketing strategies and principles that aid in smoothing agricultural activities from marketing of agricultural inputs to the marketing of agricultural outputs – the application of these strategies and methods may differ from one country to another and from one organization to another. The knowledge and content of this book fit the context of the United Republic of Tanzania, among other countries. Commenting with no doubt, this book could provide a good understanding and guidance to researchers and facilitators in other developing countries in Africa and Asia.

The book chapters give a detailed understanding on issues that are elemental in the marketing of agricultural products and provide sets of marketing tools that can be utilized to succeed in the marketing of agricultural inputs and outputs. The authors clearly narrated that "…. agricultural marketing starts from the farm (production place) when a farmer plans his production to meet specific demands and market prospects. This is because the point of production is the basic source of supply. Marketing process begins at that point and continues until a consumer buys the product…" (p. 6). That is to state that understanding all the processes from farm production to the supply of the goods to the ultimate consumer or customers is crucial when giving a clear thought in the marketing of agricultural products. This good book comprises 15 chapters.

Chapter one provides a clear understanding on the introductory issues to marketing of agricultural products and the approaches to the study of agricultural marketing. In this chapter, the author also provides an understanding of the term "Agribusiness", of which from this understanding it means that to better market the agricultural products, it is crucial to understand all the operations involved in the manufacture and distribution of farm supplies; production operations in the farm; and the storage, processing and distribution of farm commodities as well as items made from them (p. 7). The understanding of agricultural marketing system is provided in this chapter and the authors clearly established the uniqueness of agricultural marketing and its role to our economy. The approaches to the study of agricultural marketing provided insights to the structural analysis of agricultural marketing, which is crucial to understand the implications on middlemen, institutions and agents in the flow of agricultural products. Definitely, this chapter provides a clear introductory picture of agricultural marketing activities and structure; this can clearly be recalled from market structure approach (p. 22).

The second chapter of the book provides a critical analysis of the elements of marketing mix in agricultural marketing (product, price, place, promotion, positioning, physical evidence, people, process, packaging, policy). The authors pointed a brief understanding of the elements, and the best part of this is that they provide exhausted list of the elements, far from the traditional marketing mix elements (product, price, place, promotion); the other elements provide that in marketing, we need to reason beyond the elements that directly facilitate the movement of the products. The authors in this chapter clearly narrated that marketers need to realize that success in any marketing activity is not determined by the size or volume of the promotion budget or the most physical locations of the business or based on product features or the best price; this will not make a business stand out. They need also to think about 3 Cs of marketing, namely customer, content and connection (p. 27). A more notable context in this chapter, the authors provide a good analysis of the marketing mix and promotional mix applied in marketing of agricultural products and provides sub-elements for almost each element as applied in marketing of agricultural products.

Chapter three is about agricultural marketing functions. These are the facilitating services that must be performed within the agricultural marketing system. These functions are necessary to ensure that agricultural products attain form, place, time and possession utility. The authors pointed out a good point that "…marketing functions play a critical role in linking the producers, sales agents and customers…" (p. 70). This means that agricultural marketing functions link farmers, middlemen/facilitating institutions and ultimate customer/consumers. The authors demonstrated the marketing functions as value adding functions and the functions explained as classified by Kohls and Uhl (2002) in three sets: exchange, physical and facilitating functions. On these functions, the authors explained the economic activities that create form, place and possession utilities. In this chapter, authors managed to explain how marketing information as a crucial function in agricultural marketing is performed in Tanzania (p. 132). Transportation being one of the most important facilitating functions in agricultural marketing functions, the authors explained about its role, the importance of railway in agricultural products transportation, and transportation problems in Tanzania. '…Tanzania like other developing countries is critically handicapped by her transport system which in most cases is inefficient and inadequate…" (p. 116). The authors suggested ways to minimize transportation problems in Tanzania.

Chapter four is dedicated to "agricultural market liberalization in Tanzania". As it is indicated, it explains the need as well as positive and negative effects of market liberalization. The authors in pages 138 to 140 explain about the history in the changing agricultural marketing system in Tanzania. This shows important phases, institutions and boards enacted to the reality of the current agricultural marketing arrangement in Tanzania, not forgetting the existence of cooperative societies as on the matter. It is clearly pointed out by the authors that "…the main aim of agricultural market liberalization was to increase income growth and poverty alleviation…" (p. 144). Remarkably, in terms of marketing of agricultural inputs and inputs, the key aim here was to facilitate trade by controlling input and output prices and eliminating regulatory control over input and output marketing, inter alia. Following liberalization of agricultural marketing, the state became more involved in setting up the regulatory framework to guide on how the market should be operated, and despite the liberalization of agricultural marketing in Tanzania, the marketing of all traditional export crops such as coffee, tobacco, tea, cotton, cashew, pyrethrum, sisal and sugar is still regulated by the board.

Chapter five is grounded in agricultural marketing agents and institutions in Tanzania. This chapter establishes the role of agricultural marketing agents and institutions in Tanzania and provides narrations of agents and institutions that take part in agricultural marketing system in Tanzania. A marketing agent is essentially a middleman operating between a producer and a wholesaler or a consumer or industrial buyer. Marketing institutions are organizations or companies performing various marketing and facilitating functions. The authors established that agents and institutions play a pivotal role in the marketing of agricultural products; and essentially, a well performing agricultural marketing system depends on their existence. For instance, on pages 149 – 150, the authors demonstrate that apart from providing direct services to the marketing system, agricultural marketing agents and institutions also provide a number of useful services to the farmers. Sometimes, marketing agents especially those supplying inputs can also provide finances or credit in kind to farmers. This chapter reveals the importance of the agricultural marketing agents and institutions in Tanzania, emanated from exchange, physical and facilitating functions in the marketing system.

Chapter six is captioned 'agricultural marketing cooperatives'. This chapter provides discussion on the principles and values of cooperatives and their role on the effectiveness of agricultural marketing system. Mainly the chapter deals with agricultural marketing co-operatives, which are business organizations collectively owned by farmers to sell their products and get other necessary services (p. 180). The authors show that agricultural marketing cooperatives allow farmers to accomplish collectively functions they could not achieve on their own. Farmers with little power in the market may opt to form or join cooperatives so that they easily market and sell their agricultural products. The authors demonstrate the existence and position cooperative societies in the marketing and selling of agricultural products. Then in pages 191-192, they discussed the achievements and problems of marketing co-operatives in Tanzania. Among the achievements they pinpointed were elimination of unfair marketing practices done by all the non-African traders…' and 'provision of marketing services to smallholder farmers…'. Moreover, they hold that '…co-operatives have assisted in the development of modern markets in rural areas through provision of ready markets for products produced by scattered small farmers'. Here, the authors argue that co-operatives play a crucial role of joining forces of the small famers to market and distribute their products and empower them to compete with large scale farmers.

Chapter seven presents warehouse receipt system in Tanzania. Among other things it was implemented to improve the marketing of agricultural products by having regulated warehouse receipt system (WRS). This system operates by converting a stable, stored agricultural product into a tradable form. This chapter provides that WRS works only on storable agricultural products. The authors provide that '…the main objective of WRS is to enable farmers to benefit from seasonal increases in prices, increase in competitiveness of traders and raise product prices through collective marketing and bulking of product' (p. 199). The components of the WRS include warehouse, commodities, warehouse receipt, loan, market and legal framework. The composition portrays that WRS ensures good storage of the products and has proper documentation and may also ease access to finance and links to different buyers and it is regulated. The key actors in WRS may include farmers, primary co-operative societies, co-operative unions, marketing boards and financial institutions.

In chapter eight, the authors recount on commodity marketing, with an illustration that commodities form a set of products or are the basic agricultural products that are either in their original form or have undergone only primary processing (p. 215). Commodity marketing deals with marketing of both food and non-food products. It covers marketing of commodities like grains, livestock and fresh meat, poultry and eggs, fresh milk, horticulture, tobacco, cotton and rubber. The authors discussed the marketing of grain and horticulture products; precisely they discussed the distribution channels of grain and horticulture products and the problems of horticulture marketing in Tanzania. The book shows that the trading of these products needs a system of institutions and associations that facilitate the trade and that despite the fact of having problems as a country, we still have to improve in terms of production, infrastructure and market research.

Chapter nine is about the theory of demand and supply in agricultural marketing, demand and supply being among the important elements of the market mechanism in agricultural products. In this chapter, the authors explain the applicability of the laws of demand and supply in the marketing of agricultural products and a model that helps to explain how prices and quantities are determined in a market. In pages 226-227, the authors portray the practical meanings of demand and supply and in page 232, they discuss the narration behind the assumption of ceteris paribus. There are many factors that affect consumers' decision to buy and producers' decision to produce. To isolate the effect of prices on the quantity demanded and supplied, we must hold all of these other potential influences constant. The authors in this chapter explain how elasticity of demand and supply is very important connotation to demonstrate the theory of demand and supply in agricultural marketing. Farmers and producers need to understand the trend analysis and the seasonality and how the consumer behavior toward the products are given a moment of time.

In chapter ten, the authors provide analysis on the pricing and price trends, '…price acts as an indicator of scarcity of products.' (p. 249). The authors term the factors that affect prices in a free market economy as 'invisible hand'; this means that these factors are uncontrollable in some instances. In this chapter, they profile the functions of price, to include distributive function, allocative function, signaling function, equilibrating function, rationing function, transmission function, provision of incentives, enhancing marketing efficiency and performance, determining decision, competitive tool as well as promotion function. The authors provide a clear line between farm gate prices, wholesale prices, retail price and export prices of the agricultural products. Considering the seasonality nature of the agricultural products and production, in pages 258 - 270 they provide the narration behind price fluctuation, the reasons for price fluctuation, causes of price fluctuation, problems of price fluctuations and measures to control price fluctuation for agricultural product.

Chapter eleven is about the analysis of marketing costs, margins and returns. In this chapter, the authors provide discussion on the agricultural marketing costs (transportation costs, processing costs, storage costs, product losses, handling costs, packaging costs, capital and financing costs). Marketing costs are payments made for the service provided in getting the product to the consumer in the form, at the time and place desired by the consumer…' (p. 274). The authors also focus on the factors influencing marketing costs and the strategies which marketing organizations can consider in reducing marketing costs. The authors provide the strategies that may be employed to reduce marketing costs in the marketing of agricultural products. '…Agricultural marketing organizations are supposed to develop strategies of reducing marketing costs if they are to survive in the market.. .' (p. 297). In this chapter, the authors also provide an analysis on the difference between the purchase price of the agricultural products and the price received on re-sale. This is the marketing margins, which entail the price of all utility-adding activities and functions performed by food marketing organization.

Chapter twelve is concerned with marketing of agricultural inputs. This chapter basically explains about the structure of input market and input supply system in Tanzania. In page 308, the authors explain why fertilizers market in Tanzania attracts unattractive margins. This illuminates on the nature of the input itself and the problems that are rooted inadequate business, technical knowledge, and skills at the distributor and retailer levels of fertilizers and inadequate flow of market information. '…The agricultural input marketing is uncertain due to the fact that access to finance and market information is limited…' (p. 309).

Chapter thirteen is captioned as "agricultural marketing research". 'Market research is a technique which is designed to give decision makers further information about problems and opportunity areas in agricultural marketing…'

(p. 313). In this chapter, the authors provide a clear understanding of the agricultural marketing research by illustrating the scope of agricultural marketing research, profiling the marketing research process, and narrate on the role of agricultural marketing research. '…Agricultural marketing research has proved to play a significant role towards the development of local producers, agricultural institutions, organizations, and the country as a whole' (p. 319). The importance of agricultural marketing research can be viewed in such areas as consumer analysis (attitudes, believes, motivations, perception, behavior, personalities), competitors and industry analysis, product planning, branding, pricing, promotion, market segmentation, test marketing and distribution.

In chapter fourteen, the authors provide discussion and critical observations in international agricultural marketing, as one of the important parts in trading. This chapter explains about the issues pertaining to exporting and importing of agricultural products. International marketing takes place because there is an advantage to be gained from it. In pages 341-344, the authors discuss about the reasons and benefits of international marketing. Here, the authors aim to give the clear understanding on the rationale behind international marketing and why we need to engage producers and consumers/customers beyond borders. Despite its the benefits, international marketing suffers from a number of disadvantages (p. 344). In page 349, the authors profile the process of international agricultural marketing; here they want readers to get a synopsis of what is needed systematically to engage in international trade. The chapter also details on the need for conducting environmental analysis in international marketing to that organization to make rational and informed decisions in relation to the undertaking of international trading. Considering the process as in importing and exporting, the chapter exhausts on the important documentations in international agricultural marketing, the market entry strategies and the international commercial terms.

Chapter fifteen, which actually is the last one, presents discussion on agricultural marketing success, problems and challenges in Tanzania. Here, the authors aim to provide a critical analysis of the efforts made to improve agricultural production and marketing as well as the challenges still facing Tanzania agricultural marketing systems. The major problems are provided in terms of transportation system, storage facilities and strengths of farmers' institutions, agricultural policies, and marketing channel. Agricultural production and marketing depend on other sectors (such as transport and communication) and related markets (such as financial and foreign exchange markets). Due to the fact that these other sectors and markets are not functioning well in favor of agricultural sector, the efficiency of agricultural marketing is severely limited in its scope (p. 377). Finally, in pages 377- 379, the authors provide an exhausted discussion on the possible solutions to marketing problems. The overall point in the pinpointed pages is that we still have opportunities to improve the agricultural marketing systems.

1.1 Evaluation and Discussions

The authors provide a well-focused and practical analysis on the marketing of agricultural products and mostly based on Tanzania local context, and provide information on the entire necessary stakeholders with vested interest in agricultural activities. This book gives a good analysis that helps readers understand how agricultural markets operate and deep insights on how this can be improved. The scenarios provided in the book give the practitioners, academicians, students and consultant an in-hand tool to understand the basic concepts and cases to the understanding of marketing methods that aid in the success of the agricultural sector. The insights in the books are resourceful to marketing and agricultural marketing professionals who are always challenged with the marketing issues and selling in their operations; managers who are involved in decision making related to agricultural marketing operations. The presentation of ideas can also provide good insights to marketing and agricultural marketing professionals in other developing countries in Africa. The good news is that agricultural marketing is not challenging developing countries in Africa only. In this book, the authors provided questions on every chapter that help students and academicians to probe things more deeply.

The authors clearly state that "the marketing mix variables are not what going to make the business stand out' (p. 27). Thus, the marketers need to focus on customers, compelling content and connection; this sends message to the practitioners and professionals in the field of agricultural marketing that marketing of the products should also focus on the actual needs of the customers and make sure they create good content and maintain the pool of customers in their operations. Agreeably, all over the world, the food sector stands to be very critical. Success in this sector depends on the success in the marketing of agricultural products. The book provides insights in the process on proper storage of the products which is very paramount in food security. Also, it provides information related to WRS, which is also very crucial in the storage and marketing of the agricultural products (storable). Furthermore, the authors provide insights in terms of marketing the products in foreign countries, if harvests are in surplus, and in processed products. The marketers and farmers may opt to supply the products in foreign countries and this may help to generate revenues but also may import on deficit. The authors narrate all the necessary procedures for importing and exporting, though most of the details on this part are on a "nutshell". In the case of international agricultural marketing, the authors should have gone far to highlight the logistical issues for importing agricultural produces and elaborate issues of exemptions as well as political issues that affect the importing of agricultural products.

The authors connect the thoughts or explain the concepts of market orientation in agricultural marketing. According to Grunert *et al* (1997), for a business to be a market oriented, it is crucial to replace the predominant dyadic view of company activities with a chain view by the market-oriented product development.

The authors further explain about the implications of consumers' behavior in the marketing of agricultural products. They examine the importance of 3Cs (p. 27), one of the Cs being 'customer'. This shows that it is important to understand the customers. Thus, while focusing on the market, it should be built on the assumption that the success of new product to be determined in that market by the customers' perception. Therefore, it is crucial to build the understanding on the customer buying behavior (understanding of the customers' needs and wants) in the process to improve the chances of success (Grunert *et al*., 1997). The authors also build an understanding on approaches to analyzing consumer behavior. This also goes to building a strong analysis in international agricultural marketing on proceeding discussion in chapter fourteen (14) of the book. In defining the characteristics of the marketing mix, what matters most involves defining who the customers of a firm are (Malcolm *et al*., 2006).
Chapter three provides good understanding in the theory of demand and supply.

Since the base was in developing countries (having Tanzania in the case study), the authors failed to explain and distinguish between three principle fields for agricultural marketing analysis in developing countries: the interactions between supply and the marketing system, interactions between demand and the marketing system, and the dynamic nature of the marketing system itself. According to Grunert *et al*. (1997), these three fields need to be clearly distinguished when explaining the demand and supply in agricultural marketing for a developing country. Norwood and Lusk (2018) maintain that 'in the case of food consumption, eating salad might result from a utilitarian (meaning functional or practical) need such as weight loss or nutritional improvement, whereas eating a hamburger might result from a hedonic (meaning related to pleasure) need such as the need to experience good taste'. This shows that it is critical to consider customer buying behavior in marketing of agricultural products.

The fact that agricultural marketing took a separate chapter (chapter six) to analyze, it shows the importance of marketing cooperatives in the development of agricultural marketing in a developing country like Tanzania. However, considering the good discussion done in chapter five - the authors should have connected "dots" that agricultural marketing channel (as an umbrella term) to constitute special marketing institutions, such as auctions, marketing cooperatives, marketing boards, commodity boards and future markets, to explain the role of each. Grunert *et al*. (1997) reveal that:

> The marketing channels for agricultural and food products are made up of a number of companies, such as, breeders, mixed feed producers, farmers, traders, processors and retailers. The role of these companies in the marketing channel is as a marketing institution, that is an organization which is engaged in the marketing planning and the marketing functions related to a specific product.

The good resourceful analysis by the authors in chapter seven (warehouse receipt system), rationing demand and supply and the attached forces in chapter nine, coupled with the pricing and price analysis in the chapter (chapter seven) demonstrate that there is a risk of price fluctuation and shifting or just to say the changes in demand. The authors should have explained the ways to mitigate this. One of the potential price-risk management instruments for farmers is future contracts. Grunert *et al* (1997) state that "because of increased fluctuations in agricultural prices, some exchanges are creating new futures contracts"; that is to comment that authors had to provide a good analysis on future contracts as instruments for price-risk reduction. The lack of understanding by farmers and firms in general about how to use future contracts has caused many failures in price-risk management. A future contract can be defined as 'a legal contract enforceable by the rules of the Future Exchange, to deliver or accept delivery of a definite amount of commodity of specified grade, during a specified month at a specified price' (Malcolm *et al.*, 2006). Common goals of farmers are for the businesses to survive and grow as well as to set and overcome challenges - the biggest challenge a farm business person has to deal with is that the future cannot be known with certainty; future contract is very crucial at this point (Williams, 2014).

