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Faculty of Tropical AgriSciences

MASTER'S THESIS

Farm calendars as coping mechanisms to climate variability? A case study of rice farming systems in Barotse floodplains, Zambia

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Declaration

I hereby declare that I have done this thesis entitled "**Farm Calendars as coping mechanisms to climate variability? A case study of rice farming systems in Barotse Floodplains, Zambia**" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged using complete references and according to Citation rules of the FTA.

In Prague-Suchdol, 20th April 2023

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Vraj Ureshkumar Thakar

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Abstract

One of the biggest challenges to sustainable development today is climatic variability and change, which negatively impacts the sustainability and productivity of farming systems. This is particularly relevant for resource-poor farmers in less developed regions who have only limited options for coping strategies. This master's thesis focuses on small-scale rice farmers in the Barotse floodplain of western Zambia and aims to explore observed changes in the cropping calendar in response to climate variability and the adoption of improved rice varieties. Data were collected through a series of group discussions with key farmers, interviews with local authorities and a household survey, which allowed the identification of variables that influence the decision to adopt improved rice varieties in response to climate variability. Various methods were used to analyse the data. To understand farmers' decisions on changes in the cropping calendar, descriptive analysis was used. To understand factors that influenced the decision on the adaptation of improved rice variety, a logistic regression model was used. The results show that female farmers with more years of education, irrigation facilities and off-farm income adopted improved rice varieties and did not rely on possible shifts in rice cropping calendars. Relevant stakeholders (extension services, cooperatives, development organisations and government) should therefore provide more training to women to increase the sustainability and effectiveness of the adoption of improved varieties and work with farmers who are still using traditional varieties to improve their calendars to mitigate the negative effects of climate change.

Keywords: food security, Western province, rainfall, farming system, diversification, and irrigation system

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1. Introduction

When all human populations have social, physical, and economic access to nutritious, safe, and sufficient food for their healthy and active life, it's called food security (Mirzabaev et al., 2023). Food security is not related to the agricultural production level but the continuous, reliable production level. It can also be derived by utilisation, approach, obtainability, and production arrangement. Climate variability is affecting the accessibility of irrigation and drinking water, changes in agriculture growing seasons, growing more pests and diseases in crops and changes in flowering time (Seppelt et al., 2022). The agricultural product availability is derived from various statistical indicators at a national level, like agriculture production, available storage of food items, and exports and imports. Various social and economic indicators of the country can be used to find the data for access to the food item. Additionally, the physical aspect of access to the food item data can be found in infrastructure availability data (Singh et al., 2022).

The agricultural sector has both positive and negative impacts on climate change. The agriculture production system produces CO_2, one of the main sources of greenhouse gases leading to climate change. It is also responsible for impounding carbon gases via agricultural land. In the world, air temperature is rising, and it is anticipated to rise by 1.5-4.5°C in this century because of climate change. More warm or hot air in the climate means more moisture in the weather, which can harm water, land, and agriculture production (Reza & Sabau, 2022).

Developing countries are among the major ones affected by climate change due to the expanse of adaptation processes and destruction. The people from rural areas in poverty and mainly dependent on agriculture production are among the ones who are not protected or are powerless against climate change (Dawadi et al., 2022). Additionally, there is a lack of research on the livestock sector for agriculture, which is very important for any agriculture-dominant country. A total number of 80% of land in the African continent are for livestock grazing purposes.

There is a need for in-depth research on the relationship between the livestock sector and crop production and how farmers can combine or integrate both sectors, which can also be helpful against climate variability challenges (Seo, 2010). There is work to be needed to understand the effect of climate variability on food security and agriculture production by various research institutions, local governments, and development organisations around the world as per the climate changes. Additionally, there is also a need to have various studies for various regions around the world to understand the impact of climate change on the poverty level and the approach towards adaptation strategies and mitigation levels in rural areas for farmers (Thornton et al., 2010). Climate change negatively affects agriculture through weather temperature and precipitation variations, making it more challenging for farmers to diversify their agriculture system (Das et al., 2023).

This research will mainly focus on climate change's impact on the rice-producing farmer and the change in the crop calendar due to climate change in the western province of Zambia. The main reason behind this study is also to see how various household or socioeconomic characteristics affect the adaptation of new rice varieties due to climate change. The western province of Zambia is considered one of the poorest regions with high rice production ratio. Additionally, the reason behind choosing this region is the lack of research on the impact of climate variability on rice farmers in Zambia and the understanding of the challenges, problems, and opportunities in the rice sector in the western province of Zambia.

2. Literature review

2.1. Effects of climate change on farming systems in sub-Saharan Africa

In general, climate change refers to changes in regional and global climate patterns. It is typically manifested in increased temperatures in the atmosphere, on land and in other parts of the Earth. These temperature changes are also known as global warming. Climate change can be measured or studied by looking at changes in surface temperatures on a monthly, annual, and global basis from satellites (Colucci and Pesaro, 2011). There is an accompanying vision of climate change to better understand it when strategizing adaptation and mitigation strategies to reduce its negative impacts (Hay et al., 2016).

Climate change affects two critical factors: the production and consumption of food (Figure 1). The industrialisation of the food industry has led to various negative environmental impacts such as deforestation, soil degradation and biodiversity loss (Reza & Sabau, 2022). Climate change has a long-term effect on rainfall and climate variability (temperature) zones and also negatively affects Africa's trade, food, water, and agriculture sectors. The weather in Zambia is variable and uncertain. As a result, the region is prone to floods, dry seasons and extreme weather conditions. Agriculture and food security are negatively affected by the increasing extremity and frequency of floods and dry seasons (Nhemachena, 2007). Signs of climate change, such as an increase in heat waves, changes in rainfall, an increase in CO_2 in the climate, and various extreme climatic events, also negatively affect the agricultural sector (Reza and Sabau, 2022).

As many researchers have stated, the agricultural sector in Africa is negatively affected by climate change and irregularity and will cause more problems in the future (Aydinalp & Cresser, 2008; Yegbemey et al., 2014; Musafiri et al., 2022). African countries are highly dependent on rainfall for irrigation, and any climate change in this region would negatively affect production and yields (Yegbemey et al., 2014). It is important to underline that despite the continuous decline in value added to GDP, the agricultural sector is the most important sector for rural livelihoods in most countries of the global south (Nhemachena, 2007). On the other hand, the agricultural sector is also responsible for 20% of greenhouse gas emissions. Methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) are the main emissions that contribute to global warming from the agricultural sector. Biomass burning, livestock and manure industries, soil and land management, chemical fertilisers containing nitrogen and rice cultivation are the main contributors to the production of various greenhouse gases for global warming (Aydinalp and Cresser, 2008).

There are different types of impacts of climate change on agricultural systems. However, one of the most important impacts on people and agriculture is (i) the impact of climate variability on agricultural production, (ii) the increase in commodity, input and distribution prices, and (iii) the impact on nutrition and food security (IFPRI, 2009; Long et al., 2006). Changes in weather variability, mainly temperature and precipitation, have both direct and indirect impacts on agriculture. The direct impact on agriculture can be seen in changes in precipitation and temperature on yields and indirect changes in the variability of water availability for agricultural practices. The agricultural practices under the rainfed irrigation system have some negative impacts directly from the temperature changes. In addition, due to climate change and lack of resources, agricultural yields in developing countries are declining compared to developed countries. The impact of climate change varies from region to region, for example, South Asia is a region negatively affected by climate change, but with the availability of fertiliser and resources, there is less production loss. Similarly, Latin America and the Caribbean have mixed responses to climate change. Irrigated agriculture is directly affected by climate change. For example, the irrigation of crops can be strongly affected by changes in groundwater levels due to climate change (IFPRI, 2009; Long et al., 2006).

Livestock production is also one of the sectors affected by climate variability. The livestock sector is indirectly affected by climate change through higher feed prices due to climate variability, which increases the cost of meat and milk. Agricultural output and prices for any purpose are determined by supply and demand (International Food Policy Research Institute (IFPRI), 2009).

2.2. Adaptation to climate change among African Farmers

The world's population has grown dramatically since the 1960s and, despite the current slowdown, has now reached nine billion. Such population growth leads to increased demand for goods and services in all sectors of production, including agriculture. In particular, the agricultural sector is one of the most vulnerable to population growth and climate change. While projections for population growth show a tendency towards stagnation and the problems are linked to structural problems, future scenarios for climate change work with a high degree of uncertainty and therefore include high-risk scenarios (Musafiri et al., 2022). An important fact is that agricultural production in developing countries, particularly in Africa, is based on smallholder farming. In addition, more than 45% of GDP (gross domestic product) in developing countries comes from the agricultural sector, which also provides more than 70% of employment (Salami et al., 2010). Adaptation to climate change is therefore necessary. Climate change mitigation focuses on reducing or eliminating greenhouse gas emissions from the environment by governments, international organisations and various stakeholders. In addition, adaptation to climate change is predicting future climate changes and planning strategies according to climate change predictions (Luyten et al., 2023). Awareness and understanding of climate change is the first and fundamental step towards climate change adaptation for farmers. There are various issues that prevent smallholder farmers from adopting climate change such as lack of infrastructure, poverty, low agricultural productivity, population displacement and food security (Asfaw et al., 2018; Karienye & Macharia, 2020; Chepkoech et al., 2020).

In general, the basic impacts of climate variability on agriculture are floods, dry spells (droughts), biodiversity issues, food insecurity, irrigation and water resources, and soil fertility issues. Adaptation to climate variability is the acclimatisation or adaptation of current agricultural practices as a response system by farmers and communities to the impacts of climate change. Nowadays, adaptation to climate change is not considered as another option, but as an original element by the farmers. Moreover, the adaptations in their farming practices are seen as crucial steps to maintain production that is important for human survival. The level of adoption of climate change measures is very low in

Africa due to a lack of capital to invest in sustainable and efficient climate-smart practices (Karienye and Macharia, 2020).

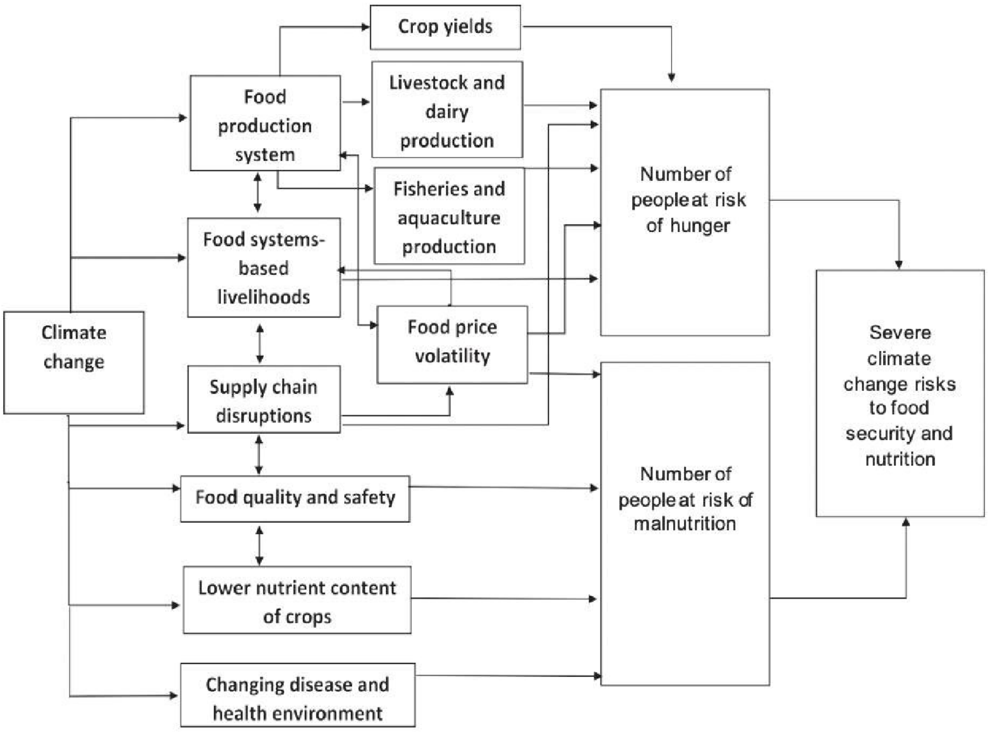

Figure 1. Climate change effects on food security and nutrition

Source: Mirzabaev et al., 2023

In addition, adaptation is an ongoing part of one of the risk management processes that can be used to identify the main drivers of risk. Climate risk management agricultural practices are promising to achieve various possible improvements against climate change, such as (1) water or irrigation management for erosion, waterlogging and nutrient drainage in the situation of high precipitation, (2) modifying or changing the place and timing of agricultural activities, (3) diversifying income or other occupations along with farming, (4) tracking or using weather-related information to reduce risk, (5) using new irrigation and crop residue retention methods when precipitation decreases, (6) increasing the capacity of the farm to adapt to climate change, irrigation and crop residue retention methods when rainfall decreases, (6) increasing the capacity of pest, weed and disease management activities through the use of more pathogen and pest management, (7) using more crop varieties and species that are resistant to pests and diseases, (8) adapting new input varieties that are more familiar and resistant to heat shock and drought, and (9) increasing tree planting activities through reforestation and community nursery activities (Howden et al. , 2007). The new research area that has been raised recently on an adaptation to climate change covers (1) discovering limitations, hurdles and gateway for the system, (2) interpreting sustainable and effective adaptation in promoting appropriate technological areas of adaptation, (3) logical exercises of threat assessment and articulation, and, (4) various stakeholders' relevant part for adaptation to climate change (Gunderson and Light, 2006; Nelson et al., 2007).

