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An Analysis of the Impacts of Climate Variability on Smallholder Farmers' Livelihood Assets in the Kilimanjaro Region, Tanzania

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Abstract

Climate variability is emerging as a significant challenge that affects local livelihood in developing countries. This paper seeks to analyse the multifaceted ways that climate variability affects smallholder farmers' livelihoods in Kilimanjaro region, across villages located in three agro-ecological zones. It analyses the impact of climate variability on livelihood assets and its implications on farmers' ability to make a living. Data for this paper were collected through a rigorous process of homogenous focus group discussions, household surveys, and key informants' interviews. These methods were carefully chosen to ensure validity and reliability of data. Qualitative data were analysed thematically while quantitative data analysis was carried out using Statistical Package for Social Sciences. The results indicate that the impact of climate variability on financial assets involve decrease in income and increase in farming costs. It also affects natural capital by diminishing the supply of surface water and thus limiting irrigation practices. The study also suggests that climate variability affects social capital by decreasing household and community support, primarily through poor harvests. The results further establish that climate variability through increase in temperature affects human health and reduces labour force due to the prevalence of malaria and climate-induced migration. More effective adaptation measures are recommended to increase farmers' capacity to adapt to existing climate variability, and help them protect and improve their livelihood assets.

Keywords: *climate change, adaptation, livelihood assets, smallholder farmers*

1. Introduction

Climate variability is emerging as a global concern that affects smallholder farmers' livelihood assets (Caruso et al., 2024). It is manifested through rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events. Such changes affect smallholder farmers' livelihood assets; particularly natural capital, physical capital, human capital, financial capital and social capital (Hallegatte & Rozenberg, 2017; Caruso et al., 2024). Households and individuals are supported by different types of capital, each one saving a unique livelihood purpose. As outlined by the UK Department for International Development (DFID) (1999), financial capital refers to stocks

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(such as cash or gems) and flows (including income) that are used to achieve a person's daily goals (Abegunde et al., 2019). Human capital constitute the skills, knowledge, health and strength of workers. Social capital includes different groups, networks and trustful relationships that encourage collaboration. Natural resources—such as air, biodiversity, land and trees—form naturfal capital, as they provide important services and materials for the needs of people (DFID,1999). Roads and water systems form part of physical capital, together with the equipment or tools that assist in making work more efficient in meeting important needs.

Climate variability causes soil damage, less availability of freshwater, and degrade ecosystems used for farming in many parts of the world. In their study, Jain et al. (2024) indicated that climate variability contributed to decreased biodiversity, increased desert areas and water scarcity; thus impairing the ability of rural communities to handle emergencies. Concurrently, physical capital—including infrastructure such as roads, irrigation systems and housing—are becoming damaged by extreme events related to climate variability (Sillmann et al., 2021; Frame et al., 2020). Also, climate variability impacts on physical assets and increases instability in the local economy by blocking access to areas where businesses, inputs and vital services are found. On the other hand, Wheeler and von Braun (2013) highlight that climate variability negatively affects human capital around the world, mainly through its impact on human health caused by limited food supply.

A number of studies from the U.S. and Sweden report that climate variability seriously affects the financial, natural and social capital of people in rural communities. For instance, Weiskopf et al. (2020) uncovered that more frequent extreme weather events and shifting production in agriculture in the US placed financial capital in danger by disrupting income and jobs. Likewise, according to Ibrahim and Johansson (2022), climate variability is causing organic farmers in Sweden to adapt, forcing them to learn new skills.

Moreover, there is a body of research in Asia that outlines how climate variability damages livelihood assets. According to Abedin et al. (2019), climate variability in Nepal and Bangladesh contributed to water scarcity and adverse health impacts making, it harder for people to participate in livelihood activities. Chandra et al. (2017) pointed out that climate variability impacted soil fertility, water shortage and forest resources in India; causing rural economic activities to become less productive. Similarly, both Kumar and Sharma (2013) in India, and Chandio et al. (2023) in South Asia, observed that less cereal crop production and forest products were ascribed to climate variability; leading to serious threats to natural and financial capital.

Studies conducted in Africa indicate that climate variability affects rural communities in the same way as elsewhere, except that such impacts are more intense due to their low adaptive capacity. For example, studies carried out in Ethiopia, Uganda, Ghana and Zimbabwe suggest that soil, water and forest resources in these countries have been seriously damaged due to climate variability (Antwi-Agyei et al., 2014; Gifawesen et al., 2020; Nsubuga et al., 2021). Due to this environmental change, both food production and the income farmers earn from farming decrease, which eventually reduces their financial capital (Ubisi et al., 2017). Climate variability also affects people's health and their work efficiency by limiting them from to appropriating skills and knowledge on adaptation (Caruso et al., 2024). Just as climate variability disrupts community's social capital in Asia and Europe, it also affects communal cooperation and increases migration or conflicts over resources in Africa (Dapilah et al., 2020; Frame et al., 2020). It is apparent from the above that climate variability places people's livelihood assets at risk.

In Tanzania, the impacts of climate variability on livelihood assets have been reported in semi-arid areas like Dodoma and other rural zones reliant on rain-fed agriculture. For example, studies carried out by Afifi et al. (2014) and Kangalawe et al. (2017) revealed that less rain and higher temperatures have reduced access to water, caused soil damage and decimated pastures: all leading to the loss of natural capital. Subsequently, these impacts have contributed to food insecurity, malnutrition, illnesses and reduced income (Kitole et al., 2024). Climate variability is also weakening connections between people in communities due to increased migration as people compete more for scarce resources (Afifi et al., 2014). While these challenges resemble those observed in the US, Sweden, and South Asia, Tanzania's heavy reliance on climate-sensitive sectors, together with its limited adaptive capacity, renders its farmers' livelihood assets more vulnerable to climate variability.