To provide a good analysis in price trends, the authors should have employed some mathematical model for price analysis in chapter ten (10) and give an explanation of the determinants of the changes of agricultural products prices. In agricultural price analysis, orwood and Lusk (2018) employed varieties of analysis models. Among them is time-series analysis that the authors could have used on this stand and probably hedonic price analysis. These models could also provide a better understanding of estimating supply and demand for agricultural commodities.

In chapter fourteen about international agricultural marketing, the authors failed to explain about the balance of trade and issues like counter-trade and reciprocity which are norms in international agricultural marketing and trade. In this chapter, the authors should have also given an insight on the concepts of exchanges rates and the role of regional integration.

Norwood and Lusk (20018) explain about an international trade in agriculture with the narration of, inter alia, balance of trade, mathematics of international market equilibrium, barriers to trade, and exchange rates in trade. They state that 'when trade flows change in response to market changes, such as an increase or decrease in exports, such changes usually benefit one party and harm another'. This means that in international trade, it is crucial to think and get an understanding of the balance of trade.

Finally, the authors should have included the implications and the role of Information Communication Technology (ICT) in agricultural marketing, as ICT can accelerate agricultural development by facilitating knowledge management. ICT plays a crucial role in the economy of any country and has impact in smoothening communication and gathering of information about markets and also the use of modern technology in improving the processing activities and communication between the actors in agricultural products supply chain. ICT can enhance productivity and generate more income by adopting new technologies, including new varieties, adding value and marketing of agricultural products (Hoque *et al*., 2021).

2. Conclusion and Recommendations

Conclusively, this book is of greater importance to researchers, entrepreneurs, faculty members and students at all levels. It provides both theoretical and practical illustrations which can be adopted by other authors as it orients a reader in aspects of practical realities. However, the reviewer recommends the inclusion of risk mitigation strategies in the prevalent and all time risks in price fluctuations (for example, use of future contracts), e-marketing and commerce in international agricultural marketing, risks associated with international agricultural marketing and the application of ICT in agricultural marketing. Furthermore, marketing boards ought to play a significant role in marketing of agricultural produces in most of developing countries, but their strategic role and efficiency have received inadequate analytical attention from the authors. Additionally, it is recommended that a rigorous discussion on different types and roles of marketing boards would help to determine various dimensions of their problems and hindrance factors toward full utilization of their potentials in local and international commercial activities by citing live examples from the EAC member countries; this will make the book more appropriate, readable and useful.

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Influence of Effective Micro-Organisms in Vegetable Production: The Case of Two Climatic Zones in Tanzania

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Abstract

The aim of the study is to describe the nature of effective microorganisms (EMs) and how they influence growth, yield, quality and protection of vegetable plants. EMs comprise a mixture of living cultures of natural microorganisms isolated from fertile soils that are used to improve crop production. A study in two agro-ecological zones was undertaken to assess the impact of EMs in vegetable production of Swiss Chard and Chinese Cabbage. The results indicated that the use of EMs has a positive effect on the growth of vegetables. Application of EMs in combination with organic compost had significant effect on leaf width and height. In Dar es Salaam site, the use of a combination of organic composts, Hakika and EMax Bio Liquid (HKEE) proved to create the average of 23.9±7.7 cm of leaves of the Swiss chard, followed by the application of EM Mazao Booster (MB) 35 cm with the same average as HKEE, followed by application of EMax Bio Liquid (EE) with an average of 21.1 ± 6.1 cm. Maximum leaf width was observed using MB 26 cm, averaging 19.8 ± 4.2 cm. In the Arusha site study, yields with EE and MB were also observed in root and shoot lengths and leaf size. The grown vegetables were always green and delicious. It is concluded that EMs can improve the quality and yield of vegetables by reducing the outbreak of pests and diseases

and protecting them from weeds, thereby contributing to sustainable agriculture.

Key words: vegetables, effective microorganisms, compost, yield.

1.0 Introduction

Vegetables and fruits are the major source of food nutrients that are vital for better health. They are the source of food which is the richest in vitamins (especially vitamins A and C) and minerals which are very important in our bodies as they play a crucial role in preventing us against pathogenic micro-organisms such as bacteria, fungi and viruses. Fruits and vegetables are basically rich in antioxidants which are necessary in our bodies to prevent health disorders that result in the non-communicable diseases such as cancer, diabetes, coronary diseases, etc. They are also a good source of fibre which is required in our bodies to facilitate digestion by increasing the substrate surface area for the digestive enzymes to act on and hence increasing digestion efficiency and consequently improve food nutrients uptake by our bodies.

According to WHO/FAO, a consumption of 400g of fruits and vegetables per day per capita (excluding potatoes and other starchy tubers) is recommended. In Tanzania, consumption of fruits and vegetables is far much less than the WHO/FAO recommended rate since independence to date (FAOSTAT, 2017) (Figure 1).

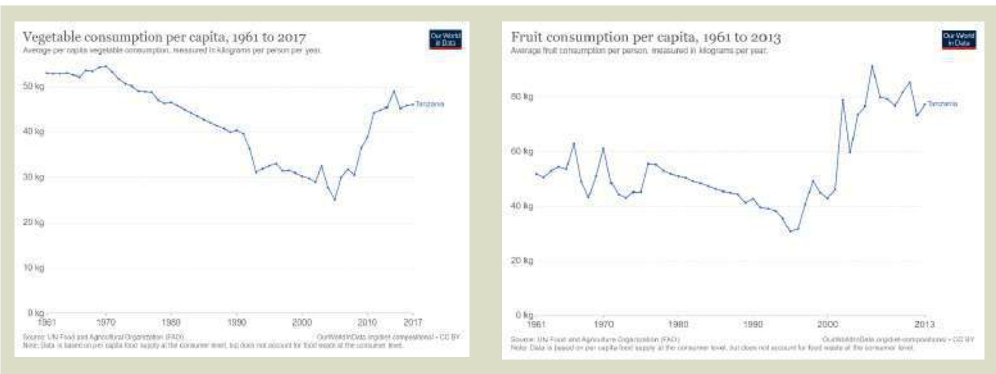

Figure 1: Per Capital Consumption of Vegetables and Fruits in Tanzania from 1961 to 2017

Source: UN Food and Agricultural Organization (FAO)

The vegetable sector in sub-Saharan Africa is severely underdeveloped and vegetable consumption is extremely low. Africa's diverse agro-climatic zones are enormously potential for smallholder farmers to produce numerous types of vegetable crops for domestic and international markets.

Vegetables are among the most important sources of cash income for smallholder farmers and for the nation as the horticulture sub-sector in the country accounts for 26.7% of Tanzania's GDP and provides employment for the majority of the population (Ekka and Mjawa, 2020; HODECT, 2010). Indigenous vegetables also provide an important source of nutrition, particularly for poor societies. Improved varieties and good management practices have been developed and extended through training programs for research and extension workers and smallholder farmers. Despite the potential need for vegetables and fruits for human health, for a long time, its production has been constrained by various abiotic and biotic factors resulting in either partial or total loss of yield depending on the type and intensity/severity of the factor(s) in question (Ekka and Mjawa, 2020; Everaarts *et al.,* 2014). Abiotic factors include low soil fertility due to unfavourable soil pH, salinity levels, soil type (texture, depth, soil water retention capacity), etc. (Efthimiadou, 2021). As for biotic factors, these include lack of beneficial soil macro and micro-organisms to improve soil fertility; plant pathogenic micro-organisms (e.g. bacteria, fungi, viruses/viroid, etc.); invertebrate pests such as insects (e.g. aphids, whiteflies, leaf miners, thrips, flies, etc.); nematodes (e.g. root knot nematodes); vertebrate pests (e.g. rodents, primates, etc.); and plant based pests (e.g. weeds) (Yasin and Rehman, 2021; Dijkxhoorn *et al*., 2013; Weinberger and Msuya, 2004). Of the few examples of biotic factors which hinder farmers from reaching the expected yield in terms of quantity and quality, microorganisms, insect pests and nematodes are leading in causing more losses than the other types of factors mentioned and are the ones to which almost all farmers concentrate their efforts on to mitigate their effects by controlling/managing them (Savary *et al*., 2019).

Control and management of crop pests and diseases by farmers globally is mainly through the use of synthetic pesticides (e.g., insecticides, acaricides, nematicides, herbicides) which have proven to cause health problems to humans and animals (both land and aquatic) causing negative impacts to the environment as a whole (toxicity to the soil macro/microorganisms, untargeted and beneficial flora and fauna such as the plant pollinators) (Boedeker *et al*., 2020; Defarge *et al*., 2018). Due to these negative impacts of synthetic pesticides, consumers of agricultural products (both edible and ornamental) have started to worry about the suitability of consuming the products which are produced (Efthimiadou, 2021). As such, the world is desperately searching for products/substances which are friendly to human/animal health and the environment that can be used as an alternative to the synthetic pesticides (Boedeker *et al*., 2020; Defarge *et al*., 2018). It consequently has (and is still going on) resulted into development of a number of products/technologies that are based on biological and/or botanical means (sometimes integrated with good cultural practices) which are effective in controlling various pests and diseases, EM1® being among them. There are various studies done on the potential of EMs applications in Tanzania, but they are quite few as the EM1 technology is relatively new since it has been commercially a recent technology (it commenced in 2018). In this study, two experiments were conducted in Tanzania to realize the potentiality of EM1 in vegetable production. One was conducted at the University of Dar es Salaam and the other at the World Vegetable Center in Arusha site.

2.0 Theoretical and Empirical Literature

2.1 Effective Microorganisms

Effective microorganisms (EMs) are a mixture of specially selected and cultured naturally occurring beneficial microorganisms that have been studied and known for significantly improving soil quality and plant growth (Higa, 1994). EMs contain selected species of microorganisms, including predominant populations of lactic acid bacteria and yeast, and smaller amounts of photosynthetic bacteria, actinomycetes and other types of organisms. All of these are claimed to be mutually compatible with one another and are able to co-exist in liquid culture. EMs improve soil structure, increase its fertility and radically improve biological diversity of essential micro-organisms, suppress soilborne pathogens, fix the nitrogen in soil and enhance nutrient uptake (Higa and Parr, 1994). EMs work by being dominant over other soil microbes. Effective microorganisms help to improve and maintain the soil chemical and physical properties. When they are applied properly, they can specifically enhance decomposition of organic matters (including organic wastes and plant residues) and the improvement of fertilizer uptake efficiency by plants, increase availability of plant nutrients and suppress soil-borne pathogens and thus improve soil aggregation.

2.2 Empirical Studies

The use of industrial fertilizers is widely recognized as a way to increase productivity. However, widespread use of industrial fertilizers may adversely affect soil health, as they destabilize soil macro and micro-biota, which can directly affect the native microbial populations present in the soil (Kalia and Gosal, 2011). The global trend in tea consumption emphasizes organic tea to be grown without the use of industrial fertilizers or chemicals. However, the use of industrial fertilizers has several challenges, including lack of financial capacity to purchase them and low yields associated with these challenges. Nature management considers the use of compost and animal manure to supplement depleting nutrient elements in the agricultural soils to improve its fertility. The use of microorganisms in the form of biofertilizers and biopesticides is considered the most effective method to manage soil fertility and control pests and diseases in modern agriculture (Bhardwaj *et al*., 2014). According to Raja (2013), there is a growing trend towards organic farming, which uses bio-based organic products instead of industrial fertilizers and pesticides.

3.0 Materials and Methods

3.1 Site set up

A total of six (6) trials with three (3) replications were undertaken to measure the impact on the use of EM technology in the growth and production of Swiss Chard and Chinese Cabbage, both at the University of Dar es Salaam and the World Vegetable Center, in Arusha Region. The field layouts were as shown in Table 1 and Figure 1 in a randomized complete block design. The plot sizes were 0.75 m x 1.5 m for both Dar es Salaam and Arusha experiments and six (6) plants were planted in each plot . The planting of the Swiss Chard was done on 20th June 2016 and the harvesting on 26th August 2016, while in Arusha site the planting was on 14th March 2021 and harvesting between late May and early June 2021 .

A mix of semi decomposed cow manure (2 buckets of 20 kg each) and field shrubs (1 bucket – about 10 kg) was mixed with a liquid solution comprising 10 litres of water, 150 mil of Molasses and 150 mil of extended EM.1 known as EMax Bioliquid. The mixture and the liquid solution were mixed to an extent that it was neither wet nor dry. The mixture was then kept in airtight non-transparent plastic bags and kept in a room temperature with no direct sunlight for a period of 14 days; this forms a product known as *Mazao* Booster. About 500 kg were made in Dar es Salaam and Arusha sites. The mixture was then applied to the field. Table 1 depicts the set-up of the Trials in Dar es Salaam site:

Table 1: Set up of the Trials – Dar es Salaam

Plot #	Trial	Plot #	Trial
1	Control	10	Mazao Booster + EMax Bio
2	EMax Bioliquid	11	Hakika
3	Mazao Booster	12	Hakika + EMax
4	Mazao Booster + EMax Bioliquid	13	Control
5	Hakika	14	EMax Bio
6	Hakika + EMax bioliquid	15	Mazao Booster
7	Control	16	Mazao Booster + EMax Bio
8	EMax Bioliquid	17	Hakika
9	Mazao Booster	18	Hakika + EMax

Explanations:

1. Control (CC) = Normal cultivation without adding any type of fertilizer.
2. EMax (EE) = This is a liquid which is made out of EM.1, it is also known as extended EM.1 with natural addictive. This addictive was named as EMax Bio Liquid. EMax Bio Liquid is made out of water, EM.1 and other natural food substances. A ratio of 10 ml of EMax Bio Liquid to 5 litres of clean tape water was applied in an irrigation can.
3. *Mazao* Booster (MB) = *Mazao* Booster is a type of a fermented material made with EM.1 extended (EMax Bio Liquid), Molasses and Water. These materials are named as Feedpro^{TM} Mazao Booster. 200 gm of MB was applied to each plot based on this trial.

4. Mazao Booster + EMax (MBEE) = A combination of FeedPro *Mazao* Booster and EMAX Bio Liquid on the ratios outlined in each individual treatment.
5. *Hakika* (HK) = This is a compost which is commercially available from the market. The details of the compost are as shown in Table 2. The application was based on 1 kg per plot.
6. *Hakika* + EMax (HKEE) = Application of Hakika bio fertilizer EMax Bio Liquid to the rate stated in individual treatments.

During the period of the trial, no additional artificial or industrial fertilizer or pesticides were applied.

For Arusha site, the experiment consisted of 15 plots, each having 2.5 m x 10 m with drip irrigation system. The plots were as indicated in Figure 1 where T1 = Inorganic fertilizer + chemical spray (conventional – farmers' practice), T2 = Cow manure + 10 kg compost + EM1 + Biopest made by the use of EM1 and T3 = Control (without any of the above – T1 and T2):

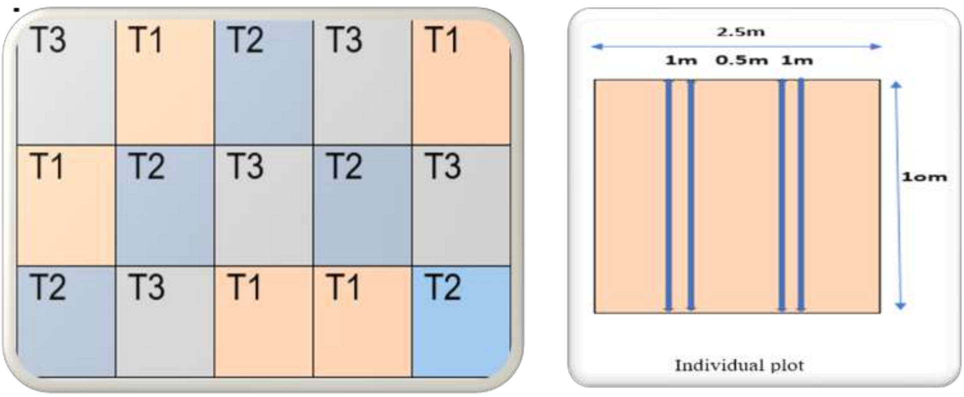

Figure 1: Experimental Setup in Arusha Site

3.1 Data Collection

A number of parameters were measured for Dar es Salaam plots as indicated in Table 2.

Table 2: Measurement of Parameters in Application of EMs Experiment on Vegetables in Dar es Salaam

Parameter	Indicators/Comments
Shoot/stem length and canopy width	Depending on the type of crop (in cm)
Number of leaves	Categorized as 1. Marketable and 2. unmarketable
Root length	Conducted as destructive sampling
Leaf width	The leaf width across the margins (in cm)
Other parameters: > Root structure, colour of the leaves	We could think about analysis of nutrient elements in the leaves – a reflection of soil fertility (the challenge may be equipment)
Number of insects and plant damage severity due to the insects	Insect count on the underside of the fully opened leaves from randomly selected plants on each plot
Disease symptom severity	Use of disease severity scales, 1 to 5 where 1 is healthy (no symptoms) and 5 is the most severe symptom
Weight > total weight of the harvested vegetables	Categorized as 1. Marketable and 2. Unmarketable (in kg)

For Arusha experiment, destructive and non-deductive measures were considered. For the deductive measures, this considered sampling 2 plants every week on each elementary plot. Additional variables measured included the following: 1) Leaf Area Index (LAI) measured by Leaf width x leaf length, 2) Fresh biomass – (whole plant) weighted both root system and aerial parts), and 3) Dry matter – the plat was dried/sterilized in an oven at 100°C and the plant was weighed. Non-destructive measurements involved 1) observational procedure: observations are done on the same labelled plants once a week on 2 individuals selected per rows, excluding the edge rows.

