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The effects of climatic variability on farmers household welfare in Zambia

BACHELOR'S THESIS

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Declaration

I hereby declare that I have done this thesis entitled ‘‘ The effects of climatic variability on farmers household welfare in Zambia‘‘ independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 14 April 2023

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Kristýna Šulcová

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Abstract

Climate change is described as the gradual shift in the Earth's climate. It is ascribed to human activities that modify the composition of the global atmosphere, contribute to natural variability, and are detected across comparable time periods. Climate change is devastating the global economy and taking the lives of individuals, communities, and countries. Weather patterns are shifting, sea levels are rising, weather events are becoming more intense, and greenhouse gas emissions have reached historic highs. Without intervention, the average global surface temperature is expected to exceed 3 degrees Celsius this century. The poorest and most vulnerable individuals suffer the most.

Results show that climate change is characterized by climate shocks, affecting human activities and leading to poverty, malnutrition, and a general deterioration in human life, especially in Africa. Climate change in Zambia has a long-term negative impact on socio-economic relations, leading to poverty, malnutrition, food insecurity, and decreased income. Farmers must learn to adapt to climate variability by applying climate-smart agriculture strategies such as soil and water conservation, crop rotation, agroforestry, grazing management, multi-cropping, conservation agriculture, and organic farming. Additionally, agricultural extension services provide vital meteorological, educational and technological information to farmers.

Key words: Climate, vulnerability, adaption, welfare, Zambia

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List of the abbreviations used in the thesis

IFPRI – International Food Policy Research Institute

ACDEP – Association of Church-based Development

DRC – the Democratic Republic of Congo

CREWS – Climate Risk & Early Warning Systems

ZICTA – Zambia Information & Communication Technology Authority

CGIAR – the Consultative Group on International Agricultural Research

GFRAS – Global forum for rural advisory services

UNCH – United Nations Climate Change

WMO – World Meteorological Organization

WFP – World Food Program

USAID – United States Agency of International Development

AGNES – Africa Group of Negotiators Experts Support

1. Introduction

The modern world is a place whose development is influenced by forces of different natures. These include geopolitical, socio-economic and environmental pressures, which can be expressed in creating several types of problem situations. Suppose humanity can fully or partially regulate geopolitical and socio-economic problems both at the local-regional and global levels. In that case, environmental problems are distinguished by their often inability to manage them, resulting in some unfavorable for human's the local-regional and global levels. Environmental problems are characterised by their often inability to manage them, resulting in some unfavorable for human development scenarios. One of them is climate change. Climate change appears not just locally – it affectss world's ecosystems with all its elements included. Nowadays, it affects every region on Earth (IPCC 2021), posing a great danger to the future of humankind. It also threats human health and development (WHO 2018). Although itt is worth mentioning, climate change, despite beinga worldwide phenomenon, influences some regions more than others, creating short-term and long-term damage. One of them is the African region.

According to UNCH (2020), climate change is an increasing threat to Arica, which can destabilize countries and entire African continent (WMO 2022) by creating more water stress and other hazards. As the disruptor of human and natural systems, climate change in Africa is responsible for people's displacements, droughts, wildfires, increased poverty, food insecurity, and decreased overall quality of life (WMO 2022). These problems multiply, especially in Southern Africa because the region is heating up twice the rate of the global average (WFP 2021). It is projected that by 2050 increase in mean annual temperature could reach 2ºC (USAID 2015). Additionally, during each summer month Southern Africa could experience 8 to 9 additional hot days that will further disrupt not only ecosystem but also human-economic society linkages. Climate change presents a threat not only to the environment directly but also to other dimensions that affect human life. WMO (2022) stated that increased temperatures in Africa resulted in a 34% reduction in agricultural productivity, which is also present in the Southern Africa region.

Among Southern Africa countries, Zambia faces adverse impacts of climate change, including droughts, flash floods, changes in the growing season, increased spread of diseases such as malaria, and a sharp decrease in agricultural productivity (Kalantary 2010). Observed annual mean temperature in Zambia is also been increasing since the second half of the 20th century: in 1960 – 21.5ºC, in 1990 – 22.1ºC, 2005 – 23.1ºC, 2021 – 22.1ºC (Climate Change Knowledge Portal of the World Bank 2021). Those changes significantly affect households relying on agriculture as a primary source of welfare, pushing 13% of the country's population into severe food shortages (ReliefWeb 2022). On top of that, agriculture-related food insecurity and poverty are already severe in Zambia, disrupting resilience of the farmer's household welfare (Stadtbäuner 2022).

Zambian farmer's household is a fragile system facing many challenges that accelerates climate change-related problems. Predominantly, abnormal climatic variabilities, such as frequent droughts, put immense pressure on Zambian farmers because agriculture in Zambia is mostly rainfed (Ngoma et al. 2021). Therefore, Zambian household's welfare suffers from crop failure, livelihood assets losses, increased food insecurity, and economic shocks that further drag farmers into poverty. As a substantial problem, climatic variability in relation with Zambian farmer's households can still be tackled. In a modern globalized world, technology can be a solution that will help farmers, especially in developing countries like Zambia, quickly adapt to climate changes. One tool in that regard is agricultural extension services in form that disseminating agricultural and climate-related information can help farmers balance their livelihoods and agricultural activities. Agricultural extension services are in use in Zambia, presenting in such formats as dissemination through radio, television, mobile phones, and the Internet, facilitated with the help of the Government of the Republic of Zambia. Extension services can help mitigate the climate-related losses affecting farmer's livelihoods in Zambia, creating a more resilient and productive environment for their development (Chavula et al. 2022). Although, it is worth mentioning that the paradigm of climate-related problems affecting Zambian farmers' households is a multifactorial problem with many variables. Therefore, further theoretical investigation is needed. The study's main aim was to analyze the effects of climatic variabilities on farm households' welfare in Zambia.

2. Aims of the Thesis

Climate variability leads to a change in geophysical, biological and socio-economic systems. The recurrent climate variability includes changes in rainfall patterns and temperatures that impact agricultural production, livelihood activities, and household welfare.

The study aims to analyze the effect of climate variability on farm households' welfare in Zambia.

Specific objectives

1. To understand the paradigm of climate change and climate variability.
2. To examine the influence of climate change on farm production and household welfare.
3. To explore the farmers' adaptation options in climate variability.

3. Methodology

This Bachelor's thesis methodology is established on the literature review of secondary sources that examine the effects of climatic variability on farmers household welfare in Zambia. To establish the pattern of searching for suitable information, four main subtopics were chosen.:

1. Climate change and variability.

2. Zambia: climate and agriculture: overall perspective, common linkages, and characteristics.

3. Role of agricultural extension services in agriculture predominantly among the farmers in Zambia.

4. Farmers' adaptations to climatic variabilities: an overall perspective and in Zambia.

The search for scientific articles, reports and other sources was conducted using the following databases: JSTOR, ScienceDirect, Google Scholar, and Researchgate. The following portals and databases were also used to get the most relevant information for the research: Climate Change Knowledge Portal, FAO, UN, and UNDP. Other sources of information – news portals, official websites of various authorities, and other relevant websites – were also used to get the necessary information. The literature sources' selection is based on the literature source's name and content. The literature source must 1) be written in the English language, 2) have the intention to examine those as mentioned above four main subtopics, 3) have the time scope between 2000-2020 for Zambia's climate-related statistics (2021, 2022 – if data is available), 4) contain relevant for the study information.

The main search to investigate the climate pattern, agriculture, farmer's adaptation to climate variability, and linkages to farmer's household welfarefocused on the following topics:

1. Climate: climate change and agriculture, changes in temperature and precipitation between 2000 and 2020 (2021 – if the data is available), agroecological zones, agricultural production, climate-smart agriculture and its approaches.

2. The role of agricultural extension services in disseminating climatic information among farmers.

3. Farmer's household welfare.

4. The effect of climatic variabilities on farmers' household welfare in Zambia: here, the ten studies were investigated to find the adaptation strategies that can help cope with climatic variabilities. The search's aim was to find out the following information in these studies: aim of study, study area, sample size, methods, key findings, references.

4. Literature Review

4.1. Climate change and variability

Climate change is defined by the United Nations Framework Convention on Climate Change as a change in climate ascribed directly or indirectly to human activity modifying the composition of the global atmosphere, and is in addition to natural climate variability over similar periods (Boadu 2016). Climate change's effects are global in scope and unparalleled in scale, ranging from altering weather patterns that imperil food production to rising sea levels that raise the risk of catastrophic flooding. Adapting to these repercussions in the future will be more complex, and costly if action is not taken today (United Nations 2022).

Flooding, drought, heat waves, lower food production, and decreased labor productivity are all problems associated with climate change in Africa. Health consequences might be caused directly by environmental shocks or indirectly through socially mediated effects (Lukoye et al. 2022). The effects of climate change on several areas of society are interconnected. Drought may have a negative impact on both food production and human health. Flooding can potentially spread illnesses like cholera and destroy ecosystems and infrastructure (WHO 2023). Human health difficulties can raise death rates, reduce food availability, and reduce labor productivity. The effects of climate change may be observed in every part of our world. However, the effects of climate change vary across the country and worldwide; even within a single community, the impact of climate change might differ between neighborhoods or people.

Long-standing socioeconomic imbalances can render underserved populations more susceptible, as they are frequently the most sensitive to risks and have the fewest means to respond (NOAA 2023). 2022 was the sixth hottest since worldwide records started in 1880, with temperatures 0.86°C higher than the 20th-century average of 13.9°C. This number is 0.13°C lower than the 2016 record and only 0.02°C higher than the 2021 value, which is currently the eighth highest.

The ten warmest years on record have all happened after 2010, with the previous nine years (2014-2022) rating as the nine warmest. Notably, 2005, the first year in the twenty-first century to establish a new global temperature record, is now tied with 2013 as the eleventh-warmest year (NCEI 2023).