In Tanzania, among the most affected by climate variability are smallholder farmers who dominate the country's rural economy. Approximately 75% of the rural population depends on smallholder agriculture for both food and income (Komba & Muchapondwa, 2018). These farmers—typically managing plots between 0.5 to 2 hectares—face structural constraints such as limited access to credit, modern inputs, and agricultural extension services (Kangalawe & Lyimo, 2013; Gwambene & Saria, 2024). Since Tanzania's farming sector is mainly rain-fed, fluctuations in rainfall and temperature as elements of climate variability highly affect its productivity, which in turn affects food supplies and farmer's income (Kangalawe & Lyimo, 2013; Mohanty et al., 2024).

Available data show that between 1991 and 2020, minimum and maximum temperatures increased by 0.3°C and 0.4°C, respectively; with future projections

estimating a rise of up to 0.21°C per decade (Magang et al., 2024). Rainfall patterns are also becoming more erratic, with some regions in the country experiencing deficits of over 100mm below historical averages, while others see only marginal increases. Such shifts have led to prolonged dry spells, reduced river flows, and water scarcity in critical catchments; as well as raising the numbers of crop pests and diseases (Ndaki, 2014; Gwambene & Saria, 2024).

While many studies unveil the impact of climate variability in Tanzania, less effort is being made to study its overall impact on smallholder farmers' livelihood assets. Rural families depend on natural, financial, human, social and physical capital to make a living. This paper aims to investigate how climate variability is affecting the main assets of smallholder farmers in Tanzania. Understanding the impact of climate variability on farmers' livelihood assets is necessary for making effective policies. The generated knowledge may also help in uncovering urgent areas that require targeted interventions to improve smallholder farmers' livelihoods. It may also guide in building farmers' resilience to the specified livelihood assets.

2. Theoretical Framework

This paper adopted the sustainable livelihood framework (SLF) in analysing the impact of climate variability on smallholder farmer's livelihood assets in Kilimanjaro region. The framework was introduced by the DFID in the late 1990s (DFID, 1999). It is based on earlier research work which argued for development that supports individuals and communities (Nef et al., 2023). The SLF helps in understanding how rural poor people maintain their livelihoods and handle shocks such as those triggered by climate variability (Reed et al., 2013; Tanner et al., 2015). It also assists in clarifying the content of natural, physical, human, financial and social capital. Since its inception, the framework has been applied in a wide range of fields, including in climate variability-related issues (Chuong et al., 2024).

Though the SLF covers a wider scope – e.g., the vulnerability context, structures and processes, livelihood strategies and outcomes—this paper is limited to livelihood assets, and how the same are affected by climate variability. Here, the SLF served as a tool in explaining and identifying how climate variability affects smallholder farmers' livelihood assets.

3. Context and Methods

3.1 Description of the Study Area

Data for this paper were generated from a study that was conducted in Kilimanjaro region, in the north-eastern part of Tanzania Mainland. The region is located at 3.0758° S latitude, and 37.3533° E longitude. It is bordered to the north and east by Kenya, to the south by Tanga region, to the southwest by Manyara region, and to the west by Arusha region (Figure 1).

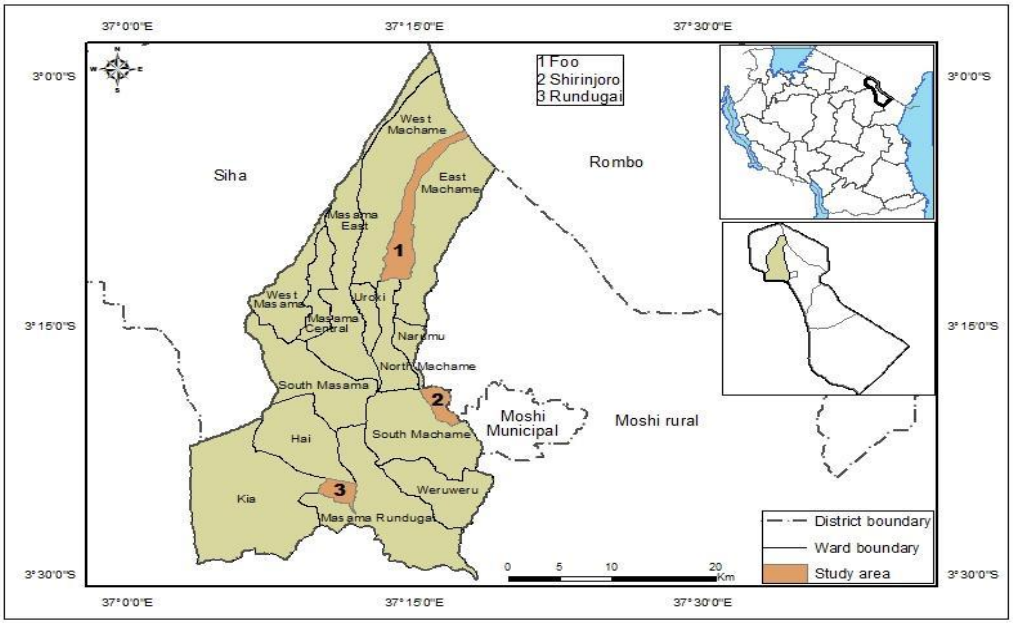

Figure 1: Location of the Study Villages in Hai District, Kilimanjaro Region

Source*:* University of Dar es Salaam, Cartographic Unit, 2024

The study was conducted in Hai district because it is one of the districts in the region affected by climate variability; and also it has the three agro-ecological zones that features the landscape of the region. The region is divided into four agro-ecological zones: the forest reserve and Mt. Kilimanjaro peak, where no farming activities take place; and the highland, midland and lowland zones where farmers are located. Although all zones receive rainfall twice a year, the amount differs in each zone. Specifically, the study was conducted in three villages that are located in Hai district: Foo, Shirinjoro and Rundugai; representing highland, midland and lowland agro-ecological zones, respectively.

