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Vulnerability of Horticulture Producers to Climate Variability and Change: The Case of Chókwe District, Mozambique

ACDI MINOR DISSERTATION

MSc in Climate Change and Sustainable Development

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Declaration

I declare that the dissertation that I hereby submit for the degree of MSc in Climate Change and Sustainable Development at the University of Cape Town, Department of Environmental and Geographical Science, is my own work and has not previously been submitted by me for a degree at another university or institution of higher education. I also certify that no plagiarism was committed in writing this dissertation.

Signature:

Delfim Júlio Vilissa

February, 2016

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BM	Bank of Mozambique
CCAFS	Climate Change Agriculture and Food Security
CEPAGRI	Centre for Promotion of Agriculture
CIS	Chókwe Irrigation Scheme
CPL	Limpopo Producers Savings and Credit Cooperative
EKN	Embassy of the Kingdom of the Netherlands
FAO	Food and Agriculture Organization of the United Nations
FEWSNET	Famine Warning Systems Network
GOM	Government of Mozambique
HICEP	Public Hydraulic Company of Chókwe
IAC	Agrarian Institute of Chókwe
IFAD	Fund for Agricultural Development
IIAM	National Institute for Agricultural Research
INGC	National Institute for Disaster Management
IIAM	Mozambique Institute of Agrarian Research
INAM	Mozambique National Institute of Meteorology
IPCC	Intergovernmental Panel on Climate Change
ISPG	High Polytechnic Institute of Gaza (ISPG)
ISDR	International Strategy for Disaster Reduction
JICA	Japanese International Cooperation Agency
MASA	Ministry of Agriculture and Food Security
MICOA	Ministry for the Co-ordination of Environmental Affairs
NAPA	National Adaptation Programme of Action
PROSUL	Pro-poor value chain development in the Maputo and Limpopo corridors
UNISDR	Disaster Risk and Resilience of the United Nations
USAID	United States Agency for the International Development
WB	World Bank

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Abstract

Climate change is projected to have continued and globally severe environmental, economic and socioeconomic effects. These effects are forecast to be more severe in the agriculture sector, considering that it is one of the most sensitive industries to climate change. Studies from the Mozambican National Institute for Disaster Management (INGC) suggest that Mozambique is among the countries highly vulnerable to climate change due to its geographical location, in the coastal zone. In addition, the majority of its population is entirely dependent on agriculture activities for food and income. For example, in the Chókwe district, tomato production plays a key role in farmers' livelihood; however, this district is prone to weather variability and climate stresses, affecting the region's agricultural performance and making farmers' livelihood even more precarious. There is indeed limited information on this vulnerability, how farmers cope with the risks as well as their need to manage these stresses. The study conducted includes a survey of 43 farmer households in two villages of Chókwe: Massavasse and Muianga. The study then compares farmers' perceived effects of climate variability with actual climate data observed between 1980 and 2012. Meteorological data was analyzed using R software. The findings revealed that tomato producers are vulnerable to climate stresses such as floods, extreme rainfall and temperatures, and pests and diseases, which all have a significant impact on farmers' livelihood, socioeconomically. In order to curb the effect of these challenges, farmers rely on other sources of income, such as *xitique,* poultry sales, off-farm works, reed sales and livestock sales. Farmers implement tactical and strategic adaptation techniques, including sowing along river beds and under shady trees, covering the surface of soil with the husk of rice, changing seed varieties, changing harvesting and delivery times, increasing use of water and pesticides, cleaning and opening drainages to dissipate water. Although farmers use a variety of coping strategies, the above-mentioned are often ineffective in responding to climate stresses. This is due to several reasons: inefficient technology to improve drainage and irrigation systems, lack of reliable climate information, low extension services, inability to access credit services, and various market barriers. Therefore, this study recommends several measures that could enhance farmers' resilience to climate stresses. These adaptive strategies include improving farmers' access to financing services, using mulching techniques, introducing drip irrigation and vertical drainage, the use of shade cloths, the improvement of road networks, promoting drought tolerant varieties, and introducing biological control and agroforestry technics. Implementation of these

strategies needs strong coordination of all stakeholders, including farmers, government and research institutions.

1. Introduction

The fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC 2014) projects rising temperatures and changing precipitation patterns in many regions of the globe. For the Southern Africa region, projections for the end of the 21st century indicate an increase in intensity and frequency of extreme weather events, including rising temperature (at least 3.4 - 4.2°C), shifting precipitation patterns, and the occurrence of floods and cyclones. These changes are predicted to cause substantial challenges to agricultural production and related processes due to the fact that the agriculture sector is highly dependent on land and natural resources, which are very sensitive to climate stresses.

The impact of climate stresses in Mozambique is already manifesting. According to the National Institute for Natural Disaster Management (INGC), the country is extremely vulnerable to climate shocks due to its geographical location and the weak socio-economic development of its population (INGC, 2011). The country lies along an inter-tropical zone that has high vulnerability to changes in weather and climate. Therefore, Mozambique is cyclically hit by floods, heavy precipitation, warmer temperatures, tropical cyclones and other related events of an extreme nature (INGC, 2009; INGC, 2011). In fact, the country ranks third on the African continent as the most exposed to risks from multiple weather-related hazards (WB and ISDR, 2009), closely following Ethiopia and Ghana. Consequently, Mozambique's agricultural performance is occasionally, and substantially so when it is, affected by climate changes, which resultantly reduces the country's food security and economy (WB, 2010; FAO, 2012). This is because 80% of its inhabitants are heavily reliant on agriculture for their livelihood (BM, 2014).

For instance, in the Chókwe district, the agricultural performance is cyclically affected due to climate stresses. According to Embassy of the Kingdom of the Netherlands (EKN) report, Chókwe is the most important horticulture producing region in Southern Mozambique, including three provinces: Gaza, Inhambane and Maputo (EKN, 2014). Tomatoes play a key role in the farmers' livelihood since it is one of the most important sources of income and food. However, tomato, similarly with other crops in the region, is threatened by weather and climate variability. Chókwe lies along the Limpopo River Basin which is highly vulnerable to warmer temperatures, floods and changes of precipitation patterns (Mendelsohn, 2009; FAO 2012). The Limpopo basin ranks as the most vulnerable to floods among Mozambique's five river basins, including Umbelúzi, Incomati, Buzi and Save (NAPA, 2007). A 2003 INGC Report indicates that between 1953 and 1994, a total of 51 years, the district of Chókwe was hit by floods in almost half the years, precisely 20 years. Furthermore, tomato crops are very sensitive to changes in temperature, waterlogged soils, and pests and diseases (Pressman *et al.,* 2002; Camejo *et al.,* 2005). Therefore, even the slightest of change in climate patterns can result in the loss of crops, or a decreased crop yield or crop quality (Camejo *et al.,* 2005). In fact, tomato production in Chókwe fluctuates according to the season (EKN, 2014). Production is particularly high during the fresh season, between March and August; whereas during the hot season, from September to April, production falls. Thus, tomato horticultural production cannot be considered a stable and reliable income to farmers throughout the year.

Despite the broad scientific debate concerning the impact of climate change in Mozambique's agriculture industry, there is limited information on farmers' vulnerability to different agricultural risks. Recent studies in Mozambique (e.g. Hahn *et al.,* 2009; Artur and Hilhorst, 2012; Salazar-Espinoza *et al.,* 2015) uncovered important aspects of how climate risks affect each stage of crop production, how local communities adapt their activities in response to those shocks and what adaptation measures are needed to reduce farmers' vulnerability to these.

Due to the present lack of information, it is possible that future risks are underestimated, thus leading to the adoption of policy that is inadequate. As noted by Bryan *et al.* (2013, p 27) "*A better understanding of farmers' perceptions of climate change, ongoing adaptation measures, and decision-making process is important to inform policies aimed at promoting successful adaptation measures of the agricultural sector*". Therefore, the present study examined how smallholder farmers in the Chókwe district's Massavasse and Muianga villages perceive climate changes as well as the implication of these climate-related risks in agriculture production, livelihood, existent coping measures and farmer needs.

1.2 Contextualization within larger project

This study is in line with the National Adaptation Programme of Action (NAPA) launched by Ministry for the Co-ordination of Environmental Affairs (MICOA) in 2007, of which one of its specific objectives seeks to develop the capacity of Mozambican farmers to better deal with climate change and variability. The research is also associated with an important project in which the Mozambique government, through the Ministry of Agriculture and Food Security (MASA), is working with the International Fund for Agricultural Development (IFAD) in implementing a project called PROSUL (Pro-poor value chain development in the Maputo and Limpopo corridors) in South Mozambique, including Maputo, Gaza and Inhambane Provinces. The project aims to increase production and productivity of three value chains: cassava, red meat and horticulture. In addition, the project intends to provide 20,350 smallholder farmers with climate change-related decision support, climate information, as well as assistance in identifying low-cost production techniques. Therefore, it is expected that insights from this research will serve the PROSUL project in contributing to building adaptive capacity among horticulture producers in the three provinces of Southern Mozambique, as they are already facing challenges in coping with climatic stresses.

2. Research aim and objectives

This study seeks to understand climate vulnerability among horticulture producers in Mozambique's Chókwe district. In doing so, this study will identify climate-related risks at each stage of the tomato production process as well as analyze the efficacy of adaptation strategies developed to respond to these risks.

To this end, this study will:

i. Describe the horticultural cycle of tomatoes;
ii. Determine how weather and seasonal climate impact on each stage of production, based on farmers' personal experiences (exposure);
iii. Identify the physical and socio-economic consequences of climate impact at each stage of production over the farming period (sensitivity);
iv. Identify strategies used to manage the risks associated with each stage of production over the farming period (coping/adaptive capacity), as well as farmer's further suggestion;
v. Assess the efficacy of these coping strategies.

3. Literature review

3.1 Vulnerability to Climate Change

According to a 2014 IPCC report, climate change vulnerability is defined as "*the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change*" (p. 883). Climate change vulnerability is dependent on three components, namely: the extent to which the system is exposed, its sensitivity and its capacity to adapt. Thus, agricultural vulnerability to climate change can be defined as "*the function of characteristics of climate variability, magnitude, and rate of variation within the agricultural system, and the system's sensitivity and adaptive capacity, and it is the degree to which the agricultural system is susceptible to, or unable to cope with adverse effects of climate change including climate variability and extreme events*" (Tao *et al.,* 2011, p. 205).

According to Adger (2006), exposure is the degree and duration to which a system experiences stresses resultant from the changes in the climate system; stresses such as changes of temperature and precipitation patterns. However, the level of exposure depends on several aspects, like the frequency of a climate hazard, its intensity, duration, and the system's geographical location. Thus, for example, a system located in lower lands is more exposed to floods than one in upper lands. In the same way, if a certain community is frequently hit by climate stresses it is considered more exposed to that hazard than others who are hit with less frequency. Conversely, sensitivity is the degree to which a system is modified or affected by the climate system, either adversely or beneficially (IPCC, 2007). Such effects on a system can be direct or indirect. For example, decreasing crop yields as a consequence of warmer temperatures is regarded a direct impact; while damage to properties due to floods is considered an indirect impact. Therefore, sensitivity is a prompt reaction of a certain system to any changes of the climate system (Adger, 2006).

Lastly, adaptive capacity is defined as "*the ability (or potential) of a system to adjust successfully to climate change (including climate variability and extremes) to: (i) moderate potential damages; (ii) take advantage of opportunities; and/or (iii) cope with the consequences*" (IPCC, 2014, p. 1251). Adaptive capacity depends mainly on three aspects: human behaviour, availability of resources, and the ability of a system to use those resources effectively to curb climate-related impacts (Adger *et al.,* 2007; Brooks and Adger, 2005). However, other researches emphasize the importance of governance for the success of an adaptation capacity (Smith and Pilifosova, 2001; Engle, 2011). Moreover, adaptive capacity is indicated to be linked to socio-economic considerations, including education, income and health. For example, a number of findings associate increased adaptive capacity with a higher educational level (Deressa *et al*., 2009). Wealthier members of communities are more likely to use resources such as money in attempts to curb the impact of climate stresses, unlike poorer members who typically do not have access to such. Thus, lower levels of adaptive capacity in poor communities can be associated with elevated rates of poverty among its people (IPCC, 2012).

3.2 Farmer adaptation to climate change

A number of coping measures used by farmers in response to climate change have been reported on (e.g. Baudoin, 2013; Bryan et al. 2012; Debela et al. 2015; Gbetibouo 2009; Kihupi et al., 2015; Moyo et al. 2012; Osbahr et al. 2007 and Sanfo et al., 2014). Farmer adaptation to climate encompasses three dimensions: tactical adaptation, strategic adaptation, or both (Smit and Skinner, 2002). Tactical adaptation refers to adjustments made within seasons to deal with climate stresses in the short-term (e.g. selling of livestock, borrowing money, taking out a bank loan); while strategic adaptation encompasses arrangements in place to cope with challenges in the long-term (e.g. changing crop varieties, use of insurance, amendments in land use) (ibid). Apart from the timing of the climate stresses, an adaptive measure is also dependent on socioeconomic aspects such as gender, financial capacity, level of education and extent of agricultural knowledge (Fosu-Mensah *et al*., 2012).

A number of researches argue that the gender of the head of the household is crucial in taking an adaptive measure to deal with climate stresses; however, it remains unclear whether males adapt better than females or vice versa. For example, Bryan *et al.,* (2012) found that in Kenya, male-headed households took better decisions to deal with water stresses to feed livestock. These farmers were able to change livestock feeds. The authors supported this finding with the belief that as men are more experienced in such activities, they had more abilities to purchase animal supplemental feed. It was also found that male-headed households could better adapt because they typically have more access to alternative source of feed which can be used to overcome the climate stresses. Based on my personal experience poverty is connected to gender. Female-headed households in general have lesser economic power, thus less capacity to buy inputs in order to cope with climate stresses. Conversely, Nhemachena and Hassan (2007) found that female-headed households in South Africa were more likely to take better decisions regarding adaptive measures than their male counterparts as women do much of the agricultural work in rural communities. As a result, women have more experience in farming and dealing with climate stresses than males. Moreover, they have more network connections (for example friends) that help them to uptake various agricultural management practices. Therefore, they are able to take more effective measures in anticipating changes of climate variability.

