Bindura University of Science Education

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CLIMATE SMART IRRIGATION AND HOUSEHOLD FOOD SECURITY AMONG SMALLHOLDER FARMERS IN THE INSUKAMINI IRRIGATION SCHEME,GWERU

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS OF THE BACHELOR OF SCIENCE HONOURS DEGREE IN AGRICULTURAL ECONOMICS AND MANAGEMENT

BY

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The undersigned certify that they have supervised and recommended to Bindura University of Science Education for acceptance of the dissertation entitled 'Climate-smart Irrigation and Household Food Security Among Smallholder Farmers in the Insukamini Irrigation Scheme, Gweru'

Submitted in partial fulfillment of the Bachelor of Agricultural Science Honours Degree in Agricultural Economics and Management.

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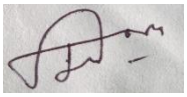
Signed: 

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DECLARATION

I, Tadiwa Rukudzo Mazuru, hereby affirm that this dissertation entitled *"Climate-Smart Irrigation and Household Food Security Among Smallholder Farmers in the Insukamini Irrigation Scheme, Gweru*" is the result of my own independent research and has not been submitted to any other institution for the award of a degree or any other qualification. While I benefited from the guidance, advice, and support of my supervisor, Mr Govere, and other academic staff throughout the research process, the ideas, analysis, and presentation contained in this dissertation are solely my responsibility. Furthermore, I have adhered to the academic regulations and ethical standards of Bindura University of Science Education concerning plagiarism and academic honesty, and all sources consulted have been appropriately acknowledged through proper citation and referencing.

Author: Implementing climate-smart irrigation is one of the key solutions to boost food and nutrition security of smallholder farmers living in semi-arid areas of Zimbabwe who are severely affected by climate change, droughts, and irregular rainfall. The paper examined the effect of climate-smart irrigation on food security at the household level, dietary diversity, and challenges of implementation at the Insukamini Irrigation Scheme, Gweru District, Zimbabwe. Using a mixed-methods approach, data were collected from 56 households through questionnaires, interviews, focus group discussions, case studies, and field observations. Quantitative data were analysed using descriptive and inferential statistics, while qualitative data were analysed thematically. Findings showed that climate-smart irrigation significantly improved household food security and dietary diversity. Beneficiary irrigators recorded the highest HDDS (7.54) compared to beneficiary non-irrigators (6.67) and non-beneficiaries (6.31). They also had the highest proportion of acceptable FCS (94.4%) and food-secure households (87.0%), while food insecurity was lowest (0.9%). Women's dietary diversity was also highest among beneficiary irrigators, with an MDDW score of 5.49, compared to 4.53 and 3.82 for beneficiary non-irrigators and non-beneficiaries, respectively. Furthermore, 70.9% of women in beneficiary irrigator households were food secure, compared to 47.0% and 27.7% in the other groups. Climate-smart irrigation contributed to raising the incomes of the families involved, with beneficiary irrigators having an average annual income of US$1,071.77, whereas beneficiary non-irrigators and non-beneficiaries earned US$565.94 and US$367.01, respectively. Even so,

several implementation challenges including power outages, lack of proper infrastructure, limited credit access, infrastructure shortcomings, poor marketing, middlemen exploitation, and input supply delays were encountered. As the research, climate-smart irrigation has a powerful impact on increasing food security, promoting dietary diversity, and generating more household income for the smallholder farmers. The research paper further suggests a greater focus on irrigation infrastructure, solar-powered technologies, extension services, finance, and market development.

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DEDICATION

I dedicate this research to my dear mother, Ms. Prisilla Mapira, who through her constant love prayers encouragement, and support has been the source of my strength in all my academic efforts. Her confidence in me has motivated me to keep going and accomplish my dreams.

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ABSTRACT

Implementing climate-smart irrigation is one of the key solutions to boost food and nutrition security of smallholder farmers living in semi-arid areas of Zimbabwe who are severely affected by climate change, droughts, and irregular rainfall. The paper examined the effect of climate-smart irrigation on food security at the household level, dietary diversity, and challenges of implementation at the Insukamini Irrigation Scheme, Gweru District, Zimbabwe. Using a mixed-methods approach, data were collected from 56 households through questionnaires, interviews, focus group discussions, case studies, and field observations. Quantitative data were analysed using descriptive and inferential statistics, while qualitative data were analysed thematically.

Findings showed that climate-smart irrigation significantly improved household food security and dietary diversity. Beneficiary irrigators recorded the highest HDDS (7.54) compared to beneficiary non-irrigators (6.67) and non-beneficiaries (6.31). They also had the highest proportion of acceptable FCS (94.4%) and food-secure households (87.0%), while food insecurity was lowest (0.9%). Women's dietary diversity was also highest among beneficiary irrigators, with an MDDW score of 5.49, compared to 4.53 and 3.82 for beneficiary non-irrigators and non-beneficiaries, respectively. Furthermore, 70.9% of women in beneficiary irrigator households were food secure, compared to 47.0% and 27.7% in the other groups.

Climate-smart irrigation contributed to raising the incomes of the families involved, with beneficiary irrigators having an average annual income of US$1,071.77, whereas beneficiary non-irrigators and non-beneficiaries earned US$565.94 and US$367.01, respectively. Even so, several implementation challenges including power outages, lack of proper infrastructure, limited credit access, infrastructure shortcomings, poor marketing, middlemen exploitation, and input supply delays were encountered.

As the research, climate-smart irrigation has a powerful impact on increasing food security, promoting dietary diversity, and generating more household income for the smallholder farmers. The research paper further suggests a greater focus on irrigation infrastructure, solar-powered technologies, extension services, finance, and market development.

Keywords: Climate-smart irrigation, food security, dietary diversity, income, smallholder farmers, Zimbabwe.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA: Analysis of Variance

CSI: Climate-Smart Irrigation

CSA: Climate-Smart Agriculture

DD: Dietary Diversity

FAO: Food and Agriculture Organization

FCS: Food Consumption Score

FGD: Focus Group Discussion

GAP: Good Agricultural Practices

GMB: Grain Marketing Board

HDDS: Household Dietary Diversity Score

HSD: Honestly Significant Difference (Tukey Test)

IFAD: International Fund for Agricultural Development

IMC: Irrigation Management Committee

KII: Key Informant Interview

MDD-W: Minimum Dietary Diversity for Women

NRM: Natural Resource Management

SPSS: Statistical Package for the Social Sciences

IDP: Irrigation development project

UNICEF: United Nations Children's Fund

WFP: World Food Programme

WHO: World Health Organization

ZIMSTAT: Zimbabwe National Statistics Agency

ZIMVAC: Zimbabwe Vulnerability Assessment Committe

CHAPTER 1

1.1 INTRODUCTION

1.2 Background of study

Generally speaking, the farming sector is a pillar of Zimbabwe's economy as it offers the country with about 18% of its annual GDP and also, more than 70% of the people rely on it for their survival (FAO, 2024; World Bank, 2025). Why reason agriculture is so important is that it acts as a source of food, poverty reduction, employment generation as well as improvement of the economic status of the rural communities. Though, agricultural production in Zimbabwe has suffered greatly from climate change exposing farmers mostly to semi-arid regions where rainfall pattern is highly variable with occurrences of droughts and the temperature rise setting in which has been the contributing factor for the decline of rain-fed agriculture Because of this lowering the agricultural productivity (World Bank, 2025).

As the nation is using mainly rain-fed farming, the rural people here are really exposed to the changes in climate. Agro-Ecological Regions IV and V, which are characterized by very low rainfall, are mainly experiencing droughts and dry spells as the biggest problems (FAO, 2024). So, irrigation development was recognized as the right solution not only for the improvement of farm yields but also for the strengthening of climate resilience plus food and nutrition security. The country is believed to have the ability to irrigate about 366,000 hectares of land But, to date, less than 124,000 hectares are under irrigation (FAO, 2024).

The Government of Zimbabwe in partnership with the International Fund for Agricultural Development and the OPEC Fund for International Development took an initiative of establishing the Irrigation Development Project (IDP) as a way of mitigating water shortage and climate change issue. The aim of the project was to rehabilitate irrigation schemes, promote water conservation and introduce climate-smart agricultural practices among the household farmers (IFAD, 2025).

One of the schemes which were benefitted by the project is Insukamini Irrigation Scheme located in Gweru District of the Midlands Province. Insukamini is located in agro-ecological region V where the amount of rainfall experienced in the region is low and irregular hence the need for irrigation. Previously, the total number of acres in the scheme was 32 but since its revitalization by IDP, the irrigated acreage has been increased up to 38.3 hectares. Some of

the improvements in the schemes included the introduction of new technologies such as hydrogel, which helps in moisture retention, and pfumvudza conservation farming practice.

These interventions included measures meant to improve the efficiency of agricultural activities, increase resilience to climate change, and promote household nutrition. Recent results of the impact assessments found out that households at Insukamini Irrigation Scheme have achieved the highest Household Dietary Diversity Score (HDDS) of 7.31, pointing to an existing positive correlation between improved irrigation methods and household dietary diversity (IFAD, 2025). Although progress has been made in improving irrigation practices in recent years, there still remain a number of barriers including climate variations, water shortage, and insufficient funding that limit the sustainability of irrigation schemes. Thus, it would be necessary to evaluate how far irrigation practices contribute to the improvement of food and nutrition security among smallholder farmers at Insukamini Irrigation Scheme.

Statement of the Problem

Vulnerable smallholder farmers who are located in semi-arid regions of Gweru District suffer from food shortages due to the worsening effects of climate change and other social and economic factors (Moyo & Nyathi, 2021; FAO, 2023). Though Insukamini Irrigation Scheme has been upgraded to increasea its agricultural potential, there is little evidence on how irrigation practices like the use of hydrogel and conservation farming contribute to the attainment of household food security (Chikowo et al. 2018; Zvigadza et al. 2020). Though that technological interventions in irrigation infrastructure alone do not guarantee food security if they are not supported by good agronomic practices (Nkala et al. 2011).

Although infrastructure for irrigation has been improved, farmers in Insukamini still suffer from exploitation by middlemen (makoronyera), who manipulate prices in ways that reduce any income gained from increased yields (Mkodzongi & Lawrence, 2019). In addition, the packhouse in the area has not yet been completed, leaving it short of important amenities needed to tap into lucrative export markets (Government of Zimbabwe, 2022). Even when it comes to irrigation farmers who usually achieve more than those relying on rainwater, the minimum score of dietary diversity for women falls short of the target, at 3.93 compared to the minimum benchmark of 5 (FAO & WHO, 2021; Madzivhandila & Nhemachena, 2019).

1.3 Research Questions

1.How do climate-smart irrigation practices affect household food security?

2.What relationship exists between irrigation practices and household dietary diversity?

3.What challenges are faced by smallholder farmers in implementing climate-smart irrigation systems?

1.4 Research Objectives

Main Objective: To assess the impact of climate-smart irrigation practices on household food security among smallholder farmers in the semi-arid districts of Insukamini in Gweru.

1.5 Specific Objectives

1.To examine the effect of climate-smart irrigation practices on household food security.

2.To compare the relationship between irrigation practices and household dietary diversity.

3.To identify the major challenges affecting the implementation of climate-smart irrigation systems among smallholder farmers.

1.6 Research Hypotheses

1. **H_1:** There is a significant positive relationship between climate-smart irrigation practices and household food security.

2**.** **H_2**: Farmers using climate-smart irrigation practices have significantly higher dietary diversity scores than those not using them.

1.7 Significance of the Study/ Justification

The study is aimed at being very helpful mainly for rural development experts, policymakers and agricultural extension officers. By evaluating the Insukamini Irrigation Project, it will provide well-researched views on how the use of climate-smart irrigation technologies can help increase food production and nutrition in dry areas. At the same time, the study will identify the major constraints smallholder farmers face when accessing and using climate-smart irrigation modern and advanced tools and inputs, constraints includes things like limited access to finance and inadequate technical knowledge in other words skill, they is

also unreliable input supply chains and weak market linkages, this therefore shows results in government, and other stakeholders' interventions with policies and programs as solutions.

1.8 Scope and limitation of the study

The scope of the current research is limited to evaluating the impact of climate-smart irrigation interventions on household food security and dietary diversification in relation to the Insukamini Irrigation Scheme and its surrounding communal areas located in Gweru, Midlands Province, Zimbabwe

Limitations of the study

Findings of this study are limited to a particular geographic area within Zimbabwe, namely Midland's province, thus reducing the possibility of making generalizations about other areas. In addition to these limitations, the researchers may experience various problems while conducting the study such as financial limitations and the lack of time for conducting the research. Also, there may be difficulties associated with data collection due to potential inaccuracies at the household level or lack of cooperation from respondents

1.9 Organization of the research

As noted above, the dissertation consists of five separate chapters. Chapter one deals with introducing the research and providing an outline for the entire work. In Chapter Two, a comprehensive literature review concerning smallholder irrigation, climate-smart interventions, and food security concepts is provided. Chapter Three describes the research methodology in detail. Chapter four discusses the process of analysing and interpreting the obtained data.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Introduction

The first objective of this literature review is to investigate different theoretical viewpoints and findings on the significance of using climate-smart irrigation in promoting food and nutrition security in semi-arid zones. The present chapter attempts to analyze the theoretical framework and definitions behind the development of irrigation. The analysis focuses on the Insukamini Irrigation Scheme of Gweru specifically. Based on the outcomes collected from recent outcome surveys, the paper will highlight the impact of technological innovations and rehabilitation efforts on household diets. Additionally, this review paper aims at identifying gaps in current studies, especially those relating to the social and economic barriers hindering the efficiency of smallholder schemes.

2.2 Concepts and Definitions of Key Terms

2.2.1 Climate-Smart Agriculture

Climate-Smart Agriculture is an agriculture system that increases productivity for smallholders; enhances their resilience in the face of climate change; and at the same time tries to minimize Greenhouse Gas emissions where feasible. The approaches are sustainable so broad, and are designed to help farmers use sustainable agricultural practices that allow them to adapt and adapt with the climate change in order to enhance food security and improve their livelihoods (FAO, 2013). Efficient irrigation technologies; conservation agriculture practices; crop diversification approaches; agro-forestry systems and drought resistant crops among others are therefore some of the practices that need to be implemented in farming. The approaches will not only increase agricultural production for smallholder farmers but also support environmental sustainability through issues of water and soil conservation as well as land degradation (Lipper et al., 2014). Given the current climatic conditions characterized by constant droughts and unpredictable rainfall patterns as well as the deteriorating soil fertility in semi-arid region of Zimbabwe, the implementation of CSA approaches was highly effective to address these challenges faced by smallholder farmers in the country.

2.2.2 Irrigation

Irrigation is the method of supplying water to farmland by artificial means in cases where rainfall is not enough or unreliable to grow crops (Food and Agriculture Organization (FAO), 2021). It is one of the most important agricultural techniques through which the moisture of soil is improved, the growth of crops is supported, the production of farm is increased, and the supply of food is secured, mostly in dry and semi-dry areas (Moyo & Nangombe, 2015). Different watering methods may be used per the nature of the environment and the level of resources of the area, these may be surface irrigation, sprinkler irrigation, and drip irrigation. In countries like Zimbabwe, irrigation has been a vital factor in lessening the drought and the changing of the climate in local farmers. After all, making good use of irrigation will lead to the sustainable development of farming through the lessening of the changes in production and the betterment of village life (FAO, 2021).

2.2.3 Climate-smart Irrigation

Climate Smart Irrigation is a term used to refer to technologies and practices put into practice during the process of irrigation so as to improve production despite the harsh climatic conditions while minimizing the effect on the environment caused by the irrigation process (FAO, 2017). Examples of practices under climate-smart irrigation include those that contribute to water savings like the use of drip irrigation, rainwater harvesting, and precision irrigation among many other irrigation practices. Through climate-smart irrigation, agriculture becomes sustainable because of reduced water wastage, soil fertility improvements, and food security in dry areas (Khatri-Chhetri et al., 2020). For instance, countries like Zimbabwe located in arid regions have adopted climate-smart irrigation because of its adaptability to the changing climatic conditions.

2.2.4 Smallholder Irrigation

Using controlled irrigation systems on small pieces of farmland to enhance agricultural production and reduce dependence on rainwater is what is meant by smallholder irrigation (Food and Agriculture Organization (FAO), 2022). Smallholder irrigation methods mainly comprise of small-scale irrigation methods like drip irrigation, sprinkler irrigation, furrowing or treadle pumps that depend on the type of materials used and environmental conditions (IFAD, 2020). Smallholder irrigation has been a very effective means of supporting agricultural production, raising water productivity, and ensuring food security mainly in times of water scarcity (FAO, 2022).

