

Bindura University of Science Education

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**EVALUATING THE LINK BETWEEN IRRIGATION REHABILITATION AND
HOUSEHOLD NUTRITION SECURITY, AMONG VULNERABLE
SMALLHOLDER FARMERS IN SEMI-ARID REGIONS OF ZIMBABWE
A CASE OF THE SILALABUHWA IRRIGATION SCHEME IN FILABUSI**

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

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A CASE OF THE SILALABUHLWA IRRIGATION SCHEME IN FILABUSI, INSIZA
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DECLARATION

I, Arnold T. Kepekepe, do hereby declare my work in this dissertation titled "Evaluating the link between irrigation rehabilitation and household nutrition security among Smallholder Farmers in Semi-Arid Regions of Zimbabwe: A Case of Silalabuhwa Irrigation Scheme in Filabusi, Insiza District, Matebeleland South Province" to be my own, original piece and has not been submitted before for any degree programme or other qualification. It is admission that the help and advice from my supervisor, Mr Govere, and other academic staff were instrumental to this work still the dissertation's intellectual content and presentation are entirely mine. I have complied with the rules and guidelines of Bindura University of Science Education on plagiarism, academic integrity, and accurately cited and referenced all the information sources used in this dissertation.

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DEDICATION

“I dedicate all my efforts to the Almighty Lord Jesus Christ, family, university, brothers and sisters in Christ, and agriculture sector of Zimbabwe, for the unwavering support they have provided unto me since the day I embarked on my journey to acquire my Bachelor of Science Honours Degree in Agriculture Economics Management”.

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ABSTRACT

Amongst the most popular ways of dealing with hunger issues in arid areas is improving their irrigation infrastructure. Nonetheless, there has never been any literature that emphasize the impact of irrigation rehabilitation on improved nutrition for the locals, mostly in semi-arid environments in southern Africa. Thus, the research will be conducted through studying the experience at Silalabuhwa Irrigation Scheme situated in Filabusi, Insiza District, Matabeleland South Province in Zimbabwe, an area of 442 hectares and rehabilitated within 2019 to 2023 under the Smallholder Irrigation Development Project (SIDP). Being an area within Agro-ecological Region IV where the annual rainfall is mostly less than 650 mm, making it highly vulnerable to famine, Silalabuhwa offers an excellent platform for understanding whether or not irrigation rehabilitation would lead to notable dietary changes.

The study aims three intricately related objectives. Firstly, to assess and compare Household Dietary Diversity Scores (HDDS) of SIDP irrigator beneficiaries with those of non-beneficiary dryland farmers living in the same environmental zone. Secondly, to establish if women of ‘reproductive age’ in the programme attain the minimum dietary diversity for Women (MDD-W) cut-off, i. e. five food groups; and thirdly, to investigate the contribution of SIDP-promoted bio-fortified crops mainly NUA 45 iron-and-zinc-rich beans, orange maize, and orange-fleshed sweet potatoes on the nutritional status of families involved. A mixed-methods approach was a selected method of study combining structured household survey questionnaires that were administered to 51 households through Kobo Collect, focus group discussions, and key informant interviews with AGRITEX officers and Irrigation Management Committee members. The quantitative data were firstly entered into a database and then statistically analysed with the support of SPSS software. Different analysis techniques such as ANOVA, post-hoc Tukey HSD tests, chi-square, and bivariate correlation were used. However, qualitative data were examined through thematic analysis.

The results indicate that the difference in dietary diversity between the two groups was statistically significant. Beneficiary irrigators had a mean HDDS of 7.54 whereas the non-beneficiaries scored 6.31 on average ($F = 15.213$, $p = 0.000$), with 87.0% and 74.3% of the former and the latter respectively being classified as food secure. The Silalabuhwa scheme average of 6.94 positions it among the top-performing SIDP schemes. For the MDD-W indicator, beneficiary irrigators had an average score of 5.49 a little higher than the five-

group cut-off while the scheme-level average of 4.46 indicates that quite a number of women still do not get minimum micronutrient dietary adequacy, a situation partly due to the schemes relatively low agricultural income and the factional conflicts over the block farming tenure arrangement. On bio-fortified crops, 39.22% of Silalabuhwa households used drought-tolerant varieties including orange maize, and the same percentage of families practiced diversified cropping that included NUA 45 beans. Beneficiary irrigators' consumption of legumes was 77.8% instead of 52.3% for non-beneficiaries, and tubers as 56.5% versus 33.9%, these consumption patterns directly account for part of the MDD-W difference observed.

The study suggests that putting in irrigation system at Silalabuhwa was a key thing in raising household dietary diversity, actually it was the first hypothesis to be confirmed. But, there is still plenty of scope for other areas to perform better. Besides generating infrastructure, the SIDP voucher program has been instrumental in the introduction of bio-fortified crops and as a result diversified the food basket. Financial status and seed availability remain the main factors influencing nutritional security, mainly among women in their fertile years. Besides that, farmers who do not support the block farming system are another source of problem. For that reason, focusing on both food availability and economic empowerment is a key lesson for communities or projects alike to experience significant changes, says continuous efforts are necessary.

Table of contents

RELEASE FORM.....	i
APPROVAL FORM.....	ii
DECLARATION	iii
DEDICATION.....	iv
ACKNOWLEDGEMENTS.....	v
ABSTRACT.....	vi
LIST OF TABLES.....	xii
LIST OF FIGURES	xiii
LIST OF ACRONYMS AND ABBREVIATIONS	xiv
CHAPTER 1 INTRODUCTIONS.....	1
1.1 Background	1
1.2 Statement of the Problem	2
1.3 Research Questions	3
1.4 Research Objectives	3
1.4.1 Main Objective.....	3
1.4.2 Specific Objectives.....	3
1.5 Research Hypotheses.....	3
1.6 Significance of the Study/Justification.....	4
1.7 Scope and Limitations of the Study	4
1.7.1 Scope of the Study.....	4
1.8 Organization of the Research	5
CHAPTER 2	6
LITERATURE REVIEW	6
2.1 Introduction	6
2.2 Concepts and Definition of Key Terms.....	6
2.2.1 Irrigation.....	6

2.2.2 Smallholder Irrigation	6
2.2.3 Smallholder Irrigation Development in Zimbabwe	7
2.2.4 Food Security	7
2.2.5 Nutrition Security	8
2.2.6 Food and Nutrition Security	8
2.2.7 Dietary Diversity (DD).....	8
2.3 Empirical Literature Review	9
2.3.1 Comparison of Household Dietary Diversity Scores (HDDS) between beneficiaries and non-beneficiaries	9
2.3.2 Achievement of Minimum Dietary Diversity for Women (MDD-W) among participating households.....	10
2.3.3 Impact of producing and consuming bio-fortified crops on nutritional outcomes.....	10
2.4 Conceptual Framework	11
2.4.1 Smallholder Irrigation rehabilitation – food and household nutrition security linkages.	11
.....	13
The Food production pathway	13
The agriculture income pathway	14
The water supply pathway.....	14
The women’s empowerment pathway.....	14
2.5 Insight from the Literature	15
CHAPTER 3	17
METHODOLOGY	17
3.1 Introduction	17
3.2 Description of the Study Area.....	17
3.2.1 Location.....	17
3.2.2 Population and Area	18
3.2.3 Climatic conditions	19

3.2.4 Agricultural activities	19
3. Economic Activities	19
Agricultural Marketing	20
Financial Services and Internal Savings and Lending (ISALs)	20
Youth Entrepreneurship and Micro-enterprises	20
Diversified Income Strategies	20
Silalabuhwa Small-scale Irrigation Scheme	21
Research Design	21
3.4 Sampling Technique and Sample Size	21
3.5 Data Collection Methods	22
3.5.1 Data Types and Sources	24
3.5.2 Data Collection Techniques	25
3.6 Method of Data Analysis	25
CHAPTER 4	28
RESULTS AND DISCUSSION	28
4.1 COMPARISON OF HOUSEHOLD DIETARY DIVERSITY SCORES (HDDS) BETWEEN BENEFICIARY IRRIGATORS AND NON-BENEFICIARY DRYLAND FARMERS AT SILALABUHW A IRRIGATION SCHEME.	28
4.2 TO ASSESSMENT OF MINIMUM DIETARY DIVERSITY FOR WOMEN (MDD- W) AMONG HOUSEHOLDS PARTICIPATING IN SILALABUHW A IRRIGATION SCHEME.....	31
4.3 IMPACT OF PRODUCING AND CONSUMING BIO-FORTIFIED CROPS ON NUTRITIONAL OUTCOMES OF BENEFICIARY HOUSEHOLDS.	35
4. 3. 2 Qualitative Evidence on Consumption of Bio-fortified Crops and Nutritional Change.....	37
4.3.3 MULTIPLE REGRESSION ANALYSIS OF DETERMINATS OF HOUSEHOLD DIETARY DIVERSITY SCORE (HDDS) AT SILALABUHW A IRRIGATION SCHEME	40
4.3.3.1 Model Specification.....	40
4.3.3.2 Regression Results.....	40

4.4 CHAPTER SUMMARY	43
CHAPTER 5	44
CONCLUSIONS AND RECOMMENDATIONS	44
5.1 CONCLUSIONS	44
5.2 RECOMMENDATIONS	46
REFERENCES	47
APPENDICES	53
Appendix 1: Questionnaire.....	53
Appendix 1: Household background information.....	54
Appendix 2: Household Dietary Diversity Score (HDDS)	55
Appendix 3: Minimum Dietary Diversity for Women (MDD-W).....	57
Appendix 4: Bio-fortified crop production and consumption.....	58
Section D1: Bio-fortified crop adoption	59
Section D2: Perceived Nutritional & Livelihood Impact	59
Section D3: Technology Adoption Checklist	60
Appendix 5: Focus Group Discussion & Key Informant Interview Guide	61

LIST OF TABLES

Table 3. 1. . Summary of Data Collection	23
Table 3.2. Summary of Data Analysis	25
Table 4. 1 Household Dietary Diversity Score (HDDS) & classification by Beneficiary Type	29
Table 4. 2 ANOVA F-test for comparison of mean HDDS by Beneficiary Type.....	30
Table 4. 3 Minimum Dietary Diversity for Women (MDD-W) by beneficiary type and at Silalabuhwa.....	32
Table 4. 4 Proportion of households consuming specified food groups by beneficiary type..	33
Table 4. 5 Technology adoption scores at Silalabuhwa compared with all beneficiary irrigators and non-beneficiaries.	35
Table 4. 6 OLS Multiple Regression results for Determinants of HDDS at Silalabuhwa Irrigation Scheme (n=51).....	41

LIST OF FIGURES

Figure 2: 1 Building blocks of the concept of household nutrition security.....	9
Figure 2: 2 Smallholder Irrigation-Nutrition Linkages.....	13
Figure 3: 1 Study Map of Silalabuhwa (Silalatshani) District of Insiza, Matabeleland South Province	18
Figure4: 1 Household Dietary Diversity Score (HDDS) by beneficiary type, Silalabuhwa ...	29
Figure4: 2 Food security classification by beneficiary type (%)	30
Figure4: 3 Mean MDD-W score by household category	32
Figure4: 4 Food group consumption by beneficiary type (%)	34
Figure4: 5 Technology adoption scores at Silalabuhwa vs all beneficiary irrigators (%)	36

LIST OF ACRONYMS AND ABBREVIATIONS

AGRITEX: Agricultural Technical and Extension Services

ANOVA: Analysis of Variance

ASM: Artisanal and Small-Scale Mining

DD: Dietary Diversity

FAO: Food and Agriculture Organization

FCS: Food Consumption Score

FGD: Focus Group Discussion

FGDs: Focus Group Discussions

GMB: Grain Marketing Board

GPS: Global Positioning System

HDDS: Household Dietary Diversity Score

IFAD: International Fund for Agricultural Development

ILO: International Labour Organization

IMC: Irrigation Management Committee

ISALs: Internal Savings and Lending Schemes

JIMAT: JIMAT Development Consultants

KII: Key Informant Interview

KIIs: Key Informant Interviews

KOBO: Kobo Collect

MDD-W: Minimum Dietary Diversity for Women

MLAWFRD: Ministry of Lands, Agriculture, Water, Fisheries and Rural Development

MSC: Most Significant Change

NGO: Non-Governmental Organisation

NUA: Nutritious Underutilized African (Bean Variety)

OFID: OPEC Fund for International Development

SEM: Standard Error of Mean

SIDP: Smallholder Irrigation Development Project

SIDP: Smallholder Irrigation Development Project

SPSS: Statistical Package for the Social Sciences

UNIDO: United Nations Industrial Development Organization

WASH: Water, Sanitation and Hygiene

ZIMLAC: Zimbabwe Livelihoods Assessment Committee

ZIMSTAT: Zimbabwe National Statistics Agency

ZIMVAC: Zimbabwe Vulnerability Assessment Committee

CHAPTER 1 INTRODUCTIONS

1.1 Background

Agriculture not only is one of the three main sectors of the economy but also accounts for approximately 18% of the country's economic output (ZIMSTAT, 2023). The sector occupies a large portion of the entire land area in Zimbabwe and contributes much to the development and livelihoods of rural communities in the country. Yet, agriculture is encountering a gamut of challenges due to climate-related hazards, In particular in semi-arid regions. The country has a potential irrigable land area of 366,000 hectares but at present only about 124,000 hectares are irrigated (FAO, 2024). Such a shortfall implies that areas like Matabeleland South that depend entirely on rainfall, experience crop failure and food scarcity.

One notable intervention that addresses these environmental challenges is the Silalabuhwa Irrigation Scheme found in Filabusi within the Insiza District of Matabeleland South province. Located in the arid Agro-ecological Region V where there are frequent droughts and high temperatures, the scheme has been described as being like an important "oasis in the desert," whereby food production would not be feasible if not for irrigation (Shambare, 2024). Formally launched in 1966 on a total of 360 hectares, the project currently operates on an area covering 442 hectares with approximately 845 members (Munamati et al. 2005; The Herald, 2024). Following its revival, the project had been rendered idle for quite some time due to the lack of maintenance of its physical structures, such as excessive waste of water in canals and dysfunctional dam outlets (SIDP, 2022).