3.2 Research Design

This paper is an output of a case study research design that involved smallholder farmers in Kilimanjaro region. The region was chosen because therein are evidences of climate variability; hence it provides a unique context for understanding the interaction between climate variability and smallholder farmers' assets in the study area.

3.3 Sampling Process

The studied villages were randomly selected from a list of the villages across each zone within Hai district. Stratified random sampling was used in selecting households from each village to be involved in the survey. Purposive sampling

was adopted in selecting focus group participants, and participants for key informant's interviews. The sample size was 106 households, which is approximately 5% of the total households in all the three villages. The list of households was accessed through the village household registers in the respective villages. Since the population in the studied villages is distributed unevenly between the three villages, posing a homogenous nature, the use of stratified random sampling helped to ensure that all strata were proportionally represented. The sample size for the households in the three selected villages was 47, 35, and 27 for Foo, Shirinjoro, and a Rungugai, respectively.

3.4 Data Collection

A triangulation of household survey, homogenous focus group discussions (FGDs) and key informant interviews (KIIs) was used to collect data. Two separate focus group discussion were conducted in each study village; one with men and the other with women. In this respect, the participants of the FGDs were recruited by the researcher, with the assistance of the respective village authorities. The participants were selected based on certain inclusion criteria, such as age difference, level of education, and different cadres of heads of households. Gender-based FGDs–involving 10–12 participants–were carried out in all the three villages. Interviews were conducted with key informants consisting of extension officers in agriculture and livestock, a community development officer, and a focal person from the Tanzania Coffee Research Institute in Kilimanjaro.

3.5 Data Analysis

Interview transcripts and FGD inputs were analysed thematically. The transcribed data ware first reviewed repeatedly before being analysed qualitatively. This enabled the researcher to gain a good understanding of the responses by the respondents (Taylor-Powell, 2003). The interview texts generated from every key informant and each FGD conducted were reviewed; and then sentences, paragraphs and narratives depicting the impact of climate variability to livelihood assets were coded as a way of summarising what was said (Basit, 2003).

The generated codes were later grouped into sub-themes and themes. Descriptive and multiple response analysis of the quantitative data from the household survey were conducted using SPSS, version 26. Participants were coded; and it is their code names that are used in the content of this paper. For example, the code 1FFGDF suggests the number assigned to the participant, sex/gender, level of engagement during data collection–e.g., FGD, Key Informant, Interview, Questionnaire, etc.–and the last code represents the initial code of the study village. Abbreviation for the study villages were F, S and R for Foo, Shirinjoro, and Rundugai villages, respectively.

4. Results and Discussion

4.1 Impacts of Climate Variability on Livelihood Assets

This section presents results on the impact of climate variability on financial, natural, social and human capital; excluding physical assets as there was no reported impacts on this type of assets.

4.1.1 Impact of Climate Variability on Financial Capital

The study findings indicate that reduced income stands as the main financial consequence of climate variability that farmers in Shirinjoro (52%), Foo (45%), and Rundugai (30%) experienced most frequently (Figure 2). Also, the results demonstrate that climate variability has brought financial loss to numerous rural households. These losses affect farmers' ability to fund adaptation needs such as water supply systems, improved seeds, and enhanced farming methods, thus limiting their coping capacities. This observation was made in all the FGDs across the three villages, as reported by participant 3MFGD during one FGD:

> *People practice farming in an effort to get income from production, but due to rainfall unpredictability, today we cannot produce adequate food to feed ourselves-let alone surplus for sale* (Female FGD, Foo village, November 2023).

The quote from 3MFGD affirms what was observed in the household survey with regard to the consequences of rainfall fluctuations on smallholder farmers' crop yields. Farming is the main source of income in the study area; hence unreliable rainfall negatively impacts crop production, and consequently farmers' means of income-earning. Decreased income also constraints smallholder farmers from purchasing farming inputs, and/or diversifying to other income-earnings activities to adapt to climate variability.

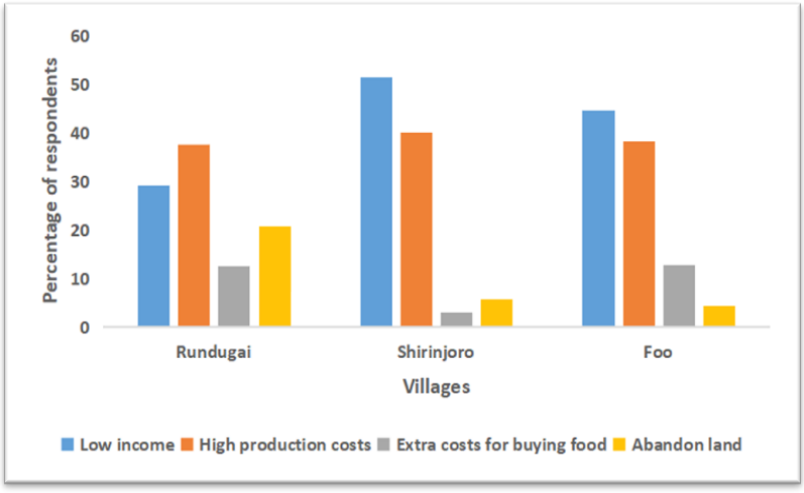

Figure 2: The Main Impacts of Climate Variability on Financial Assets
Source: Fieldwork, 2023