According to the study's findings by Barati (2023), CO2 emissions and temperature have constantly grown from 1966 to 2015. The most significant growth in CO2 emissions occurred from 2003 to 2012. Nonetheless, the temperature rose sharply between 1989 and 2000. In 2015, CO2 emissions and temperature increased by 99% and 5.5%, respectively, compared to the baseline (1966–1990). Over the last several centuries, atmospheric CO2 has increased temperature (Barati, 2023). Climate change's potential impacts on agricultural systems' ability to provide food, feed, fiber, and fuel, as well as the maintenance of ecosystem services (e.g., water supply and habitat for crop landraces, wild relatives, and pollinators), as well as the integrity of the environment, are significant concerns (Pragya 2012). Africa is predicted to account for more than half of the global population increase between now and 2050 and has the fastest population growth rate of any major region. Sub-Saharan Africa's population is expected to treble by 2050 (United Nations 2022).

The North African countries have many similarities in vulnerability to average and extreme temperature rise. Droughts will increase, with Morocco and Algeria experiencing the most significant increases. Climate change will have an impact on the already low water supply in all of the nations evaluated. Algeria, Tunisia, and Egypt are the most vulnerable to these changes (Schilling et al. 2020) The climate of North Africa varies greatly between the region's coastal and inland regions. North Africa has a Mediterranean climate along the coast, with moderate, rainy winters and warm, dry summers, with an average annual rainfall of 400 to 600 mm. Inland regions feature semiarid and arid desert climates, with daily high and low temperatures ranging from 200 to 400 mm per year for semiarid regions to less than 100 mm per year for desert regions (DNI 2023).

The research in West Africa looked at how rising temperatures affected agricultural output in ten West African nations from 1990 to 2020. According to Iheonu’s (2022) data, increasing temperatures have a greater negative impact on Togo and Mali.

These findings are robust regardless of the estimator employed. The study recommends that West Africa use green energy since existing evidence indicates that green energy minimizes climate change. It is also suggested that Gambia, Mali, and Togo implement climate adaptation measures to increase agricultural output. The study's weakness is that thresholds were not considered (Iheonu et al. 2022). Under current climate conditions, precipitation in Mali and Niger has increased by 20 mm each year, for 300 mm. This quantity rises as one moves south, reaching 150 mm in Nigeria and 200 mm in Guinea. In the current climate, these two locations receive more than 2000 mm of rain yearly. This increase in precipitation is exacerbated by +3°C global warming (Impact2c 2023).

According to East African research, climate change will severely impact the massive population centers of Sudan and Ethiopia under extremely high emissions scenarios. The expected regional climate change includes a general warming of mean temperatures over the region with a magnitude of roughly 2.0 °C, resulting in more frequent and severe climate extremes. Port Sudan, a city near the Red Sea, is the most sensitive to heat stress. The East African low plains are particularly vulnerable to heat extremes soon, with temperatures reaching or above the severe risk threshold of 31 °C. Without urgent climate change mitigation solutions, East Africa will face increased hazards of extreme climatic events such as dangerous heat and heavy rainfall within a few decades. These heat extremes exacerbate the current semi-arid conditions, contribute to food shortages, and constitute a considerable health risk (Choi 2022).

Sub-Saharan Africa is now the world's most food-insecure area. Climate change is expected to exacerbate the issue if solid actions are not implemented. Some regions may become uninhabitable for some organisms due to being too hot, wet, dry, or severely plagued with pests or illnesses (Chintu et al. 2011). Scientists expect that Southern Africa will get drier while rainfall in regions of East Africa will rise. Drought areas in Botswana, Ethiopia, Sudan, and Zimbabwe are predicted to be more affected by climate change than in humid regions in Tanzania or Zambia. Drought is already becoming more prevalent and persistent in Southern Africa's drylands, and drought is predicted to rise as temperatures rise and rainfall decreases (IFAD 2023). Zambia's central and southern regions are the driest in the country, with annual rainfall ranging from 400 to 800 mm. It is reasonable to predict that the areas will get drier with time.

As a response to the rising water stress circumstances in drier places, the climate crisis has led some farmers and agricultural professionals to turn to irrigation anddrought-resistant crops (Chintu 2011).

4.2. Agroecological Zones in Zambia

Zambia is divided into three Agro Ecological Regions - AER I, AER II (IIa and IIb) and AER III (Ashlian et al. 2014). Climate change influences the country's Agro Ecological Regions, as indicated by reported progressive rises in average temperatures of 0.3 degrees Celsius each decade and a falling trend in rainfall levels. The Southwest Region (primarily AER I) and Western sections (AER II) of Zambia have received less rain and have seen a higher frequency of climate severe events such as droughts and flash floods than other Agro Ecological Regions of the nation (Climate Change Knowledge Portal 2023).

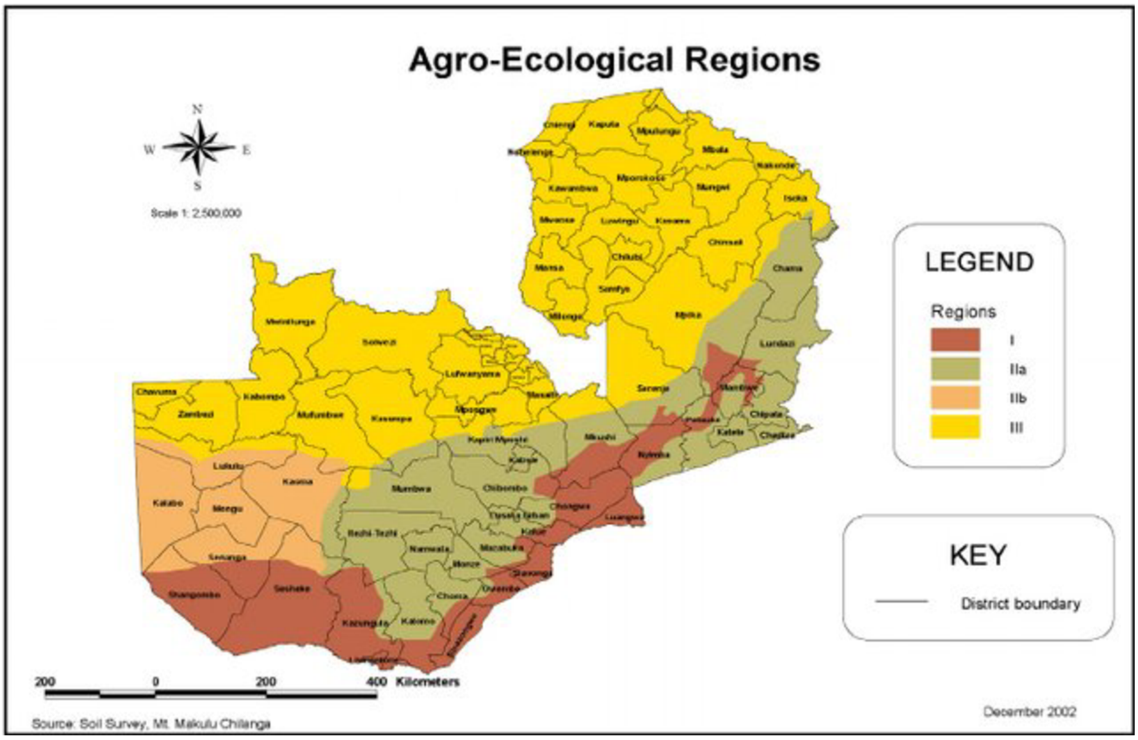


Figure 1 - Agro-Ecological Regions

Ashlian et al. 2014

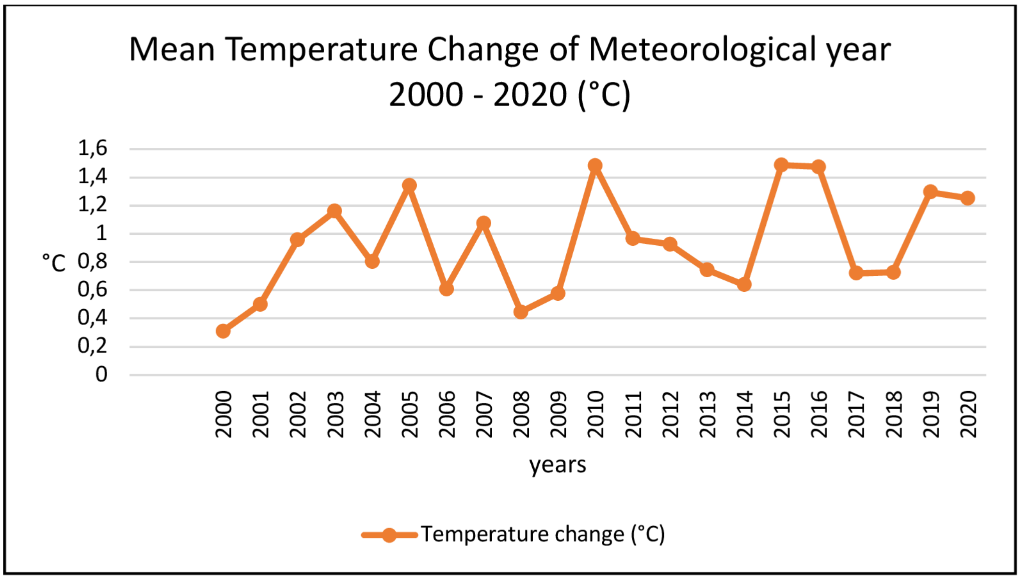
Zone I has an annual mean precipitation of 800 mm and annual mean temperatures of roughly 26.7 ℃ (UN CC: Learn 2021). The Luangwa-Zambezi rift valleys dominate it. Soils in this region are characterized as loamy to clay soils. Crops cultivated in this zone are cotton, sorghum millet, seseme and cashew nuts (Meyer et al. 2018). This is usually referred to be Zambia's low-rainfall zone (Shitumbanuma 2021).