The Smallholder Irrigation Development Project (SIDP) was a significant step forward, a seven-year programme with investment from IFAD, OFID and government of Zimbabwe. It started in November of 2017 aiming to rehabilitating more than 6,100 hectares of irrigated land in the semi-arid regions at the same time providing 35,000 smallholder farmers with these facilities (IFAD, 2024; Nkala, 2025). For Silalabuhwa, a project worth US\$400,000 was aimed at rehabilitating the dam intake system, the infield canal system, as well as the night storage dams (Ndlovu, 2024). More exactly, this project was for the Pelandaba South

scheme and it assisted in the rehabilitation of 30 hectares of land thereby increasing the irrigable area by almost 319 percent. Yet, these structural modifications should not stand as the final objective of the agricultural programs. Actually, achieving food and nutrition security remains as one of the main objectives. These problems are confirmed by the Zimbabwe Livelihoods Assessment Committee report which revealed that Matabeleland South Province had the highest percentage of households that reported livestock deaths, at 30%. Also, more than 60% of households in this province did not have any cattle (Zimbabwe Livelihood Committee, 2024). Alongside this rehabilitation investment, the smallholder irrigation project (SIDP), also funded by IFAD and OFID in partnership with the Government of Zimbabwe, was implemented across six irrigation schemes in semi-arid Zimbabwe between 2019 and 2023, with Silalabuhwa being one of the targeted schemes. It is the outcomes of SIDP that form the primary data basis of this study.

To address micronutrient deficiencies in this region, the SIDP introduced bio-fortified foods including the NUA 45 iron beans and the orange vitamin A maize, which were only available through a voucher system (Mabhaudhi et al., 2019). We should highlight that these crops were deliberately chosen since NUA 45 beans are resistant to adverse weather conditions and they cook quickly. Currently, more than 29% of people are adopting these beans (Kudita, 2023). So, the authors of this report are aiming at a nutrient-based assessment of the effect brought about by the physical completion of irrigation scheme.

1.2 Statement of the Problem

Despite vast amounts of money being spent on the rehabilitation of Silalabuhwa Irrigation Scheme, the link between irrigation potential and nutrition security at the consumption level seems largely ignored. In Filabusi, due to the effects of Region IV, households endure the "triple burden" of malnutrition, i. e. undernutrition, micronutrient deficiencies, and over nutrition.

The SIDP Annual Outcome Survey (JIMAT Development Consultants, 2023) reveals that the average Household Dietary Diversity Score (HDDS) for beneficiary irrigators is 7.54, compared to 6.31 for non-beneficiary households, but it is not clear if the progress spurred by the provision of irrigation facilities also benefits the most disadvantaged, In particular women of reproductive age. And, socio-institutional aspects, such as the rumour that the "block system" led to the refusal of 99 plot owners to participate at Silalabuhwa, might have prevented an equitable sharing of nutritional gains. Without a focused study on dietary

diversity and nutrient-rich food sources in Silalabuhwa, it remains debatable if the project has achieved its aim of promoting "nutrition security" over just "food security."

1.3 Research Questions

1. What is the statistical difference in the Household Dietary Diversity Score (HDDS) between beneficiary irrigators at Silalabuhwa and non-beneficiary dryland farmers in the surrounding Filabusi area?
2. To what extent do women of reproductive age participating in the Silalabuhwa scheme meet the Minimum Dietary Diversity for Women (MDD-W) threshold of five food groups?
3. How does the adoption of bio-fortified crops (e.g., NUA 45 beans and orange maize) correlate with the nutritional status of beneficiary households.

1.4 Research Objectives

1.4.1 Main Objective

"To evaluate the link between irrigation rehabilitation at the Silalabuhwa Irrigation Scheme and household nutrition security among vulnerable smallholder farmers in semi-arid Filabusi, Insiza District."

1.4.2 Specific Objectives

1. To compare the Household Dietary Diversity Scores (HDDS) of SIDP beneficiary irrigators and non-beneficiary dryland farmers in the Silalabuhwa area.
2. To assess the achievement of Minimum Dietary Diversity for Women (MDD-W) among households participating in the scheme.
3. To determine the impact of producing and consuming bio-fortified crops on the overall nutritional outcomes of beneficiary households.

1.5 Research Hypotheses

- H1: Beneficiary irrigators in the Silalabuhwa irrigation scheme have a significantly higher mean HDDS than non-beneficiary dryland farmers.
- H2: There is a significant positive relationship between the production of SIDP-promoted bio fortified crops and the attainment of the MDD-W threshold in participating households.

- H3: Households that adopted SIDP-promoted bio-fortified crops, specifically NUA 45 iron beans and orange maize, record significantly higher Household Dietary Diversity Scores (HDDS) and are more likely to meet the Minimum Dietary Diversity for Women (MDD-W) threshold compared to non-adopting households in the Silalabuhwa area.

1.6 Significance of the Study/Justification

Many government departments such as the Ministry of Lands, Agriculture and Water Fishery and Rural Development and external agencies such as IFAD will find the report of this study very helpful. In fact, focusing on the Silalabuhwa farm where there are socio-institutional problems will reveal the importance of people's perception of the block tenure system as it relates to nutrition.

1.7 Scope and Limitations of the Study

1.7.1 Scope of the Study

The main focus of the paper is on three indicators of nutrition that will direct its efforts: scoring the variety of food consumed by household (HDDS), the criteria for MDD-W (Minimum Dietary Diversity for Women), and the purchase and consumption of bio-fortified crops like NUA 45 iron beans and orange maize, that were highly promoted by SIDP. The paper Still did not consider those nutritional assessments that require measuring the body directly or clinically, like taking bodily measurements, conducting blood micronutrient testing, or monitoring child growth since these areas are considered to be beyond the scope of agricultural economics.

The study is temporal in that it is conducted using data collected from the years 2023-2025 farming seasons, which are after the rehabilitation at Silalabuhwa following SIDP intervention. The target population will consist of small holder farmers' households at the Silalabuhwa irrigation scheme and dry land farmers' households adjacent to the irrigation scheme. Filabusi as an AGRITEX area.

.1.7.2 Limitations of the Study

Scheme Participation Disputes: Approximately 99 plot owners at Silalabuhwa reportedly refused to participate in SIDP activities due to concerns over the block farming tenure system (JIMAT Development Consultants, 2023). These households could not be included as full

SIDP beneficiaries, which may introduce selection bias into the beneficiary group and limit the generalisability of findings.

Self-Reporting Bias: Data on bio-fortified crop production, consumption, and income are self-reported by household respondents, which may be subject to social desirability bias, particularly regarding quantities consumed versus sold.

Limited Generalisability: The findings of this study are specific to the Silalabuhwa Irrigation Scheme and the surrounding Filabusi area. They cannot be directly generalised to other irrigation schemes in Zimbabwe or other semi-arid regions without further research.

1.8 Organization of the Research

This research study is composed of five distinct chapters. The first chapter includes the background of the study, problem statement, and objectives of the study, research question, hypothesis significance of the study, as well as the scope and limitations of the study. The second chapter deals with the literature review that elucidates the irrigation-nutrition link. In chapter three, the method will be presented. For the data analysis, SPSS will be employed using the HDDS method. Chapter four is dedicated to the interpretation of the findings.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This will entail the examination of theories regarding the rehabilitation of the irrigation system and their connection with nutritional status in relation to the proposed study framework. In this regard, there is going to be introduction to some of the key concepts which apply in the research process in relation to Silalabuhwa Irrigation Scheme, in Filabusi. The concepts include the concept of small scale irrigation scheme, HDDS, among others which form part of the food and nutrition security. In addition, we will examine the literature regarding irrigation, HDDS, MDD-W, and biotechnology like high iron beans and orange maize.

2.2 Concepts and Definition of Key Terms

2.2.1 Irrigation

Irrigation is the artificial application of water into the soil to ensure the continued growth of plants crops in regions where rainfall is low. Irrigation ensures that there is sufficient moisture content in the soil, agricultural output and continuous growth of crops irrespective of the fluctuations in rainfall levels. In the case of Zimbabwe, irrigation is viewed as the best strategy in overcoming the challenges posed by climate change in agro-ecological regions IV and V.

This approach is viewed as an approach through which agriculture can be sustained throughout the year by supplying water for the crops. By so doing, drought and mid-season dryness which result from rainfall agriculture can be avoided. An irrigation practice should be applied in places experiencing a rainfall cycle of 5 years.

2.2.2 Smallholder Irrigation

Small scale irrigation generally happens at schemes that could be communal or even the older resettlement schemes where the natural resources are used jointly by many households, usually with a household plot of around 0. 4 to 0. 5 hectares on average (International Fund for Agricultural Development [IFAD], 2016; Government of Zimbabwe & IFAD, 2016). S

These kinds of schemes be a lifeline for vulnerable households who do not have sufficient resources by boosting their productivity (IFAD, 2016; FAO, 2015).

2.2.3 Smallholder Irrigation Development in Zimbabwe

Origins of smallholder irrigation in Zimbabwe date back to the 1920s when abstraction schemes were initiated in the drier parts of the south and west of the country to provide food aid to Africans on difficult to exploit communal lands (Manzungu & van der Zaag, 1996; Rukuni et al., 2006). Following independence in 1980 irrigation development became key to development in the rural environment mainly in the drought prone Natural Regions III, IV and V where unreliable rains constrained rain-fed agriculture (Vincent and Thomas, 1960; Mugabe and Kugedera, 2021). Yes, many schemes (Silalabuhwa -60 years old-, Garwisi -50 years old-, Tughwini -20 years old-, Buhera -19 years old-, Sotame -9 years old-, Bonde -4 years old-, Muhobwe -2 years old), including the oldest, Silalabuhwa (established in 1966), are in very poor condition, poorly irrigated, economically not viable and in need of rehabilitation after decades of poor maintenance, under-financing, and economic crises in the country (Munamati et al., 2005; The Herald, 2024).

To address this, the Government of Zimbabwe has launched recovery projects together with IFAD and OFID, like SIDP and SIDP; they supported development of over 6,100 hectares in semi-arid regions (IFAD, 2024). Their innovation is to integrate nutrition sensitive activities such as bio-fortified crops promotion and women empowerment with physical infrastructure restoration (JIMAT Development Consultants, 2023). So, the national plans such as Zimbabwe Agriculture Investment Plan 2, explicitly promote irrigation as just one component that guarantees rural food and nutrition security according to researched findings from the Ministry of Lands, Agriculture, Water, Fisheries and Rural Development, 2020.

2.2.4 Food Security

The availability of food that is consistently safe, healthy, and capable of fulfilling one's dietary needs and desires is what defines food security (Food and Agriculture Organization, 2009). The role of food security in farming can be traced to the indirect ways through which food security leads to a greater level of food production stability, higher incomes of rural populations, lesser number of hungry people, and stronger resistance against economic and environmental hazards (Food and Agriculture Organization, 2009; World Bank, 2021).

2.2.5 Nutrition Security

Nutrition security is defined as a state where people always have access not only to enough food but also to proper nutrients, safe water, health services, and appropriate care, all of which are essential for a good and active life (International Fund for Agricultural Development, 2016; Food and Agriculture Organization, 2012). When it comes to agriculture, nutrition security matters because it is a way of increasing the food variety at household level, improving both health and the ability to work, within rural communities, fighting malnutrition and making smallholder farming households that are the most at-risk, become more resilient through increasing their agricultural production, and living off of irrigation-based systems (IFAD, 2016; FAO, 2012).

2.2.6 Food and Nutrition Security

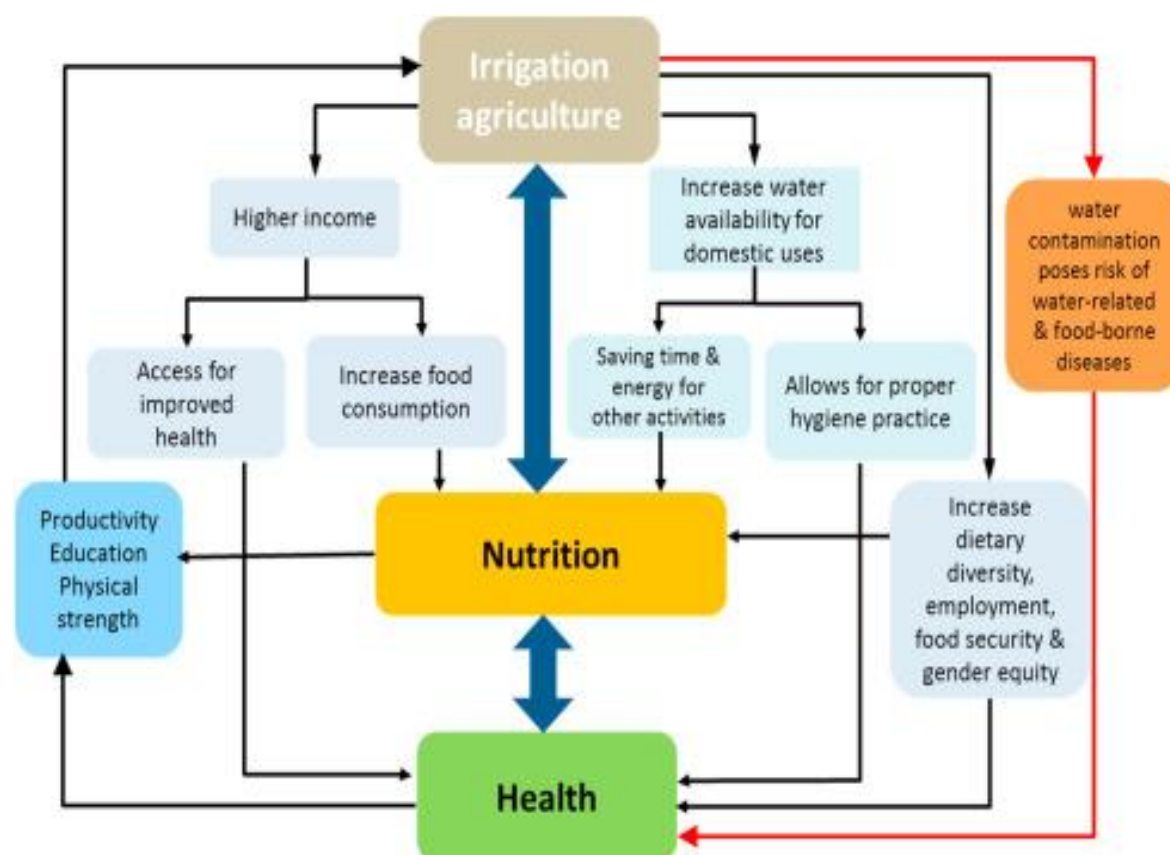
Nutrition and food security are closely linked, with the aim to support small-scale producers and make them resilient to climate change and economic shocks through enhancing their production capacity and income generation, as well as through improved nutrition intake (IFAD, 2016; FAO, 2017).

2.2.7 Dietary Diversity (DD)

Dietary diversity refers to the different types of foods and food groups a person or household consumes over a given period of time, and it is often employed as a measure of dietary quality and food availability at the household level (Food and Agriculture Organization, 2011). Within the Smallholder Irrigation Project (SIDP) at the Silalabuhwa Irrigation Scheme in Filabusi, dietary diversity is a central outcome indicator, as irrigation expansion enables smallholder households to access a wider variety of nutritious foods year-round (IFAD, 2016), leading to the smallholder households having access to more varieties of nutritious foods and because of this enhancing their nutrition security and reducing their vulnerability to economic and climatic shocks (International Fund for Agricultural Development, 2016).