4.0 Results and Discussions

4.1 Dar es Salaam-Based Experiments

Measurement was done on four parameters of Swiss Chard, after it has been harvested in each plot. Three randomly selected plants were subject to measurements which included number of leaves as well as height of the roots and shoots. Weight in kg was also measured in each of the harvested plot. The descriptive analysis of such measurement is as shown in Table 3 and also in Figure 2:

Table 3: Descriptive Analysis of Number of Leaves, Height of Roots and Shoots for the Average Plots

Description	Number	Minimum	Maximum	Mean	Std. Deviation
CC_Roots	9	15.00	32.00	20.8	5.2
EE_Roots	9	13.00	34.00	21.1	6.1
MB_Roots	9	17.00	35.00	23.9	5.2
MBEE_Roots	9	11.00	27.00	19.1	5.2
HK_Roots	9	10.00	27.00	19.3	5.8
HKEE_Roots	9	13.00	37.00	23.9	7.7
CC_LWidth	9	13.00	19.00	16.2	1.9
EE_LWidth	9	17.00	22.00	18.7	1.9
MB_LWidth	9	12.00	26.00	19.8	4.2
MBEE_LWidth	9	16.00	24.00	18.0	2.7
HK_LWidth	9	13.00	22.00	18.3	3.1
HKEE_LWidth	9	17.00	25.00	19.9	2.3
CC_Lheight	9	35.00	51.00	44.2	5.1
EE_Lheight	9	43.00	60.00	52.1	5.8
MB_Lheight	9	45.00	67.00	57.0	7.0
MBEE_Lheight	9	43.00	60.00	51.1	5.9
HK_Lheight	9	21.00	62.00	48.3	12.0
HKEE_Lheight	9	48.00	62.00	54.1	4.0
Valid N (listwise)	9				

The maximum roots size was on the application of the *Hakika* and EMax Bio Liquid (HKEE) with 37 cm and the maximum average of 23.9 ± 7.7 cm, followed by the application of *Mazao* Booster (MB) 35 cm with the same average as HKEE, followed by application of EMax Bio Liquid (EE) with an average of 21.1 ± 6.1 cm. The maximum leave width was observed in the application of MB 26 cm, average 19.8 ± 4.2 cm. Length of the leaves was recorded the highest in the application of MB 67 cm with average height of 57 ± 7 cm followed by HKEE and EE with both with 62 cm. On average, second place was for HKEE application with 54.1 ± 4 cm. Figure 2 shows an average number of leaves and weight of the Swiss Chard:

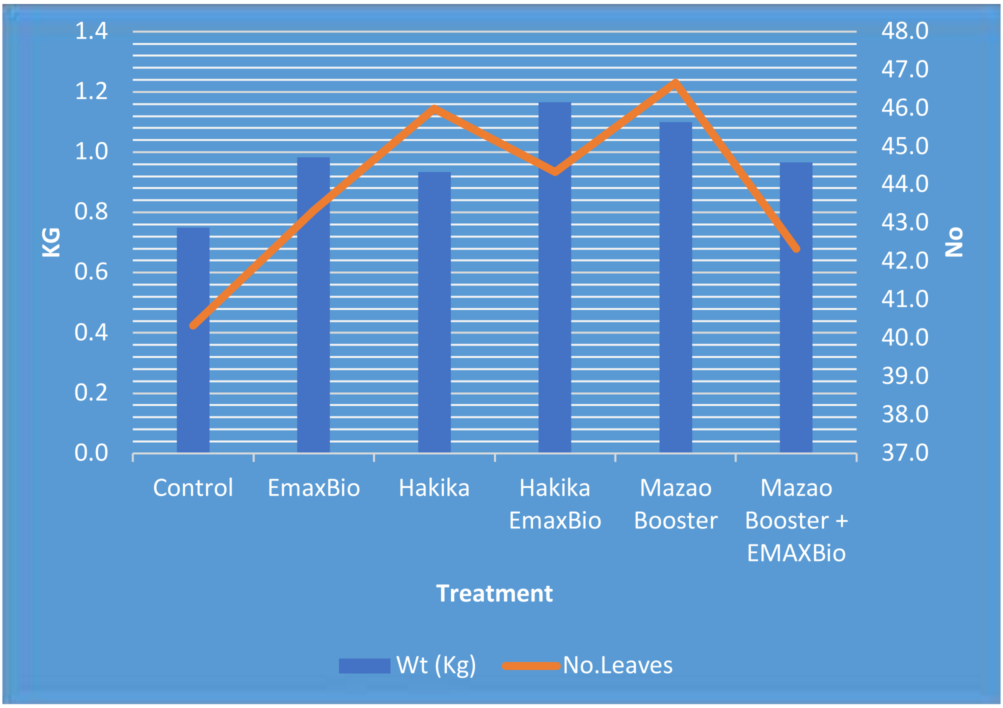

Figure 2: Average Number of Leaves and Weight of the Swiss Chard

Figure 2 and Table 3 present a descriptive analysis of the number of leaves and the number of leaves in each plot size in average based on the six replica plots. The analysis indicated that the maximum average number of leaves was based the application of *Mazao* Booster (MB) with 46.7 ± 4 leaves followed by application of *Hakika* (HK) with average leaves of 46 ± 9.5. Table 4 summarizes the weight and number of leaves of Swiss Chard in various treatments:

Table 4: Summary of the Weight and Number of Leaves of Swiss Chard in Various Treatments

Treatment	Wt. (Kg)	Std. Dev.	Difference	No. Leaves	Std. Dev.	Difference
Control	0.75	0.1	0.0%	40.3	4.2	
EMax Bio	0.98	0.3	31.1%	43.3	6.5	7.4%
Hakika	0.93	0.3	24.4%	46.0	9.5	14.0%
Hakika EMax Bio	1.17	0.1	55.6%	44.3	8.3	9.9%
Mazao Booster	1.10	0.1	46.7%	46.7	4.0	15.7%
Mazao Booster + EMAX Bio	0.97	0.4	28.9%	42.3	15.0	5.0%

Maximum average weight was observed in the application of *Hakika* and EMax Bio Liquid (HKEE) with mean of 1.17 ± 0.1 kg. This was followed by the application of Feedpro *Mazao* Booster (MB) with 1.10 ± 0.1 kg and application of EMax Bio Liquid (EE) 0.98 ± 0.3 as presented in Figure 1. The growth of the plant by 35.8% and by 26% on the application of EM on the *Hakika* product is also noted.

Further observations on the number of plots have indicated the following as summarized in Table 5:

Table 5: On Field Observation of Various Treatment on the Application of EM in Swiss Chard Plots

Treatment No.	Code	Leaves
Control	CC	Short and few leaves, yellowish in colour
EMax Bio	EE	Long leaves and greenish Leaves
Mazao Booster	MB	Long and very green leaves, many leaves
Mazao Booster + EMax Bio	MBEE	Many leaves, long and green in colour
Positive Control - Hakika	HK	Medium height leaves and green in colour
Positive Control + EMax	HKEE	Medium and healthy leaves and green in colour

From the descriptive statistics, the following can be observed:

1. Roots: Strongest positive effect on roots length is seen with *Mazao* Booster and *Hakika*+ EMax Bio treatments when compared to control. This is saying, *Mazao* Booster and EMax Bio used with organic fertilizer promote root development in Swiss Chard, that may help plants to get more water and nutrients for growth.
2. Leaf width: All treatments gave wider leaves than control plants, with more increase on the width of the leaves being observed on Feedpro *Mazao* Booster, EMax Bio, *Hakika* + EMax Bio and *Mazao* Booster + EMax Bio Treatments.
3. Height: All treatments values are higher than control, especially with FeedPro *Mazao* booster, EMax Bio, *Hakika* + EMax Bio and Mazao Booster + EMax Bio Treatments.

Further observations were as follows:

1. There are significant changes in the application of EM.1 technology in form of secondary products in the growth of the plant.

2. On average, the application of EMs seems to have more impact when applied with organic matter for this case Hakika Bio Fertilizer as noted in Table 3.
3. Based on the field observations, the application of EMs especially on the EE seems to create a biological control against pests affecting the leaves of the plants.

The statistical results were based on the mean comparison analysis of three observed items, namely number of leaves, size of roots and shoots in centimetres. For each case, a paired sample comparison was based on the control (CC). The sample for each was 3 observations x 3 treatments giving 9 observations in each of the 15 pairwise considerations. Table 6 summarizes the paired samples correlations:

Table 6: Paired Samples Correlations

	Description	N	Correlation	Sig.
Pair 1	CC_Roots & EE_Roots	9	.036	.926
Pair 2	CC_Roots & MB_Roots	9	-.253	.511
Pair 3	CC_Roots & MBEE_Roots	9	-.146	.707
Pair 4	CC_Roots & HK_Roots	9	-.385	.307
Pair 5	CC_Roots & HKEE_Roots	9	-.368	.330
Pair 6	CC_LWidth & EE_LWidth	9	.333	.381
Pair 7	CC_LWidth & MB_LWidth	9	-.686	.041
Pair 8	CC_LWidth & MBEE_LWidth	9	-.707	.033
Pair 9	CC_LWidth & HK_LWidth	9	.242	.531
Pair 10	CC_LWidth & HKEE_LWidth	9	.302	.429
Pair 11	CC_Lheight & EE_Lheight	9	-.608	.083
Pair 12	CC_Lheight & MB_Lheight	9	-.056	.887
Pair 13	CC_Lheight & MBEE_Lheight	9	-.254	.509
Pair 14	CC_Lheight & HK_Lheight	9	-.068	.861
Pair 15	CC_Lheight & HKEE_Lheight	9	.240	.534

It is observed that there is a negative correlation on the leaves with positives in MBEE and HKEE. The growth of the roots seems to be negative as compared to the control which suggests a good growth of the EMs applied plots. The shoots as for the leaves observed a positive correlation. There is a significant relationship based on the application of EMs as a liquid, combination of *Hakika* and EMs and on *Hakika* vs. control as indicated in Table 7, based on 90% Confidence Interval. In testing the statistical results, we used mean comparison tests. Table 8 shows pairwise Mean Difference on EMs Application:

Table 7: Pairwise Mean Difference on EMs Application

Description		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	90% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	CC_Roots - EE_Roots	-0.33	7.86	2.62	-5.20	4.54	-0.13	8	.902
Pair 2	CC_Roots - MB_Roots	-3.11	8.27	2.76	-8.24	2.01	-1.13	8	.292
Pair 3	CC_Roots - MBEE_Roots	1.67	7.89	2.63	-3.22	6.56	0.63	8	.544
Pair 4	CC_Roots - HK_Roots	1.44	9.18	3.06	-4.25	7.13	0.47	8	.650
Pair 5	CC_Roots - HKEE_Roots	-3.11	10.76	3.59	-9.78	3.56	-0.87	8	.411
Pair 6	CC_LWidth - EE_LWidth	-2.50	2.18	0.73	-3.85	-1.15	-3.44	8	.009
Pair 7	CC_LWidth - MB_LWidth	-3.61	5.66	1.89	-7.12	-0.11	-1.92	8	.092
Pair 8	CC_LWidth - MBEE_LWidth	-1.83	4.26	1.42	-4.47	0.81	-1.29	8	.232
Pair 9	CC_LWidth - HK_LWidth	-2.17	3.24	1.08	-4.18	-0.16	-2.01	8	.080
Pair 10	CC_LWidth - HKEE_LWidth	-3.72	2.51	0.84	-5.28	-2.16	-4.44	8	.002
Pair 11	CC_Lheight - EE_Lheight	-7.89	9.79	3.26	-13.96	-1.82	-2.42	8	.042
Pair 12	CC_Lheight - MB_Lheight	-12.78	8.93	2.98	-18.31	-7.24	-4.29	8	.003
Pair 13	CC_Lheight - MBEE_Lheight	-6.89	8.72	2.91	-12.30	-1.48	-2.37	8	.045
Pair 14	CC_Lheight - HK_Lheight	-4.11	13.40	4.47	-12.42	4.20	-0.92	8	.384
Pair 15	CC_Lheight - HKEE_Lheight	-9.89	5.71	1.90	-13.43	-6.35	-5.20	8	.001

Based on the 90% confidence interval, it can be observed that there is a significant effect on the application of EMs to leaves width and height. Based on the height – application of *Hakika* - a well industrial prepared compost seems to be not significant to the control. Also, application of MBEE was not significant for the width of the leaves. No significant differences were recorded on the roots. Further details are as observed in Table 7.

4.2 Arusha Based Experiments

Based on the data analysis, it was clearly found that an application of EM1 significantly increased plant survival and yield as compared to the farmer's practices and the control experiments where EM1 treatment was applied (Figure 1). Similar results were obtained for the number of leaves, fresh and dry weight of the plants from the plots where EM1 was applied by having more biomass than those which did not receive the treatment (farmer's practices and control experiments) (Figures 2 and 3). However, when comparing the performance of the crops between the farmer's practices and the control experiment, there are no significant differences among the measured parameters (plant survival, yield – biomass and number of leaves) (Figures 1, 2 and 3).

This implies that the presence of EM1 in the soil supplied effective microorganisms it contains to the soil and hence improved the fertility of the soil as compared to the other two treatments (farmer's practices and the control experiments) where the soil was not treated with EM1, thus having fewer biological activities to assist the soil to release and make the nutrient elements available to the plants (Higa, 1994). Apart from biological improvement of the soil by EM1, soil physical fertility (porosity, water holding capacity, etc.) which is necessary for plant growth and productivity also got improved, resulting into high biomass production by the EM1-treated plants (Higa, 1994; Higa and Parr, 1994). With the results obtained in this study, farmers could increase Swiss Chard and Chinese Cabbage production to a greater extent than to keep on applying their commonly used production practises.

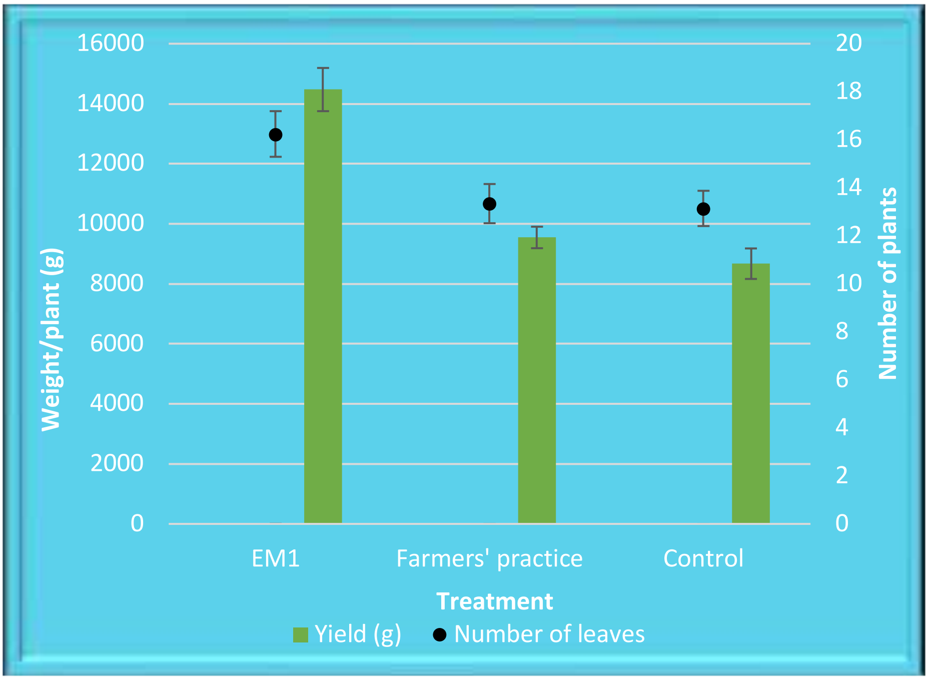

Figure 3: Combined Weight Parameters (Fresh/Dry Leaf and Root Weight and Yield) and Number of Leaves

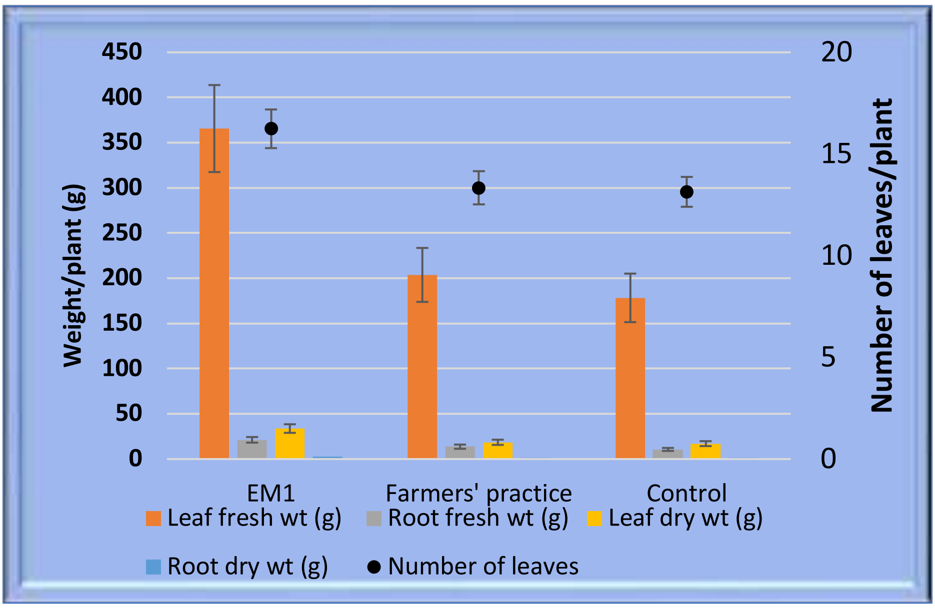

Figure 4: Parameters Leaf/Root Fresh and Dry Weight and Number of leaves

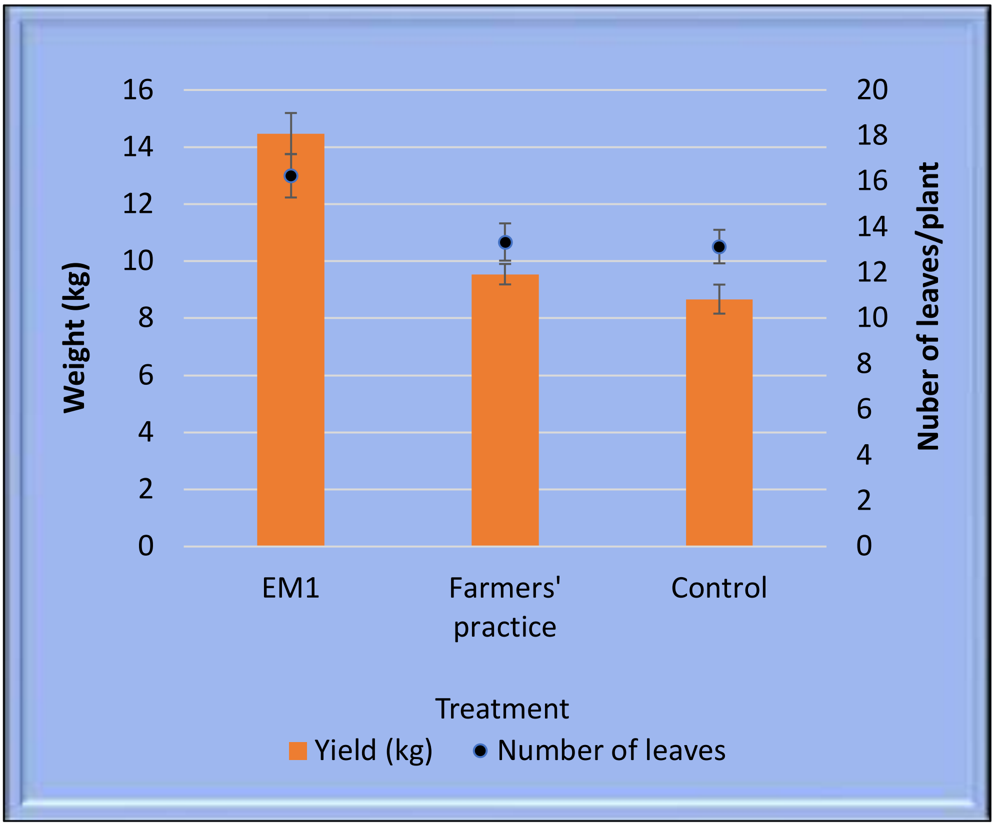

Figure 4: Parameters Yield and Number of Leaves

5.0 Conclusion

The results of the trials conclude that there is a significant increase in production and productivity of Swiss Chard and Chinese Cabbage by applying EMs along with irrigation as well as application of the same technology as a bio-addictive to the soil along with manure/compost (organic matter). There is both an increase in the weight by 35% by applying EMs as compared to none (control experiment). Also, when applied on the organic matter, the increase is over 40%. Elsewhere around the world, similar studies have recorded similar results.

