

Assessing Gender Vulnerability to Climate Change among Avocado Smallholder Farmers: The Case of Southern Tanzania Highlands

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Abstract

Climate change is impacting on climate dependent activities such as Avocado farming in Tanzania. The extent of the impact of climate change in agriculture depends on the level of vulnerability or exposure of farmers to these impacts. This study addresses gender vulnerabilities to Avocado smallholder farmers to climate change in the Southern Highlands regions of Tanzania where the temperature and rainfall stresses are relevant using the Livelihood Vulnerability Index (LVI) and tested for significant difference in their vulnerability levels by applying independent two sample student's t-test based on gender by using a sample of 104 Avocado smallholder farming. The results in this study revealed that both male and female avocado farmers were vulnerable to the effects of climate change and variability, but the vulnerabilities varied with gender. Female small holder farmers were more vulnerable to socio-demographic profile, livelihood strategies, social network, water and food major components of the LVI, whereas were more vulnerable to social network and health. The vulnerability indices revealed that female small holder farmers were more sensitive to the impact of climate change and variability. It was also found that female small holder farmers have the least adaptive capacities. In all, female small holder farmers are more vulnerable to climate change and variability than male. There is a need for better gender-sensitive approaches to adaptation planning and implementation to ensure that both men and women have equal opportunities to benefit from adaptation options in agriculture.

Keywords

Livelihood Vulnerability, Climate Change and Variability, Gender, Smallholder Farmers, Southern Highlands of Tanzania

1. Introduction

Africa faces profound vulnerability to climate variability and change. By 2030, as many as 118 million people in Africa, grappling with extreme poverty, are expected to be exposed to the harsh realities of droughts, floods, and extreme heat (World Meteorological Organization, 2021). The poorest countries are more vulnerable and bear the brunt of climate change impacts yet contribute the least to the crisis (IPCC, 2022). This is because there is high dependence on climate sensitive sectors such as agriculture, livestock keeping and fossil fuels (Comer et al., 2012). This underlines the critical necessity for vulnerability assessments to inform effective intervention measures.

Vulnerability can be defined differently from different perspectives. Turner et al. (2003) defined vulnerability as the extent of injury likely to be caused to a system as a result of its exposure to a hazard. Cutter et al. (2008) and Nelson et al. (2010) view vulnerability as the predisposition of any group of people, location or system to disorders determined by exposure and sensitivity to distresses, including their adaptive capacity. The fifth assessment report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) defines vulnerability to climate change as the “degree to which biological, geophysical and socio-economic systems are susceptible to and unable to cope with adverse impacts of climate change including variability and climate related extremes” (IPCC, 2014). The IPCC definition of vulnerability is the most often used framework. This framework recognizes that the susceptibility for harm is not only defined by a stressor but also by a system’s sensitivity and its capacity to cope with losses or resist impact.

According to IPCC (2007), adaptive capacity of a system is its ability to reduce the possible consequences of climate variability through prevailing opportunities or using measures to deal with these consequences; sensitivity is the extent to which a system is affected by climate-related stimuli either positively or negatively; covertly or overtly; and exposure is the extent to which a system is unshielded from major climate-related events. In the context of this study, vulnerability is the extent to which avocado smallholder farming is susceptible to, or unable to adapt to, the negative effects of climatic stresses.

Tanzania is one of the countries in developing countries vulnerable to the impacts of climate change (Borhara et al., 2020; URT, 2022), attributed to natural and anthropogenic activities such as agriculture, livestock, mining, water utility, and fossil fuel. The country has been experiencing sensitive climate conditions and is highly inclined to changes in rainfall and temperature patterns (URT, 2022). As a result, extreme rainfall events and drought affect communities’ livelihoods (Borhara et al., 2020).

The prominent avocado producing areas are in the regions of Mbeya, Njombe, Songwe and Iringa in the southwest, as well as in Kilimanjaro, Arusha and Tanga in the northeast of the country. The Southern Highlands is a socioeconomically valuable area in the regions of Mbeya, Iringa and Njombe with 4.3 million inhabitants (National Bureau of Statistics, 2022). Despite the region being among the

richest in fertile soil in Tanzania, over 60% of the population is facing poverty (UNDP, 2015). Small-scale, low efficiency agriculture is the main economic activity, with minor cash cropping, livestock and beekeeping and tree planting supplementing local economies. The majority of the growers are smallholder farmers, who own a couple to hundreds of avocado trees around their homesteads and in distant farms (Mutayoba and Ngaruko, 2018).

Tanzania is the third largest avocado producer in Africa, after South Africa and Kenya (TanzaniaInvest, 2023). For the first time, thousands of small-scale farmers in Tanzania started to produce and sell high-quality avocados to large European markets by 2010 and is listed by the Tanzania Revenue Authority among the top ten export products with annual export revenue of US\$ 12.7 million (Juma et al., 2019). Despite the impressive growth and economic potential of the avocado sub-sector in Tanzania, the production which is dominated by smallholder farmers is below both the yield and market potential due to several constraints. Key among them include poor market linkages, pre-and post-harvest losses, pests and diseases and fragile natural ecosystem. This prevailing condition exacerbates Avocado farmers' vulnerability to the climate change impacts (Malekela, 2022).

According to Gwambene and Saria (2024) study on Smallholder Farmers' Resilience in adapting to Climate Changes in the Southern Highlands of Tanzania noted that Smallholder farmers in the Southern Highlands of Tanzania confront significant challenges and face risks from shifting rainfall patterns, temperature fluctuations, and extreme events such as floods and droughts. These farmers employ diverse adaptation strategies, including local knowledge and conventional measures, to mitigate their vulnerability to climate variability. Factors such as education level, labor force size, access to meteorological information, past experiences with droughts, availability of financial services, farm outputs, and access to extension and technical information: all impede the sustainability of agricultural development in Tanzania (Gwambene, 2020; Tilumanywa, 2021).

Gender roles and expectations impact climate change, affecting individuals' experiences and responses to risks and impacts. These vulnerabilities stem from unequal access to resources, limited decision-making power, social norms, cultural practices, and institutional constraints. Gender roles are crucial in climate change adaptation and mitigation, as males and females in agriculture face distinct impacts (Prakash et al., 2022; Deji, 2020). As such, there is a growing concern that women are more vulnerable to the impact relative to men counterparts because of unequal gender relations, which tend to downgrade women in the sphere of access to and control over resources, social norms, cultural practices, and institutional constraints. Women headed smallholder farm households in sub-Saharan Africa are found to be the poorest and more food insecure (Byela et al., 2015). As a result, they are expected to be highly vulnerable with changes in climatic conditions. Considering the vulnerability to climate change between the different social groups is essential to tackle the differential effect of climate change.