Agricultural knowledge is vital to farmers' adaptation to climate stresses (Bryan *et al.,* 2012; Fosu-Mensah *et al.,* 2012). For example, Bryan *et al.,* 2012 found that livestock farmers who received field visits from the extension services adapted better than those that received few visits. The reason is that the extension officers encourage farmers on adopting new technologies to deal with agricultural constraints (Fosu-Mensah *et al.,* 2012). Extension officers are representative of public or private institution and are responsible for providing farmers with agricultural knowledge. The extension officers are not always successful due to several challenges, including lack of information on how to cope with climate stresses, deficient technologies, and lack of transport to cover all community farmers.

A number of researchers have found a positive correlation between a farmer's access to credit and their level of adaptation to climate stresses (Gbetibouo 2009; Bryan *et al.,* 2012; Tambo and Abdoulaye, 2013). These researchers argue that improving farmers' access to financing services could enable them to purchase inputs such as improved seed varieties, fertilizers, and irrigation schemes. Thus, the poor farmers are indicated to implement inefficient measures to curb climate change as they are unable to access these. For example, Tambo and Abdoulaye (2013) indicate that due to inaccessibility to credit farmers commonly adopt less expensive measures. However, these measures are in general inefficient to respond the stresses.

3.3 Impact of climate stresses on tomatoes horticultural crop

Tomatoes are highly sensitive to weather and climate changes. Evidence suggests that tomato crops are extremely sensitive to inundated soils, warm or low temperatures, and pests and diseases (Wada, 2006; Weerakkody *et al.*, 1997; Miller *et al.,* 2001; Pressman *et al.,* 2002; Ayoade, 2008; Camejo *et al.,* 2005). For example, Ayoade (2008) argued that as tomato roots are less adaptive to inundated soils, excessive moisture in the soil decreases the level of oxygen for the crop. Consequently, photosynthesis and growing processes are severely affected, leading to reduced crop yields and fruit quality. This is also supported by Weerakkody *et al.* (1997) who claim that heavy precipitation causes flowers to drop off, also reducing crop yield and fruit quality. Moreover, heavy rain at flowering stage is cited to cause fruit cracking (Ayoade, 2008), dropping the product's overall market value.

Warmer temperatures have adverse effects on tomato crops. Warmer temperature refers to the temperature above certain value from which is verified an adverse effect on the crop production. Miller *et al.,* (2001), Pressman *et al.,* (2002) and Camejo *et al.,* (2005) indicate that higher temperatures reduce vegetative growth, which impacts on the reproduction rate. Higher temperatures are also indicated to burn leaves, reduce roots development, decrease potential yields and change the color of fruits (Vollenweider and Gunthardt-Goerg, 2005). Furthermore, high temperatures have been shown to reduce pollen production and consequent flower and fruit abortions (Sato *et al*., 2002; Golam *et al.,* 2012); however, the temperature threshold is dependent on the seed varieties. For example, Camejo *et al.* (2012) found 30˚C as a maximum threshold for germination, while Miller *et al.,* (2001) found 35˚C as the overhead temperature at germination, seedling and flowering stages. Pressman *et al.* (2002) stated that 32°C was the maximum temperature for farming tomato. Suggesting that before farming, it is necessary to know the specific climate exigency of the seed varieties.

Lower temperatures, which refers to the value of temperature below from which is verified an adverse effect on the crop production; also have negative consequences for tomatoes crop. For example, Jacob *et al.* (2007) found that lower temperatures increases the breeding rate of mildew. According to the authors, temperatures ranging between 15 and 25°C during weeks one to four combined with relative humidity of between 60-90% over weeks two to four are ideal conditions for mildew development. Meaning that if farmers envision a successful crop, they need to be mindful of this and do the respective control of fungus.

4. Material and methods

4.1 Data collection and analysis

The study area comprises Massavasse and Muianga villages in Chókwe district, located in the south of Mozambique (Fig. 1). The field research was carried out in July 2015 and was based on semi-structured face-to-face interviews (Bryan *et al.*, 2012; Sanfo *et al.* 2014) conducted with 43 farmer households in the aforementioned villages. Farmer households were selected through random systematic sampling. This consisted of randomly surveying every fifth household in each village until the required sample was obtained (Nyantakyi - Frimpong and Bezner – Kerr, 2015). The survey interviewed 20 farmer households in Massavasse, while in Muianga 23 households were interviewed. In Muianga were interviewed more households since they were more open to participate than farmers of Massavasse. The study did not access why more smallholder farmers in Muianga were more open to the survey. Farmer households participated on a voluntary basis. Interviews focused on households that had a head-of-house that was of age 30 or above and rely on horticulture as their main source of income. The goal was to collect personal observations and experiences of climate stressors and changes in weather patterns among smallholders, and over the time as described by Baudoin (2013) revealed to be reasonable good since it captured quality information. The survey interviews were conducted by the author of this paper and translation was provided by the extension officer responsible for the two villages, Mr. Gerinho.

The survey instrument was prepared through a review of existent literature. The surveyor used qualitative techniques, including individual interviews and key-informants, to help further findings. The interviews varied in duration from 45 – 60 minutes per household and were conducted in the language preferred by the participants: Xitsonga or Portuguese. Interviews were recorded on permission from participants; hand-written notes were taken where permission was not granted.

Through an open-ended questionnaire the survey covered a range of data. The study captured farmers' sentiments on climate change given their experiences on tomato horticultural production over the years. Blignaut *et al.,* (2009) argue that farmers perceive changes of climate through changes in the timing, frequency and intensity of weather variability within a growth season. They also state that climate change can be assessed through the impact of these changes in vegetative growth and crop production. Therefore, each farmer household was asked to list the major climate concerns for tomato production at each stage of sowing, transplanting, flowering and harvesting. Then, farmers were asked to enumerate the impact of the climate stresses in their livelihood. Finally, households were asked about the coping measures they have adopted to deal with the climate stresses, constrains to adaptation and what they would like to do but for various reasons have not been able to.

The accuracy of farmers' perceptions of climate change and variability were also assessed. The historical daily maximum temperature and rainfall for the study area from 1980 to 2012 (33 years), with the omission of 2010 due to a lack of data, were analyzed. Using 'R' statistical software, tests were undertaken to determine at 95^{th} percentile the mean of maximum daily temperatures and rainfall for each tomato horticultural cycle (ONDJ, FMAM and JJAS). The number of days above the 95^{th} percentile for each cycle over the period was also determined. This data was then plotted as a time series to examine long-term trends of extreme events between the study years, 1980 and 2012. Finally, the trend of extreme events (temperatures and rainfall) was compared to farmers' description on climate stresses for each stage of tomatoes horticultural crop.

A number of studies have undertaken similar analysis. For example, Mulenga and Wineman (2014) and Moyo *et al.* (2009) examined how maize farmers in Zambia and Zimbabwe, respectively, perceived changes of climate. To access the accuracy of farmers' perceptions, these researches compared farmers' sentiments to long-term trend meteorological data (rainfall and temperature). Basannagari and Kala (2013) examined how apple producers in the Indian Himalayas perceived changes of climate. The accuracy of farmers' perceptions was accessed by comparing the farmers' view on changing of rainfall and snowfall over the years to meteorological climate data. Kihupi *et al.,* (2015) analyzed smallholder farmers' perceptions of climate change in Iringa district, in Tanzania, by comparing observed climate data to farmers' sentiments captured through the interviews. Gbetibouo (2009) assessed how farmers from the Limpopo River Basin in South Africa perceived variability and changes of climate; the author compared annual trends of temperatures and rainfall with the responses given by farmers during interviews. As such, a similar approach was considered for this study.

4.2 Description of study site

The study area is located in Mozambique's Chókwe district, in the Gaza province, at the latitude 26°.31'59 South and the longitude 32°.58'59 East. The survey included two villages of the district: Massavasse and Muianga, which are both within the Chókwe Irrigation Scheme (CIS) (Fig. 1). These villages were selected for the survey because tomato production dominates the total vegetable production; and both areas are threatened by climate variability. The distance between the two villages is 5 km.

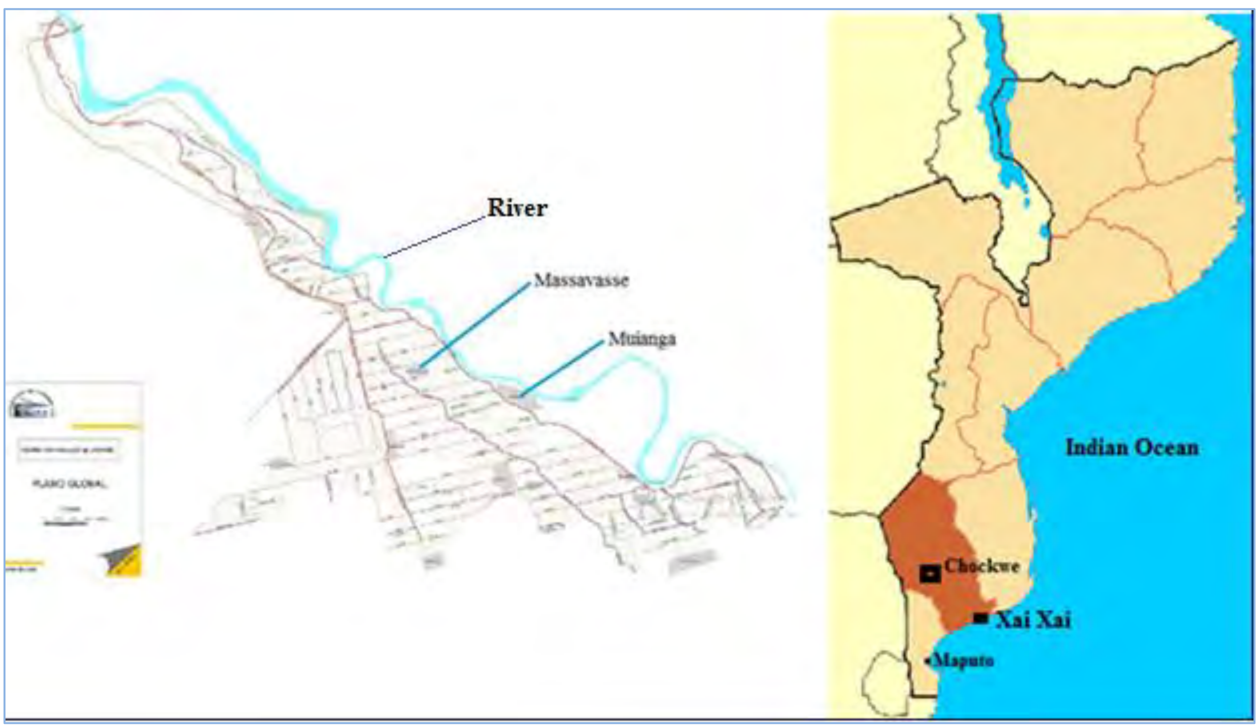


Figure 1 Map of Chókwe Irrigation Scheme (CIS).
Source: Public Hydraulic Company of Chókwe (HICEP), modified by the author

The climate in Chókwe is semi-arid, with great variability in rainfall patterns. The mean rainfall ranges between 500 and 800 mm, decreasing from the coastal zone to the interior (GOM, 2005); while its potential evapotranspiration is extremely high (varies between 1400 and 1500 mm), which makes droughts recurrent in the district. January is the wettest month (120 mm) of the year and July is the driest month (16 mm); the rainy season runs from November to March. The cooler season falls between April and July, and the warmer falls between August and March (USAID and FEWSNET, 2011). The annual mean temperature is 23.7°C. The highest average temperature is in January (27.3 °C), whereas the lowest is observed during July (18.6 °C) – Fig. 2. Chókwe humidity does not vary substantially through the year; it ranges between 60 – 65%.

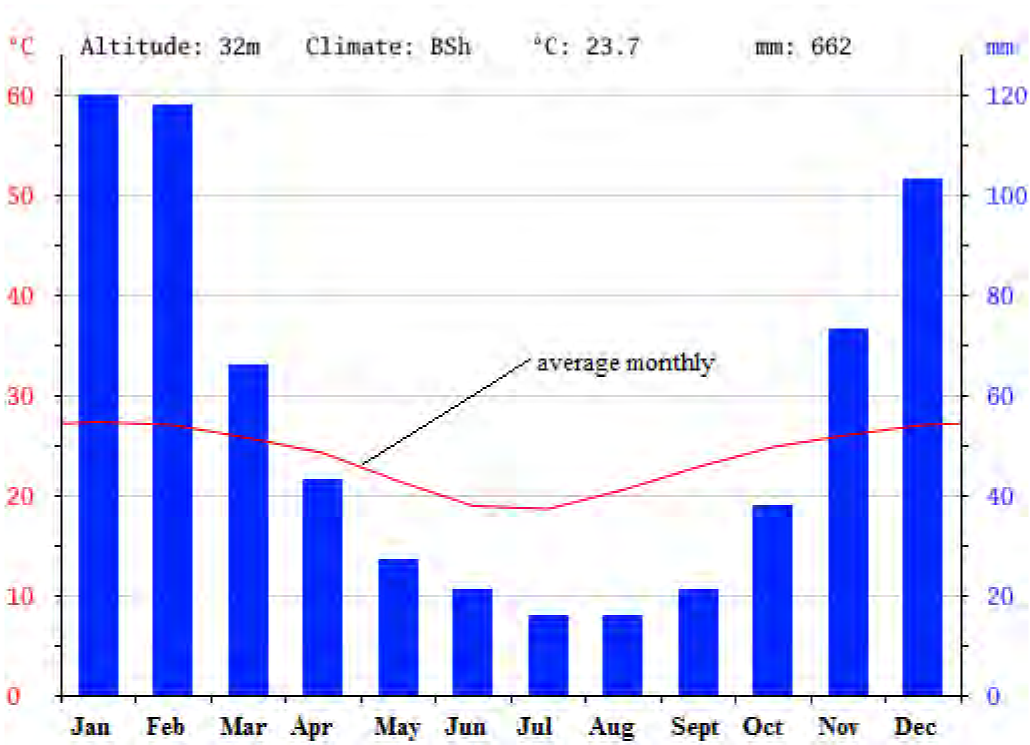


Figure 2 Variability of temperature and rainfall in the Chókwe district over the year.
Source: http://pt.climate-data.org/location/765242/

Chókwe is also prone to floods. The Chókwe river basin is the most exposed to floods among the five river basins in Mozambique, which include Umbelúzi, Incomati, Búzi and Save (NAPA, 2007). Flooding is mainly caused by heavy precipitation and water discharge from dams in neighboring countries situated upstream.

