ASSESSMENT OF FACTORS AFFECTING THE INTENSITY OF ADOPTION, PRODUCTION, AND CONSUMPTION OF BIOFORTIFIED CROPS IN MAZOWE DISTRICT

FOR THE MASTER OF SCIENCE DEGREE IN FOOD SECURITY AND SUSTAINABLE AGRICULTURE
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DECLARATION

I hereby declare that the research project entitled "**Assessment of Factors Affecting the Intensity of Adoption, Production, and Consumption of Biofortified Crops in Mazowe District**" submitted to Bindura University of Science Education, Department of Agricultural Economics, Education and Extension is a record of an original work done by me under the guidance and supervision of **Dr. L. Musemwa** and this work is submitted in partial fulfilment of the requirements for the award of a Master of Science Degree in Food Security and Sustainable Agriculture. The results embodied in this thesis have not been submitted to any University or Institute for the award of any degree or diploma.

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DEDICATION

This study is dedicated to Sandra Rutendo Chawafambira, Joseph Munyaradzi Kambarami, and Gogo Kambarami for their unwavering support during my studies.

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ABSTRACT

More than 2 billion people suffer from hidden hunger globally due to inadequate intake of micronutrient rich diets. Zimbabwe is not spared from this predicament as it is battling recurring food insecurity challenges which have been exacerbated by climate change and its adverse effects. In Zimbabwe on average 22% of the general population are Vitamin A deficient and 65% iron deficient as such efforts to combat these deficiencies have been adopted through the food systems approach. Most studies on biofortified crops have focused on adoption leaving a gap on production and consumption hence this study aims to bridge the gap between factors affecting adoption, intensity of production and consumption. The study was conducted in Mazowe district with focus on ward 12. From a sampling frame of 300 households that was availed by the Agritex officer responsible for the ward, the researcher interviewed 183 randomly selected respondents. A household questionnaire was administered at household level to collect survey data.

Descriptive statistics, binary regression analysis and linear regression analysis were used in the analysis of data. A lesser proportion of households (17.5%) had adopted and were cultivating biofortified crops at the time the survey was conducted whilst 82.5% had not adopted. Adoption of bio fortified crops was significantly influenced by contact with agricultural extension services, knowledge and area of arable land a household had access to. The intensity of production was affected by income a household had access to monthly and area of arable land that can be accessed whilst consumption was mostly affected by health consciousness, knowledge and social networks within the community. It is key for households to have a revolving fund that will help in boosting agricultural activities at household level through purchase of seeds, fertilizers and other key inputs. The misconception between GMOs and biofortified crops portrays a knowledge gap and this calls for awareness campaigns at national and subnational level so that consumers are capacitated. At policy level there is need to mainstream and incorporate the biofortified crops in the educational curriculum so that people are informed from grass root level upwards on the importance of these crops to human health.

Keywords: Adoption, Bio fortification, Consumption, Deficiency, Production, Vitamin

LIST OF ACRONYMS AND ABBREVIATIONS

BF	Biofortified Foods
BV	Biofortified Varieties
FAO	Food and Agricultural Organization
GOZ	Government of Zimbabwe
GMO	Genetically Modified Organisms
HH	Household
IFPRI	International Food Policy Research Institute
LFSP	Livelihoods and Food Security Program
OFSP	Orange Fleshed Sweet Potatoes
SBCC	Social Behavior Change Communication
SPSS	Statistical Package for Social Sciences
UN	United Nations
VAC	Vitamin A rich Cassava
WHO	World Health Organisation
ZIMSTAT	Zimbabwe Statistical Agency

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Chapter 1
Introduction

1.1 Background of the study

Zimbabwe is amongst some of the Sub-Saharan countries with highest levels of food insecurity, regardless of the outcome of its agricultural seasons. Approximately 70 percent of the population relies on subsistence rainfed agriculture for their livelihood and food and nutrition security. The majority are smallholder farmers, tilling an average of 1 ha or less per household. The high reliance on subsistence rainfed agriculture renders a large majority of the rural population vulnerable to climate-related shocks and seasonal stressors. Zimbabwe's already precarious food security and nutrition situation is further exacerbated by poverty, poorly functioning markets, low soil fertility, and farmers' limited access to credit, knowledge and best practices.

Malnutrition in its various forms continues to be a public health concern worldwide. From undernutrition, over-nutrition, micronutrient deficiencies, and diet-related non-communicable diseases, countries face one or more of these burdens at a time (FAO, 2015; IFPRI, 2016). Globally, 2 billion people suffer from hidden hunger caused by infections and diets lacking in essential micronutrients such as vitamin A, iron, and zinc. This is more prevalent in the developing world, where diets mainly consist of starchy staples and not enough nutrient-rich foods such as fruits, vegetables, beans and pulses, and animal source foods (Mourad, 2015). Even in the presence of adequate food where energy requirements are met, micronutrient deficiencies can prevail if micronutrient-rich foods such as fruits, vegetables, and animal source foods are regularly lacking from the diet (Nabuuma *et al*., 2021). According to the Micronutrient survey of 2012 in Zimbabwe, the prevalence of vitamin A deficiency in children 6-59 months and women 15-49 years is 21% and 24% respectively while prevalence of iron deficiency in children 6-59 months and women 15-49 years is 72% and 62% respectively. This shows that the majority of the population including vulnerable under 5 children are exposed to food insecurity induced morbidities and ultimately mortality. This highlights the essential role of nutrition education and promoting the health benefits of nutritionally sound food choices.

Reviving the importance of locally available nutrient-dense foods such as fruits, vegetables, and beans and pulses within food systems and ensuring greater market access are key strategies to achieve a more diversified diet. This can be accomplished through supportive policies at national level and locally developed solutions, including integrated homestead food production and greater integration of locally available nutrient-dense foods into market systems that can reach both rural and urban consumers. Biofortified crops present a huge opportunity to provide basic missing nutrients, but also to educate consumers about the benefits of a diverse diet and to promote other locally available nutritious crops.

Because food staples are consumed regularly in large quantities, biofortification is an efficient and cost-effective way of bringing more micronutrients to the diets of the poor. It contributes to improving the diet quality of populations and can be viewed as integral to dietary diversity. Biofortification is not promoted to increase consumption of staples. Rather, it is used to substitute some or all of the non-biofortified equivalent staples from the diet with better and more micronutrient-rich varieties. Such a strategy recognizes that there are limits on how much energy should be derived from carbohydrates, and does not encourage people to solely rely upon, or increase, the consumption of biofortified staples as they cannot provide the full array of nutrients. However, getting people to eat more nutrient-rich foods and fewer staples is very challenging, especially in resource-poor settings where access, availability, and affordability are constrained thus unable to eliminate hunger, be safe, reduce and protect against all forms of malnutrition, promote health, or be produced sustainably.

Nevertheless, studies concerning the intensity of production and consumption of biofortified crops are scarce, and this prompted the researcher to engage on studying the factors affecting the intensity of production and consumption of biofortified crops.

1.2 Statement of the problem

Increasing availability and access to a nutritionally diverse range of foods within and across different food groups is key to ensure adequate intake of essential nutrients required for healthy, productive lives (Fanzo *et al*., 2012; IFPRI, 2016; Mourad, 2015; Stevens, 2008). The health consequences of poor dietary quality are well known – high morbidity and infant mortality rates, compromised cognitive development for children, stunting, and low economic productivity (Bailey, 2015; WHO, 2015). Vitamin A, iron, and zinc deficiencies are recognized as the most severe mineral and vitamin public health problems throughout sub-Saharan Africa. Severe vitamin A deficiency among preschool children afflicts most countries, despite widespread vitamin A supplementation programs. The prevalence of vitamin A deficiency among preschool children ranges from 40% in West and Central Africa to about 25% in Southern Africa (WHO, 2009). Anemia affects about 40% of pregnant women and 62% of children in Africa, about half of which is estimated to be attributed to iron deficiency (WHO, 2015). Anemia levels have not significantly improved over the last 20 years. Data on zinc deficiency are limited and as country we are yet to have baseline data, but recent estimates suggest that 24% of Africans have inadequate zinc intakes, with pregnant women and young children at the highest risk of deficiency (Bailey, 2015).