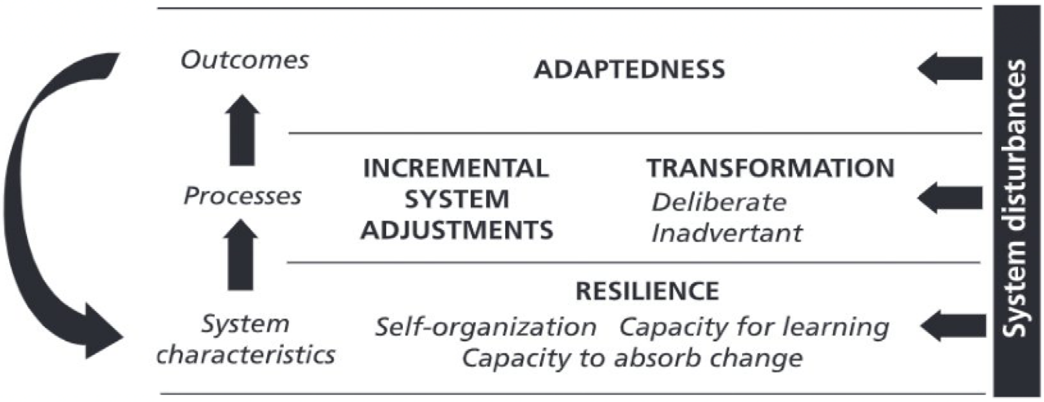

Figure 2. Outcomes, processes, and system characteristics for the adaptation process

Source: Nelson et al., 2007

There are also infrastructure needs in rural areas of sub-Saharan Africa, such as investment in roads, research and irrigation. In order to make adaptation costs affordable, it is also important to identify expenditures to reduce the number of malnourished children due to climate change to zero. There is also a need to include various agricultural adaptation measures in international climate change negotiations. There is also a need to recognise and strengthen food security and climate change adaptation together in this modern world. There is also a need to support community-based climate change planning (IFPRI, 2009). The assessment of each stakeholder and structure's perspective on adaptation comes from explicitly documented assessments in different sectors. In addition, the links between different elements such as processes, outcomes and characteristics are defined in Figure 2. The capacity to embrace is the main purpose of system characteristics. The capacity to embrace is expressed through the concept of sustainability. The capacity to embrace is described as a necessary condition for the system to embrace distraction or disruption. In addition, this capacity to embrace is underpinned by the sets of accessible assets or resources and the capacity of the structure or system to counter the distraction or disruption. The second phase of the stage is the process by which the transformational change organically generates or produces the new socio-ecological system. As shown in Figure 2, transformational change is an outcome of the ecological bridge. The transformational change can be explained by the example of climate change, as the change in climate, and the bio-network may not be able to support or sustain the traditional agricultural practices for livelihood. The last characteristic is a result of the adaptation process. The outcome of the adaptation process is the network or system of adaptability (Nelson et al., 2007; Haddad, 2005).

2.3. Rice farming systems around the world and climate change

There are various improvements needed for any agricultural products to increase food security and sufficient production. The African continent is well known for its fertile land and how climate change affects land fertility. Therefore, it is important to have climate change adaptation strategies. One strategy is creating and promoting new crop varieties per the local climate changes. There is very little research on farmer preference for adapting new crop species to adapt against climate variability (Jin et al., 2020). Various characteristics affect the farmer's preference to adopt new rice varieties, like aroma, seed quality, post-harvest qualities, agronomic characteristics, yield and texture after cooking. According to one research in Laos about rice variety preferences, local farmers were extremely satisfied with the new rice variety's milling and agronomic qualities (Siliphouthone, 2012). The outcomes from various new and improved rice varieties are rather more positive from the local farmer's point of view. The newly invented or adopted rice varieties from agriculture research help to increase production and income and improve the lifestyle of farmers by improving income and social level. One research from the Ethiopian rice industry indicated that rice farmers' production, commercialisation, and welfare have drastically increased compared to farmers with traditional rice varieties (Assaye et al., 2022).

Farmers in other tropical regions face similar problems. For example, droughts and floods have been a problem for more than 50 years in China, where rice is one of the main staple crops. Researchers have therefore adopted new strategies to adapt to climate change, such as crop diversification, increasing input use, switching to high-density crops, and identifying appropriate crop varieties for climate change (Zhou et al., 2018). In Benin, rice is a staple in all households. People in Benin tend to prefer different rice varieties from Asia over local Beninese rice varieties. Other reasons include the appearance of rice grains, cooking time, preference for foreign brands and high nutritional value. A total of six rice varieties were introduced to increase production and the national economy. In addition, after assessing local customer preferences, rice grain colour and texture were among the most preferred characteristics when deciding to purchase rice for the household (Fofana et al., 2011).

Bangladesh has one of the highest population growth rates in the world. With a growing population and demand for food, there is also a need to find new ways to promote more efficient farming practices. Research from Bangladesh shows that after the introduction of two new rice varieties, some adjustments are necessary because inputs are not affordable and new varieties require different management skills (Salam and Sarker, 2023). In an upland rice farming system, the farmer usually considered adopting new rice varieties if the crop matured earlier, with more biomass and higher yield. Rice is also one of the most important staple foods in India. Rice production has declined drastically due to population growth and old practices. The participatory varietal selection (PVC) process has been identified as a way to incorporate local farmer feedback into the adaptation of new rice varieties in India. Additionally, this process contains various four phases: 1) Discussion with farmers about their needs for variety, 2) looking for a desirable variety and materials, 3) conducting field trials with new varieties to promote and educate the farmers, and 4) marketing and spreading words about new decided variety. Lastly, in the post of conclusion the research, they found that local farmers tend to adopt and trust new crop varieties after the field test (Najeeb et al., 2018).

Each region of the world has different problems, so new rice varieties or strategies need to be adapted. Vietnam is one of the world's leading rice exporters. Vietnam's rice production industry is facing environmental and land fertility issues, so it is trying to adopt new rice varieties according to the conditions. In 2017, the Agricultural Extension Centre of the Department of Agriculture and Rural Development (DARD) developed a new rice variety that can adapt to the climatic challenges of the local environment. This new rice variety, called KH1, not only helps to adapt to climate change but also has a higher yield than traditional rice varieties. It also has other positive characteristics, such as being more resistant to typhoons and floods, and more resistant to pests and diseases. The research concluded that the adaptation plan was more effective with the help of the extension service to promote new rice varieties (Le et al., 2020).

Rice contains various nutrients such as protein, fat, carbohydrates and vitamins B1, B2 and B3. In Asia, rice is directly or indirectly used as a staple food. One of the countries where rice is a staple food is Sri Lanka, and they have researched rice preferences for traditional and new improved rice varieties. The local rice consumer chooses processed rice over unprocessed or whole rice varieties, but at the nutritional level, unprocessed rice variety has more positive value than processed rice variety (Samaranayake et al., 2022).

In developing countries, farmers' knowledge and response to climate variability are very limited, and this is a problem for agriculture worldwide. There is very little research on irrigation planning for rainfed rice production systems in climate change situations. One of the most common impacts of climate change on agriculture is drought, which occurs in all regions of the world. In the southern region of Indonesia, the lowland rice field has been affected by drought and research has been conducted on farmers' adaptation and perceptions. Various socio-economic and household characteristics also influence farmers' decisions to adopt new crop varieties. Farmers receive climate-related information through social media, newspapers, TV, radio, farmer-to-farmer and local extension agents. In some countries, the adoption of adaptation practices is measured by different indicators such as household head, gender, income, education and extension services. In the Philippines, climate variability prediction is derived from climate measures such as sun, clouds, participation, insect response and cyclones (Arifah et al., 2022).

For example, the Democratic Republic of Congo is experiencing climate change with a temperature increase of 1.7-4.5°C. The country is also experiencing less rainfall and later onset of rains. The impact of climate change in the country is profound due to the extreme poverty rate, especially in the agricultural sector. Several rice farms in the Luberizi wetlands have been severely affected by unpredictable rainfall. In addition, local rice farmers are unable to cope with and adapt to climate change due to the price of inputs, the cost of new technologies, the lack of information and poverty. In the Democratic Republic of Congo, the female farmer is the main actor in the rice field and in decision-making. In the conclusion part of this research, they found out that female farmers in the community are more than male farmers. They trust natural signs more than scientists when it comes to various climate change adaptation activities. Lastly, the security situation in the country is also one of the majors abstain for foreign researchers and scientists to visit and conduct various research and apply various farmer education activities to fight against climate change (Balasha et al., 2023).

2.4. Cropping calendars

The crop calendar is a tool to understand the changes in climate with a better understanding of local and habitual agriculture practices along with various activities and environmental indicators (Yang et al., 2019). The crop calendar consists of agriculture activities, monthly changes overview in activities over time and crop overview. This is one of the main tools for a better understanding of changes in activities over time due to climate change (Choudhary D, 2018). Changes in crop calendars demonstrate the climate change adoption strategy against various disadvantages during the crop production cycle. The morphological response of crops to climate change has been seen in reducing growing seasons. Much research has shown that changes in time for planting activities are leading to crops growing in more appropriate weather conditions with reduced need for irrigation for the plant. minimizing irrigation and preventing heat stress in areas where there are asymmetries in the water and temperature variations, drinking water is occasionally not possible. Prior research on crop calendar optimisation has generally concentrated on one growing season or one component of optimisation, ignoring specific processes in multiple cropping systems, including the effects of modifying a crop's planting and harvest dates on the crops that are grown afterwards (Moritz and Agudo, 2013; Agnolucci et al., 2020; Wang et al., 2022).

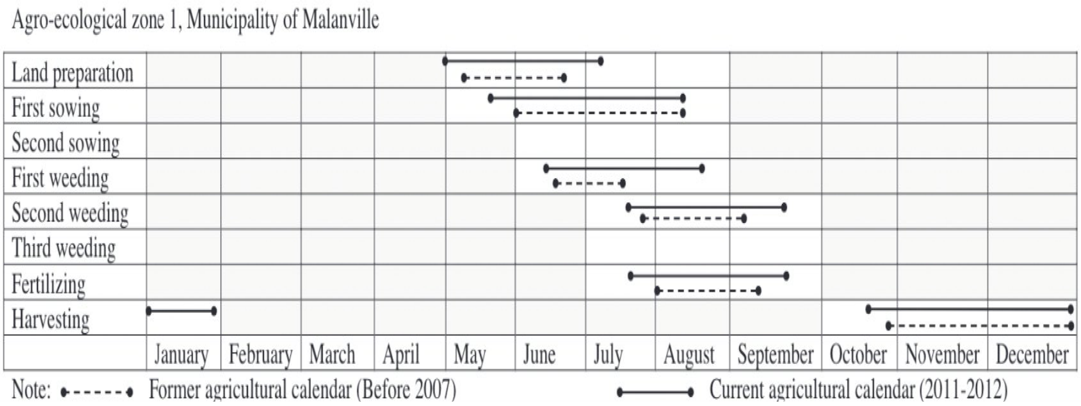

Figure 3. Example of crop calendar from the study in Benin (source: Yegbemey et al., 2014)

The crop calendar can be also used to identify various problems in crop production and provide a possible solution (Figure 3). One of the research projects in 2021 for adaptation to climate change for various crop varieties has derived few solutions or suggestions for adaptation strategies. Additionally, the common results from the research were to promote late maturing species mainly for the high land production system and promote the use of CO_2 fertilizer (Minoli et al., 2022).

2.5. Overview of farming systems in Zambia

Health and food security is a growing concern in the world, particularly in low-income countries. The number of undernourished people in sub-Saharan Africa is increasing dramatically. This is also the reason why the agricultural sector needs to be given greater importance and development. Smallholder agriculture is one of the main pillars in the fight against global food security and malnutrition in the African region. In order to achieve the Sustainable Development Goals (SDGs), various international agricultural programmes have been introduced to support farmers and the agriculture sector in various countries in sub-Saharan Africa, including Zambia. Despite its rich natural resources and agricultural history, Zambia is one of the poorest and most food and nutrition insecure countries in the world. Therefore, the fight against food and nutrition insecurity is organised by empowering smallholder farmers to increase the productivity, stability and resilience of their farming systems (Sibhatu et al., 2022).

Zambia's agricultural sector is exposed to climate variability. It has already affected the southern, western, and northern parts of Zambia with high-temperature changes and uneven participation. In addition, the vulnerability to climate change calls for strengthening the agricultural sector by increasing productivity and adapting to climate change. Economic development and job creation are linked to the growth and development of the agricultural sector (Somanje et al., 2017).

Population growth and changing food preferences are creating new problems, and there is a need to increase agricultural production. In addition, the attempt to increase agricultural production is leading to deforestation, which is also a problem in Zambia. In Zambia, reforestation is estimated at between 167,000 and 300,00 ha per year from national deforestation data. There is therefore a need to apply or introduce a climate-smart agriculture system. A climate-smart agriculture system is considered to help the agricultural sector through a positive increase in agricultural development and help local farmers adapt to the problem of climate change (Ngoma et al., 2021).

Zambia has a total land area of 752,000 km2, of which 57% to 59% has potential for various agricultural activities. In addition, 80% of the farmers in Zambia are smallholder farmers who operate their farming activities only with subsidies or help from various direct or indirect stakeholders. There are various schemes or subsidies for farmers in Zambia, such as the Fertiliser Support Programme (FSP), which was later renamed the Farmer Input Support Programme (FISP). The main reasons for this programme are to increase food security in the region and to increase income, especially for small-scale farmers in Zambia. Initially, the FISP was mainly introduced for maize, as it is a staple crop for the country and feed for livestock. In this programme, all input or production costs are covered and farmers are given the opportunity to diversify their farming business or crop diversification (Blekking et al., 2021; Markelova et al., 2009; Mason and Ricker-Gilbert, 2013).

In Zambia, 67% of the country's farmers are smallholder farmers who farm less than two hectares of land. Zambia experiences inconsistent rainfall from time to time, but recent years' rainfall data indicate that rainfall is increasing. In addition, there has been a decline in rainfall in the Northern Province in recent years. The western, central, copper belt, capital Lusaka and southern parts of Zambia are currently experiencing an increase in rainfall. It is therefore clear that Zambia's agricultural sector needs a climate adaptation strategy. Irrigation is also critical to the agricultural sector, and Zambia has limited areas with irrigation schemes. Nevertheless, most of the country needs more efforts to provide water for different activities (Blekking et al., 20-21; Markelova et al., 2009; Mason and Ricker-Gilbert, 2013).

Another programme aimed at increasing production and involving market actors is the Smallholder Productivity Promotion Programme (S3P). This initiative focuses mainly on farmers producing cassava because of the crop's value for nutrition and food security. In addition, cassava is resilient to climate change and variability and requires less fertiliser. This programme focuses on marketing cassava to increase Zambia's production capacity and food security. In addition, this programme is being introduced in three regions of Zambia, due to their high levels of poverty and farming systems. Maize is also one of the staple crops that is usually intercropped with cassava, so maize production is also increasing with cassava. This programme was introduced with some other objectives in addition to the main objective. The other objectives were to improve and promote local farming or farmer group, improve access to extension officers, promote agricultural adaptation practices and promote better and accessible inputs (Sibhatu et al., 2022). In the rural part of Zambia, agricultural activities take place on a small area or plot of land, and the smallholder farmer produces less. As a result, smallholder farmers in Zambia spend more on input costs than they receive in agricultural output. In addition, changes in rainfall, temperature, drought, and flooding can make farmers poorer because they need to invest more in new agricultural technologies in climate variability scenarios (Kuntashula & Mwelwa-Zgambo, 2022; Matchaya et al., 2022).

The main driver of deforestation in Zambia is the relationship between agricultural land use, household attitudes towards agricultural activities and deforestation. Household attitudes towards agriculture can be explained by changes in the farming system (Kasungu et al., 2021).