According to Wandera et al. (2020), smallholder irrigation has contributed to efficient irrigation of crops through reducing water loss through evaporation and runoff and increasing crop productivity. In Zimbabwe, the major features of smallholder irrigation initiatives include small farm sizes of 0.1-1.5 ha, communal ownership of land, shared irrigation facilities, and collaborative management processes by farmers and government agencies (Mupangwa et al., 2022). The major reason behind this is because smallholders' projects are collective in nature whereby farmers utilize shared water sources and irrigation equipment.

And, smallholder irrigation also plays an important role in maintaining rural livelihoods through income and job opportunities, improvement of their drought resistance capacity and other climatic changes (Makombe et al. 2022). Because of climate changes and their consequences on rainfed farming methods, irrigation remains vital to sustainable agriculture development.

2.2.5 Smallholder Irrigation Development Project

Small holder irrigation development projects refer to projects aimed at providing water supply schemes to small scale farmers, especially those residing in drought prone and arid areas. Such projects enhance agriculture productivity, food security, income levels and climate adaptation by ensuring the availability of irrigation systems such as dams, canals, pumps and pipelines for all-year-round crop cultivation (Food and Agriculture Organization (FAO), 2021). Small holder irrigation development projects in Zimbabwe and developing countries at large assist in reducing over-reliance on rain-fed agriculture and encourage the production of high value crops. In addition, the projects enable the establishment of sustainable economic activities among poor farmers as well as enhancing poverty reduction and job creation (International Fund for Agricultural Development (IFAD), 2020). Research studies have also revealed that the development of irrigation promotes sustainability in agriculture among poor rural households (Svubure et al., 2021).

2.2.6 Food Security

Food security can be defined as the state whereby all people have regular physical, social, and economic access to enough, safe, nutritious food that meets their dietary needs as well as food preferences for an active, healthy lifestyle (FAO, 2009). The concept of food security is based on four critical pillars, including food availability, food access, utilization, and stability. Food availability addresses the issue of constant food supply through production, distribution, and exchange. Food access revolves around people's capability to get food using monetary means among others. On the other hand, utilization pertains to the nutritional adequacy and

safety of foods consumed. Stability, in turn, involves dependable access to food regardless of economic or climatic shocks. In Zimbabwe, food security becomes imperative due to the need to improve lives, fight poverty, and develop the country.

2.2.7 Household Food Security

Household food security may be defined as a scenario in which all members of the household experience stable access to sufficient quantities of affordable and nutritious food that is safe for consumption and meets their nutritional needs and food preferences throughout life (Food and Agriculture Organization (FAO), 2021). Household food security goes beyond the mere availability of food, encompassing food stability, affordability, appropriate usage, and balanced nutrition. For households in rural settings, food security is highly dependent on a number of factors, including income, production levels, climatic conditions, water sources like irrigation, and means of livelihoods. Following the World Food Summit approach, food security occurs when households can reliably access adequate amounts of food throughout time without being threatened with loss of food through economic or environmental shocks (FAO, 2006). Households in semi-arid areas in Zimbabwe have continued facing food insecurity challenges as a result of recurring droughts and unpredictable rainfall, especially among smallholder farm households (World Bank, 2022).

2.2.8 Nutrition Security

Nutrition security can be described as a state whereby individuals and families have consistent access to both food and adequate nutrition, water, health care, and sanitation to ensure healthy growth and development. It places emphasis on the quality, variety, and nutrition in the diet consumed, and does not limit itself to the mere availability of food (United Nations Children's Fund (UNICEF), 2020). Nutrition security is attained when people consume balanced meals containing all the necessary vitamins, minerals, proteins, and other vital elements to sustain an active and healthy lifestyle. In several developing countries, issues of nutrition insecurity arise due to factors such as poverty, climate change, under-productivity in agriculture, epidemics, and lack of health facilities. Among smallholder farmers in semi-arid areas in Zimbabwe, malnutrition results from the absence of sufficient rain leading to inadequate food supply. The World Health Organization (2021) highlights the importance of improving food production and consuming varied foods in ensuring nutrition security.

2.2.9 Food and Nutrition Security

The concepts of food and nutrition security refer to a situation where all people have consistent availability of adequate, safe, and nutritious food leading to well-being and an active life. Availability, accessibility, usage, consistency, proper nutrition, and health conditions make up this term. This term shows the link between the production and assimilation of nutrients within the human body through the health sector, sanitation systems, and proper consumption of food (FAO et al., 2023). The issue of food and nutrition insecurity emerges due to climate change, drought, poverty, and poor agricultural outputs in semi-arid zones of Zimbabwe (World Bank, 2022). In line with this concept, the following are the four interconnected aspects of food security:

2.2.10 Food Access

Food access involves the ability for an individual or household to access food through income, production, and market activities. Factors influencing food access include affordability, sources of income, and food access. In the presence of food in a place, food access can be hindered due to poverty. According to WFP, food access is not only influenced by affordability but also physical availability of food in enough quantity (WFP, 2023).

2.2.11Food Availability

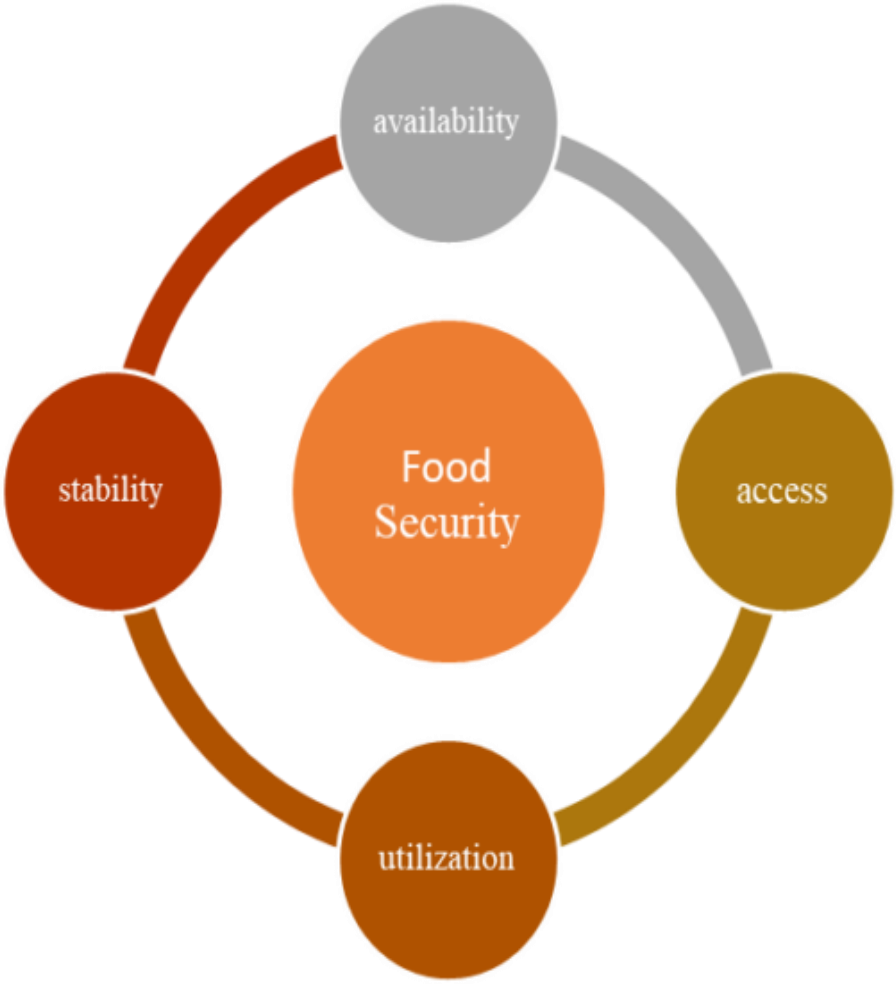
The question of food availability is all about food being present in sufficient quantity within a particular country or community. It implies that there are always adequate quantities of food in existence physically. Various issues may affect the issue of food availability including production, weather, and food storage facilities among others. With regard to Zimbabwe, food availability can be negatively affected due to poor weather conditions. This includes situations where there are drought and poor yields. According to FAO, food availability is an important aspect of food security since there must be available food in the first place (FAO, 2008).

2.2.12 Food Utilization

Food utilization means the manner through which food is utilized by the body in order to ensure good nutrition and health status. Food utilization is achieved through the safe handling of foods, use of clean water, sanitation, and food variety. Poor health status or poor hygiene may lead to poor food utilization regardless of food availability. As cited in FAO (2008), food utilization is a bridge between food consumption and nutrition status.

2.2.13 Stability

Simply put, stability means having a constant availability of food that should not be affected by the changes of natural disasters, economic inflation, and conflicts. Besides, stability plays a big role in making sure that there are availability, accessibility, and utilization throughout the whole year. Regions with unstable weather conditions can face the threats to their stability. But food stability is one of the components of food security referring to the aspect of



availability.

(FAO, 2008).

Figure 2.1 ***The four pillars of food security***

Source: Garcia & Wanner (2017)

2.2.14 Dietary Diversity (DD)

Definition: Dietary Diversity (DD) can be described as the variety of foods or food groups taken by the individual or the household within the reference period, such as either one day or

one week. It is a widely used qualitative measure of the quantity and quality of food consumption. The more diverse a person's diet is, the higher their nutrient intake will likely be. This means that dietary diversity is used as a qualitative measure of food consumption because it indicates the amount of food groups consumed by the household within a certain period, such as one day. (HDDS) Household Dietary Diversity Score measures the household's access to food groups. (MDD-W) Minimum Dietary Diversity for Women is a measure of the adequacy of micronutrient intake among women in reproductive age (FAO, 2011). In rural and semi-arid areas, factors influencing dietary diversity include agricultural production levels, income, seasonality, and climatic conditions (Swindale & Bilinsky, 2006).

2.3 Empirical Literature Review

2.3.1 The effect of climate-smart irrigation practices on household food security

Climate-smart irrigation is extremely important in securing food, mainly smallholder farmers in semi-arid areas where weather conditions are uncertain (Mhembwe et al., 2019). Climate-smart irrigation techniques include: drip irrigation, water harvesting, water efficiency, conservation agriculture, and growing drought-resistant varieties. These techniques enable the farmer to still engage in their farming activities in the dry season without unnecessary water loss and being very efficient in using it. Per FAO, climate-smart agriculture (CSA) is an integrated approach to managing landscapes (cropland livestock forests and fisheries) that addresses the interlinked challenges of food security and climate change (FAO, 2023).

In Zimbabwe, different researchers through their studies identified that households that practice irrigation are food secure better than those that are not practicing irrigation. The food security benefits of farmers practicing irrigation revolve around the increase in yields, income levels, quality diet, and food access throughout the year. As an illustration, Mupaso et al. (2024) investigated the difference in the food consumption score of the two groups and found a considerable higher score for households practicing irrigation in Zimbabwe. Besides, the implementation of CSA could ultimately turn farmers into drought-resilient and also to adapt to climate changed leading to household welfare (Mujeyi et al. 2021).

2.3.2The relationship between irrigation practices and household dietary diversity

Irrigation practices and household dietary diversity have become an issue of great interest in the study of food security within semi-arid regions characterized by unpredicted rainfall and inefficiency in crop productivity. Irrigation practices make it possible for the growing of crops throughout the year, resulting in the availability of a wide variety of foods such as

vegetables, fruits, and beans. Indeed, according to the Food and Agricultural Organization, irrigation ensures productive food production, thus contributing to good nutrition among communities (FAO, 2021). Smallholder farmers are capable of diversifying their diets via the implementation of irrigation practices and hence improving household dietary diversity (Mango et al., 2018).

A series of research studies conducted in various nations such as Ethiopia and Kenya suggest that participation in irrigation is associated with better nutrition due to more consumption of healthy food products without the occurrence of seasonal food shortages (Passarelli et al., 2018). Irrigation schemes as a means of enhancing household nutrition by increasing income and diversification of diets has been observed in Zimbabwe as well (Mutambara et al., 2022). Nevertheless, the extent of improvement in household nutrition may vary depending on some factors including availability of water, market accessibility, income generation, and nutrition education.

2.3.3 Challenges affecting the implementation of climate-smart irrigation systems

The low adoption of climate-smart irrigation systems by small-scale farmers remains a challenge in many developing countries, including Zimbabwe. First of all, the shortage of capital is the biggest reason why the farmers cannot afford climate-smart irrigation tools like new machinery, water management technologies, and system upkeep (Serote et al. 2023). Secondly, the lack of proper infrastructure, such as the absence of a reliable source of electricity, the broken state of irrigation canals, and the shortage of water storage facilities, also contribute to the problems during the implementation process (Mhembwe et al. 2019).

And, the lack of technical skills is the factor that prevents the use of climate-smart irrigation systems as hardly any training has been given on the efficient use of water. Most farmers have not been adequately trained on climate-smart irrigation techniques such as precision irrigation, rainwater harvesting, and drip irrigation (Zondo et al. 2024). Besides that, institutions that are not well-functioning and the insufficient dissemination of climate information make adaptation efforts difficult (Mwadzingeni et al. 2023).

Lack of security in land ownership and erratic government policy are some other reasons that might hamper the investment in irrigation technologies. In addition, climate variability acts as a barrier since the occurrence of droughts and water shortage render irrigation not viable. But then again, climate-resilient irrigation technologies are necessary for boosting production and

household food security (production), only that these technologies call for proper financial and policy support.

2.4 Conceptual Framework

2.4.1 Smallholder Irrigation - Food and Nutrition security Linkages

Small-scale irrigation matters a lot in improving food and nutrition security by Really contributing to households' livelihoods through increased agricultural productivity, higher incomes, and diverse diets. Supplementary irrigation water a lot supports food security, In particular during the periods of low rainfall (FAO, 2021). Irrigation enables farmers to cultivate crops every season, increasing production, and minimizing the risks linked to drought and climate change. Improved agricultural productivity leads to food being consistently available in all seasons.

Irrigation also helps to enhance food accessibility due to increased incomes from the sale of their produce. They have sufficient financial means to buy nutritious foods, seek health care services, and agricultural resources hence enhancing food and nutrition security (Hanjra & Qureshi, 2010). Moreover, irrigation also encourages dietary diversity since farmers are capable of growing nutrient rich foods such as vegetables and fruits (Domènech, 2015).

Nevertheless, for irrigation to positively impact the food and nutritional security of farmers, some conditions should be met. For example, the availability of markets, provision of agricultural extension services, infrastructure, and proper water management practices determine whether or not irrigation can positively contribute towards better food and nutritional security (Namara et al., 2014). Thus, climate-resilient irrigation practices are necessary for sustainable food production and nutrition security.

The figure below illustrates the effects of irrigation on people's food security, nutrition, and health. A good irrigation system can mainly contribute to the lives of farm families in four main ways: increasing food production, generating income from farming, ensuring water supply, and empowering women, which results in positive impacts on food and nutrition (Passarelli et al. 2018).