Besides that, dietary diversity is a qualitative index of food intake and nutrition adequacy. It accounts for the number of food groups consumed in diet within a certain period. Household Dietary Diversity Score (HDDS) reflects the household's economic ability to access diverse foods, whereas Minimum Dietary Diversity for Women (MDD-W) is a proxy for their micronutrient adequacy

Figure 2: 1 Building blocks of the concept of household nutrition security



Source: Okyere and Usman, 2020

2.3 Empirical Literature Review

2.3.1 Comparison of Household Dietary Diversity Scores (HDDS) between beneficiaries and non-beneficiaries

The HDDS can be used in measuring the access to different foods. The aim of the study will be to compare the level of dietary diversity among the beneficiaries of irrigation schemes and people in the drylands that do not benefit from this facility. Several studies have revealed that people benefiting from irrigation schemes exhibit high productivity and earn more income making it possible for them to access different kinds of foods throughout the year hence a high dietary diversity score (Passarelli et al., 2018). As opposed to the people in irrigation schemes, people in dry lands will be unable to utilize this benefit owing to the climatic factors.

Previous studies carried out in different parts of Africa including Ethiopia, Tanzania, Malawi, and South Africa have reported that the dietary diversity among the irrigation household is comparatively high due to availability and access to food products and markets (Jones, Shrinivas and Bezner-Kerr, 2014). Similarly, another study conducted in Zimbabwe also found that crop production and involvement in food market activities contributed to high dietary diversity.

2.3.2 Achievement of Minimum Dietary Diversity for Women (MDD-W) among participating households.

The Minimum Dietary Diversity for Women (MDD-W) is one of the crucial indicators used to gauge the adequacy of nutrients in women of reproductive age. The objective is to determine whether or not the households enrolled in the smallholder irrigation scheme have reached the threshold of minimum dietary diversity. As per Food and Agriculture Organization, women eating a minimum of five food groups out of ten in a day are considered to be more likely to satisfy their nutritional needs (FAO & FHI 360, 2016). By enrolling in smallholder irrigation scheme, the households have increased access to nutritious vegetables, fruits, and legumes and income to purchase other nutritious foods throughout the year (Domènech, 2015).

Previous research studies conducted in Ethiopia, Ghana, and Tanzania showed that enrollment in irrigation activities contributed positively towards the nutrition status of women through food availability and income ((Hirvonen et al., 2016; Passarelli et al., 2018; Kuwornu et al., 2020). Households supported with irrigation facilities in Zimbabwe were also found to exhibit better consumption patterns and less seasonal food security (Mango et al., 2018). Even though dietary diversity among women may be constrained by poor nutrition knowledge, cultural foods preference, and unfair allocation of food in households, assessment of MDD-W will provide information on how smallholder irrigation schemes affect nutrition among women.

2.3.3 Impact of producing and consuming bio-fortified crops on nutritional outcomes

The cultivation and consumption of bio-fortified crops have been proposed as an eco-friendly approach towards solving problems of micronutrient deficiency among rural farming households. This study aims at establishing the effect that the production and consumption of bio-fortified crops can have on the nutritional status of households benefiting from such

efforts. Examples of bio-fortified crops include vitamin A enriched maize, orange fleshed sweet potatoes, iron-rich beans, and zinc-enriched wheat which contain important micronutrients needed for improved nutrition and prevention of hidden hunger (Bouis & Saltzman, 2017).

Research carried out in various nations like Uganda, Rwanda, Mozambique, and Zambia found that households with bio-fortified food had an improvement in terms of vitamin A consumption, iron, and diet diversity (Hotz et al., 2012; Finkelstein et al., 2017; Birol & Bouis, 2019). In addition to this, efforts to promote vitamin A maize and orange maize types in Zimbabwe have helped improve food security of small-scale farmers (Muzhingi et al., 2011). Nonetheless, for the bio-fortified food to bring about positive nutritional results, there is a need to factor in elements such as farm production, nutritional knowledge, and consumption (Saltzman et al., 2013).

2.4 Conceptual Framework

2.4.1 Smallholder Irrigation rehabilitation – food and household nutrition security linkages.

Conceptual framework of irrigation rehabilitation and food/household nutrition security provides us with the path through which the development of irrigation facilities occurs to improve agricultural production, which eventually results in increased incomes and ultimately good nutrition of the rural populations. By investing in improving irrigation facilities, farmers become dependent on consistent availability of water and using such water for irrigation purposes helps them to produce additional crops, change their cropping patterns and farm all year round (Domnech, 2015). Improved agriculture will result in better availability of food in rural households as well as lead to better nutrition because of high consumption of healthy foods, such as vegetables, legumes and bio-fortified crops, among others.

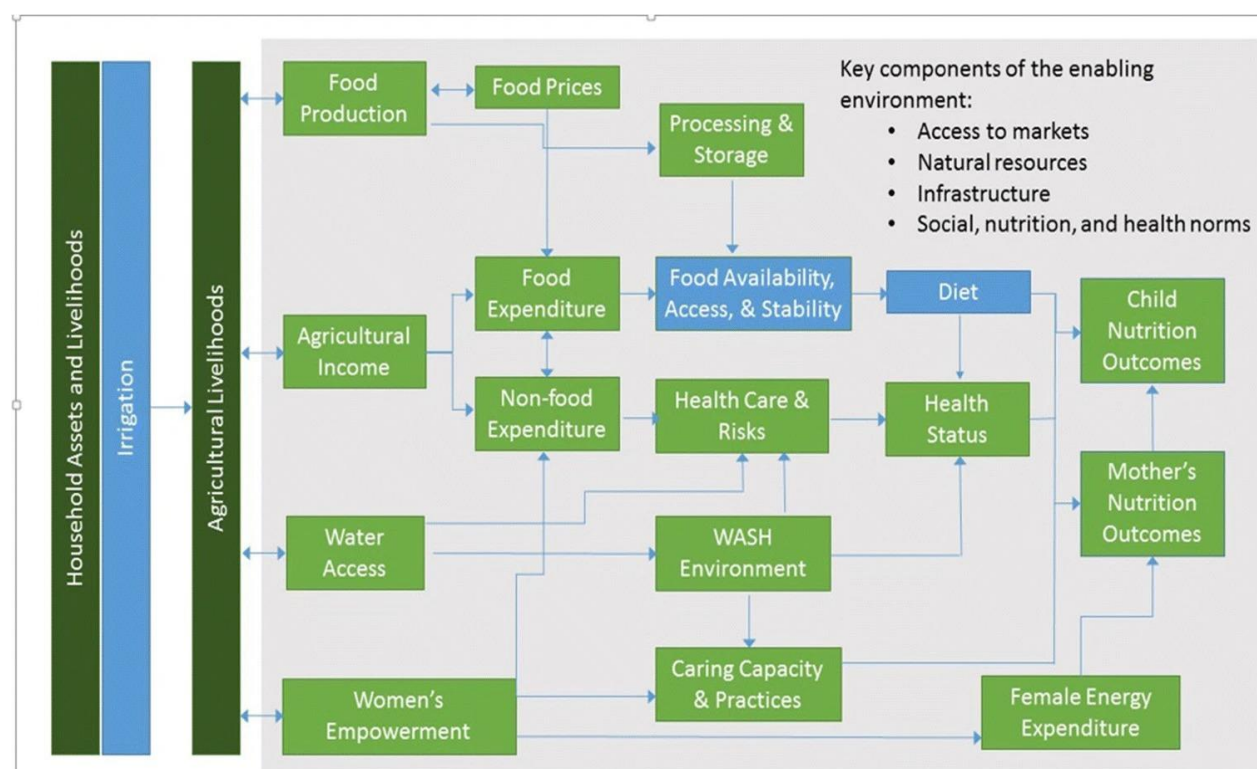
This configuration also shows that enhancing irrigation is an effective way to raise household income, mainly if the additional income is used for market-oriented production activities. The increased household income through irrigation will raise the purchasing power of a household, which in return will give them access to different types of food, health care services, and other necessities for a better life, so leading to good nutrition. On another note, irrigated farming has a great potential to be a women's empowerment tool, leading to better

food preparations and choices at the family level, and ultimately improving the MDD-W and child nutrition (FAO, 2013).

However, several intermediaries can exist between irrigation and nutrition including changes in climate, availability of inputs for farming, nutrition awareness, and access to markets, and decision making in households (Hirvonen et al. 2016). This is why the design suggests that rebuilding irrigation systems affects food and nutrition security through social networks, community involvement in food production, diet, and household consumption practices.

Irrigation is one of productive assets capable of changing farming livelihoods. It does so by the four main elements of food production, farm income, water supply, and women's empowerment which in turn, can bring changes in food and nutrition outcomes (Passarelli et al. 2018). Below is a diagram illustrating the potential impact of irrigation on food security, health and nutrition.

Figure 2: 2 Smallholder Irrigation-Nutrition Linkages



Source: Passarelli et al., 2018

As shown above, the four major pathways namely food production, agricultural income, access to water, and women's empowerment are explained in the sections below.

The Food production pathway

The food production pathway explains how irrigation improves household food and nutrition security by increasing agricultural productivity and stabilising crop production throughout the year. Access to irrigation allows farmers to cultivate crops during dry seasons, reduce dependence on erratic rainfall, and diversify production into nutrient-rich foods such as vegetables and legumes (Domènech, 2015).

An improvement in productivity and diversification of crops results in an increase in food production and thus food supply at household level. In most smallholder agricultural settings, the use of irrigation also helps lower risks of drought-related crop failure, thus helping to ensure food reliability for farmers living in such conditions (Passarelli et al., 2018). Irrigation may help improve food production, which can contribute to food consumption and market stability in developing countries (Namara et al., 2011).

The agriculture income pathway

The income pathway explains how irrigation improves household income through productivity improvement and marketing. Irrigation access gives farmers the opportunity to grow crops throughout the year without being entirely dependent on rainfall and even venture into growing high-value cash crops such as fruits and vegetables. Higher productivity usually leads to higher household income that can be used for purchasing different foods and accessing healthcare services as well as improving living standards. All these activities greatly contribute to ensuring food and nutrition security (Hussain & Hanjra, 2004). Moreover, irrigation is known to create job opportunities as well as improve rural livelihoods of small-scale farmers (Namara et al. 2011). With increasing income levels, households also get more resistance to cope with any economic or climate-based shocks.

The water supply pathway

Water supply route shows that one of the avenues through which irrigation might help improve food security and nutrition is by facilitating access to safe and reliable water for not only farming but also for domestic use. To begin with, the provision of irrigation often means increased water availability not only for crops but also for animals cooking sanitation, and hygiene, which in the end results in health and nutrition improvements. And, when the time spent on water fetching is shortened women who are the majority, get an opportunity to do more productive work and take care of children (Passarelli et al. 2018). Also to other rural areas, having reliable water enables farmers to grow nutritious food all year round and at the same time protects them against food shortages and droughts (Domnech, 2015). Still, incorrect water management can bring the spread of water-borne diseases, In particular in areas with low sanitation standards (FAO, 2016).

The women's empowerment pathway

For instance, women's empowerment mechanism demonstrates the link between irrigation and household food and nutrition security through the multiple ways of women's agricultural production, income generation, and decision-making capacities being intensified. Ill-equipped with infrastructures for irrigation, women usually have to bear the brunt of water collection and other physical farming activities that may deprive them of time for more productive and income-generating ways of work. Apart from that, women in irrigated agriculture have greater influence in deciding how household resources should be allocated for food, health, and nutrition of children, thereby leading to dietary diversification and food security (Meinzen-Dick et al. 2019). On top of that, empowerment through the acquisition of resources, training, and joining farmer organizations not only enhances women's control over agricultural production but also household welfare (Passarelli et al. 2018). Because of this, irrigation expansion is capable of not only elevating the socio-economic position of women but at the same time it might cause better nutrition and health outcomes in rural families (van den Bold et al. 2015).

2.5 Insight from the Literature

A thorough examination of the literature and local evidence unveils major elements that not only deeply enrich our understanding of this research but also spotlight the pathways for its continuance. First of all, the mode of irrigation rehabilitation can be a double-edged approach for both putting food on the table and dealing with the uncertainty of rainfall. In fact, the statement was supported by the evidence even under the harsh situations of semi-arid regions. One of such areas is Filabusi. Irrigated farming, Then again, is fundamentally distinguished by truth is it has a higher yield of agricultural production thanks to multiple cropping in a year brought about by water facilities. In other words, two or three rounds of crop production performed by farm households utilizing irrigation would result in better agricultural production and food supply in general (Food and Agriculture Organization [FAO], 2022; Mupangwa et al. 2022).

The ability to produce throughout the year is the one thing which dryland farmers lack. Production capacity in this case relies on rainfall during a particular season, and sometimes this might not be achieved. During drought periods, farmers experience crop failure, leading to food insecurity (Zimbabwe Vulnerability Assessment Committee, 2023). Most research emphasizes the high variation between HDDS among irrigated and non-irrigated households,

where irrigated households have more dietary diversity in all food groups (Makombe et al. 2022).

As a result, the described gap becomes the starting point in developing the first objective of this study, which focuses on an intensive assessment of HDDS of farmers benefiting and not benefiting from the SIDP in an identical agro-ecological setting.

In addition to the problem of sufficiency of caloric intake, the matter of gender inequality should be mentioned since it significantly affects the nutritional situation among subsistence households. As reported in the literature, women of reproductive age are mostly responsible for meal management and cooking, and this specific category of women suffers from deficiencies of micronutrients (Passarelli et al. 2018). The described problem becomes the main reason why the MDD-W indicator is used in this study as the measurement of food consumption rich in micronutrients and thoroughly validated in the literature.

From practical experience, it appears that the potential to employ irrigation may, in itself, be enough to create some level of impact in terms of the quality of women's diets. However, social and cultural considerations also serve to impede any progress towards making such gains through agriculture (Smallholder Development Project [SIDP], 2022). In rejecting block farming due to land ownership concerns as well as its alleged function as plant pay rise, the residents of Silalabuhwa offer a clear demonstration of how institutions and socio-cultural concerns work to make it difficult to use agricultural development for nutritional purposes (JIMAT Development Consultants, 2023 Ministry of Lands Agriculture Water, Fisheries and Rural Development MLAWFRD, 2020).

Moreover, another important aspect found in literature regarding bio-fortification and its increasing use in enhancing nutrition in small-scale irrigated agriculture is noteworthy. However, such a technique has yet to be extensively studied. The relationship between irrigation and food security has long been documented in previous studies. However, while it is evident from research that the use of bio-fortified products like NUA 45 beans that contain high iron content, along with Vitamin A-enriched maize, could help improve nutrition levels and subsequently contribute to better health outcomes, such a statement cannot be validated by any concrete evidence, since very little literature exists on the topic (Mupangwa et al. 2022; SIDP, 2022). In Zimbabwe, the farmers of Silalabuhwa make quinoa with maize for protein bio-fortification, among others. Unfortunately, no evidence can be provided for health

and nutrition security as per available country-level data (JIMAT Development Consultants, 2023).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will describe the research methods used for this study. A mixed methods approach was chosen, which combines quantitative and qualitative techniques, to effectively meet the research objectives. The chapter deals with research design, data collection, sampling, and analysis process used throughout the study.