Increased production costs were another significant impact of climate variability on financial assets, which was voiced by over one-third of the participants in all the three villages. The same challenge of increased costs came up in all FGDs across the three villages. The participants complained that due to the uncertainties of the rainfall regimes, sometimes they have to replant crops more than once or twice. This raised their costs of seed, labour and other emergent inputs for production purposes. For instance, the 5MFGDS participant complained,

> *"Sometimes we are forced to replant even up to two or three times since we cannot fully predict the onset or cessation of rains. We can sow crops or seeds when rains begin, or when we assume they should begin; but the reality is that it showers halfway, or only for one day. Owing to this irregular rainfall, we end up spending more than double for farming activities most of the time; and one would end up earning either poor or no income at all."* (***Men FGF, Shirinjoro village, November 2023***).

Therefore, climate variability has affected farming, and livelihood activities for smallholder farmers. Such farmers are not able to invest in technologically advanced water systems for irrigation in the event of cessation of rainfall. Whenever rainfalls are delayed, shorter or more intense, their financial assets take a hit.

All three villages showed that additional food expenses stood as another primary factor through which climate variations diminish the monetary assets of smallholder farmers. Although a small percentage of respondents in all study villages mentioned it as a concern, all of the FGDs in the three villages verified its presence. The participants noted that unexpected weather, due to climate variations, causes their harvests to fail; forcing them to purchase foods they could have otherwise produced themselves. This additional financial responsibility created additional strain on their limited resources, thereby undermining their economic stability. Participant 6MFGDF explained this thus:

> *"We mostly consume foods produced in our farms, while the income from farming is used to buy other food items such as rice or sugar. However, if we are unable to produce the food crops we consume, we have to spend to buy food which was not in our earlier priority list. Also, where there is an inadequate harvest, food prices tend to rise."* (***Men FGD, Foo village, November 2023***).

This shows a consensus by the FGD participants that farming is the core source of food, as well as livelihood among the local people. Because rainfall variability often renders impossible for local production to meet the quantities required, households are compelled to purchase the food they had not budgeted for in the first place, and sometimes at a higher price. This leads to increased household spending on food, further constraining available limited funds.

Another critical financial capital vulnerability due climate variability is the abandonment of land. This was particularly noted in Rundugai village, and less frequently in other villages. In Rundugai, 20% of the respondents reported abandoning their lands when compared to 6% in Shirinjoro and Foo villages. The high level of cereal farming in Rundugai makes land abandonment more alarming for financial capital. According to FGD participants, unreliable rainfall patterns have led people to abandon new investments in their current agricultural land. Farmers choose to abandon their fields in non-irrigated locations since they believe unpredictable rainfall presents too much risk. This is as reported by participant 4FFGDR:

> *"In places where there is no access to irrigation, some people have left their farms uncultivated for many years because they perceive it to be riskier to invest in uncertain rains. If they were able to use their farms they could have contributed to the improvement of their livelihoods."* (***Female FGD, Rundugai village, November 2023***).

The phrase 'where there is no access to irrigation' brings out what occurs when individuals have no water for irrigation. Since farmers cannot be assured of water for irrigation most of the time, they regard farming as a risk; thus leaving their land idle.

Another recurrent theme evidenced from the FGDs in all the study villages– but not captured in survey–concerns the decline of businesses due to low purchasing power of people to buy food and other goods and services. In one FGD, one respondent remarked: *'… even doing business is difficult because people have no money'* (***Men FGD, Shirinjoro, November 2023***). This remark was made by one smallholder farmer and confirms that climate variability is leading to crop failure, which is directly stripping the main source of earnings among smallholder farmers, and subsequently eroding their purchasing power. Hence, businesses that would have otherwise benefit from the incomes of these farmers are also negatively impacted.

Generally, the results show that climate variability has put pressure on the farming systems through increased production costs and decreased earnings. Yield loss as a result of climate variability related droughts, erratic rainfall, and extreme temperatures: these have also been reported to decrease the income of smallholder farmers by up to 75% (Afifi et al., 2014). The results in this paper align with those of Ubisi et al. (2017), who found that climate variability has a direct and immediate impact on agricultural productivity; translating into less earnings from crop production, and increased pressure in meeting financial requirements. The findings also match with those of Frame et al. (2020), who also reported that climate variability induced droughts and floods, which in turn lead to supply disruptions, price instability and enlarged financial risks.

Furthermore, the complexities brought about by the impact of climate variability on financial assets have led to difficulties in the management of household budgets as sometimes farmers are forced to sell their produce at low market values. In an attempt to adapt to the impact of climate variability, farmers have to invest on costly climate smart production inputs such as irrigation systems, drought-tolerant seeds, and pesticides, among others, to enable production to continue in times of climate shocks. In such circumstances, some farmers may resort to borrowing to manage the situation if their financial situations cannot handle it (El Banna, 2022). Such an investments may have a negative impact on farmer's financial resources if corresponding returns are not realized (Lamichhane et al., 2022). In such cases farmers may be forced to sell their produce at low prices to money lenders to service their debts; further eroding their financial viability and resilience to future climatic events.

4.1.2 Impact of Climate Variability on Natural Capital

The negative impact of climate variability on surface water resources (natural capital) was also reported. The declining trend of surface water is evident in all three villages. In Rundugai and Foo villages, nearly 90% of the respondents mentioned noticing reduced water levels in rivers; while 50% of the participants in Shirinjoro village observed the same scenario. Such trends reveal severe water deficit problems for smallholder farmers. The reason for such a decline, as mentioned by all respondents, was the decreasing amount of rainfall. Although the decrease in rainfall may have contributed to water shortages, there may also be other reasons–though not mentioned by the respondents–which might have contributed to a reduction in water volume in the area, including an increase in the number of people using irrigation water, and land use change (Mangi et al., 2022).