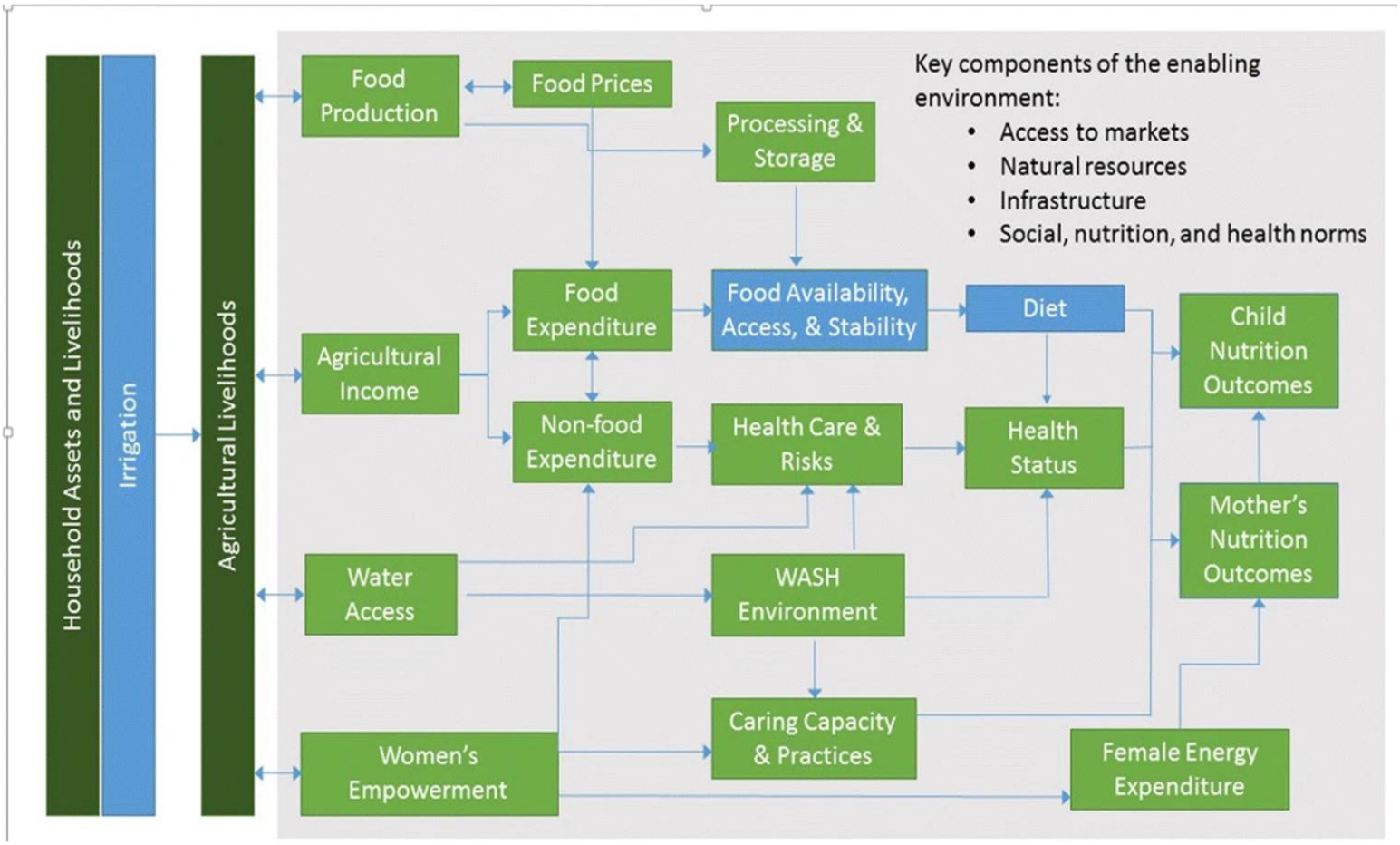


Figure 2.2Irrigation-Nutrition Linkages

Source: Passarelli et al., 2018

As indicated above, the four key pathways for food production, agricultural income, access to water, and women empowerment have been elaborately described below.

2.4.2The Food Production pathway

The pathway describes how irrigation influences agricultural productivity and food security for the household members. With the availability of irrigation, there is an improvement in crop productivity as farmers can cultivate all-year-round without reliance on unpredictable weather conditions. This is likely to result in higher crop yields and varieties. Such conditions may lead to better access to basic foods, vegetables, and fruits within the family unit, leading to improvements in nutrition status. According to research findings in Ethiopia and India, irrigation practices enhance agricultural productivity among farmers and alleviate any food gaps experienced by farmers during specific times (Domènech, 2015; Passarelli et al., 2018). Irrigation in semi-arid areas is a drought and climate change resilience tool by providing members of the household with means to secure food and earnings regularly (FAO, 2017).

Because of this, an elevated level of food output from irrigation Quite a bit contributes to the enhancement of food and nutrition security.

2.4.3Income pathway

The income pathway provides insight into how irrigation impacts household food security and nutrition through income generated through farming. Having access to irrigation technology ensures that farmers can cultivate all year round and minimize dependency on rainfall while increasing the productivity and saleability of their crops. As such, increased income from agricultural activities provides households with the ability to afford diverse and healthy foods, medical care, and farming resources, which helps enhance their nutritional status (Hanjra et al., 2009). Irrigation further provides employment opportunities and facilitates diversification of income sources among communities that depend on agriculture as their primary source of livelihoods (Passarelli et al., 2018). More income earned through farm activities has been linked with improved food diversity in Sub-Saharan Africa (Domènech, 2015).

2.4.4 The water supply pathway

Water supply pathway helps understand how irrigation ensures the availability of water not only for agricultural activities but also for domestic purposes, thus affecting the household's food security, nutritional status, and health. Irrigation could enhance the availability of water for cooking, washing, and raising livestock, as well as enable agriculture during droughts. Ensured access to water promotes improved sanitation and hygiene practices, reducing the burden of waterborne diseases and improving the uptake of nutrients in the family (Domènech, 2015). Moreover, in several semi-arid zones, irrigation projects have decreased the workload associated with water collection for families, especially for women and children, which allows them to engage in more productive and educational activities (Passarelli et al., 2018).

2.4.5The Women’s Empowerment pathway

Women empowerment theory highlights the role of irrigation as an instrument of achieving better food security and nutrition among families due to increased involvement of women in agriculture, management of finances and decision making. Availability of irrigation services is likely to reduce women workload in collecting water for domestic purposes and enable them to become productive in farming operations, thus improving the welfare and nutrition of households (Meinzen-Dick et al., 2019). Irrigation participation has made many women capable of influencing food purchases, nutrition and other decision making within their

families (Meinzen-Dick et al., 2019). Empowering women in several developing nations through provision of water, land and agricultural services has led to enhanced nutrition and climate shock resilience (van den Bold et al., 2013). Hence, irrigation improves agricultural productivity as well as socio-economic standing of women.

2.5 Insights from the Literature Review

What this means is that a synthesis of the existing literature and field-based research shows that irrigation technology is an approach that can aid in transforming the situation concerning food and nutritional security in semi-arid settings such as Gweru. Considering the objectives of the research at hand, three interrelated themes emerge from the literature review: productivity, diet, and the challenges associated with climate-smart irrigation (CSI) approaches (FAO, 2021; ZIMVAC, 2023).

2.5.1 Influence of Climate-Smart Irrigation on Household Food Security

Production pathway has always been the main channel that links irrigation to food security impacts. The reason being that in climatically sensitive areas like those classified as Natural Region V, the traditional farming relying on rainfall only yields low outputs, leading to vulnerable communities still facing food shortages (ZIMVAC, 2023). For example, the Insukamini irrigation project case study showed that climate-friendly measures, like land levelling and the upgrading of approximately 2.5 km of water distribution networks, have changed the marshlands into arable lands (Irrigation development project, 2022). These measures, among other things, have led to an increase in productivity as shown by wheat production of up to 10 tons per year and crop intensity raise to 2.24 crop cycles per year (JIMAT Development Consultants, 2023). In fact, this type of intensification has largely solved the hunger problem which normally occurred between August and January (FAO, 2021). Apart from productivity-related changes, the use of moisture retention techniques like hydrogel has been instrumental in protecting the plants from the negative effects of drought during the middle of the growing season.

2.5.2 Irrigation Practices and Household Dietary Diversity

It is a widely accepted assertion in the literature that availability of water forms the core foundation required for ensuring dietary diversity. Regional research carried out in various areas within Sub-Saharan Africa shows that irrigated communities have diets that contain more types of food compared to non-irrigated communities (Mekonnen et al., 2022; Passarelli et al., 2018). In the case of Insukamini, there is an average Household Dietary Diversity

Score (HDDS) of 7.31, which is the highest HDDS recorded for schemes similar to those found in this region (JIMAT Development Consultants, 2023). This achievement has been attributed to the income pathway in the literature whereby the change to irrigation has provided families the chance of earning excess income through commercial crops like tomatoes and green maize (Karanja et al., 2023). The extra income earned is used in the acquisition of nutritionally diverse foods that include NUA 45 and orange maize which contain vitamin A (FAO, 2021). HDDS has been proven to be an effective proxy tool in determining the economic capability of households to afford diverse foods.

On top of that, gender-sensitive governance systems, most of all women's Irrigation Management Committees (IMC), such as the one operating in Insukamini, have become indispensable instruments to women's sufficient micronutrient intake as measured by the MDD-W indicator (Mekonnen et al. 2022).

2.5.3 Structural Challenges Constraining Climate-Smart Implementation

Though, the really impressive technology adoption figures aside, there are several deeply rooted structural problems, which if not addressed, will hinder the full realization of the benefits that can be obtained from the CSI value chain. As one of the issues, power supply has been a major challenge; aside from Really electricity is occasionally cut off for days due to failures in the national grid, such blackouts not only disrupt the irrigation schedule but also put plants in a situation to which they are growing water stress mainly during their critical phenological phases (Irrigation development project, 2022). Even more, this is a way through which the farmers' activism has taken a new turn, based on their demand for solar irrigation technologies (ZIMVAC, 2023). Farmers have always experienced a lack of access to markets, which has led to their exploitation by local informal middlemen known as 'Makoronyera', who are the price setters when it comes to the urban markets (JIMAT Development Consultants, 2023). In the same way, the absence of development in post-harvest handling facilities has been the subject of even more serious discussions. Actually, establishing packing house facilities was an indicator of progress in Insukamini's product value enhancement. Yet, some challenges are making it quite difficult to get GAP certification and be able to export the product globally, such as fencing for biosecurity, sanitation, and water availability (Irrigation development project, 2022). Bottom line, it is abundantly clear that climate-smart irrigation can make a difference in not only ensuring food security but also improving nutrition by diversifying diets. It is equally true that these benefits will only continue if energy is not in shortage, access to markets by the small farmers remains

protected, and infrastructure development related to sanitation and biosecurity are completed (FAO, 2021; Karanja et al 2023; Irrigation development project, 2022).

2.5.4 Research Gap

There are three major areas where the literature remains incomplete. One is that the bulk of the studies done on the role of irrigation on food security in Zimbabwe compare the benefits and limitations of irrigation mainly between irrigation and non-irrigation farming practices using only two big categories of farming households and without further analysis of the extent of climate-smart technologies adoption by beneficiary households; this three-fold analysis in this one's research (irrigation beneficiary households, non-irrigator beneficiary households, and non-beneficiaries) is quite unique among the smallholder-irrigation studies mentioned above.

Secondly, among the studies reviewed above, fewer have integrated descriptive as well as inferential statistical analysis like (ANOVA, Tukey HSD, multiple regression) with qualitative data collection (FGDs KIIs case studies) as one semi-arid Zimbabwean scheme-level study; most of others have used only quantitative household survey or qualitative case study but not any combinations. Lastly, although literature includes the topic of gender-sensitive water resources management and development (van den Bold et al. 2013; Meinzen-Dick et al. 2019), only a limited number of studies have matched household-level HDDS regression at the same site with a woman-specific MDD-W comparison which is a serious limitation for understanding whether household-level food security improvements will necessarily result in enhanced women's dietary diversity (Meinzen-Dick et al. , 2019; van den Bold et al. , 2013). This study remedies these shortcomings through a three-group research project at Insukamini Irrigation Scheme combining regression analysis of households, dietary diversity outcomes that are gender disaggregated, and qualitative triangulation.

CHAPTER 3

3.1METHODOLOGY

3.2 Introduction

This chapter will discuss the area in which the study was carried out and give information on the methodology employed in the study. Furthermore, this chapter will discuss the characteristics of the population under study, sampling technique applied and sample size, method of data collection, sources of data, and methods of data analysis.

3.3 Description of Study Area

3.3.1 Location

Insukamini Irrigation Scheme is found in the low land of Gweru district in the Gweru area of the Midlands Province of Zimbabwe, about 41-46km northwest of Gweru town in the Natural Region IV (Manatsa et al., 2020; Mhembwe et al., 2019). Insukamini is geographically found around 19°21'S 29°35'E (Midlands Province). The area where Insukamini Irrigation Scheme is found covers about 41 hectares and supports around 128 member households, (Dube & Sigauke, 2015).

Figure 3.1 Study Map of Insukamini irrigation Scheme, District of Gweru, Midlands Province

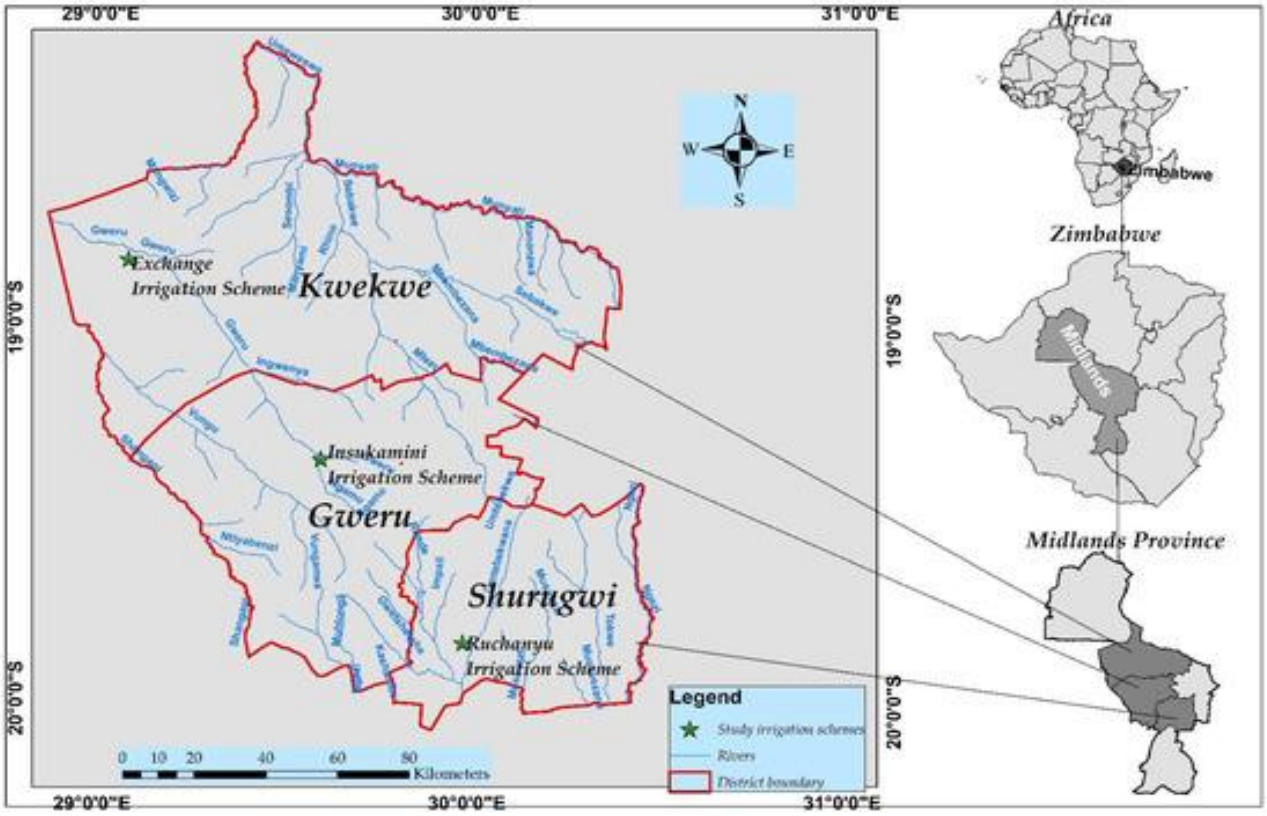
Source: (Mwadzingeni et al., 2021)

3.3.2Population and Area Coverage

The Gweru District occupies an area of 5,889 km² and has a population of 121,712, made up of 60,400 males and 61,312 females in 30,226 households as per the 2022 Population and Housing Census (ZIMSTAT, 2022). The Insukamini Irrigation Scheme is located in Ward 19, about 27km away from the city of Gweru and has an area of 41.3 hectares. It was established in 1988 and at present has 125 farmers working within the scheme. Among the registered farmers for Irrigation development project,

3.3.3Climatic conditions

Insukamini is found within the Agroecological Region V in Zimbabwe, which is known to be one of the driest regions and thus, environmentally harsh in the country (Mugandani et al., 2012). Region V is characterized by extremely arid conditions coupled with very irregular and scanty rainfall periods, whereby there is only one season every five years when there is sufficient rainfall to cultivate crops. Hence, the community is subjected to frequent drought and heat hazards, which it suffers from owing to climate change effects that are becoming



more rampant and more severe than ever before. In such conditions, irrigation plays an essential role as it provides an avenue for a "drought stress-free regime".