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Integration of the System of Rice Intensification in Smallholder Farming Systems in Tanzania: Are Farmers Ready? A Case of Lekitatu Irrigation Scheme, Northern Tanzania

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Abstract

This study was conducted to assess adoption and integration of the System of Rice Integration (SRI) principles in the farming systems of smallholder farmers in Northern Tanzania. An understanding of the adoption and integration of SRI in smallholder farmers' systems will assist in short and long-term planning and allocation of water resources. A survey was conducted to explore farmers' appropriation of SRI principles. Data were collected using semi-structured questionnaires supplemented by reconnaissance survey, observation of agronomic practices, interviews with key informants and focus group discussions. Out of six SRI principles, carefully nursery management outperformed other principles in which 100% were able to manage the nurseries well. On other principles, there were great variations among farmers; in transplanting young seedlings (< 15 days of age), adoption was 13% (below 15 days), 31% (16- 20 days), 47% (21-25 days) and 9% use > 25 days. Regarding the number and space of transplanting, 14% used one seedling at 25 x 25 cm, 33% (one seedling, 20 x 20 cm), 31% (two seedlings, 20x20 cm) and 14% (two seedlings, 15x15cm). It was found that 79% of farmers used intermittent irrigation (between 4-7 days) especially at panicle initiation stage. Weed management was through herbicides (80%) applied within three days after transplanting followed by first-hand weeding one month after transplanting and the second weeding one month later during the reproductive stage. Farmers preferred chemical fertilizers as the main supply of nutrients to plants (81%

of respondents) while 18% (mixture of chemical fertilizers with manure) and only 1% used manure. Adoption of SRI principles is hindered by various socio-economic and institutional constraints. Replacing the traditional rice-farming system with SRI may not be a one-time event. It requires investments of fund and time to prepare environment for proper integration of SRI. Regardless of the challenges in integrating SRI into local farming system, the results obtained by farmers were worth the trouble.

Keywords: System of rice intensification, adoption, smallholder farming systems, irrigation.

1.0 Introduction

Adoption of agricultural innovation is considered as an innovation-decision process where farmers are expected to go through stages of adoption. The process is stated by involving four stages, namely: (a) awareness stage where an individual becomes aware of the system, (b) acquiring knowledge about an innovation stage, (c) forming positive or negative attitude towards innovation, and (d) finally, deciding whether or not to adopt the technology (Pandey, 2019). For any new technology, the expectations are that farmers will abandon their current practices and adopt the new technology. However, it has been found that in the real environment, some of the components of the technique may not work as in controlled condition where most of the experiments are conducted. For the case of SRI, research has shown that adoption of all six recommended principles of SRI is rarely found (Xiaoyun *et al.,* 2005; McDonald *et al.,* 2006; Moser & Barrett, 2006). There has been a variation on the extent of adoption between farmers and across regions. The rate of adoption depends on farmers' characteristics, understanding of the system, farm size and proof evidence of benefits of SRI (Berkhout *et al.,* 2015). Variations on the adoption level may be due to various socioeconomic and institutional factors. Also, SRI adoption can be considered as a multi-level decision which is an individual decision and a collective or a society decision and hence, its benefit can be significant if only adopted by a large proportion of farmers (Karki, 2011).

Adoption of SRI has been criticized by researchers due to a lot of on-farm modifications by farmers. Some of questions asked mostly in relation to SRI are: Is SRI a standardized package or a customizable package in which farmers are free to choose and modify certain principles? How far can SRI principles be modified? Should farmers use improved or conventional seed variety? Should farmers use chemicals fertilizers or manure? The SRI critics believe that SRI knowledge should be transferred and adopted as a standardized package. Any deviation from the recommended principles is regarded as not SRI or simply “dis-adoption”. The reason behind is the belief that there exist synergies between SRI principles such that the benefits of the whole system are greater than those of individual principles (Uphoff, 2002). To SRI critics, farmers’ cultivation system is regarded as inefficient and should be replaced by the SRI package without any alteration.

On the other hand, SRI supporters acknowledge that adopting all SRI principles by every farmer in every agro-ecological may not be achieved in some areas due to the complexity and dynamics of smallholder systems both spatially and temporal (Thiyagarajan & Gujja, 2012). To SRI promoters, SRI is an evolving technology which requires site-specific experimentation and modification to fit farmers’ needs. The emphasis is on farmers to use whatever available in their current environment to improve both land and water productivity.

By revolving our discussions around adoption, we limit ourselves to understand what is happening within the smallholder farmers’ line. Classifying farmers as adopters and non-adopters leaves out the most important part of the subject which is to explore the changes in practice brought by SRI and the impact of SRI in smallholder farmers’ life. As in real life, it is difficult to differentiate adopters from non-adopters (Glover, 2011). It is, therefore, important to understand the mechanism beyond these variations and explore to what extent can farmers integrate SRI in their farming systems? This study aimed at evaluating the adaptation and integration of SRI under farmer-led irrigation schemes and management.

2.0 Materials and Methods

Study Area

This study was conducted at Lekitatu Irrigation Scheme, located in Lekitatu Village, Meru District, Arusha Region in Tanzania. Characteristics of the area are as shown in Table 1. The SRI was first introduced in this scheme in 2014 by JICA through KATC and Japan Policy and Human Resources Development (PHRD). Like in many parts of the world, at the beginning very few farmers gave it a try. At first, farmers experimented it on a small portion of their land or in the selected community experimental plots normally known as farmer field schools to avoid the risk of failure (Kabir, 2006). After validating the system, these farmers became the ambassadors of SRI. With the spread of knowledge and evidence of yield increase from early adopters, more farmers gave it a try and cultivated some of their portions with SRI and conventional flooding (CF) to validate the method. After impressive results of SRI, farmers have now trusted the SRI and are currently applying SRI principles in their plots. In this scheme as in many other smallholder irrigation schemes, water distribution is guided by informal management and water allocation depends on mutual agreement among irrigators.

Table 1: Climatic Characteristics of the Study Area

Parameter	Range
Altitude (amsl)	1110
Annual rainfall (mm/year)	590 - 1 460
Temperature (°C)	11.7 - 32.4
Potential evapotranspiration (mm/month)	151 -218
Wind speed (m/s)	2.4
Relative humidity (%)	56
Soils type	Silty loam to loamy sand

2.1 Data Collection

Data were collected using semi-structured questionnaires with the help of pilot-testing questionnaires. In addition, a reconnaissance survey was conducted to get an overview of the scheme in terms of infrastructure layout, agronomic practices and general water management. It intended, also, to uncover the determination of respondents. Nevertheless, observation of agronomic practices of the farmers and interviews with key informants, together with focus group discussions were conducted.

2.2 Questionnaires Administration

The survey involved a total of 115 farmers. The sample size comprised 115 farmers whose number was calculated using the formula by Gupta (2002) (Equation 1). Questionnaires were carefully designed to explore farmers' appropriation of SRI practices. The researcher made sure that the questionnaires were correctly filled by clarifying any ambiguous questions (Rundblad, 2006). A list of all farmers was obtained from Lekitatu extension office; each farmer was assigned a unique code and excel was used to generate a random list (Omair, 2014).

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

Equation

Where: n = sample size, N = population size (total number of farmers),

e = the level of precision, (0.05)

2.3 Data Cleaning and Processing

Data cleaning was done after transferring data into the excel sheet. The overall samples of the survey results comprised 115 smallholder farmers. The samples were processed according to the following criteria: For the sample to be included, it must contain data on nursery management, transplanting age, spacing and amount of seeds/hill, weed management, irrigation management and nutrient management; and comparisons for data from different correspondents in the same data cluster were made (Adèr, 2008). Where data seemed to be inconsistent or invalid, the arrangement was made to follow up on these farmers to get more valid data (Cochran, 1977). Where it was not possible to correct the data, the sample was removed from the analysis. After data cleaning, three samples were removed and remained with 112 samples.

3.0 Results and Discussion

3.1 Demographic Information

The ratio of males to females between respondents was almost equal. Large number of respondents fell under the middle aged group (41-50 years). Education level of most farmers was primary school (82%) with very little with college education (6%) (Table 2). Most of the respondents had an experience of 6 to 10 years (34%). While the average plot size was 0.75 acre and 80% and the irrigation method being alternate wetting and drying (AWD) (80%).

Table 2: Demographic information of respondents (n=112)

Variable	Characteristics	Frequency	Per cent	Variable	Characteristics	Frequency	Per cent
Gender	Male	55	49	**Cultivation**	AWD	89	80
	Female	57	51	**method**	CF	23	21
Age (Years)	20-30	6	5				
	31-40	23	21	**Farming**	< 5	28	25
	41-50	44	39	**experience**	6-10	38	34
	51-60	20	18	**(Years)**	11-20	28	25
	Age >60	39	35		> 20	18	16
Education level	Primary	92	82	**Farm size**	< 0.5	4	4
	Secondary	14	13	**(acres)**	0.5-1.0	69	62
	Diploma	2	2		1.1-1.5	27	24
	Degree	1	1		> 1.5	12	11
	Postgraduate	3	3				

3.2 Nursery Management

All farmers interviewed (112/112) were able to carefully manage their nurseries. Farmers did set aside a portion of their farm to be used for nursery establishment only. This portion allowed for easy drainage and seeds were spread widely to allow for air and sunshine. It is believed that this principle was successful due to the fact that more than 80% of farmers use improved varieties (which are relatively expensive); therefore, careful nursery management reduces the amount of seeds required.

Reduction in the amount of seeds required under SRI (from 60 Kg/ha under CF to 8 Kg/ha under SRI) was also reported in Bangladesh (Latif *et al.,* 2005). In addition, careful nursery management was accompanied by other benefits such as increased rate of germination, reduction of diseases and pests at an early developmental stage, healthier and disease resistant plans and also easy uprooting and separation of young plants during transplanting (Uphoff, 2007).

3.3 Transplanting Age of Seedling

Only 13% (15/112) were able to follow this practice. Majority of farmers (47%) preferred 21-25 days' seedlings, followed by 16- 20 days (31%), and 9% used > 25 days (Fig. 1). The reasons behind these modifications being: one, difficulties in handling young seedlings of less than 15 days since the seedlings are so small and they need special attention during uprooting to prevent root damage; and two, unreliable irrigation water supply forces farmers to use flooding before transplanting to ensure moist condition for the plants, therefore, young plants of less than 15 days are easily stacked in the muddy. This was also experienced by Uphoff (2011), where it was advised to consider physiological age (i.e. transplanting at 2-3 leaf stage) instead of calendar age when dealing with uncertain environmental conditions. Three, is lack of enough man-power within the scheme, whereby some farmers are made to wait longer for their fields to be ploughed and transplanted. As a remedy, farmers are advised to use the non-tillage technique which preserves the soil structure and saves time and cost.

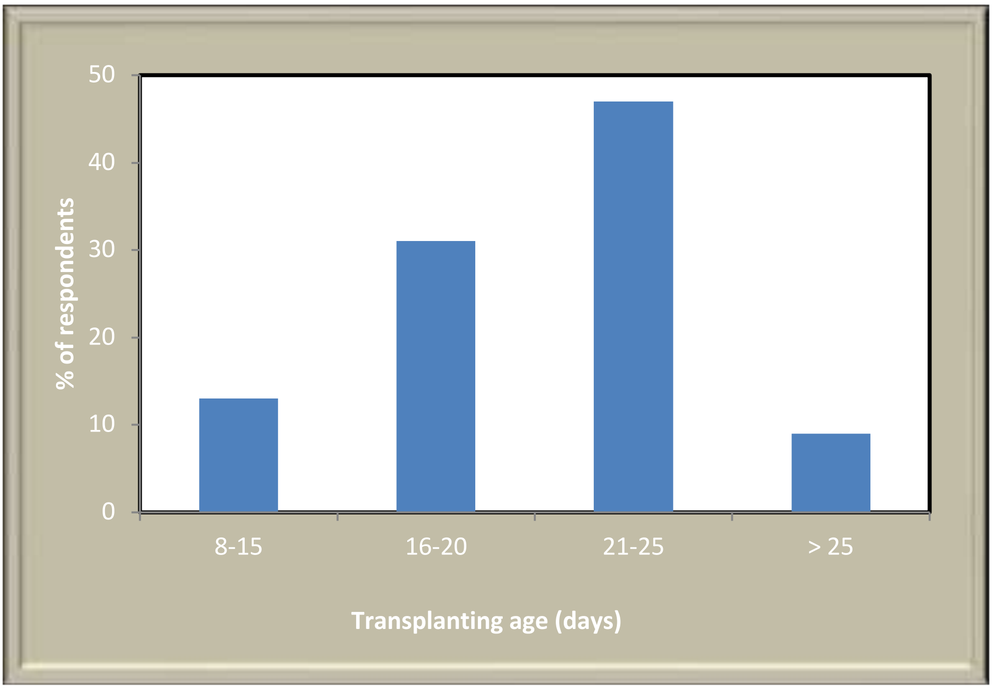

Figure 1: Farmer adaptation of transplanting age based on their local condition (n=112)

Spacing and Amount of Seedling

It was found that only 14% (16/112) of farmers were able to follow this principle. The farmers' practice was divided as 33% used 20 x 20 cm spacing with one seedling, 31% used 20 x 20 cm spacing with two seedlings, and 14% preferred to use two seedlings at 15 x 15 cm (Fig. 2). Farmers' preference to use a closer spacing of 20 x 20 cm is a mitigation measure against pests and diseases as observed during the reconnaissance survey. Transplanting two plants at closer spacing was found to help maintain sufficient plant population (Das *et al.,* 2018). Another reason is incapacity of farm laborers' to carefully separate attached plants during transplanting. As explained by Latif *et al* (2005) and Lee & Kobayashi (2018) singly transplanting is labor intensive especially at early years of adoption where farmers are still learning the process, but may reduce with time as farmers master the system.

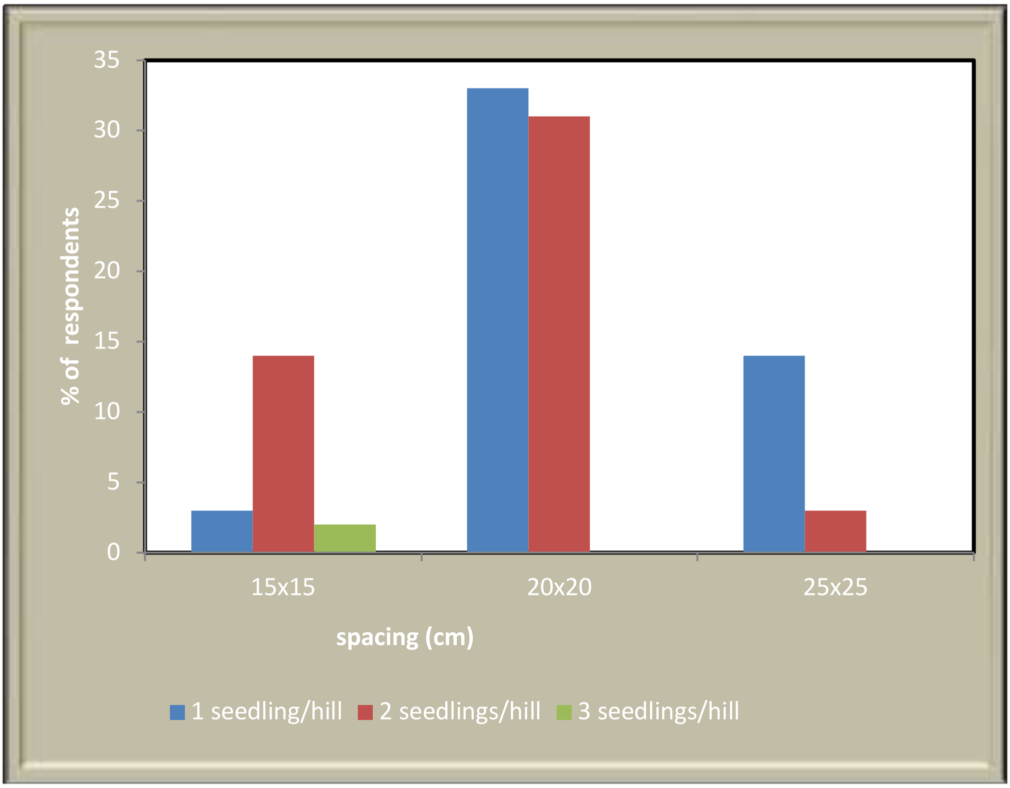

Figure 2: Number of seedlings vs. spacing as used by farmers in the study area (n=112)

3.4 Irrigation Water Management

In this study, 79% reported using intermittent irrigation, especially at the panicle initiation stage (Fig. 3). Farmers cannot use hair-like cracks as an indicator for irrigation because of lack of enough water and poor management of the available water. Water is allocated to farmers only once per week and farmers are supposed to irrigate regardless of whether there is development of hair-like cracks in the soil or not for there is little or no possibility to have water before the next schedule.