The reduction in water volume affects small holder farmers in Rundugai, Shirinjoro, and Foo villages in different ways, as displayed in Figure 3. In Rundugai, 79.2% of the participants reported that they were forced to cut down on the number of hours spent on irrigation, thus resulting in a decreased productivity. In Foo, 57.4% of the respondents had to reduce the hours of irrigation, which also affected the quality and quantity of agricultural produce. Some 8.5% of the participants had wilting crops, and had to stop horticulture as they could not compete to access water for irrigation. Shirinjoro might have had lower levels of impact as, comparatively, only 22.9% of its respondents said their irrigation hours had been cut, and only 5.7% had stopped horticultural activities. However, it was found that a larger proportion of the respondents in Shirinjoro (57%) had no source of water for irrigation. This might have, in turn, impaired their ability to adapt to the impacts of climate variability. In general, reduced water volume negatively impacts smallholder farmers' livelihood by lowering productivity, decreasing revenue, and causing food insecurity since it forces them to scale down their farm sizes, and cease horticulture.

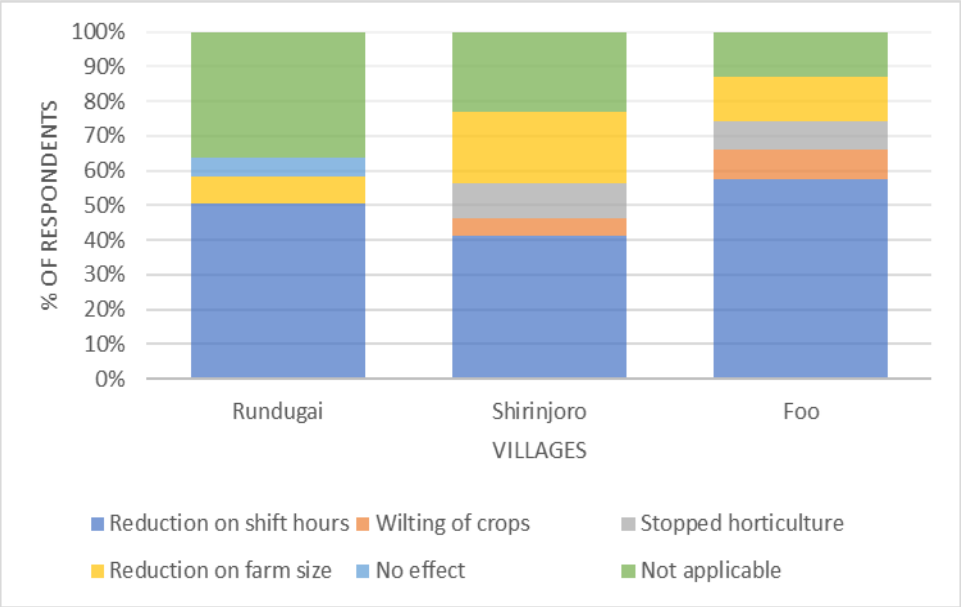

Figure 3: Household Survey Results on the Implication of the Reduction of Water Volume in the Three Study Villages
Source: Fieldwork, 2023

In addition to the input generated from the focus group participants, the representative from Tanzania Coffee Research Institute unveiled that the reduction of water volume also limited the adoption of some improved seed species that are resistant to diseases. For example, the interviewed representative reported they had tried to encourage farmers to plant disease-resistant coffee, which would potentially help farmers to not only cope with coffee berry and leaf rust disease. but also could be harvested relatively earlier than the traditional ones. However, the main challenge in this was the high water requirements as the proposed variety needed to be watered more regularly. As a result, farmers did adopt it because of water shortage.

These results reveal that climate variability, together with other factors, have affected water volume flows, hence negatively impacting farming activities. Studies in Nepal and Bangladesh also report similar results (Abedin et al., 2019). Coping strategies to shrinking water volumes, such as scaling down irrigation hours, shrunken farm size, and abandonment of horticultural activities (especially by households headed by females and old persons): all have negatively affected farmers' livelihood (Loulseged et al., 2011). Besides crops and food production in general, water shortage is also affecting the rearing of the livestock (Gifawesen et al., 2020).

4.1.3 The Impact of Climate Variability on Social Capital

One core element of social capital is the willingness of people to help each other (Dasgupta, 2011). It was observed that there were differences in the major source of social support across the three villages. As shown in Table 1, the major sources of support in Rundugai village included their children (62%); followed by informal financial institutions (45%), such as village community banks.

Table 1: The Overall Sources of Household Support (%)

Village/ Problem	Children	Clan Members	Informal Finance	Formal Finance	Neighbour	Village and Religious	Relatives	Friends
Rundugai	62.5	25.0	45.8	8.3	4.2	8.3	4.2	0.0
Shirinjoro	17.6	11.8	35.3	2.9	44.1	8.8	52.9	11.8
Foo	44.7	19.1	29.8	6.4	19.1	2.1	25.5	4.3

Source: Field work, 2023

In Shirinjoro village, the major sources of support included relatives (52%), followed by neighbours (44%); while in Foo village–as was with Rundugai village–the major sources of support were from their children (44%), followed by informal financial institutions (29%). The use of formal financial institutions, community and friends were not the common sources of support in all three villages. Note that this question was analysed using multiple response as respondents mentioned more than one source of support.

The participants in the household survey were asked to describe the trend of social capital in the form of support between households. Figure 4 shows the results.