Zone II has annual mean precipitation of 800 to 1000 mm and annual mean temperatures of around 22.1 ℃. This region is usually called Zambia's medium rainfall region (Shitumbanuma 2021). It includes the western semi-arid plains of the Zambezi Valley (IIb zone) and the Kafue Flood Plains. Rainfall range is between 800 – 1000 mm annualy. The region contains loamy to sandy soils. Major crops in this region are cassava, sorghum, millet, sesame, cashew and nuts (Meyer et al. 2018). Southern and Eastern plateaus (IIa zone) and the Luangwa Valley have the same rainfall as in region IIb. The main crops grown in this region are maize, cotton, tobacco, sunflower, soybeans, irrigated wheat, groundnuts, flowers, paprika, vegetables, cassava and millet. The inherent fertile plateau soils are specific to this region (Meyer et al. 2018).

Zone III has annual precipitation in the 1000 - 1500 mm range and includes the northern high rainfall area with moderate annual temperature averages of around 21.7 ℃ (UN CC: Learn, 2021). This is Zambia's high rainfall zone (Shitumbanuma 2021). The soils in the area are quite deep, sandy clay loam. The main crops in the region are cassava, millet, sorghum, beans, groundnuts, rice, coffee, tea, and pineapple (Meyer et al., 2018).

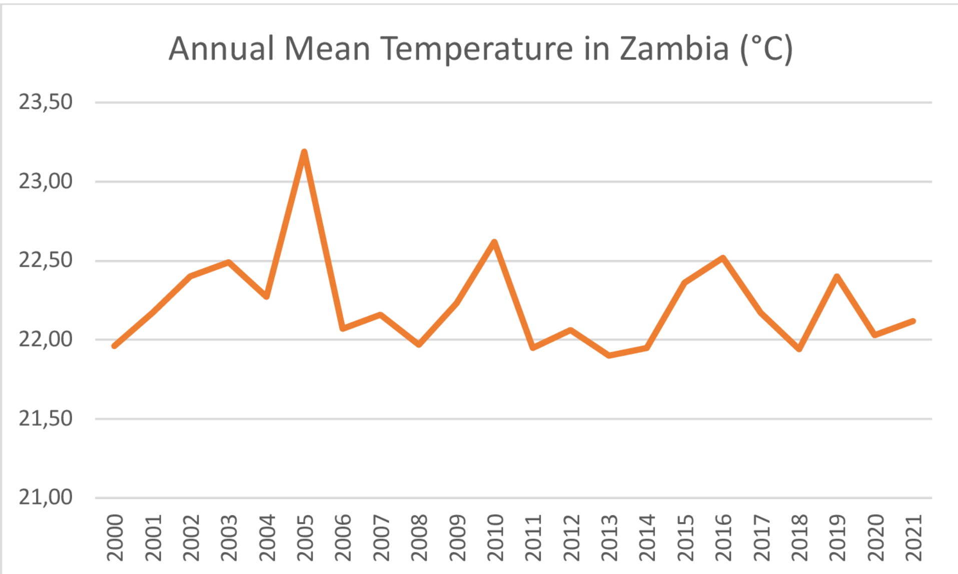
Climate trends must always be understood in the context of natural variability. Temperature and precipitation allude to how climatic conditions change yearly within their respective usual fluctuation ranges (CCKP 2023). According to FAO data, Zambia had an average annual temperature increase of 1.252 °c in 2020. If we compare the data from 2000 to 2020, we can see that the temperature increase was 0.941 (FAO 2023). The graph depicts how much the yearly temperature has been above average from 2000 to 2020. The blue curve depicts temperatures change.

Table 1 – Mean Temperature Change of the Meteorological year 2000 – 2020 (°C)



FAO, 2023

Table 2 – Annual Mean Temperature in Zambia

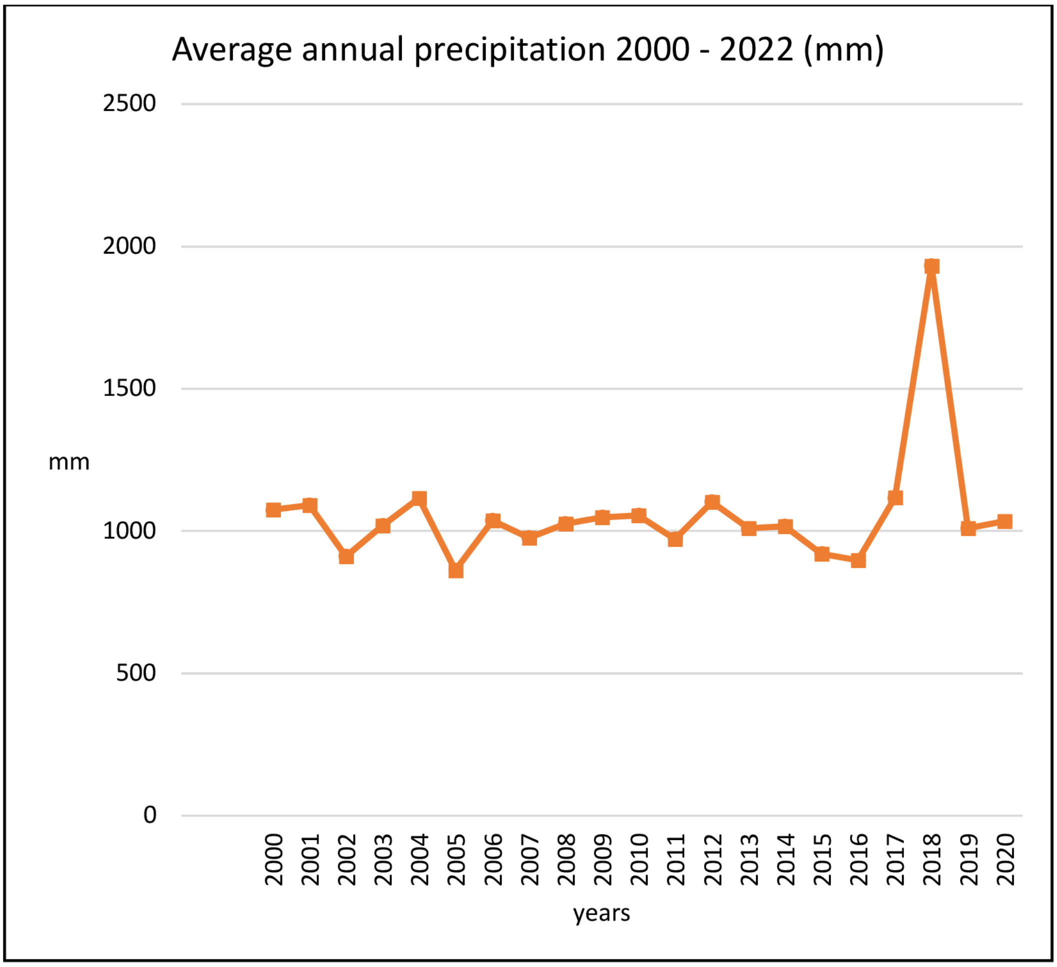


Climate Change Knowledge Portal, 2023

According to Table 2 the hottest temperature measured in period 2000 to 2021 was recorded in year 2005, with annual mean temperature of 23.19 °C. The lowest temperature was recorded in 2013, with an annual mean temperature of 21.90 °C.

Zambia has abundant water resources but has done little to leverage them through irrigation system investments, and the bulk of farmers continue to rely on rain-fed cropping cycles (International Trade Administration 2023). Zambia has likewise seen a decline in annual precipitation per decade since 2000, owing primarily to the lower rain fall in the rainy season (December to February).

Table 3 – Average annual precipitation 2000 – 2022 (mm)



Trading Economics, 2023

4.3. Agriculture in Zambia

4.3.1. The contribution of agriculture to Zambia's economy

According to Zambia's National Policy on Climate Change, the agriculture industry contributes 16 - 20% of the country's national GDP and employs more than 50%

of the people. Furthermore, according to the Seventh National Development Plan, more than 70% of smallholder farmers rely exclusively on rain-fed agriculture.

As a result, the industry is subject to climatic fluctuation, resulting in lower agricultural productivity. Smallholder farmers have implemented a variety of adaptation tactics in response to climate change and unpredictability (Musungu 2020). Agriculture is the most significant contribution to GDP, and wholesale and retail trades are second. The Zambian government considers agriculture the best alternative to mining due to its considerable contribution to GDP (Nkolola 2016).

4.3.2. The types of farmers and their characteristics

Farmers are divided into three categories small-scale, medium-scale, and large-scale. Small-scale farmers account for the great majority (about 90%) of Zambia's agricultural producers, and they are mostly subsistence producers of essential foods with the odd marketable excess. Medium-scale farmers cultivate maize and a few other cash crops for sale. Large-scale farmers grow various crops for both the domestic and export markets. Three-quarters of the population is employed in agriculture (International Trade Administration 2023). One factor for the limited use of potentially arable land is that the Zambian agricultural industry is dominated by small-scale farmers with extremely tiny plots of land. Furthermore, because most small-scale farmers lack resources, they cannot afford to invest in irrigation (Shitumbanuba 2021).

Small-scale farmers cultivate 0.1-4.99 hectares of land (Sitko et al. 2014). A smallholder farmer is sometimes referred to as a family farmer since many rely on relatives labor to satisfy production demands and save a portion of their produce for household use. Smallholder farmers, often known as small-scale farmers, comprise farmers who own the land they labor and those who do not (Heifer International 2022).

Emerging farmers are those who cultivate 5-20 hectares. As the term indicates, Emergent farmers are commonly recognized as transitioning between small-scale, semi-subsistence agriculture and larger-scale, more commercial farming (Sitko et al. 2014).

Farmers who cultivate more than 20 hectares are called large-scale farmers (Sitko et al. 2014).