In spite of growing recognition of the differential vulnerabilities as well as the

unique experiences and skills exhibited by men and women bring to development and environmental sustainability efforts, women still have less economic, political and legal influence and are hence less able to cope with and are more exposed to the adverse effects of the changing climate. Climate change impacts can exacerbate existing gender inequalities. Consequently, men and women have different adaptive strategies and spatial perceptions that reflect their activities, social positions, and differential access to and control over resources (Gwambene and Saria, 2024; Malekela, 2022; Mkonda, 2022).

Therefore, this study will try to fill these gaps by analyzing the gendered vulnerabilities of Avocado smallholder farmers to climate change. Findings could aid in designing gender-responsive climate change policies and intervention programmes to support Avocado smallholder farmers in adapting to climate change impacts.

2. Methodology

2.1. Study Area

The study was conducted in Iringa, Njombe and Mbeya regions located in the Southern Highlands of Tanzania (Figure 1). These regions were selected because it has large number of avocado farmers and traders. The production of avocado in the study area is highly supported by the Njombe Council authorities (Mwakalinga, 2014). A total of six districts were selected based on their geographical location, accessibility and having many avocado farms. The southern ecological zones respectively lie between 1200 - 1500 m and 1400 - 2300 m altitudes above mean sea level (URT, 2021). The zones contain some of the country's most fertile lands (Mkonda, 2022). The southern ecological zones contain the main four major staple food production regions (Iringa, Mbeya and Njombe). These regions are the grain basket of Tanzania growing Avocado. Rainfall pattern over southern ecological zones is Unimodal, falling from December to April on average of 100 - 200 mm per month. In recent years, rainfall has decreased whilst temperature has increased over regions receiving Unimodal patterns of rainfall (Luhunga, 2017).

2.2. Sources of Data and Sampling Procedure

Data for this study were obtained from primary and secondary sources. Primary data were obtained through small holder farmer's questionnaire administered to male and female avocado small holder farmers. Secondary data on rainfall and temperature between 1984 and 2014 were obtained from Tanzania Meteorological Authority and were included in computing the exposure components of the LVI. A multi-stage sampling technique was used. The first stage involved a purposive selection of Iringa, Njombe and Mbeya regions of the southern highlands of Tanzania, as these are the top avocado producing regions in the Country. The number of farming households selected from each community was also based on non-proportional sampling technique. Within each community visited, all households

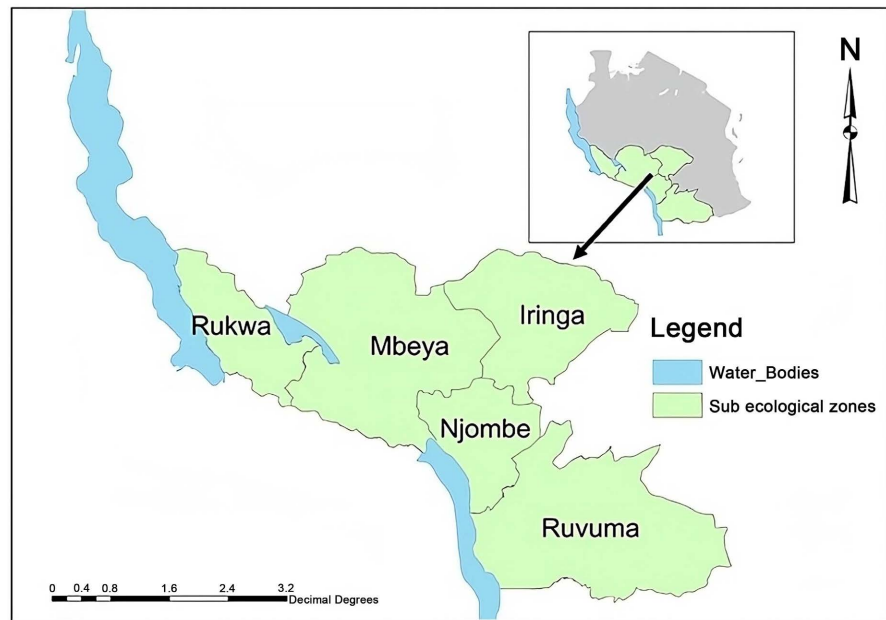


Figure 1. The southern highland regions of Tanzania.

were listed and stratified into male and female smallholder farmer, and then, simple random sampling was used to select the required number of male smallholder farmer and female small holder farmer to constitute the sample units to whom questionnaire were later administered. In all a sample of 104 smallholder farmers were interviewed, comprising 52 men and 52 women who produce avocados in the Southern regions of Tanzania as recorded in (Table 1). In order to remove gender bias the selection criteria used based on all small holder farmers with a minimum of 0.5 hectare (ha) of Avocado farmland.

Table 1. Information on number of farmers interviewed in each district.

REGION	DISTRICTS	MALE	FEMALE	TOTAL
Mbeya	Rungwe	9	9	18
	Mbeya rural	9	8	17
Njombe	Wanging'ombe	8	8	16
	Njombe rural	9	9	18
Iringa	Mafinga	9	8	17
	Mufindi	8	10	18
Total		52	52	104

2.3. Data Collection Methods and Tools

The study employed questionnaire survey, interviews and literature review as data collection techniques. Both closed and open ended questionnaires were administered to Avocado smallholder farmers to capture issues related with climate

change evidences, adaptive measures employed and challenge encountered to adapt effectively. Information collected included the socio-demographic characteristics of avocado smallholder farmers as well as the economic dependence for the Smallholder farmers with regard to other crops and farming activities, farm utilization and avocado farming. We also collected information about the challenges they face in avocado farming avocado, the duration of time in avocado farming, the number of hectares owned by avocado farmers, their average income and the effects of climate change.

2.4. Data Analysis

In this study, we have used both qualitative and quantitative methods. Qualitative analysis were used to establish the general perceptions regarding climate change and variability and their causes and various stressors that confront Avocado farmers' livelihoods. Quantitative data analysis, the study employed a descriptive analysis whereas frequencies and percentages were used to generate findings. This study also used the independent two-sample student's *t*-test (two-tailed) to test for significant differences in the means of the LVI major components, overall LVI, Intergovernmental Panel on Climate Change (IPCC) vulnerability contributory factors and the LVIIPCC indices.