Lack of adequate water supply and non-flexibility in water allocation has been reported as one of the major constraints for adopting SRI in Cambodia (Lee & Kobayashi, 2018) and at Mwea Irrigation Scheme in Kenya (Ndiiri *et al.,* 2013).

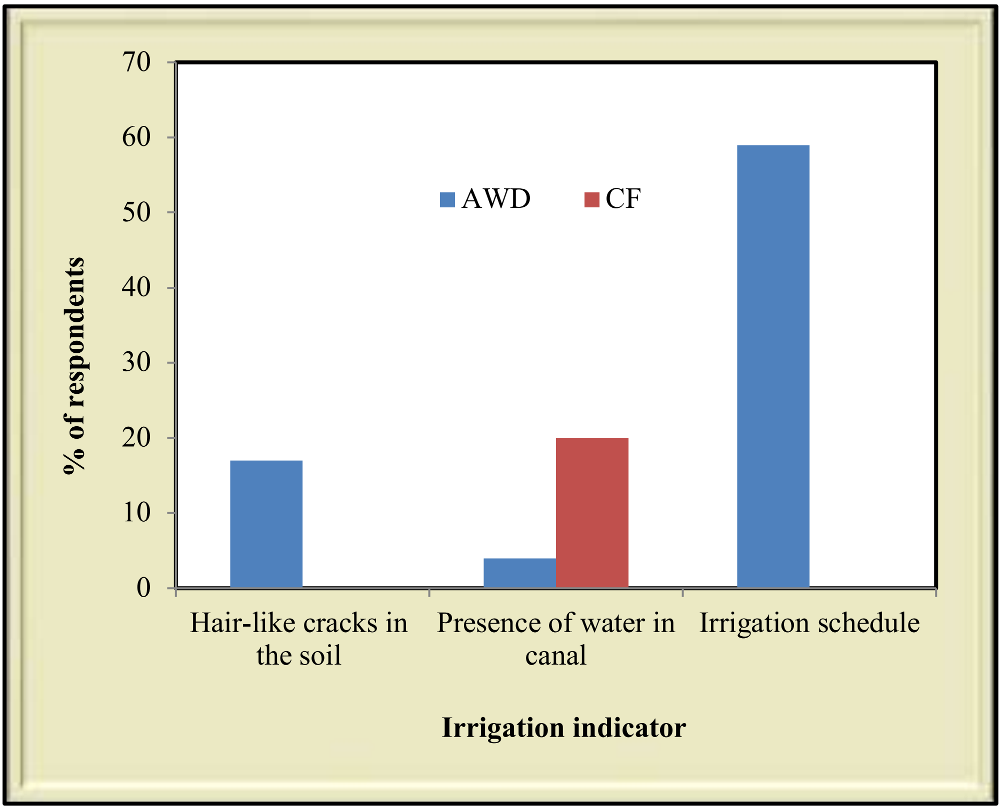

Figure 3: Irrigation indicators as used by farmers in the study area (n=112)

3.5 Weed Management

In this area, farmers neither practised early weeding (10-15 days) after transplanting nor use rotary weeder due to difficulties and the cost of obtaining and using manual labor and unavailability of rotary weeders. The commonly used method for weed management is herbicides applied within first three days after transplanting to prevent weed germination followed by two manual weeding 80% (Fig. 4). First-hand weeding starting one month after transplanting and the second weeding is done one month later during the reproductive stage. The use of herbicides is cheaper, since it requires less labor and reduces the number of weeding from four to five times into two. According to Latif *et al* (2005) the use of herbicides can be justified when it reduces the labor cost of weeding and also improves the yields. In addition, farmers may opt to manufacture their mechanical weeders that will suit their specific needs as advised by Ndiiri *et al.* (2013).

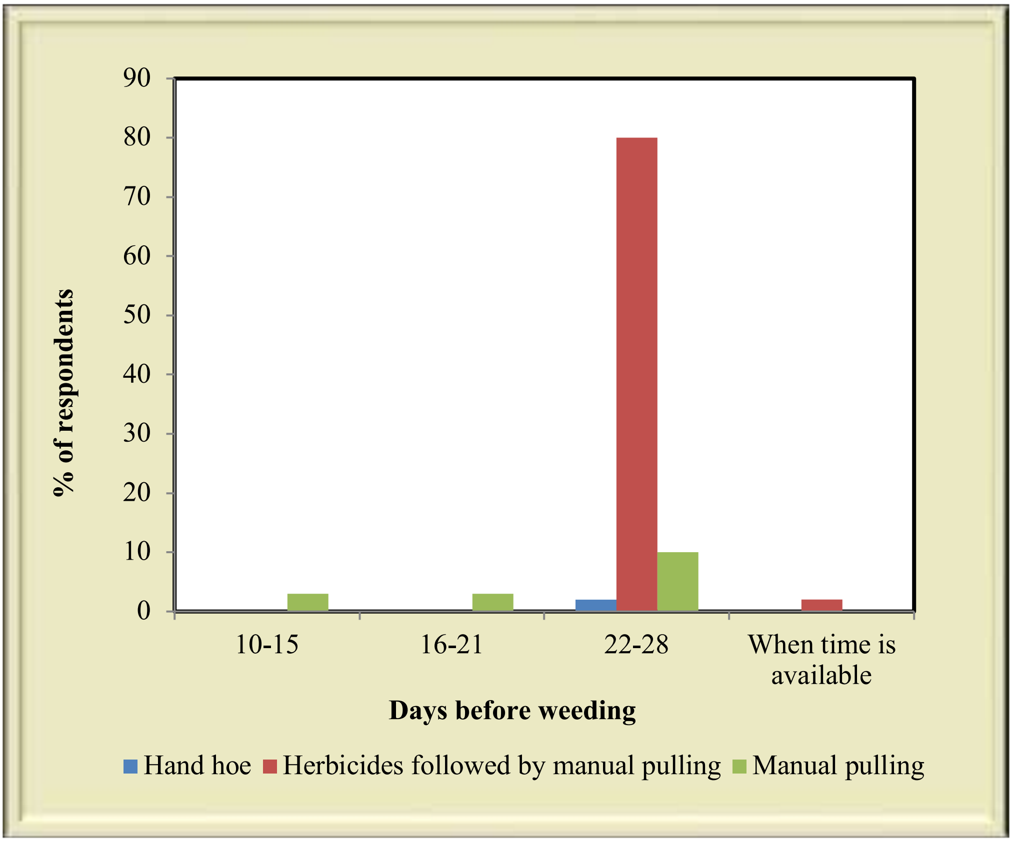

Figure 4: Time taken before first weeding (n=112)

3.6 Nutrients Management

Due to lack of cattle keeping in the study area, most farmers use chemical fertilizers as the main supply of nutrients to plants (81% of respondents), 18% use a mixture of chemical fertilizers with manure, and only 1% use manure only (Fig. 5). Due to the importance of fertilizers in improving crop production, researchers have provided room for the use of either manure, a combination of manure and chemical fertilizers or chemical fertilizer alone (whatever works for farmers) (Uphoff, 2007; Sato & Uphoff, 2007), (Uphoff, 2011). In a study conducted in Bangladesh, Latif *et al.* (2005) report higher yield when chemical fertilizers are used alone or when supplemented by organic manure, but not as a substitute.

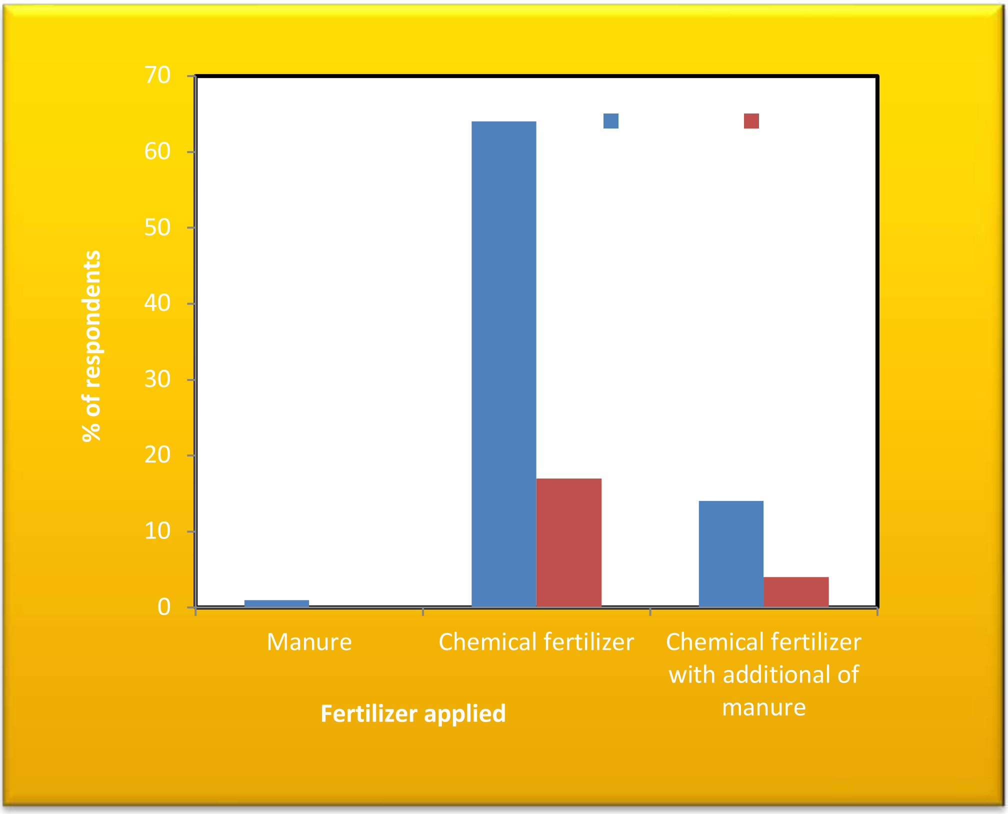

Figure 5: Nutrients Management among Farmers (n=112)

3.7 Water Reliability and Allocation Flexibility

For effective implementation of SRI, a reliable source of water is required to avoid crop stress since the seedlings are transplanted at a very young age (8-15 days) and permanent flooding is avoided in the vegetative stage. In addition, the fields need to be irrigated immediately when hair-like cracks appear in the soil to prevent stress to plants which, if critical, can damage the final yield. In this scheme, water is reliable but no flexibility in allocation (Fig. 6). Although irrigation schedule was strictly followed during high demand (November for the dry season and February for wet season), farmers in the down-stream area were still struggling to irrigate their fields due to high water losses through seepage and percolation as a result of long irrigation canals of up to 5 km. This lack of assurance on availability of water has created fear for farmers to apply intermittent irrigation as lack of water in the vegetative and reproductive stage can damage the crops and hence affect the final yield. Under this scenario, farmers are advised to make proper arrangement to make sure each farmer gets water when needed (Wallace, 2000; Sokile & van Koppen, 2004).

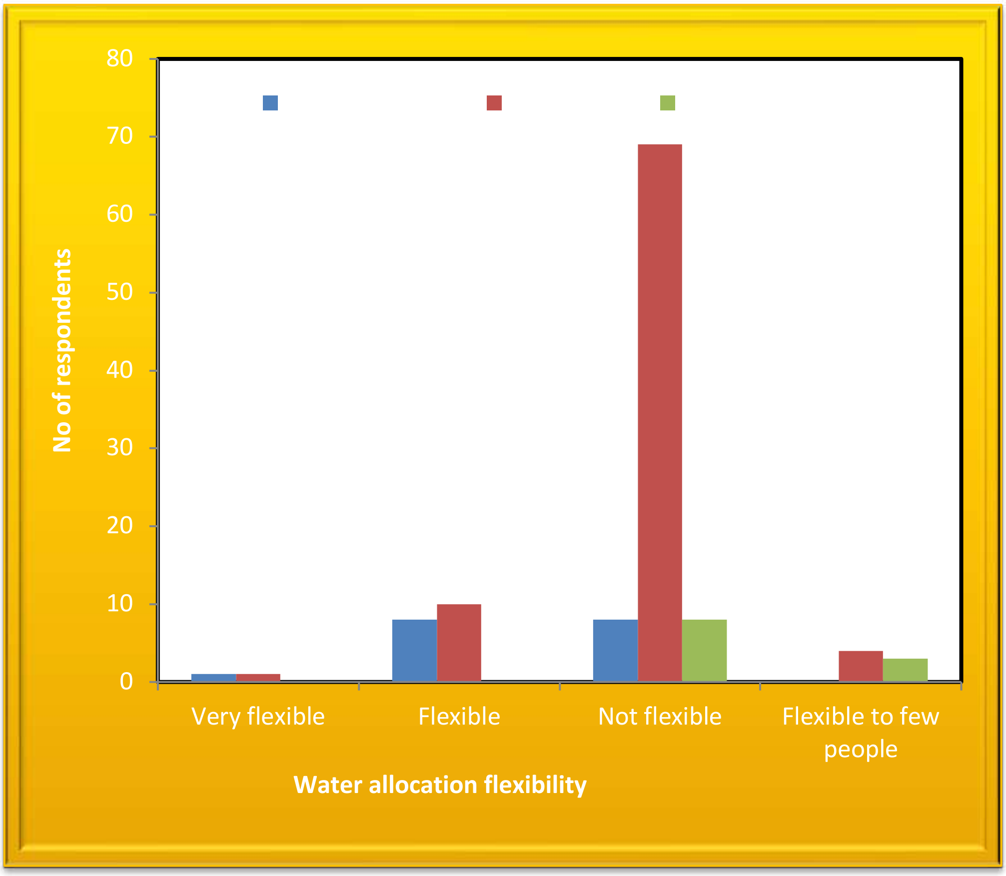

Figure 6: Farmers' opinion on water reliability vs. water allocation flexibility (n=112)

4.0 Conclusion

It is concluded that SRI was integrated in the local rice farming systems through trial and error experiments. SRI needs a reliable source of water, proper distribution and water control facilities and proper land preparation. Investments under SRI are large in terms of knowledge and labour at least in the initial years of adoption. It was also found that the decisions to adopt SRI are beyond individual's capacity especially since most of the resources such as water are commonly owned by the society. Lastly, it was discovered that replacing traditional rice farming system with SRI may not be a one-time event.

It will require investing money and time to prepare the environment for proper implementation of SRI.

5.0 Recommendations

This study recommends the following:

i. More studies should be conducted to gather more information on the site-specific adaptation of SRI principles to continue educating farmers and extension officers on SRI principles;

ii. In order for SRI to be successful, there should be strong co-operation and mutual agreement among farmers on how collective resources such as water will be shared.

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Potential for Application of Effective Micro-Organisms for Inclusive Agriculture in Tea Production – A Cost Benefit Analysis for Kagera Tea Company

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Abstract

Tea is among the cash crops growth in Tanzania. Kagera Tea Company Limited has championed to uptake Effective Microorganisms (EM) for inclusive and sustainable tea production. With installed capacity of 30 metric tonnes per year, and low level of production of green tea, the use of EM seems to contribute to the availability of green tea leaves and increase return on investment. Trial application of EM has yielded good returns both lab results and cost-benefit analysis measure. A mix of composite animal manure with EM proved to increase production and save costs of production substantially. Application of EM fermented manure for 100kg per acre and bi-weekly spray of EM at a ratio of 1:500 for extended EM and fresh tap water was applied. The use of EM to tea has proved to have contributed to 70% increase of green tea leaves for 3 acres. Further analysis indicated that Leaf size was relatively broad 100mm × 45mm, leaf visibility was deep green. Analysis of the made tea was having a blackish colour and the liquor was quite brisk, bright colour and of good task. EM has potentially reduced the cost of production; it is more sustainable in the future – and potentially be integrated to the tea growers. A cost benefit analysis indicates there is more return for tea growers on the application of the technology which could potentially reduce the level of poverty in the region.

Key words: Tea, Effective Microorganisms, Sustainable Agriculture, Investment, Cost-benefit analysis

1 Introduction

Cash crops agriculture has been practised in many countries and Tanzania is not an exception. Agriculture accounts for a large share of employment, export earnings; even GDP in Tanzania, the sector is seen as a main vehicle in many national economic strategies to combat poverty and enhanced agricultural productivity is crucial to realize this objective. Tea is among the cash crops grown in Tanzania. Tea creates wealth and employment in rural areas and supports the wellbeing of over 50,000 families. Various studies have been undertaken directing the issue of increase of productivity in tea and diseases, but none has been done on the use of effective microorganisms in the productivity of tea. Tea production, as many of agricultural crops, mainly depends on the health of soil, which is a measure of a complex set of biological, chemical and physical interactions driven by microorganisms. Effective microorganisms increase the beneficial microbial population in the soil for sustainable crop production.

Despite the potentiality of the two major cash crops in Kagera (Tea and Coffee) and availability of good weather condition, the region ranks number 3 in both food poverty and basic needs poverty (NBS, 2020). There have been various strategies and policies undertaken to boost Tea production in Tanzania and Kagera in particular. However, the use of cost effective means producing tea leaf which is also inclusive and sustainable to the environment has not been envisaged. This paper outline results of the trials which were made from Kagera Tea Company and suggests the way it can be expanded to include a wide number of community members surrounding the company.