What people eat depends on many factors, including cultural, geographical, environmental, and seasonal factors. One of the key underlying causes leading to poor dietary quality is that current food systems do not provide minerals and vitamins in sufficient quantities at affordable prices for the poor. In non-emergency situations, poverty is a major factor that limits intake of adequate, nutritious food, which must be available, accessible, and affordable to the poor. Therefore, agricultural investments and policies that improve the availability and affordability of more nutritious foods, such as biofortification, must be made an important part of the solution (FAO, 2015; Mourad, 2015), however scarce information is available on factors affecting the adoption, production and consumption of biofortified crop varieties.

While there is great national and regional variation in diets in sub-Saharan Africa, most are characterized by high staple food consumption, mainly cereal or root crops. Access to micronutrient-dense food sources, including animal-source protein, fruits, and vegetables, is a major challenge for many rural households. These foods are often inaccessible because of their relatively high cost, limited local availability, and distribution challenges (Saltzman *et al*., 2013; Fanzo *et al*., 2012; FAO, 2015). The lack of empirical evidence on factors affecting the production and consumption of biofortified crops is the motivation behind this study.

1.3 Objectives of the Study

1.3.1 Main Objective

i) The main objective of this study is to explore the level of adoption, factors affecting the intensity of production and consumption of biofortified crops.

1.3.2 Specific Objectives

The specific objectives of this study are to:

1. To determine the factors affecting the adoption of biofortified crops by smallholder farmers in Mazowe District.
2. To determine factors affecting the intensity of production of biofortified crop varieties by households in Mazowe District.
3. To determine factors affecting the intensity of consumption of biofortified crop varieties by households in Mazowe District.

1.4 Research Questions

1. What factors are affecting the adoption of biofortified crops by smallholder farmers?
2. What factors influence the intensity of production of biofortified crop varieties by households in Mazowe District?
3. What factors influence the extent of household consumption of biofortified crops in Mazowe District?

1.5 Significance of the study

This study has been motivated by the gaps that currently exists nationally pertaining to the factors affecting the adoption, intensity of production and consumption of biofortified crops. Biofortified staple foods hold the potential to alleviate micronutrient malnutrition in many impoverished regions of the world (Stevens, 2008), and researchers have started to analyze how biofortification can contribute to dietary diversification through a food basket approach where a variety of biofortified foods can be combined with other locally available foods to maximize their respective benefits (FAO, 2015; Nabuuma *et al*., 2021).

In this regard, this research study not only contributes to the existing literature but also to the development of evidence-based policies and interventions in order to combine biofortification and dietary diversification into a more integrated strategy for the betterment of the poor population in developing countries and Africa at large by addressing the burden of micronutrient deficiencies. This evidence will strengthen rural development approaches through integrating indigenous knowledge with rural livelihoods planning process in the current pressure to balance development and sustainability as within the UN Sustainable Development Goals 2030 framework.

1.6 Scope and limitations of the study

1.6.1 Delimitations

The study will be conducted in a district where biofortification programs were initially introduced through an extended program of the Livelihood Food Security Program (LFSP). Fieldwork was made easy by roping in Agritex and Harvest plus officers on the ground who have knowledge and appreciation of the traditional socio-cultural norms and protocols in the district.

1.6.2 Limitations

Data collection for the study was carried out during the rainy season and issues pertaining to accessibility due to poor road networks prevailed. Most households were occupied by agricultural production activities as they depend on rainfed agriculture to enhance their food security. This had implications on the availability of respondents for the household survey as other smallholder farmers relocate to the fields during this period. The researcher interviewed some respondents from their fields to avoid inconveniencing them from their livelihood activities.

1.7 Outline of Thesis

Chapter one presents the introduction, statement of the problem, objectives, research question, justification of the study, scope and limitations of the study. The outline of the thesis is also presented in Chapter 1.

Chapter two focuses on the literature review of other studies that aimed to solicit factors that stimulate the adoption of agricultural technology and biofortified crops, production, and consumption thereof by other researchers globally. This section mirrors the backbone of this research as it provides a guide in its structure and a baseline to reference the research findings. Chapter three commences with a brief introduction and a snapshot of the study area in which the research was conducted. This is where the research design, sampling procedures, data collection processes are explained in detail including how data analysis was carried out and packages used, and ethical considerations taken during data collection. Chapter four and five are where the research findings are presented through tables and data visualizations generated from data analysis. Interpretation of study results is clearly presented here through descriptive statistics and correlation. Finally, chapter six provides study summary, conclusions and recommendations that can be used to inform decision making and improve programming in interventions that address micronutrient deficiencies through the adoption of biofortified crops which is meant to improve uptake of nutrient dense foods. It also puts across the challenges encountered during the research process.

Chapter 2

Literature Review

2.1 Introduction

This section focuses on literature analysis of factors affecting production, consumption and adoption of biofortified crop varieties. Analysis focused on the existing data of studies that have been conducted globally, regionally, and nationally. Biofortification, is an act of breeding nutrients into food crops, is a relatively cost-effective, long-term way of increasing micronutrient delivery. Furthermore, biofortification is a viable way to address impoverished rural people who may lack access to commercially available fortified meals and supplements (Bouis *et al*., 2013). Petry *et al.* (2020) defines it as increasing the micronutrient content of staple foods by selective plant breeding, is a promising strategy for closing the micronutrient gap, particularly in hard-to-reach groups that are not served by existing nutrition interventions.

2.2 Influencing factors to production, consumption, and adoption of biofortified crops

The understanding of the driving forces of adoption is of paramount importance because it enlightens the reader as well as the researcher to comprehend factors linked with adoption of biofortified crops by farmers. From earlier studies literature shows that the theory of adoption behavior varies depending on the field of study i.e. sociology, anthropology, education or medicine etc., however most of them are anchored on the contagion theory, which links the closeness to a previous adopter to increased chances of adoption (Caswell *et al*., 2001).

2.2.1 Production of biofortified crop varieties by households

Biofortification of crop varieties comes with benefits which include increase in nutritional value, reduced adult and child micronutrient caused mortality, reduced dietary deficiency diseases and healthier population with strong and quick immune responses to infections (Jena *et al*., 2018). Consciousness of the nutritional value of biofortified varieties (BVs) and food security status of a household significantly affect farmer's verdict to produce BVs (Okello *et al.*, 2017). The latter benefits should incite an increase in intensity of production of biofortified crops, however negative factors affect the intensity of production of the nutritionally rich crops as follows;

2.2.1.1 Production costs

Technology adoption is driven by demand, and for a long time farmers are envying new innovations as a means to decrease production costs (OECD, 2001). The high costs of production of the BVs i.e. equipment, technology, patenting etc. is a hindrance to adoption and renders the improved varieties inaccessible to the general populace as the seed becomes expensive (Jena *et al.*, 2018; Obayelu, 2017). According to Taylor (n.d.) and Abunga *et al.* (2012), biofortification has high initial costs of development, and requires intense expertise. Major setback to production of BVs was lack of disposable capital and high cost of seed and other resources essential (Issa, 2016). This means that the smallholder farmers that lack financial resources and expertise cannot afford to engage themselves in production of biofortified crops at infantile stages thus affecting intensity of production.

2.2.1.2 Interaction of biofortified varieties with other plants

Potential negative interaction between biofortified crop varieties and other crops makes farmers shun production of these improved varieties as a precaution to avoid socio-cultural altercations. The provitamin A biofortified crop varieties for example orange maize has a tendance to cross pollinate the conventional varieties causing a loss in the desired traits (Jena *et al.*, 2018). This calls for the production of these biofortified varieties a distant from the conventional crop varieties, affecting intensity of production since the majority of smallholder farmers have limited areas of arable land and are concentrated in one area.