Households from both communities depend solely on agriculture for their livelihoods. This includes farming rice, maize, beans, potatoes, cassava, and vegetables such as tomato, cabbage and onions. These are farmed either in rain-fed lands or under the irrigation scheme. In the rain-fed lands, permanent crops such as cassava and sweet potatoes are farmed, whereas the irrigation system is reserved for rice and vegetables, as these are less tolerant to water stresses. Therefore, due to water stresses in certain seasons of the year, the use of irrigation system reveals to be crucial to horticultural farming. Apart from farming, households also rear livestock such as cattle, goats, chicken and other animals (ducks and pigs) on a small scale.

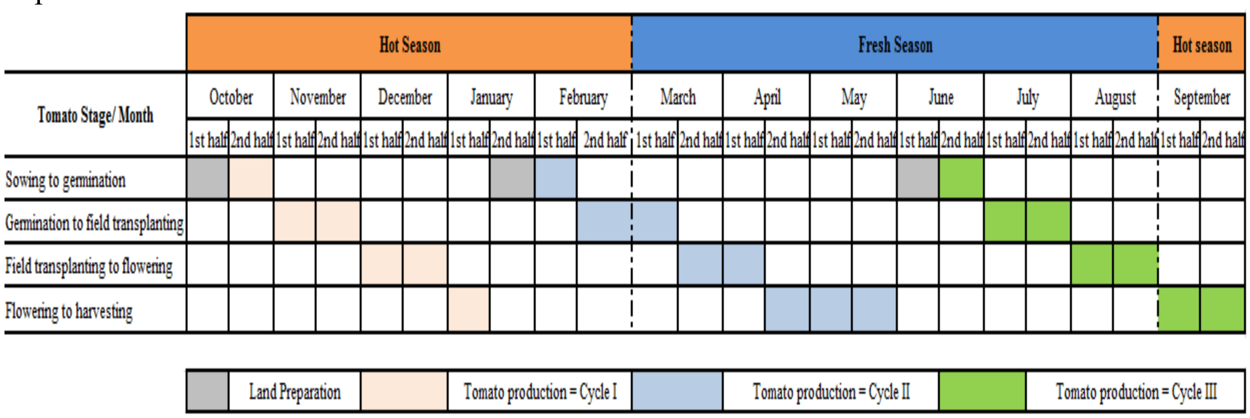
The existing irrigation scheme was constructed in the time of Portuguese colonization, around 1920s, but is currently under the administration of the Public Hydraulic Company of Chókwe (HICEP). HICEP manages the CIS and is also responsible for water and land management within the irrigation system. Thus, the HICEP's duties include managing primary channels to secure water supply and distribution; collecting water fees, and maintenance of irrigation facilities. Farmers are responsible for maintaining the secondary and tertiary canals. The primary canal is the one which taps water from the Limpopo River. Then, this water is distributed by the smaller secondary canals (the branches) to the tertiary canals which are even much smaller. However, this is a contentious issue, as farmers argue that such responsibilities demand financial capacity and technical skills that they do not have to appropriately manage and maintain the drainages. Therefore, the drainages are suffering due to farmers lacking the necessary resources to guarantee regular maintenance.

5. Results

5.1 Horticultural cycle of tomatoes

In Chókwe, as elsewhere in Mozambique, there are two rain-based cropping seasons over the year, namely: the hot season, and the fresh season – Table 1. According to respondents, the hot season, which is characterized by higher temperatures in the region, occurs approximately between September and February, with the highest temperatures observed between December and January. The hot season is also characterized by long rains, which farmers of the Chókwe District call *mananga*[1] (in the local language). The rains typically begin in October/ November and proceed until February. Conversely, farmers describe the fresh season, which occurs roughly between March and August, as much cooler, with lesser rain recorded. The coldest period over the fresh season is called *uchika*[2] and occurs between April and June.

Table 1 Tomatoes' horticultural cycle in Massavasse and Muianga according to farmers' explanations



According to interviews with farmers from both Massavasse and Muianga, tomatoes are grown throughout the year, in three production cycles in order to avoid interruptions in the supply of this vegetable. Farmers in the aforementioned villages use varieties which require two to three months between germination and harvesting of red-ripe fruit.

The first cycle of tomato production occurs over the hot season, between the third week of October and the second week of January; while the second cycle begins late in the hot season, in

[1] Name in Xichangana
[2] Name in Xichangana

the first week of February, and runs over the fresh season up to the fourth week of May. The third and final production cycle occurs from the second week of June (fresh season) to the second week of September (hot season). According to respondents, each tomato cycle encompasses five stages, namely: land preparation, sowing to germination, germination to field transplanting, field transplanting to flowering, and lastly, flowering to harvesting.

With regard to land preparation, results from household interviews suggest that this process occurs at different periods over the annual seasonal calendar. For the first and second cycles of tomato production, land preparation is done over the hot season, in October and February, respectively. However, for the third cycle, land preparation takes place in the fourth week of June, during the fresh season. Farmers indicated that land preparation in one *marracha* takes two weeks. A *marracha* is a standard unit of land roughly of 12x1.6 meters owned by one household under the Chókwe Irrigation Scheme.

Land preparation consists of plowing the soil with the use of implements such as tractors, oxen or hoes. Farmers stated that oxen and tractors are the most frequently used instruments in both communities. Oxen are more commonly used by the poorer farmers of the two communities; while tractors are used by those farmers that are in better positions financially. However, the poorest farmers till solely by hand, with the use of a hoe. In order to increase the efficiency of water use by crops, farmers prepare furrows in the soil, serving to direct the flow of water. As a result, during the irrigation process, water follows the rows with less loss. Another common practice in the land preparation process relates to improving soil by means of bedding. Bedding is the process of heaping soil in a long narrow line (Figure 3). The reason for bedding soils is that soil in Chókwe is slow draining, and bedding improves water drainage.

Figure 3. Bedding soil process
Source: *https://google.co.mz/?gws_rd=cr,ssl&ei=OmhMV7D-GaLRgAbL65qwDg#q*

In the two communities, the sowing stage occurs simultaneously as land preparation. The sowing process consists of germinating seeds in cultivation beds; after early growth, the seedlings are thinned and transplanted to crop fields. Although the land preparation and sowing occur almost concurrently, the two processes are practiced at different locations. Wealthier farmers use other lands either along the river bed or in other fields. On the other hand, for poorer farmers cultivation beds are more limited and farmers, therefore, use marginal areas for germination, such as under shady trees or small pieces of land within the larger field.

Farmers recounted that seven to ten days is the estimated period for complete emergence. In order to guarantee good quality seedlings, farmers apply several techniques, including the use of fertilizers and insecticides. Fertilizers are applied 15 days after complete emergence, while insecticides are applied ten and 25 days after complete emergence. According to farmers, three or four weeks after complete emergence, plants are then thinned and transplanted to the crop fields.

The transplanting stage occurs in both seasons of the agricultural calendar. In the first cycle of tomato production the transplanting period falls over the hot season, in November, while in the second and third cycles, the period occurs in the fresh season. The second cycle occurs between the second half of March to the first half of April, and the third cycle occurs entirely in August. Interviewees estimated that it takes roughly four weeks from transplanting to flowering.

The flowering stage is much longer in the fresh season than in the hot season. Farmers estimate that in the fresh season this process takes one and a half months, while in the hot season this occurs in merely 15 days, a third of the time. However, if flowering occurs in the transition between the fresh and hot seasons, this stage will take one month to complete. According to farmers, warmer temperatures accelerate the maturation process, while lower temperatures delay the process. The harvesting time for the first and third cycles occur over the hot season, in January and September, respectively, and harvesting for the second cycle occurs in May.

The harvesting and post-harvesting processes are cited to require particular attention. After maturation, the fruits are picked by hand and gathered; thereafter, the tomatoes' fruits are graded and packed in baskets according to size and quality, which, according to horticulturists, is based on several aspects, such as cracks, diseases, color and blemishes. Therefore, first grade fruits are more expensive than ungraded fruits. Finally, with the use of trucks, farmers transport to markets in either Xai-Xai city or Maputo. No farmer household indicated the use of any post-harvest treatment to increase the quality grading of the fruit. From my personal observation the best quality and yield are registered over the fresh season in the second cycle; while the best price is reached over the hot season in the first cycle.

5.2 Impact of weather and seasonal climate on each stage of tomato production

In interviews with farmers from both communities, respondents indicated that they had experienced severe weather and climate variability, including heavy precipitation, higher temperatures, delay of the rain season and flash floods (Fig. 4), over the years. Approximately 84% of respondents cited the issue of flash floods, which have increased in the last two decades, while heavy rainfall was cited by 72%. Delay in the start of the rainfall season and warmer temperatures were mentioned by 60% and 51% of farmers, respectively. When farmers were asked if they perceived an increase of pests and diseases over the period, 37% of respondents responded in the positive. It should be noted that the impact of weather and seasonal climate depends on the season when the tomato is grown and its stage of development, discussed in more detail below.

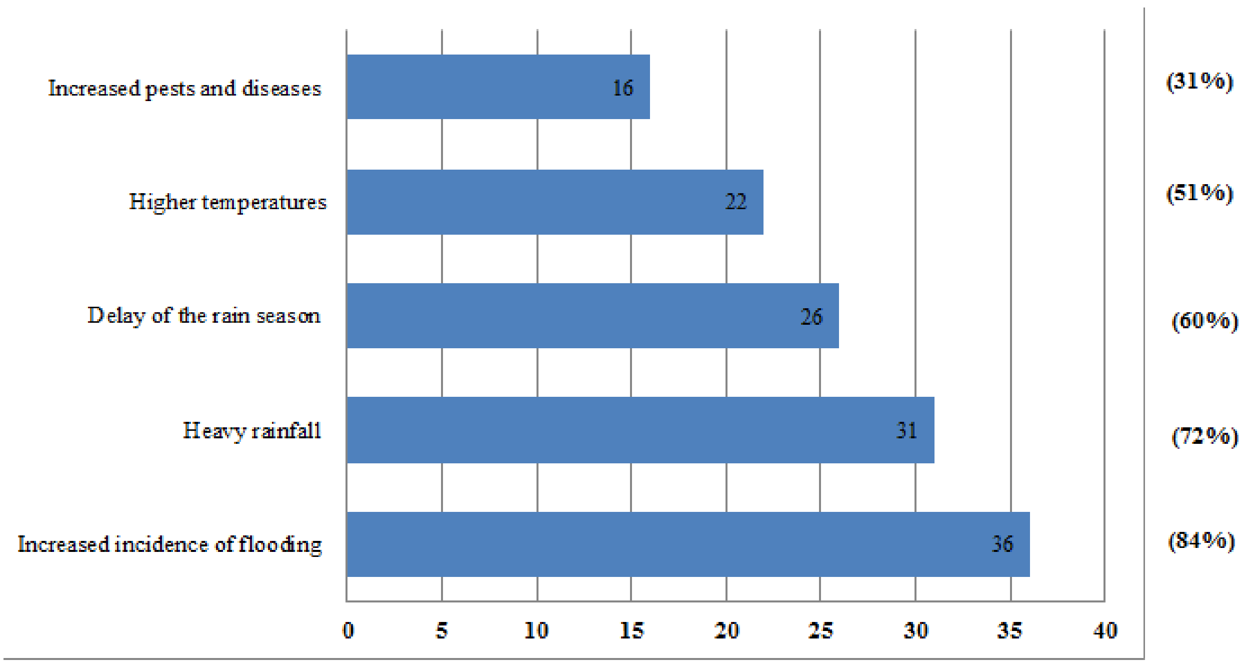


Figure 4 Changes observed by farmers and number of observers, n=43

5.2.1 Weather and seasonal climate impact in the hot season

5.2.1.1 Crop production

From the interviews with farmers it was found that the hot season was the most challenging period in which to grow tomatoes, as more than 70% of annual precipitation and associated floods, as well as significantly warmer temperatures, occur over this period. According to farmers' reports, heavy precipitation often affects the land preparation process in the first two cycles of tomato production. Land preparation for the first cycle occurs during the second half of October, while for the second cycle this falls over the first half of February. Because precipitation is heavy during this period, soil becomes waterlogged and inaccessible, to the extent that farmers cannot use machinery to prepare land. As a consequence, producers are forced to delay the land preparation process until water in the field dissipates and roads become viable for people and machinery. In addition, several farmers indicated that the delay of land preparation affects yield quality.

Furthermore, floods associated with heavy precipitation are described by farmers as having an effect on other stages of crop development. Farmers reported that both flooding and heavy precipitation impact on the district frequently between December and February, over the first cycle of tomato production, either at flowering or harvesting stages. Floods in the fields, including river-based floods, are driven by two factors, namely: heavy precipitation and water discharge from dams in neighboring countries situated upstream.

River-based floods, where water flows over the banks and localized rainfall result in the land being saturated, is described by farmers as being the most dangerous, as this type of flooding often sees households losing their assets. Many of the farmers interviewed recalled the floods of 2000 and 2013 as the most noteworthy floods to result in the loss of livestock and crops. For example, one farmer shared his experience of the 2013 floods: "*Floods came when I was planning to harvest tomatoes in the following week. I lost everything, including cattle. My farm was submerged. I and my family were forced to move to the neighboring city in Macia, 60km from Chókwe, to ask for shelter*" – Massavasse, 9 July 2015.

In addition to flooding, farmers indicated that heavy precipitation significantly impacts on tomato farming, as heavy rainfall stifles tomato crops' growth, causing them to wilt. Also, heavy rainfall inundates farms and causes the plants' flowers to fall off. The combined effect of the above-mentioned is that not only is a considerable yield of crop destroyed, the quality of the remaining crop and its fruits are reduced.

Furthermore, farmers report that the impact of the floods and heavy rainfall are exacerbated by inefficient farming practices. Farmers bemoaned that the wider drainage which spans the entire irrigation system is not cleaned regularly. This causes it to be frequently clogged with aquatic plants. This means that when it rains, drainage is minimal and water overflows, causing the fields to flood.