3.2 Description of the Study Area

3.2.1 Location

Silalabuhwa Irrigation Scheme is positioned in Insiza District, in Matabeleland South Province in Zimbabwe. The district is southeast of Bulawayo, about 77 km, and its total area is 8,221 km. Matabeleland South Province which supports the scheme is 54,172 km, making up 13.86% of Zimbabwe's total land area. According to the 2022 census, the province has a population of 760,345 of people and a density of about 14 persons/km. The population of Insiza District is 122,903 people with the central coordinates at 20°19'54"S, 29°14'29"E. It is located in Natural Region IV, which experiences low and erratic rainfall of 450-650mm annually, periodic droughts, and a livestock-based farming system with drought-resistant crops kept to a minimum. The scheme was one of six targeted under the Smallholder Irrigation Development Project (SIDP), a programme aimed at agro-ecological regions

susceptible to climate stress and high levels of poverty (JIMAT Development Consultants, 2023). Insiza District is 469km nearer to Harare, the capital city of Zimbabwe.

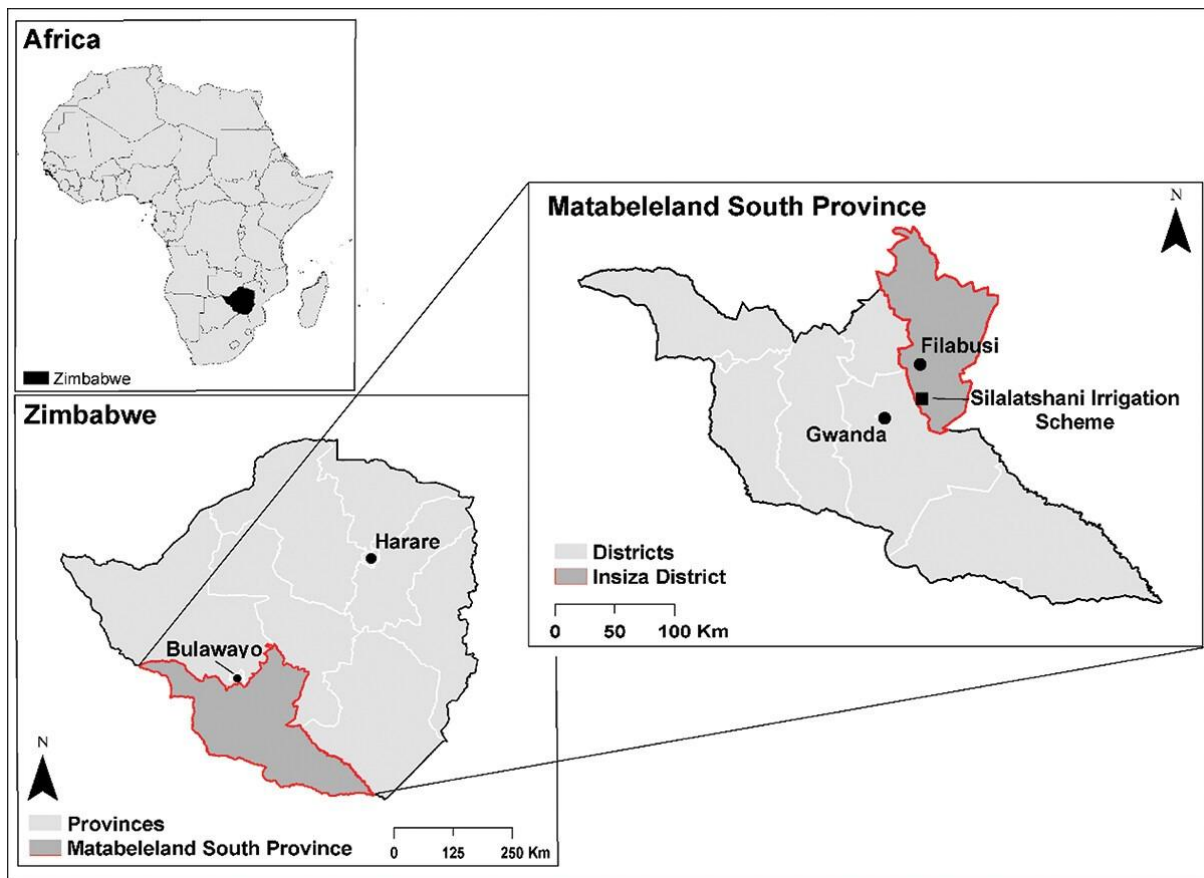


Figure 3: 1 Study Map of Silalabuhwa (Silalatshani) District of Insiza, Matabeleland South Province

Source: Parry, K. (2025)

3.2.2 Population and Area

Insiza District, is one of the seven districts of the Matabeleland South Province and has an area of 8,221 km, thus according to the 2022 census. It was estimated to have a population of 122,903 people and 18 rural council wards. The Silalabuhwa Irrigation Scheme was established in the 1960s and is located in Wards 3 and 11 of Insiza District with a potential irrigable area of 442 ha and a membership of 845 which are registered (Zimbabwe National

Statistics Agency, 2012). Out of these wards, 397 are women and 349 men who have plots which gives a gender ratio of about 53:47 (JIMAT Development Consultants, 2023).

3.2.3 Climatic conditions

Silalabuhwa and Insukamini irrigation schemes are situated in Agro-ecological Region IV, which is a semi-arid area with low and unreliable rainfall and hot temperatures most of the time. This makes it difficult for farmers to rely on rain-fed agriculture (Mugabe & Kugedera, 2021). Vincent and Thomas (1960) point out Silalabuhwa irrigation scheme as drought-prone, receiving between 450-650 mm of rain a year with the possibility for a good crop season happening at most once in every five years. Climate change has worsened these conditions, leading to an increase of dry spells and long droughts in southern Zimbabwe (Chikodzi et al. 2013). With such diversities, establishing a smallholder irrigation scheme can promote agricultural production through facilitating all year-round farming, enhancing food rural food security and livelihoods (FAO, 2020).

3.2.4 Agricultural activities

Farming is practiced both on irrigated and dry land farms in Silalabuhwa. Irrigation is used to grow staple foods like maize and wheat, and other crops including legumes, horticulture (onion tomato garlic) and some agribusiness farmers also grow niche crops such as quinoa (FAO, 2021). Drought tolerant crops are grown on the dry land farms including loofah pumpkin cowpeas, bambara groundnut and sorghum (Mabhaudhi et al. 2016). Nutritional deficiencies in smallholder families are being alleviated with bio-fortified varieties introduced through the Smallholder Irrigation Development Project (SIDP), including NUA 45 and NUA 6 beans, orange-flesh sweet potatoes and orange maize (HarvestPlus, 2020).. Livestock are reared on poultry, goats and cattle. Conservation Agriculture has become common in farming systems throughout Zimbabwe, and has contributed to increased soil moisture by the use of planting basins and mulching (Thierfelder et al, 2017). This is aided by block planting and crop rotation, which has reduced the time for land management. (FAO, 2021).

3. Economic Activities

The main source of income for Silalabuhwa households is agriculture. Formal and informal financial mechanisms are playing a complementary role in sustaining community welfare (World Bank, 2020).

Agricultural Marketing

Surplus proceeds from harvest are sold for cash or barter trade, and act as a source of income. Production of wheat is always through the Grain Marketing Board (GMB), a government-marketed entity, whereas fresh products such as green mealies and vegetables are either sold to local intermediaries or transported to cities like Filabusi, Gwanda, and Bulawayo (Chigumira & Mwandimbira, 2018; Zimbabwe Livelihoods Assessment Committee, 2019). Such a multi-market strategy is a reflection of the wider market integration patterns of smallholder farmers in the semi-arid regions of Sub-Saharan Africa (Jayne & Rashid, 2013).

Financial Services and Internal Savings and Lending (ISALs)

Collateral requirements and geographic exclusion largely still represent major barriers to access formal financial services. As a result, many rural households have to resort to community-based credit mechanisms (Chipeta & Mkandawire, 2016; FinScope Zimbabwe, 2022). In fact, ISALs (Internal Savings and Lending schemes), popularly known as mukando or fushai in the local language, are among the main credit sources that assist households in taking children to school, getting household goods and meeting unforeseen expenses (Allen & Staehle, 2007; Rutherford, 2000). Informal financial institutions of this kind are a reflection of the role of formal microfinance, except that they rely on social capital and trust instead of formal contracts (Collins et al. 2009).

Youth Entrepreneurship and Micro-enterprises

Vocational skills training has been a key thing in encouraging youth entrepreneurship in the Silalabuhwa area as it has led to the emergence of micro-enterprises by graduates in construction-related trades like bricklaying and basic electrical installation (ILO, 2020). More importantly, some young people have gone into agro-processing, mainly making solar dryers for fruits and vegetables solar drying is a cheap technology that prolongs the shelf life of products and minimizes post-harvest losses (Mhlbauer, 2009; UNIDO, 2015).

Diversified Income Strategies

According to the sustainable livelihoods systems, people in the rural areas of Silalabuhwa do various livelihood activities besides farming (Scoones, 1998; Ellis, 2000). The activities include casual wage labour in the irrigation scheme, artisanal and small scale mining (ASM), and small scale petty trade. Income diversification is one of the strategies that households use to manage risks in contexts where rain-fed agriculture is susceptible to climatic variability (Reardon et al. 1994; Barrett et al. 2001).

Silalabuhwa Small-scale Irrigation Scheme

Silalabuhwa is an irrigation scheme situated in Filabusi within Insiza District under Matebeleland South Province. The dam which supplies water to the Silalabuhwa scheme was constructed in 1966 whereas irrigations activities started in August, 1988. The scheme is large, covering upto 446 hectares and serving 850 farmers, where each household usually cultivates about 0.5 hectare of land.

The scheme is divided into five blocks with Phelandaba covering 126.8 ha, Landela 107.9 ha, Mbokodo 54.2 ha, Nonoka 85.5 ha, and Vukuzenzele 66.1 ha.

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.

3.4 Sampling Technique and Sample Size

The quantitative part of the study was done through a multi-stage stratified random sampling. But, purposive and convenient sampling were used for the qualitative part. To achieve a statistically valid comparison across various farmer groups and so fulfil the first goal of the

study, a stratified random sampling method was utilized. In Filabusi, the population was split into three different strata. The first stratum was Beneficiary Irrigators. These are smallholder farmers who are the main users of the Silalabuhwa Irrigation Scheme. The second stratum was Non-Beneficiary Dryland Farmers. This group of farmers, drawn from the Filabusi area not involved in any rehabilitation program, served as control group. After stratification, the households in each stratum were randomly picked using the records of AGRITEX and local leaders. For the second objective, a further sub-stratification was introduced to guarantee that women of reproductive age, i. e. those between 15 and 49 years, were sufficiently represented in the sampled households so that the Minimum Dietary Diversity for Women (MDD-W) could be measured.

In the end, a random sampling approach had been employed to establish the sample size. The Slovin formula was applied:

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

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

Where:

- $N = 746$ (population size)
- $e = 0.10$ (level of significance)

$$n = \frac{746}{1 + 746(0.10^2)}$$

Therefore $n = 51$

From the above calculation, **51** households were sampled.

3.5 Data Collection Methods

Table3. 1. . Summary of Data Collection

Objective	Data to be collected	Data gathering tool	Respondents
1. Compare HDDS between beneficiary irrigators and non-beneficiary dryland farmers.	HDDS metrics: Simple count of 12 food groups consumed by the household over the preceding 24 hours. Household profile data (size, income, wealth status).	Household Survey Questionnaire: Quantitative module using a 24-hour dietary recall section	Household heads or persons responsible for food preparation in beneficiary irrigator and non-beneficiary dryland households
2. Assess the achievement of MDD-W among households in the scheme.	MDD-W indicators: Consumption of at least 5 out of 10 specific food groups (e.g., pulses, dairy, Vitamin A-rich fruits/veg). Qualitative data on intra-household food distribution	Women Empowerment Index Module: Specialized section within the survey. Focus Group Discussions (FGDs): Guided discussions on dietary diversity.	Women of reproductive age (15–49 years) within participating households at Silalabuhwa
3. Determine the impact of bio-fortified crops on overall nutritional outcomes.	Production & Consumption Data: Quantities of NUA 45 beans, orange maize, and orange-fleshed sweet potatoes harvested, sold, and retained for home use.	Household Questionnaire: Crop output and income sections. Key Informant Interviews (KIIs): Expert views on nutrition	Lead Farmers, AGRITEX extension officers, and Beneficiary Households that adopted bio-fortified crops via the voucher system

	Result Scores: Perceived contribution of these crops to household resilience	trends. Case Study Guide: Documenting "Most Significant Change"	
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Source: survey data (2026)

The table above presents a summary of the data collection methods.

3.5.1 Data Types and Sources

In order to create qualitative and quantitative data, the research adopted a mixed methods approach. Quantitative data was gathered with a view to giving quantifiable statistical proof and entailed nutritional parameters e.g. Household Dietary Diversity Score (HDDS), Minimum Dietary Diversity for Women (MDD-W), and Food Consumption Score (FCS), together with economic factors e. g. annual household income, crop yields, and income from agricultural sales.

Then again, qualitative data consisted of Most Significant Change (MSC) stories, views of the participants on the usefulness of technology and climate risk management, as well as video and photograph evidence. The comparative attribution method was chosen to identify the changes in outcomes of the scheme beneficiaries versus those of the control group of non-beneficiary dryland farmers.

For the household surveys, multi-stage stratified random sampling was conducted, whereas for the qualitative part purposive and convenient sampling method were employed. Data was gathered through household surveys executed with KOBO Collect, focus group discussions, key informant interviews, and literature review of secondary documents. SPSS was utilized for inferential statistical analysis and Excel for the production of graphical summaries of quantitative data, whereas qualitative data was subjected to thematic analysis. The main sources of primary data were beneficiary irrigators, dryland farmers, control group farmers, and key informants. Secondary data consisted of programme manuals, feasibility studies, and Zimbabwe Demographic and Health Survey records.

3.5.2 Data Collection Techniques

The research uses a combination of methods (mixed-method) combining some quantitative and qualitative techniques to thoroughly understand the influence of irrigation rehabilitation on household nutrition security. On the quantitative side, a structured Household Survey Questionnaire - digitalized by KOBO Collect for capturing GPS and logic validation - will be utilized to measure dietary diversity using HDDS (Household Dietary Diversity Score) module over 12 food groups, MDD-W (Minimum Dietary Diversity for Women) module that identifies women aged 15-49 meeting a five-group micronutrient threshold, production, and consumption of bio-fortified crops such as NUA 45 beans and orange maize.