2.2.1.3 Socioeconomic factors and access to resources

The adoption of new technology is influenced by socioeconomic considerations (Adesina and Baidu-Forson, 1995; Foster and Rosenzweig, 2010). The majority of small holder farmers are poor and lack the necessary endowments to purchase seed for the biofortified crop varieties (Jena *et al*., 2018). Muvhuringi and Chigede (2021), revealed that production of biofortified crops was low due to unavailability of biofortified seeds and the longer distances to seed markets. Besides socioeconomic factors, access to propagation materials for the new crop varieties and knowledge on how to successfully use the technology would influence adoption (Kabunga *et al.,* 2012). Beyond those factors, the adoption of new innovations is influenced by awareness of the innovations and information diffusion in the population (Diagne & Demont

2007). Gilligan (2012), reveals that biofortified seeds are not delivered using the same system as conventional crops which might be a cause of concern in the slow uptake of biofortified varieties. Muthini *et al.* (2019) asserts that there is a positive correlation between area under biofortified crop production and social network size an individual farmer has. The same has been noted in cases where the farmer had high chances of access to credit (Haregu, 2018; Muthini *et al*., 2019). Most smallholder farmers, possess usufructuary privileges to property use and as such lack collateral to access necessary resources which affects the intensity of production of biofortified crops (Caswell *et al*., 2001; Deere *et al*., 2009; Mourad, 2015). The rate of adoption of agricultural technology is negatively affected by farmers' constraints to credit facilities and resources, barriers to current information, taste preference and varying agro-ecological factors (Mishra *et al*., 2020). Nguezet *et al.*, (2010) found out that in Nigeria households that took agriculture as a main livelihood were less likely to adopt and produce new varieties an issue which might affect intensity of production. It is important to note that accessibility to off-farm income sources facilitate farmers to purchase and produce BVs as they have more disposable income (Mutimura *et al*., 2018).

2.2.1.4 Yield

According to Caswell *et al.* (2001), adoption of technology is difficult if farmers realize that it's performance is limited vis a vis available resources and conditions, or does not tally with farm size and activities. If farm size is limited, farmers will automatically maximize on what they know best. The orange maize has been blamed for producing low yields per hectare according to a study in Zimbabwe on trends in production and consumption which might be affecting the intensity of production of the improved varieties (Muvhuringi and Chigede, 2021). Yield capacity of BVs can potentially drive adoption and knowledge on accurate yield estimates can enhance promotional efforts (Vaiknoras and Larochelle, 2018). De-Groote *et al.* (2016), revealed that adopters are mostly attracted by performance agronomic especially yielding characteristics.

2.2.2 Consumption of biofortified crop varieties by households

Biofortification programs should be executed in areas farmers grow the targeted crop and consumers offer a ready local market (Zapata *et al.*, 2009). In terms of consumption a study conducted in Zimbabwe by Muvhuringi and Chigede (2021) revealed that there was no association ($p > 0.05$) between gender and consumption of biofortified crops, and 30% of smallholder farmers who had not produced biofortified crops had consumed orange maize. The study showed that all the Households producing orange maize, had consumed it, showing a strong association between production and consumption, however the lower rates of consumption in most areas has affected the adoption and effectiveness of interventions that bring on board the new technologies (Gilligan, 2012). Farmers are end users of agricultural research commodities, and their personal preferences for new agricultural technology features influence their adoption and consumption decisions (Obayelu, 2017). The adoption process and consumption patterns of individuals are influenced by cultural differences in attitudes as well as unobservable variables (Obayelu, 2017).

2.2.2.1 Health concerns

Consumers are becoming sensitive to food safety and health conscious to the products they eat (Loizou *et al*., 2009). Consumers' acceptance of functional food product innovations is influenced by their perceptions of health benefits (Mack, 2018). Demand of nutritious food commodities is driven by consumers' motivation and health consciousness that brings a sense of fulfillment (Oláh *et al*., 2021). Empirical evidence shows that nutrition knowledge did not influence intake of BVs rich in Vitamin A among children 6-59 months according to a study on consumption patterns in Mozambique however in Uganda there was noticeable increase in consumption which could be accredited to the OFSP project advocacy and messages (De-Brauw *et al*., 2012). Quality of a commodity has been identified as a predictor of consumers' contentment and willingness to purchase (Nathan *et al*., 2021), nevertheless the fear that genetic engineering processes embraced may compromise immunity in humans and the increased risk of allergenicity has a negative influence on the consumption of BVs (Jena *et al*., 2018). Labrecque *et al.* (2016) asserts that consumers may believe that new food technology and functional food products are damaging to their health, or even poisonous or allergy-inducing, or that they have an unanticipated effect on the body which has a negative influence on consumption supporting Siegrist *et al.* (2015) findings that say that Individuals differ in their desire to try new meals. Lack of trust to nutritional and health benefits claims by consumers might have devastating influence on the consumption of functional foods (Siegrist *et al*., 2015).

2.2.2.2 Substantial equivalence

The majority of farmers shun the production of biofortified crops because of their inability to provide high micronutrient and protein content compared to supplements (Jena *et al*., 2018). Biofortified foods might not provide the same daily doses of micronutrients as supplements or Industrially fortified foods, but they assist by boosting the daily adequacy of micronutrient intakes among people throughout their lives (Bouis *et al*., 2011). The post-harvest processes, preparation and cooking may result in losses that disturbs the (bio)availability of the nutrients (Taylor and Taylor, n.d.). High yielding beans rich in micronutrients additionally to proteins can influence increase in consumption at household level, freeing up disposable income which can be directed towards purchase of animal products (Vaiknoras and Larochelle, 2018). Birol *et al.* (2015) findings show that lack of facts on nutritional value and benefits of BF does not affect consumers preferences and perceptions between conventional and fortified foods, however color, taste and cooking time affects consumer product choices. Consumers are unwilling to trade off nutritional benefits for other consumption features they regard highly, even if they do appreciate nutritional benefits (Birol *et al.*, 2015).

2.2.2.3 Access, availability and palatability

Farmers must be persuaded to grow the improved crops, however for consumption consumers must find food products from biofortified crops acceptable (Taylor and Taylor, n.d.). Petry *et al.* (2020) findings show that access to BVs for consumption is high in households that produce the crop and limited in non-farming households. Sensory characteristics of Vitamin A rich varieties intrigued consumers to value *Nshima* made from orange maize meal high in Zambia and *gari* from vitamin A rich cassava (VAC) meal in Nigeria (Bouis *et al*., 2020). Another study on consumer acceptability of BVs with focus on cassava revealed that consumers liked VAC to the conventional white variety (Bechoff *et al.*, 2018) concurring with a similar study in Kenya (Talsma *et al.*, 2013). Rizwan *et al.* (2021) findings show that appearance and aroma of food from BVs is key in influencing consumption of biofortified product concurring with similar studies by Woods *et al.* (2020) and Mahboob *et al.* (2020) however taste had insignificant influence which disagrees with Mack (2018) findings that show that intensity of consumption of biofortified foods and consumers' willingness to accept new products is positively influenced by perceived taste.

A study on coverage of BVs in Rwanda revealed that the main tailbacks to consumption of biofortified foods (BF) were awareness and availability of the biofortified food vehicle *(*Petry *et al.,* 2020). Empirical evidence indicates that the general public might be ready to spend for BVs however availability is a problem (Jenkins, 2015). If the BF has noticeable and possibly unacquainted traits for example color changes, flavor, or consistency, there is need to sensitize consumers through social behavior change communication (SBCC) strategies on the benefits of BVs, a move which may effect an increase on consumption (Oparinde *et al*., 2016). For Orange Fleshed Sweet Potatoes (OFSPs), which are noticeably different to conventional varieties, SBCC strategies have been a useful driver of consumption and adoption (Oparinde *et al*., 2016). Nevertheless, perpetual consumption is promoted by demand creation for BF and constant supply of inputs (De Brauw *et al*., 2018). However Consumption of nutritional and functional innovative products is hampered by their high price-to-value ratio (Mack, 2018).