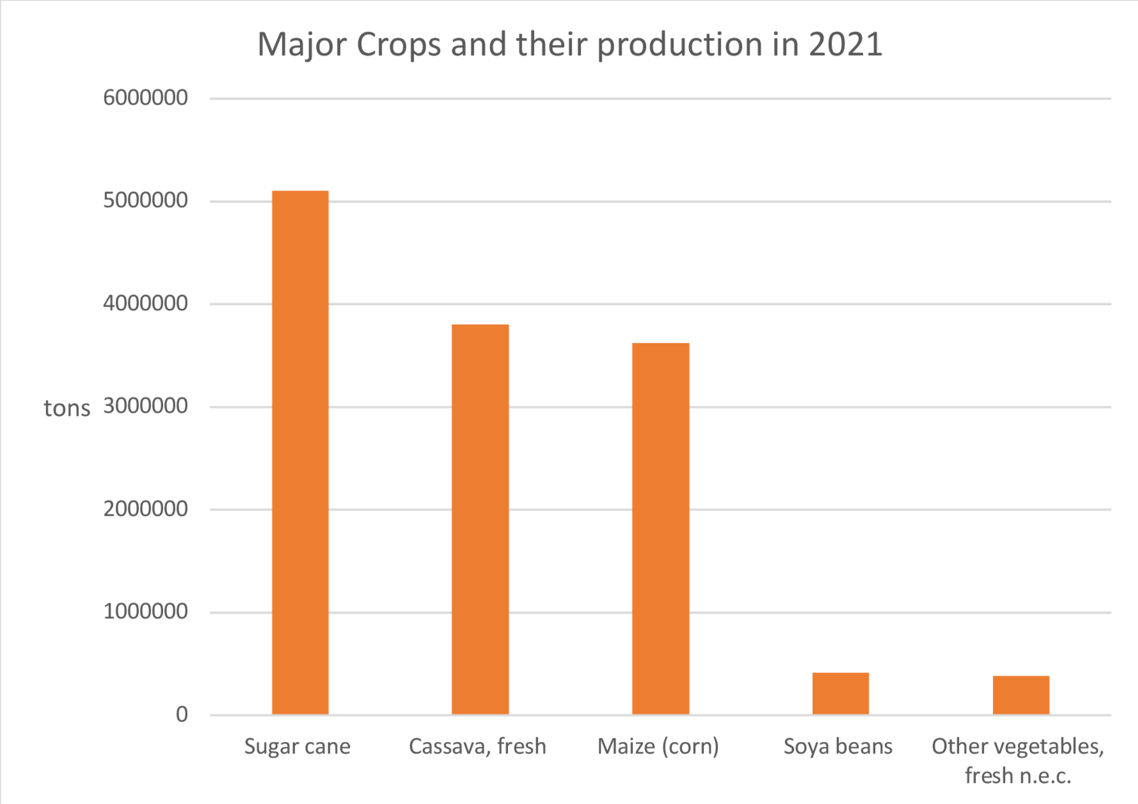
Commercial farming produces crops and cattle on a big scale and on large farms, employing technology, irrigation systems, chemical fertilizers, and other technologies (Converse energy future 2023).

Agriculture in Zambia is relatively inefficient. Smallholders grow most of the planted land with rainfed crops, which include a variety of staples, perennial and horticultural goods, and cash crops, mainly tobacco. There are also mixed agricultural methods at the family level, with fruit trees such as banana, mango, cashew, citrus, vegetables, grazing cattle, sheep, and goats (IFAD 2021).

4.3.3. Crop production in Zambia

Cereal output in the subregion was roughly 22% higher than the five-year average for 2021. The high result indicates good agricultural yields and land growth spurred by favorable grain prices. Nearly excellent weather conditions drove the rise in production and acreage in 2021 during the cropping season. The COVID-19 pandemic had a modest influence on agricultural productivity (FAO 2021).

Table 4 – Major Crops and their production in 2021



FAO, 2023

Table 5 – Cereal production in Zambia

Cereal production in Zambia				
	2017 - 2021 average	2021	2022 estimate	change 2022/2021
	000 tonnes			percent
Maize	3028	3620	2706	-25.2
Wheat	172	206	235	14.1
Rice	42	66	62	-5.5
Others	54	59	44	-24.7
Total	3296	3951	3048	-22.9

FAO, 2022

Millet and sorghum are two crops generally resistant to climate change and commonly produced in Zambia. The country's output of these grains is likely to fall somewhat to moderately, but significant regions are expected to remain suitable. Millet, in particular, will be less affected than maize, the major cereal crop. Farmers and consumers must be encouraged to use these typically unfamiliar grains, particularly as a variety of feed for livestock. Research and development are necessary to find cultivars suited to local circumstances and make better seeds available (IFAD 2021).

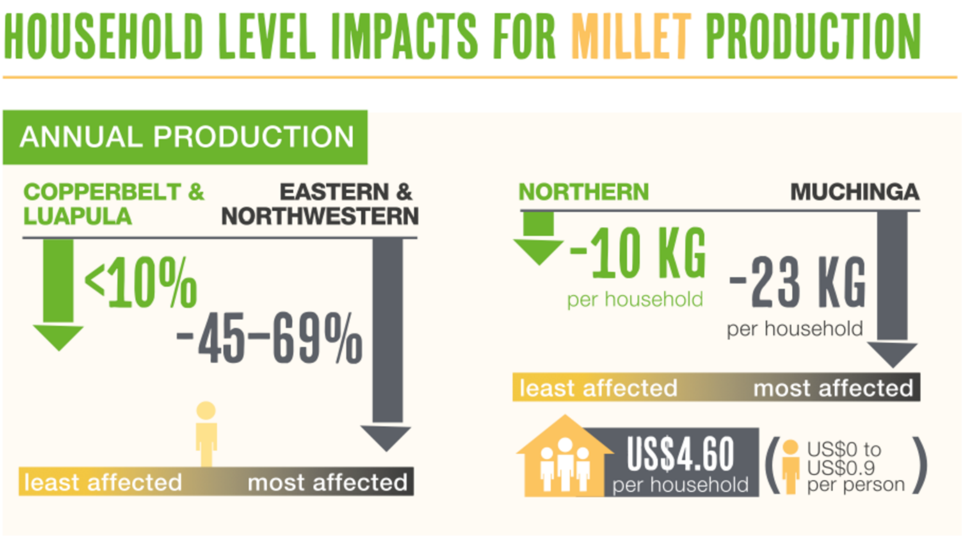
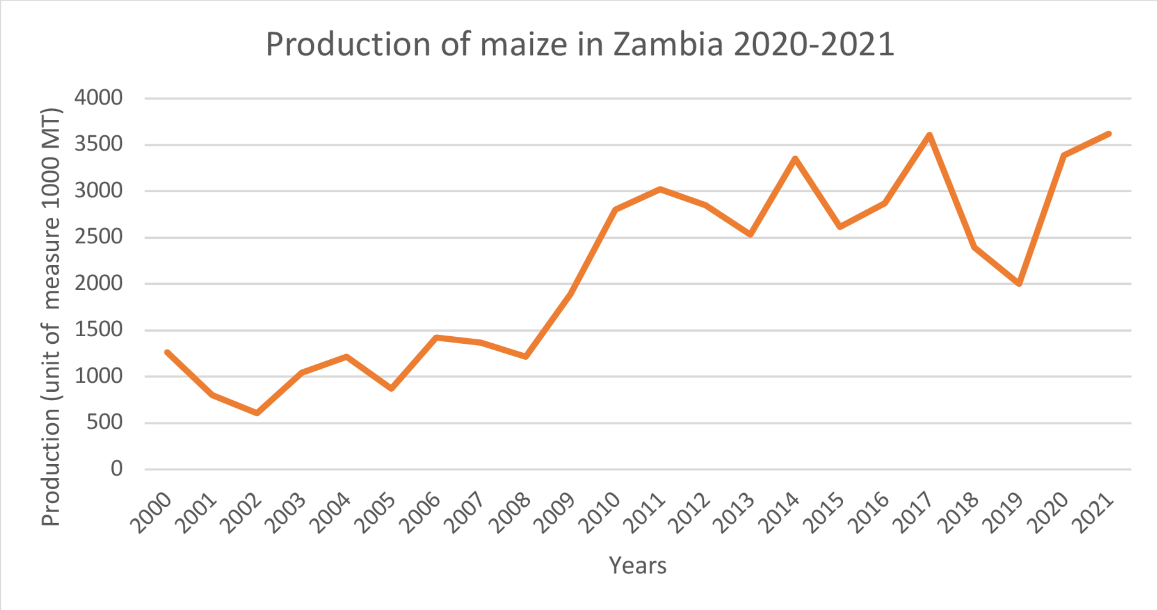


Figure 2 – Household level impacts for millet production

IFAD, 2021

Table 6 – Production of maize in Zambia 2020-2021



Index Mundi, 2023

Maize, Zambia's most significant crop, is cultivated in all ten provinces, with the Central, Eastern, and Southern provinces supplying more than half of this national staple meal. It has become a flashpoint highlighting the current government's acute financial crisis, which took office in August 2021. Zambia produced the highest maize harvest on record in the 2021-22 marketing year, reaching 3.6 million tonnes, approximately 7% more than the 3.4 million tonnes produced in 2020-21, according to the US Department of Agriculture (World Grain 2022). Maize output has increased significantly due to food needs and prospective markets. This has mostly been accomplished through growing farmed areas at the expense of virgin land (European Union 2022).

4.4. Climate Change and Agriculture

Zambia is a Sub-Saharan African country with a total land area 751 610 km² (Sitko et al. 2016). Only 58 % of the total land area is potential for agricultural cultivation, but in real life, they use only 15 % (Trade 2022). Zambia is struggling with increased poverty, which poverty and headcount ratio more accurately depicts. It shows us the percentage of the population in Zambia that lives below $2.15 a day.

World Bank (2023) has provided us with a smaller number of data only until 2015. As we can see, from 2002 to 2010, poverty increased and fell slightly in 2015. The poverty in Zambia until 2021 moves pretty much the same way. Thanks to other economic indicators like unemployment, we can expect the numbers till now.

We have to take into account at another indicator, Agriculture value added % of GDP. Since 2000, data has declined rapidly (World Bank 2023). We have to take into account that Zambia is highly dependent on agriculture and data is decreasing. All of this is influenced by the climate change this country has been dealing with in recent years.