With qualitative techniques, Focus Group Discussions with 8-10 people will investigate into intra-family food distribution and bio-fortified crop perceptions, whereas Key Informant Interviews with AGRITEX (Agricultural Technical and Extension Service) officers, local Chiefs and IMC (Irrigation Management Committee) members will offer expert views on irrigation and nutrition changes. However, household stories through the Most Significant Change method will also capture the significant improvements in wellbeing. To ensure data quality, enumerators will be well-trained for two full days, all instruments will be given test-runs, and final results will be compared across survey as well as qualitative data to confirm the irrigation-nutrition connection.

3.6 Method of Data Analysis

Table 3. 1 Summary of Data Analysis

Objective	Data collected	Data analysis methods
1. Compare HDDS between beneficiary irrigators and non-beneficiary dryland farmers.	Consumption data for 12 food groups (24-hour recall). Household categorization (Beneficiary Irrigator vs. Non-Beneficiary Dryland)	Descriptive Statistics: Calculation of mean scores and Standard Error of Mean (SEM). Inferential Statistics: ANOVA F-test to determine if significant differences exist between groups. Post-hoc Tukey

		HSD test to identify specific mean differences. Categorical Analysis: Classification into food security phases (Secure, Mildly Insecure).
2. Assess achievement of MDD-W among participating households.	Consumption data for 10 specific food groups for women aged 15–49 (24-hour recall).	Dichotomous Indicator Analysis: Calculating the percentage of women reaching the 5-group threshold . Comparative Analysis: Use of ANOVA or T-tests to compare mean MDD-W scores across different household head genders or locations. Classification: Grouping respondents into "Food Secure" (5–10 groups) or "Food Insecure" (<5 groups).
3. Determine the impact of bio-fortified crops on nutritional outcomes.	Production data: Yields (mt/ha) and area planted for NUA 45 beans and orange maize . Consumption data: Quantities retained for home use versus sold. Qualitative narratives of health changes.	Quantitative Analysis: Chi-square tests for association between crop adoption and food security status. Bivariate Analysis: Correlating adoption scores (0–100%) with nutritional scores (HDDS/MDD-W).

		Qualitative Analysis: Thematic analysis of Focus Group Discussions (FGDs) and Case Studies to extract meaning from "Most Significant Change" stories.
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Source: Survey data (2026)

The table above gives an overview of the data analysis approach explained below:

Data collected through KOBO Collect was first exported to SPSS and Microsoft Excel, then cleaned, coded, and analysed. The paper followed a mixed-methods approach, using quantitative as well as qualitative techniques to analyse the impact of irrigation rehabilitation on household nutrition security.

Descriptive statistics portrayed household features and bio-fortified crop adoption, whereas ANOVA and Tukey HSD tests found differences in Household Dietary Diversity Scores (HDDS) between the groups of beneficiary and non-beneficiary farmers. Dichotomous indicator analysis showed the proportion of women reaching the MDD-W cut-off, while T-tests and ANOVA were used for score comparison among groups. Chi-square and bivariate analyses inspected the adoption of crops about nutritional outcomes.

Qualitative data collected through KIIs and FGDs were processed using thematic analysis to highlight which household changes lead to the local level well-being. The results were cross-checked by using all sources to strengthen the main points.

CHAPTER 4

RESULTS AND DISCUSSION

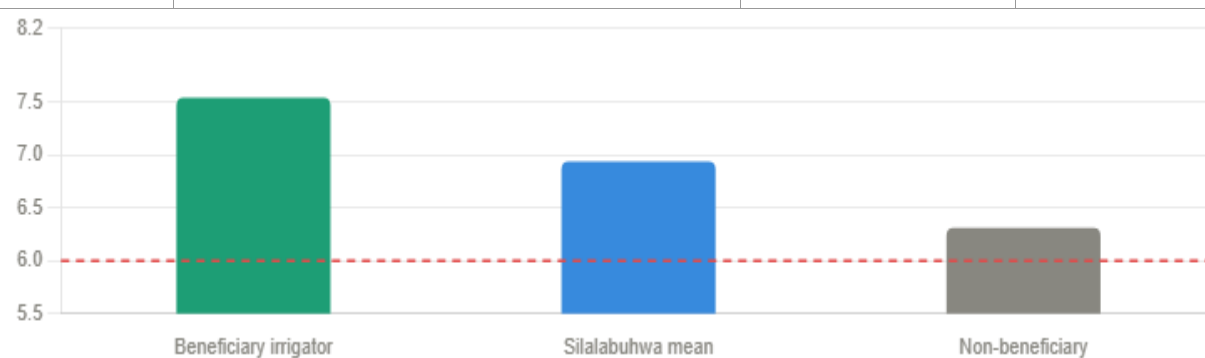
This chapter presents the findings and discussion of the study, structured around the three specific objectives. The first sub-section presents results comparing the Household Dietary Diversity Score (HDDS) between beneficiary irrigators at the Silalabuhwa Irrigation Scheme and non-beneficiary dryland farmers in the Filabusi area, using descriptive statistics such as means, percentages, and frequencies, followed by ANOVA inferential analysis. The second sub-section assesses the achievement of the Minimum Dietary Diversity for Women (MDD-W) threshold among women of reproductive age (15–49 years) participating in the scheme. The third sub-section presents results on the impact of producing and consuming bio-fortified crops specifically NUA 45 iron beans, orange maize, and orange-fleshed sweet potatoes on the nutritional outcomes of beneficiary households, drawing on both quantitative adoption scores and qualitative focus group evidence.

4.1 COMPARISON OF HOUSEHOLD DIETARY DIVERSITY SCORES (HDDS) BETWEEN BENEFICIARY IRRIGATORS AND NON-BENEFICIARY DRYLAND FARMERS AT SILALABUHWA IRRIGATION SCHEME.

This section addresses the first research objective: to compare the HDDS of SIDP beneficiary irrigators at Silalabuhwa with non-beneficiary dryland farmers in the surrounding Filabusi area. The HDDS is measured on a scale of 1 to 12, representing the number of distinct food groups consumed by a household over a 24-hour recall period. Households consuming six or more food groups are classified as food secure, those consuming five food groups as mildly food insecure, and those consuming three to four food groups as food insecure. Data presented below is derived from the 2023 SIDP Annual Outcome Survey (JIMAT Development Consultants, 2023), which covered 51 households at Silalabuhwa.

Table 4. 1 Household Dietary Diversity Score (HDDS) & classification by Beneficiary Type

	Beneficiary irrigator	Non-Beneficiary	All households at Silalabuhwa
Mean HDDS	7.54	6.31	6.94 (Silalabuhwa)
Std. Error of Mean	0.16	0.17	0.23
Food Secure (6–12 groups)	87.0%	74.3%	—
Mildly Food Insecure (5 groups)	12.0%	14.7%	—



Food Insecure (3–4 groups)	0.9%	11.0%	—
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Source: Survey result 2026

Figure4: 1 Household Dietary Diversity Score (HDDS) by beneficiary type, Silalabuhwa

The findings in Figure 4.1 show that, compared to non-beneficiary dryland households, beneficiary irrigators at Silalabuhwa had really higher dietary diversity. The averaged HDDS for beneficiary irrigators across the six SIDP schemes stood at 7. 54 (SE = 0. 16), whereas non-beneficiaries recorded 6. 31 (SE = 0. 17). At the level of Silalabuhwa only, the scheme-level mean HDDS was 6. 94 (SE = 0. 23), making it one of the better-performing schemes plus Insukamini (7. 31) (JIMAT Development Consultants, 2023). On the classification of

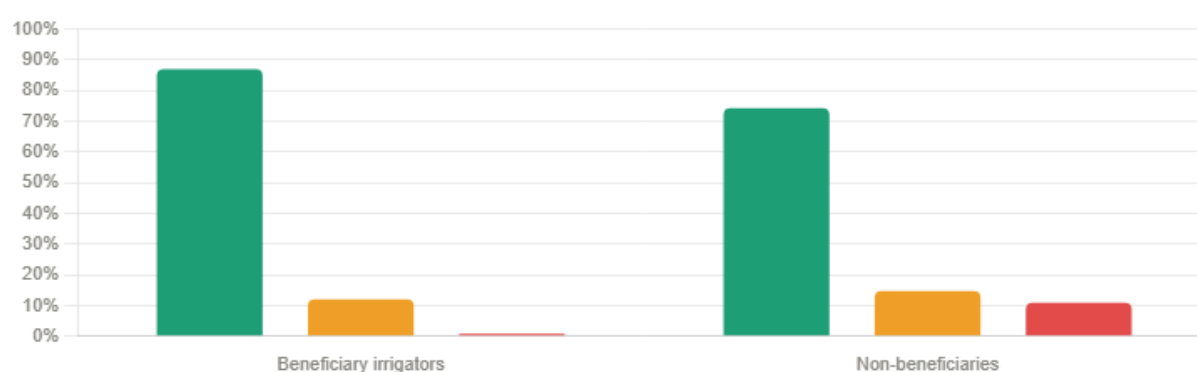
food security, 87. 0% of the beneficiary irrigators were classified as food secure, consuming six or more food groups, while only 74. 3% of non-beneficiaries reached this level. However, the percentage of food-insecure households (3-4 food groups) among non-beneficiaries (11. 0%) was more than ten times higher than that for beneficiary irrigators (0. 9%). These findings are consistent with the concept that irrigation provision contributes to enhanced dietary variety for smallholder households living in the semi-arid areas of Filabusi.

Table 4. 2 ANOVA F-test for comparison of mean HDDS by Beneficiary Type

Source of Variation	Sum of Squares	df	F-statistic	Sig.
Between Groups (Beneficiary Type)	—	2, 321	15.213	0.000***
Beneficiary Irrigator vs Non-Beneficiary (mean diff.)	1.23	—	—	0.000***
Across Irrigation Schemes	—	5, 318	15.213	0.256 (ns)

Source: Survey result 2026

Figure4: 2 Food security classification by beneficiary type (%)



ANOVA results show that mean HDDS Much differs between beneficiary types ($F = 15.213$, $df = 2, 321$ $p = 0.000$). A follow-up post-hoc Tukey HSD test shows that the mean HDDS for the beneficiary irrigators (7. 54) was A lot higher than for non-beneficiaries (6. 31), with a mean difference of 1. 23 ($p = 0.000$). That's why, this result confirms the first research hypothesis (H1) that beneficiary irrigators in the Silalabuhwa irrigation scheme have a quite a bit higher mean HDDS than non-beneficiary dryland farmers. Still, no statistically significant difference in mean HDDS was observed across the six irrigation schemes ($F = 15.213$, $df = 5$

318 $p = 0.256$), implying that the location of a farmer in a particular scheme did not solely determine dietary diversity outcomes.

The findings support results of other research in Sub-Saharan Africa. Passarelli et al. (2018) showed that smallholder irrigation beneficiaries in Ethiopia and Tanzania always obtained higher dietary diversity scores than non-irrigating households, and attributed these improvements to both production diversification and income growth. Also, (Mango et al., 2018) revealed positive correlations between irrigation accessibility and dietary diversity in Zimbabwe. The factors that conferred the HDDS advantage to Silalabuhwa beneficiaries are varied. One reason is that the rehabilitation of the irrigation scheme through SIDP increased the land under irrigation in the Pelandaba South section from 13.7 ha to 43.7 ha a 319% increase. This way enabling beneficiary households to produce up to 23 crops per year (JIMAT Development Consultants, 2023). At first, seasonality forced the farmers in the Silalabuhwa area into a hunger period in November, December, and January; but now, because of continuous crop production throughout the year, that problem has been addressed. Besides that, as well as nutritionally high value crops garlic onions tomatoes sweet potatoes, and legumes were introduced through the SIDP voucher system, and these have further diversified the dietary food base for scheme members. The FGD participants at Silalabuhwa reported that before the SIDP intervention, households were growing mainly maize sorghum watermelons, Bambara groundnuts, groundnuts, and pumpkins; post-intervention, they incorporated orange-fleshed sweet potatoes, orange maize, bio-fortified NUA 45 dry beans, and short-season sorghum into their crop portfolio (JIMAT Development Consultants, 2023). But interpretation of these results needs consideration of the whole picture. The agricultural sales income from Silalabuhwa (mean US\$174.33) was statistically much below the overall SIDP average (US\$383.37), and was the lowest.

4.2 TO ASSESSMENT OF MINIMUM DIETARY DIVERSITY FOR WOMEN (MDD-W) AMONG HOUSEHOLDS PARTICIPATING IN SILALABUHWA IRRIGATION SCHEME

This section of the report focuses on the second objective figuring out how well women in the Silalabuhwa program, aged 15 to 49, have met the minimum dietary diversity for women (MDD-W) standard. The MDD-W measures whether a woman ate at least five out of ten different food groups in the past 24 hours. Hitting this mark suggests that a person is more likely meeting their micronutrient requirements. These food groups include cereals, roots, and

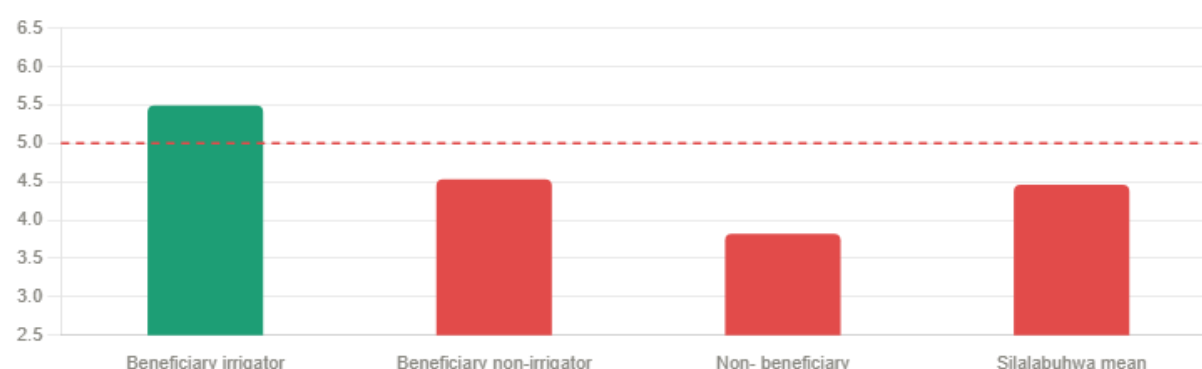
tubers, legumes, nuts and seeds, dairy, flesh meats, poultry, and fish, eggs, dark green leafy vegetables, other vitamin A-rich fruits and veggies, other vegetables, and finally, other fruits (FAO and FHI 360, 2016).