Student's *t*-test is a statistical test used to test whether the difference between the response of two groups is statistically significant or not. It is any statistical hypothesis test in which the test statistic follows a Student's *t*-distribution under the null hypothesis. When the scaling term is estimated based on the data, the test statistic under certain conditions follows a Student's *t* distribution. The *t*-test's most common application is to test whether the means of two populations are significantly different (Shahbaba and Shahbaba, 2012).

The *t*-statistic was calculated using Equation (1)

$$t = \frac{\mu_F - \mu_M}{\sqrt{\frac{\sigma_F^2}{N_F} + \frac{\sigma_M^2}{N_M}}} \quad (1)$$

where μ_F and μ_M denote the means of computed vulnerability indices for the female-avocado and male-avocado farmers, respectively, σ_F^2 and σ_M^2 denote the standard deviations of the vulnerability indices for the female and male avocado farming avocado farmers and N_F and N_M denote the sample size for female and male avocado farmers, respectively. The null hypothesis (H0) for the overall LVI is stated as: H0. There is no significant difference in the means of the livelihood vulnerability index for male and female avocado farmers ($\mu_F = \mu_M$). The alternate hypothesis (H1) for the overall LVI is stated as: H1. There is significant difference in the means of the livelihood vulnerability index for male- and female-headed avocado farmers ($\mu_F \neq \mu_M$). The same hypotheses were tested for all the LVI major components, the IPCC contributory factors and the LVIIPCC. Trend analysis of temperature and rainfall data is done using the Mann Kendal test method.

2.5. Calculating the Livelihood Vulnerability Index (LVI)

There are two main approaches of measuring vulnerability to climate change and climate variability which are the indicator and econometric approaches (Deressa et al., 2009).

Econometrics is the use of statistical and mathematical models to develop theories or test existing hypotheses in economics and to forecast future trends from historical data. This study used the indicator approach in measuring vulnerability of female and male avocado farmers to climate change and climate variability. This method emphasizes on vulnerability indicators-selection, its weight assignment, and aggregation for the vulnerability index development. It can assess vulnerability characteristics of an individual building, and it has the potential to show the relative variation of vulnerability among the houses.

In modeling the vulnerability to climate change by smallholder avocado farming households, the balance weighted approach was employed by computing the LVI as developed by Hahn et al. (2009) and employed by Etwire et al. (2013). The weighting method is based on correctly valuing each indicator in terms of its importance in contributing to making smallholder farmers vulnerable to climate change and variability (Hahn et al., 2009). The approach has been used in various studies. Etwire et al. (2013) used the approach in modeling the vulnerability to climate change to smallholder farmers in Ghana. Mwangi et al. (2020) used the balanced weighted approach to Assess Climate Change Vulnerability of Communities in Kenya. The livelihood vulnerability index is derived for all the three regions of the Southern Highlands of Tanzania, taking into consideration, the Intergovernmental Panel on Climate Change, IPCC definition of vulnerability to climatic impacts. It makes the use of seven major components, namely socio-demographic profile, livelihood strategies, social networks, health, access to food, access to water and natural hazards, and climate change. Each of these components is calculated with different scales; therefore, an index is needed to calculate all the components as a whole. The standardized sub-component equations are given by Equation (2) and (3).

$$Index_{shi} = \frac{S_h - S_{min}}{S_{max} - S_{min}} \quad (2)$$

OR

$$Index_{shi} = \frac{S_{max} - S_s}{S_{max} - S_{min}} \quad (3)$$

where S_h is the observed sub-component of indicator for household and S_{min} and S_{max} are the minimum and maximum values, respectively.

After each is standardized, the sub-component indicators are averaged using Equation (4) to obtain the index of each major component:

$$M_h = \frac{\sum_{i=1}^n Index_{shi}}{n} \quad (4)$$

where M_h is one of the seven major components Socio-Demographic Profile (SDP), Livelihood Strategies (LS), Social Network (SN), Health (H), Food (F), Water (W), or Natural Hazard, or Climate Variability (NDCV) for household h , $Index_{shi}$ represents the sub-components, indexed by I , that make up each major component, and n is the number of sub-components in each major component. Once values for each of the seven major components for a region are calculated, they are averaged using Equation (5) to obtain the region-level LVI

$$LVI_r = \frac{\sum_{i=1}^7 w_{mi} M_{ri}}{\sum_{i=1}^7 w_{mi}} \quad \text{This can also be expressed as}$$

$$LVI_r = \frac{w_{SDP}SDP_r + w_{LS}LS_r + w_H H_r + w_{SN}SN_r + w_F F_r + w_W W_r + w_{NDS}NDS_r}{w_{SDP} + w_{LS} + w_H + w_{SN} + w_F + w_W + w_{NDS}} \quad (5)$$

The method for calculating LVI incorporated the IPCC vulnerability definition by grouping the seven major components under exposure, adaptive capacity, and sensitivity using Equation (6).

$$CF_h = \frac{\sum_{i=1}^n wM_i M_{hi}}{\sum_{i=1}^n wM_i} \quad (6)$$

where CF_h is an IPCC-defined contributing factor (exposure, sensitivity, or adaptation capacity) for household, are the major components for household indexed by M_{hi} is the weight of each major component, and n is the number of major components in each contributing factor.

Once exposure, adaptation capacity, and sensitivity are calculated, the three contributing factors are combined using Equation (7):

$$LVI-IPCC_h = (e_h - a_h) * s_h \quad (7)$$

where, $LVI-IPCC_h$ is the LVI for household h expressed using the IPCC vulnerability framework, e_h is the calculated exposure score for household h (equivalent to the natural hazard and climate variability major component). The climate variability is measured by the average standard deviation in monthly minimum and maximum temperatures and monthly rainfall over a 30-year period which were obtained from Tanzania Meteorological Authority. Also, a_h is the calculated adaptation capacity score for household h (weighted average of socio-demographic, livelihood strategies, and social networks major components), and s_h is the calculated sensitivity score for household h (weighted average of the health, food, and water major components). The $LVI-IPCC$ Index is scaled from (-1) (least vulnerable) to (+1) (most vulnerable).

Given that the computed vulnerability indices are averages, there is a need to test for statistical difference in the means of the LVIs for both gender groups.

3. Results and Discussion

Analysis of livelihoods vulnerability Livelihood vulnerability index consists of

seven main components, namely, Social Demographic Profile, Livelihood Strategies, Health, Food, Water, Social Network and Natural Disaster and climate variability, and each consists of several indicators or sub-component. Each sub-component is measured by different scales that should be standardized to convert it into an index and combine it as a whole with the composite index.

Based on the level of vulnerability classification conducted by [Hahn et al. \(2009\)](#), it is known that the scale of the LVI value is set between 0 and 0.2 (not vulnerable), 0.21 and 0.40 (vulnerable or moderate) and 0.41 and 0.5 (very vulnerable). The results of the calculations for measured variables are shown in the following sections.