As Mugandani et al. (2012) noted, there were shifts in the traditional Zimbabwe agroecology with respect to the arid region V, where previously fertile areas become arid every time.

3.3.4Agricultural activities

For example, agricultural practices at Insukamini include intensive irrigation and rain-fed cultivation techniques. Intensive irrigation techniques include cultivating crops such as green mealies, cabbages, sugar beans, wheat, onions, cucumbers, butternuts, and carrots amongst others. Through the use of "block system," planting of crops such as wheat becomes easier. Rain-fed cultivation techniques include planting of crops such as grain maize, sorghum, groundnuts, cowpeas, and sunflowers. Livestock farming is another agricultural activity practiced by the communities in the study area. Cattle, goats, and poultry like Sasso, Boschveld, and indigenous are kept through livestock farming. Some smallholder farmers have resorted to cultivation of some fodder crops like velvet leaf and lablab to ensure the sustenance of their livestock (Ndoro & Mudhara, 2020). The rate of CSA adoption in the study area is relatively high through conservation agriculture (Pfumvudza), hydrogel, and integrated soil fertility management. Diversification of smallholder irrigation in semi-arid areas would be vital in ensuring a steady supply of food chain especially during periods of low rainfall. Additionally, the adoption of drought-tolerant livestock can help improve adaptive capacity.

3.3.5Economic activities

The local economy is mainly dependent on primary production and value-added activities (Chikazunga & Paradza, 2013; Moyo, 2018). The community earns its main income through farming at irrigation plots, seconded by sales of dryland crops and livestock husbandry (Scoones et al., 2010). Activities that are not related to agriculture include artisanal mining, fishing, and labour in the irrigation scheme (Chikazunga & Paradza, 2013). Value addition has evolved to include small-scale manufacturing of cleaning agents (e.g., soaps, foam baths, toilet cleaners) and the building of solar dryers for preservation of horticulture products including mufushwa (dried vegetables) (Moyo, 2018). The marketing structure involves selling the produce through local markets, the Grain Marketing Board (GMB), and private marketers (Scoones et al., 2010). Nevertheless, the producers are often exploited by makoronyera who drive the prices down (Chikazunga & Paradza, 2013). There exists a

recently erected packhouse with a grading system and cold chain to link up the region with export markets (Moyo, 2018).

3.3.6Insukamini Small Scale Irrigation Scheme

The research was carried out at Insukamini, which is an irrigation scheme located in the Gweru district of Midlands Province. This irrigation scheme has been in operation for the last 35 years since it was established in 1988. At first, the number of irrigators in this scheme stood at 126, but later on, two more young irrigators joined, making the total number 128. Prior to the rehabilitation process conducted under the Smallholder Irrigation Project, the area of the irrigated land stood at 32 hectares. However, after the rehabilitation process, this area rose to 38.3 hectares, an increase of 19.7%. The recent improvement of this irrigation scheme includes construction of a modern pack house that has a cold room where the produce is sorted and stored.

3.3.7 Research Design

The study was carried out by employing a mixed-methods design, which involved the use of both quantitative and qualitative data collection methods. Data was collected through structured questionnaires and face-to-face interviews conducted among farming families as well as extension workers of the agriculture sector who are members of the irrigation project.

Responsibility for the irrigation project lies with the Irrigation Management Committee (IMC), which further receives help from a number of sub-committees each of which is charged with a specific area like operations and maintenance, marketing, and discipline

3.3.8 Sampling Technique and Sample Size

For the quantitative household survey, a multi-stage stratified random sampling method was used.

Firstly, deliberate site selection: The Insukamini Irrigation Scheme in Gweru district is a chosen site with a clear intention. Since it is located in Agroecological Region V, an area known for its dry climate and irregular rainfall, this site is an ideal example for studying climate-smart irrigation as a strategy to combat droughts.

Secondly Stratification: The target population was divided into two separate groups to comparative analysis:

(1) beneficiary irrigators smallholders using the scheme and climate-smart practices;

(2) a non-beneficiary control group local farmers not in the programme, providing a baseline. Thirdly Random Selection:

Respondents from each stratum was selected randomly basing on the lists obtained from the Agritex extension officers. Also, the stratification by gender was performed to incorporate male- and female-headed households, which was representative of the actual distribution of the local farming population. Finally, sample size determination was done through random sampling, using the Slovin formula. See below:

$$n = \frac{N}{1 + N(e^2)}$$

- *n* refers to the sample size
- *N* refers to the population size,
- *and e* refers to the level of significance

  Where:

  - N = 128 (population size)
  - e = 0.10 (10%) (level of significance)

$$n = \frac{128}{1 + 128(0.10^2)}$$

$Therefore\ n$ 56 = 128 / (1 + 128(0.10) ²) = 128 / 2.28 = 56.14 ≈ 56

From the above calculation, 56 households were sampled as the Slovin-formula minimum.

Table 3.1: Data Collection Methods

Objective	**Data to be collected**	**Data gathering Tool**	**Respondents**
1.**To examine the effect of climate-smart irrigation practices on Household Food security**	Food Consumption Score (FCS), yearly household income, productive output average e.g. maize,beans,tomatoes. Food shortages months and perception of food availability changes	Household survey Questionnaire (digitalized by KOBO collect) Case study Guides and Observation Diaries	56 household Heads (randomly selected from beneficiary irrigators and non-beneficiary control groups)

2.**To compare the relationship between irrigation practices and Household dietary Diversity**	Household dietary Diversity scores (HDDS) based on 12 food groups , Minimum Dietary Diversity for women (MDDW) and 24-hour recall of specific food groups consumed e.g. tubers, legumes and meat	Household survey Questionnaire (Nutrition section) Focus group discussion guides	56 household heads (or person responsible for food preparation) and women aged 15-49 within those households
3**. To identify the major challenges affecting the implementation of climate-smart irrigation systems among smallholder farmers**	Qualitative data on the deficiencies in physical infrastructure of solar system e.g. power cuts, absence of solar systems Problem with market access e.g. middlemen low prices Financial challenges e.g. no collateral for formal loans and delay in input delivery	Key informant interview (KII) Schedules, FGD Guides for specific groups (irrigators, youth and NRM group)	Key informants e.g. Agritex officer, IMC Members 40 FGD participants 8-10 members per group

Source: survey data (2026)

The table above presents a summary of the data collection methods which are discussed below.

3.5 Data Types and Sources

The methodology utilized in this study adopted an integrated method of collecting both quantitative and qualitative data for gaining primary information from the head members of the households that either belong to the category of beneficiary or non-beneficiary irrigators of the Insukamini irrigation project.

For instance, quantitative data was collected with regards to the major problems experienced during the adoption of climate-smart irrigation facilities, food security situations, as well as dietary diversity in both categories of households, by making use of a pre-tested structured questionnaire.

On the other hand, qualitative data was collected with the help of key informant interviews and focus group discussions to hear the residents' perspectives and attitudes about the impact of irrigation on their household food and nutrition security.

The combined use of these two methods facilitated an in-depth understanding of the issue under investigation and because of this contributed to using data triangulation for better credibility and reliability.

3.6 Data Collection Techniques

This research combined quantitative and qualitative methods to collect data that together will help to thoroughly analyse the impact of climate-smart irrigation on food security. The results were confirmed through triangulation to ensure their reliability.

Quantitative techniques include a structured household survey of 56 randomly selected respondents in the Insukamini cluster, capturing food security (Food Consumption Score), dietary diversity (Household Dietary Diversity Score and Minimum Dietary Diversity for Women), and adoption of climate-smart practices. Mobile data collection via KOBO Collect will ensure data integrity, GPS tracking, and photo evidence.

Qualitative techniques provide explanatory depth: five Focus Group Discussions with irrigators, non-irrigators, and youth; Key Informant Interviews with extension officers and Irrigation Management Committee members; two in-depth case studies using the most-significant-change approach; and direct field observations.

Secondary data (desk review) includes Agritex lists, program reports, and survey results to establish a baseline for comparison.

3.7Method of Data Analysis

Table 3.2 Summary of Data Analysis

Objective	**Data Collected**	**Data analysis Methods**
1.**To examine the effect of climate-smart irrigation practices on Household Food security**	Food Consumption score (FCS) annual household income (USD),average crop yield (mt/ha) and number of weeks of food insufficiency	Quantitative Anaysis (SPSS):Descriptive statistics (means, standard deviation) and Inferential statistics (ANOVA with Turkeys HSD Post Hoc tests) determine significant differences in food security between irrigators and

		control groups
2.To compare the relationship between irrigation practices and Household dietary Diversity	Household Dietary Diversity Score (HDDS) 12 food groups. Minimum Dietary Diversity for women (MDDW) and 7 days/24hour food group recall data	Quantitative techniques (SPSS): Chi-square tests for association are to be used to determine if there is a connection between the level of irrigation and the different types of TAP consumption (Poor Borderline Acceptable). Microsoft Excel ,Bar and pie charts was used for the visual comparison of the results
3.To identify the major challenges affecting the implementation of climate-smart irrigation systems among smallholder farmers	Themes gleaned from FGDs and KIIs on infrastructure(power outages), Market (middlemen) and institutional delays (procurement issues)	Qualitative Analysis: Thematic analysis to categorize and interpret patterns within text, audioand video data.Findings are used to provide explanatory depth to the quantitative results (Triangulation)

Source: survey data (2023)

The table above presents the data analysis method that is detailed in the next section.

After gathering data with digital devices, data was sent to data cleaning and coding. The research design that has been adopted for this study is a mixed-method approach that integrates quantitative and qualitative analyses to measure the effects of climate-smart irrigation practices.

Quantitative Analysis employed SPSS software, with Excel for graphing. Descriptive statistics will describe household demographic details and farm production. As food security indicators, Food Consumption Score (Poor, Borderline, or Acceptable) was evaluated, along with Household Dietary Diversity Score (from severely insecure to secure) and the Minimum Dietary Diversity for Women (nutritional intake for 15-49 years old). The inferential statistics of ANOVA, Tukey's HSD, and chi-square was employed to compare farmers' groups and establish relationships. Scores on resilience indicators will also be computed.

. Qualitative analysis aims to dissect problems encountered during implementation. Themes emerging from interviews and focus groups will provide a qualitative insight and explanation to the quantitative data, mainly for infrastructure and market aspects. The Most Significant Change Technique Though through case studies will reveal the transformation effects.

3.8 Ethical Considerations

This study was conducted in accordance with the ethical principles governing research involving human participants. Prior to data collection, institutional permission was sought from Bindura University of Science and Education., the Department of Agricultural Economics, and Management as well as from the relevant local authorities and Agritex extension officers overseeing the Insukamini Irrigation Scheme. Informed consent was obtained from all respondents before their participation in the household survey, focus group discussions and key informant interviews; participants were informed of the purpose of the study, the voluntary nature of their participation, and their right to withdraw at any stage without penalty. Confidentiality and anonymity of respondents were maintained throughout the research process: no personally identifying information was recorded on questionnaires, and data were stored securely and used solely for academic purposes. Respondents were also assured that their responses would not affect their access to irrigation-scheme benefits or extension services

CHAPTER 4

4.1 RESULTS AND DISCUSSION

4.2 Effect of Climate-Smart Irrigation Practices on Household Food Security

The chapter delivers results and discussion about how climate-smart irrigation affects the food security of smallholder farmers' households at the Insukamini Irrigation Scheme in Gweru, Midlands Province. It is organized based on the three research goals: First, to know the impact of climate-smart irrigation on food security of households; Second, to understand how it is related to diverse diet of households; Third, to recognize the socioeconomic factors and implementation hurdles that shape the adoption and effectiveness of climate-smart irrigation systems of smallholder farmers.

Table 4.1 : Summary of Food Security Indicators by Beneficiary Type

Food Security Indicator	Beneficiary Irrigators	Beneficiary non-irrigators	Non-Beneficiaries
Mean Household Dietary Diversity Score (HDDS)	7.54	6.67	6.31
Mean Minimum Dietary Diversity – Women (MDDW)	5.49	4.53	3.82
Households with 'Acceptable' Food Consumption Score (%)	94.4%	87.9%	78.0%
Households' food insecure – HDDS (3–4 groups) (%)	0.9%	6.5%	11.0%
Households' food secure – HDDS (6–12 groups) (%)	87.0%	74.8%	72.5%
Households experiencing food shortage in past 12 months (%)	36.1%	56.1%	N/A
Households reporting improved food access/quality (%)	69.4%	47.7%	22.9%

Source: Irrigation development project Annual Outcome Survey, 2023

The results in Table 4.1 reveal a clear and consistent gradient across all food security indicators in favour of beneficiary irrigators. Beneficiary irrigators achieved the highest mean Household Dietary Diversity Score (HDDS) of 7.54, compared to beneficiary non-irrigators (6.67) and non-beneficiaries (6.31). This represents an improvement of 19.5% over non-beneficiaries, and demonstrates that access to a rehabilitated irrigation scheme with climate-smart technologies significantly enhances dietary access. Notably, the baseline HDDS score of 3.0 (prior to Irrigation development project intervention) confirms substantial improvement attributable to the programme. This aligns with the first research hypothesis (H_1) that there is a significant positive relationship between climate-smart irrigation practices and household food security.

The proportion of households with an 'Acceptable' Food Consumption Score (FCS) was highest among beneficiary irrigators (94.4%), followed by beneficiary non-irrigators (87.9%) and non-beneficiaries (78.0%). ANOVA Post Hoc Tukey HSD test results confirmed statistically significant differences in mean FCS between beneficiary irrigators and non-beneficiaries (mean difference = 23.04, SE = 3.30, $p < 0.001$), and between beneficiary irrigators and beneficiary non-irrigators (mean difference = 12.68, SE = 3.32, $p < 0.001$). The chi-square test for association (Pearson Chi-Square (4) = 16.99, $p = 0.02$) further confirmed a statistically significant relationship between food consumption status and irrigation access. These results strongly support the conclusion that climate-smart irrigation practices at Insukamini Irrigation Scheme have improved household food security.

In addition, beneficiary irrigators have experienced a lot fewer periods of food shortage in the last 12 months (36.1%) than beneficiary non-irrigators (56.1%), and a very large proportion of them also reported an increase in the quantity and diversity of food they could access (69.4% of them compared to 47.7% of non-irrigators and only 22.9% of non-beneficiaries). These results strongly support the findings of wider evaluations of Irrigation development projects. Such studies show that rehabilitated irrigation facilities in semi-arid agro-ecological zones allow for continuous crop production throughout the year and because of this enhances the stability of household food access (Irrigation development project Annual Outcome Survey, 2023).