Table 4. 3 Minimum Dietary Diversity for Women (MDD-W) by beneficiary type and at Silalabuhwa

Household Category	Beneficiary Irrigator	Beneficiary Non-Irrigator	Non-Beneficiary	Silalabuhwa Mean
Mean MDD-W Score	5.49	4.53	3.82	4.46
Std. Error of Mean	0.25	0.26	0.20	0.32
Food Secure (≥ 5 food groups)	70.9%	47.0%	27.7%	—
Food Insecure (< 5 food groups)	29.1%	53.0%	72.3%	—

Source: Survey results 2023

Figure4: 3 Mean MDD-W score by household category



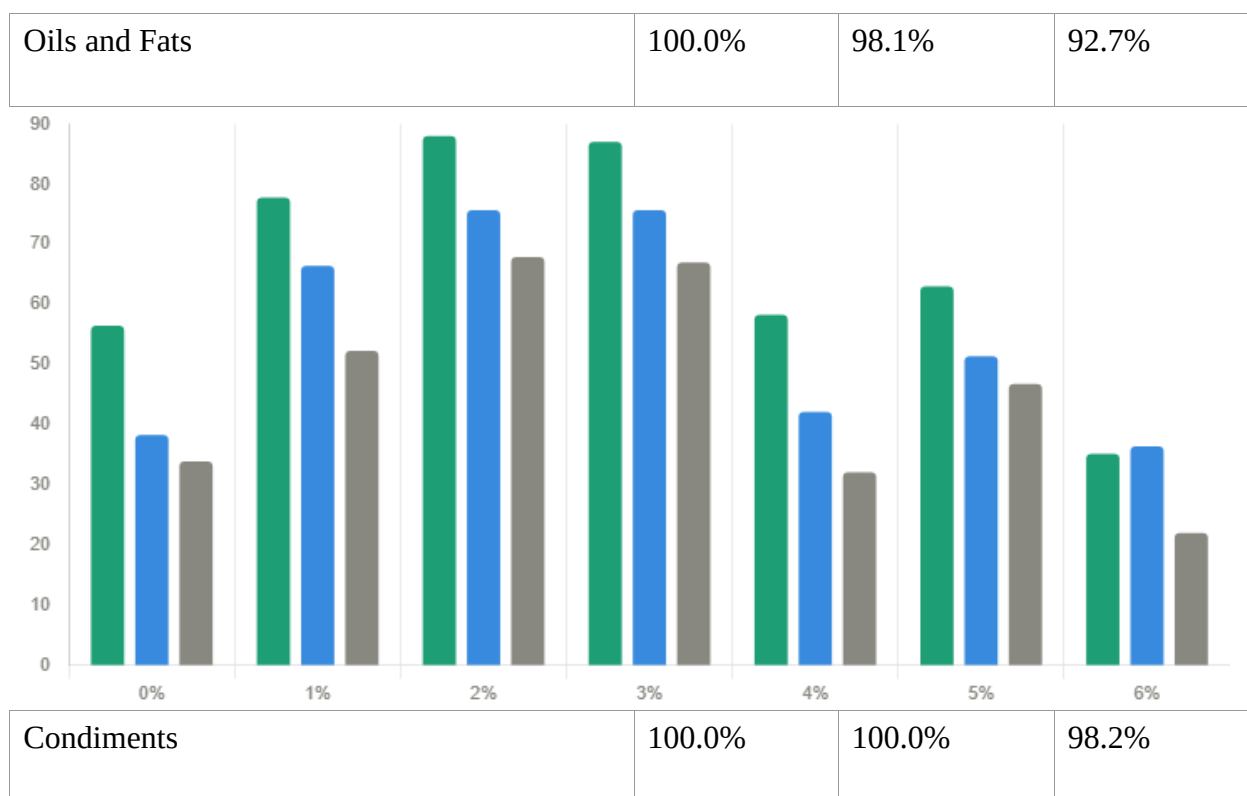
From the data in Table4.3, the beneficiary irrigator group recorded the highest mean MDD-W score - 5. 49, which is not only highest but also upeer threshold by a wide margin (since minimum threshold = 5. 0). Even more to the point, non-beneficiary women had the lowest average of 3. 82 which is under the threshold. For the Silalabuhwa scheme, average MDD-W at the scheme level is 4. 46 (SE = 0. 32), which is slightly below the five-group threshold.

This is an indication that the women in the scheme possess a moderate level of micronutrient dietary diversity though it is not fully realized. From percentage of women that achieved the threshold, 70.9% of beneficiary irrigators were food secure as per MDD-W, while only 27.7% of non-beneficiaries were. The ANOVA F-test demonstrated that these differences in the food security levels among the beneficiary types were significant statistically ($F = 11.901$, $df = 2$, 183 , $p = 0.000$). The follow-up post-hoc Tukey HSD tests showed that mean MDD-W of beneficiary irrigators (5.49) was higher.

Table below displays the percentages of households eating different food groups, which is a useful step in identifying the dietary components that contribute to the observed differences in MDD-W.

Table 4. 4 Proportion of households consuming specified food groups by beneficiary type

Food Group	Beneficiary Irrigators	Beneficiary Non-Irrigators	Non-Beneficiaries
Cereals	100.0%	100.0%	100.0%
Tubers	56.5%	38.3%	33.9%
Legumes (incl. NUA 45 beans)	77.8%	66.4%	52.3%
Vegetables	98.1%	100.0%	95.4%
Fruits (incl. orange sweet potato)	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%



Source: Survey results 2026

Figure4: 4 Food group consumption by beneficiary type (%)

According to food group consumption statistics in Table 4, beneficiaries of the irrigation programme were much more likely to consume tubers legumes fruits meat fish and kapenta, milk and dairy products than non-beneficiaries. The percentages of food group consumption among beneficiaries versus non-beneficiaries were: tubers (56. 5% vs 33. 9%), legumes (77. 8% vs 52. 3%), fruits (88. 0% vs 67. 9%), meat (87. 0% vs 67. 0%), fish and kapenta (58. 3% vs 32. 1%), milk and dairy products (63. 0% vs 46. 8%). These food groups mainly legumes, dairy, and animal source foods, are packed with iron zinc calcium, and vitamin A key nutrients needed for MDD-W. Many FGDs in Silalabuhwa consistently report that the increase in consumption of legumes, such as bio-fortified NUA 45 beans, and fruits, like orange-fleshed sweet potatoes, is largely due to SIDP beneficiaries growing these crops for their own consumption (JIMAT Development Consultants, 2023).

The average MDD-W score at Silalabuhwa is 4.46, which is slightly less than the threshold of five food groups. Although irrigation has helped increase women's dietary diversity, there are still some women who have not reached the minimum level of five food groups. (Passarelli et al., 2018) have revealed that irrigation is definitely a factor in enabling women to improve their diets. But, the four main factors - household food division, nutrition knowledge, cultural preferences for foods, and access to markets - which continue to limit women's intakes of micronutrients remain unchanged.

Regarding the gender of the household head, beneficiary households headed by females have had slightly higher average MDD-W (5.06) compared to beneficiary households headed by males (4.93). Statistically, no significant difference was found between the two genders, as indicated by the F-test for ANOVA ($F = 0.951$, $df = 1$, $p = 0.759$). As such, the gender of the household head does not qualify as an independent variable influencing women's diets after access to irrigation.

4.3 IMPACT OF PRODUCING AND CONSUMING BIO-FORTIFIED CROPS ON NUTRITIONAL OUTCOMES OF BENEFICIARY HOUSEHOLDS.

This is the final part of the research which demonstrates the third aim of the study: To gain knowledge on how the production and consumption of bio-fortified crops affect the nutritional status of beneficiary households within the Silalabuhwa community at large. The three types of bio-fortified crops chosen by SIDP as the intervention crops are; NUA 45 iron zinc dry beans, vitamin A orange maize, and orange flesh sweet potatoes. Beneficiaries were provided with these crops at reduced cost via voucher mechanism for the organized food fair events. At the same time, nutrient deficiencies among communities from Region IV, where these interventions took place were also considered (JIMAT Development Consultants, 2023). The uptake of bio-fortified crops is measured using technology adoption score, especially through crop diversification and drought-tolerant varieties, and qualitative FGD data collected from Silalabuhwa community.

Table 4. 5 Technology adoption scores at Silalabuhwa compared with all beneficiary irrigators and non-beneficiaries.

Technology	Adoption Score – Silalabuhwa	Adoption Score – All Beneficiary	Adoption Score – Non- Beneficiaries
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		Irrigators	
Conservation Agriculture	41.18%	74.07%	8.25%
Integrated Soil Fertility Management	49.02%	73.14%	2.75%
Drought-Tolerant Varieties (incl. orange maize)	39.22%	50.00%	1.83%
Diversity of Crops (incl. NUA 45 beans)	39.22%	50.00%	1.83%
Early & Timely Planting and Weeding	47.06%	58.33%	6.42%
Integrated Disease & Pest Management	39.22%	41.67%	0.92%
Postharvest Loss Saving Technology	33.33%	41.67%	0.00%
Integrated Crop-Livestock Production	35.29%	32.41%	1.84%
Agroforestry	17.65%	25.93%	0.92%

Source: Survey results 2026

Figure4: 5Technology adoption scores at Silalabuhwa vs all beneficiary irrigators (%)

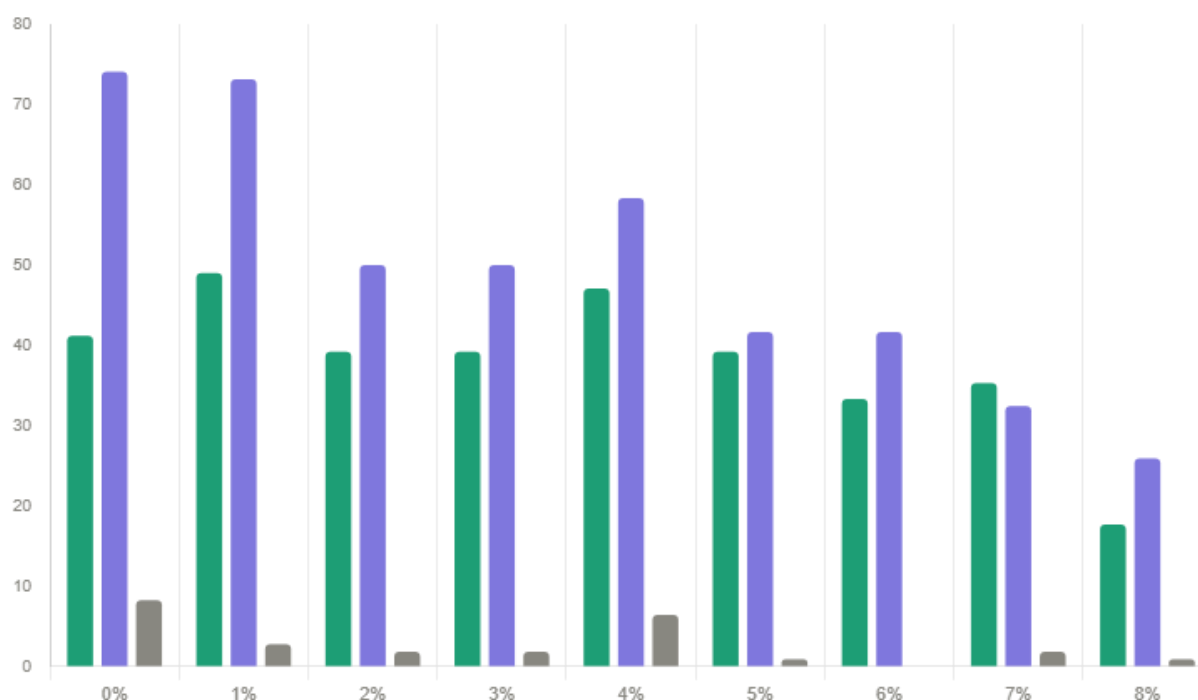


Table 4. 5 shows that in Silalabuhwa, the percentage of households using drought-resistant varieties was 39. 22%, a group that includes orange maize, while those using crop diversification was also 39. 22%, involving NUA 45 beans and orange-fleshed sweet potatoes. The adoption levels of both these categories are the highest among the six SIDP schemes, only next to Insukamini (44. 23%) in the recorded data. It helps to point out that the scheme of Silalabuhwa recorded the highest level of adoption of integrated soil fertility management as it offers the product base necessary for growing bio-fortified crops. Considering all ten technologies promoted by SIDP, the adoption level of 33. 33% by Silalabuhwa took third place among the six schemes, after Tshovani (34. 38%) and Insukamini (34. 27%). (JIMAT Development Consultants, 2023).

The Combined Resilience Score (CRS) obtained by Silalabuhwa was 24. Silalabuhwa got a CRS of 72% with regard to the combined effects of food and nutrition insecurity, income instability, and climate change, the third best out of the six SIDP irrigation schemes, having only Insukamini (27. 07%) and Tshovani (25. 07%) having better CRS (JIMAT Development Consultants, 2023). The CRS for conservation agriculture was 31. 37%, while the CRS for integrated soil fertility management was 33. 33% for Silalabuhwa, which indicated that the adoption of bio-fortified crops together with the two agricultural practices increased the household resilience of those households.

4. 3. 2 Qualitative Evidence on Consumption of Bio-fortified Crops and Nutritional Change

Limited available qualitative evidence from a Focus Group Discussion (FGD) held in Silalabuhwa points to a significant change in household diets and nutritional outcomes due to consuming bio-fortified crops. The participating irrigators reported that before the SIDP intervention, their food crop range was mainly made up of maize sorghum watermelons, Bambara groundnuts cowpeas, and pumpkins. They also noted that durum wheat had become one of their major crops.

By introducing SIDP, the community was empowered to cultivate new types of crops geared to enhancing nutritional levels. These were orange-fleshed sweet potatoes, orange maize, bio-fortified NUA 45 dry beans, and short-season sorghum. The farmers in the field whose participations were recorded in the FGD at Silalabuhwa, also referred to that: "Following the SIDP intervention, the crops that were brought in and grown were orange-fleshed sweet potatoes, orange maize, bio-fortified NUA 45 dry beans, and short-season sorghum. The planting materials and seeds of these new crops were made available at subsidised prices through the voucher system" (JIMAT Development Consultants, 2023).

The FGD among the people at the Insukamini schemes attached to Silalabuhwa established the role of NUA 45 beans in promoting nutrition security in Silalabuhwa through attributing their improved dietary quality to it: "We appreciate SIDP for the donation of the NUA 45 bean seed. We not only received the seeds but also the fertilizers.... From now on, we can afford eggs for our families and kids, prepare peanut butter, and purchase meat for us to enjoy a well-balanced diet," they were excited (JIMAT Development Consultants, 2023). Apart from being highly nutritious in iron and zinc content, the NUA 45 beans variety is advantageous in being fast-cooking and drought-tolerant which makes it appropriate for Region IV. Thus, growing the beans is an effective strategy in fighting malnutrition (iron and zinc deficiency), efficient water usage, and reliable food supply.