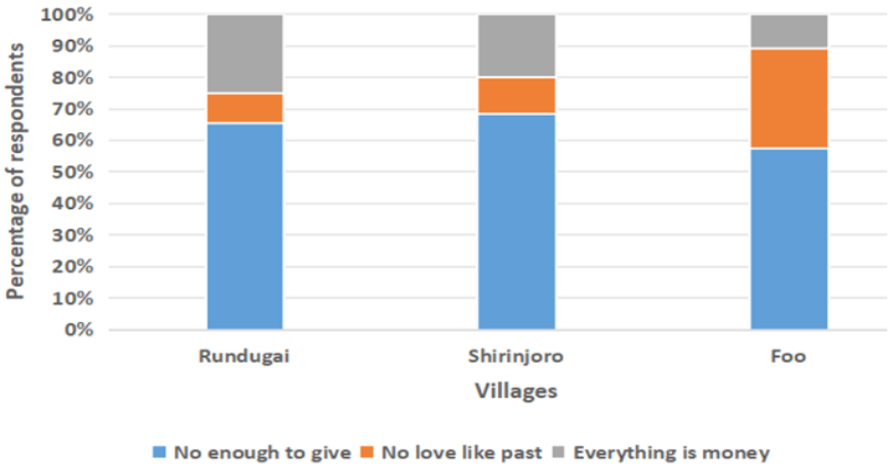

Figure 4: Main Reasons Given for Decreasing Household Support

Source: Fieldwork, 2023

The results in Figure 4 reveal that nearly 80% of all respondents in all the three villages reported a decreasing trend of social support. There were several reasons advanced to explain this. More than half of the respondents in all the three villages reported that they did not harvest sufficient crop yields to be able to donate to other households. However, some respondents (around 30%) across all the three villages noted that the rising value of items previously shared freely had led them to now being sold for money income instead of being donated.

Moreover, the participants were asked to respond on the impact of the reduction of support between households on the livelihood status of the households. As presented in Figure 5, the highest (around 60%) percentage of the participants in Foo village perceived this aspect as positive outcome, i.e., increasing family economic independence. However, 45% of the respondents in Shirinjoro village saw this as having negative effects because decreased external support harmed their income generation abilities, and complicated basic day-to-day activities.

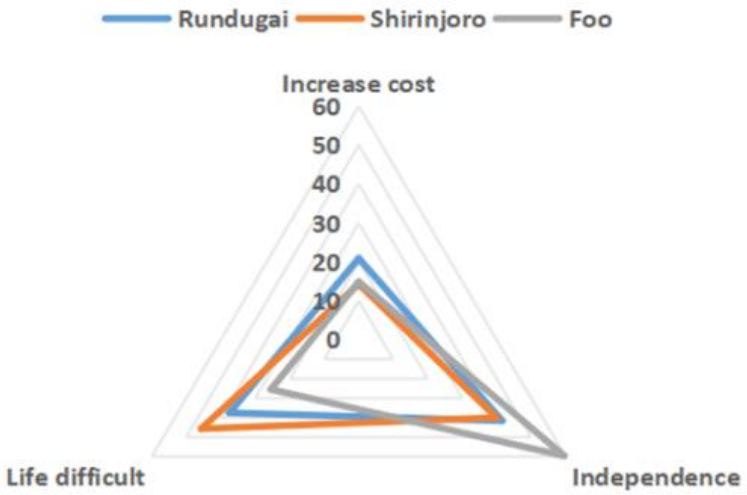

Figure 5: The Major Impact of Reduced Social Capital Reported in the Household Survey
Source: Fieldwork, 2023

We note from the above that family units changed their economic system to build resilience against the on-going climate variability by becoming more financially independent. This provided families with personal choice and power to create diverse income streams to lessens their dependence on communal support. Nonetheless, this change might have had adverse effects on traditional coping strategies, thereon affecting the overall capacity of the community to deal with the impacts of climate variability, particularly by the most affected households.

Overall, the study results indicate that climate variability erodes social capital in all the study villages, whereby more than three-quarters of the participants testified that the level of community support has declined. This decline of social support is of concern since, as previous research has established, social networks play a major role in combating the effects of climate variability (Dapilah et al., 2020). However, the majority of the respondents from Foo village (60%) reported that the reduced social capital had positively affected their lives by boosting family economic independence; with the minority (25%) perceiving it as having unfavourable effects on their livelihoods. Thus, modifications in social arrangements bring both greater independence and new obstacles to face. However, overall, a disintegration of social capital makes communities weaker since social capital and coping mechanisms are thereby negatively impacted. The disintegration of social capital affects communities' livelihoods because traditional support structures which are based on collective action and mutual assistance become less effective (Dapilah et al., 2020).

4.1.4 Impact of Climate Variability on Human Capital

The impacts of climate variability on human capital manifested in several ways as observed in the household survey and FGDs. The impacts relate to how climate variability led to a reduction of human labour through migration; and how human health was affected by the prevalence of malaria disease.

The role of migration in enhancing human capital

The household survey inquired whether there was a member of a household who had migrated to a different region for more than six months. The results showed that a greater proportion (65%) of the participants in Foo village reported that there had been outward migration from their households. In Rundugai the proportion was 62%, while in Shirinjoro villages it was 58%. The participants gave several reasons that led to migration. As Figure 6 illustrates, over one-quarter of the respondents in the three villages indicated that family members migrated to other areas in search of employment due limited non-farm earning possibilities in their area.