2.6. Climate change effect on Zambian farming systems

The Zambian economy is highly dependent on the mining sector, but fluctuations in global commodity prices call for diversification. The development and production of the Zambian agricultural sector can be one of the sectors that can increase its contribution to the national economy (Phiri et al., 2020). In addition, the agricultural sector in Zambia has been abandoned due to urban bias and focuses on one staple food (maize) rather than diversification. Agricultural irrigation in Zambia is mainly rain-fed, but the current and future challenge of climate variability makes the sector more uncertain about its production due to changes in the timing and amount of rainfall. Rain-fed farming systems in Zambia make agricultural production vulnerable to future climate dynamics, namely potential changes in the timing and number of rainfalls (Ngoma et al., 2021; Fant et al., 2015; Juliet et al., 2016).

Climate variability is unpredictable, and the main impact of climate variability on the agricultural sector is through increased frequency of climatic events. Furthermore, due to the unpredictability of climate change, farmers are unable to plan their agricultural production activities in the case of the predominantly rainfed farming system. Climate change in Zambia negatively affects the production of major staple crops such as wheat and maize in the smallholder farming system. There are other countries affected by climate change, but Zambia has been affected by climate change with failure in agricultural production, food security issues, diminishing impact on the national economy and loss of livelihoods (Ngoma et al., 2021). Every country needs to plan its scenario or action against climate variability, especially the agricultural sector (Stadtbäumer et al., 2022). In Zambia, there are some national policies related to agriculture and climate change such as the National Climate Change Policy, the National Development Plan, and the national agriculture policy. Additionally, these policies have a more important role in the Zambian agriculture sector and for their future to find out the impact of climate change, their impact location as well as how to plan climate change adaptation plans (Ngoma et al., 2021).

The agricultural sector in Zambia is more important to the national economy and has the potential to grow in the future. The agricultural sector currently contributes 20% to the national economy. Agricultural practices in the western, southern and central parts of Zambia are highly affected by the dry season or low rainfall with no irrigation system, making agricultural production vulnerable to climate variability. The country has a large amount of water availability through rivers and groundwater, but water distribution across Zambia is not well distributed, making rainfed agriculture more vulnerable to climate change. Climate variability also affects Zambia's health sector in warmer, drier and flood-prone areas. Malaria, cholera, respiratory infections and diarrhoea are health-related diseases that are increasing in both rural and urban areas of Zambia due to climate change. Changes in temperature make malaria more prevalent, and changes in rainfall can spread other diseases. Lack of medical facilities, lack of sanitation and drainage facilities, limited or no drinking water facilities and contaminated water make these reduced outbreaks more dangerous to the health sector. Zambia's forests and grasslands contribute to the economy in many ways, with forest and grassland materials such as food, fuel, fodder, medicines and construction materials. In addition, due to rising temperatures caused by climate variability, forest fires and various new pests and diseases are occurring and affecting natural resources (Phiri et al., 2020; Stadtbäumer et al., 2022).

2.7. Rice farming systems in Zambia under the climate change

Rice is the main staple food in many countries, especially for the rural population. Rice is mainly grown by smallholders on less than 1 hectare of land. It is also used as an incentive or wage in many processing units in the rice value chain. According to the Food and Agriculture Organization (FAO), rice has a high nutritional value and is a key component of food security policies in many countries around the world. In Africa, and particularly in Zambia, rice is considered a profitable cash crop with a high potential to increase farmers' income and production. The Zambian Ministry of Agriculture has decided to select rice varieties for promotion and increased production in some selected regions. Many regions in Zambia's rice production have been affected by various factors such as 1) limited availability of affordable seed and fertilizer, 2) soil fertility issues, 3) lack of road, storage and transport infrastructure, and 4) lack of access to markets for the agricultural commodity. In the rice sector, there is constant competition from top rice-producing Asian countries. Zambian rice dominates the informal market within Zambia and the DRC (Democratic Republic of Congo). In the Zambian rice value chain system, middlemen are important for farmers to sell their products, but at the same time, farmers think that the middleman is not loyal to them throughout the whole process. In Zambia, from 1981 to 2006, rice cultivation or production increased drastically by 135% (Chizhuka, 2009). Furthermore, data from the FAO (Food and Agriculture Organisation of the United Nations) shows that rice cultivation in Zambia has increased in the last 20 years from 9,270 ha in 2000 to 24,756 ha in 2020, an increase of 15,486 ha in 20 years (FAO, 2023).

Zambian consumers are sensitive to rice prices and loyal to their product brands. For rice, Zambian consumers buy rice based on quality, colour and grain size. In addition, these rice varieties in Zambia lack value chain processing units and technology, making it difficult for local rice varieties to compete with other rice producers in the world. Rice is poorly packaged in Zambia, with mixed rice grains that are dusty and unpolished, putting local farmers at a price disadvantage. There are three types of rice farmers in Zambia: smallholder, medium-scale and large-scale (Box, 2011; Makungwe et al., 2021; Mapedza et al., 2022). The rice industry in Zambia also faces some problems which are: 1) lack or underdevelopment of modern technologies, 2) poor quality of input materials, 3) lack of new or more production knowledge on irrigation, soil and water management activities, 4) poor market accessibility in rural Zambia, 5) problem of availability of intermediaries, 6) poor quality of standard for the rice industry, 7) lack of financial support to farmers, 8) problem with land laws and tenure, and 8) lack of business and technical skills. There are various targets set by the government of Zambia for the rice industry such as 1) increase the rice production market by 70%, 2) increase the market share of Zambian rice varieties in Zambia by promoting the different local rice varieties, and 3) establish and improve the rice market value chain with sub-sector coordination (Box, 2011; Makungwe et al., 2021; Wineman and Crawford, 2017).

The Western Province of Zambia is well known for its rice production and quality. The Western Province is also one of the least developed regions in the whole of Zambia and is vulnerable to climate change. The rice value chain in Western Province is not well established at the local level. The middleman is also a problem for local farmers who cannot dictate price levels (Blom, 1984). A total number of 15 different varieties are cultivated by the rice farmers in Zambia like Supa, Burma, Sumbawanga, Giza, Kajakete, Angola 1, Malawi faya, IITA, Burma 2, Koshi kari, Wahiwahi, Black rice, Narica 1, Narica 4 and Xiang Zhou 5. Supa, Kajakete, and Black rice are preferable rice varieties for lowland farming systems, whereas Nerica 1 and Nerica 4 rice varieties are preferable for upland cropping systems by the local Zambian farmers (Mutale et al., 2010).

Climate variability in Zambia mainly affects the agricultural sector and livelihoods. According to research, the agricultural sector will experience a 30% decline in income in the dry regions and a 20% decline in the wet regions of the country in the future. Therefore, climate adaptation strategies are very important for the agricultural sector in the country. Various agricultural intensification practices need to be introduced in the country with livelihood diversification to reduce the impact of climate change (Stadtbäumer et al., 2022).

3. Aims of the thesis

The master's thesis aims to explore potential changes in rice cropping calendars practised by smallholder rice farmers in the Barotse floodplain as a coping mechanism against climate variability in the Western province of Zambia.

Specific objectives of the thesis are to:

i. Document farm calendars for local rice varieties

ii. Understand the farmers' decision to adjust their farm calendars

iii. Identify factors influencing the adoption of improved rice varieties.

4. Methodology

4.1. Study site characteristics

Zambia is well known for its diverse availability of resources and mainly for their land, water, and forest (Kuntashula and Mwelwa-Zgambo, 2022). Forest and forest products are accountable for more than 20% of the local livelihood income and have an important role in the national economy (Kazungu et al., 2021). There has been decreased of the agriculture sector's contribution to the Zambian national economy compared to manufacturing, services, and other industrial sectors since 1980 (Mulanda & Punt, 2021).

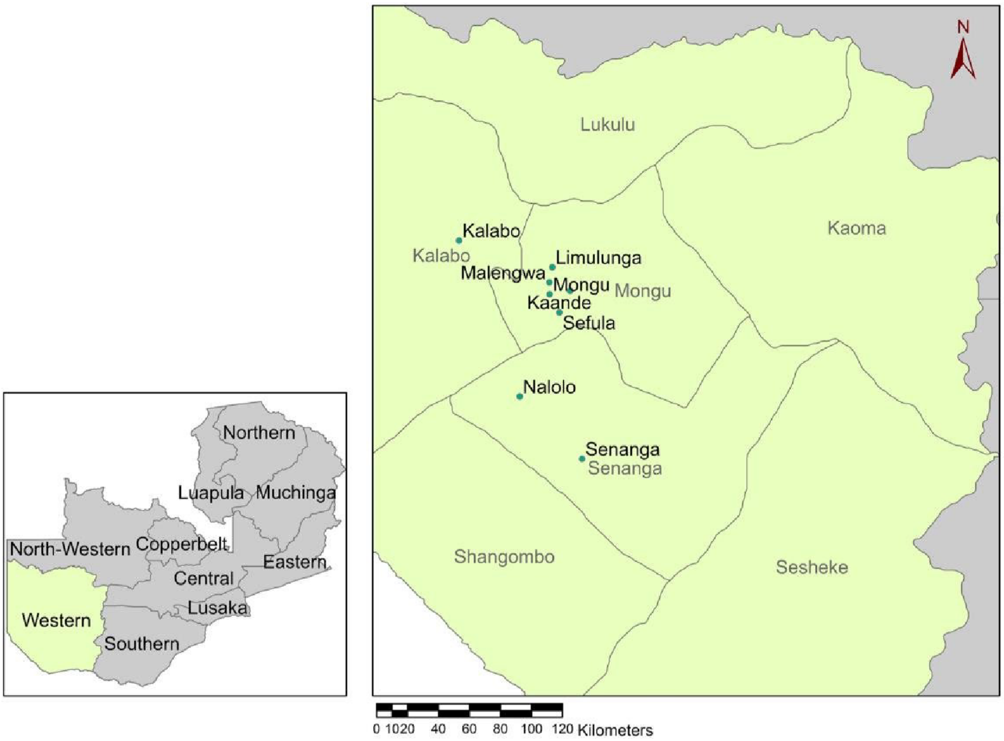

Figure 4. Study area with eight locations for data collection

The study area (figure 4) is in the western province of Zambia, which is one of the largest provinces in the country. The capital city of the province is Mongu, which is 600 km away from the capital city of the country (Lusaka). The western province has boundaries with Angola in the western part, Namibia in the southern part, the central province in the eastern part and the north-western province in the northern part of the province. The total population of the province is around 902,974. The biggest river is passing in this province called the Zambezi River from which the name of the country Zambia comes (Smart Zambia Institute, 2021).

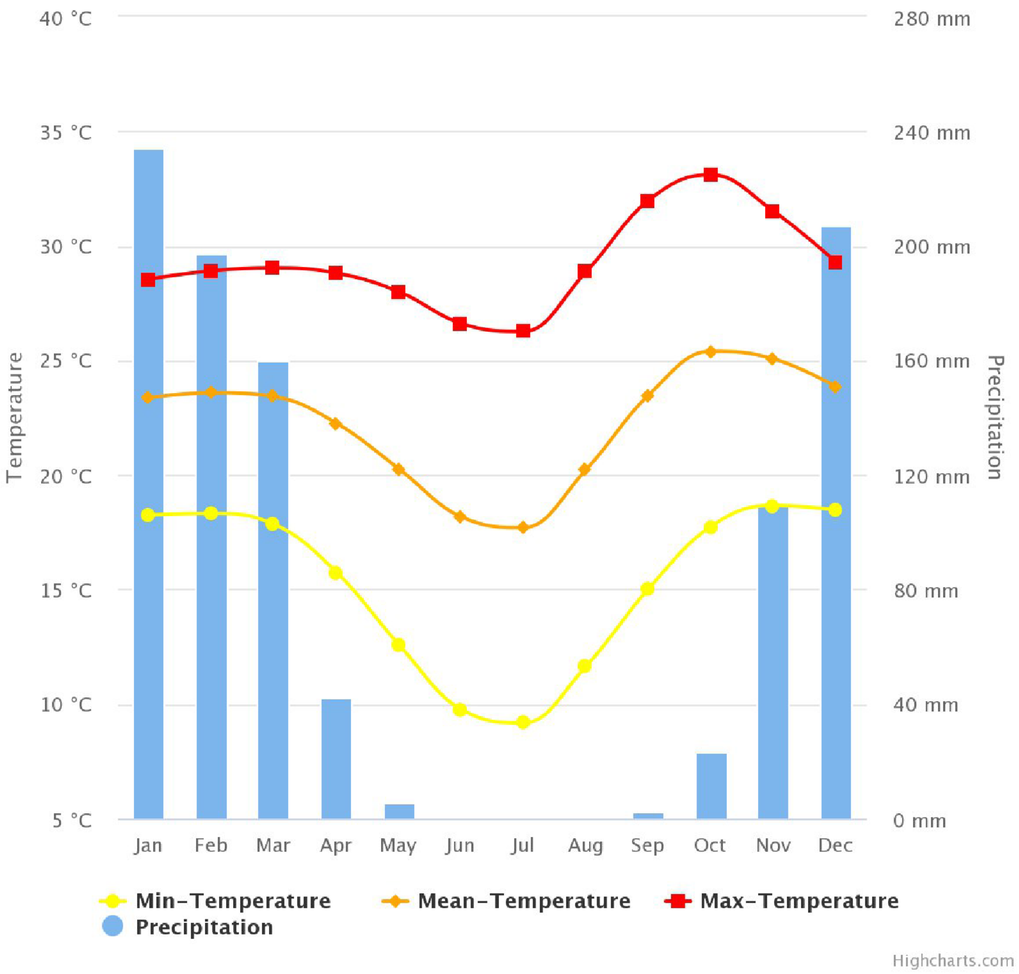

Figure 5. Monthly climate data with min temperature, mean temperature, rainfall, and max temperature of Zambia from 1991-2020

Source: World Bank 2021

The western province provides 3% of GDP contribution towards the national economy and a high unemployment rate of 19.7%. One of the main obstacles in the province is the lack or poor development of various infrastructures (Zambia and Western Province Are on the Cusp of a Promising Future, 2019). Additionally, Zambian household livelihood also depends on various forest products. There are four various types of uses of forest products in the western province of Zambia from various forest food products, charcoal forest wood, processed charcoal from woods and other non-commercial forest items for households (Kazungu et al., 2020).

Zambia is in a sub-tropical climate zone with three different seasons during a year: the summer season in August to November month, the rainy season from November to April and the winter season in August month. As per Figure 5, the average annual temperature from 1991 to 2020 is 22.2°C and the average or mean annual rainfall Zambia experiences is 982.3 mm. Additionally, the rainfall pattern in Zambia is also varied as per the area like 700 mm rainfall in the southern part of the country and 1,400 mm in the northern part of Zambia due to the Inter-tropical convergence zone (ITCZ) (World Bank, 2021).