2.2.3 Adoption of biofortified crops by smallholder farmers

Technology adoption, is a wide-ranging notion that is affected by growth, dissemination and utilization at farm level of predominant and new techniques which are enrobed in farm capital and inputs and also education, training, guidance and extension which are the root of farmers' knowledge (OECD, 2001). Personal evaluation of novel technology is subjective and is likely to change with time when a farmer acquires more information about the technology from counterparts who have previously embraced it (Bryan, 2014), the extension service, or the media. Initially when a technology is availed, lack of confidence around its performance under local environment is often high which has a negative inference on the intensity of its adoption (Caswell *et al*., 2001). Sociocultural norms have a negative influence on the adoption of BVs into their normal diets (Mack, 2018).

2.2.3.1 Knowledge of food fortification

Empirical evidence shows that adoption of BVs can be enhanced by nutrition education programs that inform communities on their health and nutritional gains thus influencing the rate of integrating them with routine menu (Woods *et al*., 2020). In the study carried out by Kairiza *et al*. (2020), out of the 25,297 households with children under 5 years that were surveyed, 3038 (12%) knew fortified foods and were considered to have adopted food fortification. This clearly deduces that knowledge maybe be a factor affecting knowledge of adoption of biofortified crops. A lot of smallholder farmers cannot distinguish between orange and yellow maize varieties which is negatively affecting adoption of biofortified crops (Muvhuringi and Chigede, 2021). For biofortified varieties, knowledge of the nutritional benefits, in addition to awareness of varieties, could potentially influence adoption and consumption (Muthini *et al*., 2019). Having understanding of the ultimate use of produce from BVs (stock feed, human consumption or sold) may stimulate adoption since this may help explain clearly the benefits from biofortification (Vaiknoras and Larochelle, 2018). According to a study in Mozambique knowledge on nutrition had slight influence on adoption of BVs, if any (De Brauw *et al*., 2018). Nguezet *et al*. (2010), asserts that there is positive correlation between number of years taken pursuing education or experience on agricultural activities and likelihood to adopt a new variety.

2.2.3.2 Household and socio-cultural characteristics

In an African context tilling with ox drawn ploughs and planting is considered a role for men, whereas weeding, harvesting, and collecting is a considered a shared role for boys, girls, men and women. For women decision making power over agricultural processes vary depending on household setting, context, and socio-cultural norms in the country. Kairiza *et al.* (2020), asserts that female headed households are less likely to adopt fortification programs as compared to their counter parts, supporting similar findings by Haregu (2018). Generally, food fortification adoption is low in Zimbabwe as only 11.2% of females and 12.3% of male household heads had heard about fortification. Females' restricted access to dire resources like land, capital and labour (Doss and Morris, 2001; Ragasa *et al.*, 2013; Tanellari *et al*., 2014), inhibit their adoption, typical of the African traditional context where most resources are under the heir of males. According to Osuafor (2016) marriage has been shown to have a negative and considerable impact on the adoption of enhanced rice producing technology. Farmers who are likely to get credit easily are deemed rich and or creditworthy meaning they are risk takers and possess high probability of adopting improved varieties (Matuschke *et al*., 2007 and Muthini *et al*., 2019).

Several studies show that there is a controversy between age and adoption of technology, however age as a variable of paramount importance and needs to be handled with caution in implementation of agricultural activities (Abunga *et al*., 2012). A study in Kenya on biofortified bean variety showed that household head age had a negative influence on the adoption of improved varieties (Muthini *et al*., 2019), meaning that farmers of old age are less likely to cultivate BVs (Okello, *et al*., 2017). The elderly normally resist change and adhere to the varieties they are familiar with and have a known track record of performance (Nguezet *et al*., 2010).

Maize productivity levels in Ethiopia are dismally low including other crop varieties and this may be as a result of partial adoption of enhanced crop varieties, particularly by women farmers (Ragasa *et al*., 2013). Household members have varied access to information and inputs depending on gender, which is a major reason of differing adoption choices made on new technology (Gezimu *et al.*, 2019), depending on whether decision is made on individual basis, jointly factoring the family setting, social and cultural customs (Doss, 2015).

In Ethiopia, a study showed that there is restricted adoption of enriched varieties of maize for female-headed households as compared to households that are headed by males where decisions are jointly made.(Gezimu *et al*., 2019). Using household head sex or headship as a gender indicator does not indicate the decision maker for agricultural production (Peterman *et al*., 2010), which might miss the role played by women as household heads or males under female headed households (Gezimu *et al*., 2019). Women often make joint decisions in male headed households with their spouses (Deere *et al*., 2009), whereas men (eldest son) in a household female headed has influence in decision making (Bourdillon *et al*., 2002). Other aspects except gender, such as social networks, asset ownership, landholding, and access to extension services, influence women's decisions to adoption of new agricultural technology (Addison *et al*., 2018; Seymour *et al*., 2016). Access to credit services is also a paramount factor to adoption of new agricultural technology (Mupenzi Mutimura *et al*., 2018). Bryan (2014) argues that even without financing constraints, women may show lower adoption rates if new technologies are mainly geared to ease the marketing of excess production.

There is a positive relationship between education and adoption of agricultural technology (Mugonola *et al*., 2013). Household head level of education influence adoption of agricultural technology (Beshir and Wegary, 2014). A positive correlation exists between education and technology adoption, the former is perceived to increase farmers' capability to make informed decision (Haregu, 2018). In Rwanda, a study showed that BVs adopters are more educated compared with non-adopters, more affluent, own agricultural equipment, have access to agricultural extension services and have direct access to markets (Vaiknoras and Larochelle, 2018). Education in terms of number of years in formal schooling is perceived to create a platform that favors embracement of new technology, as such the complexity that comes with new technology is thought to have negative influence on adoption and can only be dealt with education (Abunga *et al*., 2012). In most African states the high rate of illiteracy among women is likely to prevent them from adopting technological advancements (Mugonola *et al*., 2013).

2.2.3.3 Policy issues

Policies often send contradictory signals to the farmers which hamper the acceptance of new technology (OECD, 2001). Three strategies have been used to stimulate the adoption of biofortified varieties, (i) classical strategy where varieties with greater agronomic vigor are promoted based on their characteristics however little or no focus is given to their palatability or nutritional features; (ii) Mostly used to promote Quality Protein Maize in Kenya and orange Maize in Zimbabwe, anchored on the nutritional benefits and trades-off with reduced agronomic performance (De Groote *et al*., 2010). The last strategy, is centered on the promotion of biofortified varieties that have both good agronomic vigor and nutritional characteristics (De Groote *et al*., 2010).

Most studies on biofortification do not speak to gender issues on technology adoption. Production of biofortified varieties in the country is gender sensitive however, limited evidence is available on how gender variances affects adoption of technology which enhances crop productivity (Gezimu *et al.*, 2019). Low adoption of biofortified varieties is a challenge, which may be attributed to an increase in female headed households due rural urban migration by males. Gender is a crucial socio-economic aspect to the household agricultural operations at farm level however there is a huge gender gap that policy makers and researchers needs to understand

and address in the adoption of agricultural technology (Obayelu, 2017; Addison *et al*, 2018). The eradication of subsidies on input prices owing to the structural adjustment programs in sub-Saharan Africa has negatively interfered with the adoption of new technology (Obayelu, 2017), a matter that needs to be reviewed at policy level. So far, evidence suggests that women's gender in agricultural activities has a negative and considerable impact on the adoption of new technology (Addison *et al*., 2018).

If crops are biofortified by genetic transformation then there are additional political and regulatory issues to be addressed (Taylor and Taylor, n.d.), for instance in Zimbabwe the production of GMO crops is banned however consumption and processing is permitted under strict monitoring. For instance, subjective evidence and technical studies exists that supports the paybacks of GMOs focusing on yield, production costs and environmental effects (OECD, 2001).