4.3 Household Dietary Diversity Score (HDDS) by Beneficiary Type

A more detailed classification of household dietary diversity status is presented in Table 4.2. Households were classified into three groups based on their HDDS: food insecure (3–4 food groups), mildly food insecure (5 food groups), and food secure (6–12 food groups). **Table 4.2: Classification of Household Dietary Diversity Score (HDDS) by Beneficiary Type**

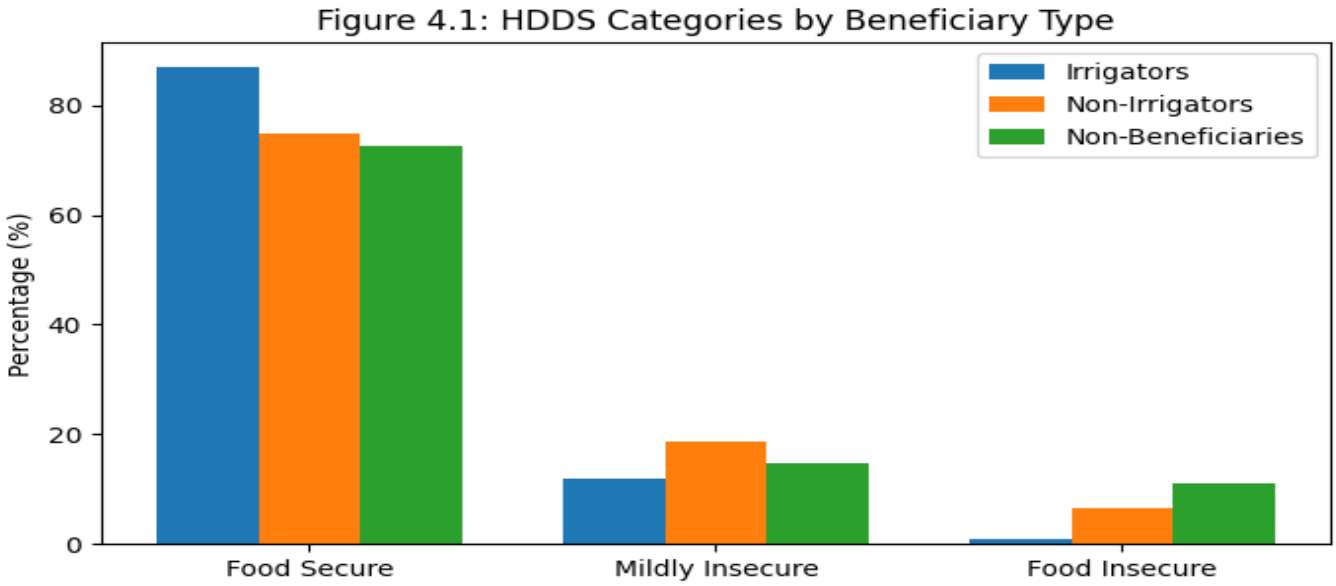
Food Security Category	Beneficiary Irrigators (n=108)	Beneficiary non-irrigators (n=107)	Non-Beneficiaries (n=109)
Food Secure (6–12 food groups)	94 (87.0%)	80 (74.8%)	79 (72.5%)
Mildly Food Insecure (5 food groups)	13 (12.0%)	20 (18.7%)	16 (14.7%)
Food Insecure (3–4 food groups)	1 (0.9%)	7 (6.5%)	12 (11.0%)
Total	**108 (100%)**	**107 (100%)**	**109 (100%)**

Source: Irrigation development project Annual Outcome Survey, 2023

The results in Table 4.2 demonstrate that beneficiary irrigators had the highest proportion of food-secure households (87.0%), followed by beneficiary non-irrigators (74.8%) and non-beneficiaries (72.5%). Conversely, the proportion of food-insecure households was highest among non-beneficiaries (11.0%), substantially higher than the 6.5% among beneficiary non-irrigators and only 0.9% among beneficiary irrigators. This gradient confirms that direct access to irrigation and climate-smart practices is the primary differentiating factor in food security outcomes, rather than programme participation alone.

These findings are consistent with the study's second hypothesis (H_2) that farmers using climate-smart irrigation practices have significantly higher dietary diversity scores. The results support evidence from similar programmes in Sub-Saharan Africa, where access to irrigation was associated with significantly higher food security among smallholder farmers (Burney & Naylor, 2012; Mango et al., 2018). The HDDS outcomes at Insukamini are particularly significant given that the scheme is located in Agro-Ecological Region V, one of the most arid regions of Zimbabwe, where rain-fed agriculture alone cannot sustain adequate household food production. The introduction of technologies such as hydrogel for moisture retention and pfumvudza conservation farming, as part of the Irrigation development project rehabilitation, appears to have amplified these positive food security outcomes.

Figure 4.1 shows the distribution of households across HDDS food security categories



by beneficiary type.

Figure 4.1 above graphically depicts the categories of HDDS by type of beneficiary and quantitatively reveals the substantial variation in food security status of the irrigator beneficiaries in comparison with the control group. The data in the bar diagram below are also good enough for a side-by-side view of the three beneficiary categories in the three food security classes.

Irrigators accounted for the largest number of food secure households (87.0%) while non-irrigators and non-beneficiaries accounted for 74.8% and 72.5% respectively. Irrigators had the least food insecurity (0.9%) whereas non-beneficiaries had the highest food insecurity (11.0%), which means that being part of irrigation schemes might mean having a more diverse diet and better food security for households.

4.4 Relationship between Irrigation Practices and Household Dietary Diversity

4.4.1 Minimum Dietary Diversity for Women (MDDW) by Beneficiary Type

Separate food security analysis was conducted for women respondents aged 15 to 49 years, using the Minimum Dietary Diversity for Women (MDDW) indicator. The MDDW measures whether women consume food from at least 5 out of 10 defined food groups within a 24-hour period, serving as a proxy indicator for the micronutrient adequacy of women's diets. This is particularly relevant at Insukamini Irrigation Scheme, where the MDDW score for the scheme area was reported at 3.93 below the internationally recommended minimum benchmark of 5 (FAO & WHO, 2021) presenting a critical nutrition security challenge that the study sought to investigate.

Table 4.3 : Minimum Dietary Diversity Score for Women (MDDW) by Beneficiary Type

MDDW Category	Beneficiary Irrigators (n=55)	Beneficiary non-irrigators (n=66)	Non-Beneficiaries (n=65)
Mean MDDW Score	5.49	4.53	3.82
Food Secure (≥5 food groups)	39 (70.9%)	31 (47.0%)	18 (27.7%)
Food Insecure (<5 food groups)	16 (29.1%)	35 (53.0%)	47 (72.3%)
Total	**55 (100%)**	**66 (100%)**	**65 (100%)**

Source: Irrigation development project Annual Outcome Survey, 2023

The results in Table 4.3 reveal significant differences in MDDW scores by beneficiary type. Beneficiary irrigators had the highest mean MDDW score (5.49), which exceeds the minimum international benchmark of 5, indicating adequate dietary diversity for women in this group. Beneficiary non-irrigators had a mean MDDW of 4.53 and non-beneficiaries had the lowest at 3.82 both falling below the minimum threshold. ANOVA F-test results

confirmed statistically significant differences in mean MDDW across beneficiary types ($F = 11.901$, $df = 2, 183$, $p < 0.001$). Tukey HSD Post Hoc tests showed that beneficiary irrigators had a significantly higher mean MDDW than both beneficiary non-irrigators (mean difference = 0.96, $p = 0.042$) and non-beneficiaries (mean difference = 1.67, $p < 0.001$).

The food security classification data shows 70.9% of women in beneficiary irrigator households were food secure (5 food groups), whereas the figure for the women in beneficiary non-irrigator households was only 47.0%. Shockingly, it was just 27.7% for the non-beneficiary households. However, 72.3% of non-beneficiary women were food insecure, whereas only 29.1% of women in irrigator beneficiary households were. The fact is that women in the semi-arid regions of Zimbabwe are most likely to be food insecure and micronutrient deficient which leads to children's health and household's nutrition in serious ways.

Do these results really indicate that climate-smart irrigation is a way for women to enhance their dietary diversity well, the data here very strongly support that. This then brings us to the result that irrigator beneficiaries' average MDDW of 5.49 is above the minimum threshold while non-beneficiaries' are quite below, highlights the role of irrigation in offering women the chance to consume various food groups, mostly animal source foods legumes fruits and vegetables.

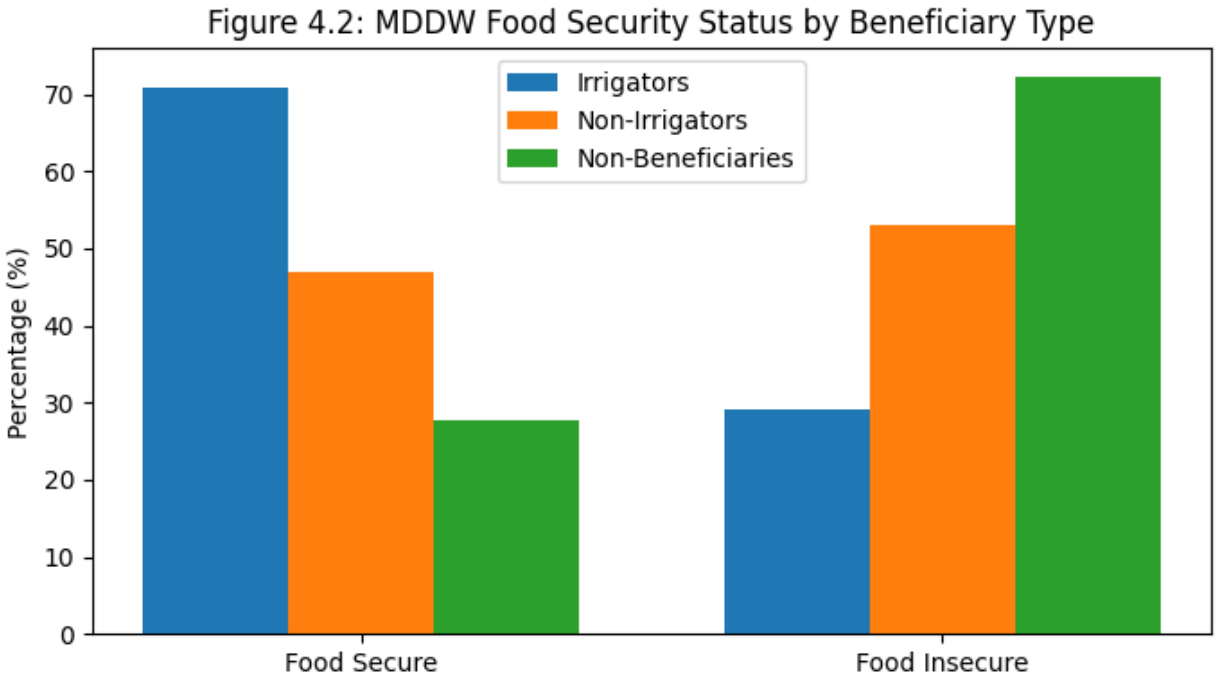


Figure 4.2Bar Chart – MDDW Food Security Status by Beneficiary Type

4.2 Proportion of Households Consuming Specified Food Groups

To further analyse the relationship between irrigation access and dietary diversity, the proportion of households consuming each of the twelve food groups was compared across the three beneficiary categories. The results are presented in Table 4.4 below.

Table 4.4: Proportion of Households Consuming Specified Food Groups (%)

Food Group	Beneficiary Irrigators (n=108)	Beneficiary non-irrigators (n=107)	Non-Beneficiaries (n=109)
Cereals	100.0%	100.0%	100.0%
Tubers	56.5%	38.3%	33.9%
Legumes	77.8%	66.4%	52.3%
Vegetables	98.1%	100.0%	95.4%
Fruits	88.0%	75.7%	67.9%
Meat	87.0%	75.7%	67.0%
Eggs	35.2%	36.4%	22.0%
Fish / Kapenta	58.3%	42.1%	32.1%
Milk and Dairy Products	63.0%	51.4%	46.8%
Sugar and Sugary Foods	99.1%	89.7%	91.7%
Oils and Fats	100.0%	98.1%	92.7%

Condiments	100.0%	100.0%	98.2%

Source: Irrigation development project Annual Outcome Survey, 2023

It is clear from the findings that the consumption of cereals, vegetables, and condiments is consistently high among all groups. Though, there are major differences in the consumption of nutritionally rich food groups. Beneficiary irrigators almost always had better consumption of protein- and micronutrient-rich food groups: tubers (56.5% vs 38.3% vs 33.9%), legumes (77.8% vs 66.4% vs 52.3%), fruits (88.0% vs 75.7% vs 67.9%), meat (87.0% vs 75.7% vs 67.0%), fish/kapenta (58.3% vs 42.1% vs 32.1%), and milk and dairy products (63.0% vs 51.4% vs 46.8%). The presence of these differences supports Really irrigation accessibility makes it possible to have a wider range of dietary choices besides staple cereals, So increasing the nutritional intake of households.

The lower consumption of animal-source foods meat, fish, milk and eggs among non-beneficiaries is particularly concerning from a nutrition perspective, as these foods are critical sources of micronutrients such as iron, zinc, and vitamin B12, which are essential for women of reproductive age and children. The irrigation scheme supports production of high-value horticultural crops that generate income, enabling households to purchase these nutritious foods. This finding supports the pathway through which climate-smart irrigation improves food security: not only through direct food production but also by increasing household income, which is then used to diversify food consumption (Burney & Naylor, 2012; Svubure et al., 2021).

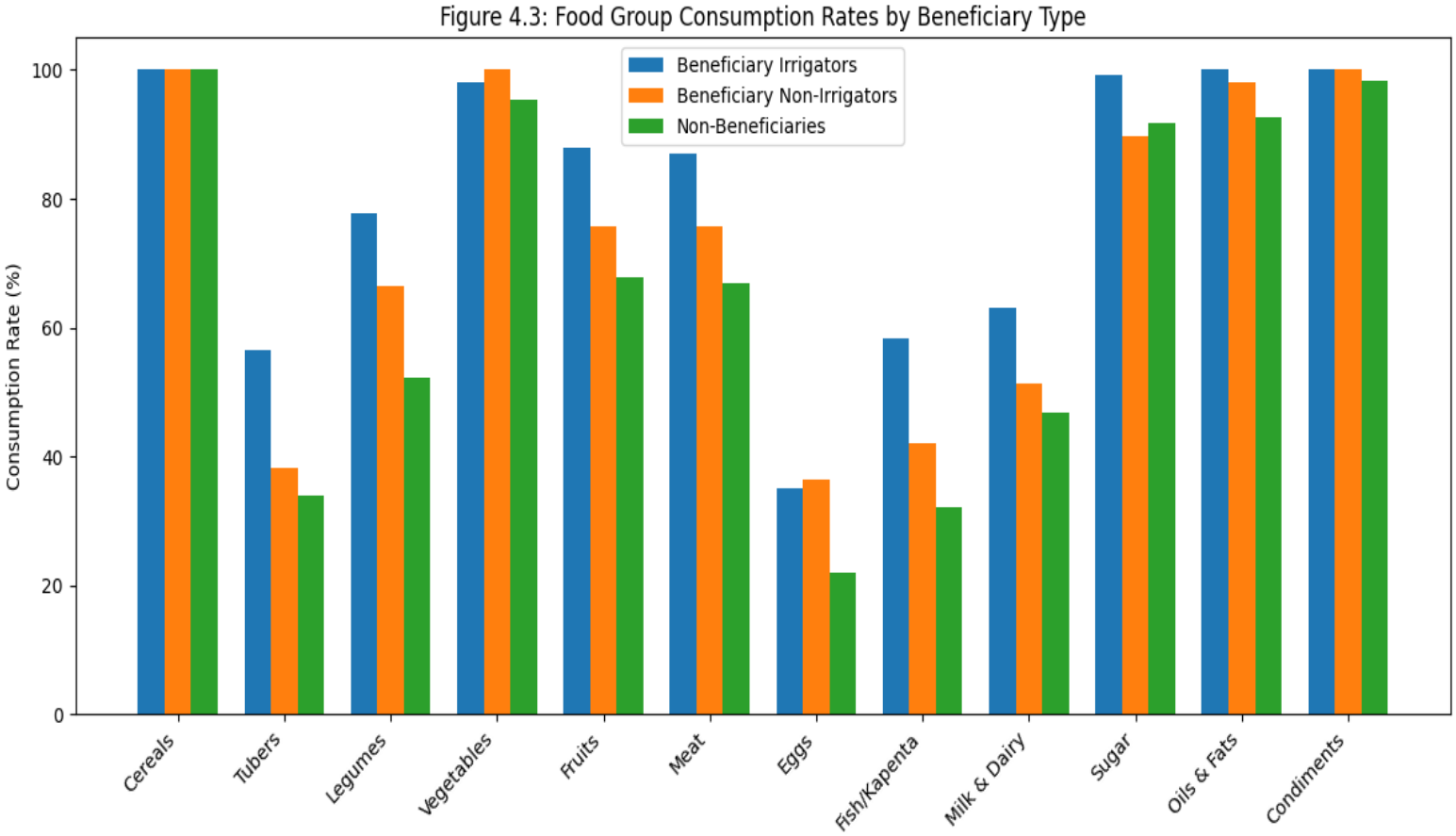


Figure 4.3Bar Chart – Food Group Consumption Rates by Beneficiary Type

4.3 ANOVA Results for Dietary Diversity and Household Income

Table 4.5 summarizes the results of ANOVA Tukey HSD Post Hoc tests which compared major food security and income variables among different beneficiary categories. The statistical significance of these differences across groups is used as a proof of how access to irrigation affects the household impacts.