The research area is the Barotse Floodplain, which is in Zambia's Western Province. With a population of roughly 250,000 people, the Barotse Floodplain has a total area of about 600,000 ha. To the west and south, it shares borders with Angola and Namibia, respectively. The Zambezi River flowing to Zambia through Angola created the floodplain. It is located in the Zambezi River's upper reaches. The Barotse Floodplain measures about 230 km long and 50 km wide (Mapedza et al., 2022). Between November and June, flooding often happens at depths of 1.5 to 3 metres. Annual floods enrich the normally nutrient-deficient sandy soils of the Kalahari. Agriculture is produced during the dry season together with livestock grazing on the flood plain's lowland grasslands. For the most part, cattle are grazed in wooded forests in the upland zone during the yearly lowland floods. The nutrient-poor soils of the uplands restrict the possibilities for agricultural development (Pasqualino et al., 2015; Rajaratnam et al., 2015).

4.2. Data collection and sampling techniques

The first stage of data collection was carried out with key informants from the Ministry of Agriculture in Mongu (Western province) for a better understanding of the rice farming system and value chain in the province (Figure 8). Additionally, after the meeting with key informants, focus group discussions were carried out to understand the rice farming system from the key farmers and finalize the household questionnaire. Lastly, household face-to-face surveys were carried out with the head of the household.

Figure 6. Face-to-face interviews with local farmers

Figure 7. Focus group discussions with key rice farmers

Figure 8. Meeting with local officers of the Ministry of Agriculture in Mongu

Figure 9. During practical training at the Diocese of Mongu Development Centre (DMDC)

Before the household survey started, six focus group discussions were carried out in each district to better understand local rice farm practices, management, history, problems, and the rice value chain in the western province of Zambia. Additionally, the purpose of the focus group discussion was to finalise and adjust the household survey questionnaire as per ground realities. A total of 12 key farmers were selected by the input taken from all local farmers and key farmers, including men and women in the focus group (Figure 7). During the focus group discussion, various questions related to rice production, crop calendar for one decade, and information behaviour were asked, noted, and understood (Ates et al., 2017).

The data for the crop calendar was collected during the focus group discussions with consensus from all 12 selected key farmers for the duration of a total of 10 years, also various key Notes were taken during the focus group discussions. The key farmers have consisted of both females and males in all five focus group discussions, like 8 female and 4 male key farmers in Malengwa, 6 female and 6 male farmers in Sefula and Kalabo, 7 males and 5 female farmers in Limulunga and 5 male and 7 female farmers in Nalolo. Additionally, two calendars were taken, documenting the current situation with the one 10 years before to see potential differences due to climate variability. The household surveys were carried out in five districts in the western province, there were 127 respondents in the Mongu district, 30 in the Nalolo district, 89 in the Senanga district, 48 in the Limulunga district and 53 in the Kalabo district.

Data were collected in eight villages in Barotse floodplains covering two major farming systems upland and lowland. (Figure 4). The places were Mongu, Senanga, Nalolo, Sefula, Limulunga, Kaande, Kalabo and Malengwa. A total number of 348 households was selected for data collection via snowball and purposive sampling methods (Naderifar et al., 2017). The household survey questionnaire was finalised and adjusted after the focus group discussion and from the local agriculture ministry's feedback and inputs on the rice sector in the western province of Zambia. The household survey questionnaire contains various aspects of the rice production system like Household characteristics, rice production characteristics, input, market and labour characteristics, and information source characteristics (Murin et al., 2015).

4.3. Data analysis

After the focus group discussions and household surveys, the data were checked as per our requirements and made sure that it was clear and collected. Consequently, the data were entered into Microsoft office excel for MacBook, cleaned, summarized, and coded. Various methods were applied to analyse the data.

The household survey data were transferred into various standard indicators used in the farming approach system (Oajide, 2013; Darnhofer et al., 2012; Kruseman et al., 2020).

Additionally, the crop/farm calendars were documented during focus group discussions in four districts: Mongu, Nalolo, Kalabo, and Limulunga. Lastly, to understand the farmer's decision to adjust their farm calendar (FGDs data – narrative/qualitative results) with special regard to rice varieties, focus group data were used to describe the reasons and understand the ground conditions.

In order to understand the household, institutional and farming factors influencing the adoption of rice varieties due to climate change, the logistic regression model was used in which data from various household, farming and institutional factors (Table 1) were selected and entered into Jamovi software for MacBook (Park and Yi, 2023; Gassama et al., 2021). The dependent variables are binary outcomes with the values 0 and 1 that indicate whether a farmer adopts an improved rice variety or not. Where y is a binary variable that represents a household's preference for an improved rice variety and x is a collection of explanatory factors (Nkomoki et al., 2018),

the equation is **(y = 1x) = (x) (1)**.

Table 1. Selected household and farm variables for the understanding of the adoption of new rice varieties due to climate change

Variable	Unit of measure	Definition	Expected effect	References
Dependant variable	Yes 1/ no 0	Adoption of improved rice variety due to climate change	To understand effects of farming household variables on the decision on adoption of improved rice variety	Kolapo and Kolapo, 2023; Siliphouthone, 2012; Teklu et al., 2023
Age	Years	Age of the rice farmer	Elder farmers might tend to follow tradition and not to change the calendar. They also, could be more restrained to improved varieties.	Adetoro et al., 2022; Khanal and Wilson, 2019; Kilimani et al., 2022; Owusu et al., 2021
Farm experience	Years	Number of years for which a rice farmer is running farm	With more farming experience, farmers can be more adaptive towards morphological characteristics of improved varieties.	Adetoro et al., 2022; Lu et al., 2022; Padhan and Madheswaran, 2022
Education	Years	Total years of rice farmer education	Educated farmers in community can provide and spread information about climate change scenario and new improved variety	Kilimani et al., 2022; Lu et al., 2022; Mesfin and Girma, 2022
Gender	Male=1/ female 0	Gender of the rice farmer	Male farmers tend to have more power in decision-making in farming activities	Aiswarya et al., 2023; Akalu and Wang, 2023; Naz and Doneys, 2022
Household size	Numbers	Total numbers of household members	Large size of household tends to provide more support in agriculture activities and decision making	Kilimani et al., 2022; Lu et al., 2022; Mesfin and Girma, 2022

Land under cultivation	ha	Total size of land under cultivation	Larger farming land can provide options for the farmers to adopt improved variety with crop diversification	Aiswarya et al., 2023; Lu et al., 2022; Tran et al., 2022
Farmer organisation	Yes 1/ no 0	Member of farmer organisation	Membership of farmer organisation can provide platform to receive climate and farming related information with input support facilities	Azhoni and Goyal, 2018; Jayasiri et al., 2023; Omodara et al., 2023; Paparrizos et al., 2023
Irrigation system	Yes 1/ no 0	Availability of irrigation system	Availability of irrigation facility can affect the cropping season with less negative effects from climate change	Ahmad et al., 2021; Arifah et al., 2022; Dono et al., 2013; Egerer et al., 2023; Yan et al., 2020
Rainfall season	Long 1/ short 0	Duration of rainfall season	With changes in duration of rainfall, the farmer can adopt improve crop variety and reduce production loss	Ademe et al., 2021; Grusson et al., 2021; Yue et al., 2023
Off-farm income	Yes 1/ no 0	Access of income from off-farm activities	With off-farm income, the farmer can invest more into input	Akter et al., 2022; Amfo and Ali, 2020; Ojo and Baiyegunhi, 2021

5. Results

5.1. Household and farm characteristics overview

Out of 348 households, a total of 26.7% of the heads of the household were men and 73.3% were female farmers. The range of age interviewed farmers was between 20 years to 84 years (Table 2). The average size of the household was 6.88 in all documented household interviews. The farming experience of the household varied from 1 year to 55 years, with an average of 15.5 years (see Table 2). Additionally, land size for cultivation was documented, with an average size of 1.76 ha in the study area. A total of 43% of farmers were reported to have completed primary school education, 50% of farmers with secondary school education, 5% of farmers to have graduated study, and a total of 2% of farmers were illiterate. A total of 53% of the household head were married, 26% of the household head were single, 5% of the household head were divorced, 4% of the household head were separated from partners and a total of 12% of the household head were documented as a widow.

Table 2. Main characteristics of rice farmers

Variable	Unit of measure	Mean value	Range	Coefficient of variation
Household head age	years	47.5 (±14.6)	(20-84)	30%
Years of schooling	years	8.3 (±3.2)	(0-20)	38%
Farming experience	years	15.5 (±11.4)	(1-55)	73%
Household size	numbers	6.9 (±2.9)	(2-21)	42%
Farm size cultivated	ha	1.8 (±1.7)	(0.25-4.00)	95%

There was a total of four various types of livestock documented among all households, which are 21% of households with cows, 64% of households with chicken, 7% of households with pigs and goats with 8% of households. Additionally, there were only three types of machinery or tools were documented from the interviews, which are tractors with 13 farmers, hand hoes with 182 farmers and drought animals from 153 farmers.

Only 26.7% of total rice-cultivating households were documented to have access to irrigation facilities near their farms while the rest were fully dependent on rainfed agriculture practices. Furthermore, 81.6% of the interviewed farmers were using recycled seeds, which is seen as a lack of input availability or affordability among rice farmers of the western province. Regarding intercropping practices, 29% of farmers were practising rice-maize systems, 3% of farmers' rice-wheat systems and more than 68% of farmers planted only rice on their fields.

A total of 79% of farmers were practising their agriculture activities in rainfed lowlands, 20% of farmers in rainfed upland and 1% of farmers in irrigated lowlands. A total of 69% of the farmers were experiencing a long rainfall season. Changes on the onset of the rainfall, a total of 52% of the farmers had responded that the rainfall onset is earlier compared to previous years, 45% of farmers with the decision of late onset of the rainfall while the remaining 3% of the farmers were on side of no changes in the onset of rainfall pattern. A total of 97% of the total farmers reported to experienced floods during the last 10 years, whereas 99% of the farmers reported to experienced drought during the last 10 years.

A total of 90% of the households had reported to received rice production-related information from local extension officers, while 89% of the households reported receiving information from farmer to farmer. About 98% of the households were getting climate-related information and 78% of that households were receiving climate-related information from the metrological department of Zambia and 22% of the households from various NGOs (Non-governmental organisations). A total of 77% of households were having an off-farm income. Additionally, 79% of the households were documented to be a member of farmer organizations. Only 35% of the households were having access to the provision of input-related subsidies.

5.2. Management and changes in rice cropping calendars

Five crop calendars for rice were documented during focus group discussions from Nalolo, Kalabo, Limulunga, Malengwa (Mongu) and Sefula (Mongu). The chosen rice variety for this crop calendar was Supa rice, which has been grown in this region by all rice-producing farmers due to market demand, colour, grain texture and price.

Various activities for rice production were captured during this interview, and it varied from place to place (Figures 10,11,12,13 & 14). The rice production activities duration was captured and documented in the crop calendar. The crop calendar from Malengwa village in Mongu district was documented without any changes from the last decade, but on the contrary crop calendar from Sefula village in Mongu district was seen to have minor changes in land preparation activity for Supa rice and harvesting and drying for Koshikari rice variety. Kalabo, Nalolo and Limulunga districts were seen to have changes in their crop calendar. Additionally, the focus group discussions also revealed that there were two types of farmers for lowlands rice farming: deep in the flood plains and normal in the non-flooded plains. The flooded type of farmers normally practised their nurseries in their homes and others practice broadcasting methods for planting.

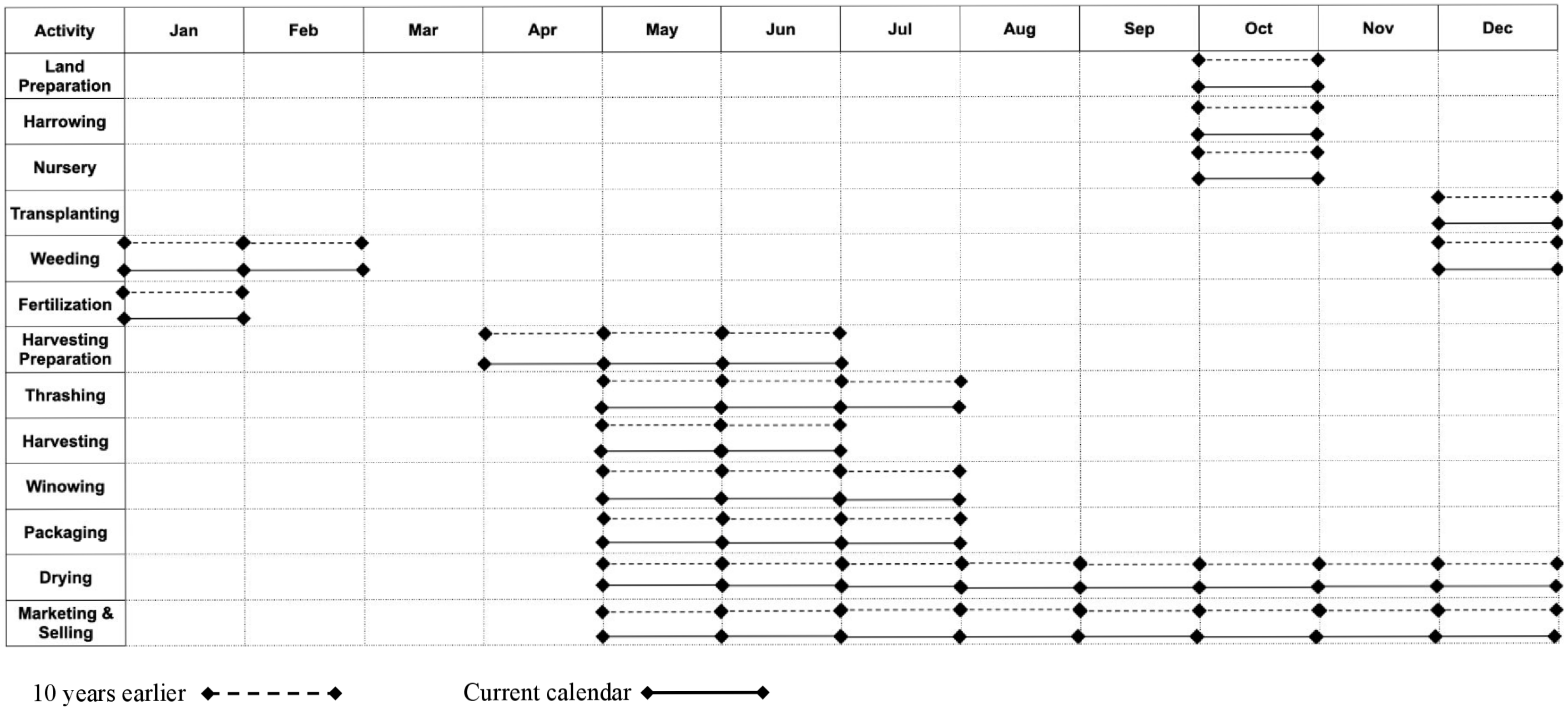

Figure 10. Rice crop calendar for Supa variety from Malengwa village in Mongu district (upland/lowland farming systems)