3.1. Socio-Demographic Profile

The socio-demographic profile consists of four sub-components as presented in [Table 2](#) and [Figure 2](#). The overall socio-demographic index of female is 0.488 men is 0.460. The proportion of the dependency level for both gender is low at non vulnerable level, where by Female index is 0.163 and Male index is 0.148. The average age of women as family heads is 54 while men is 57. The findings on education levels indicates that, 76.85% of the smallholder farmers in did not attended school. Education levels determine smallholder farmers' ability to acquire and use knowledge and skills on climate change adaptation. Illiteracy limits smallholder farmer's access to information especially from written sources, thereby increasing their susceptibility to climatic stresses.

Table 2. Computed indices for socio-demographic profile.

Component	Sub-component-index	
	Female	Male
Dependency level	0.163	0.165
Average age of Avocado household heads	0.543	0.572
Percentage of avocado small holder farmers who did not attended school level	0.763	0.754
Percentage of avocado small holder farmers with orphans	0.482	0.430
OVERAL (LVI)	0.488	0.460

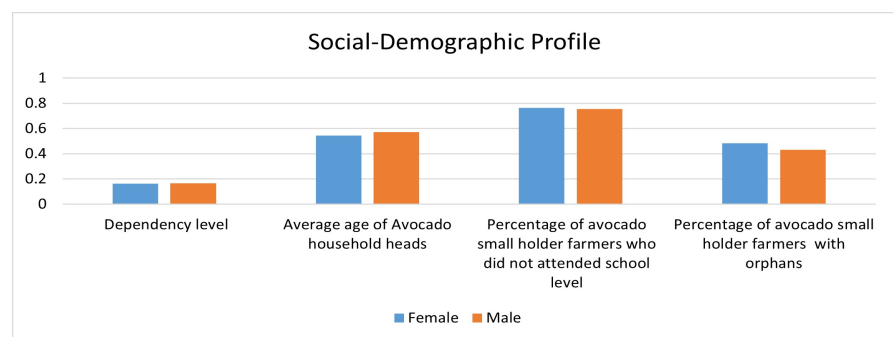


Figure 2. Socio-demographic profile.

3.2. Livelihood Strategies

Livelihoods are the strategies that people use to utilize, and transfer assets to produce income today and deal with problems tomorrow. These strategies change and adapt in response to various shocks, external influences, norms and rules, and other factors. The livelihood strategy index for Women avocado farmers is 0.352, while for men is 0.330. The computed vulnerability indices showed that female small holder farmers 0.397 were more vulnerable in terms of land ownership than male 0.240, with 39.7% of female not owning their farms relative to 24% male. 45.4% of female owns less than 5 hectares of land while men 28.5% owns a farm less than 5 hectares. This finding correlates with Swai and Ubaldus (2023), who reported that during interview one among respondents stated that:

“Most of plot lands for the household are owned by man so all costs of operations in the avocado farming are done by men”. The findings also shows that 11% of women smallholder farmers have employed more than 5 employees in their avocado farms, and men 57.9% these obstacles hinders women to adapt to climate change crisis. As described in **Table 3** and **Figure 3**, women farmers have limited rights than men, low income, less access than men to resources, land ownership authorities. Consequently, they are significantly more vulnerable to the impacts of climate change and have fewer capacities to adapt to climate change effects.

Table 3. Computed indices for livelihood strategies.

Livelihood-Component	Sub-component-index	
	Female	Male
Percent of Avocado smallholder farmers who do not own land	0.397	0.240
Average avocado livelihood diversification	0.125	0.125
Percentage of small holder farmers who solely dependent on agriculture as source of income	0.674	0.423
Percentage of avocado farmers who does not own more than 5 hectares	0.454	0.285
Percent of smallholder farmers who have employed more than 5 employees in their avocado farms	0.110	0.579
Overall LVI	0.352	0.330

The result of the focus group discussion revealed that, besides avocado farming women also engage in horticulture, beans, sunflower, sweet potato, paddy, millet, tomatoes, cashew nuts, and men are engaged in tree planting and timber production, bee keeping, cattle, poultry, casual labor and masonry works and employed. A livelihood strategy is sustainable when the community can cope with and recover from stresses and shocks and maintain its capabilities and assets both now and in the future, while not undermining the natural resource base.

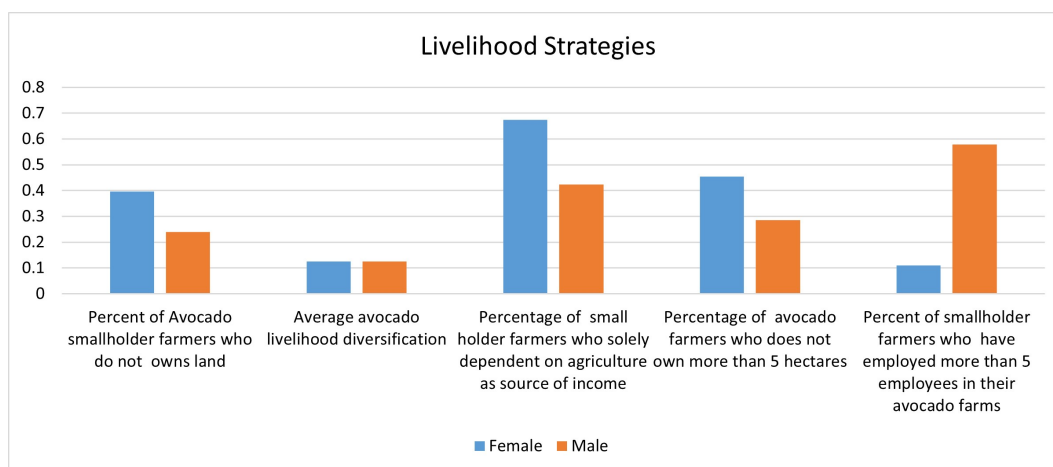


Figure 3. Livelihood strategies.

3.3. Social Networks

Social networks can help to conceptualize the role of informal information channels in determining if and how Climate information reaches certain groups. The third indicator is social networks which consists of four sub-components as described in **Table 4**. Men are found to be the most vulnerable with index of 0.586 in terms of social networking. It was also reported that the both men (89%) and female (98%) does not receive help from government as seen in **Figure 4**. Help is usually in the form of money, grants, seeds, fertilizers and marketing among others. During interview and group discussion, women reported that they receive support from NGOs which supports women farmers and women groups, they get loans from Village Community Banks and development bank loans. Most farmers are more comfortable soliciting assistance from friends and relatives than from local authorities. In resource-dependent communities, social networks are important sources of climate change information that led to group innovation (Rotberg, 2013) and livelihood diversification strategies (Antwi-Agyei et al., 2014).