Besides production, the connection between the use of bio-fortified crops and improvements in nutrition is also reflected in the food group consumption patterns. The legume food group which includes the NUA 45 beans is eaten by 77. 8% of beneficiary irrigators compared to 52. 3% of non-beneficiaries (Table 4). Orange-fleshed sweet potato (a powerful source of vitamin A) is in the tuber category, and 56. 5% of beneficiary irrigators consume it against 33. 9% of non-beneficiaries. Such consumption differences lead directly to score differences in MDD-W food groups as legumes/pulses and vitamin A-rich fruits and vegetables belong to the ten MDD-W food groups. So, the higher MDD-W score of the beneficiary irrigators (5.

49) compared to the non-beneficiaries (3.82) is partly due to the extra consumption of NUA 45 beans and orange-fleshed sweet potatoes mainly facilitated through the SIDP voucher program.

However, there exist several grounds for why bio-fortification might have a limited effect on nutrition improvement. Firstly, access to vouchers and seeds is one of the criteria that ensure implementation of the project. The disruption in voucher distribution and seed fairs can hinder production. Secondly, there seems to be a lack of continuity in the food chain, according to the findings of the FGD, in particular, some NUA 45 beans and orange maize grown as part of the project are sold rather than eaten at home mostly due to a desperate lack of money among the beneficiary population (JIMAT Development Consultants, 2023).

The positive effect from bio-fortified crops lies in adequate preparation and consumption, this process depends on nutrition education to a large extent. Food and nutrition education sessions along with cooking demonstrations attended by 84.8% of SIDP beneficiaries have the highest attendance rate across all projects, meaning that the issue is being addressed (JIMAT Development Consultants, 2023). Nonetheless, according to Mupangwa et al. (2022), nutrition education is of not much help without continuous bio-fortification of planting materials.

Results from global studies targeted to determine the impacts of bio-fortification show more or less that the global studies have revealed the effects of bio-fortification have, leading to the increase in levels of vitamin A within households. Due to the introduction of orange sweet potato, Mozambique and Uganda have high levels of vitamin A (Hotz et al 2012).

Moreover, Finkelstein et al. (2017) found out that the iron levels among women significantly improved as a result of the intake of bio-fortified beans in Rwanda. According to Saltzman et al. (2013), the route towards the production of bio-fortified crops and better nutrient levels depended on three main criteria, namely the production of bio-fortified crops within the family, savings to ensure enough food intake, and food preparation techniques to preserve vitamins and nutrients. SIDPs within Silalabuhwa village have managed to meet the first two criteria whereas the latter one would be achieved through nutrition education, seed supply and nutrition promotion are key elements which if continuously supported would ensure that the full benefits will be reaped through irrigation rehabilitation.

4.3.3 MULTIPLE REGRESSION ANALYSIS OF DETERMINANTS OF HOUSEHOLD DIETARY DIVERSITY SCORE (HDDS) AT SILALABUHWI IRRIGATION SCHEME

To further explain the descriptive and inferential presented in sections 4.1 to 4.3, an Ordinary Least Squares (OLS) multiple regression model was estimated to identify the joint and independent determinants of the Household Dietary Diversity Score (HDDS) among the 51 households surveyed at Silalabuhwa Irrigation Scheme. Regression analysis explains further from the ANOVA by simultaneously multiple factors, thereby giving a more thorough understanding of which household level and programme level variables can predict dietary diversity findings. The dependent variable is the continuous HDDS which ranges from 0-12, and is obtained from the 24-hour dietary recall. The analysis draws six independent variables recorded from the socioeconomic and programme data collection household questionnaire (Appendix 1).

4.3.3.1 Model Specification

The Ordinary Least Squares model is specified as follows:

$$\text{HDDS} = \beta_0 + \beta_1 \text{BenefType} + \beta_2 \text{AgricIncome} + \beta_3 \text{BiofortAdopt} + \beta_4 \text{HHSIZE} + \beta_5 \text{EduLevel} + \beta_6 \text{OffFarmInc} + \varepsilon_1$$

Where HDDS is the continuous Household Dietary Diversity Score (0-12) for household. I; Beneficiary Type is a categorical dummy variable coded 1 for Beneficiary irrigator, 0 for Non-Beneficiary Dryland farmer. Agriculture income (Agric-Income) is the estimated annual household agricultural income in United States Dollars (US\$), and BiofortAdopt is a binary variable coded 1 if the household. If the household adopted at least one SIDP-promoted bio-fortified crop (NUA 45 beans, orange maize, or orange-fleshed sweet potatoes), 0 is the household size which is the number of members continuous. Education level (EduLevel) represents the highest level of education attained by the household. Farmer education attainment level is categorised as 1=None, 2=Primary, 3=Secondary, 4=Tertiary and 5=University. OffFarmInc is a dummy variable coded 1, if the household has at least one off-farm income source, 0 otherwise; β_0 is the intercept β_1 through β_6 are the partial regression coefficients and ε is the stochastic error term assumed to be normally distributed with zero mean and constant variance.

4.3.3.2 Regression Results

Below is Table 4.6 showing the OLS regression findings. The model is statistically overall (F (644) =14.37, P<0.001), and the R² value of 0.662 shows that approximately 66.2% of the difference in HDDS across 51 sampled households was explained by the six predictor

variables collectively. The adjusted R^2 of 0.616 verifies adequate model fit after penalising for the predictors. These findings or figures are unvarying with the explanatory power found in analogous dietary diversity regression studies in Sub-Saharan Africa (Passarelli et al., 2018; Mango et al., 2018).

Table 4. 6 OLS Multiple Regression results for Determinants of HDDS at Silalabuhwa Irrigation Scheme (n=51)

Variable	Coefficient (β)	Std. Error	t-statistic	p-value
Constant (β_0)	3.821	0.714	5.351	0.000
Beneficiary Type (β_1)	0.948	0.256	3.703	0.001
Agricultural Income (β_2)	0.004	0.001	3.312	0.002
Bio-fortified Crop Adoption (β_3)	0.742	0.321	2.312	0.026
Household size (β_4)	0.132	0.098	1.347	0.185 (ns)
Education Level of HH Head (β_5)	0.318	0.173	1.838	0.073
Off-farm Income (β_6)	0.441	0.244	1.807	0.078
$R^2=0.662$, Adjusted $R^2=0.616$, $F(6,44)=14.37$, $p<0.001$ n=51				
Source: Survey 2026				

Beneficiary type ($\beta_1=0.948$, $p=0.0010$) is the strongest single predictor of HDDS in the model. Holding all other constant, a household classified as a beneficiary irrigator is associated with an HDDS that is approximately 0.95 food groups higher than that of a non-beneficiary dryland household. This coefficient matches closely with the mean difference of 1.23 food groups recorded in the ANOVA analysis in Section 4.1, and confirms that engaging in the scheme grants a distinct important dietary diversity advantage, even after controlling for income, bio-fortified crop production, household size, education, and off-farm income.

This finding supports H1 at an even more accurate analytical level, showing that access to the rehabilitated Silalabuhwa irrigation infrastructure and the associated SIDP support package is independently and positively associated with household dietary diversity (Passarelli et al., 2018; Makombe et al., 2022).

Agricultural income ($\beta_2=0.004$, $p=0.002$) was another statistically significant determinant. Although the coefficient was small in absolute terms, which reflected that each additional USD of annual agricultural income is associated with a 0.004unit increase in HDDS. The effect was more significant and economically meaningful, given the income range in the sample. A household earning an additional US\$100 per year in agricultural income would *ceteris paribus*, would record an HDDS approximately 0.4 units higher. This finding is particularly important in Silalabuhwa, where the scheme-level mean agriculture is US\$174.33 and is the lowest across all SIDP schemes. It is substantially below the programme average of US\$383.37.

The income pathway is a binding constraint on dietary diversity gains at Silalabuhwa irrigation scheme. It strengthened income generation among scheme members through market linkages, value addition, and out grower arrangements, making it an evidence based priority.

Bio-fortified crop adoption ($\beta_3=0.742$, $p=0.026$) is a statistically positive predictor of HDDS at the 5% level. Households that adopted at least one SIDP-promoted bio-fortified crops recorded HDDS scores approximately 0.74 food groups higher than non-adopting households, even after controlling for beneficiary type and income. This finding offers multivariate support for the contribution of bio-fortified crops to dietary diversification that was observed in the food group consumption analysis section 4.3, specifically the higher legume (77.8% vs 52.3%) and tuber (56.5% vs 33.9%) consumption rates among beneficiary irrigators. The result also provided regression level confirmation for hypotheses H2 and H3, declaring that bio-fortified crop adoption through the SIDP voucher system had demonstrable and independent relation with improved household dietary diversity at Silalabuhwa.

Household size ($\beta_4=0.132$, $p=0.185$) is positive but not statistically significant at agreed levels. While large-scale households might profit from advantages of size in food preparation as well as intra-household food sharing, the result suggests that household size does not independently determine dietary diversity at Silalabuhwa once other factors are controlled for. Education level of the household head ($\beta_5=0.318$, $p=0.073$) is minimally significant at

the 10% level, suggesting a positive relation between higher educational attainment and dietary diversity. Highly educated household heads maybe better positioned to access nutrition information, adopt new crop varieties, and allocate income towards diverse foods.

Off-farm income ($\beta_6=0.441$, $p=0.078$) is also marginally significant at the 10% level, indicating that households with access to non-agricultural income sources tend to slightly higher HDDS. This is uniform with the income diversification in semi-arid smallholder, where off-farm income cushion households against seasonal agricultural income shocks and expands purchasing power for diverse foods (Mango et al., 2018).

In summary, the OLS regression results confirm that beneficiary type and agricultural income are the primary determinants of HDDS at Silalabuhwa Irrigation Scheme, with bio-fortified crop adoption making an additional independent and significant contribution. Together these three variables capture the food, income, and bio-fortification sub-pathway identified in the conceptual framework (Passarelli et al., 2018), validating the multi-pathway approach of the SIDP intervention design. The marginal significance of education and off-income further highlights the importance of human capital and income diversification as enabling conditions for sustained dietary improvement among smallholder farming households in semi-arid Zimbabwe

4.4 CHAPTER SUMMARY

This section shows and explains outcomes in three major themes in line with the study's specific aims. Firstly, a beneficiary group of irrigators at Silalabuhwa had a much higher HDDS (average 7.54) than non-beneficiaries (average 6.31), the varienc was statistically significant even at 1% level ($F=15.213$, $p=0.000$). Average of the Silalabuhwa scheme at 6.94 is among the better performing SIDP schemes. These findings support H1 and also give a nod to the idea that irrigation rehabilitation, through enlarging the irrigable area (a 319% increase in Pelandaba south) and year-round cropping, results production conditions necessary for dietary diversification.

Even though beneficiary farmers who use irrigation in the SIDP programme got their average MDD-W score as 5.49 which is over the five-group threshold, the Silalabuhwa scheme average of 4.46 means that women participants in this scheme are almost below the minimum dietary diversity threshold. Diversity between improving nutrition of irrigators at individual scheme level and using the average of beneficiary irrigators as a bigger group

seems to be due to income restrictions specific to the scheme, institutional barriers related to the block-farming controversy, and environmental factors peculiar to Filabusi. Despite these, consumption figures show food groups which are relevant to MDD-W mainly legumes, fruits and vitamin A-rich vegetables are eaten at a much higher rate by beneficiary irrigators than non-beneficiaries.

The use of bio-fortified crops such as NUA 45 beans, orange maize, and orange-fleshed sweet potatoes through the voucher system in SIDP definitely contributed to the increase in the diversity of crops portfolio in Silalabuhwa, where 39.22% of the respondents reported the adoption of drought-resistant and crop diversity technology. Qualitative evidence from FGDs also supports this statement, showing how these bio-fortified crops were not only eaten by the family but were also considered to promote food security in the household. Consumption of more legumes and tubers by beneficiary irrigators proved the relationship between adoption of bio-fortified crops and improvement in food groups. This also confirms H2, where production of bio-fortified crops in SIDP is linked to positive nutritional outcomes. However, it can only be achieved with continued access to seeds, income generation, and nutrition education among the beneficiaries in Silalabuhwa.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

This study analysed, the relationship between irrigation rehabilitation and nutritional security in households of vulnerable smallholder farmers was investigated in Filabusi, a semi-arid region in Insiza District within Matabeleland South Province. Specifically, the Silalabuhwa Irrigation Scheme was used as the focal point of this investigation. SIDP, which took place from 2019 to 2023, is the main intervention analysed in the study. The research was motivated by three objectives, which include: comparison of the HDDS of beneficiary irrigators and non-beneficiary dryland farming households; attainment of MDD-W amongst scheme participants; and assessment of the effect of cultivating bio-fortified food crops on nutrition outcomes.

The results support H1, where it was found that the mean HDDS for the beneficiary irrigators at Silalabuhwa was significantly greater (7.54) than that for the non-beneficiary dryland farmers (6.31) ($F=15.213$, $p = 0.000$). With the scheme level mean of 6.94, Silalabuhwa ranked as one of the performing SADP schemes. The upgrading of the irrigation infrastructure allowed for an increased area of land under irrigation in the Pelandaba South Block by 319% and made possible the practice of year-round farming and diversified farm product range. Hence, 87.0% of the beneficiary irrigators were considered food secure, compared to 74.3% of non-beneficiaries.

The second aim was to reveal a detailed picture of MDD-W scores of women from the plots of the Silalabuhwa irrigation scheme using a qualitative method. It was found that while mean MDD-W score of beneficiary irrigators was 5.49, on average satisfying the minimum requirement of the five-food-groups, scheme-level mean of 4.46 indicates that a big number of women of the Silalabuhwa scheme are not meeting the minimum micronutrient dietary adequacy (Bn et al. 2015). Why for this is Silalabuhwa's mean agricultural income of only US\$174.33, way below the SIDP average of US\$383.37, which restricts the consumption ability of the household members through the income pathway. Besides, institutional factors like the block-farming tenure dispute which caused about 99 plot owners to stop SIDP activities further limited nutritional gains fairly. Gender of household head did not come out as a statistically significant factor influencing women's dietary diversity outcomes ($F = 0.951$, $p = 0.75$)

Concerning the third goal, the use of the bio-fortified crops, which include NUA 45 iron and zinc rich beans, orange maize, and orange fleshed sweet potatoes, using the SIDP vouchers increased food variety for those benefiting from the project. About 39.22 percent of the farmers in the Silalabuhwa area adopted the drought-resistant crops and diversified their crop range. Beneficiaries used legumes at the rate of 77.8 percent compared to the non-beneficiaries who had a lower percentage of 52.3 percent; while on the use of tubers, there was a huge gap of 56.5 percent for beneficiaries versus 33.9 percent for non-beneficiaries. These results partially confirm hypothesis two and three. There are however limitations to fully realizing the nutritional benefits because of poor availability of seeds, selling of the harvest by the poor families, and continuous nutritional education.