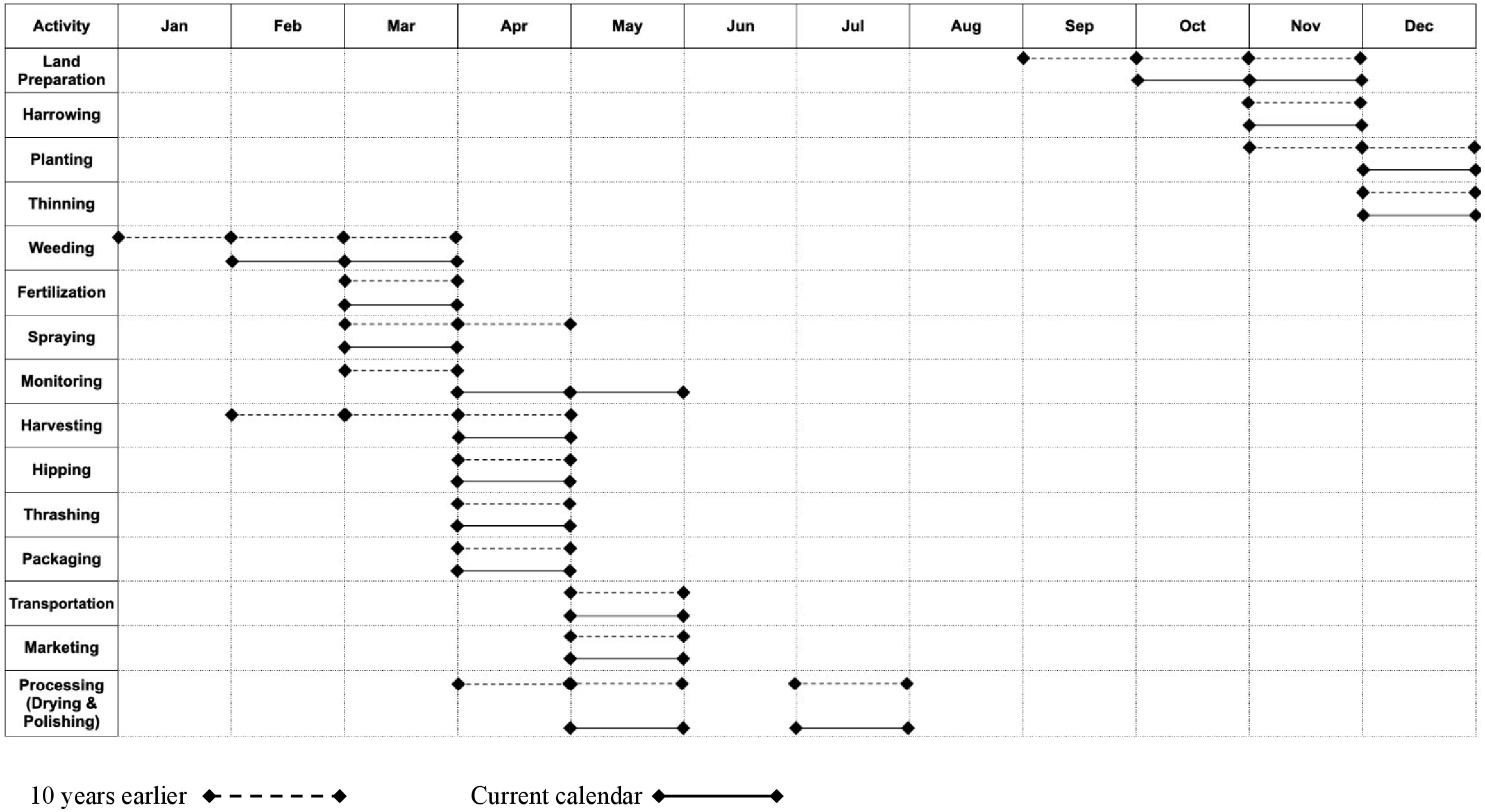

Figure 11. Rice crop calendar for Supa variety from Kalabo district

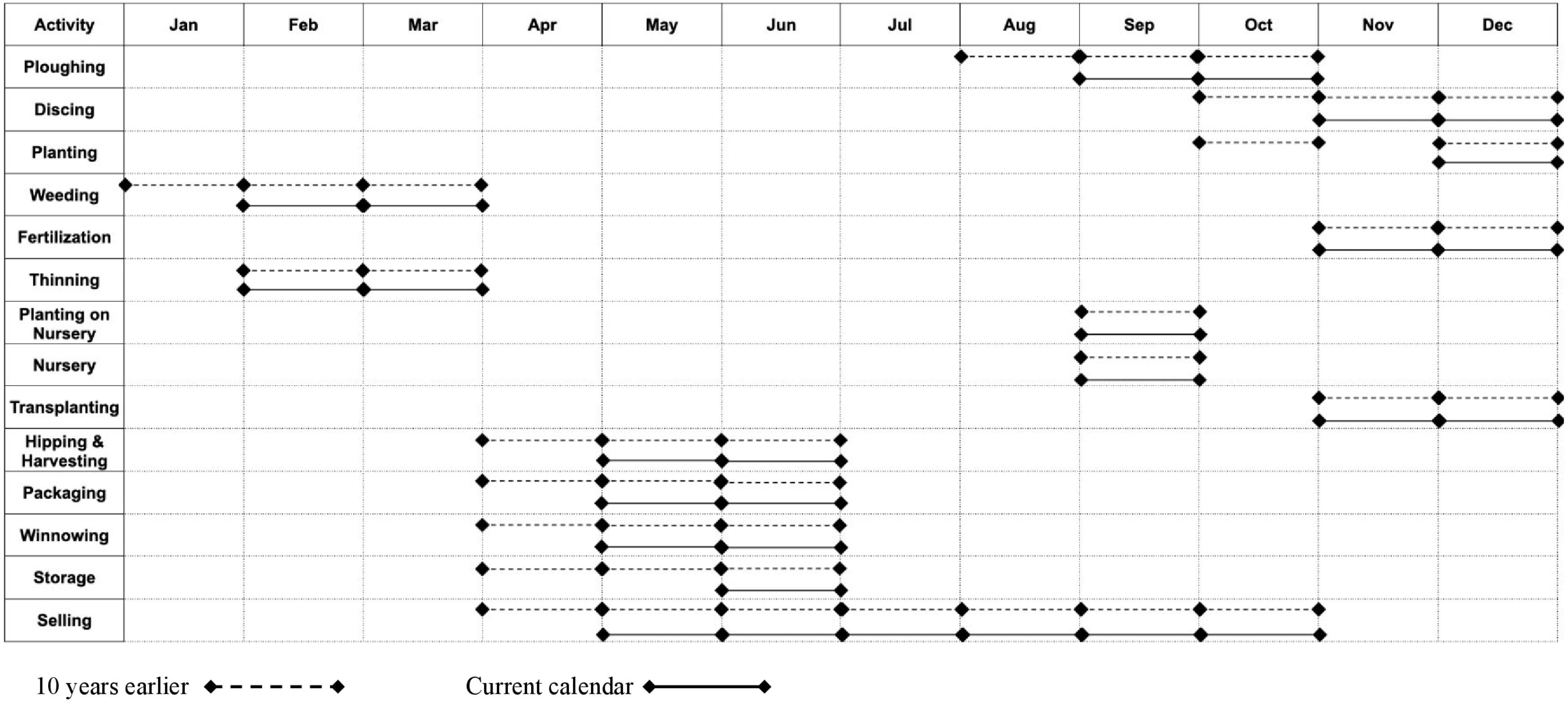

Figure 12. Rice crop calendar for Supa variety from Limulunga district

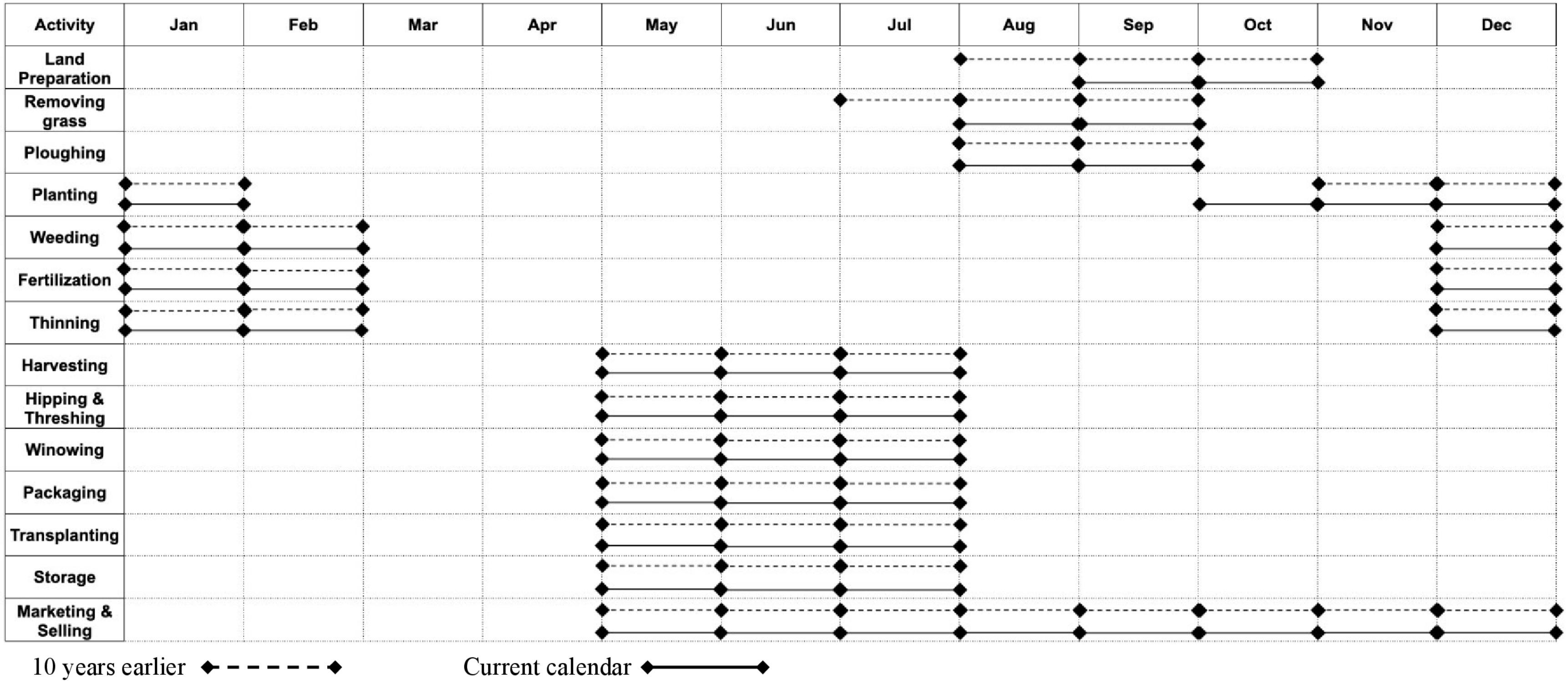

Figure 13. Rice crop calendar for Supa variety from Nalolo district

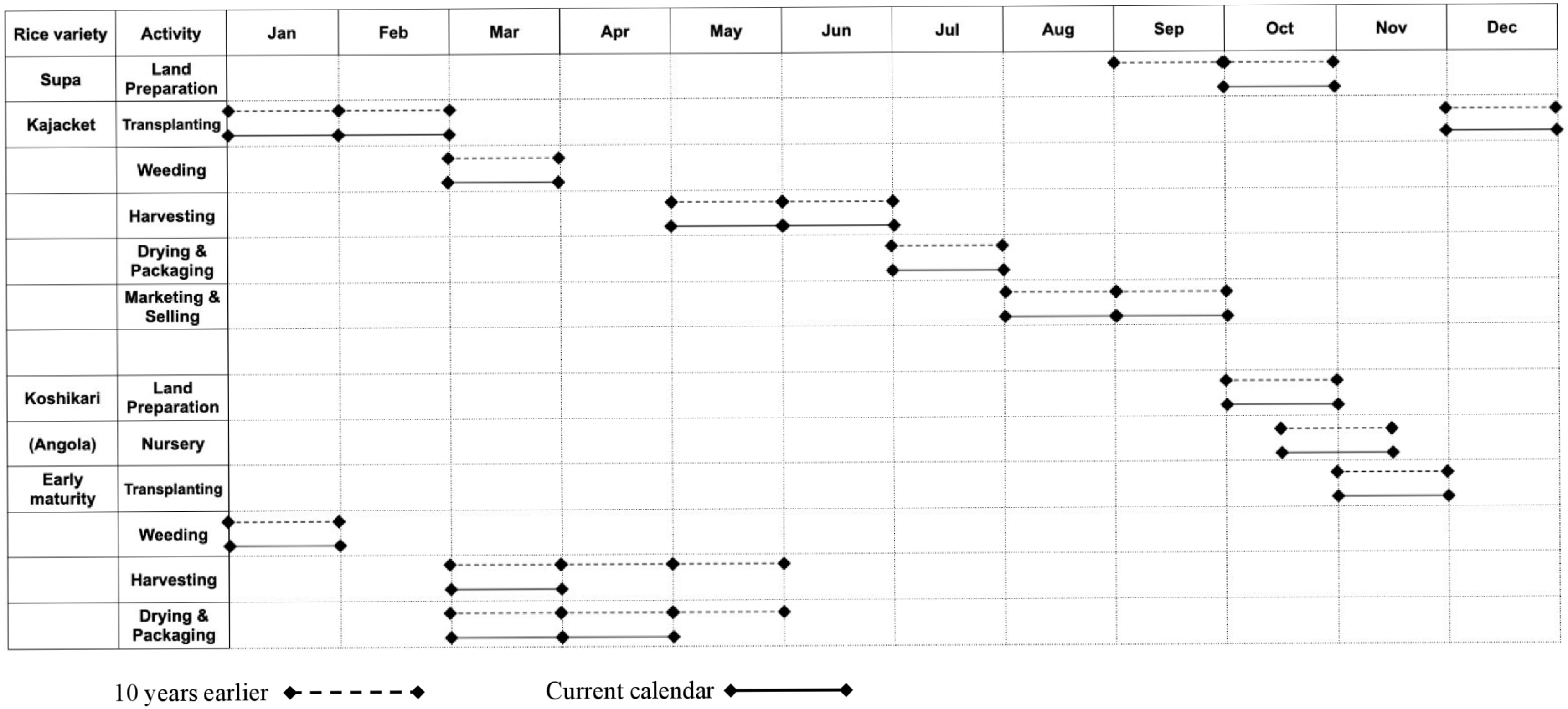

Figure 14. Rice crop calendar for Supa, Angola & Koshikari varieties from Sefula village in Mongu district

5.3. Reasons behind changes in rice cropping calendars

We had documented the current and a decade early crop calendar with a total of 13 various activities documented in Malengwa village (Mongu district) for mainly Supa rice variety (Figure 10). Not one change was seen in the last decade for rice production in malengwa and the main reason behind that was that the local farmers were not seen to accept that there is an effect of climate change on the ground and lack of input support as well.