Good social networking mostly lessens the impact of climatic stresses on individual households.

Table 4. Computed indices for social networks.

Component	Sub-component-index	
	Female	Male
Percentage of smallholder solely dependent on Avocado as source of income	0.464	0.523
Percentage of livelihood activities in addition to Avocado as a source of income	0.461	0.483
Percentage of Avocado farming households did not receive help from Government	0.987	0.895
Percentage of Avocado farming households receiving salaries	0.230	0.456

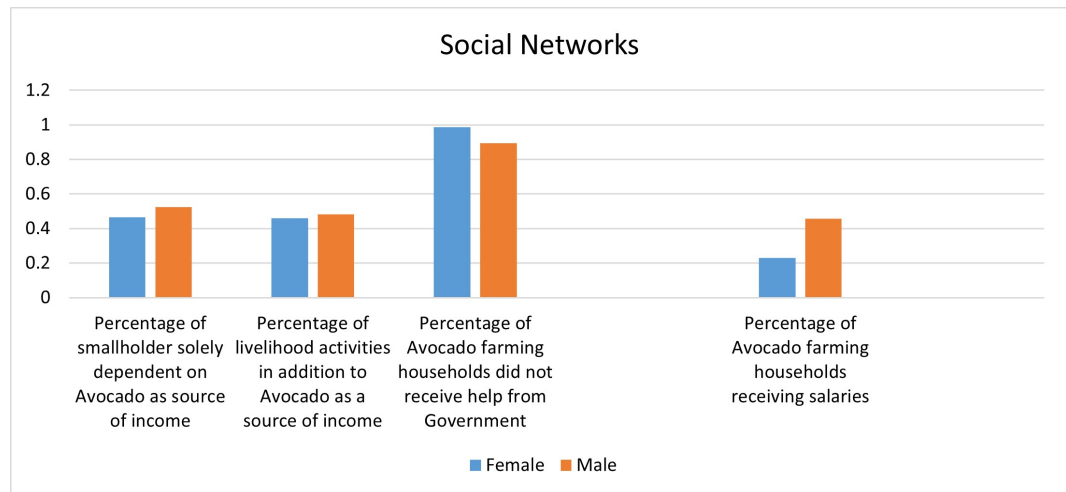


Figure 4. Social networks.

3.4. Water

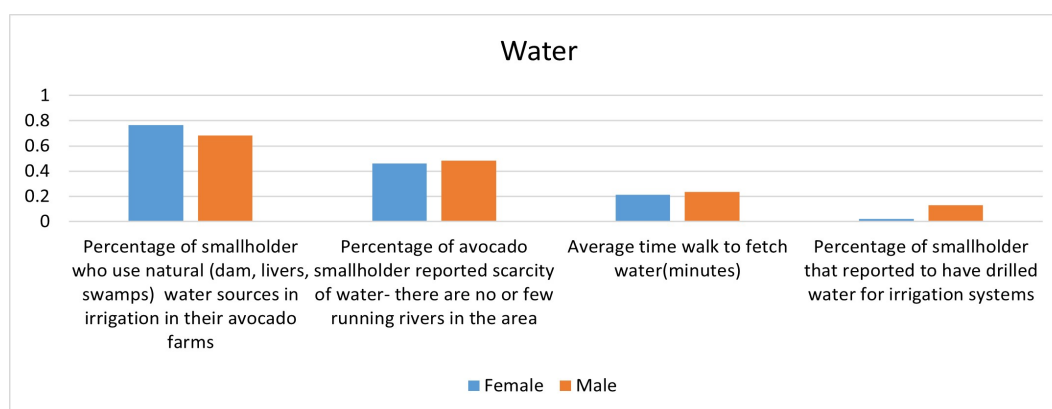
Changes in the quantity, timing, intensity and duration of rainfall as a result of climate change contributes to greater water stress and making people more vulnerable (Mwakalila, 2011). The fourth major component of the LVI is water, and it consists of four sub-components as described in Table 5 and Figure 5. Regarding the source of water, 76.6% of female and 68.4% of men reported natural sources of water are streams, wells, rain, and rivers. About 46% and 48.4% of female and male respectively, reported scarcity of water. The average times to a source of water by female and male 12 and 13 minutes, respectively. This suggests that men travel farther for water than women. Almost 60 percent of both male-headed and female smallholder farmer shave no consistent source of water. When all the five sub-components indices were averaged, female smallholder farmers were significantly more vulnerable to the water major component (LVIW = 0.511) than male smallholder farmers (LVIW = 0.449). It was revealed during the focus group discussions that water fetching for household use is the sole responsibility of women. Men, on the other hand, fetch water form construction, especially building a house, and also for watering and bathing of animals. While women often source water from boreholes, rains, dam and well, men often go to the river, dam and spring for water. The reason from the focused group discussions was that men have bicycles and motor bikes which they can use to go to fetch water at distant places than women. Also, the uses of the water fetched by men do not need to be very clean and pure compared to the water fetched by women, which is used for drinking and cooking.

Table 5. Computed Indices for water.

Component	Sub-component-index	
	Female	Male
Percentage of smallholder who use natural (dam, rivers, swamps) water sources in irrigation in their avocado farms	0.766	0.684

Continued

Percentage of avocado smallholder reported scarcity of water—there are no or few running rivers in the area	0.460	0.484
Average time walk to fetch water (minutes)	0.212	0.235
Percentage of smallholder that reported to have drilled water for irrigation systems	0.021	0.130
Overall LVI	0.365	0.383

**Figure 5.** Water indices.**3.5. Food**

The Food major component is made up of three sub-components. From **Table 6** the computed vulnerability indices and the two-sample t-test showed that female were more vulnerable to food (0.523) than male 0.397. Both male and female attained average Avocado diversity index of 0.335. About 55.4% of female and 20.2% men avocado farmer's struggle to obtain food. The number of households struggle to find food was found to be higher for women as shown in **Figure 6**. The results of the focus group discussion showed that women often cultivate on small scale and very close to their house where the lands are not fertile and have been abandoned to fallow. The result is often that the farm outputs of women are usually low, in which they are unable to depend on for the entire year, making female more food-insecure than male. Food security enhances household's resilience to external stresses including extreme climatic events.

Table 6. Computed indices for food.