Along with flooding and heavy precipitation, farmers stated that high temperatures (value above the average) affect tomato crops at all stages of the vegetative cycle. At sowing stage, respondents suggest that higher temperatures delay the germination process. At transplanting and flowering stages, farmers indicated that higher temperatures were associated with an increase of pests and disease. Examples of pests associated with high temperature reported by interviewers in the two villages included thrips (*uvulu*)[3] and leafminers (*nhambozana*)[4]. A higher incidence of pests leads to a deficient growing process and, consequently, lower yields.

Higher temperatures were also described as having an effect on fruit quality. According to respondents, higher temperatures at the flowering stage lead to the tomatoes' flowers falling off prematurely, resulting in reduced yields and tomatoes and fruit become smooth and having little weight. Another effect mentioned was that high temperatures cause tomatoes to ripen as orange or yellow, adversely affecting their market value. Lastly, farmers cited the problem of tomatoes' reduced shelf life and attributed this to high temperatures.

5.2.1.2 Infrastructure

Farmers stressed that flooding and heavy precipitation resulted in negative physical impacts in both communities, including damage to roads and agricultural infrastructure. Massavasse and Muianga are characterized by very poor road infrastructure, and most roads therein are particularly sensitive to sustained and heavy rainfall. Farmers stated that over the heavy rainfall season, between December and February, even vehicular access along roads is not possible.

Damage to agricultural infrastructure leads to a substantial decrease in agricultural productivity. For example, farmers recalled the floods of 2000 which caused tremendous damage to drains in the CIS. As a result, farmers were forced to grow crops over three agricultural years (three tomatoes horticultural cycle for each year) relying on rain before the system was rehabilitated. However, the rainfall was not at sufficient levels to sustain plant needs. This resulted in low yields and a substantial reduction in the farmers' financial capacity.

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[3] Name in Xichangana
[4] Name in Xichangana

5.2.2 Weather and seasonal climate impact in the fresh season

Although respondents did not mention any physical impact to either infrastructure or fields, for example flooding, over the fresh season, crop production was reported to be affected differently. Farmers claim a higher incidence of pests and diseases can affect at least two stages of the tomato crop. With regard to diseases, mildew[5] was cited as the most noteworthy disease at the germination to transplanting stage. Farmers associated this disease with colder temperatures between April and June. The second stage affected was flowering to harvesting, due to higher incidence of mice, which eat tomato fruits. According to farmers, the higher incidence of mice is positively correlated to the lack of rain for an extended period of time, already described as a characteristic of this season. Lack of rain increases the rate of mice breeding, as plentiful rainfall fills mice nests in the ground with water, limiting the rate of breeding and therefore reducing their population.

5.3 Socio-economic consequences of climate impact at each stage of tomato horticultural cycle

Results from household interviews in the two villages suggest that farmers are highly dependent on tomato farming, as tomato production plays a key role in income generation, providing residents the resources to purchase food and ensure food security. Of course the income also helps with other aspects of maintaining residents' well-being. Respondents mentioned that growing a tomato crop offers employment and income to household members that otherwise would not have employment. In particular, poorer non-farm members of the communities are able to find employment working for those that are wealthier, therefore receiving some income and contributing to the alleviation of poverty in their communities. Thus, the effects of any weather or seasonal climatic stresses that threaten the horticultural cycle of tomatoes have a potentially significant impact on farmers' livelihood.

However, according to interviewees, the impact of these stresses is dependent on three major aspects: season, type of climate-related disaster and stage of crop development.

[5] Mildew is a disease of plants caused by fungi. Usually the surfaces of affected parts become cottony.

5.3.1 Impact of weather and/ or seasonal climatic stresses in the hot season

A number of socio-economic consequences are associated with climate shocks during the hot season. According to farmers, heavy precipitation may substantially impact on a farmer's financial position. For example, at sowing stage, due to germination failures, farmers are forced to allocate extra resources to purchase more seeds in order to replace the failed seeds. Germination failures also affect farmers' profits, since the crop yield is reduced. Floods were also described as one of the major constraints to farmers' livelihood. Apart from crop losses in the field, respondents also stated the loss of many heads of livestock. As some farmers rely on selling crops and animals to cope with any social crises that may arise, their ability to do so is reduced by the farmers' diminished financial capacity. Moreover, floods and higher precipitation are cited to affect commercialization opportunities due to the occurrence of blocked road networks. For example, losses from the floods of 2000 resulted in famine and necessitated the provision of food aid by government and local NGOs; however, this was still insufficient to meet farmers' needs since they lost all assets.

Floods are also considered to have some socio-economic impact on an individual's general circumstance. Respondents reported damage to property and a substantial increase in human morbidity as a result of flooding incidents. Farmers from both communities recalled that in the floods of 2000 and 2013, many houses were destroyed, prompting economic hardship, as farmers were forced to use funds likely reserved for other, or specific, needs to repair the damage.

Additionally, damage to properties was cited as a cause of emotional strain among community members. Damage to properties frequently causes deaths among the households, as residents may be injured by fallen structures. According to farmers, during the above-mentioned floods, Muianga was the worst-affected area as the majority of residents live in reed houses, which are more susceptible to flooding; unlike in Massavasse, where many live in houses made of bricks and are better protected against the elements.

Respondents further concurred that floods can contribute to the deterioration of one's health condition. The most frequently mentioned diseases by farmers include malaria and diarrhea, of which the impact typically results in a reduced labour force to work the fields.

Farmers also cited higher temperatures as an important contributor to their socio-economic situation during tomato production over the hot season. Households claimed to use more resources to buy insecticides and pesticides, further exacerbating their poverty as they had to allocate resources that were not necessarily anticipated. However, respondents indicated that the impact of this is associated with only the crop stage.

Lastly, higher temperatures at flowering and maturation stages were cited as the cause of lower yields and reduced fruit quality. Respondents concurred that any failure at this stage of the horticultural cycle would be extremely difficult to recover, and as such, have a direct and negative effect on farmer profits.

The impact of the climatic risks mentioned above is exacerbated by several socio-cultural aspects. Farmers' constraints include low access to credit, lack of access to agricultural inputs, lack of transport and distance to market. None of the household respondents claimed to have benefited from any credit line for tomato production; however, one farmer confirmed to be a beneficiary of credit support provided by CPL (Limpopo Producers Savings and Credit Cooperative), to grow onions. According to this beneficiary, CPL is open to funding onion farming due to their belief that onions are more resistant to pests and diseases than other horticultural crops, and are, therefore, a more reliable avenue for revenue. However, this farmer stated that he had not reimbursed the loan since he lost the production due to higher precipitation when it was at harvesting stage. This suggests that climate hazards can increase the risks of farmers being unable to pay loan/ credit amounts.

While there are several banks in Chókwe, none of these were open to agriculture credit lines. Moreover, the majority of farmers claimed to not have the required collateral to secure credit, with collateral being one of the most important requirements for eligibility.

Farmers' inaccessibility to improved seeds, fertilizer and pesticides were also cited as contributors of lower productivity, further impacting on farmers' economic situations. Farmers stated that the local market did not offer good quality inputs since most seeds are not adapted to the local conditions. For example, fruits are described as becoming flat-sided and cracking under warmer temperatures. Therefore, farmers' agricultural performance was limited by the lack of seed quality.

A lack of transport for farmers is considered to play a key role in market accessibility. This is particularly important during the hot season, when high temperatures occur with more frequency, therefore reducing the shelf-life of tomatoes. Speedier or more frequent delivery of goods is then needed; however, the majority of farmers are poor and do not have their own transport to deliver their produce to the market in Maputo. According to respondents, it is the poorer farmers in both communities who were most severely affected by reduced shelf-life of tomatoes.

In particular, over the harvesting period the demand for transport becomes much higher, and farmers have to endure long queues to hire transport to deliver their product. Therefore, tomato fruits lose their quality and sometimes even spoil. This is exacerbated by the long distance that farmers have to travel to reach the nearest big market in Maputo. The estimated distance between Chókwe and Maputo is 250km; the combined journey takes roughly 5 hours. Because of these constraints on the delivering process, some farmers are forced to sell their products in the village, obtaining lower prices and, therefore, making less profit. Wealthier farmers in the communities are able to use their own vehicles to deliver products to Maputo, reducing the risk of decreased quality and profit losses, and, therefore, maintaining a healthy income.

5.3.2 Impact of weather and/ or seasonal climatic stresses in the fresh season

Although the fresh season was described as the least impacted by climate variability, farmers did mention some socio-economic challenges. According to farmers, the prevalence of mildew reduces their financial capacity in that they are forced to allocate money to buy fungicides to reduce the occurrence. They also mentioned the need to allot money to buy rodenticides to combat mice. Both these purchases have a negative bearing on farmers' financial capacity.

Respondents also revealed that over the fresh season their financial capacity is reduced as a result of market constraints. Farmers mentioned that during this period, prices are lower than in the hot season, as there is ample supply at the market; supply outweighs demand. This is exacerbated by two main reasons. Firstly, respondents complained that they receive no information in advance about the prices they will receive in the market; therefore, they are unable to decide whether to sell at the local market or in Maputo. Selling at the local market aims to minimize the costs of transporting goods. In addition, farmers are not party to decisions regarding market prices, and the best price was dependent on the market agents. This group of agents is responsible for setting prices and selling all farmers' products. In addition, the use of agents means that farmers make less profit since they receive only between 50 to 75% of the products' value. Secondly, farmers recount that the excessive importation of tomato over this period from South Africa floods the local market and significantly reduces prices. Farmers believe that their marginal cost of production is much higher than their South African counterparts, leading to an uncompetitive price and less profit for local farmers. In light of this, farmers argue that the importation of tomato should be restricted to the hot season, when the local farmers are indeed not able to meet the demand.

5.4 Alternative sources of income for farmers

Smallholder farmers in both communities stated the need to have alternative source of income in light of agriculture related-hazards such as higher temperatures, incidence of pests and diseases and heavy precipitation over the tomato horticultural cycle – Fig. 5. Approximately 72% of respondents emphasize the use of cash from *xitique*[6] to solve social constraints, including agricultural climate stresses. Xitique is an informal loan system which consists of saving money through monthly deposit with community households that are socially linked to each other. The interviewees stated that, generally, a xitique cycle lasts between four and six months, of which the period is equal to the number of household members. Through an elicitation process followed by the general consent of members, the households define the fixed amount that each member should contribute monthly. Therefore, each household contributes the same amount every month, and one member takes the whole sum at each monthly meeting. Farmers are also willing to make decisions (in assembly) to reschedule the payment time so as to get money from xitique in the event that a member needs money to overcome an urgent problem.

[6] Name in Xichangana

Participating households described xitique as an advantageous method in the community since it reduces the risk of saving money at home and avoids interaction with bureaucratic financial institutions. Saving money at home is considered a serious risk due to the fact that resident have easy access to the money and are more likely to spend the money wastefully/ recklessly. Participants stressed that they can adhere to xitique without any demands of interest payments, requirements for documentation or collateral, or any legal bearing. Because the xitique process is perceived to be less complex than the financial services provided by the formal banking sector, locals consider this a secure method of financing for the majority of farmers. This is primarily because many farmers are poor and do not own any personal documentation, which constrains their ability to access formal banking services. In contrast, 14% of respondents, who happen to be considered among the wealthier in the communities which was assessed only through the researcher´s personal observation, stated the use of both informal and formal financial services. This group of farmers saves some money using formal banking services so that they can access funds easily in the event of an urgent need. However, these farmers stressed that their savings were not sufficient to respond in the event of considerable climate shocks; therefore, they also use additional sources to generate income.

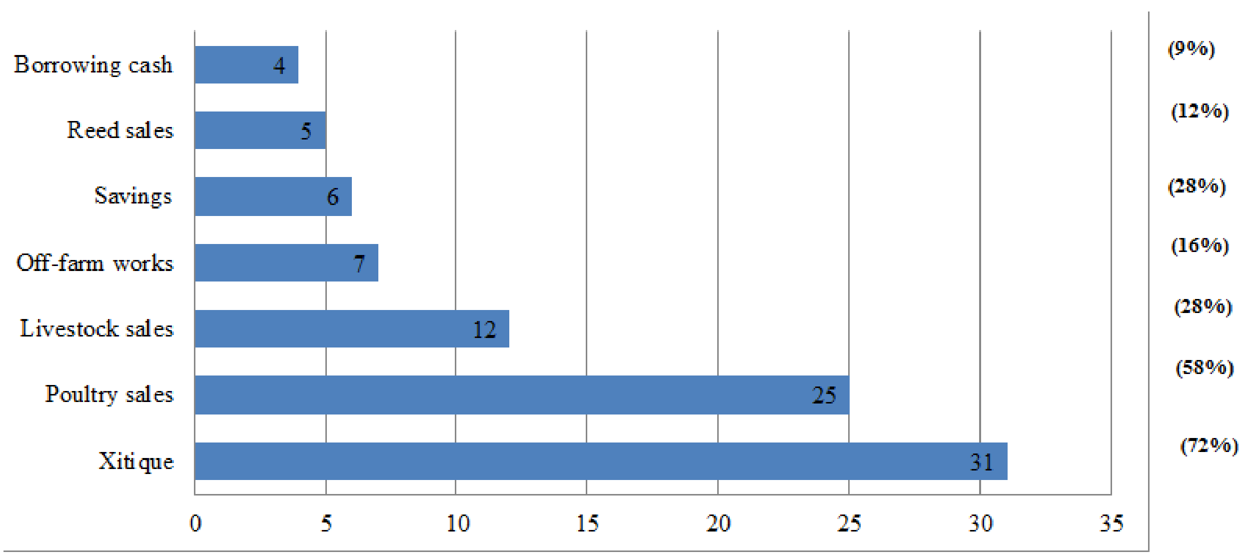

Fig. 5 Alternative income stream and number of respondents, n=43

Household interviews also reveal that selling livestock and poultry is one of the most common sources of alternative income in both communities. Approximately 58% of respondents reported that they sell poultry as a means of generating additional income, which was considered necessary for their day-to-day needs. The majority of these households sell poultry throughout the year, most notably over the hot season, when smallholders are particularly vulnerable to financial hardship due to a substantial decline in agricultural production. However, farmers claimed that the income generated from selling poultry was not sufficient to cover all their needs, such as buying food and agricultural inputs, and preference is given to the purchase of food (food security) rather than agricultural activities. This reduces farmers' production and consequent financial capacity. Apart from poultry, farmers indicated that other livestock such as cattle is also considered a source of income. Although the majority of farmers interviewed claimed to own at least one head of livestock, only 28% of respondents indicated that they actually sell livestock to respond to emergencies. This low percentage can be attributed to the social and cultural prestige that is associated with having an array of livestock; as such, farmers prefer to keep their stock rather than sell it as a means of preserving their social standing.