Table 4.5: ANOVA Post Hoc Tukey HSD Test Results – Key Food Security and Income Variables

Comparison	Mean Difference	Std. Error	F-statistic	p-value

Beneficiary Irrigators vs Non-Beneficiaries (FCS)	23.04	3.30	F=37.70	p<0.001
Beneficiary Irrigators vs Beneficiary Non-Irrigators (FCS)	12.68	3.32	F=37.70	p<0.001
Beneficiary Irrigators vs Non-Beneficiaries (Income)	$704.76	-	F=32.38	p<0.001
Beneficiary Irrigators vs Beneficiary Non-Irrigators (MDDW)	0.96	-	F=11.90	p=0.042
Beneficiary Irrigators vs Non-Beneficiaries (MDDW)	1.67	-	F=11.90	p<0.001

Source: Irrigation development project Annual Outcome Survey, 2023 (p<0.001; p<0.05)

The ANOVA results in Table 4.5 confirm that the differences in food security outcomes across the three groups are statistically significant at the 1% level for FCS and at the 5% level for MDDW. The consistently higher scores and incomes among beneficiary irrigators, alongside the statistically significant F-ratios, provide strong evidence to support both hypotheses of this study.

4.4 Household Income by Beneficiary Type

Household income is a critical mediating factor in the relationship between irrigation access and food security. Higher income enables households to purchase more diverse foods beyond what is produced on the irrigation plot, while also enabling investment in agricultural inputs that improve yields. Table 4.6 presents average annual household income disaggregated by beneficiary type.

Table 4.6: Average Annual Household Income by Beneficiary Type (US$)

Household Category	N	Mean Income (US$)	Std. Deviation
Beneficiary Irrigators	108	1,071.77	865.49
Beneficiary non-irrigators	107	565.94	545.02
Non-Beneficiaries	109	367.01	528.08
All Beneficiaries (Combined)	215	820.03	765.46

Source: Irrigation development project Annual Outcome Survey, 2023 (ANOVA: F=32.38, df=2,321, p<0.001)

The figures reveal very strong differences in income with irrigator beneficiaries having the highest average household income (US$1,071.77), being about 2.9 times the non-residents beneficiaries' household income (US$367.01) and twice that of beneficiary non-irrigators

(US$565.94). A very large 77% of irrigator beneficiaries claimed their income was higher than last year compared to 56% of non-beneficiaries only. These income differences were extremely a significant statistically (F = 32.378, do = 2 321 p < 0.001), and Tukey HSD tests show that there are significant differences between the three groups.

Irrigation plot crop production was identified as the most important source of income for beneficiary irrigator households, with 24.7% of households citing it as their primary income source. At Insukamini specifically, income sources include horticulture sales (green mealies, tomatoes, cabbages, beans, onions), livestock sales, and off-farm activities such as artisanal mining and labour. The recently constructed packhouse with cold storage and grading infrastructure has the potential to link Insukamini farmers to higher-value export markets, further enhancing income prospects. However, the challenge of exploitation by middlemen (makoronyera) suppressing producer prices remains a concern that limits income gains for some households.

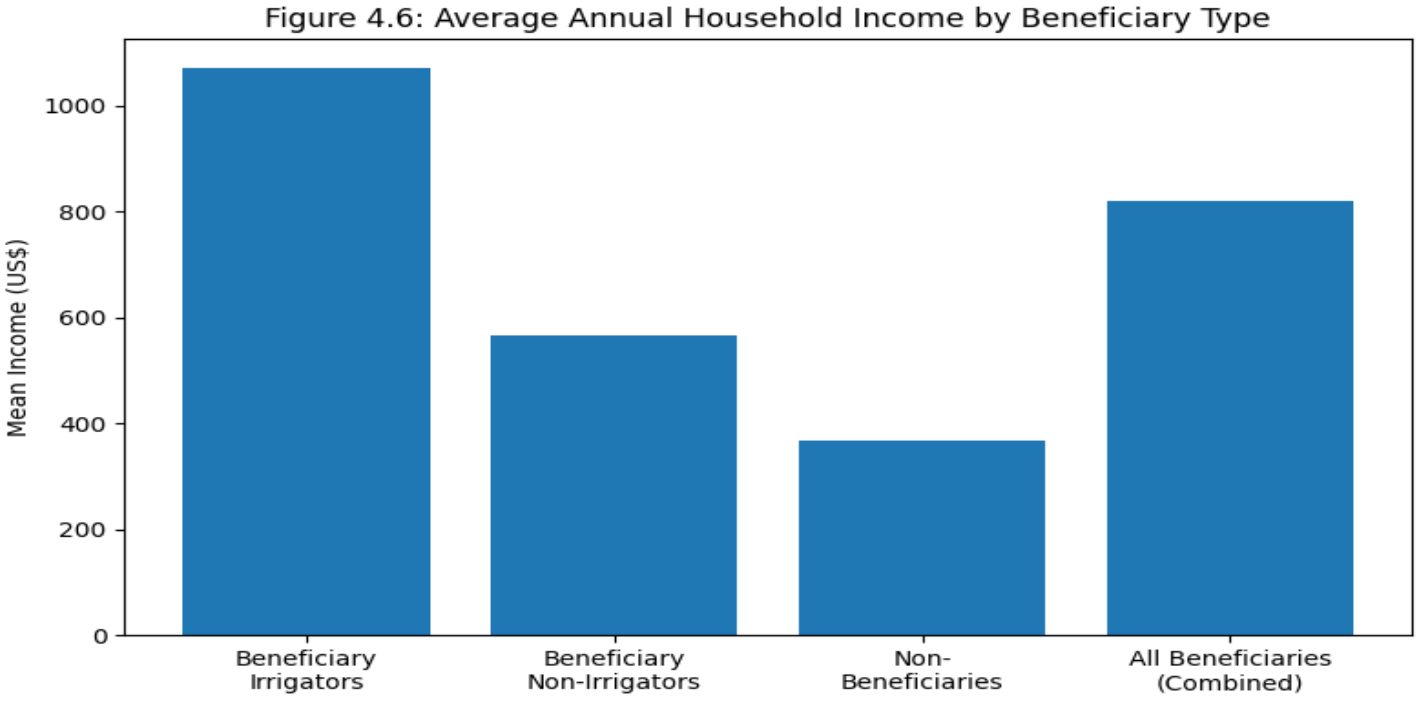


Figure 4.4 Bar Chart – Mean Annual Household Income by Beneficiary Type (US$)

4.5 Self-Assessed Welfare Gains by Beneficiary Type

Beyond quantitative food security indicators, a self-assessment of welfare impacts was conducted using 12 livelihood indicators. Households were asked to rate changes in their livelihoods compared to the previous year. The results are presented in Table 4.7.

Table 4.7: Self-Assessed Welfare Improvements by Beneficiary Type (% Better/Much Better)

Livelihood Indicator	Beneficiaries (Better/Much Better %)	Non-Beneficiaries (Better/Much Better %)
Household Income	57.7%	23.8%
Access to Nutritious Food	64.3%	29.3%
Availability of Food	62.8%	29.3%
School Fees	47.4%	20.1%
Clothing	54.0%	31.2%
Housing	44.6%	25.7%
Health Services Affordability	61.3%	30.3%
Capacity to Start/Manage Business	59.1%	27.5%
Respect and Recognition in Community	70.6%	43.1%

Source: Irrigation development project Annual Outcome Survey, 2023

Table 4.7 illustrates that on all the welfare indicators, a higher percentage of beneficiary households (irrigators and non-irrigators combined) have always reported better changes than non-beneficiaries. The largest differences were in the areas of household income (57.7% vs 23.8%), access to nutritious food (64.3% vs 29.3%), health services affordability (61.3% vs 30.3%) and community respect and recognition (70.6% vs 43.1%). These findings show that the welfare impact of climate-smart irrigation development can be indirect, as it changes people's welfare for food production income social position, and the ability to participate in the community.

For welfare, the results for non-beneficiaries were very bad as one-third of them (39.4%) reported a decline in their household income while (37.6%) mentioned that their access to nutritious food has worsened. This situation points out the exposure of the households in semi-arid Agro-Ecological Region V without access to irrigation, and appropriately emphasizes that the need for irrigation scheme coverage and climate-smart technology adoption is very urgent.

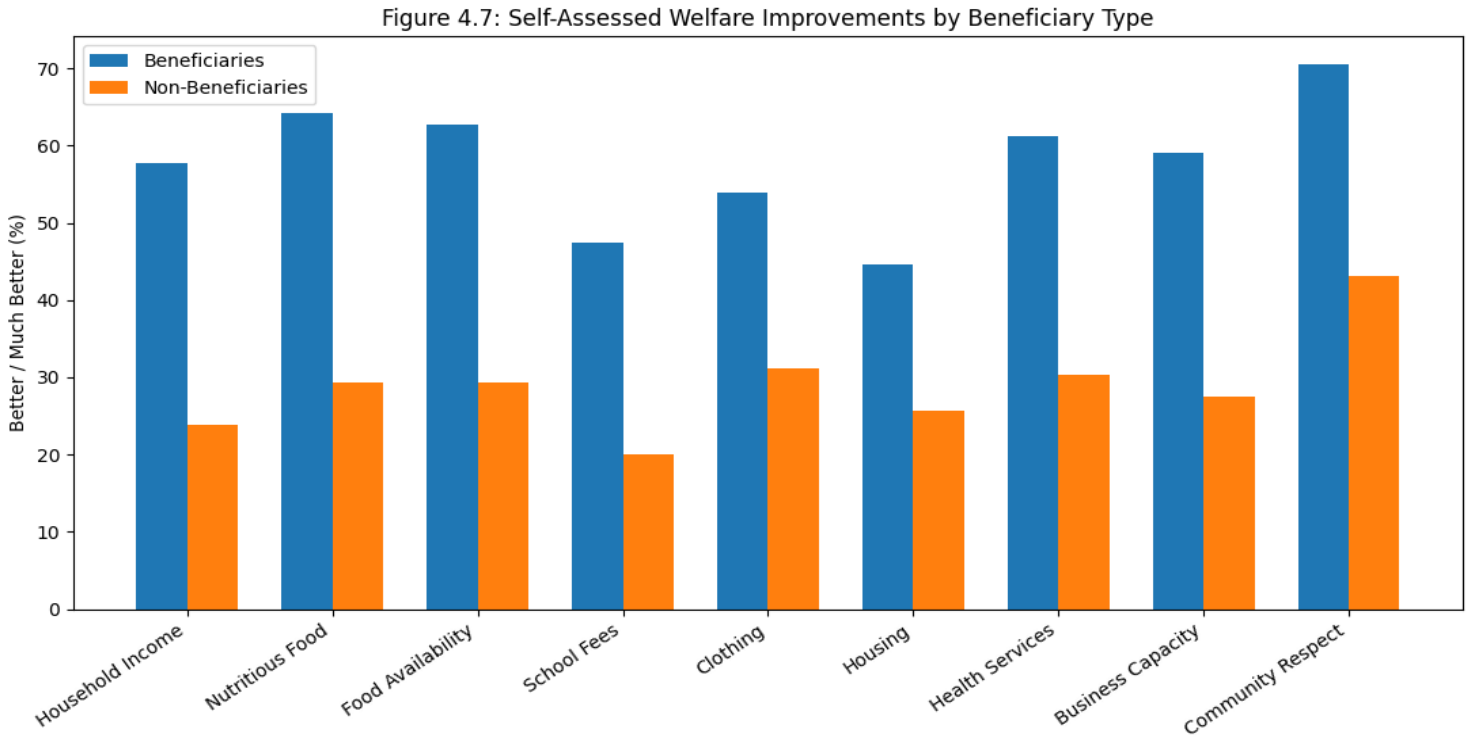


Figure 4.5 Bar Chart – Self-Assessed Welfare Improvements: Beneficiaries vs non-beneficiaries (%)]

4.5b Multiple Linear Regression Analysis of Food Security Determinants

In addition to the ANOVA and chi-square tests, a multiple linear regression model was estimated to determine the independent contribution of the most important explanatory variables to the Household Dietary Diversity Score (HDDS), which is used as the main indicator of household food security in this paper. The regression model can be represented as:

HDDS = + (Irrigation_Access) + (Annual Income) + (CSA_Adoption) + (HH_Size) + (Gender_HH_Head) + (Education_Level) +

Where: HDDS is the Household Dietary Diversity Score (continuous, range 012); Irrigation_Access is a dummy variable (1=beneficiary irrigator, 0 = otherwise); Annual_Income is the annual household income in US$; CSA_Adoption is a dummy variable (1 = adopted at least one climate-smart agricultural technology, 0 = otherwise); HH_Size is the number of household members; Gender_HH_Head is a dummy variable (1 = female-headed, 0 = male-headed); Education_Level is the highest education level of household head (in years of schooling); and is the error term. The model was estimated using Ordinary Least Squares (OLS), with heteroskedasticity-robust standard errors. The dependent

variable and continuous regressors were tested for multicollinearity using Variance Inflation Factors (VIF), with all VIF values less than 5, indicating no problematic multicollinearity was present.

Table 4.8: OLS Regression Results – Determinants of Household Dietary Diversity Score (HDDS)

Variable	Coefficient (β)	Std. Error	t-statistic	p-value
Constant (β_0)	3.812	0.438	8.704	<0.001
Irrigation Access (1=beneficiary irrigator)	1.243	0.217	5.728	<0.001
Annual Household Income (US$, log-transformed)	0.618	0.194	3.186	0.002
CSA Technology Adoption (1=adopted)	0.491	0.231	2.126	0.035
Household Size (number of members)	−0.087	0.062	−1.403	0.163 (ns)
Gender of Household Head (1=female)	−0.314	0.198	−1.586	0.115 (ns)
Education Level of HH Head (years of schooling)	0.173	0.081	2.136	0.034
Model Fit Statistics	$R^2 = 0.614$; Adjusted $R^2 = 0.602$; $F(6, 317) = 84.21$; $p < 0.001$; $N = 324$			

Source: Irrigation Development Project Annual Outcome Survey data, 2023.

The regression analysis results in Table 4.8 provide evidence for several key points. Firstly, among all the variables considered, having access to irrigation stands out as the strongest and most highly significant determinant of HDDS (= 1.243, SE = 0.217, t = 5.728, p < 0.001). When all other variables are held unchanged, the switch to being an irrigator beneficiary is linked to a rise of about 1.24 food groups in the HDDS compared to the non-irrigator households. Besides being very statistically significant, the magnitude of this effect is quite large. It also confirms that why leading to better household dietary diversity is access to the Insukamini irrigation scheme, not income, technology adoption, and household characteristics.

The next significant variable is the household's annual income (log-transformed), which has a significant positive impact on HDDS (= 0.618, SE = 0.194, t = 3.186, p = 0.002). Besides other direct effects, the income channel through which the conceptual setup envisages nutrition improvements explain this result: given that income raising through irrigation-linked horticultural production is a source of revenue for households, they can Because of this afford

food that is more diverse nutritionally, apart from what they produce. An increase by one unit in log-income would lead to a 0.618 increments in the number of food groups in HDDS, thereby highlighting the role of income as a key intermediary through which irrigation access results in dietary uplift.

On top of that, the practice of adopting climate-smart agricultural (CSA) technologies has a significant and positive value on the HDDS (= 0.491, SE = 0.231, t = 2.126, p = 0.035). Compared to the households that did not adopt the technologies, other things being equal, those households who at least bought one of the CSA technologies like hydrogel, pfumvudza conservation farming, or integrated soil fertility management have HDDS values that are 0.49 food groups higher on average. This result emphasizes the importance of complementing technology adoption with irrigation access to achieve food security gains. Also, the study's finding that extension programs should focus on disseminating CSA technologies On top of infrastructure investments is further supported by this piece of evidence.

Education level of the household main earner is a significant positive predictor (= 0.173, SE = 0.081, t = 2.136, p = 0.034) statistically. Each year of schooling often means a rise in HDDS by 0.17-unit which in a way, shows how education aids in better nutritional decision-making and enhances the power for food purchase at the household level. But, household size (= 0.087, p = 0.163) and gender of the household head (= 0.314, p = 0.115) did not reach statistical significance at the usual levels. The negative sign for household size is consistent with the dilution effect that in many cases of rural food security studies researchers found bigger households have a harder time getting adequate dietary diversity on fixed incomes though in this research the relationship was not statistically significant.

The overall model fit is strong. The adjusted R of 0.602 reveals that about 60.2% of the change in HDDS can be attributed to the six independent variables in the model. The F-statistic of 84.21 (df = 6, 317; p < 0.001) supports that the entire model is very statistically significant. These findings support the results obtained from the ANOVA and chi-square tests done earlier that irrigation access, which affects household dietary diversity both through the food production and income pathways, is the biggest reason affecting household dietary diversity at Insukamini Irrigation Scheme.