In Kalabo district (Figure 11), a total number of 15 various production activities are documented for the supa rice variety. There were some changes in the seven activities documented and the activities are land preparation, planting, weeding, spraying the water, monitoring, harvesting, and processing (drying and polishing). Some of the farmers are practising nurseries for their rice production in the Kalabo district which was the main reason behind the change in land preparation. Due to changes in rain patterns, the planting activity period was shifted one month late in the crop calendar. As per the head farmers, the land for rice farming in Kalabo was more fertile 10 years back compared to the current calendar. Additionally, this district lacks any irrigation facilities for agricultural activities. Also, the processing activity was documented with a change in the crop calendar due to a lack of processing and transportation facilities in the district.

The crop calendar from the Limulunga district was documented to have shifted in a total of nine activities out of fourteen (Figure 12). The calendar moved one month late in all reported activities which are: ploughing, discing, planting, weeding, hipping & harvesting, packaging, winnowing, storage and selling. In this focus group discussion, many of the reasons were provided to justify the changes in climate change. As per the farmers, the supa rice variety consumes lots of water, also 10 years before they were using the broadcasting method and currently, they are using the transplanting method for planting. Additionally, they were experiencing early rainfall compared to 10 years ago.

Nalolo district crop calendar was documented with a total of 14 various production activities, from which only grass removing process was seen to have changed in the crop calendar (Figure 13). The main reason behind this was that they were experiencing changes in rain patterns.

In Figure 14, the crop calendar from Sefula village (Mongu district) was documented for two types of production patterns. The crop calendars were combined for four types of rice varieties in that village due to the availability of an irrigation scheme, and input providing scheme from JICA (Japan International Cooperation Agency). The rive varieties were supa, kajacket, Angola and koshikari. According to key farmers, these rice varieties were maturing early, providing more productivity. There were some changes in the crop calendar where the current crop calendar was showing early harvesting and processing activities due to support from JICA and government schemes with seeds, fertilizer, and irrigation schemes.

5.4. Drivers of adoption improved rice varieties

Instead of making shifts in rice calendars, farmers tend to adopt improved varieties that are resistant to climate change. A similar situation was observed in our study site. A total of six various household and farm characteristics were selected to see the relation with the decision for new rice varieties due to climate change. The selected indicators were the age of the household head (years), gender of the household head, total years of schooling, number of members in the household, and total land under cultivation in ha (table 3). Out of a total of 348 respondents, 31.6% of the respondents were seen to continue with the traditional rice varieties but on the other hand, 68.4% of the respondents were reported to adopt new rice varieties due to climate change. 27% of households were represented by males.

Table 3 documented the mean or average value between the farmers with an adaptation of the new variety and without adaptation of the rice variety. The farmers with the decision to adapt to the new rice variety were seen to have more age compared to another group of farmers. Total years of schooling were also documented with more years with the farmer group with an adaptation of new rice variety. There was no difference derived for the data collection of both groups of farmers regarding total years of farming experience. The land with cultivation was more with the farmers with an adaptation of new rice varieties due to climate change.

Table 3. Overview of major characteristics of farming households regarding to decision on improved rice varieties adaptation

Variables	**Adoption of new rice varieties because of climate change (yes 1/no 0)**	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Age	0	110	46.99	13.929	1.328
	1	238	47.80	14.912	0.967
Total years of schooling	0	110	7.95	3.149	0.300
	1	238	8.51	3.165	0.205
Years of farming experience	0	110	15.53	11.078	1.056
	1	238	15.54	11.581	0.751
No. of household members	0	110	7.21	3.335	0.318
	1	238	6.73	2.599	0.168
Total land under cultivation (ha)	0	110	1.43	1.738	0.166
	1	238	1.48	1.524	0.099

Table 4 is indicating various institutional and farming characteristics regarding the decision on improved rice varieties. The female-headed farmers were in high numbers compared to male farmers. 79% of the farmers were registered as a member of the farmer organisations. There were differences of 46.6% in between farmers with the availability of irrigation facilities and without irrigation facilities. A total difference of 56.8% of the farmers were having various types of off-farm income compared to the farmers without off-farm incomes. 69% of the farmers documented changes in rainfall duration longer and the rest of the farmers documented changes in rainfall duration rather shorter compared to 10 years before.

Table 4. Overview of institutional and farming characteristics regarding to decision on improved rice varieties adaptation

Variables (N=348)	**Unit of measure**	**Yes/male/longer**	**No/female/shorter**
Gender of household head	male 1/ female 0	26.7%	73.3%
Member of farmer organisation	yes 1/ no 0	79%	21%
Off-farm income	yes 1/ no 0	78.4%	21.6%
Availability of irrigation system	yes 1/ no 0	26.7%	73.3%
Changes in rainfall duration	longer 1/shorter 0	69%	31%

Table 5. Factors affecting the adoption of improved rice varieties

Indicator	**Estimate**	**SE**	**Z**	**p**
Age	0.023	0.012	1.895	0.058**
Total years of schooling	0.089	0.045	1.970	0.049**
Years of farming experience	-0.002	0.015	-0.113	0.910
household size	-0.029	0.051	-0.563	0.573
Total land under cultivation (ha)	0.006	0.100	0.061	0.951
Gender of household head (male 1/ female 0):				
1 – 0	-0.972	0.324	-2.991	0.003***
Member of farmer Org. (yes 1/no 0):				
1 – 0	0.142	0.327	0.435	0.664
Off farm income (yes 1/no 0):				
1 – 0	2.105	0.333	6.321	< .001****
Availability of irrigation system (yes 1/no 0):				
1 – 0	2.554	0.515	4.958	< .001****
Changes in rainfall duration (long 1/ short 0):				
1 – 0	-0.309	0.310	-0.990	0.317

Note: Estimates represent the log odds of "Adoption of new rice varieties due to climate change = 1" vs. "Adoption of new rice varieties due to climate change = 0"

Note: ****p < 0.001, ***p < 0.01, **p < 0.05, *p < 0.1

Out of all selected variables, the gender, age, total years of education of the household head, off-farm income and availability of irrigation system were signification with regards to the adaptation of new rice variety due to climate change (Table 5). The age of the household head, total years of schooling, off-farm income and availability of irrigation system were positively significant with the adoption of improved rice variety decision, while the gender of household head was negatively significant with the decision of adoption of improved rice varieties.

6. Discussion

The change or adjustment in the crop calendar is showing the adaptability to climate change. The change in planting activities time in the crop calendar seems like a reaction to changes in climate change and mainly farming season is getting longer in duration (Maddison, 2006; Nhemachena and Hassan, 2007). After the focus group discussions in various places from the research area, we found that out of a total of five crop calendars, only one crop calendar from the Nalolo district of the crop calendars documented with longer farming season compared to 10 years earlier crop calendar but the farming season seems to be shorter due to use of fertilizer and new farming methods.

Research from Benin about changes in crop calendars, they have published from their research that the crop calendars in the same agroecological zone also had differences among them (Yegbemey et al., 2014; Agassiz, 2001). Our results for the documented all crop calendars also varied from each other regarding the agriculture activities and duration. Additionally, two crop calendars from the same districts were also documented with differences due to the availability of irrigation schemes and input support from various agencies in Sefula village compared to malengwa. There were no recommendations or suggestions from the extension office in the research area on how to adjust their crop calendar in Benin (Yegbemey et al., 2014). We had documented that out of five crop calendar locations, a total of two places did not have any extension officer and the rest of the three crop calendars were adjusted by the farmers themselves after experiencing changes in rainfall on the grounds.

The loss from production due to temperature rise and changes in rainfall can be minimized by changing planting duration with the use of a crop calendar (Wang et al., 2022). From our data collection, we found that 45% of the farmers were reported to have late onset of rainfall and they had started to do planting activities with one month delay compared to 10 years earlier in Nalolo, Limulunga and Kalabo crop calendars (figure 7, 8 & 9). The crop calendar was helping the farmers to increase yield and decrease the effect of climate variability in Vietnam (An, 2020). Our results for the crop calendar were documented to have benefits for the farmers to decrease negative effects from climate change with no effect on yield in the last 10 years.

Various agroforestry methods, changes in planting timing and change in farm activities are one of the main techniques against climate change. There are negative effects of climate change on agriculture in Zambia. The availability and support of various types of inputs are limited in Zambia for the agriculture sector (Kalantary, 2010; Stadtbäumer et al., 2022). We have found that from documented crop calendar is that there are changes in various planting methods for rice crops due to climate change. The reasons behind that are that there is no existence of transplanting method for rice farming in the study area 10 years earlier and no availability of input. Additionally, out of eight data collection locations, four of the study area farmers revealed no support or availability of input material.

The availability of climate-related information, extension officer services and access to credit makes climate adaptability easier. The majority of farmers (51.41%) indicated that temperature is increasing and rainfall is decreasing (45.1%) with the onset of the rainfall in Zambia. 13% of the farmers reported the decision to new variety adaptation in Zambia due to climate change. Female farmers were seen to adopt new varieties against male farmers (Nhemachena, 2007; Orindi and Eriksen, 2005; Seo and Mendelsohn, 2007). Our result shows that there were not much input-related support and farmers were unaware of climate change problems. 52% of the farmers reported that the change in rainfall onset with early rainfall. A total of 68.4% of the farmers were documented to adopt new rice varieties due to climate change and the majority of the household head were female farmers (73.3%). Additionally, the female-headed household head with more education, off-farm income and with the availability of irrigation systems was more likely to adapt to improved rice variety.

The adaptation level against climate change and various household variables were significant, especially for the farming experience, education of household head, group membership and farmer's perception of climate change (Musafiri et al., 2022). The result from our research shows that the out of a total of six selected variables, a total of two variables was significant with the adoption of new rice variety due to climate change. The female-dominated gender of the household head and the education of the household head were seen as significant. Additionally, females were documented to adopt more improved rice varieties due to also that the female tends to also take livelihood-related decisions in the household. There was a higher education ratio with the household head group who adopted improved rice variety due to climate change and the reason was that those with more education know more about how to work with technological gadgets for climate-related information.

The changes in temperatures and rainfall amounts are the basic indicators to see the climate change effects on a local level (Endale et al., 2021; Hanson et al., 2007). During the data collection, 52% of the farmers were supporting the early onset of the rainfall, 45% of the farmers with late onset of the rainfall and the remaining 3% of the farmers with no change in the onset of rainfall. Additionally, 69% of the farmers had documented a change in rainfall with the long season. The majority of the farmers 97.1% were documented to experienced floods during the last 10 years.

There was an increase in the cropping cycle for millet in Benin due to climate change. Various temperature-related changes were documented between 1970 and 2016 (Emediegwu et al., 2022; Seo, 2010). Our documented crop calendars explained that climate variability has an effect, but the cropping season, even after experiencing climate change, was shorter than 10 years before. The reason behind this is that the local farmers were having more support for seeds, fertilizer, and machinery from various stakeholders with improved cropping methods.

Several studies have noted shifts in sowing dates, considering the methods farmers have evolved to deal with climatic fluctuation (Owusu et al., 2021; Yegbemey et al., 2014). The crop calendar in the Nalolo district was showing a longer cropping season in the current calendar as compared to 10 years earlier. Crop calendars from Malengwa and Sefula have not experienced any changes in planting activities in their crop calendars, while crop calendars from Limulunga and Kalabo districts experienced shorter planting seasons compared to 10 years earlier. The reasons behind changes in every district in their crop calendars were the different problems faced by the farmers in different districts.

According to data for the distribution of rainfall and problems in the western province of Zambia in 2017-18, there were 11.4% of the problems with waterlogging, 38.4% with prolonged dry spells, 16.7% with floods and heavy rain and 66.3% of problems with the probability of the water risk (Adetoro et al., 2022; Matchaya et al., 2022). Our result shows that a total of 97.1% of the farmers reported to experienced floods during the last 10 years and 99.4% of the farmers experienced drought during the last 10 years as well. Additionally, 52% of the farmers reported having a change in the onset of rainfall with early rainfall, 45% with late rainfall and 3% were not experiencing any changes in the onset of rainfall. This data from our results were indicating that there are climate variability problems in the western province and mainly that changes are documented for the rainfall changes.

This study can help local government officials and NGOs (Non-governmental organisations) comprehend the actual circumstances faced by rice farmers in the western province of Zambia. With relation to numerous input and infrastructure-related initiatives, more work has to be done. Various in-depth research about climate change effects on various agriculture industries is needed to get a better understanding of ground realities for the institutions, local government organisations, NGOs, and educational and research organisations.

The cropping calendar is a constraint of this study since each local rice farmer has somewhat distinct cropping activities and durations. Future farmer development programmes that focus on women are required to diversify diverse off-farm activities and enhance local livelihood in the Western province of Zambia.

7. Conclusions

This study examines rice crop calendars, reasons for changes in crop calendars, and drivers of adoption of improved rice varieties in Western Province, Zambia. The study area is located in the Western Province of Zambia in a total of five districts. A total of 348 household heads were interviewed and six focus group discussions were held with a total of 12 key farmers in each group discussion. Data were analysed using binary logistic regression and descriptive analysis. A total of five crop calendars for the Supa variety of rice were documented in four districts. The crop calendar from Malengwa village was documented without any changes in the last 10 years, while all the other four crop calendars were documented with changes in the planting period. The reasons for the changes were different in all five crop calendars. The documented crop calendars of the farmers in Sefula village have shortened the cropping season due to the availability of an irrigation system and input supply system from various stakeholders. The crop calendars from Nalolo, Senanga and Limulunga had various limitations in terms of the availability of tools, infrastructure, irrigation, and inputs. A total of ten household, institutional and farm variables were selected to identify the drivers of the adoption of improved rice varieties. The selected variables were the age of the household head, gender, total years of education, years of farming experience, household size, membership of farmer organisation, off-farm income, changes in rainfall duration, availability of irrigation facilities and total area under cultivation. Five out of ten variables had a significant effect on the decision to adopt improved rice varieties. It can be concluded that women with an average age of 47 years, higher education, off-farm income, and irrigation facilities were more likely to adopt improved rice varieties due to climate change.

References

Ademe D, Zaitchik BF, Tesfaye K, Simane B, Alemayehu G, Adgo E. 2021. Analysis of agriculturally relevant rainfall characteristics in a tropical highland region: An agroecosystem perspective. Agricultural and Forest Meteorology **311**:108697.