African farmers are more exposed than their counterparts in rich nations to increased temperatures, fluctuating rainfall, and inconsistent harvests. Some parts of adaption may also be challenging. Agriculture accounts for one-fifth of Sub-Saharan Africa's economic production. African farmers are often more sensitive to greater temperatures, irregular rainfall, and unpredictable yields than farmers in wealthy nations, who can usually obtain crop insurance, modify what they plant, water their fields, or apply crop protection chemicals and fertilizers more readily (McKinsey sustainability 2020).

4.4.1. Farmer's adaption to climate variability

Zambia is already vulnerable to climate-related threats (e.g. droughts, dry spells, seasonal, flash floods, and severe temperatures). Droughts and floods, in particular, have become increasingly often and severe in recent decades. These dangers endanger people's food, water security, water quality, energy, and livelihoods, especially in rural regions (Chavula 2022). Climate change has had the negligible impact on cotton output, with no discernibledifferences in the Central and Eastern provinces. Second, the effects of climate change will vary by location, with the Southern and Western regions expected to be the most affected by crops like maize (Ngoma et al. 2021).

Climate-smart agriculture is a strategy for guiding actions to change agri-food systems toward more environmentally friendly and climate-resilient practices. Climate-smart agriculture contributes to achieving internationally agreed-upon goals such as the SDGs and the Paris Agreement.

It strives to achieve three major goals: sustainably, increasing agricultural production and incomes; adapting to and creating resilience to climate change; and decreasing and/or eliminating greenhouse gas emissions whenever practicable (FAO 2022). This premise underpins implementing climate-smart agriculture technologies and practices in highly degraded landscapes throughout various developing countries; soil and water conservation, grazing management, crop rotation, crop residue incorporation, and perennial-crop-based agroforestry systems are all examples of climate-smart agriculture practices in these areas. Regarding agricultural yield, Climate-smart agriculture technologies focus on enhancing soil health and nutrient recovery (Chavula 2022).

Highlighted strategies explicitly focusing on adaptation to specific climatic stresses and techniques that minimize production risks while lowering greenhouse gas emissions. Most of these techniques reduce soil degradation, releasing carbon and water into the atmosphere, encouraging soil and water conservation, and boosting production (FAO 2022). Climate-smart agriculture technologies (e.g., organic farming, agroforestry, conservation agriculture, multi-cropping) are designed to increase household income, agricultural productivity, climate change resilience, and mitigation by incorporating tree crops into farming systems and reducing the use of synthetic fertilizer (Chavula 2022). Research from Nkomoki et al. (2018) shows that crop diversification, intercropping, agroforestry, and plant basins are among Zambia's most frequent sustainable farming practices.

One explanation for the underutilization of potentially arable land is that the Zambian agricultural industry is dominated by small-scale farmers who own extremely tiny plots of land. Furthermore, because most small-scale farmers lack resources, they cannot afford to invest in irrigation (Shitumbanuma 2021). Planting basins are a good solution in low rainfall locations such as Zambia's southern and eastern provinces, the Lusaka area, and the southern sections of the central regions. Crops in basins are less prone to withering during dry times because basins store more moisture, which can enhance yields. Basins can be used to cultivate maize, soya beans, cotton, groundnuts, and sunflowers. Such basins are useful in small fields, but farmers with a large labor force or those who can employ workers may utilize basins in large areas (PlantwisePlus 2016).

The Golden Valley, Agricultural Research Trust, researchedresearched biochar's effect on maize grain yield in Region II - Chisamba, Batoka and Region I - Magoye to assess the agronomic impact on maize grain yield performance. The results revealed that adding biochar at 3965kg/ha with regular fertilization enhanced yields by 16% in Chisamba, 88% in Magoye and 48% in Batoka. The ability of biochar to neutralize soil acidity and boost nutrient and water retention capacity was primarily responsible for these findings. (Cornelissen 2013). The article's key findings by Ngoma et al. are that planting basins also favourably influence yields, boosting maize yields by 191 kg/ha on average when tillage is done before the rains begin. These findings imply that when combined with early field preparation, minimal tillage with ripping and basin tillage only significantly increases smallholder maize yields compared to conventional tillage (Ngoma et al. 2015).

Growing two or more crops in close proximity is known as intercropping. The most common purpose of intercropping is to increase the yield on a particular plot of land by using resources that would otherwise go unused by a single crop (Smith et al. 2000). This can be done throughout the whole crop life cycle or just a portion of it, which is known as relay intercropping. Intercropping can provide spatial or temporal complementarity. Intercropping employs various fundamental spatial, temporal, or functional arrangements, and most practical systems are variants on these configurations – row intercropping, strip intercropping, mixed intercropping, relay intercropping, and push pull intercropping (Burgess 2022). Row intercropping is the parallel cultivation

of two or more crops, at least one grown in rows (Schulz 2020). Strip intercropping is the method of growing two or more crops in thin strips down the length of a field to enhance yield. Because the strips are broad enough, each one may be controlled separately (FAO 2020).

Mixed cropping, also known as intercropping, is the oldest kind of systemized agriculture technique of planting many crops on the same plot of land simultaneously (Lizarazo et al. 2020). Relay cropping is a method of repeated cropping in which one crop is planted into a rising second crop well before the second crop is harvested (Tanveer et al. 2017). Push-pull technology is an intercropping practice for pest management that combines repelling push plants and trapping pull plants. Cereal crops, such as maize and sorghum, are frequently plagued by stem borers (Cook et al. 2006). Intercropping can improve climate resilience by increasing plant resource efficiencies like space, nutrients, and water, naturally suppressing insect pests, diseases, and weeds.

Despite increasing management complexity and labour requirement, these effects frequently improve farmer profitability (Huss 2022). Higher production yield per unit surface area means less space is necessary to feed the world's growing population, decreasing deforestation and the greenhouse gas emissions produced by agricultural growth (Jayathilake et al. 2021). Compared to cowpea and soybeans, intercropping of legumes resulted in a negligible drop in cassava tuber production for common beans. Intercropping these legumes in cassava over time may increase organic matter content and nitrogen fixation while offering a cheaper source of protein, ensuring food security (Kaluba et al. 2022). Efficient intercrops frequently have compatible UV radiation needs; moderately shade-tolerant plants can grow well beneath a shade-intolerant crop, maximizing space (Zhou et al. 2019). Supportive intercrops require distinct varieties and amounts of nutrients, allowing them to live with little rivalry (Li et al. 2020). Intercropping may improve agricultural stability and resilience during climate change and reduce inter-annual variance in yields induced by weather extremes (Raseduzzaman 2017). It can help with natural management in conservation by combining food and refuge for natural enemies (Gontijo 2019). Intercrops also increase the structural complexity of below-ground habitat by increasing organic matter and improving microclimates for natural soil enemies. When used appropriately, animal waste fertilizers may improve insect suppression. However, when manure is used, additional expenses are associated with excess fertility, pest control, and water quality (Rowen, 2019). Natural enemies can be provided with alternative foods like nectar, pollen, and prey through intercrops (Gontijo 2019). Intercropping has a number of disadvantages, including a limitation on the use of machinery for sowing, weeding, and harvesting. Individual crops in intercropping are difficult to manage, for example, fertilizer management and weed control with herbicides. Intercropping also necessitates more work per unit area and can reduce crop yields if not managed properly (Blessing 2022).

Zambian smallholder farmers have been exposed to agroforestry practices that numerous researchers have applied for over two decades (Chavula 2022).

Agroforestry refers to land-use systems and technologies in which woody perennials (trees, shrubs, palms, bamboos, and so on) are intentionally employed on the same land-management units as crops and/or animals in some spatial arrangement or temporal sequence.

The many components of an agroforestry system interact in ecological and economical ways (FAO 2022). Agroforestry is a type of land management in which trees or shrubs are cultivated around or amid crops or pastureland. Fruits, nuts, drugs, wood products, and other valuable and commercial things are produced by trees (USDA 2022). This deliberate integration of agriculture and forestry offers several advantages, including better yields from staple food crops, improved farmer livelihoods through revenue production, increased biodiversity, better soil structure and health, decreased erosion, and carbon capture. Agroforestry systems are classified into three types: agrisilvicultural, silvopastoral, and agrosylvopastoral (FAO 2022). Silvopastoral systems include a combination of trees, grasslands, and cattle. Trees help boost pasture production while providing natural shelter for animals (FAO 2017). Agrisilviculture is an agroforestry system in which trees and crops are grown on the same plot of ground, either sequentially or simultaneously (Fungo 2021). Agrosylvopastoral system combines trees, crops and animals in the same area (Burgess 2022).

To address the issue of climate change, climate-smart agricultural methods such as agroforestry are a critical approach for increasing agricultural productivity, establishing food self-sufficiency, and relieving poverty among Zambia's smallholder farmers. The adoption of agroforestry technology improved farmland household income and agro-ecological parameters (Chavula 2022). Crop diversification using intercropping cereals with legumes and Gliricidia trees has boosted variety, synergy, resilience, cultural and food traditions, ascultural and food traditions, improved soil organic matter and nutritional quality, and the prevalence of the mycotoxin. Governmental and institutional assistance is required to boost smallholder farmers' adoption of agroforestry systems (Burgess 2022). Research from eastern Zambia shows a that lack of seeds and information appears to be two variables influencing agroforestry implementation (Kabwe 2016).

Crop diversity is the addition of new crops or cropping systems to agricultural output on a specific property while accounting for the various yields from value-added commodities with complimentary selling possibilities (FAO 2018). The causes for the absence of agricultural diversity from the points of view of smallholder households, market actors and extension workers. According to the findings, smallholder farmers comprehend the advantages of diversification but find it challenging to execute.