Component	Sub-component-index	
	Female	Male
Percentage of small holder famers dependent on family farm for food	0.535	0.413
Percentage of avocado farmer's that struggle to obtain food	0.424	0.202
Percentage of household who do Intercropping	0.584	0.442
Overall LVI	0.514	0.351

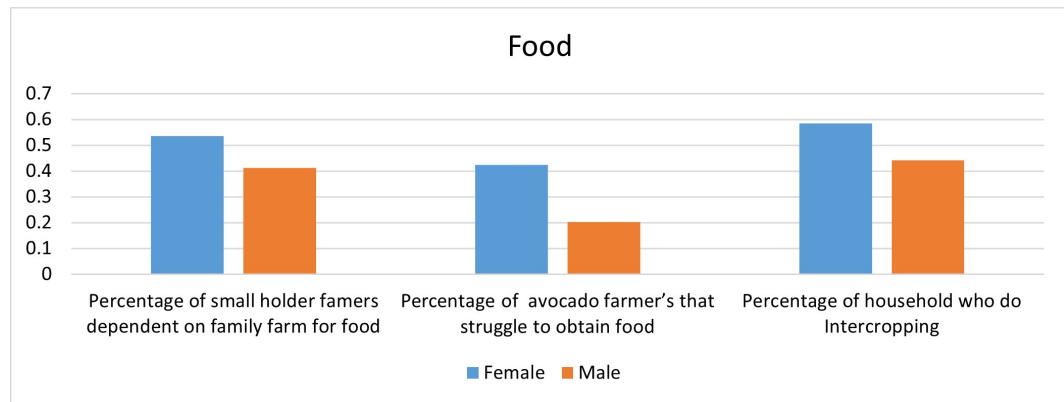


Figure 6. Food indices.

3.6. Health

The sixth indicator is Health. The computed indices of health from **Table 7** shows that male small holder famers with LVI = 0.250 appeared to be significantly more vulnerable than female small holder famers with LVI = 0.268 in terms of the health major component of the LVI, and the two sample t-test. The average time male spend in reaching health facilities is 30 minutes more time than female who spent 20 minutes. In terms of Malaria prevalence, Male were more vulnerable in terms of average malaria exposure of 0.321 than female with index value of 0.28. However, 32% of both men and female reported lack health centers as shown in **Figure 7**. Inadequate access to health services tends to decrease the health status of smallholder farmers, thereby increasing their vulnerability to extreme climatic events. The results correlate with that of **Kangalawe (2012)** who stated that temperatures have steadily increased over the last forty to fifty years, and are closely associated with increasing prevalence of malaria and other health risks as confirmed by existing hospital records in the Southern Highlands of Tanzania.

Table 7. Computed indices for health.

Component	Sub-component-index	
	Female	Male
Average time to health facility by foot	0.142	0.162
Percentage of smallholder who report lack health centers	0.320	0.320
Average exposure to Malaria prevalence	0.287	0.321
Overall LVI	0.250	0.268

3.7. Natural Disasters and Climate Variability

When all the seven major components of the LVI were aggregated from **Table 8** and **Table 9**, female farmers with an overall LVI of 0.430 were considered to be more vulnerable to climate change and variability than male smallholder farmers with an overall LVI of 0.410. Based on the computed vulnerability contributory factor indices in **Table 11**, female smallholder farmers were more vulnerable to

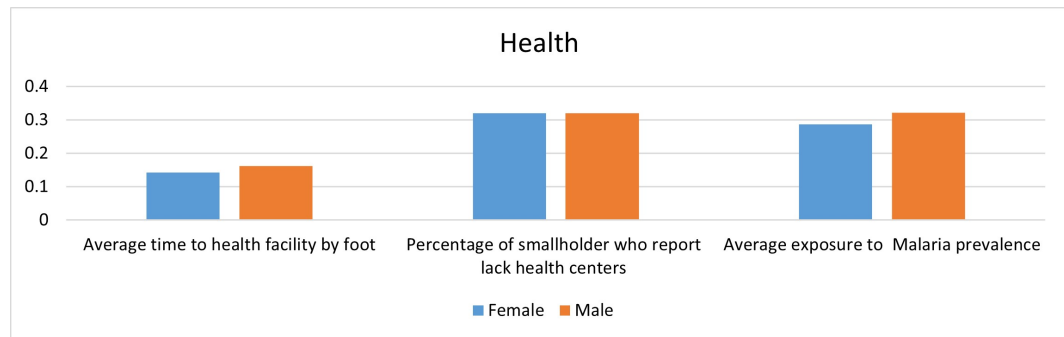


Figure 7. Health Indices.

adaptive capacity = 0.463 than male smallholder farmers with 0.456 in adaptive capacity. Yet, female smallholder farmers were more sensitive to climate change and variability (With LVI = 0.375) than male smallholder farmers = 0.339. Both male—smallholder farmers LVI = 0.470 and female smallholder farmers LVI = 0.481) were vulnerable in terms of exposure to climate change and variability. This is because they were within the same geographical location and experience similar climatic conditions. The computed LVI IPCC indicates that female were more vulnerable to climate change and variability (LVI IPCC = 0.00685) than male smallholder farmers LVI IPCC = 0.00475 as shown in **Table 11**. The results of the independent two-sample student t-test revealed a significant difference at 1% significant level between the computed LVIs of the female-headed and male smallholder farmers (**Table 10**). The computed vulnerability indices of the major components of the LVI and the overall LVI for female-headed and male smallholder farmers are presented in **Figure 10**.

The findings from this study as shown in **Table 8** indicates rainfall decline to be the major indicator of the changing climate as pointed out by 87.7% of female respondents. Decreased rainfall was explained based on rainfall duration, intensity and intervals. During the interviews, smallholder farmers emphasized on the increased intensity of rainfall decline and temperature increase as compared to the past 15 to 30 years. Temperature increase and rainfall decline were linked to frequent crop failure and drought incidences as it was reported by **Kangalawe, 2012; Mlengule, 2019** that long term climate records for the southern highlands of Tanzania confirm that the climate of the region is changing. The results of the two-sample t-test revealed that there is no significant difference in the indices of natural disasters and climate change major component of the LVI. This study discussed only components with significant difference in the computed indices for male avocado smallholder farmers and female avocado smallholder farmers. Farmers in Iringa, Njombe and Mbeya regions generally concurred that in the 1980s it was easy to predict the coming season and the seasons were distinct but now the rains have become more and more unpredictable. Moreover, they also highlighted that now they are experiencing shorter rain seasons than before. Rains would start from October and stretch up to May but now rains are coming late around November or December and in most cases ending around March.