Poor inter-ministerial coordination and lack of cost-effective delivery strategies to promote biofortification as an alternative to supplementation and commercial fortification has retarded the adoption of biofortified technology by small holder farmers (Gilligan, 2012). Adoption rates in smallholder farms and large commercial farms is different, an issue that policy makers needs to take into consideration in driving for adoption of new technology (Abunga *et al*., 2012).

Farm households are enticed to manage their resources and produce agricultural products through the use of support services and policies (Mutambara, 2016). Policy has a huge impact on semi-arid farming systems, such as promotion of cash-crop exports to supply much-needed foreign currency in the country (Simatele, 2006), however in terms of food production it has presented as a disincentive it has negatively affected the adoption of improved varieties including BVs.

2.2.3.4 Market dynamics

Griliches (1957), studies on hybrid maize revealed that profitability is a major determination of adoption, this assertion was corroborated by Rogers *et al*. (1983), revealing that technology is important however profitability is one component that pushes motive. Relative advantage, compatibility, complexity, trialability, and observability are characteristics of innovation and denotes expenses to a possible adopter since they cover new evidence and modifications to be done (Caswell *et al.*, 2001). Obayelu (2017) and Djibo and Maman (2019) iterates that one of the determining factor for adoption of new technology are the returns to the adopter inclusive of cost embracing the technology. The market for biofortified crop varieties is limited with those producing under the harvest plus intervention linked with the ready market to sell to, however the producer prices for orange maize are unfavorable with Grain marketing board offering the same price as that of white maize thus retarding the adoption the adoption of the improved varieties (Muvhuringi and Chigede, 2021). Attractive prices effect positive adoption of BVs, a case revealed in Rwanda where market prices influenced increase in adoption and consumption of biofortified beans (Vaiknoras and Larochelle, 2018). Empirical evidence suggests that inputs, product and factor market access is important for the adoption of new ideas (Bryan, 2014).

Longer distance to the market is also a major factor that negatively affect the probability of adoption of biofortified crop varieties (Muthini et al., 2019), as this increases production costs (Okello *et al*., 2017) . Farmers' access to a market place, with readily available seed, ready market for agricultural produce, and information on different varieties influences positive adoption of BVs (De Groote *et al*., 2010), contrary to farmers in remote areas far away from markets. In Ethiopia adoption of improved maize varieties was influenced by the distance between the farmers residential place and the local market, with farmers closer to the market exhibiting high adoption rates (Beshir and Wegary, 2014).

2.2.3.5 Agronomic performance

Competitive agronomic vigor and performance of a biofortified variety contributes to increased adoption by farmers (De Groote *et al*., 2010). Improved crop varieties acceptance is explained by farmers' opinions of yield and marketing (Djibo and Maman, 2019) which reinforces findings from other studies that revealed that agronomic performance was rated more vital than nutritional benefits by most adopters (Issa, 2016). This means that, individuals that are aware of a certain variety but lack knowledge of its agronomic perfomance and nutritional qualities may fail to adopt it (De Groote *et al*., 2016). Diversified crop production already practised on the farm increases the chances for a farmer to adopt new varieties including biofortified seeds (Muthini *et al.*, 2019).

2.2.3.6 Access to Extension services

Access to, and involvement in extension services empowers farmers through exposure to recent information and existing packages, that may improve their knowledge, attitude and behavior (Haregu, 2018). Literature shows a strong influence of agricultural extension exposure on adoption of crop technology (Beshir and Wegary, 2014), however farmers mostly have a limited understanding of modern technologies, as they lack proper guidance on how new technology will affect yield, prices in product markets and interaction with climate (Bryan, 2014). There is a positive relationship between area under biofortified crops and social networks (Vaiknoras and Larochelle, 2018), the probability by which the latter influences adoption is insignificant and access to information and extension services increases possibilities of a smallholder farmer in adopting biofortified varities (Gezimu *et al*., 2019; Muthini *et al*., 2019). Studies show that increased communication between farmers and extension officers increased the likelihood of adoption of new varieties (Dontsop Nguezet *et al.*, 2013; Elias *et al.*, 2013), as farmers gain access to agro-ecological factors including varieties that suit their context (Okello *et al*., 2017).

In Nigeria, farmers who embraced new varieties of maize profited from awareness, yield, and income and sourced most required information from radio, associate farmers, extension officers, cooperatives, and commercial agro-dealers (Issa, 2016) . Public health based extension helps increase consumer awareness and interest which stimulate an increase in demand on the market thus prompting farmers to embrace new technology, however cognizance and comprehension of the nutritional value of new varieties are key to increased adoption of biofortified varieties

(De Groote *et al*., 2010; Muthini *et al*., 2019).

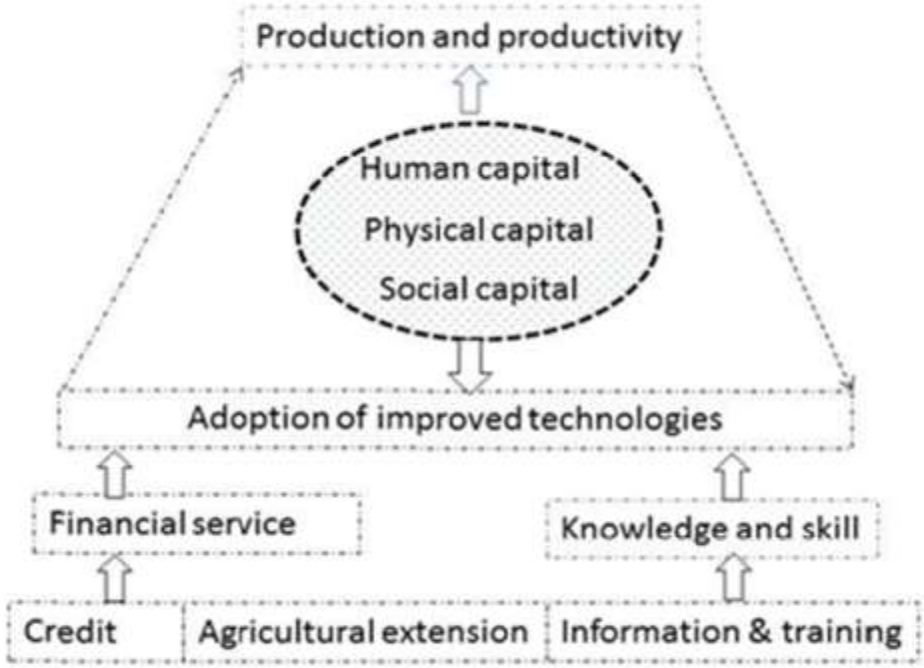

Figure 1: Impact Pathway of Agricultural Extension on Farm Productivity

Source: (Elias *et al*., 2013)

2.2.3.7 Land Size

Land size is absolutely connected with the likelihood of improved crop adoption (Gezimu *et al.*, 2019; Bryan, 2014), an assertion that concurs with Doss and Morris (2001) and Djibo and Maman (2019) deductions. This assertion explains the low intensity of adoption of biofortified crops by small holder farmers who consider it expensive and risky to gamble with new varieties on their small pieces of arable land as land is limited (Jena *et al.*, 2018; Gezimu *et al.*, 2019). Issa (2016); Abunga *et al.* (2012); Mutimura *et al*. (2018) findings show that there is a positive correlation between farm size and adoption of improved varieties production. Farmers with larger farms are more likely to accept new technology because they can afford to dedicate a portion of their land to experimenting with new technologies, whereas farmers with smaller farms are less likely to do so (Obayelu, 2017).