Off-farm employment, reed sales, and borrowing cash were the least reported responses with regards to alternative sources of income. Approximately 16% of households cited working off-farm for the wealthier in the community as an alternative means of earning some money. According to these households, the most common off-farm activities include transplanting, harvesting, opening and cleaning drainage. Selling reeds and borrowing cash from friends or relatives to deal with an immediate constraint was cited by 12% and 9% of respondents, respectively.

5.4.1 Farmers' coping mechanisms in response to climate-related hazards

5.4.1.1 Heavy precipitation and floods

Interviews with farmers revealed that tomato producers lack efficient and effective measures to cope with heavy rainfall and floods, and farmers claimed to not have the capacity to implement any adaptive measures to curb the effects thereof. However, farmers did indicate that they had put in place some measures to minimize the impact of heavy rainfall, including cleaning drainage systems and opening field drainages.

By cleaning secondary and tertiary canals; and opening field drainages, farmers are able to dissipate water. However, the success of the two techniques is correlated to the extent and length of precipitation; therefore, the two measures may be inefficient if the aforementioned factors are not sufficiently met. For example, if water levels are low, draining the field of excess waters is much easier. Despite this adaptive measure, opening and cleaning drainage reveals a deficiency in the technology used in that farmers drain fields manually, which requires quite some time. In addition, successful drainage is further hampered by the characteristics of soil in Chókwe, which is clayey and has low infiltration rates, further delaying the process of water drainage. Furthermore, as the drainage cleaning process is done manually, farmers indicated that they would prefer to use machinery to complete this task since machines are more efficient.

5.4.1.2 Extreme temperature that cause crop damage

Farmers reported the implementation of several measures in order to minimize the impact of higher temperatures. One such measure is the use of seed varieties from South Africa which are described to be more tolerant of higher temperatures, including HTX 14, KAMATLA, TIMA, QWANTO and JAGUAR. However, the use of the aforementioned varieties was not a foregone conclusion as various factors had to be considered in the selection of seed varieties, such as price, market preference, fruit quality, yields of production, shelf life, and resistance to pests and diseases. Given these aspects, the majority of farmers in both villages stated a preference for HTX 14, followed by QWANTO and JAGUAR. Although these varieties respond well to climate stresses in Chókwe, farmers are aware of other varieties that can better tolerate the region's adverse climate conditions; however, financial constraints impact on farmers' ability to afford such varieties, as these are substantially more expensive and out of reach for the majority of households. As such, options are limited to the above-mentioned varieties. Farmers are aware of some varieties in the local market which can better deal with climate stresses. However, farmers cannot buy because they are very expensive.

Results from the household interviews suggest that apart from selecting seed varieties as a strategy to minimize the negative impact of higher temperatures, farmers implement other agricultural techniques – Fig. 6. Approximately 63% of interviewees stated the use of the mulching technique to minimize the effect of frequent exposure to sun and, consequently, soil water losses through evaporation. The mulching technique consists of covering the surface of the bedding soil with wastes of rice after sowing. Both communities Massavasse and Muianga grow rice. In fact, Chókwe is the highest rice producing over the South Mozambique including Maputo, Gaza and Inhambane Provinces.

Another strategy used by the horticultural producers is sowing either under shady trees or along river beds. Approximately 30% of households sow under shady trees, whereas sowing along the river bed was mentioned by 16% of respondents. These numbers are not entirely representative of the advantages/ disadvantages associated with these options, but are more a reflection of the socio-economic dynamics in the two communities. Sowing under shady trees is most common among poorer farmers, who face limitations on crop lands; while wealthier famers, who typically have additional crop lands, sow along river beds. Although these measures reduce the impact of higher temperatures on crops, they can be considered inefficient in some aspects, particularly as the seedlings yield fruit that is of a lower quality. Thus, farmers would be happy using shade cloths as an alternative technology to minimize the impact of warmer temperatures while maintaining the quality of seedlings.

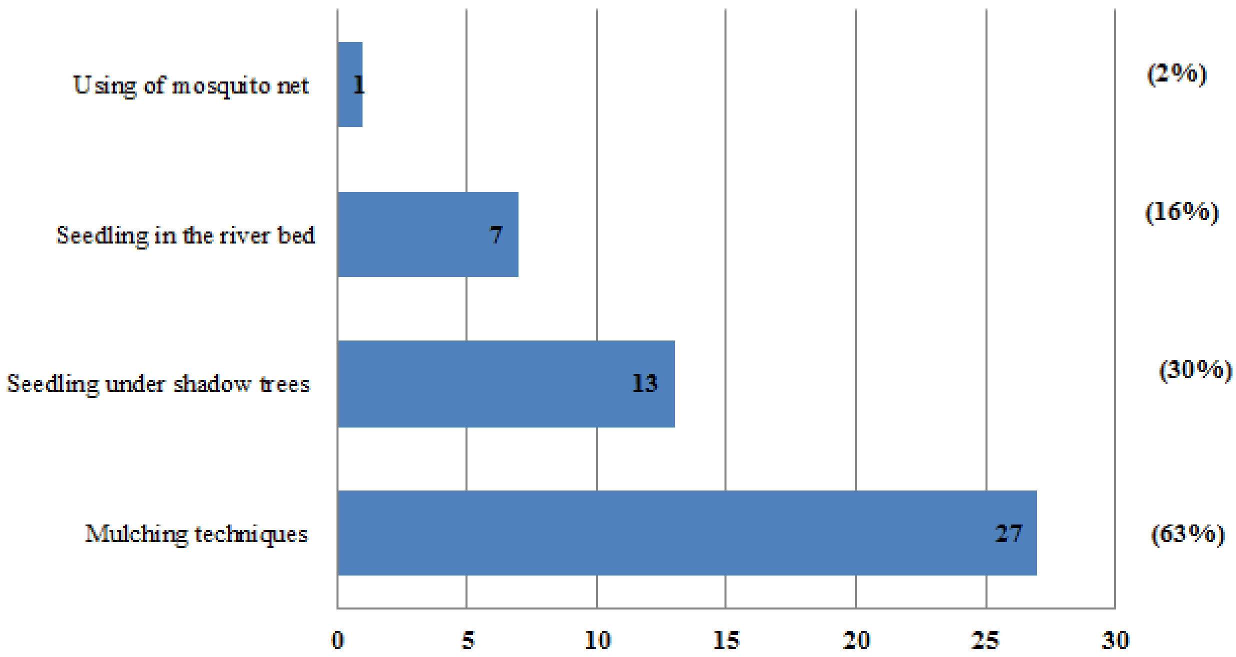

Figure 6 Techniques used by farmers and number of respondents, n=43

The use of mosquito nets was also cited as an option to contend with higher temperatures. Mosquito nets are used to cover the sowed land, providing shade, which minimizes the impact of direct and intense sun. Only 2% of interviewees mentioned their personal use of this strategy. This may be due to the fact that use of mosquito nets either for agricultural or fishery activities are strictly prohibited by community leaders. As the district of Chókwe is vulnerable to mosquitoes which carry malaria, the government and some local NGOs provide people with nets intended for use in their homes; nonetheless, some people use these in the field and this is frowned upon.

With increased temperatures comes the need for increased irrigation, or the implementation of more efficient irrigation patterns. During the hot season, at transplanting stage, respondents reported using three times more water than over the fresh season; while at flowering stage they increase the amount of water so that they irrigate four times more water than over the fresh season. Besides this measure, interviewees reported altering their irrigation patterns. Rather than irrigating at any time of the day, as they do over the fresh season, this activity is limited to specific time of the day; farmers claimed to irrigate two times per day at sunset either in the early morning or afternoon in order to avoid losses through evapotranspiration. In the same way, the transplanting process takes place in the afternoon. Therefore, farmers cited drip irrigation as alternative that could take place to minimize the impacts of higher temperature. Drip irrigation is an irrigation system which consists of supplying water to soil very close to crop and is known for reducing the impact of higher temperatures by saving water.

Lastly, making some amendments to harvesting and delivering processes was also identified as a measure to cope with warmer temperatures. Rather than harvesting during the day, farmers do this activity in the afternoon, when solar radiation is less intense and fruits are less likely to lose quality. The delivery process is shifted from being a morning or daytime activity to being done overnight. This is done because at this time of the day, the environmental temperature is relatively lower and is more suitable for tomatoes fruit, therefore avoiding losses in the delivery process. Because of these constraints, farmers mentioned that they would be happy if there was a storage facility nearby to the producers so that they could store their produce when temperatures are higher. This would avoid losses during the delivering process.

5.4.1.3 Pests and disease

From interviews with farmers it was found that several measures are used to deal with pests and diseases, including the application of pesticides and fungicides. Farmers commonly apply C*ypermethrin*[7] and *Tamron*[8] to combat thrips and leafminers; while *Mancozeb*[9] was indicated to be suitable to enhance resistance against mildew. Farmer interviews suggest that the amount of chemical applied varies by farmer and is dependent on the season. In the hot season farmers apply three times more pesticides as they do over the fresh season, as the hot season typically sees a substantial increase in pests and diseases. No specific strategy is implemented for the control of mice.

While farmers apply pesticides to their crops, they do not implement safe practices for the use of these. For example, farmers in both communities are highly exposed to chemicals when using pesticides; however, they do not use any protective equipment for the use of these, such as

[7] Commercial name of insecticide
[8] Commercial name of insecticide
[9] Commercial name of insecticide

coveralls, gloves or chemical-resistant clothing. The long-term effect of this may result in health problems. Farmers are aware of this and would like use protective gear; however, they are facing financial constraints to buy such equipment. Therefore, their suggestion is to be supplied with protective material.

Moreover, farmers complained that recent pesticides were not as effective as those previously used. Farmers stated that there are pesticides which appear to be more efficient, but are prohibitively more expensive. Therefore, farmers would like to apply new pesticides which are described as more efficient.

5.5. Barriers to coping strategies

Farmers mentioned inefficient extension services as one of the main reasons for the weak implementation of agricultural measures to cope with climate stresses. Respondents claimed to receive weak agricultural assistance from government or local NGOs that deal with agricultural issues. According to households, only one extension officer from government covers the two communities. This technician regularly visits (roughly 4 times a week) the fields to see how farmers develop agriculture activities and provides advice on farming techniques. Extension officers are usually qualified in crop and livestock production. Despite this, the majority of farmers claimed to not benefit from the services provided by the extension officer as he is often not able to reach all farmers' fields. Moreover, the extension officer is also responsible for other activities in both communities, including assisting in the maintenance of rice bark removing machineries in the two communities, which is a demanding task, thus reducing his availability to assist farmers in other aspects.

Lack of reliable climate information was also cited as a reason for limited coping mechanisms. Approximately 77% of respondents access daily weather forecast information which is disseminated by the National Meteorological Services through radio and television – Fig 7. Of those who confirmed receiving information, 89% claimed to not be satisfied with the provided services. Respondents bemoaned the inaccuracy of information and, therefore, its inability to aid in planning future agricultural activities and making important decisions. Farmers allege that the information they receive does not correspond with their local conditions. Indeed, radio and television disseminate metrological information regarding Xai-Xai city, which is the capital of Gaza Province and is located roughly 120km from Chókwe, which does not accurately describe the situation in the two districts. Furthermore, farmers are aggrieved that forecast information consists of predicted minimum/ maximum temperatures and precipitation only, as opposed to including important advice on how farmers should cope with existing and anticipated climate challenges such as delay of the rain season, heavy rainfall and hot temperatures.

Farmers also allege that no local institution, neither governmental nor NGOs, made any meteorological information available to them. Despite the existence of *Aviso prévio*, a government-owned newspaper by the Ministry of Agriculture that aims to provide farmers with climate related information, none of the farmers interviewed recalled ever receiving this publication. *Aviso prévio* consists of disseminating forecasted regional weather information (mainly precipitation) for the three regions: South, Centre and North; where each region encompasses roughly 3 Provinces. Therefore, farmers complained that the provided information does not match the local conditions. Likewise, meteorological information provided by the National Meteorological Services (INAM), the aforementioned newspaper lacks of information on what farmers should do to cope with the challenges.

Although farmers complained about not receiving accurate climate information through radio, television or newspaper platforms, they did confirm the receipt of yearly warnings regarding floods. In addition to media platforms, community leaders were also tasked with gathering community members and providing this information verbally. At these gatherings, households receive explanations on precautionary procedures when the flood risk is elevated. As government has in place various systems to warn communities of anticipated flooding, farmers are of the belief that in the same way, government can use the same system to provide farmers with other climate-related information.