2 Theoretical and Empirical Literature

2.1 About Effective Microorganisms

Effective Microorganisms (EM) are mixed cultures of beneficial naturally-occurring organisms that can be applied as inoculants to increase the microbial diversity of soil ecosystem (Higa, 1994). They consist mainly of the photosynthesizing bacteria, lactic acid bacteria, yeasts, actinomycetes and fermenting fungi. EM improve the structure of the soil, increase its fertility, radically improve biological diversity, suppress soilborne pathogens, fix the nitrogen in soil and enhance nutrient uptake (Higa and Parr, 1994). EM accelerate the decomposition of organic waste, residues and composting, increase beneficial minerals in organic compound, enhance the activities of indigenous microorganism and boost the strength of plants and yield of crops. EM work by being dominant over other soil microbes. As a result, this encourages the bulk of the other microbes in the soil to follow them and in doing so the activity of the smaller group of negative or opportunistic microbes is suppressed. EM can help to improve and maintain the soil chemical and physical properties.

2.2 Intended Purpose of the Use of EM

The intended purpose of agriculture is to consistently supply food that is safe for consumption. The ideal form of agriculture, as stated by Higa (1994), is not only to achieve food production but also to protect the environment, resources and human health while being economically successful. Therefore, farming with the use of EM•1 has the following goals:

1) To produce food to maintain and improve human health
2) To create a situation that is both economically and physically beneficial to both producers and consumers
3) It can be implemented by anyone and has durability
4) To respect nature and be responsible for preserving the surrounding environment

When applied properly, EM•1 can specifically decompose the organic matter (including organic wastes and residues) and the improvement of organic fertilizer effects, increase availability of plant nutrients and suppress soil-borne pathogens and thus improve soil aggregation. The use of EM•1 is an economical way to promote a sustainable, resource-recycling agriculture that is environmentally friendly (Than and Tin, undated).

2.3 Tea Production

Global tea production is ever increasing. The reason for the growth in world output is the considerable increase in population and consumption of tea. China, Kenya, Sri Lanka and India are largest tea-producing countries in the world. Table 2.1 indicates world top ten tea exporters. China is leading with earnings of around 2.1 million US$, accounting for more than 29% of the world total. Kenya's export worth about 1.2 million US$. On the other hand, exports in 2021 from Tanzania increased by 3% from the previous year, with a global market share of only 0.4 (ITC, 2021).

Table 1: Tea production

S/N	Exporter	Value exported in 2021 (US$ thousand)	Quantity exported in 2021	Quantity unit	Unit value (US$/unit)	Annual growth in value between 2017-2021 (%)	Share in world exports (%)
1	World	7,318,377.00	-	No quantity		0	100
2	China	2,096,169.00	337,272.00	Tons	6215	7	28.6
3	Kenya	1,192,788.00	556,552.00	Tons	2143	-5	16.3
4	Sri Lanka	732,383.00	-	No quantity		-2	10
5	India	687,890.00	197,239.00	Tons	3488	-3	9.4
6	Poland	262,807.00	21,818.00	Tons	12045	10	3.6
7	Germany	242,467.00	21,912.00	Tons	11065	-2	3.3
8	Japan	189,891.00	6,322.00	Tons	30037	9	2.6
9	United Arab Emirates	152,185.00	-	No quantity		-8	2.1
10	United Kingdom	135,733.00	-	No quantity		-1	1.9
11	Viet Nam	130,728.00	78,535.00	Tons	1665	1	1.8

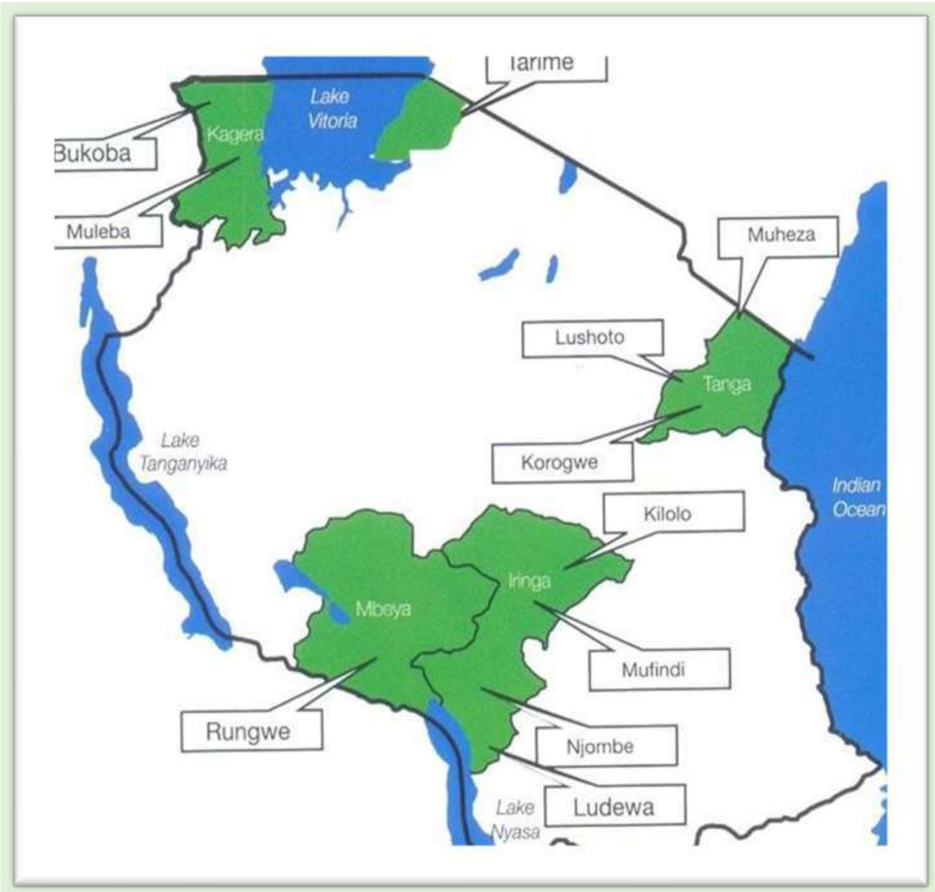
Source: ITC calculations based on UN COMTRADE statistics**.**

World exports of green tea stood at 7.3 billion US$ in 2021, growing at a compound annual growth rate (CAGR) of approximately 2% over the past 5 years. While green tea imports have recorded growth in almost every region, substantial growth has been observed in Hong Kong, Viet Nam and Malysia, and, to a lesser extent, the Middle East, UK and Russia in the past 5 years.

In Tanzania, tea is cultivated in 11 districts. The main producer districts – in terms of total production by Estates and small holder farmers and in order of importance – are Mufindi, Rungwe, Njombe, Muheza, Korogwe, Lushoto, Kagera (Bukoba and Muleba Districts), Kilolo and Tarime (Tanzania Tea Board, Various).

In terms of SHFs' production, the leading tea producing districts are: Rungwe (5,174,444 MT), Njombe (2,517,418), Mufindi (1,739,811), Lushoto (1,175,301), Korogwe (658,743), Muheza (184,400) and Kagera (Bukoba and Muleba) (164,274 MT).

Figure 1: Tea cultivating areas in Tanzania



Source: Tanzania Tea Board

Tea ranks fifth among the leading foreign exchange earning export crops in Tanzania. In 2021, tea contributed a total of US$ 32,881 million from exporting of 24,239 MT (ITC, 2022). Analysis of a 5-year trend indicated that from 2017-2021, there has been a decrease of 11% per annum of the exported value. The tea industry in Tanzania contributes substantially in providing employment opportunities. It is estimated that it provides over a million direct and indirect jobs.

2.4 Tea Catchment Area in Kagera

Tea growers in Kagera rely on Kagera Tea Company Limited (KTCL) for its tea cultivation initiative. KTCL is the only tea company operating in Kagera. The company acquired and took over the operations of the government owned Kagera Tea plantation. KTCL is a private company which was established in 2000 with the aim of growing tea and a vision of establishing a farmer linked tea processing factory. KTCL has a potential catchment area for tea growers with about 3000 Ha of land for growing green tea. The area covers 48 villages with 1,455 farmers. Other details are as indicated in Table 2. Only 1,003 Ha are planted and only 85.4 Ha are in active production.

Table 2: Tea growing areas in Kagera

District	Division	Ward	No of villages	No of farmers	Active farmers	Ha planted	Ha under prodn
Bukoba Rural	Kyamutwara	Maruku	4	155	19	83	8.4
		Kanyangerelo	3	146	12	110	4
		Karabagaine	5	243	22	138	9
		Katoma	3	121	13	91	15
	Bugabo	Nyakato	5	76	16	55	6
		Buhendangabu	3	48	6	32	2
		Kaagya	3	62	2	47	1
		Kishanje	4	72	8	53	2
	Kateleto	Bujigo	3	95	8	71	3
		Kemondo	2	90	11	67	5
		Katelero	2	78	3	58	1
Muleba	Izingo	Mayondwe	1	28	1	21	0
		Muhutwe	3	67	3	48	2
		Izingo	2	59	5	44	3
		Katoke	4	91	15	67	24
		Kagoma	1	24		18	
Total			48	1455	144	1003	85.4

Source: Kagera Tea Company

KTC sources green tea leaf grown by individual farmers around Bukoba rural and Muleba villages, representing 60% of the total requirement capacity. Over a number of years, the company has struggled to increase productivity and revive the tea production among the small holder farmers due to the increase in input prices, especially industrial fertilizers. Attempts to increase productivity without the use of industrial fertilizers is quite welcomed due to economic and environmental reasons as well as market requirements. Analysis of the production and potential for tea in the catchment areas of KTCL is as indicated in Table 3.

Table 3: Analysis of the catchment area

Area	Ha planted	Ha under production	Utilization
Maruku Estates - KTCL	204	177	87%
Katoke Estate - KTCL	151	123	81%
Prisons	102	94	92%
Small Holder farmers	1,240	200	16%
Research	5	5	100%
Total	**1,702**	**599**	**35%**

Source: Kagera Tea Company

As it can be noted, only 35% of the production area is utilized.

2.5 Empirical Studies on the Use of EM to Increase Productivity

The use of fertilizer is widely acknowledged as a way to increase productivity. However, the extensive use of chemical fertilizers has a harmful effect on soil health as the chemicals can destabilize soil fertility and thereby directly affect the native microbial populations present in soil (Kalia and Gosal, 2011). The world trend for tea consumption has been putting value to the organic tea – the tea that is grown without industrial fertilizers and chemicals. However, there has been several challenges in the use of fertilizers including lack of funds to buy fertilizers as well as low yield associated with pure organic farming. This leaves one option which is nature farming. Nature farming considers the use of compost and animal manure which add to the farming to improve soil fertility. Tea plucking and pruning leave a lot of residuals which can be used to create increased microbial activities in the soil. Application of microbes in form of biofertilizers and biopesticides have been considered as the most effective practices for pest management in modern agriculture (Bhardwaj et al., 2014). According to Raja (2013), there is a rising trend towards organic agriculture using biological-based organics as an alternative to agrochemicals.

Microbial application has been posed to create various beneficial properties to plants such as nitrogen fixation, phosphate solubilisation, production of plant growth regulators and other mineral nutrients, and biocontrol mechanisms, hence increase in crop productivity and plant protection (Miransari, 2011). There is a few studies (if any) on the application of microbes to inform tea growing in Tanzania. However, in India for instance, biofertilizer application in tea plantation has been reported to result in increased production (Bhardwaj et al., 2014). Globally the use of microbes for biofertilizer and biopesticides has been a recognized farming practice for the production of safe and healthy food and beverages.

Organic matter has an immensely important influence on the growth and proliferation of different kinds of microbial bioinoculants (Bhattacharyya and Sarmah 2018). The application of the microbes for bio fertilizers has been evaluated in various aspects including growth promotion (Dutta et al., 2015), and improvement of tea plants (Chakraborty, et al., 2013).

According to Bhattacharyya and Sarmah (2018), the biological techniques such as the use of EM create sustainable tea cultivation which is ideal for agricultural growth with minimal generation of adverse environmental impacts that may affect water resources, ecosystems or the quality of human life.

3 Methods and Data

3.1 Field Experiment Design

Filed experiment design was conducted in Kagera Tea Company (KTCL) plantations in Kagera Region. The experiment treatment was prepared after pruning involved and applied in October. The design involved 6 acres of land (about 2.4 Ha), with 3 replications. The plots were pruned in early October, which is pruning season for tea. Normally, pruning generates organic matter in the soil which can take time to decompose.

3.2 Data Type, Source and Statistical Measurements

Semi-decomposed cow manure (2 buckets of 20kg each) and field shrubs (1 bucket – about 10kg) were mixed with a liquid solution comprising 10 litres of water, 150 mil of molasses and 150 mil of extended EM.1 (EMAx). The mixture and the liquid solution were mixed to an extent that it was neither wet nor dry. The mixture was then kept in airtight non-transparent plastic bags and put in a room temperature with no direct sunlight for a period of 14 days. After

14 days, the mixture was then applied to 1 acre of a tea plantation in the three plots. About 1 ton of such mixture was made and applied equally in the three treatment plots. The application was done spatially; the way a farmer would sow sorghum seeds in a field.

A weekly spraying of the extended EM was applied in the leaves for a period of three months at a solution rate of 1:500 for extended EM; fresh tap water was applied. The other three acres of control were left as control for the period of study, monitored as for normal plantations. The application was done during rainy season. Data was taken by weighing production of green tea leaves for three months during plucking season, for both the application and the control plots. Industrial fertilizers were not added to the control plot, and normally the company does not use industrial fertilizers.

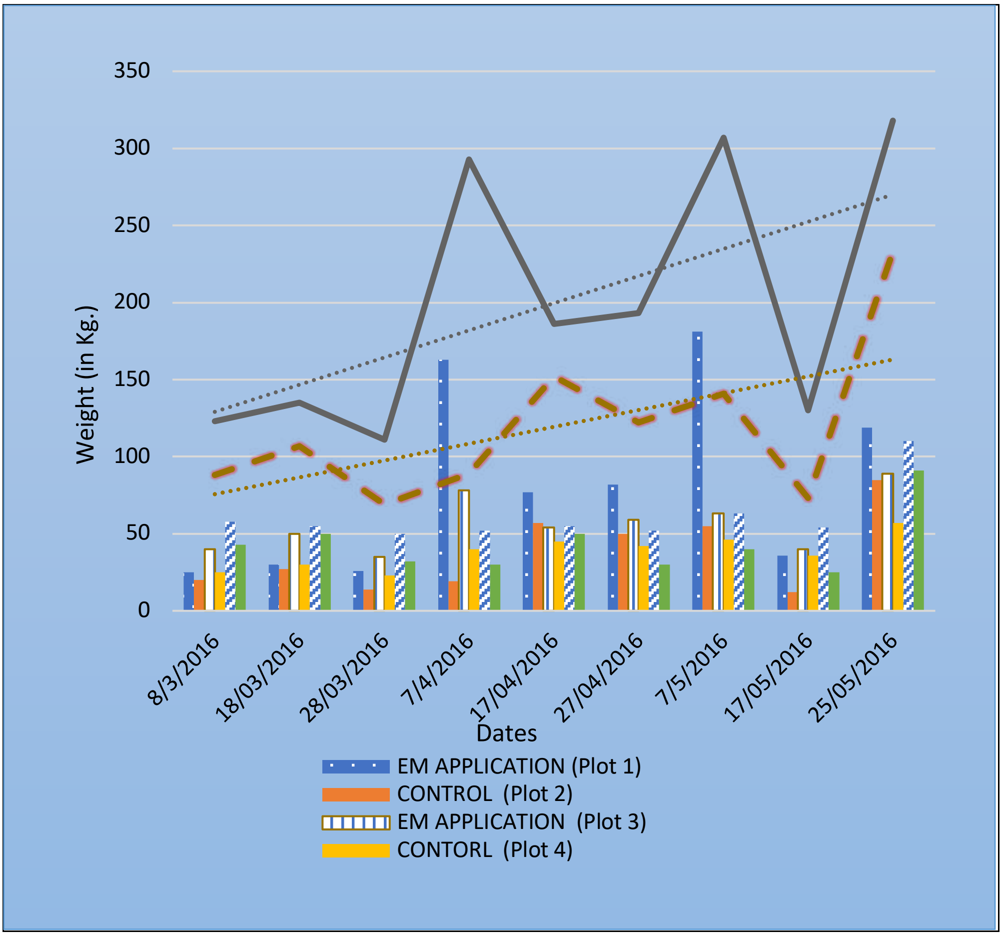
Observation and laboratory test were undertaken by leaf visibility, colour and liquor of the tea after harvesting. To analyse for the cost benefit of the application of EM and potential for scaling up for the project, a cost benefit model was applied. This involves identification of the cost incurred in the application of the materials used as well as labour costs taking into consideration effective labour usage for one acre. The overall methodology for the experiment is as summarized in Appendix 1.

4 Results and Discussion

4.1 Productivity Analysis

A total of 8 harvests were done in an interval of 10 days. Normally, harvests are done in intervals of 14 days. The influence of EM has accelerated the number of harvest days to 10, and further reduced to 8 days in the last plucking days monitored. This was due to the fact that the treated plots yielded the required plucking leaf size faster than normal plots. The plucking period was for March to May, the highest rainy months in Kagera. The harvested tea leaf was the plucking after pruning. The results are presented in Figure 1.

Figure 1: Harvest of green tea leaf from experimental plots



Source: Field Data

Based on Figure 1, it can be revealed that there is an increase in the weight of green tea leaf after fist plucking at an increasing rate. In total, there is a substantial difference for the plots with treatment as compared to those which were not treated. The maximum difference was 85% increase between treated plots and untreated ones which was recorded in month of April. On average, the increase was 65%. A based year analysis was established, a year before the application for the total number of kilograms (kgs) harvested. From the analysis, the three months generate about 33% of the total production of the green tea leaf. Based on the current price of green tea leaf (i.e. TZS 314 per kg), the increase would have yielded a saving of TZS 226,708/- from the 1.2 Ha of plots for the first three months. Details are as indicated in Table 4.