Adetoro A, Ngidi M, Danso-Abbeam G, Temitope O, Ogundeji A. 2022. Impact of Irrigation on Welfare and Vulnerability to Poverty in South African Farming Households. Scientific African **16**:e01177.

Agnolucci P, Rapti C, Alexander P, De Lipsis V, Holland RA, Eigenbrod F, Ekins P. 2020. Impacts of rising temperatures and farm management practices on global yields of 18 crops. Nature Food **1**:562–571. Nature Publishing Group.

Ahmad M-D, Peña-Arancibia JL, Yu Y, Stewart JP, Podger GM, Kirby JM. 2021. Climate change and reservoir sedimentation implications for irrigated agriculture in the Indus Basin Irrigation System in Pakistan. Journal of Hydrology **603**:126967.

Aiswarya TP, Parayil C, Bonny BP, Nameer PO, Prema A, Sreya PS. 2023. Gendered vulnerabilities in small-scale agricultural households of Southern India. International Journal of Disaster Risk Reduction **84**:103475.

Akalu LS, Wang H. 2023. Does the female-headed household suffer more than the male-headed from Covid-19 impact on food security? Evidence from Ethiopia. Journal of Agriculture and Food Research **12**:100563.

Akter A, Geng X, Endelani Mwalupaso G, Lu H, Hoque F, Kiraru Ndungu M, Abbas Q. 2022. Income and yield effects of climate-smart agriculture (CSA) adoption in flood-prone areas of Bangladesh: Farm level evidence. Climate Risk Management **37**:100455.

Amfo B, Ali EB. 2020. Climate change coping and adaptation strategies: How do cocoa farmers in Ghana diversify farm income? Forest Policy and Economics **119**:102265.

Arifah, Salman D, Yassi A, Bahsar-Demmallino E. 2022. Climate change impacts and the rice farmers' responses at irrigated upstream and downstream in Indonesia. Heliyon **8**:e11923.

Asfaw A, Simane B, Hassen A, Bantider A. 2018. Variability and time series trend analysis of rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin. Weather and Climate Extremes **19**:29–41.

Assaye A, Habte E, Sakurai S, Alemu D. 2022. Impact assessment of adopting improved rice variety on farm household welfare in Ethiopia. Journal of Agriculture and Food Research **10**:100428.

Ates HC, Yilmaz H, Demircan V, Gul M, Ozturk E, Kart MÇO. 2017. How did post-2000 agricultural policy changes in Turkey affect farmers? – A focus group evaluation. Land Use Policy **69**:298–306.

Aydinalp C, Cresser MS. 2008. The Effects of Global Climate Change on Agriculture. Environ. Sci.

Azhoni A, Goyal MK. 2018. Diagnosing climate change impacts and identifying adaptation strategies by involving key stakeholder organisations and farmers in Sikkim, India: Challenges and opportunities. Science of The Total Environment **626**:468–477.

Balasha AM, Munyahali W, Kulumbu JT, Okwe AN, Fyama JNM, Lenge EK, Tambwe AN. 2023. Understanding farmers' perception of climate change and adaptation practices in the marshlands of South Kivu, Democratic Republic of Congo. Climate Risk Management **39**:100469.

Blekking J, Gatti N, Waldman K, Evans T, Baylis K. 2021. The benefits and limitations of agricultural input cooperatives in Zambia. World Development **146**:105616.

Blom PS. 1984. Agricultural development in the Western Province of Zambia with special reference to rice cultivation. Netherlands Journal of Agricultural Science **32**:167–174.

Chepkoech W, Mungai NW, Stöber S, Lotze-Campen H. 2020. Understanding adaptive capacity of smallholder African indigenous vegetable farmers to climate change in Kenya. Climate Risk Management **27**:100204.

Chizhuka F. 2009. Study on the rice value chain in Zambia. CUTS Africa Resource Centre, Lusaka. Available from https://scholar.google.com/scholar_lookup?title=study+on+the+rice+value-chain+in+Zambia&author=Chizhuka%2C+Felix.&publication_year=2009.

Colucci A, Pesaro G. 2022. Introduction: Resilience, climate change, and sustainability in practice from approaches to action.

Darnhofer I, Gibbon D, Dedieu B. 2012. Farming Systems Research: an approach to inquiry. Pages 3–31 in Darnhofer I, Gibbon D, Dedieu B, editors. Farming Systems Research into the 21st Century: The New Dynamic. Springer Netherlands, Dordrecht. Available from https://doi.org/10.1007/978-94-007-4503-2_1.

Das S, Majumder S, Sharma KK. 2023. Assessing integrated agricultural livelihood vulnerability to climate change in the coastal region of West Bengal: Implication for spatial adaptation planning. Regional Studies in Marine Science **57**:102748.

Dawadi B, Shrestha A, Acharya RH, Dhital YP, Devkota R. 2022. Impact of climate change on agricultural production: A case of Rasuwa District, Nepal. Regional Sustainability **3**:122–132.

Dono G, Cortignani R, Doro L, Giraldo L, Ledda L, Pasqui M, Roggero PP. 2013. Adapting to uncertainty associated with short-term climate variability changes in irrigated Mediterranean farming systems. Agricultural Systems **117**:1–12.

Egerer S, Puente AF, Peichl M, Rakovec O, Samaniego L, Schneider UA. 2023. Limited potential of irrigation to prevent potato yield losses in Germany under climate change. Agricultural Systems **207**:103633.

Fant C, Gebretsadik Y, McCluskey A, Strzepek K. 2015. An uncertainty approach to the assessment of climate change impacts on the Zambezi River Basin. Climatic Change **130**:35–48.

FAO. (n.d.). FAOSTAT: Rice Cultivation. Available from https://www.fao.org/faostat/en/#data/GR.

Fofana M, Futakuchi K, Manful JT, Yaou IB, Dossou J, Bleoussi RTM. 2011. Rice grain quality: A comparison of imported varieties, local varieties with new varieties adopted in Benin. Food Control **22**:1821–1825.

Gassama BC, Ndiaye ML, Lecor PA, Diop S, Toure B. 2021. Mandibular bone changes and dental status: A radiomorphometric study by the mandibular cortical index on a Senegalese female population aged 40 years and over. Advances in Oral and Maxillofacial Surgery **4**:100200.

Grusson Y, Wesström I, Joel A. 2021. Impact of climate change on Swedish agriculture: Growing season rain deficit and irrigation need. Agricultural Water Management **251**:106858.

Gunderson L, Light SS. 2006. Adaptive management and adaptive governance in the everglades ecosystem. Policy Sciences **39**:323–334.

Haddad BM. 2005. Ranking the adaptive capacity of nations to climate change when socio-political goals are explicit. Global Environmental Change **15**:165–176.

Hanson CE et al. 2007. Modelling the impact of climate extremes: an overview of the MICE project. Climatic Change **81**:163–177.

Hay JE, Easterling D, Ebi KL, Kitoh A, Parry M. 2016. Introduction to the special issue: Observed and projected changes in weather and climate extremes. Weather and Climate Extremes **11**:1–3.

Howden SM, Soussana J-F, Tubiello FN, Chhetri N, Dunlop M, Meinke H. 2007. Adapting agriculture to climate change. Proceedings of the National Academy of Sciences **104**:19691–19696. Proceedings of the National Academy of Sciences.

Jayasiri MMJGCN, Dayawansa NDK, Yadav S. 2023. Assessing the roles of farmer organizations for effective agricultural water management in Sri Lanka. Agricultural Systems **205**:103587.

Jin S, Mansaray B, Jin X, Li H. 2020. Farmers' preferences for attributes of rice varieties in Sierra Leone. Food Security: The Science, Sociology and Economics of Food Production and Access to Food **12**:1185–1197. Springer & The International Society for Plant Pathology.

Karienye D, Macharia J. 2020. Adaptive Capacity to Mitigate Climate Variability and Food Insecurity of Rural Communities Along River Tana Basin, Kenya. Pages 1–12 in Leal Filho W, Oguge N, Ayal D, Adelake L, da Silva I, editors. African Handbook of Climate Change Adaptation. Springer International Publishing, Cham. Available from https://doi.org/10.1007/978-3-030-42091-8_57-1.

Kazungu M, Ferrer Velasco R, Zhunusova E, Lippe M, Kabwe G, Gumbo DJ, Günter S. 2021. Effects of household-level attributes and agricultural land-use on deforestation patterns along a forest transition gradient in the Miombo landscapes, Zambia. Ecological Economics **186**:107070.

Kazungu M, Zhunusova E, Yang AL, Kabwe G, Gumbo DJ, Günter S. 2020. Forest use strategies and their determinants among rural households in the Miombo woodlands of the Copperbelt Province, Zambia. Forest Policy and Economics **111**:102078.

Khanal U, Wilson C. 2019. Derivation of a climate change adaptation index and assessing determinants and barriers to adaptation among farming households in Nepal. Environmental Science & Policy **101**:156–165.

Kilimani N, Buyinza F, Guloba M. 2022. Crop commercialization and nutrient intake among farming households in Uganda. Food Policy **113**:102328.

Kolapo A, Kolapo AJ. 2023. Implementation of conservation agricultural practices as an effective response to mitigate climate change impact and boost crop productivity in Nigeria. Journal of Agriculture and Food Research **12**:100557.

Kruseman G, Bairagi S, Komarek AM, Molero Milan A, Nedumaran S, Petsakos A, Prager S, Yigezu YA. 2020. CGIAR modelling approaches for resource-constrained scenarios: II. Models for analyzing socioeconomic factors to improve policy recommendations. Crop Science **60**:568–581.

Kuntashula E, Mwelwa-Zgambo L. 2022. Impact of the farmer input support policy on agricultural production diversity and dietary diversity in Zambia. Food Policy **113**:102329.

Le TQA, Shimamura Y, Yamada H. 2020. Information acquisition and the adoption of a new rice variety towards the development of sustainable agriculture in rural villages in Central Vietnam. World Development Perspectives **20**. Elsevier. Available from https://econpapers.repec.org/article/eeewodepe/v_3a20_3ay_3a2020_3ai_3ac_3as2452292920300825.htm.

Long SP, Ainsworth EA, Leakey ADB, Nösberger J, Ort DR. 2006. Food for Thought: Lower-Than-Expected Crop Yield Stimulation with Rising CO2 Concentrations. Science **312**:1918–1921. American Association for the Advancement of Science.

Lu Y, Chen M, Weng Z. 2022. Drivers of the peasant households' part-time farming behavior in China. Journal of Rural Studies **93**:112–121.

Luyten A, Winkler MS, Ammann P, Dietler D. 2023. Health impact studies of climate change adaptation and mitigation measures – A scoping review. The Journal of Climate Change and Health **9**:100186.

Maddison D. 2007. The Perception of and Adaptation to Climate Change in Africa. The World Bank, Policy Research Working Paper Series.

Makungwe M, Chabala LM, Van Dijk M, Chishala BH, Lark RM. 2021. Assessing land suitability for rainfed paddy rice production in Zambia. Geoderma Regional **27**:e00438.

Mapedza E, Rashirayi T, Xueliang C, Haile AT, van Koppen B, Ndiyoi M, Sellamuttu SS. 2022. Chapter 11 - Indigenous Knowledge Systems for the management of the Barotse Flood Plain in Zambia and their implications for policy and practice in the developing world. Pages 209–225 in Sioui M, editor. Current Directions in Water Scarcity Research. Elsevier. Available from https://www.sciencedirect.com/science/article/pii/B978012824538500011X.

Markelova H, Meinzen-Dick R, Hellin J, Dohrn S. 2009. Collective action for smallholder market access. Food Policy **34**:1–7.

Mason NM, Ricker-Gilbert J. 2013. Disrupting Demand for Commercial Seed: Input Subsidies in Malawi and Zambia. World Development **45**:75–91.

Matchaya GC, Tadesse G, Kuteya AN. 2022. Rainfall shocks and crop productivity in Zambia: Implication for agricultural water risk management. Agricultural Water Management **269**:107648.

Mccarthy J, Canziani O, Leary N, Dokken D, White K. 2001. Climate Change 2001: Impacts, Adaptation, and Vulnerability. Cambridge University Press, USA.

Mesfin AH, Girma F. 2022. Understanding sorghum farming system and its implication for future research strategies in humid agro-ecologies in Western Ethiopia. Journal of Agriculture and Food Research **10**:100456.

Ministry of Agriculture and Cooperatives (MACO). 2011. Zambia National Rice Development Strategy (2011-2015). Page 29. Zambia. Available from https://riceforafrica.net/wp-content/uploads/2021/09/zambia_nrds1-1.pdf.

Minoli S, Jägermeyr J, Asseng S, Urfels A, Müller C. 2022. Global crop yields can be lifted by timely adaptation of growing periods to climate change. Nature Communications **13**:7079. Nature Publishing Group.

Moritz C, Agudo R. 2013. The Future of Species Under Climate Change: Resilience or Decline? Science **341**:504–508. American Association for the Advancement of Science.

Mulanda SM, Punt C. 2021. Characteristics of Zambia's agricultural sector and the role for agricultural policy: Insights from CGE modelling. Structural Change and Economic Dynamics **58**:300–312.

Murin I, Marková I, Zelený J, Jaďuďová J. 2015. Green Marketing as a Tool Influencing Consumerś Behavior: Slovak Case Study of Regional Mark Preference. Procedia Economics and Finance **34**:260–267.

Musafiri CM, Kiboi M, Macharia J, Ng'etich OK, Kosgei DK, Mulianga B, Okoti M, Ngetich FK. 2022. Smallholders' adaptation to climate change in Western Kenya: Considering socioeconomic, institutional and biophysical determinants. Environmental Challenges **7**:100489.

Mutale, C., Lungu, D.M, Muuka, F. P. (n.d.). Adaptability of rice cultivars to different ecologies in western province of Zambia | RUFORUM Institutional Repository. Available from http://repository.ruforum.org/documents/adaptability-rice-cultivars-different-ecologies-western-province-zambia-0.

Naderifar M, Goli H, Ghaljaie F. 2017. Snowball Sampling: A Purposeful Method of Sampling in Qualitative Research. Strides in Development of Medical Education **14**. Kerman University of Medical Sciences. Available from https://sdme.kmu.ac.ir/article_90598.html.

Najeeb S, Sheikh FA, Parray GA, Shikari AB, zaffar G, Kashyp SC, Ganie MA, Shah AB. 2018. Farmers' participatory selection of new rice varieties to boost production under temperate agro-ecosystems. Journal of Integrative Agriculture **17**:1307–1314.

Naz F, Doneys P. 2022. Gender-based differences in access to and use of loans from rural credit programs for flood adaptation in the farming-dependent char communities of Bangladesh. Women's Studies International Forum **95**:102651.

Nelson DR, Adger WN, Brown K. 2007. Adaptation to Environmental Change: Contributions of a Resilience Framework. Annual Review of Environment and Resources **32**:395–419.