The main obstacles are restricted access to land, a lack of various farming inputs, insufficient funding, a lack of small-scale irrigation machinery, and insufficient access to and absorption capacity of marketplaces for diverse and nutritious foods (Mockshell 2020). Crop diversification is often recognized in these policies as a weather and price shock mitigation technique, particularly among smallholder farm families whose main economic activity is agriculture (Sichoonge et al. 2014). Crop diversification has several advantages, including increased income for small farm holdings; less risk for price fluctuations, climatic variability, and so on; balancing food demand; boosting the production of quality fodder for livestock animals; being beneficial for conserving natural resources; minimizing environmental pollution; reducing reliance on off-farm inputs; and increasing community food security (FAO 2018). The economic consequences of crop diversification have been widely explored in various nations in recent literature, but little is known about the livelihood effects in Zambia. This research gap was addressed in the study by looking at the factors associated with smallholder crop diversification in Zambia and their impact on rural livelihoods as measured by farm and household income, Household Dietary Diversity Score, Months of Adequate Household Food Provisions, and Food Consumption Score (Islam et al. 2018). Crop diversity became even more prominent in policies following the 2003/2004 growing season's drought (Sichoonge et al. 2014).

4.5. The role of agriculture extension in disseminating climatic information

Digitalization, as one of the current trends of the world's development (Kravchenko et al. 2019), influences different economic sectors worldwide. One is agriculture, where new technologies aim to create a unique pattern of how this segment evolves. Although, along with digitalization, another trend affects agriculture – climate change. As Chakraborty et al. (2014) mentioned, climate change is the most troublesome hindrance facing the world. Climate characteristics play one of the most significant roles in the agricultural sector. Therefore, there is a need for tools that can help control the climate information in many agricultural processes. One of the tools that act as help is the agricultural extension services phenomenon.

Despite the fact that agricultural extension services face a vast variety of interpretations (FAO 1985), it can be defined as the set of organizations that support and facilitate people in the agricultural production sector to obtain information, skills and technologies to improve their livelihoods (Hlatshawayo & Worth 2019). Agriculture extension services also contribute to the SDGs (IFPRI 2022). They are connected with the following goals: SDG 1, ''No poverty''; SDG 2 ''Zero Hunger''; SDG 4 ''Quality education''; and SDG 8 ''Decent work and economic growth'' (The Global Goals 2015). With the agricultural extension services work in three main sectors: organizations from the public sector, the private non-profit sector, and the private for-profit sector (Syngenta 2020). Moreover, these three sectors areare the main information source to disseminate. As a multidimensional paradigm, it also includes services that assist farmers in various forms (Danso-Abbeam et al. 2018). These forms involve advisory, technology, and facilitation services (Nzuma et al. 2019).

The primary goals of agriculture extension services are expressed by Anderson & Feder (2004), stating that it allows to transfer information from the global knowledge base and local research to farmers and to educate them about how to make better decisions to meet better agricultural development. This goal correlates with many effects of agricultural extension services' implementation. One of the effects is enhancing yield, which is especially helpful for small-scale farmers to be competitive on the market (Baloch & Thapa 2018).

According to Ogundari (2022), it also assists in improving farm management practices and farmers' overall welfare. Agricultural extension services also can increase awareness of the best available local adaptations that can be used to manage climate risks (Antwi-Agyei & Stringer 2021).

Agricultural extension services provide benefits of both agricultural and social nature. Sumo et al. (2022) provided an example of extension services' usage in post-conflict Liberia. The author stated that agricultural extension services served not only for reaching agricultural productivity but also for economic transformation and maintenance of peace. Agricultural productivity is crucial for this country because it is the primary source of livelihood for about 80 percent of the population. To enhance agro-economic relationships, several extensions were established among these are National Rice Development Strategy and National Agriculture Extension and Advisory Services policy (Sumo et al. 2022).

As a result, those farmers who used extension services showed more significant results in rice sales and thus improved livelihood. In Northern Ghana, such services are also in use among farmers. Their work is mainly based on collaboration between the country's Ministry of Food and Agriculture and the Association of Church-based Development NGOs (Danso-Abbeam et al. 2018). Over the years, it created a network of over 40 NGOs to help farmers to improve their access to technologies, as well as to input and output markets. One of the main tools of ACDEP is building good agricultural practices among many actors in Ghana's agricultural market. Good agricultural practices include creating communication among the value chain actors, disseminating information regarding skill development and successful farm practices. As a result, this practice has shown improvements in food security level in Ghana, agricultural productivity and poverty reduction. Leuveld et al. (2018) also showed linkages between the farmer's access to agricultural extension services in the DRC and improved food security.

One of the greatest benefits of agricultural extension is the provision of additional educational capacities that can be achieved with different instruments. One of them is the farmer field school, first introduced by FAO in the late 1980s (FAO 2020). The main aim of this school is to create an environment not just for knowledge exchange and also for farmer education and empowerment.

Although the agricultural sector dominates the field of knowledge share within this school, other topics can be brought up. Among them are a business, youth, climate change, COVID-19, forestry, gender and social inclusion, nutrition and others. All of the topics create linkages, allowing farmers, especially in the developing countries, to gain knowledge to enhance their work on many levels (FAO 2020). In Sub-Saharan Africa, this initiative gains more and more recognitionmore and more recognition. The case of Zimbabwe showed that several positive changes were detected after implementing the farmer field school in the coffee sector. Among them is the knowledge about identifying insect pests and diseases, as well as the chance for illiterate farmers to gain knowledge due to the ''learning by seeing'' approach. Moreover, it helped create a positive environment among the farmers, allowing them to pursue collaborative projects in the coffee sector (Chemura et al. 2013). Understanding the fact that government support is important for developing agricultural extension services in Zimbabwe, the Land and Agriculture Ministry in 2022 agreed to set up 9 000 farmer field schools to improve the country's agricultural extension services sector (NewsDay 2022). In the neighboring Zambia, there is also an ongoing initiative with the farmer field schools. According to the World Bank (2019) there are 239 farmer field schools aim to teach local farmers about climate-smart agriculture approaches to boost yields and conserve forests. For now, this initiative covered around 11 000 farmers, aiming to cover more than 118 000 farmers. Despite the successful implementation of farmer field schools, there are some leading issues with this form of agricultural extension services. Some issues include the level of competencies of farmer field schools facilitators, short training duration, monitoring and evaluation (Berg et al. 2020), sustainability and feasibility of such projects and cost effectiveness (GFRAS 2019).

As one of the examples of agricultural extension services, technology services in a modernized world play a vital role in disseminating information among farmers. Among the technical instruments of information dissemination are radio, television, Internet, and mobile phones. In Zambia, there is an ongoing trend about technically efficient agriculture (Mwalupaso et al. 2019). More and more farmers use technologies, such as mobile phones, to get the necessary weather information.

Mwalupaso et al. (2019) found that using mobile phones for accessing agricultural information shows tangible benefits in terms of enhanced agricultural productivity, reduction of hunger and general poverty alleviation. Although mobile phones provide easy access to climate-related information that is viable to farmers, there are existing problems in this area. The case of Ethiopia described by Tegegn & Dafisa (2017) showed that in the country, there is a low rate of adapting such technologies due to low ICT skills, inadequate information, poor and expensive connectivity, inappropriate ICT policies, and language barriers. Similar problems were stated by Etwire et al. (2017) in the Upper West region of Ghana, including poor infrastructure and overall high costs that prevent farmers' more wide implementation of such technologies. Therefore, there is a need for collaboration between farmers and government that has to identify existing technical challenges to overcome them using modern approaches and positive results from the countries that successfully use technical instruments to disseminate climate information among farmers.

Despite the rise of mobile phones as a tool for information dissemination, radio plays a vital role in this process too. In Zambia, there is the Zambia Information & Communication Technology Authority that promotes further digitalization of the country and more reliable paths for disseminating different nature’s information, including important information for the agricultural sector (ZICTA 2017). Moreover, the Media Institute of Southern Africa (2022) stated that radio is still a trusted source of information in Zambia. Radio is an agricultural extension service in Zambia for farmers, especially female farmers. Zambia farmers trust this source of information more than other means of information delivery. One of the radio programs is the ‘‘Farm Talk’’ which allowed female farmers to gain important practical information about agricultural production. Radio information is more trusted because some women in rural Zambia communities cannot read and radio helps them overcome this challenge (Lifeline Energy 2020). Although radio is one of the most popular information sources, especially in rural Africa, there are some constraints. Among them are the following: it is sometimes challenging to understand the scientific jargon, most of the rural radio sets are donor-funded (no donors – no radio), availability of radio sets, and it might be costly to manage (National Policy Dialogue Synthesis Report 2009).

Alongside mobile phones and radio, television is also a great source for dissemination of climatic information (Chhachhar et al. 2012). Sometimes some innovative methods can be used as well,for example, in 2022, Zambia's first farming reality TV show ''Munda Makeover'' was launched by Zambia National Broadcast Corporation. The reality TV show aim aims to bring closer all the participants involved in developing the agricultural sector by enhancing the climate-smart agriculture approach. This show will also promote best farming practices, usage of market information services, farmer cooperation, and nutrition support (CGIAR 2023). In Zimbabwe, television is a popular source of information among farmers due to its engaging, convenient and detailed content (Moyo & Salawu 2019). One of the programs that gained popularity in this sense is ''Talking Farming'' – a live program about agriculture and its development in Zimbabwe.

The process of climate-related information dissemination, regardless of the dissemination tool, is based on the collaboration between various governmental, non-governmental, and international actors. One of them is meteorological agencies that has significance in the process of dissemination of climatic information.

In Zambia, as part of the Ministry of Green Economy and Environment, there is the Zambia meteorological department. Its main aim is to produce and disseminate weather and climatic information to different sectors, including agriculture, through radio programs, mobile phone services and the Internet. This organization works closely with UNDP Climate, implementing different projects and instruments to fight extreme weather and help Zambia farmers be more resilient. Although although agriculture extension services can be helpful for farmers, it is one of the challenges – to convince them to trust the scientific forecast and adopt sustainable agricultural practices (UNDP 2020). To gain farmers' trust, the UNDP-supported project and the Zambia Meteorological Department installed more than 20 automated weather stations in addition to the existing 68 around the country (UNDP 2021). This step helped to provide more accurate weather information to the farmers. This initiative also is a part of the ongoing project ''Strengthening climate resilience of agricultural livelihoods in Agro-Ecological Regions I and II in Zambia'' from UNDP to assist in adapting to climate change by allowing farmers to plan for and managing water resources, access agricultural markets, and improve livelihoods (UNDP 2018).