Table 4: Analysis of the experimental yields and financial gain

Month	Baseline (green leaf in Kg) [A]	% Annual harvest baseline year [B]	Experimental Harvest Green Tea Leaf (Control in Kg) [C]	Experimental harvest green tea leaf (EM application in Kg) [D]	Variance percentage [D/C-1] [E]	Baseline gain experiment [TZS 314/kg* C) in TZS [F]	Baseline gain experiment [TZS 314/kg*D) in TZS [G]	Net gain experiment [TZS 314/kg) in TZS [H]
March	271,353	11%	264	369	40%	82,896	**115,866**	32,970
April	282,925	11%	363	672	85%	113,982	**211,008**	97,026
May	283,075	11%	447	755	69%	140,358	**237,070**	96,712
Total Base Year	**2,463,606**	**100%**			**65%**	**337,236**	**563,944**	**226,708**

Source: Data from the Field

Considering the gains in an annual production estimates, taking into consideration the experimental yield of a 65% increase as well as the current price of green tea leaf, it can be indicated that the annual production per Ha is estimated to be 4,106.01 kg. This is below 50% of the average yield of tea per Ha. However, with the application of EM, it is estimated that the yield per Ha would reach 6,775kg per acre on average, which could potentially yield TZS 2,127,324 per Ha. With a potential for 1,700, it is anticipated that there will be a gain of TZS 1.4 billion for the tea growers per year. Details are as indicated in Table 5.

Table 5: Comparison of yield based on annual production estimates

Month	2015 Base year (kg)	EM effect (Kg) effect +65%)	Income control (Price TZS 314/kg)	Income EM effect (Price TZS 314/kg)	Financial gain (TZS)
January	328,175	541,489	103,046,950	170,027,468	66,980,518
February	240,917	397,513	75,647,938	124,819,098	49,171,160
March	271,353	447,732	85,204,842	140,587,989	55,383,147
April	282,925	466,826	88,838,450	146,583,443	57,744,993
May	283,075	467,074	88,885,550	146,661,158	57,775,608
June	172,984	285,424	54,316,976	89,623,010	35,306,034
July	101,255	167,071	31,794,070	52,460,216	20,666,146
August	98,174	161,987	30,826,636	50,863,949	20,037,313
September	123,864	204,376	38,893,296	64,173,938	25,280,642
October	206,994	341,540	64,996,116	107,243,591	42,247,475
November	163,866	270,379	51,453,924	84,898,975	33,445,051
December	190,024	313,540	59,667,536	98,451,434	38,783,898
Total	**2,463,606**	**4,064,950**	**773,572,284**	**1,276,394,269**	**502,821,985**
Potential Ha	1,700				
Total	**6,980,217**	**11,517,358**	**2,191,788,138**	**3,616,450,428**	**1,424,662,290**
per ha	**4,106.01**	**6,775**	**1,289,287**	**2,127,324**	**838,037**

4.2 Observation and laboratory

The experimental plots were subjected to observations during the period of study, which involved 8 months of treatment and harvesting. Soil structure of the treated plots were dark with worms and other natural organisms living in the soil. Untreated soil was not as decomposed as the treated soil. The leaf size was relatively broad 100 mm × 45 mm in the treated plots. For the treated plots, leaf visibility was deep green. The tea was processed separately in a laboratory environment. The tea exhibited blackish colour and the liquor was quite brisk, bright colour and of good task.

4.3 Cost Benefit Analysis

Cost-benefit analysis (CBA) is the process used to measure the benefits of a decision or taking action minus the costs associated with taking that action (Hayes, 2021). For this case, analysis is made on whether an individual or institutional farmer should consider adaptation of EM, given the benefits and costs associated with the technology. CBA involves measurable financial metrics such as revenue earned or costs saved as a result of the decision to pursue a project. It also considers the intangible benefits and costs or effects from a particular decision such as an employee's morale and customer satisfaction. The study considers costs for the experimental plot based on the individual farmer's plot size of 0.4 Ha or 1 acre. Similarly, a comparison was made to the institutional farmer i.e. Kagera Tea Company which has 599 Ha of tea plantation. The costs are based on the current commercial rates.

Table 6: Cost analysis

S/N	Variable	Individual farmer	Institutional farmer
Application to Soil			
A	No. of Ha	0.4	599
B	Organic EM. Made Fertilizer Kg. per Ha	300	300
C	Application Cycles per Year	1	1
D	Total Kg. EM. Made Fertilizer (A*B*C)	120	179,700
E	EM. Extended Used (1:20)	6	8,985
F	EM.1 Required (1:20L)	0.30	449.25
Application of EM -Foliar Spraying			
G	Liters per Ha.	*80*	*80*
H	Cycles of Spraying (per Week)	2	2
I	Weeks Spraying	20	20
J	Total Liquid Required	1,280	1,916,800
L	Application Ratio (1:500) (EM - Extended Required)	2.56	3,833.60
M	EM.1 Required (1:20L)	0.128	191.68
O	Total EM.1 Required	0.43	640.93
P	Molasses Required (1:1 for EM.1)	0.43	640.93
Cost Analysis			
Q	Cost of EM.1 (in TZS)	25000	25000
R	Cost of Molasses (in TZS)	2000	2000
S	Cost of Materials (in TZS)	11,556	17,305,110

S/N	Variable	Individual farmer	Institutional farmer
T	Additional Management costs (per Ha) (in TZS) per Months	200,000	200,000
U	Effective management Months	3	3
V	Total Management Costs (TxUxA)	240,000	359,400,000
W	**Total Costs (S+V)**	**251,556**	**376,705,110**

Base on the analysis of the costs, it can be revealed that for an individual farmer, a total of TZS 251,556 will be incurred for the application of EM on the plot in year one of the application. This additional costs, however, involve TZS 240,000 as management costs which are non-payable. The actual cost for the material will be TZS 11,556. The benefit for the individual farmer is TZS 335,215/- per year. This is based on the benefit derived from the trials, which is TZS 838,037 (Table 5). A net gain for a farmer with 0.4 Ha is estimated to be TZS 83,658.66 (Table 7). This is, however, a minimum benefit, but the farmer will also gain in terms of the return on the efforts worth TZS 240,000 as indicated in Table 6.

Table 7: The Benefits for individual and institutional farmer

S/No	Variable	Individual farmer	Institutional farmer
A	Benefits per acre in TZS (derived from the trials)	838,037	838,037
B	No of acres	0.4	599.0
C	Total benefits	335,214.66	501,983,947.96
D	Net benefits (Costs) per farmer	83,658.66	125,278,837.96

As presented in Table 7, there is a potential benefit for the application of EM resulting from labor and income gained. A total benefit of TZS 323,300 is anticipated in the application of EM.1 for tea growers in Kagera per acre. These are estimated to be 1,240 growers who are assumed to have potential of cultivating at least one acre. With this increase in income per year, it will decrease substantially the level of poverty in the region as well as in Tanzania at large.

5 Conclusions and Policy Implications

Adaptation of nature farming in tea can potentially increase yield, contribute to the incomes of the farmers and create good avenue for investment for tea investors. Where no fertilizer is used, application of effective microorganisms can potentially increase the yield per acre and the quality and marketability of the tea. While our analysis considered only current yield and increased yield based on the application of EM.1, elsewhere tea yields are up to 10,995 kg made tea per hectare under commercial tea production (Oyamo, 1992). It is, thus, noted that the yield obtained would potentially increase in the future, given consecutive application.

This study has considered the experimental design for the tea production by the use of already grown tea. The study does not account for investment costs and return, rather, the measure of the current yield and the improved yield as a result of the EM.1 application. The cost benefit analysis for institutional investors and individual farmers – and as a whole, indicates that there could be additional income to the farmers if they opt to adopt for EM.1 application in tea production. Our analysis has not accounted for nutrient balances, pests and diseases. More consumers are aiming for consumption of naturally grown organic farm produce and thus, the application of EM.1 is highly recommended, as it is a non-chemical formulation.

Application of EM.1 for the tea growers in Kagera area can potentially add about TZS 1 billion to the economy per year as direct benefits. Similarly, it can potentially create about 300 new jobs as well as increase market for tea grown. Further research, given the wide use of technology, may consider the aspects of the technological adoption and uptake of readiness of the technology to the farmers. For policy implication, the following are recommended:

1) There should be purposeful measures to revive the tea plantations in Kagera. This will help to add income to the farmers and create more decent jobs in the tea plantations and the factories.
2) The tea farmers and association should uptake the technology and train farmers on its application. They can be linked to a developmental project and seek seed funding for such investment.
3) Local government authorities should advance loans to the farmers through special loan programs. This is due to the fact that adaptation of the technology will increase the possibilities for high production.
4) There should be purposeful engagement of development partners, the government, community groups and the private sector to revive tea production and marketing in Kagera.

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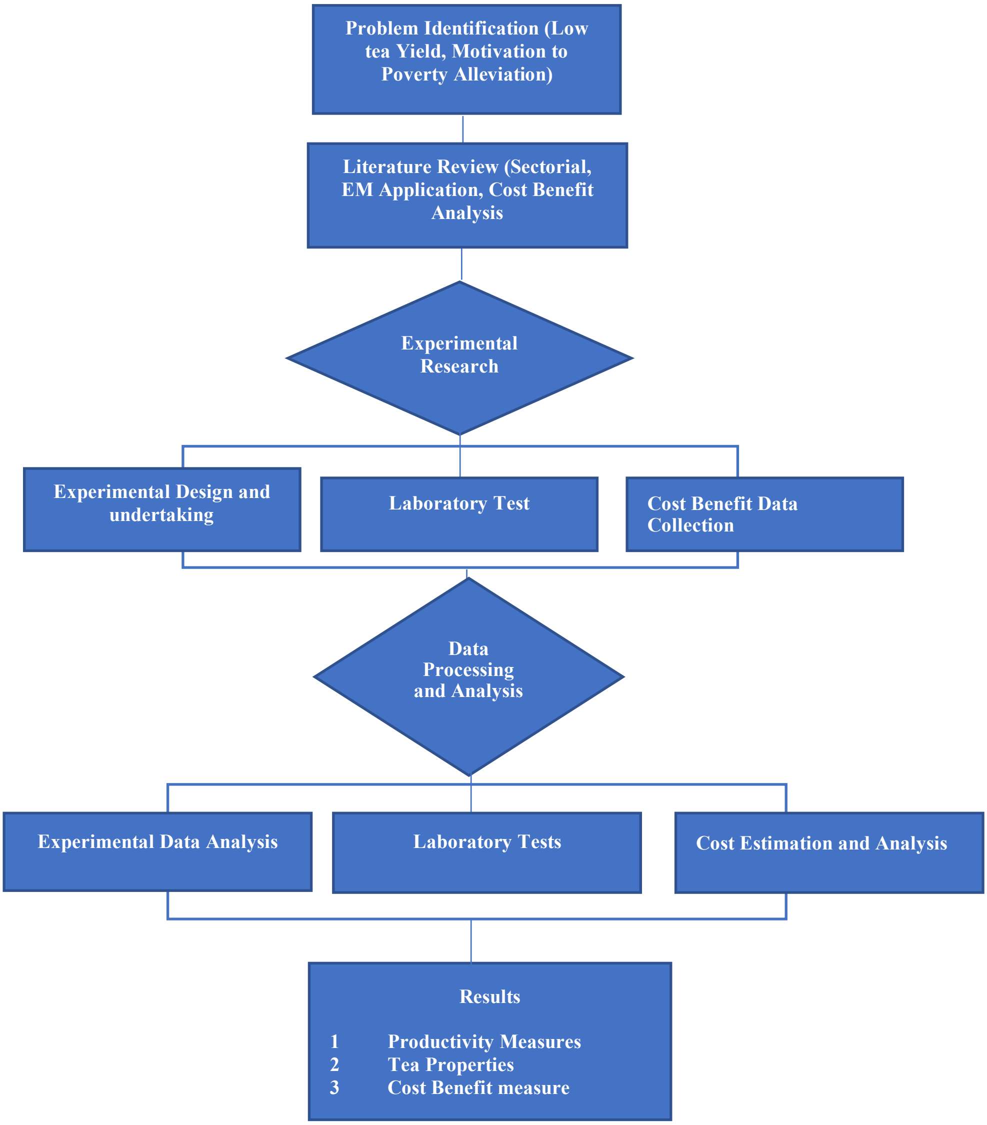
Appendix 1: Research methodology Summary



Low Fertilizer Use as the Determinant of Low Land Productivity in Smallholder Coffee-Banana-based Farming System: A Case of Bukoba and Misenyi Districts, Tanzania*

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Abstract

The coffee-banana cropping system in Bukoba District is a predominant system in the highlands of Eastern Africa areas including Uganda and Western Kenya. Traditionally, this was one of the most productive farming systems as it relied on farmyard manure that sustained the productivity of farms. In recent time, the farming system suffers from a high and increasing population density with a declining soil fertility status which is imposing pressure on the available land, exacerbating the societal poverty. This paper reviews socio-economic factors that fuel low or no use of mineral fertilisers for enhancing farm productivity in the farming system. The farming system is characterised by increased conversion of the formerly communal land including grasslands (Rweya) and forests by emerging farmers leading to shaky land tenure systems. This review unveils the factors that lead to farmers not to have access to information on fertiliser recommendations including the type of fertilisers and the rate of application to farms to enhance productivity. The overall nutrient balances for nutrients in their parcel of land are negative. The findings further indicate that soil nutrient stocks are on the decline even in fields that receive large amounts of organic inputs. In fact, if no urgent and intentional measures are taken by appropriate stakeholders including the government, the situation is likely to worsen

because other socio-economic processes were not considered during the present review. Besides the stated findings, the paper concludes by suggesting potential remedial measures to be taken that could be focused by stakeholders and policy environment to reverse the threatened collapse of the system.

Key Words: Land productivity, coffee-banana systems, soil fertility, fertiliser use, smallholder farmers

1.0 General Background of the Area and the Farming System

Administratively, Bukoba and Misenyi districts comprise 49 wards. Based on the researcher's previous knowledge of the farming system, this review is founded on two villages that were purposely selected, namely Butulage (1°29'S, 31°30'E) and Butayaibega (1°7'S, 31°48'E), to represent the farming system. Rainfall distribution in the farming system has a bimodal pattern with annual ranges from 750 to 2200 mm. Soils are classified as Alumihumic Ferrasols, inherently poor in fertility, developed from sandstones and shale materials that are highly leached (Touber & Kanani, 1994). There are predominantly three basic land use types conveniently called in local parlance as *kibanja*, *kikamba* and *rweya*. Soil fertility and productivity of the home garden (*kibanja*) largely depends on application of organic inputs mainly mulching and farmyard manure.

The *kibanja* component of the system is dominated by the highland bananas, grown as a staple food crop in mixture with coffee as a major cash crop. Presently, according to Mwijage et al. (2009), the current yield level of bananas in the farming system ranges from 600 – 1000 kg DM $ha^{-1}yr^{-1}$ depending on farmers' management. However, with different levels of nitrogen and potassium, the estimated potential banana yield is between 1000 – 8000 kg DM ha^{-1} at the second crop growth cycle with dry matter content of 25% (Nyombi et al., 2009). A yield of clean dry coffee currently averages at 300 kg ha^{-1} $year^{-1}$. However, potential coffee yield is reported to be at 2000 kg ha^{-1} $year^{-1}$ depending on soil fertility and farmers' management. This means only about 10% and 15% yields are realised for bananas and coffee respectively, in relation to theoretical potential productivity. Nitrogen (N) and Potassium (K) are the most limiting nutrients in the system. Although these nutrients work in synergy with Phosphorus (P), the latter is generally not a constraint as it is available in adequate amount in Bukoba soils (Deugd, 1994).

2.0 The Banana–Coffee Intercrops System

Banana–coffee intercrops are more profitable and resilient than the production of either crop grown as mono-crop (Wairegi et al., 2015). This is often done by either establishing new fields with banana–coffee intercrops using Arabica or Robusta coffee, or planting coffee in existing banana fields and/or planting bananas in the existing coffee fields.

Theoretically, success in growing inter-cropped banana and coffee depends to a large extent on an adequate supply of nutrients from the soil and the recycled crop residues that also provide mulch as well as mineral fertilisers. In most cases, banana and coffee yield less than their potential if poor soil fertility is not corrected by the addition of organic manure or mineral fertilisers. A good mulch layer ensures the development of strong root systems for target crops that in turn improves the recovery of nutrients, whether applied in the form of mineral fertilisers or crop residues.

Figure. 1: Banana–coffee system where banana canopy is estimated at 1–2m above coffee and provides good shade for coffee to enhance productivity

Where soil fertility is poor, the fundamental principles for managing the interaction between coffee, banana and mineral fertiliser application is that coffee grown under the shade from banana often yields better and is a more resilient system. This is because plantation life is longer, and production is more stable than if coffee is grown without the shade. If the shade is too dense, the yield potential of coffee is reduced, and the coffee will respond poorly to fertilisers. Adding fertilisers to coffee that is heavily shaded is not recommended because the increase in coffee yield may not be sufficient to cover the investment in fertiliser. Reducing the number of bananas to reduce shade can improve the benefits of fertiliser in such fields.

3.0 Land Productivity Crisis

Productivity in this context is defined as the ratio of output to input. Yield in this case is a measure of land productivity. Although the current productivity records are low, still it is on the downfall trend (Mwijage et al., 2016). For large parts of Tanzania, Bukoba inclusive, land productivity has tended to decline as a result of degradation and limited organic inputs and virtually no mineral fertilisers are applied by farmers (Mwangi, 1996). The decline in productivity of both labour and land reduces the capacity of farmers to produce a surplus which provides the necessary basis of capital accumulation and fighting societal poverty. Forms of surplus production, therefore, should be conceptualised and discussed in relation to improved land productivity and developments of strategies of fertiliser usage by farmers for raising the productivity of labour and land and hence enhance surplus production.

On the other hand, the growth in agricultural production in Bukoba over the last several decades has not kept pace with the growth of population. As land gets more and more scarce, rising degradation with increasing population, it becomes necessary, therefore, to switch from extensive forms of land-use characterised by a large per capita acreage to more intensive systems with a reduced per capita acreage. Average land ownership per household ranges from 0.5 – 3 acres in Bukoba (Mwijage et al., 2009). It is imperative, therefore, to institute all necessary efforts to increase the productivity per unit of land in this farming system in this context of critical and shortage of land coupled with the rising population and increased land fragmentation among household members.