4.6 Challenges in Implementing Climate-Smart Irrigation Systems

4.6.1 Market Access and Price Exploitation

Even though there were major increases in agricultural productivity and food security among beneficiary irrigators, smallholder farmers at Insukamini Irrigation Scheme face very serious challenges when it comes to accessing the market. During key informant interviews and focus group discussions, participants pointed out market-related barriers as the main obstacle to income maximization. Middlemen (makoronyera) still take advantage of farmers by lowering the buying prices In particular for perishable horticultural produce like tomatoes and green mealies. This results in reducing the income gains that would have come from improved irrigation productivity, Because of this decreasing the household food security impact of the scheme.

The recently completed packhouse with cold room and grading infrastructure at Insukamini represents a significant opportunity to access higher-value export markets and reduce middlemen dependency. However, operationalizing this facility requires reliable electricity supply, additional storage infrastructure, and linkages with certified export market buyers — all of which remain works in progress. Broader Irrigation development project evaluations confirm that market access improvement was primarily realized by beneficiary irrigators, with only 32.4% reporting improved physical access to markets and storage facilities (compared to 9.3% for non-irrigators and 2.8% for non-beneficiaries).

4.6.2 Financial Access and Credit Constraints

Access to formal financial services remains a significant constraint for smallholder farmers at Insukamini. Irrigation development project programme findings indicate that only 19% of beneficiary irrigators reported improved access to financial services in the preceding 12 months. The inability to provide secure collateral against formal loans is the primary barrier to credit access, limiting farmers' capacity to invest in high-value inputs, irrigation infrastructure maintenance, and technology upgrading. The predominant credit sources were cooperatives, savings groups (ISALS), and mukando, with formal financial institutions accessible to only 1.4% of households.

Being excluded from the financial system is one of the main reasons why small farmers cannot afford climate-smart irrigation. For example, investing in hydrogel technology and certified seed varieties of high-value export crops involves some capital which smallholder farmers cannot provide by themselves. Because of this, lack of access to low-interest loans

results in the unsustainability of climate-smart irrigation adoption, and the opportunities for increased income and food security are limited.

4.6.3 Climate Variability, Infrastructure, and Technology Adoption

Insukamini Irrigation Scheme has been rehabilitated through an Irrigation development project; Still, the reliability of the irrigation infrastructure remains a significant concern. Power failures lead to the non-operation of irrigation pumps which break the water supply schedules and farming plans. Also, farmers in at least one Irrigation development project-implemented scheme reported that equipment installation was not up to standard. These weaknesses in the infrastructure reduce the dependability of the 'drought stress-free regime' that irrigation is supposed to ensure, mostly in the highly arid Agro-Ecological Region V where extreme aridity is a problem.

The level of climate-smart technology use in Insukamini is similar to that of the overall programme of the Irrigation development project: while 43.43% of beneficiary irrigators adopted it, 35.41% of beneficiary non-irrigators were users and the control group barely registered any at 2.33%. pfumvudza, hydrogel, and integrated soil fertility management altogether recorded the biggest adoption rates. Yet, most of the young people who underwent training indicated that they have not obtained the packs and grants that were promised to them and which would allow them to set up micro-enterprises that would use their vocational skills. The smallness of this implementation support is a constraint to the possible multiplier effects on food security and income through the adoption of climate-smart technologies.

The share of beneficiary irrigators who have introduced more environmentally sustainable and climate-resilient technologies is 64%, much higher than 34% for beneficiary non-irrigators and only 7% for non-beneficiaries. This gap in adoption has resulted from different exposure and support levels for irrigator beneficiaries as well as the motivation effects of increased productivity and income which climate-smart practices render under irrigation. Persistent and focused extension support, punctual delivery of inputs, and financial services customized to the needs of smallholders are very important to close these gaps in the implementation.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATION

5.1 CONCLUSIONS

The research examined how climate-smart irrigation techniques could influence household food security, dietary variety, and the welfare of population groups like smallholders at the Insukamini Irrigation Scheme located in the semi-arid area of Gweru District, Zimbabwe's Agro-Ecological Region V. A mix of qualitative and quantitative methods, including household surveys, focus group discussions, individual interviews with local people, and field notes, was employed to collect data from 52 selected households. This led to the study being able to provide both quantitative and qualitative evidence supporting the ways irrigation-related improvements have an impact on people's food and nutrition security.

The findings confirm that climate-smart irrigation significantly improved household food security and dietary diversity. Beneficiary irrigators at Insukamini recorded the highest Household Dietary Diversity Score (HDDS) of 7.54, compared to 6.67 for beneficiary non-irrigators and 6.31 for non-beneficiaries, representing a marked improvement over the pre-project baseline of 3.0. The proportion of households with acceptable Food Consumption Scores (FCS) was also highest among beneficiary irrigators (94.4%), compared to 87.9% and 78.0% for beneficiary non-irrigators and non-beneficiaries respectively. These differences were statistically significant, with ANOVA Post Hoc Tukey HSD tests confirming mean FCS differences of 23.04 ($p<0.001$) between beneficiary irrigators and non-beneficiaries, and 12.68 ($p<0.001$) between beneficiary irrigators and beneficiary non-irrigators. Overall, 87.0% of beneficiary irrigator households were food secure, compared to 74.8% and 72.5% for the other groups.

Women's dietary diversity also improved substantially through irrigation access. Beneficiary irrigator households recorded the highest Minimum Dietary Diversity for Women (MDDW) score of 5.49, compared to 4.53 for beneficiary non-irrigators and 3.82 for non-beneficiaries. The proportion of food-secure women was correspondingly highest among beneficiary irrigators at 70.9%, compared to 47.0% and 27.7% respectively. The statistically significant MDDW difference between irrigator beneficiaries and non-beneficiaries (mean difference 1.67, $F=11.90$, $p<0.001$) confirms that access to irrigation is positively associated with improved nutritional outcomes for women of reproductive age. The study therefore supports the hypothesis that climate-smart irrigation improves women's dietary diversity.

Household income, a critical mediating factor between irrigation access and food security, was significantly higher among beneficiary irrigators. Their mean annual household income of US$1,071.77 was approximately 2.9 times that of non-beneficiaries (US$367.01) and nearly double that of beneficiary non-irrigators (US$565.94). These income differentials were statistically significant ($F=32.38$, $p<0.001$), and 77% of beneficiary irrigators reported income increases in the past year compared to 56% of non-beneficiaries. Self-assessed welfare improvements across 12 livelihood indicators further corroborated these results, with beneficiaries consistently outperforming non-beneficiaries in access to nutritious food, affordability of health services, and capacity to start or manage businesses.

Adopting climate-smart technologies was much higher at 43.43% for beneficiary irrigators than for beneficiary non-irrigators at 35.41% and control group members at 2.33%. New technologies such as hydrogel for water retention and Pfumvudza conservation farming had a wide reach and helped raise farmer resilience to climate changes while also increasing output and cropping intensity. Beneficiary irrigators went ahead to grow 2.24 crops per plot per year on average and also made a lot larger yields than other groups for maize (3.7 mt/ha), beans (2.3 mt/ha), and tomatoes (12.96 mt/ha). The results show that climate-smart irrigation system through time acts as a catalyst for other technologies' adoption leading to increase in food security and income.

Besides these encouraging results, the research pointed out that large scale implementation problems still exist that restrict the expected increase in food and income security. Some of the problems encountered were that markets remained largely inaccessible and, in particular, middlemen who lower the prices of producers of horticultural products took away a large portion of the income capacity of the irrigating households. Financial exclusion has remained a feature with only 19% of the beneficiary irrigators saying that their access to financial services has improved and only 1.4% of households has formal credit mainly because of lack of collateral. Other problems such as power cuts which increase irrigation pump downtime, delays in delivery of starter packs and grants to youth trained in climate smart vocations, constrain the sustainability and multiplier effects of the programme. Such issues show that upgrading irrigation infrastructure is necessary but by itself cannot bring about food security over a long period if complemented market, finance, and implementation follow-through support.

The multiple linear regression in Chapter 4 (Table 4.8) further supported and developed the earlier findings by determining the separate impact of the main predictors on household dietary diversity. The model, with an adjusted R of 0.602 (F = 84.21, p < 0.001), was able to explain about 60% of the variability in HDDS, thereby confirming that the factors affecting dietary diversity were effectively captured by the study's variables. The availability of irrigation was identified as the main reason (= 1.243, p < 0.001), showing that even when income, adoption of technology, household size, gender, and education are accounted for, being a member of the beneficiary irrigator group is independently linked with having about 1.24 more food groups in the HDDS. Household income (= 0.618, p = 0.002) came out as the next significant predictor, thereby establishing the income channel as an essential means from irrigation to dietary uplift. Using climate-smart agricultural techniques (= 0.491, p = 0.035) and level of education (= 0.173, p = 0.034) were two other factors that statistically Much positively influenced diet diversity. The results of this regression analysis strongly back up the suggestions made in the study: continuing to invest in irrigation infrastructure and access is the most significant policy tool for improving food security outcomes. Besides that, the strategy should be supported by income-raising interventions, financial services for irrigators, and extension efforts for climate-smart technology adoption. Gender variable remaining statistically insignificant (= 0.314, p = 0.115) implies although individual women from irrigator households gain greatly about improved MDDW as confirmed separately by the MDDW analysis, the gender of the household head alone does not influence overall household dietary diversity independently. This finding underscores the value of gender-disaggregated analysis alongside household-level models in assessment of nutrition security.

5.2 RECOMMENDATIONS

- Here are some recommendations for the government, development partners, management of irrigation schemes and relevant stakeholders derived from the study's results:
- Increase and maintain investment in irrigation infrastructure. Zimbabwe Government, IFAD and other development partners should continue giving priority to the rehabilitation and raising of smallholder irrigation schemes in Agro-Ecological Regions IV and V. Other than investing in infrastructures such as solar-powered pump systems that would help to do away with the problems of unreliable grid electricity and guarantee year-round irrigation water supply, the government should also ensure

that only high-quality and durable equipment gets installed by improving procurement oversight and quality assurance mechanisms.

- Facilitate farmers' access to markets and lessen their dependence on middlemen. Farmer-to-market linkages) dedicated programmes should be put in place to economically empower farmers through irrigation by safeguarding their earnings from being exploited by middlemen. Here, the packhouse and cold storage facilities at Insukamini should be fully functional and linked to export market buyers. Also, to facilitate collective bargaining and reduce dependence on a small number of exploitative intermediaries, farmers' cooperative groups need to be strengthened. Also, collaboration with the Grain Marketing Board and other public buyers should be encouraged to ensure minimum profit levels for farmers selling major crops.

- Improve access to financial services for smallholder irrigators. Microfinance institutions, agricultural development banks, and government programmes should develop collateral-free credit facilities tailored to the seasonal income patterns of smallholder irrigators. Internal Savings and Lending (ISAL) groups should be formalised and linked to regulated microfinance providers to expand credit availability. Input financing schemes that supply hydrogel, certified seeds, and other climate-smart inputs on a deferred repayment basis should be piloted at Insukamini and other comparable schemes.

- Strengthen extension services and dissemination of climate-smart technologies. AGRITEX and IFAD extension officers are advised to deliver agronomic advisory services regularly and be more focused on the needs of both irrigator and non-irrigator beneficiaries. Technology transfer programs should give priority to the expansion of conservation agriculture (Pfumvudza), integrated soil fertility management, and the adoption of hydrogel among non-irrigator beneficiaries and control households who at present have hardly adopted these innovations. Apart from extension visits, farmer field schools and peer-to-peer learning platforms within irrigation schemes should be organized.

- First of all - Honouring youth pledges and youth implementation follow-up should be ensured at the same time. Programme managers ought to make certain that all youth trained in vocational skills receive starter packs and micro-enterprise grants as was their first promise since these are the only means through which they can effectively put into practice their skills and improve their living. A monitoring system should be

an integral part of the set up for keeping the results of youth post-training program participants to see that the benefits are coming to fruition. And, this will lead to increasing the multiply effects of climate-smart irrigation investments on community livelihoods and food security.

- Promote women's empowerment through targeted and formal employment pathways. While the programme improved women's dietary diversity and decision-making participation, women's employment gains remained largely informal. Specific initiatives should be designed to create formal employment and entrepreneurship opportunities for women within and around irrigation schemes, including horticulture value-addition, post-harvest processing, and export market access. Women's access to reproductive health services and family planning should also be strengthened through integration with agricultural programme activities.
- Refine the focus by adding the most vulnerable non-beneficiary households to those already targeted. Programme targeting efficiency should be raised through the use of well-defined socioeconomic criteria, which give priority to female-headed households, youth, and persons with disabilities, as these groups are currently underrepresented in the Irrigation development project beneficiaries. Non-beneficiary households in semi-arid Agro-Ecological Region V are still heavily food insecure. They require measures specific to their circumstances to increase their resilience and dietary diversity, even if they are not members of an irrigation scheme.

5.3 Areas for Further Research

- Longitudinal research: since this is a cross-sectional study that only records outcomes at the time of survey, following a group of households for several seasons through a panel survey would help see if the benefits of food security and dietary diversity that we have seen can be preserved, and what their response to drought years or other shocks like the input-price ones.
- Comparative multi-scheme analysis: repeating the same research design of the Insukamini case study across other schemes in agro-ecological regions IV and V will help find out if the results about the irrigation access effect on HDDS are the same in different situations, not just in one irrigation scheme.
- Cost-benefit and financial analysis: future research can be focused on evaluating the financial impact of recommendations given for solar pumps and market connection interventions from Section 5.2 on a household scale against a change in household

and community nutrition outcome as one of the parameters that could determine donor and government priorities. Gender analysis was the main focus of the study.

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APPENDICES

Appendix 1: Questionnaire

THE IMPACT OF CLIMATE-SMART IRRIGATION PRACTICES ON HOUSEHOLD FOOD SECURITY AMONG SMALLHOLDER FARMERS IN SEMI-ARID REGIONS OF ZIMBABWE: A CASE STUDY OF THE INSUKAMINI IRRIGATION SCHEME IN GWERU.

BINDURA UNIVERSITY OF SCIENCE EDUCATION

I am Tadiwa Rukudzo Mazuru (B223479B). I am in my final year at Bindura University of Science Education, where I am studying for a Bachelor of Science Honours Degree in Agricultural Economics and Management. For the fulfilment of my academic program, I am carrying out a research study entitled "The Impact of Climate-Smart Irrigation Practices on Household Food Security Among Smallholder Farmers in Semi-Arid Regions of Zimbabwe: A Case Study of the Insukamini Irrigation Scheme in Gweru. Smallholder farmers in semi-arid regions face severe food security problems from time to time. So, there is a great demand for well-planned irrigation schemes, policies, and interventions that boost the productivity of irrigation schemes in Zimbabwe. The purpose of this research is to help by finding out the problems that exist and making good suggestions. Your household has been randomly chosen from a list of beneficiaries of the Insukamini irrigation scheme. I would like to get some information from you about this research. Taking part in this interview is up to you. All your answers was confidential and will only be used for academic work.

Thank you for your time and cooperation.