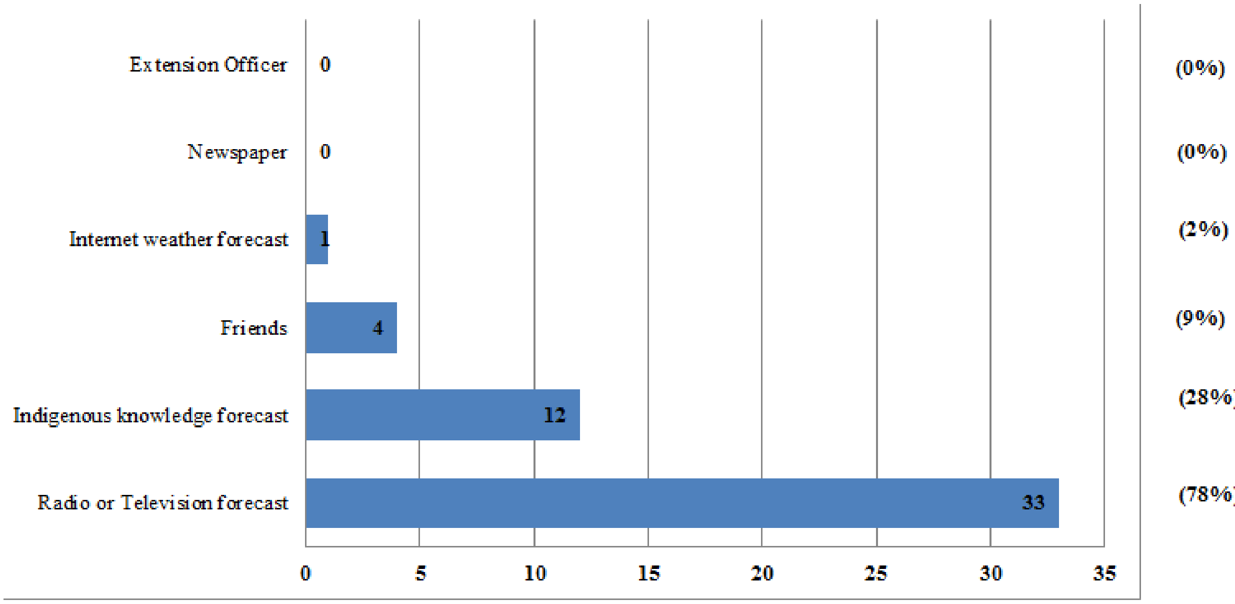

Figure 7 Farmers' source of weather forecast information and number of households, n=43

Apart from receiving weather forecast information disseminated by the meteorological services on the radio and television, farmers also access information through electronic media and community channels. Approximately 2% of respondents reported accessing the internet for daily weather forecasts; while 28% of households use indigenous climate knowledge – Table 2. This group corresponds with the poorer farmers who face constraints in accessing technologies as well as those farmers that are elderly. Elderly farmers face additional barriers in accessing weather forecasting information, as this is disseminated in the official language (Portuguese), in which they are not proficient, rather than in the local language. On the other hand, approximately 9% of respondents claimed to receive information from friends, who usually share information sourced from the internet. No farmer household confirmed receiving weather forecast information from the extension officer.

Table 2 Anticipated weather events based on farmers' observation of environment features

Object	Feature	Related event
Moon	Full moon covered by clouds	Precipitation
Plants	Higher flowering density of *Mangane* trees	Regular rains
	Higher than normal density of weeds such as *Xilhowone*, *Mudlacumba*, *Chawbanibwa*, *Tsotogoni*	Onset of dry season
	Higher fruit ripening of *ncanhi* (marula trees), *ndzanga nguva* and *pfute*	Transition from fresh to hot season
Animals	Bearing of Quelea birds	Beginning of rainy season
	Occurance of birds (*tihuni* and *tlua*) and frogs (yellow-brown)	Flooding
	Higher than normal occurrence of swallow birds flying in the sky	Precipitation
	Cows shivering in the legs and displaying signs of fatigue	Onset of dry season

Source: Author based on farmers' interview

Farmer interviews revealed that the subjects are able, through the observation of environmental factors, to make plans to produce tomatoes. The decision to undertake agricultural activities is in part based on the aforementioned observation of environmental occurrences. For example, if a full moon is covered by clouds, farmers will delay watering their crops, as good rainfall (which is anticipated) after water supply may waterlog the fields and reduce the yield.

6. Discussion

The previous section details results from the survey interviews conducted. In this section the key results are discussed in the context of the research aims and the wider literature. First, farmers' perceptions of climate change and variability are assessed. The chapter then discusses the most important impacts of the identified climate stresses on the tomatoes crop, completing previous papers on this point. Thereafter, the chapter discusses the effectiveness of the adaptive options already taken by farmers discussed in previous section. Finally, the section ends with suggestions on the actions that could be implemented to add to the efforts already in place.

Presented below (Table 3) are the key findings of the research. This indicates hazards which affect farmers' horticultural production, including flooding, delay of rains and warmer temperatures, the consequence of which is a higher incidence of pests and diseases. These climate impacts affect farmers in three aspects: crop production, which is linked to the reduction of crop yields or fruit quality; infrastructural impact, which refers to damage sustained by properties; and lastly, socioeconomic impact, which aims to assess the impact of climate stresses on farmers' livelihood.

Table 3 Impact of climate stresses on tomatoes' horticultural crop and responses according to farmers' explanations

Season	Climate Stress	Affected level	Stage of horticultural cycle	Related - impact	Existing Response
Hot	Heavy precipitation/ floods	Crop production	Land preparation	Inundation of fields	Opening and cleaning drainages
				Delays of land preparation	
			Sowing - germination	Germination failures	Opening and cleaning drainages
					Replacement of failures
			Transplanting - flowering	Loss of crops	Opening and cleaning drainages
			Flowering - harvesting	Lower yields Loss of crops	Opening and cleaning drainages
		Physical	N/A	Damage to irrigation scheme, road networks, and farmers' possessions, including houses and animals	Government support to farmers (food and temporary accommodation)
		Socio-economic	N/A	Reduced farmer profits	Use of alternative source of income, including xitique, off-farm work, selling animals, borrowing cash, selling reeds
				Increased risks of hunger and food insecurity	
	Higher temperatures	Crop production	Sowing - germination	Decreased germination rate	Sowing under shady trees and along the river bed
					Mulching technique
					Use of mosquito nets
			Transplanting - flowering	Higher insolation	Altering amount of water used (3x)
					Altering timing of irrigation (at sunset in the early morning or afternoon)
					Transplanting later in the day (at sunset in the afternoon)
				Pests and diseases	Increased application of pesticides and insecticides (3x)
			Flowering - harvesting	Higher insolation/ Decreased yields	Altering amount of water used (4x)
				Reduced quality of fruits	Altering of harvesting time (at sunset in the afternoon)/ Altering of delivering times (to overnight)
				Pests and diseases	Increasing use of pesticides and insecticides
		Socio-economic		Decrease of farmers financial capacity Increased risk of hunger (diminished food security)	Use of alternative source of income
Fresh	Lower temperatures	Crop production	Sowing - germination	Incidence of mildew	Application of fungicides
			Flowering - harvesting	Incidence of mice Damage to fruits Reduced yields	N/A
		Socio-economic	N/A	Decrease of farmers financial capacity Increased risks of hunger and food insecurity	Use of alternative source of income

6.1 Comparison between farmers' perceptions of changes in climate and recorded meteorological data

The study indicates that tomato producers in Massavasse and Muianga are aware of their vulnerability to changes of weather and seasonal climate, including increasing floods, heavy precipitation, warmer temperatures and delayed rainfall. Similar expressions of awareness by farmers about change of climate have been reported by a number of researchers investigating climate change in Africa (e.g. Osbahr *et al.,* 2007; Sanfo *et al.,* 2014; Gbetibouo 2009; Bryan *et al.,* 2012; Moyo *et al*. 2012; Debela *et al.,* 2015 and Kihupi *et al.,* 2015). For example, Moyo *et al*. (2012) found that respondents in the two districts of Zimbabwe that were investigated were aware of delays of rainfall, extremes in temperatures, and higher intensity of precipitation. Similarly Sanfo *et al.* (2014), in analyzing farmers' perceptions of climate change in Burkina Faso found that farmers were aware of rainfall variability within seasons and higher temperatures. Furthermore, Kihupi *et al.* (2015) in Tanzania stated that farmers identified increases of temperature, variability of rainfall and high incidence of pests and crop diseases as consequences of climate change. Lastly, Gbetibouo (2009), who focused on the Limpopo River Basin in South Africa, indicated that farmers were aware of increasing temperatures and changes in the frequency of floods.

An examination of observed climate data for the period 1980 to 2012 supports farmers' sentiments on weather and climate variability. The recorded data confirms that the first cycle of tomatoes horticultural crop is the most vulnerable to climate stresses, followed by the second and third cycles (Table 4). Thus, farmers' perception on high variability of climate stresses between the three cycles of tomatoes horticultural crop is accurate.

Table 4 Means of maximum daily temperature and rainfall for the three horticultural cycles

Tomatoes horticultural cycle	Mean of maximum daily temperature (95th percentile)	Mean of rainfall (95th percentile)
First	38.2° C	42.86 mm
Second	36° C	34.4 mm
Third	34° C	24.27 mm

The first cycle reveals an increase trend (temperature and rainfall) over the entire 33 years (Fig. 8). A similar trend was found by Tadross (2009), who argues that in southern Mozambique, a positive trend of maximum temperatures (90^{th} percentile) between 1960 and 2005 was recorded.

But, these findings are slightly different to the present study. Tadross' research suggests that the highest increases in the days of extreme maximum temperatures registered over March – May; while the lowest were found between December and February. Lastly, September to November was the third period with the highest increase in temperature. This study did not go further to investigate the reasons for this difference, thus it remains unclear; in this regard more research is needed.

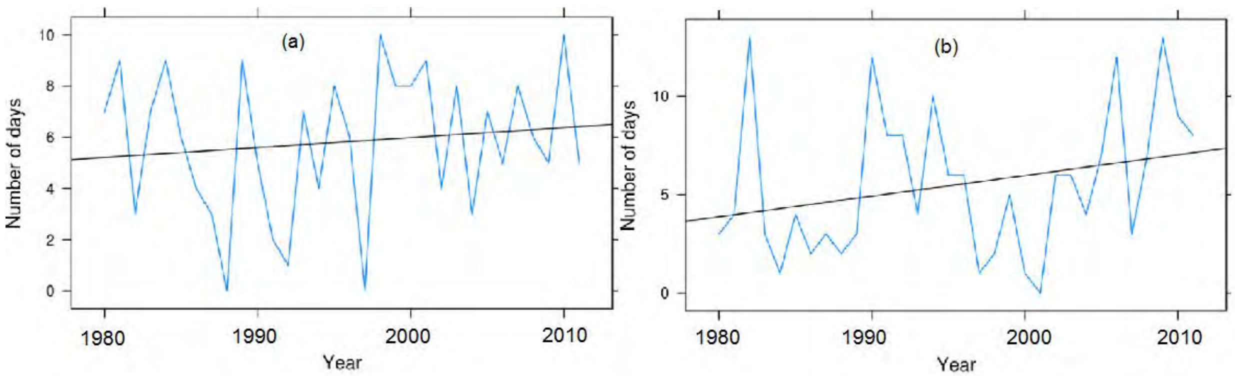

Figure 8 Trend of number of days above the mean at 95th percentile for the Chókwe district between October and January from 1980 – 2012: (a) precipitation above 42.86 mm and (b) temperature above 38.2°C

Neither number of days of maximum temperatures nor rainfall has increased over the second cycle of tomatoes horticultural crop (Fig. 9). Thus, the study argues that a considerable number of farmers noticing increase in the number of days of extreme events over this period can be explained by the fact that during the last decade of the study (2000 to 2012), there has been a steep increase in the number of days of extreme events. This is consistent with Madison (2006), who argues that farmers may remember the most recent events than the past.

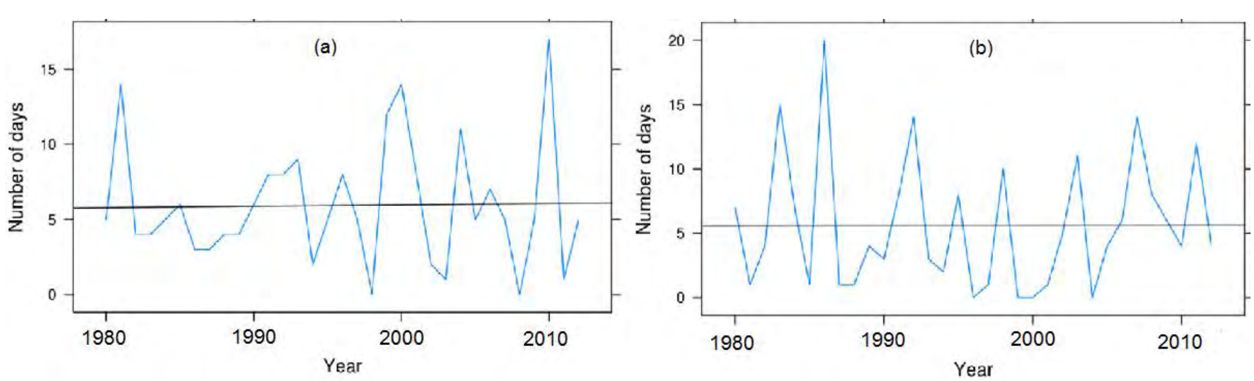

Figure 9 Trend of number of days above the mean at 95th percentile for the Chókwe district between Februarys and May from 1980 – 2012: (a) precipitation above 34.4 mm and (b) temperature above 36°C

The third cycle of tomatoes registered opposite trends (Fig. 10). Precipitation registered a negative trend; while temperature shows a steep increasing in extreme events. However, similarly to the two other cycles, over the last decade have been increasing the number of days of extreme events. This also suggests that farmers' perception of events is driven by the most recent events that have taken place in the last decade. Thus, it can also be associated with Madison (2006), who states that farmers remember better about recent than past episodes. Because the extreme events have increased in the last decade for the three cycles, the study argues that there is evidence that the frequency of extreme events has increased. This finding supports the IPCC (2014) which predicts a rise in the number of extreme events in both magnitude and frequency. Also, Eriksen *et al*. (2008) argues that there is significant evidence that rainfall and droughts are increasing in the southern Africa region.