Effective adaptation and disaster risk reduction measures are needed to reduce the economic and social impact of natural disasters, including extreme climate events, on agriculture and rural areas including, the adoption of new stress tolerant varieties and enhancing technologies that minimize the risk of crop losses.

Table 8. Computed indices for natural disasters.

Component	Sub-component-index	
	Female	Male
Percentage of smallholder who feel the pattern of weather is generally changing	0.862	0.857
Percentage of smallholder who think that climate change is affecting or going to affect avocado production	0.840	0.857
Percentage of smallholder who are currently experiencing high temperatures	0.302	0.280
Percentage of smallholder who are currently experiencing more rainfall	0.112	0.09
Percentage of smallholder who are currently experiencing drought	0.798	0.792
Percentage of smallholder who perceive other climate stressors among avocado farmers	0.210	0.180
Mean, standard deviation of monthly average minimum daily temperature (years: 1984-2014)	0.341	0.341
Mean, standard deviation of monthly average maximum daily temperature (years: 1984-2014)	0.732	0.732
Mean, standard deviation of monthly average precipitation (years: 1984-2014)	0.128	0.128
Overall LVI	0.481	0.470

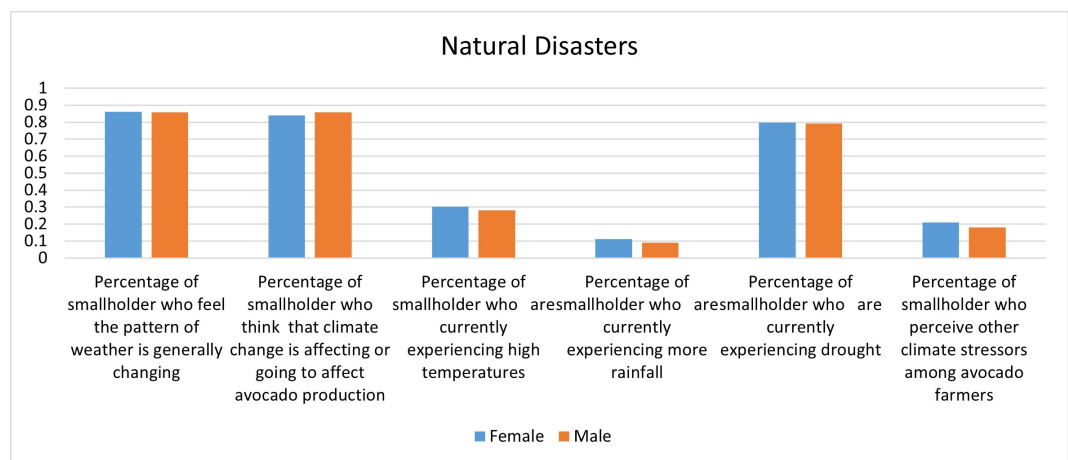


Figure 8. Natural disaster indices.

With regards to temperature, farmers in Mafinga district -Iringa region when interviewed witnessed that temperatures have become hotter than before. The

computed LVI for Natural disasters shows that 30% of female smallholder are experiencing high temperatures while men are 28% as shown in **Figure 8**. The findings also from this study as shown in figure indicates that farmers are experiencing drought to be the major indicator of the changing climate as pointed out by 79.8% of females and 79.2% by men. Specifically, they reported that for the past five years, while the duration of the summer season has remained consistent, that is between June and October, the highest temperatures have been witnessed for an extended period from July to November and sometimes in December with high winds accompanied with dusts.

Rainfall data from Tanzania Meteorological Agency from 1984 to 2014 for the Njombe, Iringa and Mbeya were also fitted Linear Regression model (LR) using R software to test for trend, the following are the results in **Table 10**.

Table 9. Computed indices major component and t-tests results.

Major Component Index Value	Major Component Index Value		Two Sample t-test	
	Female	Male	t-test	P-value
Socio-demographic profile	0.488	0.48	3.18	0
Social networks	0.536	0.589	3.161	0.005
Livelihood strategies	0.352	0.33	2.776	0.008
Food	0.514	0.351	4.303	0.005
Water	0.365	0.383	-0.26	0
Natural disasters	0.481	0.47	2.36	0.008
Health	0.25	0.268	4.302	0
OVERAL (LVI)	0.43	0.41	19.822	0.026

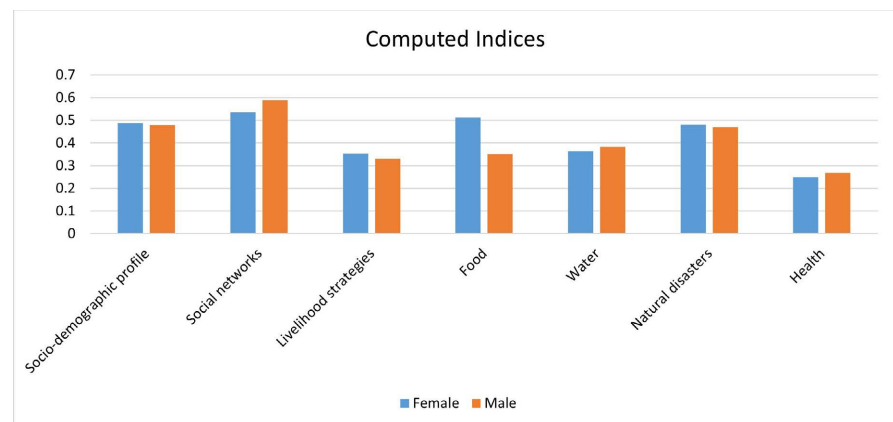


Figure 9. The summary of the computed indices by gender.

Table 10. Rainfall and temperature trends.

Weather Station	Rainfall-trend	T-dry, °C	T-Max, °C	T-Min, °C	P-value
Iringa	-1.619	0.023	0.018	0.016	0.542
Njombe	-3.051	0.017	0.002	0.016	0.573
Mbeya	-0.251	0.017	0.014	0.017	0.532

T-dry-means dry air temperature, T-Max—maximum air temperature, T-min—Minimum air temperature. The results show positive significant trend of maximal air temperatures for all regions (Iringa, Njombe and Mbeya) weather stations. As well dry air temperature and minimal air temperature also shows similar positive trend. The results on rainfall analysis indicate insignificant decreasing trends ($p = 0.542$, $p = 0.573$ and 0.532) at 5% significance level for Iringa, Njombe and Mbeya stations, respectively.

The research findings on temperature and rainfall decrease and slightly increase tally with what is reported by (Kangalawe, 2012; Luhunga, 2017; Mkonda & He, 2018) in Tanzania, who also noted declining and increasing rainfall trends in their study areas.