The second reason stated—and supported by over 10% of the participants from Rundugai and Shirinjoro villages—was that failed farming was behind out-migrations. This happened when household members initially intended to stay and farm but, after several years of unsuccessful attempts, decided to move elsewhere to pursue other livelihood opportunities. Education was another notable reason for migration; and this was mentioned by around 15% of the participants in Foo village. This mainly referred to people who left to study away from home. Although this may initially appear to be a temporary migration, the lack of secondary and tertiary-educated household heads suggests that those pursuing education were unlikely to return to participate in household or smallholder farming on a long-term basis.

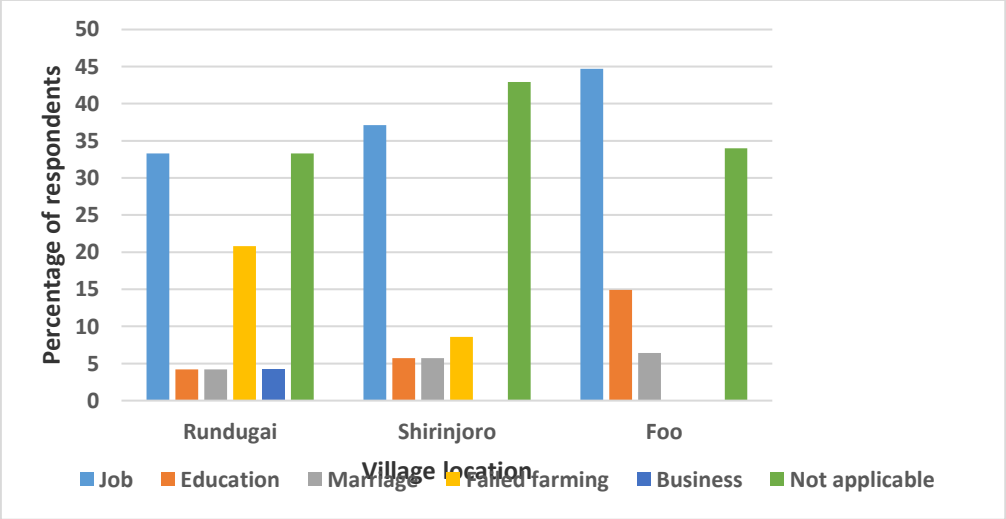

Figure 6: The Main Reasons for Household Members Moving Away
Source: Fieldwork, 2023

Also, participants were asked about the impact of migration on their livelihoods; and the responses revealed mixed opinions across the three villages (Figure 7).

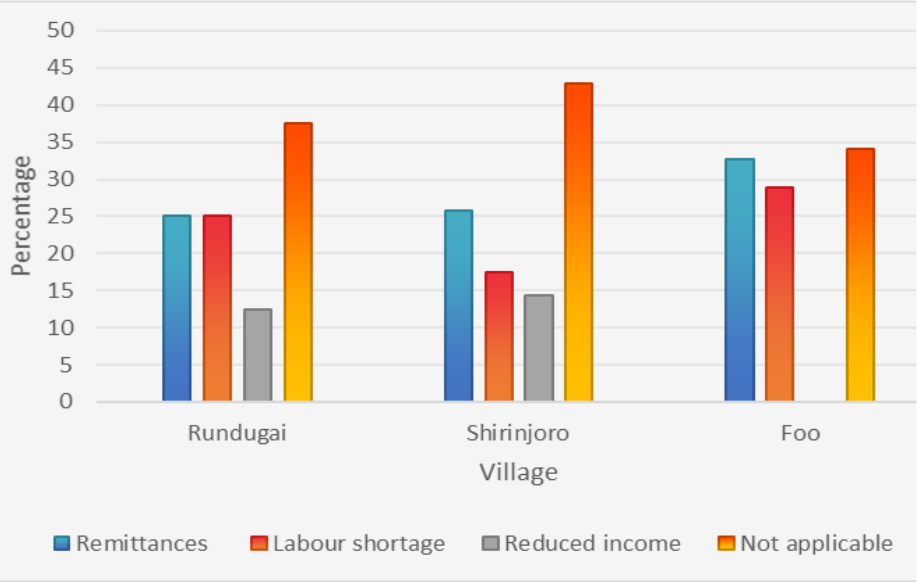

Figure 7: The Main Impact of Human Migration
Source: Fieldwork, 2023

Excluding household with no migrants, the majority of the participants in Foo and Shirinjoro villages reported that migration was positive mostly due to the income received from migrants. However, in the case of Rundugai village, the views were mixed: 25% of the participants reported that remittances had made a positive impact; while the same percentage was of the view that migration had resulted to labour shortage. A low percentage (12%) of the participants, both in Shirinjoro and Rungugai villages, expressed this as their main worry.

Hence, it is clear from the above that migration has both positive and negative effects on the human assets of a household that experiences migration. Receiving remittances is believed to make household income constant. even in the face of negative impacts of climate variability on farming. The money received can as well be channelled towards the acquisition of education, health care, or be invested in better agricultural practices that will enhance production and enable a household withstand the ill-effects of climate variability. On the other hand, as people move from households, they erode the household workforce as this cuts down human labour power farming activities. This may limit the possibility of appropriately managing farms since smallholder farmers depend much on human labour power in their farming.

The prevalence of malaria and its impact on livelihoods

Temperatures across the three villages were on a rising trend. According to the majority of the respondents from all the three villages, this has led to the prevalence of malaria cases in the studied villages (Figure 8). Warmer temperatures attract the breeding of mosquitoes, which leads to more malaria transmission (Alum et al., 2024; Kripa et al., 2024). As a tropical disease, malaria received the attention of respondents because, according to Kulkarni et al. (2016), it was an existing problem in the study area that affects their manpower and reduces productivity. The results indicated that participants from Shirinjoro expressed the most concern about malaria at 94%, followed by Rundugai at 91%, and Foo had the least at 75%.