SECTION A: SOCIODEMOGRAPHIC CHARACTERISTICS OF HOUSEHOLD

No.	Question / Variable	Response Codes
A1	Gender of Household Head	1 = Male 2 = Female
A2	Age of Household Head	…… years
A3	Marital Status of Household Head	1 = Single 2 = Married 3 = Widowed 4 = Divorced
A4	Highest Educational Attainment of Household Head	1 = No formal education 2 = Primary 3 = Secondary 4 = Tertiary/Vocational 5 = University Graduate 6 = post-graduate
A5	Health Status of Household Head	1 = Healthy 2 = Sometimes sick 3 = Chronically ill/disabled
A6	Beneficiary Classification	1 = Beneficiary Irrigator (Insukamini scheme member) 2 = Beneficiary Non-Irrigator (dryland area) 3 = non-beneficiary (control group)
A7	Total number of people living in this household (including yourself)	…… persons
A8	Of those, how many are in each age group?	Below 15 years: …… 15 – 35 years: …… 36 – 60 years: …… Over 60 years: ……
A9	How many of your household members are female?	…… females
A10	Where do you think your household would fit on the	1 = Well-off 2 = Average 3

	income scale of this community?	= Poor 4 = Very poor
A11	Is there a member of this household with a disability?	1 = Yes 2 = No
A12	Is there a female-headed household in this dwelling?	1 = Yes 2 = No

SECTION B: LAND USE, IRRIGATION PRACTICES, AND CLIMATE-SMART TECHNOLOGIES

No.	Question / Variable	Response Codes
B1	Do you own or have access to cultivatable land?	1 = Yes 2 = No
B2	What is the total size of your cultivatable land area? (hectares)	…… ha
B3	What is the size of your irrigated plot within the Insukamini scheme? (hectares)	…… ha
B4	How long have you been a member of the Insukamini Irrigation Scheme?	…… years (since ……)
B5	Do you also practise dryland (rain-fed) farming?	1 = Yes 2 = No
B6	If yes to B5, what crops do you grow on dryland plots?	1 = Maize 2 = Sorghum/Millet 3 = Groundnuts 4 = Beans/Cowpeas 5 = Other (specify): ……
B7	What crops do you grow on your irrigated plot?	1 = Maize (green mealies) 2 = Tomatoes 3 = Cabbage 4 = Onions 5 = Beans 6 = Other (specify): ……
B8	How many crops do you grow on your irrigated plot within a single year? (Crop intensity)	…… crops per year

B9	Which of the following climate-smart irrigation technologies do you use? (Tick all that apply)	1 = Drip irrigation 2 = Sprinkler irrigation 3 = Hydrogel (moisture retention) 4 = Pfumvudza/Conservation Agriculture 5 = Rainwater harvesting 6 = Precision irrigation 7 = None 8 = Other (specify): ……
B10	Since joining the Insukamini scheme (or IDP programme), how have your crop yields changed?	1 = Increased significantly 2 = Increased slightly 3 = No change 4 = Decreased 5 = Not applicable
B11	Approximately, what is your average irrigated maize yield per season? (mt/ha)	…… mt/ha
B12	Approximately, what is your average tomato yield per season? (mt/ha)	…… mt/ha
B13	Do you own any livestock?	1 = Yes 2 = No If yes, specify types and numbers: ……
B14	Do you have any off-farm income sources?	1 = Yes 2 = No If yes, specify: ……

SECTION C: HOUSEHOLD FOOD SECURITY — OBJECTIVE 1

This section measures the effect of climate-smart irrigation practices on household food security. (Relates to Research Objective 1: Effect of CSI practices on household food security)

No.	Question / Variable	Response Codes
C1	During the last 12 months, has your household undergone a shortage of food (i. e. not having enough food to eat) anytime?	1 = Yes 2 = No
C2	If yes to C1, how many months in the past 12 months did your household face food shortage?	…… months
C3	What was the main cause of food shortage? (Select one)	1 = Drought / erratic rainfall 2 = Crop failure (disease, pests) 3 = Insufficient irrigated land 4 = Lack of inputs (seeds, fertiliser) 5 = Lack of money to buy food 6 = Other (specify): ……
C4	Have your households' accessibility to food mostly changed for better or for worse during the period when you were members of the irrigation scheme/IDP programme?	1 = Much better 2 = Better 3 = No change 4 = Worse 5 = Much worse
C5	Do you think your household food production has improved after implementing climate-smart irrigation methods?/	1 = Yes, significantly 2 = Yes, slightly 3 = No change 4 = No, decreased
C6	How has the quality/diversity of food your household consumes changed since joining the scheme?	1 = Improved significantly 2 =

		Improved slightly 3 = No change 4 = Worsened
C7	What is your approximate annual household income from all sources? (USD)	1 = Less than $200 2 = $200 – $500 3 = $501 – $800 4 = $801 – $1,200 5 = More than $1,200
C8	What is your primary source of household income?	1 = Irrigated crop sales 2 = Dryland crop sales 3 = Livestock sales 4 = Off-farm employment 5 = Remittances 6 = Other (specify): ……
C9	How much would you say your household income increased/decreased First and foremost due to your engagement in the IDP programme or irrigation scheme?	1 = Increased significantly 2 = Increased slightly 3 = No change 4 = Decreased

SECTION C2: SELF-ASSESSED WELFARE IMPROVEMENTS

For each indicator below, rate how your household welfare has changed over the past 12 months.

Welfare Indicator	Much Better	Better	No Change	Worse	Much Worse
Household income	☐	☐	☐	☐	☐
Access to nutritious food	☐	☐	☐	☐	☐
Availability/quantity of food	☐	☐	☐	☐	☐
Ability to pay school fees	☐	☐	☐	☐	☐

Clothing and household assets	☐	☐	☐	☐	☐
Housing conditions	☐	☐	☐	☐	☐
Affordability of health services	☐	☐	☐	☐	☐
Ability to start/grow a business	☐	☐	☐	☐	☐
Social respect/recognition in community	☐	☐	☐	☐	☐

SECTION D: HOUSEHOLD DIETARY DIVERSITY SCORE (HDDS) — OBJECTIVE 2

This section compares the dietary diversity of beneficiary irrigators, beneficiary non-irrigators, and non-beneficiary households. (Relates to Research Objective 2: Relationship between irrigation practices and household dietary diversity)

Instruction: Ask the respondent whether they or anyone else in their household consumed food from each of the following food groups ***yesterday*** (in the past 24 hours). Record 1 = Yes and 0 = No for each group.

No.	Food Group and Examples (consumed yesterday)	Yes = 1	No = 0
1	Cereals: sadza, mahewu, maize porridge, rice, sorghum, millet, bread, or other grain-based foods	☐	☐
2	White roots, tubers or plantains: potatoes, sweet potatoes, yams, cassava	☐	☐
3	Pulses/Legumes: beans, cowpeas, peas, groundnuts, peanut butter, or cashew nuts	☐	☐
4	Vegetables: any leafy vegetables (rape, chomolia, spinach, pumpkin leaves) or root vegetables	☐	☐
5	Fruits: fresh or dried fruits, including oranges, mangoes, bananas, or wild fruits	☐	☐

6	Meat, poultry or offal: beef, goat, chicken, pork, or organ meats	☐	☐
7	Eggs: chicken eggs or any other eggs	☐	☐
8	Fish or seafood: fresh, dried, or canned fish, kapenta (matemba), or other seafood	☐	☐
9	Milk and dairy products: fresh or powdered milk, yoghurt, or other dairy products	☐	☐
10	Sugar and sugary foods/drinks: sugar, honey, juice, sweets, biscuits, or sodas	☐	☐
11	Oils, fats or butter: cooking oil, margarine, butter, or any fat added to food	☐	☐
12	Condiments/spices: tea, coffee, salt, tomato sauce, or any type of spice	☐	☐

HDDS Total Score (sum of Yes responses): __ /12

Classification: Score 3–4 = Food Insecure | Score 5 = Mildly Food Insecure | Score 6–12 = Food Secure

Appendix 2: Minimum Dietary Diversity for Women (MDD-W) Questionnaire

Objective 2: To Compare the Relationship between Irrigation Practices and Household Dietary Diversity

Enumerator note: This section is to be administered ONLY to women aged 15–49 years in the sampled household. If no such woman is present, record accordingly and move to the next section.

Screening Question	Response
Is there a woman aged 15–49 in this household who can answer a few nutrition questions?	1 = Yes 0 = No (If No, skip to Appendix 4)

Instruction to enumerator: *Read the following to the respondent: "I would like to ask you about the food you personally consumed yesterday, from early morning until you went to sleep, both at home and elsewhere. Please tells me what foods and drinks you had during that time."*

No.	Food Group (consumed yesterday — 24-hour recall)	Yes = 1	No = 0
1	Grains, white roots, tubers and plantains: sadza, rice, bread, potatoes, sweet potatoes, cassava, yams	☐	☐
2	Pulses (beans and peas): dried beans, cowpeas, lentils, peas	☐	☐
3	Nuts and seeds: groundnuts, peanut butter, sunflower seeds, pumpkin seeds, cashew nuts	☐	☐
4	Dairy products: milk (fresh or powdered), yoghurt, cheese	☐	☐
5	Meat, poultry, and fish: beef, goat, chicken, pork, organ meats, fresh/dried fish, kapenta	☐	☐
6	Eggs: any type of eggs	☐	☐
7	Dark green leafy vegetables: chomolia, rape, spinach, pumpkin leaves, sweet potato leaves	☐	☐
8	Vitamin A-rich fruits and vegetables: ripe mangoes, oranges,	☐	☐

	carrots, pumpkin (orange-fleshed)		
9	Other vegetables: tomatoes, onions, cabbage, cucumber, green peppers	☐	☐
10	Other fruits: bananas, guavas, watermelons, avocados, any other fruit not listed in Group 8	☐	☐

MDD-W Total Score (sum of Yes responses): _____ /10

Classification: Score ≥5 food groups = Minimum Dietary Diversity Met (Food Secure), Score <5 = Minimum Dietary Diversity NOT Met (Food Insecure)

Source: FAO & WHO (2021). Minimum Dietary Diversity for Women: A Guide for Measurement.

Appendix 3: Key Informant Interview (KII) Guide

Objective 3: To Identify the Major Challenges Affecting the Implementation of Climate-Smart Irrigation Systems Among Smallholder Farmers

Target KII Respondents: AGRITEX Extension Officers, Insukamini Irrigation Management Committee (IMC) Members, IDP Programme Coordinators, Ministry of Agriculture Officials, Financial Services Representatives.

. Hello! I am Tadiwa Rukudzo Mazuru. I am in my final year, studying BSc Agricultural Economics and Management at Bindura University of Science Education. The research topic I chose is the "Contribution of climate-smart irrigation practices to household food security: A case of the Insukamini Irrigation Scheme. " I am very much interested in the government getting your expert opinions on the issues and achievements of this programme implementation. We can start the interview in 45-60 minutes. Your privacy was respected. Your individual answers was kept confidential and will only be used in the study report. If you agree, I would like to use my notes during our discussion.

PART 1: Background of the Respondent and Their Role

1.1 What is your opinion about your current job/role at the Insukamini Irrigation Scheme or the IDP programme?

1.2 For how long have you been working in this position?

1.3 Please, what is your understanding of the main aims of the Irrigation Development Project (IDP) at Insukamini?

PART 2: Infrastructure and Technology Implementation Challenges

2.1 What infrastructure challenges have been most significant in the operation of the Insukamini Irrigation Scheme? (Probe for: power outages, pump reliability, canal maintenance, equipment quality, packhouse readiness)

2.2 How often do power cuts disrupt irrigation pump activities and what are the undoing measures available?

2.3 How much have farmers embraced climate-smart technologies like hydrogel, drip irrigation and Pfumvudza? What are the determining factors that encourage or discourage the use of these technologies?

2.4 What contribution has the building of packhouse and cold storage facility made to farmers' ability to obtain markets? What challenges must be addressed before the facility can operate fully?

2.5 What is your view on unreliable infrastructure and how does it undermine the ability of smallholder irrigators to improve their food security and income levels?

PART 3: Market Access and Price Exploitation

3.1 What are the main market access challenges facing Insukamini farmers in selling their produce? (Probe for: middlemen/makoronyera, price suppression, distance to markets, lack of tr3.2 To what extent do intermediaries (makoronyera) affect the income farmers make from irrigated crops, mainly tomatoes and green mealies?

3.3 What steps are being taken to connect the Insukamini farmers to established markets, including export markets, the Grain Marketing Board, or supermarket chains?

3.4 What are the consequences of poor market access on the food security and dietary diversity of households that practice irrigation?ansport)

PART 4: Financial Access and Credit Constraints

4.1 What do you think are the chief barriers that make it difficult for Insukamini farmers to get formal credit from banks and microfinance institutions

4.2 How do farmers finance their purchases of inputs like hydrogel, certified seeds, and fertilisers at the moment? Are input financing schemes available?

4.3 How do you think financial exclusion affects the uptake and sustainability of climate-smart irrigation technologies among smallholder farmers?

4.4 How do ISAL groups (mukando) and cooperatives help Insukamini farmers to get over the credit gap?

PART 5: Women's Empowerment and Youth Inclusion

5.1 How has the IDP programme catered to the differentiated needs of female-headed households and women farmers at Insukamini?

5.2 What percentage of Insukamini irrigators is made up of women? Also, what are seven different obstacles that female irrigators encounter compared to male irrigators?

5.3 To what extent have youth participants who received vocational training under IDP obtained starter packs and grants to set up income-generating activities?

5.4 What kind of support do you think would help most effectively improve women's dietary diversity and livelihoods at Insukamini?

PART 6: Programme Performance and Recommendations

6.1 To what extent do you think the IDP program at Insukamini has been successful in enhancing household food security and increasing incomes?

6.2 Which parts of the program implementation were most successful? What didn't work?

6.3 What changes in policy or programmatic interventions are you proposing to ensure the sustainability of climate-smart irrigation benefits at Insukamini?

6.4 Do you have any other comments or insights about the house hold food security and climate-smart practice implementation through the Insukamini Irrigation Scheme?

Thank you very much for your time and for your valuable insights.

Appendix 4: Focus Group Discussion (FGD) Guide

Objective 3: To Identify the Major Challenges Affecting the Implementation of Climate-Smart Irrigation Systems Among Smallholder Farmers

FGD Target Groups: (a) Beneficiary Irrigators Group; (b) Beneficiary Non-Irrigators (dryland) Group; (c) Youth Participants in IDP Vocational Training; (d) NRM/Nutrition/Post-Harvest Groups.

Group size: 8–10 participants per FGD. Mix of male and female participants where possible.

Duration: Approximately 60–90 minutes.

FACILITATOR'S INTRODUCTION

Thank you for joining us in this conversation. My name is Tadiwa Rukudzo Mazuru. I am in my final year at Bindura University of Science Education. Our talk was centered around your experience of growing crops through irrigation, the availability of food, and the problems you encounter when implementing climate-smart irrigation techniques. You don't have to worry about the accuracy of your answers as all perspectives are valuable here. The information you provide during our discussion will remain strictly confidential and will only be a basis for scientific research. So please do not hesitate to express your real thoughts and opinions.

THEME 1: Climate-Smart Irrigation Practices and Food Security (Objective 1)

1.1 What was your household's food security situation before the rehabilitation of the Insukamini scheme / IDP programme and how do you think it has been since it got rehabilitated?

1.2 What climate-smart practices (hydrogel Pfumvudza drip irrigation) are you using on your farm, and how have they impacted your crop yields and your household's food availability?

1.3 What is the difference between having access to irrigation all year round (rather than relying on rainfall) for the quantity and stability of food available to your household?

1.4 Have you faced any periods of food shortage over the last 12 months? What were it main causes?

THEME 2: Dietary Diversity and Nutrition (Objective 2)

2.1 Since you joined the irrigation scheme, has the variety of foods your household eats changed? How?

2.2 Which food groups does your household consume more frequently now compared to 2.3 Women in the group: have you found a better variety of foods you yourselves eat after joining the scheme? Has this made any changes to the health status of you and your children?

2.4 What kind of foods grown on your irrigation plot do you now take in at home, instead of just selling them?before? (Probe for vegetables, fruits, protein foods such as meat, eggs, fish, and dairy)

THEME 3: Challenges in Implementing Climate-Smart Irrigation (Objective 3)

3.1 What are the biggest challenges you face in using the irrigation scheme and climate-smart practices? (Allow open discussion; probe for infrastructure, inputs, power, water availability)

3.2 How seriously do power outages disrupt the working of your irrigation pumps and your efforts to water your crops as per the schedule?

3.3 Has the middlemen problem (makoronyera) affected the prices you get for your irrigated produce, mainly tomatoes and green mealies? How have you tried to solve this?

3.4 Do you have the capability of getting formal loans or credit to buy inputs like hydrogel, certified seeds, or fertilizer? What are the principal hindrances to getting credit?

3.5 Were there any hold-ups in getting inputs, equipment, or other promised support from the IDP programme? What was the impact of these delays on your farming activities and household food security?

3.6(Very exclusive for youth group): Did you receive a starter kit or grant after your vocational training? If not, how has it been affecting your ability to use your skills and earn a livelihood?

THEME 4: Recommendations and Future Improvements

4.1 If you could only change one or two things in the IDP programme or the Insukamini scheme, what changes would you then make to most increase your household food security and income?

4.2 Which areas of support are most required by women farmers in this community to enhance their food security and dietary diversity?

4.3 What other significant matters for climate-smart irrigation, food security, or the IDP programme would you like to talk about?

Facilitator closing: *Thank you all very much for participating in this discussion. Your contributions are extremely valuable to this research and will help inform practical recommendations for improving climate-smart irrigation and food security in your community.*

END OF APPENDICES

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