2.2.3.8 Labour

Another key factor that influences farmers' adoption decision is labor availability (Addison *et al*., 2018; Haregu, 2018). Farmers' human capital is thought to have a considerable impact on their decision to accept new technologies (Obayelu, 2017). Availability of labor is of paramount importance when it comes to agricultural production. In the african context tillage is mostly done using oxdrawn ploughs as such ownership and immediate availability of oxen positively and significantly determine the intensity of adoption of improved varieties (Gezimu *et al.*, 2019). A study in Ethopia put forward the claims that abundance of adult male labour force at household level might effect adoption of biofortified crops positively whereas feminine labour possibly will negatively stimulate adoption (Gezimu *et al.*, 2019). Nin-Pratt and McBride (2014) assserts that due to women's restricted access to resources, high labor costs are likely to deter female adoption of enhanced rice technologies. Monfared (2011) findings show that there is a positive relationship between family labor availability and technology adoption.

2.3 Conceptual framework

The conceptual framework for the study has been adopted from the livelihoods food security program which was implemented in Zimbabwe between 2015 and 2019 with support from Food and Agricultural Organization.

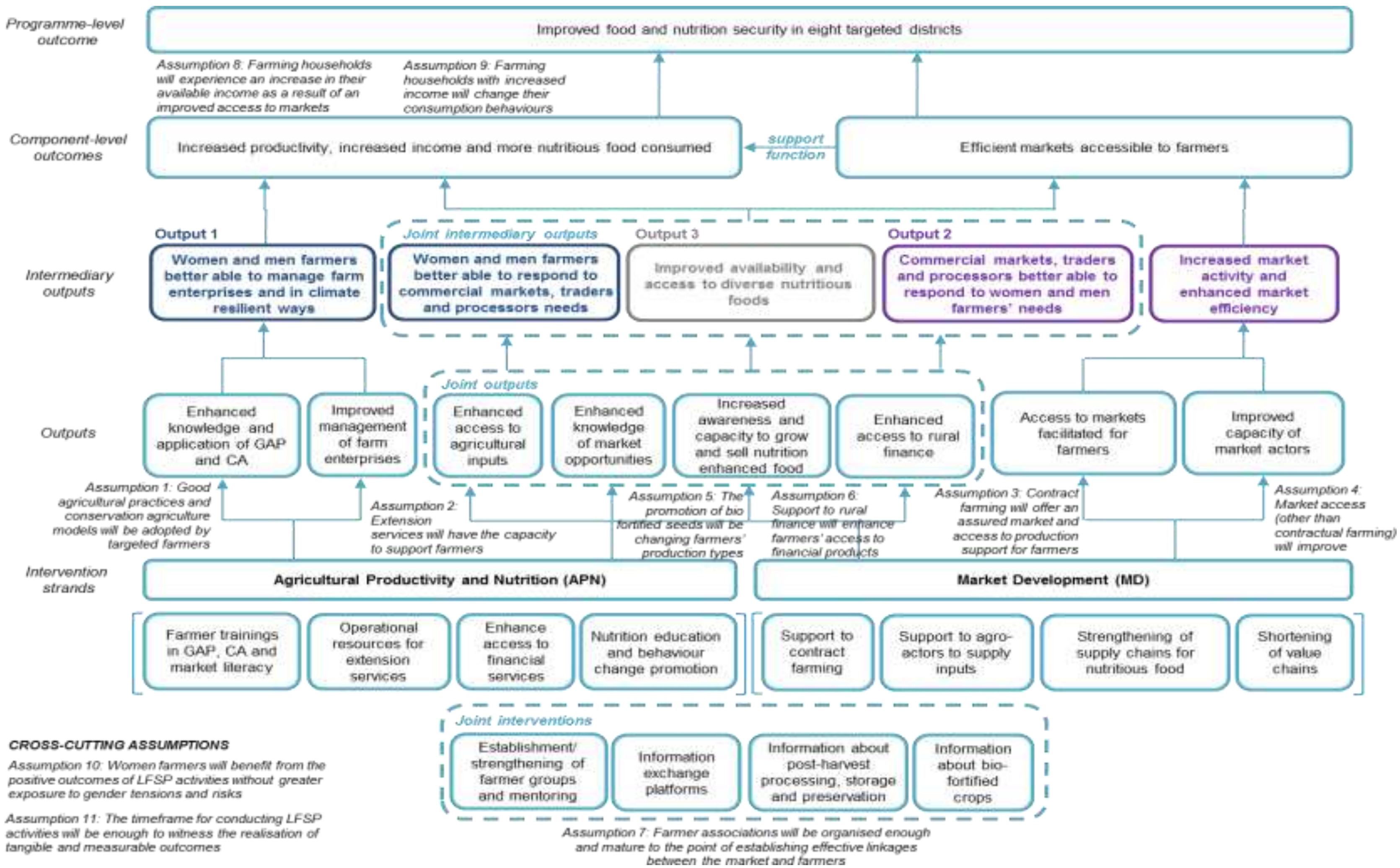

Figure 2: Conceptual Framework LFSP

Source: (Bisiaux and Brewin, 2016)

2.4 Summary of Literature Review

In conclusion this chapter focused on the factors that influences the intensity of production, consumption, and adoption of biofortified crop varieties. These factors include production cost, agronomic performance or yield of a variety, socio-economic factors at household level and access to resources affecting the intensity of production, whilst health concerns, substantial equivalence, access, availability and palatability influenced mostly the intensity consumption of BVs products. Lastly the adoption of biofortified varieties is influenced by knowledge of food fortification, household characteristics, policy issues, market dynamics and access labour and extension services.

Chapter 3
Methodology

3.1 Introduction

The aim of this section is to express the methods used in collecting data for this study in Mazowe district with special emphasis on assessing factors influencing the production, consumption, and adoption of biofortified crops. The focus is on the approaches adopted for data collection and explanation of sections within this chapter as follows, description of the study area and sites, research design, sampling procedure, data collection and analysis procedures, ethical considerations and lastly chapter summary.

3.2 Description of study site

Mazowe is a district located in Mashonaland central province, sharing boundaries with Harare, Goromonzi, Muzarabani and Guruve districts. It houses 233 450 individuals of which 49.8% (116 255) are males and 50,2% (117195) females and 58478 households (ZIMSTAT, 2012). The district has the second largest town, Mvurwi and its major settlements are Nzvimbo, Glendale, Concession, Mazowe, and Christon Bank with 34 wards. It covers a 1 444km2 of surface area and the major economic activities in the district are agricultural production and mining activities. The District is one of the twelve districts which piloted the biofortification programme under the Livelihoods Food and Security Programme (LFSP) (LFSP Zimbabwe, 2015).