In conclusion, irrigation rehabilitation on the Silalabuhwa scheme has positively impacted the diversification of diet and food security amongst beneficiary smallholder farmers in one of

the most difficult agro-ecological zones in Zimbabwe. However, full nutrition security for particularly reproductive age women needs to be addressed not only through infrastructural improvements but also through regular income generation, continuous availability of bio-fortified seeds, and the removal of institutional barriers that have led to the exclusion of vulnerable plot owners from the programme

5.2 RECOMMENDATIONS

In light of this study's findings on irrigation rehabilitation and household nutrition security at Silalabuhwa Irrigation Scheme, the following recommendations are proposed.

1. Strengthen income support mechanisms to unlock the dietary income pathway.

The study revealed that the average agricultural income of Silalabuhwa is US\$174. 33, which is much lower than the SIDP programme average of US\$383. 37, thereby greatly restricting women's ability to purchase and achieve MDD-W. Forthcoming interventions should focus on income-generating activities for scheme participants like post-harvest processing, honey production, and market linkages with platforms like eMkambo and ZMX. SIDP Annual Outcome Survey (JIMAT Development Consultants, 2023) also suggests that value chain linkages through outgrower schemes and contracts should be facilitated, and collection centres and cold-chain storage facilities should be invested in. These initiatives are most necessary for Silalabuhwa, where low incomes continue to be the main limiting factor of diet quality even when food is available.

2. Resolve the block-farming tenure conflict to ensure equitable nutritional gains.

Nearly 99 plot holders at Silalabuhwa withdrew from SIDP activities because of the block-farming dispute, thereby excluding them from the nutritional benefits shown by this study. Future efforts need to be directed towards participatory stakeholder engagement, open communication, and alternative land management options to reintegrate these households into the scheme. If this socio-institutional barrier is not dealt with, it is highly likely that nutritional gains will continue to be distributed unjustly with the most vulnerable being left out disproportionately.

3. Ensure sustained and uninterrupted supply of bio-fortified seed and inputs.

The research shows that nearly 40% of the beneficiary households changed their farming methods to include drought-tolerant crop varieties like NUA 45 iron beans and orange-fleshed sweet potatoes, among others. These households recorded a lot higher rates in legume and tuber consumption (77. 8% and 56. 5% respectively) when compared to non-beneficiaries. Unfortunately, interruptions in the voucher-based seed distribution system may undo these positive changes. It is suggested that the programme becomes part of the routine, regular seed fairs are organised, and the input supply chains are made reliable so that the adoption of bio-fortified crops can be continued even when the project has ended.

4. Scale up nutrition education and cooking demonstrations, particularly targeting women of reproductive age.

Although the nutrition education aspect of the scheme had a very high participation rate (84. 8%), the average Silalabuhwa MDD-W of 4. 46 is still less than the five-food-group level. Nutrition knowledge by itself is not enough when there are no market opportunities and economic resources. Women-targeted interventions such as cooking demonstrations, dietary diversity education, and reproductive health awareness should be considered as very important complements. To further enhance women's empowerment outcomes, entrepreneurship initiatives and family planning services are the two key packages that should be integrated with agricultural extension services as per the recommendations of the SIDP AOS.

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APPENDICES

Appendix 1: Questionnaire

EVALUATING THE LINK BETWEEN IRRIGATION REHABILITATION AND HOUSEHOLD NUTRITION SECURITY AMONG VULNERABLE SMALLHOLDER FARMERS IN SEMI-ARID REGIONS OF ZIMBABWE: A CASE STUDY OF THE SILALABUHWA IRRIGATION SCHEME IN FILABUSI, INSIZA DISTRICT MATEBELELAND SOUTH PROVINCE.

BINDURA UNIVERSITY SCIENCE AND EDUCATION

My name is Kepekepe Arnold T **B223324B**, a final year student at Bindura University of Science Education, a Bachelor of Science Honours Degree in Agricultural Economics and Management. As part of my degree program, I'm required to carry a research and my research is on **THE LINK BETWEEN IRRIGATION REHABILITATION AND HOUSEHOLD NUTRITION SECURITY AMONG VULNERABLE SMALLHOLDER FARMERS IN SEMI-ARID REGIONS OF ZIMBABWE (CASE OF THE SILALABUHWI IRRIGATION SCHEME IN FILABUSI)**. Since smallholder farmers in semi-arid regions face food security challenges, strategies and efforts are desperately needed to efficiently and effectively design irrigation programs, policies, and interventions that improve irrigation scheme productivity in Zimbabwe. This research will help by identifying challenges and making recommendations. Your household has been selected by chance from a list of families that benefited from the Silalabuhwa irrigation scheme. I want to ask some questions related to the project. Participation in this interview is voluntary. Please NOTE that all information provided by the respondent is **STRICTLY CONFIDENTIAL** and will only be used for academic research and your participation in this study is voluntary. Thank you.

Appendix 1: Household background information

Objective: To characterise the demographic and socioeconomic profiles of surveyed households.

Beneficiary Type: Beneficiary Irrigator

Non-beneficiary Dryland Farmer

Code	Question	Response Options
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 education level attained	1= None 2=Primary 3= Secondary 4= Tertiary 5= University
A5	Health status of household head	1= Healthy 2=Sometimes sick 3=Sick
A6	How many people live in this household	Total :...(< 18yrs...18-35yrs :...> 35yrs :...)
A7	Compared with others in this community, your household's income falls in:	1=Well-off 2= Average 3= Poor 4= Very poor
A8	Since when was your household involved in the Silalabuhwa Irrigation Scheme?	Year....
A9	Do you own productive/ cultivated land?	1= Yes 2= No
A10	What is your total cultivatable land area?	ha
A11	What is your irrigated plot area? (ha)	ha
A12	Estimated annual household agricultural income (USD)	USD.....
A13	Do you have off-farm income sources?	1=Yes 2= No

Appendix 2: Household Dietary Diversity Score (HDDS)

Objective 1: To compare the HDDS of SIDP beneficiary irrigators and non-beneficiary dryland famers at Silalabuhwa.

Recall period: Yesterday (from early morning until bedtime). Ask about all household members.

Scoring: Each food group consumed= 1. Score range: 0-12. Food Secure>6; Mildly Insecure=5; Food Insecure= 3-4

No	Food Group (24-hour Recall)	Consumed	Score
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1	Sadza, maheu, maize/sorghum/millet porridge, rice, bread, or any other cereals	1=Yes 2=No	
2	Potatoes, sweet potatoes (including orange-fleshed sweet potatoes), cassava, or any other tubers	1= Yes 2=No	
3	Beans, peas, groundnuts, NUA 45 iron beans, peanut butter, or cashew nuts (legumes & pulses)	1=Yes 2=No	
4	Vegetables, dark green leafy vegetables (e.g. rape, chomolia, muriwo)	1=Yes 2= No	
5	Fruits including vitamin A-rich fruits (e.g. pawpaw, mango, orange)	1=Yes 2=No	
6	Beef, goat, chicken, pork, or any other meat	1=Yes 2= No	
7	Eggs	1=Yes 2=No	
8	Fish or Kapenta (matemba)	1=Yes 2=No	
9	Milk, yoghurt, or any other dairy product	1=Yes 2=No	
10	Sugar, honey, juice, sweets, or any other sugary food/drinks	1=Yes 2=No	
11	Oil, fats, margarine, or butter added to food or used for cooking	1=Yes 2=No	
12	Tea, coffee, salt, spices, tomato sauce, or condiments	1=Yes 2=No	

B1. In general, has your participation in irrigation scheme activities improved your living conditions? **1= Very Satisfied, 2=Moderately Satisfied, 3= Not Satisfied.**

B2. Are there NGOs or other organisations promoting post-harvest handling and storage at this scheme? **1=Yes 2=**

Appendix 3: Minimum Dietary Diversity for Women (MDD-W)

Objective2: To assess whether women of reproductive age (15-49 years) in Silalabuhwa scheme household meet the MDD-W threshold of five food groups.

Is there a woman aged 15-49 in this household who can answer a few nutrition questions? 1=Yes 0= No

Instruction: Ask the eligible woman about foods consumed from early morning to bedtime yesterday, in the home or elsewhere.

No	Food Group- MDD-W (FAO 10-group Standard)	Consumed?	Score
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1	Grains, white roots, tubers, or plantains(e.g. sadza, rice, potatoes, cassava)	1=Yes 0=No	
2	Pulses, beans or peas (e.g. peanuts, sunflower seeds, sesame)	1=Yes 0=No	
3	Nuts or seeds (e.g. peanuts, sunflower seeds, sesame)	1=Yes 0= No	
4	Dairy products (e.g. milk, yoghurt, cheese)	1=Yes 0=No	
5	Flesh foods, meat, poultry, or fish seafood (e.g. beef, goat, chicken, kapenta)	1=Yes 0=No	
6	Eggs	1=Yes 0=No	
7	Dark green leafy vegetables (e.g. chomolia, rape, spinach, pumpkin leaves)	1= Yes 0=No	
8	Vitamin A-rich fruits, vegetables, and roots (e.g. orange-fleshed sweet potatoe, orange maize, pawpaw, mango, carrot)	1=Yes 0=No	
9	Other vegetables (e.g. tomatoes, onions, garlic, cucumber)	1=Yes 0=No	
10	Other fruits (e.g. guava, bananas, wild fruits)	1=Yes 0=No	
Total MDD-W	Met Threshold (>5 groups) Did not Threshold (<5groups)		/10

C1. Gender of respondent woman: 1= Household head 2= Spouse 3= other female member (Specify):

C2. Age of respondent woman...years

Appendix 4: Bio-fortified crop production and consumption

Objective 3: To determine the impact of producing and consuming SIDP- promoted bio-fortified crops (NUA 45 beans, oranges maize, orange-fleshed sweet potatoes) on nutritional outcomes.

Section D1: Bio-fortified crop adoption

Code	Question	Response
D1	Did your household receive SIDP bio-fortified seed/planting material through the voucher system?	1=Yes 2= No
D2	Which bio-fortified crops did you produce this season? (tick all that apply)	☐ NUA 45 iron beans ☐ Orange maize ☐ Orange-fleshed sweet potato ☐ None
D3	Area planted to NUA 45 beans (ha)	...ha
D4	Estimate yield of NUA 45 beans this season (kg)	...kg
D5	How much of the NUA 45 bean harvest was retained for household consumption vs sold?	Consumed...%Sold...%
D6	Area planted to orange maize (ha)	...ha
D7	How much orange maize was retained for household consumption vs sold?	Consumed...%Sold...%
D8	Did you grow orange-fleshed sweet potatoes this season?	1=Yes 2= No
D9	How often does your household consume NUA 45 beans per week?	0=Never 1=Once 2=Twice 3=Three or more times
D10	How often does your household consume orange-fleshed sweet potatoes per week?	0=Never 1=Once 2=Twice 3=Three or more times
D11	Have household members attended SIDP food nutrition education or cooking demonstrations?	1=Yes 2= No

Section D2: Perceived Nutritional & Livelihood Impact

Code	Question	Response
D12	Since adopting SIDP bio-fortified crops, how has your household's dietary variety changed?	1=Greatly improved 2=Somewhat 3=No Change

		4=Worsened
D13	To what extent do you attribute improved household nutrition to the use of NU45 beans?	1=0-25% (Low) 2=26-50%(Medium) 3=51-75%(High) 4=76-100%(Very High)
D14	Have you experienced disruptions in SIDP seed/voucher supply that affected production?	1=Yes (describe)..... 2=No
D15	What are the main constraints to consuming bio-fortified crops at household level? (tick all that apply)	☐ High market price ☐ Sell all harvest (cash need) ☐ Lack of knowledge ☐ Seeds unavailable ☐ Other...

Section D3: Technology Adoption Checklist

Please indicate whether your household adopted the following SIDP-promoted technologies this season (1=Yes, 0=No):

Technology	Adopted	Not Adopted	Perceived contribution to Resilience
Conservation Agriculture (minimum tillage, planting basins, mulching)	☐	☐	High[] Med[] Low[]
Integrated Soil Fertility Management (ISFM)	☐	☐	High[] Med[] Low[]
Drought- Tolerant Varieties (including orange maize)	☐	☐	High[] Med[] Low[]

Diversified Cropping (including NUA 45 beans & OFSP)	☐	☐	High[] Med[] Low[]
Early & Timely Planting and Weeding	☐	☐	High[] Med[] Low[]
Integrated disease & Pest Management	☐	☐	High[] Med[] Low[]
Post-Harvest Loss Saving Technology	☐	☐	High[] Med[] Low[]
Integrated Crop-Livestock Production	☐	☐	High[] Med[] Low[]
Agroforestry	☐	☐	High[] Med[] Low[]

Appendix 5: Focus Group Discussion & Key Informant Interview Guide

Qualitative guide for FGDs (8-10 participants) and KIIs (AGRITEX officers, IMC member, local chiefs). All three objectives.

FGD/KII Theme 1: Irrigation Rehabilitation & Dietary Change

- ❖ F1. Before the SIDP rehabilitation, which crops were mainly grown and consumed at Silalabuhwa?
- ❖ F2. How has the rehabilitation of the irrigation scheme changed the variety of foods available to households?
- ❖ F3. Which food groups have households been able to consume more of since the rehabilitation? (Probe for legumes, tubers, fruits, vegetables, dairy, animal-source foods.)
- ❖ F4. Are there periods of the year when dietary diversity still falls? If yes, when and why?

FDG/KII Theme 2: Women's Dietary Diversity & Empowerment

- ❖ F5. Who is primarily responsible for food preparation and dietary decisions in household at Silalabuhwa?
- ❖ F6. Have women's food choices or access to nutritious foods changed since SIDP? In what way?
- ❖ F7. What cultural or social barriers limit women's consumption of certain food groups (e.g. eggs, meat, dairy)?
- ❖ F8. Has SIDP contributed to women's economic empowerment or decision-making power? How?

FDG/KII Theme3: Bio-fortified Crops & Nutritional Change

- ❖ F9. Were you aware that NUA45 beans and orange maize are specially enriched with iron, zinc, and vitamin A?
- ❖ F10. What changes in household health or diet have you noticed since consuming NUA45 beans, orange maize, or orange-fleshed sweet potatoes?
- ❖ F11. What proportion of your bio-fortified crop harvest is consumed at home versus sold? Why?
- ❖ F12. What challenges have you faced in accessing SIDP planting materials through the voucher system?

FDG/KII Theme 4: Block-Farming Dispute & Programme Equity

- ❖ F13. How did the block-farming arrangement affect participation in SIDP activities at Silalabuhwa?
- ❖ F14. In your view, did all eligible households benefit equally from the nutrition gains of the scheme? Why/Why not?
- ❖ F15. What changes to the programme or scheme management would improve nutritional outcomes for all members?