3.1 Social Differentiation

Farmyard manure has been and is still the basis of soil fertility replenishment in the farming system. In the survey conducted by Mwijage et al. (2009), it was revealed that only 19% of the surveyed households (N=1640) were found to have at least one cow. Goats, pigs and chicken were also available for a few limited households that contribute to the supply of farmyard manure in their parcels of land. Apparently, the use of mulch in the *kibanja* per household which is basically from the *rweya* is also important although it is rather a labour demanding activity. In this system, in fact, family labour is generally the most used one for collecting mulch from the *rweya* and these grasses are mulched in the banana-coffee fields. It is estimated that 20 Mg of dry mulch ha $^{-1}$ is necessary for the production of 15 Mg ha $^{-1}$ y $^{-1}$ of fresh bananas and 0.225 Mg ha $^{-1}$ y $^{-1}$ of hulled coffee (Mwijage et al., 2016). This means that most *kibanja* are established and maintained without manure or fertilisers. The mulch grasses from the *rweya* have low nutrient value. Most farmers depend on initial quality of the soil, which apparently explains the inherent variations in *kibanja* productivity. Without external inputs including adequate farmyard manure and supplementation of mineral fertilisers, nutrient deficiencies will continue to hamper the productivity more and more with time.

Depth range (cm)	**00 -20**		**50-75**	
Annual rainfall range (mm)	Nkenge (900-1400)	Maruku (1500-2200)	Nkenge (900-1400)	Maruku (1500-2200)
Parent material*	SS	SS	SS	SS
Texture*	L	SL	SCL	SL-SCL
pH H_20	**5**	**4.8**	**5.3**	**4.6**
C (%)	1.2	2.3	0.6	13
C:N	**15**	**21**	**-**	**-**
av.P mg kg^{-1}	**6**	**>28**	**5**	**21**
Ca meq100g^{-1}	1.6	0.1	1	0.1
Mg meq100g^{-1}	0.9	0.1	0.7	0.1
K meq100g^{-1}	**0.21**	**0.08**	**0.2**	**0.12**
B.Sat (%)	52	6	28	8
Al.Sat (%)	28	40	47	83
Ca:Mg	1.8	1	1.4	1

* SS = sandstone; SCL = Sandy Clay Loam; L =Loam; SL= Sandy Loam; HRZ = High Rainfall Zone; LRZ – Low Rainfall Zone

Table 2: Ideal soil characteristics for banana-coffee system

Component	Units	Value
pH	1.5 soil/water	>5
Organic matter	%	>3
Soil Organic Carbon	%	>1.7
Total N	%	>0.15
Available P	Mg/Kg	>15
Exchangeable K	cmol/Kg	>0.3
Exchangeable Ca	cmol/Kg	>2
Exchangeable Mg	cmol/Kg	>2

Source: Wairegi et al. (2015)

3.2 Nutrient Balances

Nutrient balances provide information about environmental pressures. A nutrient deficit (negative value) indicates declining soil fertility that is predominant in the farming system. A nutrient surplus (positive data) for some nutrients may indicate a risk of polluting soil, water and air. Nutrient balance is basically defined as the difference between the nutrient inputs entering a farming system (mainly through livestock manure and mineral fertilisers) and the nutrient outputs leaving the system (the uptake of nutrients through crop harvest for consumption and sales and pasture production). Inputs of nutrients are necessary in any farming systems as they are critical in maintaining and raising crop and forage productivity. Nutrient balances for different land use types as sustainability indicator are presented for the two main nutrients, namely nitrogen and potassium that are essential in the banana-coffee system (Table 3).

		High rainfall zone			Low rainfall zone		
	FRG	Total inputs	Total outputs	Balance (kg ha-1)	Total inputs	Total outputs	Balance (kg ha-1)
Kibanja							
	FRG1	47	17	**31**	2	6	**-3**
N	FRG2	41	13	**28**	3	20	**-17**
	FRG3	0	11	**-11**	0	20	**-20**
	FRG1	15	2	**12**	0	1	**0**
P	FRG2	12	2	**10**	1	3	**-2**
	FRG3	0	2	**-2**	0	3	**-3**
	FRG1	58	6	**52**	2	2	**0**
K	FRG2	53	7	**46**	3	9	**-6**
	FRG3	0	7	**-7**	0	9	**-9**
Kikamba							
	FRG1	0	4	**-4**	0	28	**-28**
N	FRG2	0	12	**-12**	0	1	**-1**
	FRG3	0	8	**-8**	0	3	**-3**
	FRG1	0	1	**-1**	0	4	**-4**
P	FRG2	0	2	**-2**	0	0	**0**
	FRG3	0	2	**-2**	0	1	**-1**
	FRG1	0	5	**-5**	0	11	**-11**
K	FRG2	0	3	**-3**	0	2	**-2**
	FRG3	0	13	**-13**	0	4	**-4**

Source: Mwijage et al. (2009)

Banana-coffee system is generally a low-input system that is characterised by low land productivity. To grow enough food to feed the ever-increasing population in this farming system, farmers must expand the cultivated area by moving to previously marginal but communal areas like grasslands (*rweya*), that is of lower quality and they tend to be easily degraded. Land scarcity with rising population implies that food needs cannot be met in this system because agricultural production is largely based on traditional practices; thus in this context, farm intensification is inevitable.

3.3 The Fertiliser Policy in Tanzania

Tanzania does not have a fertiliser policy that specifically focuses on fertiliser use. However, there is a policy statement on fertiliser issues in the National Agricultural Policy produced in 2013 (*National Agricultural Policy 2013*, 2013). In this policy statement, Tanzania acknowledges the increased use of productivity, enhancing technologies including fertilisers as a pre-requisite for achieving sufficient agricultural production and growth to meet economic development and poverty reduction in the country.

Several agricultural input subsidies were implemented in Tanzania since 1967 with the intention of reducing the cost of using agricultural inputs among smallholder farmers. One of the major agricultural input subsidy programmes was introduced as pan-territorial fertiliser price subsidy under the National Input Voucher Scheme (NAIVS) in 2003, but focused on the major paddy and maize-growing regions in the southern highlands of Tanzania.

Policy interventions are imperative towards lowering the cost of agricultural inputs including fertilisers among smallholder farmers. This could be achieved through provision of credit schemes in the form of inputs through farmer organisations. The credit could eventually be recovered through the same farmer organisations during the crop harvesting season.

4.0 Conclusion

Improvements in productivity in the banana-coffee-based farming system must now come primarily from high yield per unit of land rather than from land expansion because of increasingly land shortage in the farming system. Historically, the use of organic manure as a source of soil nutrients has been the only source of soil fertility management in the system; however, now its availability and use is limited.

In the banana-coffee farming system, fertiliser use has been slowed by absence of institutional structures, farmers' unawareness of the importance of inorganic fertilisers, and lack of information and credit schemes. Most inorganic fertilisers appropriate for the robust functioning of the system are imported. It is urgent for the government to come up with a pleasant subsidy policy to farmers and traders because fertilisers are expensive. The policy could ensure price incentives to make the use of fertilisers profitable to both farmers and suppliers.

Nitrogen, Phosphorus and Potassium are the most important soil nutrients for land productivity in the system. Future research to N, P and K and the available balances of these elements for fields that receive manure and fertilisers is important. Research is needed to explore feasible limits that can be determined and included in the sustainable essential nutrient management programmes. Future work will focus on evaluating between farms and within-farms balances in combination with application rate studies for these elements.

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Deploying and Diffusing Biotechnologies for Food Security and Poverty Reduction (DDBFP) : In Rural Communities Agrodyke for Biological Soil Amendment and Enhancements of Soil Productivity

Gosbert Rugangira

1.0 Introduction

"*If nothing changes about estimated 821 million people who are facing hunger in the world, the immense challenge of achieving zero hunger target by 2023 cannot be achieved; hunger and malnutrition are the biggest risks to hearth worldwide, greater than AIDS, malaria and tuberculosis combined*" (WFP).

Tanzania has been working with World Food Program since 1963 to provide assistances and support to minimize consequences of food insecurity and promote the resilience of smallholder farmers. Agricultural biotechnologies provide opportunities to address the significant challenges of ensuring food security without destroying the environment resource base. Because most of poor Tanzanians live in rural areas, there is a need to facilitate greater access to technologies that can increase the productivity of smallholders in agriculture and help reduce rural poverty for poor rural producers.

The Problem of Decline of Crops Production and Soil Fertility, Humic Acid and C-Carbon and Beneficial Microorganisms in the Soil

Many of the farmers, extension agents and agricultural personnel in the Ministry of Agriculture are lacking knowledge and skills about fertilizers and livestock manure or organic matter. Many think and consider a mere livestock dung or manure and a mere raw organic matter can and is a good fertilizer without considering the process they must undergo first and the agents needed to make that process complete in order for manure/dung to be a good fertilizer. Livestock dung and all organic matter that make compost must undergo decomposition or stabilization process (anaerobic or aerobic decomposition and stabilization).

It is in these processes, microorganism-bacteria, fungi, maids, protozoa, actinomycetes, and other ssaprophytic organisms feed upon decaying organic materials initially, while in the later stages of decomposition mites, millipedes, centipedes, springtails, beetles and earthworms further break down and enrich the compositing materials. Reclamation of organic waste material such as vegetable matter, livestock or animal manure, and other organic refuse can be converted from otherwise wasted material to a more stable form for use as a soil amendment. The process of decomposing organic matter yields final product which is a ‘compost,' or the fertilizer. A farmer, an extension agent or an agricultural officer can say it is a good fertilizer – a balanced fertilizer which is normally dark, uniform, soil-like, damp and without any odor and can be used for all kinds of ground as well as potted plants. However, without microorganisms’ action on manure or any other organic matter, one cannot have a good fertilizer and good plant development. This is why one can find cakes of livestock dung in smallholders’ farms are not rotten in a year or more.

Apart from their function of producing good fertilizers for the plant development, other microorganisms contribute to roots development and control of plant pathogens infections in the soil. They also compete with diseases causing microorganisms; when they are depleted from the soil, the development of roots will be affected, hence the plant development is affected because the roots are not protected against root pests and diseases.

At a given time, the plant is not able to develop in allocation it used to grow for years; a good example is the production of native varieties of banana (*NVOB*) in Kagera Region. At a time, 50 years ago *NVOB* were grown in all parts of Kagera Region, while today less than a quarter of the region soils can produce these varieties on some smallholder farms on plateaus and highland soils. The situation of *NVOB* farming in Kagera Region is illustrated by Figures 1 to11as follows:

Figure 1: Poor native banana plants

Figure 2: Easily uprooting native banana plant

Figure 3: Drying up native banana plant

Figure 4: Weak roots of a native banana plant

Figure 5: Dwarfed native banana plant

Figure 6: Easily falling native banana plant

Figure 7: Weak native banana farm

Figure 8: Another weak unusually spacious native banana farm

Figure 9: Very thin native banana plants

Figure 10: Poorly cared for native banana farm

To grow and produce native banana varieties, you need to do soil amendment. This is important and only possible by bio-fertilizers and correct bio-technological knowledge and skills. Training of local personnel (extension workers) and smallholder farmers is required for food security and poverty reduction. Below are the pictures depicting some results of *Agrodyke* on reviving the production of better farms of native banana, 'EBITOOKE'. We also refer to them as revived native varieties of banana (RNVB)

Figure 11: RNVB results at Itahwa

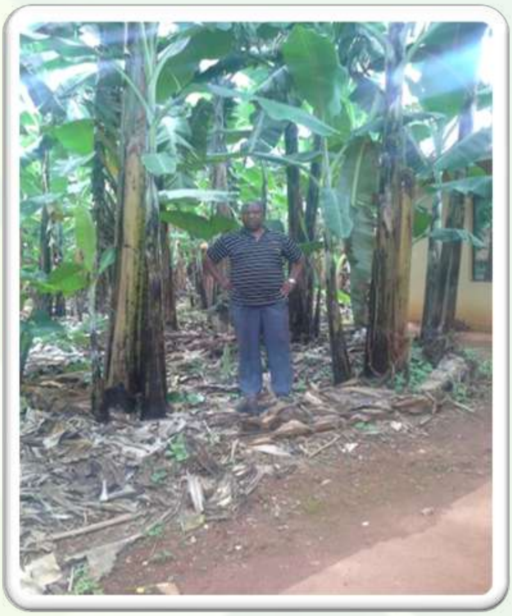

Figure 12: RNVB results at Kamachumu

Figure 13: RNVB results at Nshambya

Figure 14: RNVB results at Kitunga

Figure 15: Healthy Native banana tree as a result of RNVB

Figure 16: Healthy native banana seedling resulting from RNVB

Biotechnological agriculture solves the problem of plant productivity as proved in restoring native varieties of banana project [RNVB] to indicate the importance of biological soil amendment for enhancing plant productivity. These pictures below prove that the initiatives of the project need to be done at large scale with a government support. Roots development is what will restore the production of native varieties of banana. Beneficial microorganisms enhance soil fertility, availability of plant nutrients and enable the roots to fight root enemies in the soil as seen below. Note the action of *agrodyke* on roots in the soil, the mass of suckers produced by quantity and quality:

Figure 17: RNVB productivity

Biotechnological agriculture and *agrodyke* are inevitable for soil amendment to sustain food security, livelihood and hunger reduction in the communities of rural smallholder farmers. Restore Native Varieties of Banana (RNVB) Farming Project has been proven in 72 tests up to date. RNVB farming project is the base of the proposed DDFP concept project/program. It started in 2016 by Bio-earth Group and funded by Bio-earth Global founder members. The project results have been inspirational to many small scale farmers in Kagera Region.

Mission of RNVB Project

The mission of RNVB farming project was to introduce, educate, preach and spread biotechnology skills; knowledge and input benefits to soil, human health and environment for restoration of native varieties of bananas as a mitigation measure of hunger and poverty reduction in Kagera Region.

Objectives:

1. To choose different locations in the region which were used for native varieties of banana in last 10, 20, and 30 + years respectively by visiting locations and discussing with people there.
2. To start demonstration farms/test farms to early adopter farmers who were able to accept tests in their farms, met and fulfilled requirements, did farm practices themselves and bought bio- fertilizers/bio-inputs at 50% discount.
3. To provide 100% services and costs to early adopter farmers who are unable to meet costs, but their location is a good teaching class for others to acquire the knowledge intended.

Results:

There were two types of results, namely:

1. Early adopter's farmers: for 70 farms obtained, refer to the attached sheets of names, villages, and districts as well as positive results on test farms as illustrated by Figures on the results
2. Photos and pictures of results on command root development in soils, suckers productivity, banana plant development, fruiting and maturing period are some of inspiring results.

Deploy and Diffuse Biotechnologies for Food Security and Poverty Reduction in Rural Communities (DDBFP) Project

DDBFP is a project committed to deploy and diffuse knowledge and skills of *agrodyke* as important product for food security and poverty reduction in rural communities. The project is cost effective to contributing to the government existing efforts in collaboration with WFP and other development partners. DDBFP project is designed for all regions and all major food and cash crops in developing a significantly better agricultural technology for smallholder farmers in the rural communities for food security and poverty reduction. The project will be extended to other essential crops in Tanzania step by step. Regions to be covered by DDBFP are: Kagera, Geita, Kigoma, Mwanza, Morogoro, Simiyu, Mbeya and Njombe. The plan is one region after the other depending on the resources available.

Kagera and Native Varieties of Banana (NVOB)

Prosperity of Kagera Region in 1960's to 1970's cannot overemphasize the times when native banana varieties production was good almost the whole region. In other words, native banana varieties were the backbone of development of Kagera in all socioeconomic aspects. Kagera, by then West Lake Region, ranked 3 in the best three regions of Tanzania in terms of development and income. It was when people from neighboring countries came in groups to seek jobs. Decline of native banana varieties due to soil problems caused a decline of development of the region up to date as the region ranks in the poorest regions in Tanzania in terms of livelihood and food security.

It was the idea of Bioearth Global Group in 2016 that the soils used for banana production for 20-30 years gradually lost essential microorganisms due to harmful human actions to soils, age and climate change. In other words, the soil lost microbial life which used to help, among other many functions, the plant roots to survive and develop to make a plant get its food. With *agrodyke* innovations and initiatives, Bioearth Global Group started experiments and tests in 2016.

Key questions to finding solutions production of native banana varieties

The villages and wards where no one expected to grow native banana varieties are: Nshambya, Kibeta, Itahwa, Bugabo, Kanyigo, Bugandika, Muhutwe, Izigo, to mention but a few. Tests included all the crops, fruits, vegetables, coffee, tea, vanilla, lemon, oranges, avocado, cocoa, among others and were made on smallholder farmers who ultimately came to be innovative to biotechnology and their neighbors and village mates have learned from them now. Biological soil amendment for enhancing banana reproductivity is a technology the government and partners must support in the whole country, especially farmers in Kagera who must revive the production of native banana varieties for food security and reduction of poverty.

Reasons to improve 200 smallholder farms of native banana varieties for food security and poverty reduction in rural Kagera farmers

1. Native varieties of banana used to be food staple and source of income for many years for the people of Kagera and the great lakes in general.

2. Native varieties of banana are the most preferred varieties in Kagera, all regions of Tanzania and outside Tanzania.

3. Native varieties of banana are perennial, non-seasonal food security and livelihood throughout the year.

4. Native varieties are low cost food staple, reliable income source, easy farm management and produce useful wastes and are sustainable.

5. Native varieties of banana are inter-cropped with a range of very useful crops such as legumes species, fruits, vegetables and many others which provide nutritional balance and favor vanilla production than any other banana species. Vanilla has over recent years become a very profitable crop in international markets with very good price per kilogram.

6. Despite all qualities they have in four decades, native varieties of banana are declining in productivity in Kagera Region due to a number of reasons, the main one being soil problems. More than three quarter of the land of Kagera has failed the production of native banana species and most people have switched to exotic varieties which cannot be compared with native banana varieties at any quality. The decline of productivity of these varieties started long time ago around Lake Victoria and the east side of Kagera Region in the districts of Bukoba (rural and urban), Misenyi, and Muleba on the east and along the lake. Productivity of native species of banana was seen to prosper on high lands and plateaus of Muleba and Bukoba rural districts, but over the past two decades, there has been a decline of productivity.

7. The research conducted by Bioearth Global (NGO) using biotechnology since 2016 in different geographical areas and soils for production of

native species of banana proved that biotechnology inputs (biological soil amendments for the enhancement of soil productivity) are essential and useful to our agriculture, especially to restore the production of native banana species.

8. Demonstration farms and pioneer smallholder farmers are the backbone of this project, because by seeing the results, the around and neighbor small farmers diffuse the innovations and get attracted to do for themselves.

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Dar es Salaam University Press