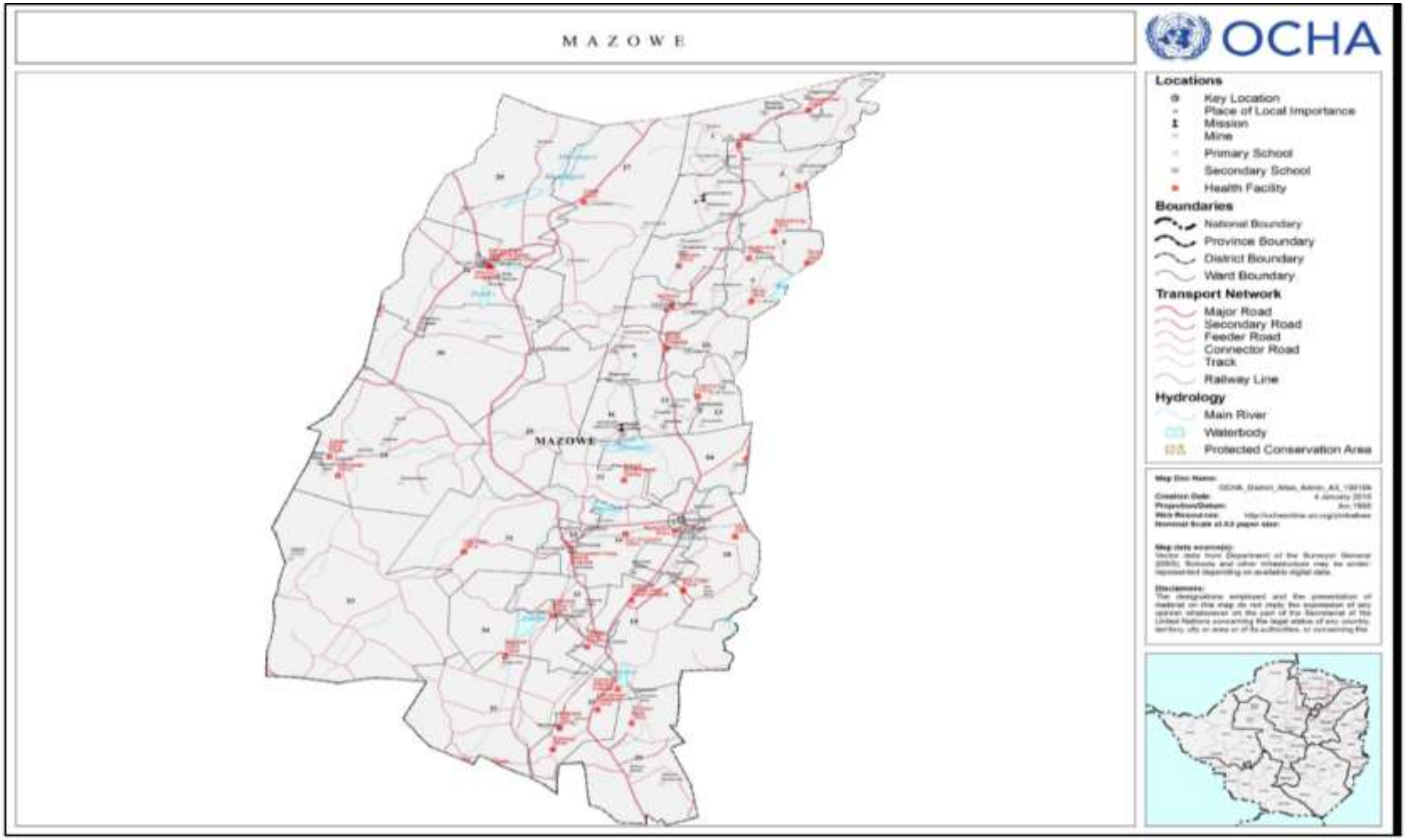

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Figure 3: Mazowe District Map

Source: (OCHA, 2008)

3.3 Research Design

A descriptive cross sectional survey design was used during this survey. This has been adapted from earlier studies on factors that influence consumer adoption to functional foods and biofortified crops that have been carried out in German and Rwanda respectively (Mack, 2018; Petry *et al*., 2020). This is a once off study to investigate factors affecting the intensity of production, consumption, and adoption of biofortified crops in ward 12 of Mazowe district.

3.4 Sampling Procedure

A multi-stage cluster sampling procedure was used to come up with the required sample for the study in Mazowe district based on other adoption studies that have been carried out globally (Caswell *et al.*, 2001; Haregu, 2018; Mack, 2018; Dinku and Beyene, 2019). Firstly, the district was divided into 3 clusters A, B and C, where simple random selection was used to select one cluster. Secondly, one ward was randomly selected from the selected cluster. Thirdly, from 25 villages in ward 12 a sampling frame that is the list of all the households that are producing maize, beans and sweet potatoes was availed and used to come up with the required sample with help from the agriculture extension officers. Simple randomization was done to come up with 7 households from each village giving us a target sample size of 172 households to be interviewed. Slovin's formula below was adopted to facilitate the calculation of a random sample from the sampling frame (Israel, 2013).

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

Where n = sample size; N = population size, 300 in this case and e = degree of precision (95%).

$$n = \frac{300}{1+300(0.05)^2}$$

$$n = 172$$

3.5 Data Collection Methods

A mixed method approach was used for primary data collection involving qualitative (key informant interviews and focus group discussions) and quantitative (household questionnaire). The use of two approaches enhanced corroborating and triangulation of facts solicited from the respondents. Qualitative studies strive to explore and ascertain issues surrounding the problem at hand, since little information is known about the problem (Allwood, 2012; Mehrad and Tahriri, 2019), assisting researchers to comprehend individuals, their social and ethnic setting surrounding them (De Leeuw et al., 2006). Surveys are pertinent to gather information directly from the public in an organized and consistent manner, used as a constructive pursuit directed towards helping implementers and other stakeholders to use findings well particularly towards improving the strength of interventions (Stufflebeam and Coryn, 2014).

Household survey data was collected using an electronic android based offline platform Kobo collect, sent to an online server hosted by amazon in real time once it connected to the internet. Data was downloaded as an excel sheet ready for data cleaning and analysis. The household head was interviewed during the study and in absence the any adult present was interviewed.

3.6 Data analysis methods

Quantitative household survey data was cleaned and analyzed using excel and Statistical Package for Social Sciences (SPSS) version 20. Descriptive statistics, regression analysis and correlation and were used for analysis of quantitative data and thematic analysis the analysis of qualitative data from key informant interviews. Below is the Objective analysis matrix for the assessment.

Table 1: Objectives Analysis Matrix

Objective	**Data required**	**Analytic tools**
1. To determine the factors affecting the adoption of biofortified crops by smallholder farmers.	Dependent variable – *Household adoption of biofortified crops* Independent variables- *HH head age, sex of HH head, HH size, Access to farm machinery, Number of draft animals, Amount of income earned by a HH monthly, availability of BF crop inputs, hectares of arable land a HH had access to, and HH contact with extension services.*	-Binary Regression analysis
2. To determine factors affecting the intensity of production of biofortified crop varieties by households in Mazowe district.	Dependent Variable – *Size of arable land under biofortified crops* Independent variables – *Number of draught animals, HH size, Amount of income earned by a HH monthly, availability of BF crop inputs, hectares of arable land a HH had access to, and HH contact with extension services.*	-Descriptive Statistics - linear regression
3. To determine factors affecting the intensity of consumption of biofortified crop varieties by households in Mazowe district.	Dependent variable – *Frequency of Consumption of BF crops* Independent Variables – *nutrient composition, texture, source of vitamins, flavour, taste, health benefits, health education, social networks, HH contact with agriculture extension services, amount of income earned by a HH monthly, HH size, and knowledge of BF crops*	-Descriptive Statistics - linear regression

3.7 Ethical Considerations

This study was guided by research and ethical principles which include seeking permission to carry out the study from the responsible authorities, seeking consent from the respondents and respecting the sociocultural norms of the region where the study was conducted. Privacy and anonymity were observed and no harm was caused by the study.

3.8 Summary

Following the methodology above, a cross sectional survey was conducted using multistage random sampling procedure and one ward was selected for data collection during this research. Farming households in this ward constituted the sampling frame where the households to be interviewed were picked.

Chapter 4

Results and Discussion

Assessment of Factors Affecting the Intensity of Adoption and Production of Biofortified Crops in Mazowe District

Abstract

More than 2 billion people suffer from hidden hunger globally due to inadequate intake of micronutrient rich diets. The high reliance on subsistence rainfed agriculture renders a large majority of the rural population vulnerable to climate-related shocks, seasonal stressors, food insecurity and malnutrition conditions including hidden hunger. Zimbabwe's already precarious food security and nutrition situation exacerbated by poverty and poorly functioning markets has seen households consuming monotonous diets limited in micronutrients which has led to increased micronutrient deficiencies. On average, 22% of the general population are vitamin A deficient and 65% iron deficient, as such efforts to combat these deficiencies have been adopted through the food systems approach. The area under biofortified crop production is limited, 0.06% of total arable land and the number of farmers who have embraced biofortification is not known in Zimbabwe. It is against this background that the researcher was motivated to investigate the factors affecting the intensity of adoption and production of biofortified varieties.