The results of all the seven major components are summarized in Figure 9. The vulnerability spider diagram as shown in Figure 10 ranges between 0 (least vulnerable) and 0.6 (most vulnerable). Female small holder farmers were most vulnerable in terms of socio-demographic profile, livelihood strategies, food, water and natural disasters and climate variability while men were most vulnerable in terms of health and social network.

Table 11. Contributing factors.

Contributing factors	Major components	Factor value		Computed index	
		Female	Male	Female	Male
Adaptive Capacity	Socio-demographic profile	0.488	0.460		
	Social networks	0.536	0.589	0.463	0.456
	Livelihood Strategies	0.352	0.330		
Sensitivity	Health	0.250	0.268		
	Food	0.514	0.351	0.375	0.339
	Water	0.365	0.383		
Exposure	Natural Disasters	0.481	0.470	0.481	0.470
Final IPCC weighted LVI scores				0.00675	0.00475

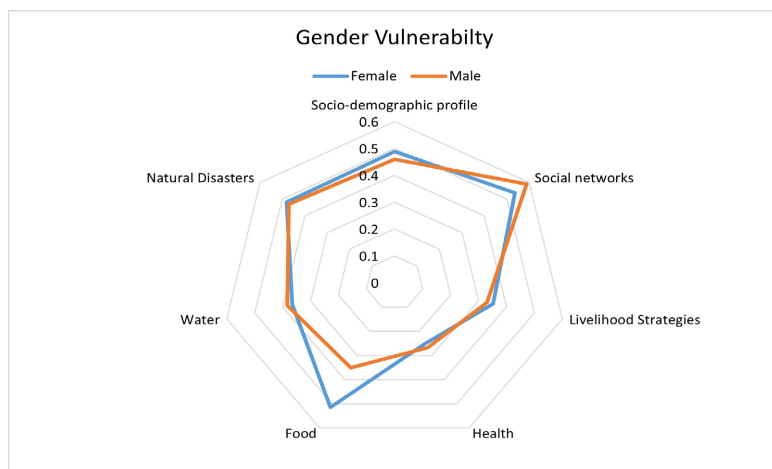


Figure 10. Gender vulnerability radar diagram.

From;

$$\text{Adaptive Capacity} = \frac{\sum_{i=1}^n wM_i M_{hi}}{\sum_{i=1}^n wM_i} = \frac{4(0.488) + 4(0.536) + 5(0.352)}{4 + 4 + 5} = 0.463_{\text{Female}}, 0.456_{\text{Male}},$$

$$\text{Sensitivity} = \frac{\sum_{i=1}^n wM_i M_{hi}}{\sum_{i=1}^n wM_i} = \frac{3(0.250) + 4(0.365) + 3(0.514)}{4 + 3 + 3} = 0.375_{\text{female}}, 0.339_{\text{Male}}$$

$$\text{Exposure} = \frac{\sum_{i=1}^n wM_i M_{hi}}{\sum_{i=1}^n wM_i} = \frac{9(0.481)}{9} = 0.481_{\text{Female}}, 0.470_{\text{Male}}$$

Livelihood Vulnerability Index Intergovernmental Panel on Climate Change approach

Livelihood vulnerability index/LVI-IPCC is a measure of vulnerability of Avocado small holder farmers in disaster-prone areas with three measurement indicators, namely, exposure, sensitivity and adaptive capacity. The formula LVI calculation formula based on the IPCC is:

$$\text{LVI-IPCC}_h = (e_h - a_h) * s_h = (0.481 - 0.463) \times 0.375 = 0.00675, 0.00475$$

The LVI IPCC estimates for the female avocado farmers and Male avocado small holder farmers are 0.0067524 and 0.00475 respectively. This implies that overall, in terms of climate change and variability, Female avocado small holder farmers are more vulnerable as compared to male counterparts. The results in this study revealed that both male and female avocado farmers were vulnerable to the effects of climate change and variability, but the vulnerabilities varied with gender. The results of the current study are also consistent with previous research regarding households' vulnerability to social capital, human capital, and natural hazards within the context of the various livelihood frameworks (Boniphace et al., 2023; Malekela, 2022; Swai and Ubaldus, 2023).

This finding is consistent with the that of Boniphace et al., 2023, who revealed that smallholder producers had positive perceptions about the effects of avocado production on livelihoods and biodiversity in Hai and Rungwe Districts, Tanzania; by Kabote, 2018, indicates that women, elders, children and sick people are more exposed to climate change effects than other groups due to low adaptive capacity and by Myeya, 2021, Bongole et al., 2020 and Gebre et al., 2023, who reported that semiarid areas of Tanzania to be more vulnerable to the changing climate than other parts of the country.

4. Conclusion

The results in this study revealed that both male and female avocado farmers were vulnerable to the effects of climate change and variability, but the vulnerabilities varied with gender. The result of this study is also consistent with previous

research regarding households' vulnerability to social capital, human capital, and natural hazards within the context of the various livelihood frameworks.

This study showed that male and female smallholder farmers perceive climate change differently, and have different experiences and varied levels of adaptation practices. Although men have access and control over tangible asset-based resources more than women in the study area. Women had more access to intangible yet strategic asset-based resources that included basic knowledge and skills, as shown in the gender perceptions of climate change. The females have gender roles like fetching water for household chores, taking and firewood for cooking connected closer to nature. The study concluded that females' perception of climate is quite different from that of male farmers and that it is playing a crucial role in their inability to adapt. Also, male farmers had more access to land than females in the study area. Females who cultivated smaller plots around their homesteads had more knowledge and information that could govern their lands than males. Therefore, there is a need for policymakers to integrate gender into the distribution of climate finance to help smallholder farmers respond to adapt appropriately. This study concludes that there is a need for better gender-sensitive approaches to adaptation planning and implementation to ensure that both men and women have equal opportunities to benefit from adaptation options in agriculture

Gender-responsive adaptation strategies are crucial to address these vulnerabilities. Empowering women through access to education, leadership positions, training, and resources can enhance their resilience. Encouraging women's participation in decision-making processes ensures that their unique knowledge and needs are incorporated into adaptation planning. Implementing climate-smart agriculture techniques, such as drought-resistant crops, irrigation systems and water-saving technologies, can benefit both women and men. Addressing this variation requires best approaches that integrates scientific climate data with indigenous knowledge and local observations. Encouraging communication between farmers, researchers, and policymakers can enhance understanding and adaptation strategies. Additionally, empowering women in agriculture by recognizing their unique insights and challenges is crucial for comprehensive climate change adaptation and mitigation efforts.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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