It was reported that in the distant past, only very few people in the three villages suffered from malaria. The focus group participants in all the three villages agreed that there has been an increase of malaria incidences in their area as a result of increased temperatures, even in places such as Foo village where the temperature used to be very low for the survival of mosquitos bearing malaria parasites. As reported by 1MFGDF:

> *"The current rise in temperature levels has led to the development of a malaria problem in our community. In previous times, Foo villagers considered the illness as a lowland and coastal urban phenomena as mosquitoes could not survive the former colder temperatures in this place)."* (***Men FGD, Foo Village, November, 2023***).

This implies that high temperatures, which are associated with climate variability, are shifting disease vectors like malaria to new regions, including Foo village, thereon exposing residents to new ailments associated with warmer weathers.

Participants were asked to describe how the existence of malaria affected their livelihoods. Figure 8 illustrates the results. In Rundugai and Shirinjoro villages, over 50% of the participants admitted that malaria had lowered productivity as those affected by the disease could not engage in farming. In Foo village, 70% of the participants responded that malaria has led to reduced incomes since people now spend money on medical bills rather than in investing in farming activities. Hence, malaria affects farmers and their families, thereby limiting the availability of the labour force needed for farming activities.

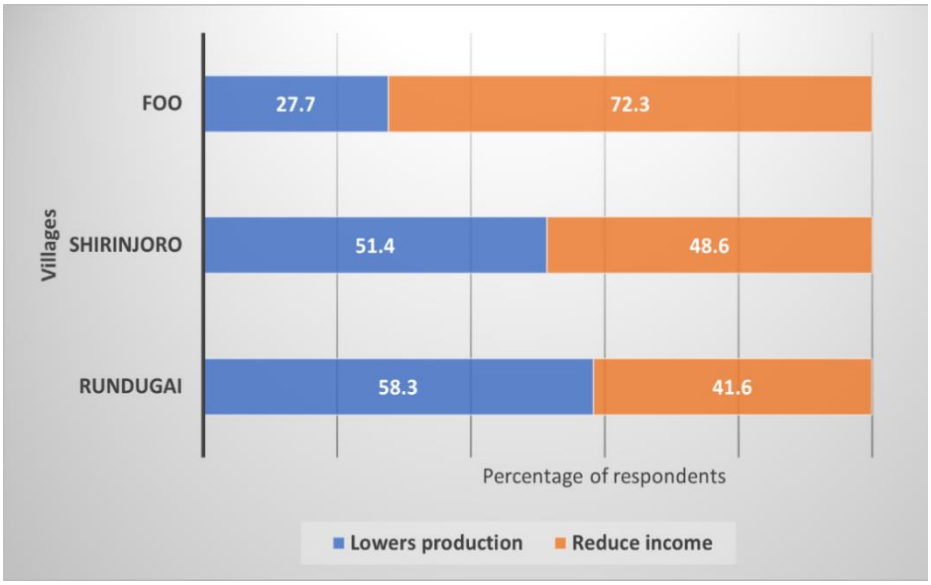

Figure 1: The Effect of Malaria on Livelihoods
Source: Fieldwork, 2023

What we can also read from the foregoing is the fact that when infectious diseases appear in new regions, they require additional healthcare funds which could otherwise support other developmental undertakings.

5. Conclusion and Recommendations

This paper sought to analyse the perceived impacts of climate variability to the livelihood assets of small-holder farmers.It can be concluded that the climate variability impacts multiple kinds of natural, human, financial, and social capital of smallholder farmers in the study area.

Natural capital is affected through reduced water availability caused by changing rainfall patterns and land use, which leads to diminished farm sizes and the abandonment of water-intensive activities such as horticulture. This reduction in water supply has had a direct effect on agricultural productivity and the sustainability of natural resource use in the affected communities.

Moreover, human capital is severely strained as rising temperatures have contributed to increased incidence of malaria, directly affecting the health and productivity of farming households. In villages such as Rundugai and Shirinjoro, over half of the participants reported that malaria has significantly reduced farm labour availability as sick individuals are unable to work. This finding aligns with Lundgren et al. (2023), Sillmann et al. (2021), and Kulkarni et al. (2016), who confirm the link between climate variability and the prevalence of climate-sensitive diseases. Projections by Ermert et al. (2023) further suggest that climate variability may expand malaria transmission zones, especially into highland areas.

Similarly, financial capital has been affected in multiple ways. On one hand, climate variability has increased costs related to healthcare (especially for treating malaria), and farming inputs such as seeds and fertilizers. On the other hand, it has reduced income through crop failure and declining productivity. Although some households view migration positively due to remittances—particularly in Foo and Shirinjoro villages—an equal proportion note its negative effects on household labour availability. This duality mirrors findings by Alarm et al. (2017) and Thomas et al. (2024), who argue that migration can simultaneously offer financial benefits and labour shortages, thereby complicating investment in local livelihoods.

Finally, social capital has been eroded as poor harvests have reduced mutual support among households. Communities are experiencing a weakening of traditional support systems, which are vital for resilience during environmental stress. This decline in collective coping capacity leaves many smallholder farmers more exposed to climate risks.

From the above, it is recommended that proper integration between water and land management practices be made to enhance farming. Also, better social networking systems should be established because they create resilient communities, while at the same time providing necessary resources for adapting to climate variability. Too, the healthcare system requires improvement through new malaria prevention programs to better address climate-related disease burdens. Lastly, new financing systems should be established to support smallholder farmers in obtaining adaptive technologies that will allow them safeguard their resources and maintain their livelihoods in the face of climate variability.

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