Similar initiatives also appear in other Sub-Saharan countries, stating the importance of meteorological agencies. In the Democratic Republic of Congo, the National Weather Authority collaborated with the World Bank. In 2017, they jointly launched the project about strengthening hydro-meteorological and early warning services. The project aims to build capacities, modernize information dissemination equipment and infrastructure and improve service delivery (CREWS 2017). Otim et al. (2022) also reported about another initiative from National meteorological authorities in Nigeria, Uganda, and South Sudan known as the ‘‘Weather Information Dissemination System’’ that provided weather information by SMS service. Although in this regard, there was one challenge related to occurring inaccuracy of the weather forecast that created a barrier between farmers and services because farmers were hesitant to pay for such information.

Although regardless of benefits in terms of agricultural extension services use, there is a set of broader challenges and problems that constrain further development.

Ponnusamy & Padaria (2021) enumerated several challenges, including pitfalls in teaching, anomalies in professional ethics, balancing farmers and controlling officers, and focus on unproductive extension methods. Daum (2019) listed other challenges: geographical dispersion of farmers, governance obstacles, and lack of ICT infrastructure. Electricity provision is also one of the main challengess in developing extension services, especially in Sub-Saharan Africa. This statement proves the example from Southwest Nigeria, where sporadic electricity failures sabotage the effectiveness of mobile phones in the climatic information dissemination for farmers (Dare & Ojebuyi 2016). In Zimbabwe, the electricity shortages also negatively affected mobile network quality, which can be a constraint for farmers not using mobile phones efficiently (Global Business Outlook 2023). Youth and female farmers also face some challenges in developing agricultural extension services. In Zambia, lack of technical assistance is one of the problems that youth face, which also decreases their participation level in the agricultural sector (Trevor & Kwenye 2018). Besides that, Zambia also has other challenges.

Chavula et al. (2022) mentioned the following: lack of engagement between farmers and service providers, shortage of extension field workers, constraints in delivering technologies to farmers, weather unpredictability, and a weak general agricultural extension culture. In terms of female farmers, they are often a minority in the process of agricultural decision-making (Solidaridad 2022). Therefore, they are often lacking in agricultural extension services participation due to insufficient knowledge on how to use them (Owusu et al. 2017) or theinsufficient knowledge on how to use them (Owusu et al. 2017) or general lack of access to technologies. it is necessary to provide women with access to extension services, allow women to participate fully in agricultural decision-making, and facilitate their financial stability (Spielman et al. 2021).

4.6. Farmer's household welfare

According to the 2022 Global Report on Food Crises 2022 Mid-Year Update, at least one in every five Africans goes to bed famished, and an estimated 140 million Africans experience severe food shortages (IPC 2022). African people are suffering due to climate change and dependence on imports of wheat and sunflower oil from Ukraine and Russia, which is affected by war in Ukraine. The situation has influenced the rapid growth of prices, which is unacceptable for ordinary people (Worldbank 2022).

Food security occurs when all people have physical, social, and fiscal access to adequate, secure, and nutritious food that fulfills their daily dietary requirements and dietary choices for a busy and healthy lifestyle (USAID 2023). African farmers are often more sensitive to greater temperatures, irregular rainfall, and unpredictable yields than farmers in wealthy nations, who can usually obtain crop insurance, modify what they plant, water their fields, or apply crop protection chemicals and fertilizers more readily (Ngoma et al. 2021). The effect of farm exports and imports on food security is significant. According to the results, agricultural export has a detrimental and insignificant effect on food security. Furthermore, the results show that agricultural imports positively and substantially affect food security. When measured in terms of availability, the exchange rate has a favorable and substantial effect on food security (Enilolobo, 2022).

According to an analysis done by Integrated Food Security Phase Classification (2023) in Figure 3 of the food security situation in 91 shock-affected districts, 1.35 million people were in IPC Phase 3 Crisis between July and September 2022, necessitating immediate humanitarian action to close food gaps, protect and restore livelihoods, and prevent acute malnutrition. Prolonged drought periods, floods, pest and disease breakouts, high corn prices, and the continuing effect of COVID-19 are among the disruptions. According to the results, 14 districts are in Crisis, 76 under Stress, and 1 in Minimal. Zambia's food vulnerability has increased due to poverty, the COVID-19 pandemic, financial insecurity, and exposure to climatic disturbances. Most of these shocks happened between December 2021 and March 2022, during most essential crops' flowering and cereal filling times. Maize prices have fallen since the start of the 2022/2023 marketing year but remain higher than the 5-year norm (IPPC 2023).

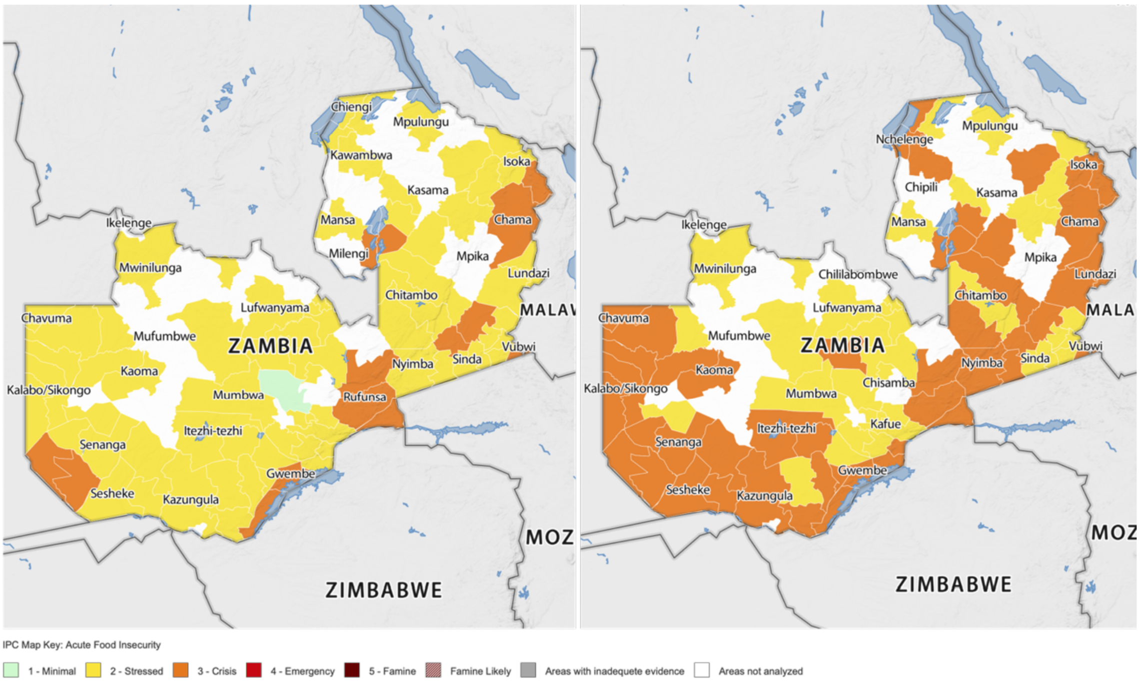


Figure 3 – Acute food insecurity situacion: July – September and Projection for October 2022 – March 2023

IPC, 2023

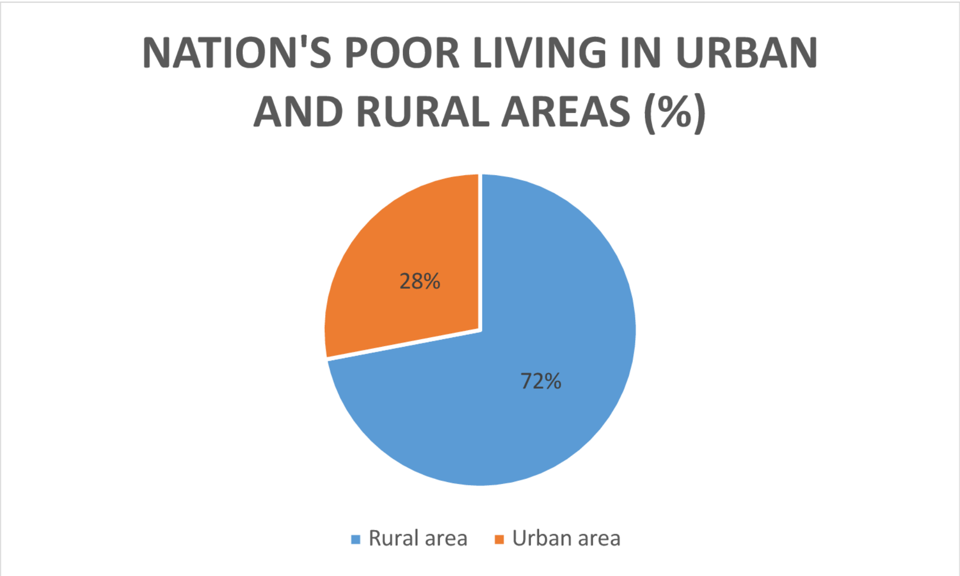
Smallholder involvement in Zambian horticulture markets is hampered by distance from infrastructure and price volatility; however, policies and investments can increase accessibility and promote spatial and seasonal arbitrage, lowering price volatility. Horticultural marketing in Zambia leads to a 242% increase in total household income, more pronounced for smaller farms and poorer households. It also reduces the gender gap in rural household income (Munguzwe et al. 2015).

Despite having one of the world's fastest-expanding economies, Zambia remains one of the world's poorest countries. Currently, over 64% of Zambians live on less than $2 per day, while the majority of those earning more struggle to make ends meet.

Indeed, more than 40% of them are deemed to be living in severe poverty, earning less than $1.25 per day (Habitat for Humanity 2023). Poverty and core poverty rates for urban and rural households separately in figure 7.

Poverty is the largest in rural regions, home to two-thirds of Zambia's population. As a result, the impoverished are concentrated in rural regions. Rural areas are home to 72 percent of the impoverished.