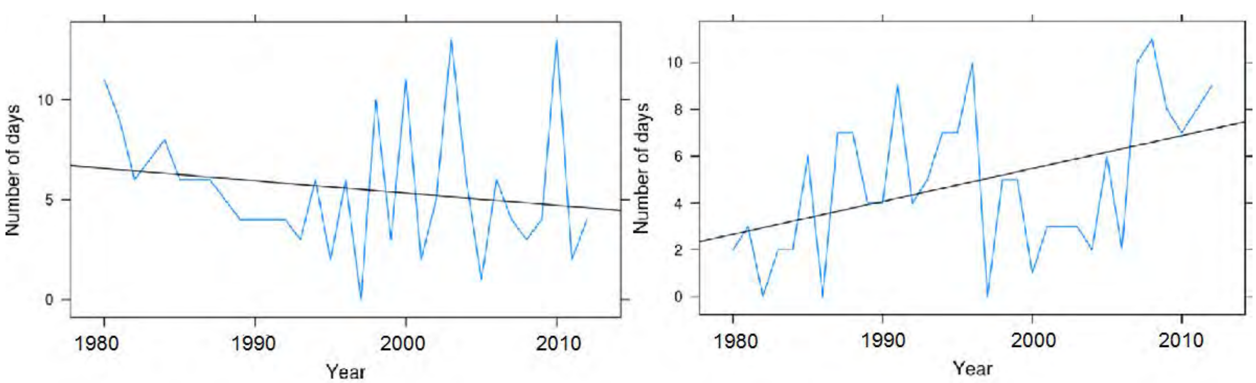

Figure 10 Trend of number of days above the mean at 95th percentile for the Chókwe district between June and September from 1980 – 2012: (a) precipitation above 24.27 mm and (b) temperature above 34°C

6.2 Related impact of each climate-related hazard on tomato production

6.2.1 Heavy precipitation and floods

This study found that heavy precipitation and floods impact on all stages of tomatoes' crop. The two hazards are indicated to cause substantial challenges to agricultural performance. For example, heavy precipitation and floods are attributed to delay field preparation and other agricultural activities, which can lead to lower crop yields and fruits' quality. Farmers' views are consistent with a number of findings. For example, Agble (1995) in Ghana conducted an experiment on one variety of tomatoes. The experiment was to evaluate the effects of delays in sowing and transplanting on the crop yield, seedlings quality and maturation. Agble concluded that delays in sowing and transplanting date reduce the chances of seedling survival in the field, leading to late fruit maturity and decreases in crop yield and fruits´ quality. Ayoade (2008) also analyzed the effect of delayed transplanting in five varieties of tomato. He found that delays of at least two weeks in transplanting resulted in significant decreases in the growth rate and crop yields of all varieties studied.

The present study also found that heavy precipitation at flowering stage reduces crop yield and fruit quality. This corroborates Weerakkody *et al.* (1997), who argue that heavy precipitation causes flowers to drop-off and, consequently, a substantial decrease in the crop yields. Furthermore, Ayoade (2008) found that heavy rain after a long dry spell leads to fruit cracking. Apart from that, heavy precipitation may stop the growing process altogether. According to Ayoade (2008), excessive moisture in soil decreases the level of oxygen and as a result, the root respiration process drops. This is because tomato roots are less adapted to inundated soils, therefore photosynthesis and growing processes are severely affected. Thus, this study argues that tomato production in the study area is severely reduced due to the occurrence of heavy precipitation.

6.2.2 Higher temperatures

The findings of this study suggest that tomato producers are mostly concerned with hot temperatures at sowing, flowering and harvesting stages. Warmer temperatures are described to decrease growth rate, crop yield and fruits' quality. This confirms earlier findings of Miller *et al.* (2001), Pressman *et al.* (2002) and Camejo *et al.* (2012) who revealed that warmer temperatures lead to adverse effects on the vegetative and reproductive development of tomato crops. However, the overhead temperature varies broadly. Camejo *et al.* (2012) found that in Cuba, environmental temperatures above 30˚C decrease the germination rate and leads to reduced yields; while in Canada, Miller *et al.* (2001) concluded that 35˚C was the threshold temperature at germination, seedling and flowering stages. Moreover, Pressman *et al.,* (2002) concluded that in North Carolina, in the USA, 32°C was the threshold maximum temperature for growing a tomato crop. The reason is that higher temperatures result in burnt leaves, reduced development of roots, lower yields and a change of fruits' color (Vollenweider and Gunthardt-Goerg, 2005). Higher temperatures are also cited to reduce pollen production and consequent flower and fruit abortions (Sato *et al*. 2002; Golam *et al.* 2012).

Results from the aforementioned researchers lead to the assumption that the farming of tomatoes in Massavasse and Muianga under higher temperature conditions is trying, with the first cycle possibly being the most challenging. As can be seen from figure 8 (page 37), the period between 1980 and 2012 indicated an increase in the number of days of extreme temperatures (above the 38.2°C). This is above the overhead temperature for both vegetative and reproductive development as defined by Miller *et al.* (2001), Pressman *et al.* (2002) and Camejo *et al.* (2012). Thus, this study argues that tomato producers in Massavasse and Muianga are particularly vulnerable to high temperatures. And in the hot season, tomato production is marginal for these farmers; this is likely to continue this way without prompt adaptation. Therefore, the study suggests that more attention is needed to deal with higher temperatures for tomato crops, especially at sowing and flowering stages, which are more sensitive.

6.2.3 Pests and diseases

This study indicates higher incidence of pests and diseases as barriers to tomato production. The key stages affected over the hot season include transplanting and flowering, with aphids and weevils the most troublesome pests during the hot season.

Farmers' perceptions are supported by the IPCC's report which argues that the impact of climate change will lead to higher temperatures and decreasing water availability. Consequently, these changes will increase pests and diseases on crops (IPCC, 2014). The reason is that most insect species are more likely to accelerate their breeding rates with higher temperatures and less humidity (Collier *et al.,* 2008). However, a number of findings suggest that in Mozambique, temperatures will increase in the next 40 years, ranging between 2.5°C and 3°C, and water will become a scarcity (INGC, 2009; Tadross, 2009; INGC, 2010). Thus, it is reasonable to assume that farmers in Massavasse and Muianga are likely to experience more difficulties in the years to come if no adaptive strategies are put in place.

The study also found that mildew and mice are the most noteworthy pest and disease over the fresh season. Mildew is cited to cause damage to crops mainly between germination and flowering stages; while mice destroy fruits at harvesting stage. The two pests and diseases are indicated to cause substantial financial constraints.

Farmers' descriptions are supported by Yanar *et al.* (2011), who stated that mildew can cause damage to all components of tomatoes crop. They also argued that this disease reduces plant growth and crop yields, which leads to a significant financial impact on farmers. However, from this study it remains unclear whether the incidence of mildew has increased due to climatic conditions that are conducive to its growth or whether the increase is due to poor fungicides treatment. Jacob *et al.* (2007) analyzed the conditions for development of powdery mildew of tomato. They found that the breeding rate was associated with lower temperatures and elevated relative humidity. The optimal development rate was found when environmental temperatures ranged between 15 and 25°C during weeks one to four after planting and relative humidity levels varied between 60-90% over weeks two to four. Because the lowest temperature among the three tomatoes horticultural cycles was found over the fresh season, associated with scarcity of rainfall it is possible that mildew can occur. But this needs more research to identify whether the pathogeny is or is not mildew.

6.3. Effectiveness of coping options

In light of the challenges brought by climate change, farmers have put in place several measures in their attempt to handle these. These measures are dependent on the climate-related hazard, stage of crop development and financial capacity of the individual farmer. Therefore, opening and cleaning drainage systems are the most common measures to deal with heavy precipitation and floods. To curb the impact of warm temperatures, farmers put in place several measures such as changing seed varieties, showing under shady trees or along the river beds, using mosquito nets, increasing the amount of water and pesticides used, and changing the times of irrigation, harvesting and delivering processes. Increasing the use of pesticides was also cited as a coping measure to deal with a high incidence of pests and diseases during the hot season. Despite the above, the implemented measures are not always effective in dealing with the effects of climate stresses.

Discussed below is the efficiency of such measures based on farmers' practices and existent literature.

6.3.1 Changing seeds varieties

The study proposes that the improved varieties used by farmers are not efficient to cope with warmer temperatures in Massavasse and Muianga. These improved varieties, including HTX 14, QUANTO and JAGUAR, are short cycle crops, meaning 3-4 months for vegetative growth. The varieties were selected by farmers to increase the chances of growth and harvesting in a shorter period of time, which may enable farmers to avoid shocks from warmer temperatures. This finding is similar to those reported by other investigations into strategies used to adapt to climate change in Africa (Newsham *et al.,* 2001; Gbetibouo 2009; Deressa *et al.,* 2009; Moyo *et al.,* 2012; Bryan *et al.*, 2012), who stated that farmers cultivated short cycle crops to deal with hot conditions.

Despite using improved seeds in Massavasse and Muianga, these varieties are not entirely suitable for the local conditions. The three varieties are cited to present lower agricultural performance and their fruits are described to be less tolerant to warmer temperatures and become flat-sided. The study is mindful that farmers in Massavasse and Muianga are trying to identify new varieties that may respond to the climate stresses.

6.3.2 Mulching techniques

The study found that at sowing stage, farmers use the mulching technique, which consists of covering the soil with the husk of rice. The mulching technique has been described as beneficial to crop performance (Roldan *et al.,* 2003; Challinor *et al.,* 2007). The benefits of mulching include improvements in soil moisture retention and soil quality (due to the addition of organic matter nutrients), and reducing the loss of nutrients in soil as a result of run-off (Khan *et al*., 2014). Mulching also protects seeds from heat and helps in preventing weeds and the rapid growth of roots, reducing evaporation from the soil surface, as well as increase porosity in compacted soils which increases drainage process (Liu *et al.*, 2000).

Despite the above, the use of this technique in both Massavasse and Muianga reveals inefficiencies as farmers in both communities use rice wastes only at the sowing stage rather than all. Therefore, it is possible that the full advantages of using this organic material are not exploited. Morongwe *et al.* (2012) and Khan *et al.* (2014) have both shown that mulching techniques indeed brings considerable results only if applied at all stages of crop development.

6.3.3 Sowing along the river beds or under the shady trees

Another coping strategy identified and used over the sowing stage to minimize the impact of higher temperatures during the hot season is sowing either under shady trees or along river beds.

Sowing under dense shady trees can result in maladaptation to higher temperatures. The reason behind this is that tomatoes require at least six hours of direct sunlight every day in order to generate enough energy for vegetative growth (Lazaneo, 2008). Naturally, seedlings in shadier conditions receive less sunlight, resulting in reduced quality of crops. This is because seedlings will become spindly due to the tighter competition for sunlight (Fredricks *et al*., 2014). After transplanting, these plants will show a weaker performance, including lower yields, lower resistance to pests and diseases, and less tolerance to higher temperatures.

Apart from that, excessive shading increases the chances of flower and fruit abortions, which also lead to lower crop yields (Wada *et al.,* 2006). Thus, the study argues that rather than implementing coping measures to curb high temperatures, farmers in both communities are implementing maladaptation measures that may be reducing their agricultural performance.

6.3.4 Increasing use of insecticides

The study found that farmers apply more pesticides to deal with the high incidence of pests and diseases. However, in spite of regular application of drugs, its incidence on crops remains high, causing substantial yield losses. This can be attributed either to consequences of climate change, will change the environmental conditions, thus speeding the breeding rate of new pests and diseases with impact on crops (IPCC, 2014) or to an inefficient pesticides rotation over the years (Cloyd, 2010). For example, from the interview with farmers it was found that some respondents had never changed pesticides since they started growing tomatoes, for some this was as long as 10 years ago. Because of that, it is possible that inefficient pesticide rotation may have lead insects to develop mitigation resistant genes (Cloyd, 2010). Thus, farmers are implementing maladaptation measures, increasing the impact of the specific climate-related risk (Grothmann and Patt, 2005). This gap needs more research, on different pesticides, control and experimental plots to identify whether or not the applied drugs are effective in controlling pests and diseases.

6.3.5 Increasing water supply

The irrigation system used by farmers was revealed to not be efficient in responding to higher temperatures. The reason is that farmers use gravity irrigation system, meaning that this technology requires graded fields with furrows for the water flow by gravity. However, the fields run across low slopes, resulting in increased exposure of water to sunlight and, consequently, water evaporation. Therefore, over the hot season farmers spend considerable time only irrigating fields, rather than other activities such as rearing animals, in an attempt to limit the effect of reduced water saturation because of evaporation.

Another disadvantage of gravity irrigation is the risk of increasing weed occurrence. As all points of the furrow are irrigated, this increases the chances of weed production. Therefore, the study argues that although farmers in both villages use water to minimize the impact of warmer temperatures, these measures are not completely efficient and need some improvement.

6.3.6 Improving water drainage

The survey shows that farmers implement some coping methods to mitigate the impact of heavy precipitation. These include opening and cleaning drainage systems, which aims to force water flow from the field crops to wider drainages. However, opening and cleaning has revealed to be inefficient because farmers are not able to drain all water from the fields due to inefficient technology. This is exacerbated by a lack of machinery to drain the water. As a result, and similar to irrigating fields, farmers are forced to spend much time trying to drain water, keeping them from other important duties.

7. Suggestions of adaptation measures

Given the climate risks of farming in Massavasse and Muianga, the previous section discusses several coping measures implemented by farmers in their attempts to build resilience. However, the measures are inefficient to respond to the current challenges. Thus, the present section discusses several options of adaptive strategies which could be implemented to add to farmers' efforts – Table 4. These options are based on the documented experiences of a number of organizations working on building resilience in agriculture (e.g. FAO, UNFCC and CCAFS). These organizations all indicate Climate Smart Agriculture (CSA) as the most suitable approach to build climate resilience in the agriculture sector.

The CSA approach consists of combining four aspects, namely: water management, weather information, carbon enhancing, and reduction of GHG emissions (FAO, 2013). This approach presents several advantages and simultaneously contributes to soil rehabilitation, increases farmers' production and reduces the impact of climate change (Neufeldt *et al.,* 2011; FAO, 2013).