Nelson GC et al. 2009. Climate change: Impact on agriculture and costs of adaptation. International Food Policy Research Institute (IFPRI). Available from https://ebrary.ifpri.org/digital/collection/p15738coll2/id/130648.

Ngoma H, Lupiya P, Kabisa M, Hartley F. 2021a. Impacts of climate change on agriculture and household welfare in Zambia: an economy-wide analysis. Climatic Change **167**:55.

Ngoma H, Pelletier J, Mulenga BP, Subakanya M. 2021b. Climate-smart agriculture, cropland expansion and deforestation in Zambia: Linkages, processes and drivers. Land Use Policy **107**:105482.

Nhemachena C, Hassan R. 2007. Micro-Level Analysis of Farmers' Adaptation to Climate Change in Southern Africa.

Nkolola N, Libanda J, Nyasa L. 2016. Economic Significance of Agriculture for Poverty Reduction: The Case of Zambia. Archives of Current Research International **5**.

Ojo TO, Baiyegunhi LJS. 2021. Climate change perception and its impact on net farm income of smallholder rice farmers in South-West, Nigeria. Journal of Cleaner Production **310**:127373.

Olajide OA, Adeola W, Doppler, Adeola, Doppler W. 2013. Perspectives on Food Security: A Gender based Comparison of Rural Households in South East Nigeria Perspectives on Food Security A Gender based Comparison of Rural Households in South East Nigeria Perspectives on Food Security: A Gender based Comparison of Rural Households in South East Nigeria.

Omodara OD, Ige OA, Oluwasola O, Oyebanji AT, Afape OO. 2023. Factors influencing cassava farmers' choice of climate change adaption practices and its effect on cassava productivity in Nigeria. Heliyon **9**:e14563.

Orindi VA, Eriksen S. 2005, January 1. Mainstreaming Adaptation to Climate Change in the Development Process in Uganda. African Centre for Technology Studies (ACTS). Available from https://www.africaportal.org/publications/mainstreaming-adaptation-to-climate-change-in-the-development-process-in-uganda/.

Owusu V, Ma W, Emuah D, Renwick A. 2021. Perceptions and vulnerability of farming households to climate change in three agro-ecological zones of Ghana. Journal of Cleaner Production **293**:126154.

Padhan N, Madheswaran S. 2022. Effectiveness of post-disaster coping strategies among the farming households in the coastal districts of Odisha, India. Natural Hazards Research DOI: 10.1016/j.nhres.2022.12.006. Available from https://www.sciencedirect.com/science/article/pii/S2666592122000658.

Paparrizos S, Baggen Y, van Dalen M, Ploum L, Ludwig F. 2023. Commercialization pathways for climate services for smallholder farmers in the global South. Climate Services **30**:100354.

Park S-J, Yi Y. 2023. Decomposing main effects in moderated regression models. Journal of Business Research **157**:113577.

Pasqualino M, Kennedy G, Nowak V. 2015. Market surveys: Barotse floodplain system. Biodiversity International. CGIAR. Available from http://www.bioversityinternational.org/e-library/publications/detail/market-surveys-barotse-floodplain-system/.

Phiri J, Malec K, Majune SK, Appiah-Kubi SNK, Gebeltová Z, Maitah M, Maitah K, Abdullahi KT. 2020. Agriculture as a Determinant of Zambian Economic Sustainability. Sustainability **12**:4559. Multidisciplinary Digital Publishing Institute.

Rajaratnam S, Cole SM, Fox KM, Dierksmeier B, Puskur R, Zulu F, Teoh SJ, Situmo J. 2015. Social and gender analysis report: Barotse Floodplain, Western Province,Zambia. Monographs. The WorldFish Center. Available from https://econpapers.repec.org/bookchap/wfiwfbook/40567.htm.

Reza MS, Sabau G. 2022. Impact of climate change on crop production and food security in Newfoundland and Labrador, Canada. Journal of Agriculture and Food Research **10**:100405.

Salam MA, Sarker MNI. 2023. Impact of hybrid variety adoption on the performance of rice farms in Bangladesh: A propensity score matching approach. World Development Sustainability **2**:100042.

Salami A, Kamara A, Brixiova Z. 2019. Smallholder Agriculture in East Africa: Trends, Constraints and Opportunities. Page 52 African Development Bank - Building today, a better Africa tomorrow. African Development Bank Group, Ghana. Available from https://www.afdb.org/en/documents/document/working-paper-105-smallholder-agriculture-in-east-africa-trends-constraints-and-opportunities-20266.

Samaranayake MDW, Abeysekera WKSM, Hewajulige IGN, Somasiri HPPS, Mahanama KRR, Senanayake DMJB, Premakumara GAS. 2022. Fatty acid profiles of selected traditional and new improved rice varieties of Sri Lanka. Journal of Food Composition and Analysis **112**:104686.

Seo SN. 2010. Is an integrated farm more resilient against climate change? A micro-econometric analysis of portfolio diversification in African agriculture. Food Policy **35**:32–40.

Seo SN, Mendelsohn R. 2007. Climate Change Adaptation in Africa : A Microeconomic Analysis of Livestock ChoiceDOI: 10.1596/1813-9450-4277. World Bank, Washington, DC. Available from http://hdl.handle.net/10986/7462.

Seppelt R, Klotz S, Peiter E, Volk M. 2022. Agriculture and food security under a changing climate: An underestimated challenge. iScience **25**:105551.

Sibhatu KT, Arslan A, Zucchini E. 2022. The effect of agricultural programs on dietary diversity and food security: Insights from the smallholder productivity promotion program in Zambia. Food Policy **113**:102268.

Siliphouthone I, Hanboonsong Y, Taweekul K. 2012. Assessment of farmer's satisfaction and preference using improved rice varieties in the southern Lao PDR. International Journal of Environmental and Rural Development **3**:72–77.

Singh RK, Joshi PK, Sinha VSP, Kumar M. 2022. Indicator based assessment of food security in SAARC nations under the influence of climate change scenarios. Future Foods **5**:100122.

Somanje AN, Crespo O, Zinyengere N. 2017. Chapter 5 - Conservation Agriculture Among Farmers in Kalomo, Zambia: Potential for Productivity Under Climate Change. Pages 77–99 in Zinyengere N, Theodory TF, Gebreyes M, Speranza CI, editors. Beyond Agricultural Impacts. Academic Press. Available from https://www.sciencedirect.com/science/article/pii/B9780128126240000053.

Stadtbäumer C, Ruesink B, Gronau S. 2022. Climate change scenarios in Zambia: modeling farmers' adaptation. Agriculture & Food Security **11**:52.

Teklu A, Simane B, Bezabih M. 2023. Multiple adoption of climate-smart agriculture innovation for agricultural sustainability: Empirical evidence from the Upper Blue Nile Highlands of Ethiopia. Climate Risk Management **39**:100477.

Thornton PK, Jones PG, Alagarswamy G, Andresen J, Herrero M. 2010. Adapting to climate change: Agricultural system and household impacts in East Africa. Agricultural Systems **103**:73–82.

Tran VT, An-Vo D-A, Mushtaq S, Cockfield G. 2022. Nuanced assessment of livelihood resilience through the intersectional lens of gender and ethnicity: Evidence from small-scale farming communities in the upland regions of Vietnam. Journal of Rural Studies **92**:68–78.

Wang X, Folberth C, Skalsky R, Wang S, Chen B, Liu Y, Chen J, Balkovic J. 2022. Crop calendar optimization for climate change adaptation in rice-based multiple cropping systems of India and Bangladesh. Agricultural and Forest Meteorology **315**:108830.

Western Provincial Administration Zambia. (n.d.). About Western Province – Western Province. Available from https://www.wes.gov.zm/?page_id=1192.

Nkomoki, W., Bavorová, M., Banout, J., 2018. Adoption of sustainable agricultural practices and food security threats: Effects of land tenure in Zambia. Land use policy 78, 532–538. https://doi.org/10.1016/j.landusepol.2018.07.021

Wineman A, Crawford EW. 2017. Climate change and crop choice in Zambia: A mathematical programming approach. NJAS: Wageningen Journal of Life Sciences **81**:19–31. Taylor & Francis.

Yan Z, Zhang X, Rashid MA, Li H, Jing H, Hochman Z. 2020. Assessment of the sustainability of different cropping systems under three irrigation strategies in the North China Plain under climate change. Agricultural Systems **178**:102745.

Yang H, Ranjitkar S, Zhai D, Zhong M, Goldberg SD, Salim MA, Wang Z, Jiang Y, Xu J. 2019. Role of Traditional Ecological Knowledge and Seasonal Calendars in the Context of Climate Change: A Case Study from China. Sustainability **11**:3243. Multidisciplinary Digital Publishing Institute.

Yegbemey RN, Kabir H, Awoye OHR, Yabi JA, Paraïso AA. 2014. Managing the agricultural calendar as coping mechanism to climate variability: A case study of maize farming in northern Benin, West Africa. Climate Risk Management **3**:13–23.

Yue X, Zhang T, Li Y. 2023. Effects of rainfall regime during the growing season on the annual plant communities in semiarid sandy land, northeast China. Global Ecology and Conservation **43**:e02456.

Zambian Ministry of National Development Planning. (n.d.). Zambia: On the Cusp of a Promising Future. Available from https://www.prb.org/resources/zambia-on-the-cusp-of-a-promising-future/

Appendix

Appendix 1. Focus group discussion questionnaire

Focus Group Number:
Names of Respondents:
Phone Numbers:
District:
Village:

PART I – RICE PRODUCTION

1) **Would you please specify your rice production system?**

___

2)

Name of varieties	Improved seed (1) Traditional seed (2)	Farm location (upland, lower land, scheme irrigation)	Approximate yield per hectare	Main attributes of the preferred rice varieties (consumers)	Cultivating more or fewer varieties from the past (+, – or =)	Advantages of rice varieties	Barriers to the rice varieties
e.g., Africa Rice	2	Lowland	2 Tons	Aroma	–	Drought resistant	Prone to pests

3) **What are the methods of rice planting?**

___

4) **What type of machinery/equipment do you use to cultivate your land?**

___

5) **What are some of the rice cropping systems you use(d)? e.g., rice-wheat system, rice only, …**

6) **What type of hazards affects the production of rice? Please may you rate the effect of the risk?**

Hazards Affecting Rice Production	Lowest	Low	Moderate	High	Highest

7) **How do you perceive the following changes in the past 5 years?**

a) The onset of rainfall

□ No change □ Early □ Late

b) Distribution of rainfall

□ No change □ Poor □ Good

c) Amount of rainfall

□ No change □ Decreased □ Increased

d) Rainfall season (long, short)

□ Long □ Short

8) **What are some of the activities for adapting to climate change promoted at the community level? How would you rate the acceptance of the activities?**

Activities	Lowest	Low	Moderate	High	Highest

9) **What are some of the effects of climate variability on rice cultivation? Please rate the effects from 1 (Less) – 5 (more).**

Effects	1	2	3	4	5

10) Have you adopted new rice varieties because of climate variability? If yes, may you mention it?

____

____

a. From where do farmers access your rice seeds? ______________________

11) What are some of the off-farm income activities? ______________________

____

12) How do farmers acquire information about rice production? How do you rate the delivery of the information? Scale 1- Poor to 5-Excellent.

Information sources	1	2	3	4	5

13) What are some of the challenges for information delivery to rice farmers? Please rate these on a scale of 1-Least to 5- Most.

Challenges	1	2	3	4	5

14) What prominent institutions provide information about climate change and environmental data?

15) Crop Calendar – 10 years Before and Recent calendar

Rice Variety	Activities	January	February	March	April	May	June	July	August	September	October	November	December

Appendix 2. Household survey questionnaire

SECTION B: HOUSEHOLDS

Name of Respondent:
Phone Number:
District:
Village:

1) **Age** _________________

2) **Gender**
- □ Male
- □ Female

3) **Marital status**

- □Single
- □Married
- □Divorced
- □Separated
- □Widow(er)

4) **Highest level of completed schooling**
- □Illiterate
- □Primary school
- □Secondary school
- □College/University degree

5) **How many years of schooling do you have?** _________________

6) **Do you have any farming knowledge?**

□ Yes □ No

7) **If yes, how many years have you been involved in farming?**

8) **How many people are living in your household?**

9) **If yes, which livestock?** _________________

PART II – RICE PRODUCTION

10) **How many hectares are under cultivation?** _________________

11) Please specify your rice production system

□ Rainfed upland □ Irrigated lowland
□ Rainfed lowland

12) What are some of the rice cropping systems?

□ Rice – Wheat □ Rice only
□ Rice – Maize □ Other (Specify) ________________

13) What type of machinery/ equipment did you use to cultivate your land in the past farming season?

□ Hand hoes □ Tractor
□ Draught power (oxen plough) □ Other (Specify)

14) What methods of rice planting did you use in the past 3 growing season?

□ Broadcasting □ Transplanting
□ Other (Specify) _______________

15) Do you have control of the water (irrigation system)?

□ Yes □ No

PART III – INPUT AND LABOUR COSTS AND MARKETS

16) What type of rice seed did you use in the previous growing season?

□ Improved seed □ Traditional seed

Is it recycled seed?

□ Yes □ No

17) Have you experienced floods during the last ten years?

□ Yes □ No

18) Have you experienced drought during the last ten years?

□ Yes □ No

19) How do you perceive the following changes?

a) The onset of rainfall

□ No change □ Early

□ Late

b) Distribution of rainfall

□ No change □ Poor

□ Good

c) Amount of rainfall

□ No change □

Decreased

□ Increased

d) Rainfall season (long, short)
□ Long □ Short

20) What are some of the effects of climate variability on rice cultivation? Please rate the outcomes from 1 (Less) – 5 (more).

Effects	1	2	3	4	5
Low yields					
Crop loss					
Soil degradation					

21) Have you adopted new rice varieties because of climate variability?
□ Yes □ No

22) Where do you access your rice seeds?
□ FISP – Ministry of Agriculture □ Market – Agro dealers

□ Food Security Package □ Recycled □ NGOs

PART IV – INFORMATION SOURCES

23) Did you have any access to credit facilities in the past season?
□ Yes □ No

24) Do you have an off-farm income?
□ Yes □ No

25) Are you a member of a farmer's organisation?
□ Yes □ No

26) Did you have access to the provision of input subsidies?
□ Yes □ No

a. If yes, from where?
□ Government support □ NGO □ Other

____

_____

27) How do you acquire information about rice production?

Source	Yes/ No	Please rate the quality	Usage (Never, Occasionally,

		(Poor, Fair, Good, Very Good, Excellent)	Moderately, Frequently, Very Frequently)
Extension officers			
Farmer to farmer			
Radio			
Television			
Internet			
Agricultural newspaper			

28) Do you receive information about climate change?

□ Yes □ No

29) From where do you get information on climate related impacts and consequences?

□ Meteorological Department □ Extension

□ NGOs □ others _________