Table 7 – Nation's poor living in urban and rural areas



SARPN, 2005

Zambian agriculture policies lower by 3-5 percentage points the proportion of households whose consumption falls below the poverty line. Although this does not cure the country's poverty problem, it significantly impacts emerging countries. The degree of poverty reduction varies on whether just the direct effects of the policy are studied or whether behavioural impacts that lead to changes in agricultural productivity are also included (The conversation 2023).

4.6.1. The effects of climatic variability on farmers' household welfare

Climate change can have various effects on poverty, including displacement and movement due to climate hazards, an influence on food costs, and greater poverty traps due to severe weather events such as pronounced droughts. These routes are linked because displacement and migration from rural regions can decrease agricultural output in those areas, causing food costs to rise. Similarly, an increased chance of precipitation or drought and the lengthening of growth seasons can cause actual costs to rise (Thornton 2010). The frequency of agricultural shocks caused by extreme weather events in the last decade has increased food prices, harming most consumers and some producers in the food chain, including farmers, agricultural product exporters, and food suppliers (Terazono 2014). There are numerous reasons why climate change presents such a significant challenge to African agribusiness. Many staple products in African diets, such as wheat, maize, sorghum, and millet, will battle to thrive as temperatures rise. Crop production in Sub-Saharan Africa will fall by 10% if temperatures rise by 2°C. Crop production will decline by up to 20% if temperatures rise above 2°C. If the global temperature exceeds 3°C, all current corn, millet, and sorghum cropping regions in Africa will become unsuitable. This would be disastrous for Africa’s food security because sorghum and millet are essential grains in most African diets, and maize provides almost half of the calories and protein eaten in southern and eastern Africa (ILRI 2022). It is worth mentioning that it will affect farmer’s household welfare not only in terms of lower yields, but also in a case of higher food prices, decrease in food availability, migration and displacement, which inevitably will lead to more hunger and poverty.

Climate change indeed impacts the agricultural sector by reducing production capabilities and increasing production risks (Shiferaw et al. 2015).

This happen due to the lack of agriculture adaptation techniques to changes in climate changes resulting in more severe forms of poverty and food insecurity (Ofori et al. 2021). Sirba & Begna (2022) mentioned climate change and climate change-related droughts as one of the reason for food insecurity and malnutrition. Moreover, droughts appear more frequently now putting pressure on already fragile farmer's household welfare. Climate and agriculture is interconnected, so various climatic variabilities affect yields.

In Africa, especially in Sub-Saharan Africa, agriculture welfare is strongly connected with rainfalls and adequate level of precipitation (Akpoti et al. 2022). There appear correlation: ''less rain → more droughts → less agricultural productivity → less farmer's household resilience''. It is projected that droughts will hit harder Southern Africa. According to the IFAD (2021), small-scale farmers in some part of Angola, Lesotho, Malawi, Mozambique, Rwanda, Uganda, Zambia and Zimbabwe could be worse affected by climate change-related problems.

Woetzel et al. (2020) noticed that nowadays in Africa more and more farmer's households will suffer from yield volatility, e.g. by 2030, Ethiopia will face an annual median 10% yield drop in wheat and 25% yield decline in coffee, whereas on Mozambique by 2030 10% decline in cotton production will be registered and 25% decline in maize yields. Apart from climatic variabilities-related yield problems, climate change pose also the following problems that have a direct impact on farmer's household welfare: land degradation, conflicts, land grabbing (Nyambe et al. 2020). In general, land is a precious asset for a farmer in Africa therefore decrease in arable land for agriculture activities presume threat to its welfare. Despite the fact that land degradation is a global issue, in African countries this problem appears much quicker that has a direct impact on land availability for agriculture (Kgomotso 2022), accounting for 46% of the total land area (AGNES 2020), and up to 65% of productive land is degraded (UN 2021).

Water is another valuable element for agricultural productivity, and climatic variations negatively influence the availability of water for farmers in Africa. According to Global Citizen (2022), by 2025 approximately 230 million Africans will be facing water scarcity. Water is vital for irrigation, especially in a growth phase for plants, for livestock, and its shortage can create adverse scenarios for farmers (Ziervogel 2018). Water scarcity impacts not only agricultural sector as well as health of population.

Without proper water supply, households will face increased risk of famine, illnesses, and even deaths. Therefore, the problems with water scarcity and other climate change-related problems need to be combated.

4.6.2. The effects of climatic variability on farmers' household welfare in Zambia

Climate change, according to the research, would cut GDP and increase poverty in Zambia. Climate change is projected to cut expenditure for rural households in Zambia's vulnerable Southern and Western areas suggesting a possible relationship between climate change and poverty (Ngoma et al. 2021). According to Nkomoki (2019) higher education levels of household heads, growing livestock earnings, secure land ownership, increasing land area, and group participation all increased the likelihood of household food security. Nkomoki's (2019) study shows that land tenure stability improves food security. Implementing a more effective property rights protection legislation is crucial in this regard. To expedite the process, parties such as the National Farmers Union and local governments must urge the central government to enact more effective legislation. Based on Mafwela (2022) findings, the Monze area has been facing extreme climatic changes, which has resulted in coping strategies such as charcoal burning for sale, moving children to other cousins in large cities for education, and marrying several women as inexpensive labor. Because of their dependence on rain-fed agriculture, 83% of the Monze district's food intake was jeopardized. Based on these results, the research found that mean yearly temperature and rainfall were not the most important predictors of rural household food security. To address the impact of climatic change on food security, the research indicates that rural families embrace crops other than corn that can perform well under the current climatic conditions (Mafwela 2022). Chipando (2023) found that conservation farming offered users the greatest advantages regarding corn production, soil fertility, and efficiency. Farming can help to alleviate poverty in the long term by increasing family income, agricultural production, and climate change resistance among smallholder farmers.

Aim of study	Study Area	Sample size	Methods	Key finding	References
determine factors that influence the adoption probability of sustainable agriculture practices	Southern province	400	Questionnairre server	households with customary land tenure had a lower probability of adopting crop diversification, agroforestry and planting basins	Nkomoki et al . 2018
determine the adaptation strategies that are adopted by rural households to floods	Mwandi District of Zambia	93 farmers	household surveys, focus group discussions, observations and informal discussions	the majority of households coped with floods by means of charcoal production, the sale of firewood, as well as the sale of grass and reeds	Mabuku et al. 2019
impacts of climate variability	Pemba district of Southern province of Zambia	87 farmers	Questionaires, interviewing key informants	smallholder famers have knowledge of climate variability and experience changes in weather patterns	Kaliwile 2020
the impact of climatic variability on maize and soybean yield under a high input management system	Zambia	1980-2012 years	records from the weather station	regression analysis revealed a negative relationship between El Niño and soybean yield, and a positive relationship between La Niña and maize and soybean yields	Lubinga et al. 2019
determinants of poverty due to climatic conditions and year-specific weather shocks affect	Zambia	19389 observed households	comparison between the household per-capita total consumption expenditure	flood shocks are associated with a 35% decrease in total and food per-capita consumption and 17% increase in extreme poverty	Azzari et al. 2020

expenditure per capita					
deliver livelihood benefits and development in rural communities	Namanongo and Ndubulula regions in Zambia	93 participants	Interview Questionnaire, Focus Group Discussions	private capital convergence in rural spaces leads to resource restrictions, unequal benefit sharing, and poor community agency	Mandan et al. 2023
compares local narratives of climate change with meteorological records in Zambia.	Zambia's three major agro-ecological regions	128 farmers	focus groups, meteorological data	all focus groups in the three provinces agreed that the rainy season has grown shorter	Mulenga et al. 2017
determine each household's wealth status, and to assess the relationship between wealth and the adoption of various agricultural related climate change adaptation strategies	six districts of Zambia	1231 households	Random sample	the more well-endowed households than their poorly endowed counter parts, adopted most of the climate change adaptation strategies, well-endowed households are more likely to embrace crop rotation, minimum tillage, fertiliser trees and change crop varieties due to climate change	Kantashula et al. 2015

5. Conclusions

The first objective was to understand the paradigm of climate change and climate variability. The findings showed that the modern climate change is characterized by climate shocks, expressed in more severe and prolonged droughts, floods, soil degradation, reduced water availability and other aspects. Environmental impacts of climate variabilities do not only affect the nature of the resilience ecosystem, but also all human activities. Climate change is present nowadays on every continent, but it is the most noticeable in Africa. Climate change on the African continent contributes to the deterioration of agricultural activities, as one of the main sources of income for the population, which leads to an increase in poverty, malnutrition and a general deterioration in human life.

The second objective was to examine the influence of climate change on farm production and household income. The findings showed that this problem is significant because in the long-term perspective, it qualitatively and quantitatively affects the established socio-economic relations in society in a negative way. The southern region of Africa, including Zambia, suffers from climate change, which influences various areas of economic activity within the country, especially agriculture. The average temperature in Zambia is on a rise, the amount of precipitation is gradually decreasing, which leads to the degradation of agricultural land, a cut in water levels for irrigation, and a decrease in crop yields. This cause a spike in poverty in Zambia, a decline in the resilience of farmer's household welfare, malnutrition, food insecurity, decline in farmer's income.

The third objective was to explore the farmers' adaptation option in climate variability. Agriculture is an important source of income for farmers in Africa, specifically in Zambia, and the changing climate alter the realities of this activity, making things worse. In this regard, farmers must learn to adapt to the changing environment by applying various adaptation strategies. One such strategy is climate-smart agriculture. This strategy includes many practices related to soil and water conservation, crop rotation, agroforestry, grazing management, multi-cropping, conservation agriculture, organic farming. These strategies help to target better agricultural productivity, higher farmer's income that will lead to enhancement of farmer's household overall welfare. In today's technological world, farming is also associated with various innovative technologies.

In this regard, another strategy to cope with climatic variabilities is agricultural extension services. These services provide vital meteorological, educational and technological information to farmers through different sources like radio, television, mobile phones, Internet, farmer filed schools.

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