Table 5 Suggestions of adaptation measures by climate risk based on the literature

Season	Climate Stress	Affected level	Stage of horticultural cycle	Related - impact	Suggested adaptive measure
Hot	Heavy precipitation/ floods	Crop production	Land preparation	Inundation of fields Delays of land preparation	Improving technology for water drainage Vertical drainage
			Sowing - germination	Germination failures	Provide farmers with seedlings Improving technology for water drainage Vertical drainage
			Transplanting - flowering	Loss of crops	Improving technology for water drainage
			Flowering - harvesting	Lower yields Loss of crops	Vertical drainage
		Physical	N/A	Damage to irrigation scheme, road networks, and farmers' possessions, including houses and animals	Improving road networks Financial assistance
		Socio-economic	N/A	Reduced farmer profits Increased risks of hunger and food insecurity	Financial assistance
	Higher temperatures	Crop production	Sowing - germination	Decreased germination rate Pests and diseases	Use of shade cloths/ Conservation agriculture (mulching technique and intercropping)/ Agroforestry technic (legume trees)
			Transplanting - flowering	Higher insolation Pests and diseases	Training farmers in Integrated Pest Management (IPM) Monitoring and control of migratory and seasonal pests and diseases Development of infrastructure for drip irrigation system Promotion of drought tolerant varieties Biological control
			Flowering - harvesting	Higher insolation Decreased yields Reduced quality of fruits	Building storage facilities and processing units
		Socio-economic		Decrease of farmers financial capacity Increased risk of hunger (diminished food security)	Financial assistance
Fresh	Lower temperatures	Crop production	Sowing - germination	Incidence of mildew	Training farmers in IPM Biological control
			Flowering - harvesting	Incidence of mice Damage to fruits Reduced yields	
		Socio-economic	N/A	Decrease of farmers financial capacity Increased risks of hunger and food insecurity	Financial assistance

Experiences of working with CSA implementation projects are exciting. For example, the Climate Change Agriculture and Food Security (CCAFS), together with the Food and Agriculture Organization of the United Nations (FAO) have applied this technique on maize production in Tanzania, Kenya and Zambia. Their results suggest that using this practice has reduced implementation time, increased water management, and declined the impact of weeds, increased crop yield and soil health (WB, 2011).

7.1 Improving water drainage and road networks

To improve water drainage and road networks this study suggests three options that can be explored: strengthen farmers' financial capacity, HICEP technical assistance, and build vertical drainages. Strengthening farmers' financial capacity could be accomplished through financial grants or credit lines. Both measures would facilitate the purchasing of water pumps to drain water from the fields. HICEP would assist farmers in building resilience by providing regular maintenance of the irrigation scheme.

A number of studies also argue that vertical drainage is one of the most effective measures to adapt to inundation. Vertical drainage consists of opening digs or inserting tube wells into the soft clay subsoil. Thus, through hydraulic gradient process water is fast squeezed out from the soil. Valipur (2012) analyzed the efficiency of drainage systems in clay soils in California, in the USA, including horizontal and vertical drainage systems. Valipur found that vertical drainage was the most suitable in accelerating water drainage. However, vertical drainage was revealed to be more expensive than horizontal drainage. Yusufzai and Grismer (1995) argue that vertical drainage is the most appropriate system to reduce water levels and overlying soils when compared with traditional tilling systems. Furthermore, the authors found that vertical drainage may reduce the salinity of soils. The CCAFS also recommends the use of vertical drainage as it helps crops overcome flooding stresses (Aggarwal *et al.,* 2013); however, it remains unclear whether the drainage conditions in Chókwe are suitable for such a drainage system or not. Therefore, this aspect calls for researchers to identify the efficiency of this technology in the local conditions, an area needing further exploration.

Another aspect to be considered among adaptation strategies is the enhancing of road networks, particularly those linking the two villages to the main road (between Macia and Chókwe). Improving road networks is the responsibility of commercialization efficiency. This would assist farmers in the distribution of their production all year around. By doing so, farmers would increase their profits.

7.2 Building drip irrigation systems

In order to minimize the loss of water, drip irrigation is an option for both communities. This will help farmers build resilience against this challenge. Although material and labor costs for the implementation of a drip irrigation system are relatively high, the system has several advantages, including more efficient water use, greater water application uniformity and less water-quality hazards (Awulachew *et al*., 2009; Shock, 2013; ENCON, 2012). Studies suggest that drip irrigated vegetables use 40% less water than a sprinkler irrigation system, and even less than the furrow irrigation used in farms. Moreover, it was also found that drip irrigation minimizes the impact of weeds. The reason is that using drip irrigation only some located points are irrigated while others remain dried (Schonbeck, 2015). This reduces the chances of weeds growth. Yield increases were also reported when the drip irrigation was used in association with the mulching technique in tomato crops (Schonbeck, 2015). The current study argues that drip irrigation in the focus areas would bring considerable advantages, as the current system of gravity irrigation is not efficient.

7.3 Breeding new varieties

The study suggests that there is a need to identify new alternative tomatoes varieties suitable to the climate stresses in both communities. The better quality seeds would help farmers in building resilience. Thus, the government needs to work with both the National Institute of Agricultural Research (IIAM) and the High Polytechnic Institute of Gaza (ISPG) in order to breed new varieties. Then, the extension officers need to conduct experiments in the farmers' field with the aim to help farmers to identify the best varieties. This would assist farmers´ uptake of new varieties.

7.4 Conservation agriculture

In order to build farmers' resilience, the study argues that farmers need to be encouraged to use vegetative wastes at all stages of crop development. Vegetative wastes include rice wastes, tree leaves, wood shavings, legumes, and cow manure. The use of different mulch types would also help farmers test the hypothesis that mulches have varying effectiveness for improving crop production (Liu *et al.*, 2000; John *et al.,* 2005). The great advantage of these organic materials is that they are more accessible to farmers due to its abundance in the community and do not need money to buy. Despite being more accessible, farmers' knowledge concerning the use of vegetative wastes is limited; therefore, the study suggests that the implementation of this technology be accompanied by field demonstration to show how best the use of organic material can be applied to tomatoes. Demonstrations should ideally be facilitated by extension officers. Such an approach is more likely to convince farmers to adopt the technology.

7.5 Use of shade netting + seedling improvement

This study suggests that farmers could be supported with shade netting as an alternative approach to reducing the impact of heat stress. Most farmers currently do not have netting because it is prohibitive expensive. Netting is effective because it provides covering while allowing enough sunlight to reach the crops. Furthermore, shade cloths reduce light intensity and effective heat; this helps plants regulate photosynthesis activities and optimize their growth (Oren-Shamir *et al.*, 2001; Retamales *et al*., 2008; Stamps, 2009). Shade cloths are also considered to provide physical protection from pests and diseases (Stamps, 2009).

In light of the above, CEPAGRI is urged to provide the ISPG or the Agricultural Institute of Chókwe (IAC) with such material, including shade netting and other agricultural inputs, in order to improve farmers' technical and financial capacities. The ISPG would produce quality seedlings and then provide farmers, building their capacities to deal with heat stresses. By doing this, farmers would be in a better position to overcome their lack of seedlings, improve their productivity and increase their financial capacities. This approach could be implemented in two ways, either through credit line or financial grants. Through credit line farmers would be provided with improved seedlings as loans so that they could pay back the amount after harvesting; while financial grants aims to allocate seeds for free.

7.6 Introduction of Integrated Pest Management (IPM) and biological control

The study suggests that the use of IPM to control pests and diseases would be of huge advantage to farmers in the study area. IPM consists of using fewer chemicals and more eco-friendly inputs such as botanicals and bio-pesticides (Gajanana *et al.,* 2006). Therefore, this technology is more economically viable and environmentally friendly. Recent experiments have shown that the IPM technique brings considerable results. IPM decreases the chance of incidence of health hazards associated with the spraying of chemicals; on the other hand it increases the yield and farmers' profit.

Apart from the IPM technique, biological control is also necessary to decrease the impact of mice in the study area. Biological control consists of using an organism to reduce the numbers of another (Potter, 2004; Olson *et al.,* 2012) for example owls can be used to reduce mice. The great advantage of this technique is that it is environmentally friendly, since the predator feeds on the pest, contributing to a balanced ecosystem (Olson *et al.,* 2012). A number of researchers have shown the importance of owls in controlling the occurrence of mice in the field. For example, Potter (2004) reported the use of owls to control mice in wheat farmlands in Western Province, South Africa. The experiment found that using owls was twice as effective as using poison and more economically viable in the long-term.

Despite the benefits, owls have associations with traditional cultural beliefs. As mentioned by Botha and Komen (2012), many people in Africa believe that owls are associated with bad luck, in particularly spotted owls. Therefore, it is difficult to predict if this method would be well received or even implemented by farmers. This study suggests that before the introduction of this technique a pilot survey should be conducted to get some insight as to whether farmers in Massavasse and Muianga would be happy with this measure. If positive, financial grants are needed to implement this strategy. Grants would be necessary to need to cover the costs of purchasing owls; then, nest them in boxes in areas surrounding farmer' fields. This would facilitate all farmers to benefit from the owls.

7.7 Introduction of agroforestry techniques

This study suggests the co-planting of leguminous trees (e.g. leucaena - *Leucaena leucocephala*) close to the field or by using these to make a fence for the field. The reason is that leguminous trees can convert nitrogen gas from the atmosphere into usable nitrogen for plants, improving the local environment and contributing to soil improvement (FAO, 2010). Therefore, leguminous trees contribute significantly in the reduction of GHG emissions and decrease farmers' need to buy fertilizers (FAO, 2013; Aggarwal *et al.,* 2013). Leguminous trees also represent other advantages. The leguminous leaves can be harvested to feed cattle, which would minimize farmers' lack of green pasture in certain seasons of the year (FAO, 2011).

During the execution of field research, the researcher observed a dispute between livestock owners and HICEP officers. The dispute was due to farmers grazing their animals in the irrigation scheme. The officer responsible for the system argued that the procedure would destroy the drainage system; however, the livestock owners bemoaned having limited options to graze. Therefore, the study argues that conservation agriculture, associated with the co-planting of leguminous trees, would be of great importance in Massavasse and Muianga. This would simultaneously increase crop and livestock productions as well as decrease the risks of environmental pollution. To meet this end, leguminous trees need to be allocated to farmers as financial grants. Likewise, seedlings for these plants could be produced under an agreement between CEPAGRI and the research institutions.

8. Limitations of the study and future research directions

8.1 Limitations of the study

Despite fulfilling the study objectives, some limitations were identified during the field research. These are discussed below.

Due to time constraints, this study was conducted only in two villages and covered a small number of households. Because of that, it is possible that the perceptions of this group do not accurately reflect sentiments of the majority of farmers. Thus, to generalize the results for the entire district of Chókwe, the research should have involved more villages and increased the sample population. Time limitations also did not allow the researcher to contact some stakeholders working on agricultural research nor credit financing institutions such as ISPG, IAC, IIAM or CPL. This interaction would have helped to better understand how different institutions could work with farmers to build their technical and financial capacities.

In addition, the selection of respondents was based on two criteria: high dependence on agriculture and the age of the head of household. Given the fact that the majority of farmers in the study area do not own any personal documentation, it is possible that some respondents were below 30 years old. Only farmers that were above 30 years old were considered for participation. Thus, the hypothesis that farmers above 30 are more experienced might not be efficiently exploited.

Third, the complete socioeconomic impact of climate change was not well assessed; neither does the study go further to investigate the impact of climate stresses in farmers' livelihood. This was also prohibited by time constraints, which limited the use of lengthy surveys and observations to support farmers' sentiment. Apart from that, the study did not use any statistical qualitative software to perform the analysis. Because of this, it is possible that the number of respondents attesting certain perceptions on climate variability might not be statistically significant, potentially misleading the results. The study also fails to use scientific criteria to define poor and wealthier farmers in the community. These indicators were rather assessed through the researcher's personal observation, based on his opinion, which may have also affected the results.

8.2 Future research directions

In order to better develop responses to the research objectives of this study as well as new research questions that were prompted while completing the investigation, suggested future research could include:

1. Field experiments that test the effectiveness of the mulching technique using different organic materials;
2. A socioeconomic study to assess the impact of climate stresses on tomato crops;
3. Study into how best to transmit market information or weather-related information and crop advisories to farmers in different seasons;
4. Experimenting on different pesticides, control and experimental plots to identify whether or not the drugs applied in Massavasse and Muianga are efficient to control pests and diseases;
5. Field study to identify whether the described pathogeny during the fresh season is or not mildew.
6. Field experiment to analyze the efficiency of vertical drainage in the soil conditions of Massavasse and Muianga;
7. Analyzing the process of providing loans to smallholder farmers by CPL.
8. Analyzing the impact of applying agricultural chemicals in the health effects.

9. Conclusion

The aim of this study was to understand climate vulnerability among horticulture producers in Chókwe district, in Mozambique. The objectives of the research were to describe the horticultural cycle of tomatoes; determine how weather and seasonal climate impact on each stage of production according to farmers' personal experiences; identify the physical and socio-economic consequences of climate impact at each stage of production over the farming period; identify strategies used to manage the risks associated with each stage of production over the farming period; detail farmer's further suggestions regarding these strategies, and lastly, assess the efficacy of these coping strategies.

The study found that farmers in both villages grow tomatoes in three cycles over the year. In general, producers use short cycle varieties which last four months. The first cycle occurs between October and January; while the second and third cycles fall over February to May and June to September, respectively.

The study also states that farmers in Massavasse and Muianga are vulnerable to climate stresses, and that farmers' perceptions of climate variability match the observed climate data. The most impactful hazards include floods, heavy precipitation, warmer temperatures and a consequent increase of pests and diseases. These stresses are more severe over the first cycle and less dangerous in the third horticultural cycle. The most significant stresses are damage to crop, decrease of fruits quality and yields, and damage to road networks, all of which have a substantial impact on farmers' livelihood.

Farmers use several sources of income to overcome the impact of climate stresses, including xitique*,* poultry sales, off-farm works, reed sales and livestock sales.

Coping measures put in place include sowing along river beds and under shady trees, covering the surface of soil with the husk of rice, changing varieties of seeds, use of mosquito nets, changing harvesting and delivery times, increasing the amount of water and pesticides used, and cleaning the wider drainage and opening small drainages in the field to dissipate water. However, the study found that the implemented measures were not efficient to respond to the above-mentioned challenges. These measures fail due to several factors, such as lack of seed varieties that may respond to the local climate stresses, use of inefficient technologies to drain water and produce seedlings, financial constraints, poor road networks, lack of reliable climate information, inadequate extension services and various market barriers.

Therefore, this study recommends several measures to enhance farmer resilience to the effects of climate change. These adaptive strategies are mulching technique, introduction of drip irrigation, vertical drainage, use of shade cloths, improvement of road networks, promotion of drought tolerant varieties of tomato seeds, building storage facilities and processing units closer to farmers, training farmers in IPM, and the introduction of biological control and agroforestry techniques.

In conclusion, the study also recommends strong coordination of all stakeholders, including farmers, government and research institutions.

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