The study was conducted in Mazowe district with focus on ward 12. The researcher interviewed 183 randomly selected farming households. A household questionnaire was administered at household level to gather data pertaining to adoption and production of biofortified crops.

Binary and linear regression analysis models were used in analysing survey data. The findings showed that knowledge of biofortified varieties, area of arable land a household had access to, and contact with agricultural extension services were major drivers of adoption. The amount of income a household earned monthly and area of arable land in hectares they had access influenced the intensity of production of biofortified varieties. Farmers' economic strengthening and revitalization of agricultural extension services is of paramount importance to increase the rate of adoption and production through information dissemination and knowledge sharing.

Keywords: adoption, biofortified, intensity, production,

4.1 Introduction

Malnutrition especially micronutrient deficiencies are of public health importance regarding under 5 years children and women of childbearing age. In most African countries these are diet-related due to food insecurity problems that have seen households failing to consume a balanced diet (FAO, 2015; IFPRI, 2016). High morbidities in the vulnerable age groups have been associated with poor eating habits as such, food systems approaches have been recommended to address hidden hunger globally. through the adoption of biofortified crop varieties. Increased micronutrient density in diets through biofortification of staple crops is a promising strategy for improving human health (Talsma *et al*., 2017).

Over 90% households in the rural areas depend on staples for their consumption (Oparinde *et al*., 2016), in Zimbabwe the crops are grown in each agricultural season yearly and across all agro-ecological zones, with varying soil types, and rainfall patterns. Maize, rice, beans, potatoes, millet, and cassava are among the staple crops that have undergone biofortification. The majority of biofortification is done by conventional or classic plant breeding, agronomic procedures such as soil fertilization, and genetic modification (Saltzman *et al*.,2013).

Improved varieties are bred to boost production, whereas biofortified crops provide nutritional benefits in addition to yield gains. As a result, the motives for adoption of biofortified crops may differ from those concerning other improved types (Vaiknoras *et al*., 2019). The willingness of consumers and farmers to adopt newly produced crop types is critical to the success of biofortification as a strategy. Producers' willingness to use biofortified crops will be influenced by characteristics such as yield, disease resistance, drought tolerance, and marketability (Peters *et al*., 2013). Adoption in this context is a progressive and chronological decision-making process in which households collect new knowledge over time and decide whether to start, continue, quit, or restart the cultivation of a biofortified variety each farming season.

According to the crop and livestock assessment report 2021, biofortified crops occupied 0.06% of total cultivated land under maize and beans, a quest that drove this research (GOZ, 2022). Acceptance of biofortified crops is influenced by a variety of factors, including crop type and country, as well as consumer characteristics such as age, sex, socioeconomic level, and whether or not they detest or enjoy biofortified foods (Darnton-Hill *et al*., 2005). Children under the age of five and women of reproductive age are the groups most at risk of micronutrient deficiencies, and nutrition interventions are frequently directed at them. Studies conducted in Brazil and South Africa on adoption showed that availability of the product, its flavour, participation in participatory research, knowledge and understanding of its nutritional health advantages were major factors that influenced adoption and production of biofortified crops (Gonzalez *et al*., 2011; Govender *et al.,* 2014). Biofortified crops confront many of the same challenges and opportunities that other agricultural technologies encounter in Sub Saharan Africa, as well as some novel ones. Small-scale farmers will not adopt new technology unless they believe the benefits of adoption, whether monetary or not, will outweigh the costs of their current practices (Foster and Rosenzweig 2010; Jack 2011). This chapter focuses on analysis and presentation of factors affecting the intensity of adoption and production of biofortified crops in Mazowe district.

4.2 Material and Methods

A household survey questionnaire was used to solicit information from the respondents and key informant interviews conducted with agricultural extension officers at district level.

4.2.1 Description of study area

The survey was conducted in Mazowe district Mashonaland central province. The district is one of the biofortification project pilot districts within the LFSP (LFSP Zimbabwe, 2015). Details of the study site are provided in Chapter 3.

4.2.2 Research Design

In relation to the methodology section, the study adopted a cross sectional design based on previous adoption studies that have been conducted (Petry *et al*., 2020). Details of the research design are provided in Chapter 3.

4.2.3 Sampling procedure

A multistage cluster sampling procedure was used to come up with the sample which was interviewed during the study and simple random sampling was utilized to eliminate respondent bias in line with previous studies as described in Chapter 3.

4.2.4 Data collection procedure

Concerning primary data collection, a mixed method approach was used with a survey questionnaire being used at household level and a key informant interview guide used to solicit information concerning the study subject from professionals within the district. A detailed account on data collection procedure is in Chapter 3.

4.2.5 Data analysis procedure

Descriptive statistics, binary regression analysis, linear regression analysis and frequency tables were used in analysing survey data. Parametric statistics were used during data analysis with binary logistics used for analysis of adoption objective and linear regression on the intensity of production.

4.2.5.1 Factors affecting the intensity of adoption of biofortified crops

Determination of factors affecting adoption of biofortified crops was done using binary regression analysis. The dependent variable (Adoption) is a dichotomous variable (0=No Adoption, 1=Adoption) and the predictor variables are both continuous (age, income, hectares of arable land, HH size and number of draught animals) and categorical (sex, access to BF inputs, knowledge of biofortified crops and contact with agricultural extension services). The equation below shows the variables included in the model.

Model Specifications:

$$Logit(p) = \alpha + \beta_{1Age} + \beta_{2MS} + \beta_{3Sex} + \beta_{4HHS} + \beta_{5FM} + \beta_{6DA} + \beta_{7HIN} + \beta_{8ABFIw} + \beta_{9HAL} + \beta_{10KBF} + \beta_{11CAE} + e$$

Where,

Y= dependent variable, that is adoption of biofortified crops

α = constant variable

β1…...β11 = coefficients of factors affecting adoption of biofortified crops

$_{Age}$ = household head age

$_{MS}$ = Marital status of HH head

$_{Sex}$ = HH head sex

$_{HHS}$ = HH size

$_{FM}$ = Access to farm machinery

$_{DA}$ = Number of draft animals

$_{HIN}$ =HH monthly income

$_{ABFI}$ = Access to biofortified crop inputs

$_{HAL}$ = Hectares of arable land

$_{KBF}$ = Knowledge of biofortified crops

$_{CAE}$ = Contact with agricultural extension services

e = is an error term which captures all other factors neglected but affecting adoption

4.2.5.2 Factors affecting the intensity of production of biofortified crops

To determine factors affecting the intensity of production of BF crops linear logistic regression analysis was adopted. The model consists of a dependent variable (area under BF crop production in hectares) as a continuous variable whilst all the predictor variables (HH size, number of draft animals, income earned monthly by a household, and hectares of arable land) are continuous except for availability of BF crop inputs a dichotomous variable. The regression logistic model used for the analysis is as below.

Model Specifications:

$$y = \alpha + \beta_{1HHS} + \beta_{2DA} + \beta_{3HIN} + \beta_{4ABFIw} + \beta_{5HAL} + e$$

Where,

Y= the dependent variable, intensity of production of biofortified crops

α = constant variable

β1…...β5 = coefficients of factors affecting adoption of biofortified crops

$_{HHS}$ = HH size

$_{DA}$ = Number of draft animals

$_{HIN}$ =HH monthly income

$_{ABFI}$ = Availability of biofortified crop inputs

$_{HAL}$ = Hectares of arable land

e = is an error term which captures all other factors neglected but affecting intensity of BF crop production.

4.2.6 Challenges encountered during data collect

Data collection for the study coincided with the political campaigns and the by-election polls for the councilors and parliamentarians. Gathering people wasn't possible during the period with participants scared of being alienated with political factionalism thus the researcher had to compromise and deflect on the focus group discussions. The key informant interviews were also disturbed due to the census enumerator training which saw the researcher using online platforms (email and WhatsApp) to relay the key informant guide and responses however, responses were minimal.

4.3 Results and Discussions

4.3.1 Household Demographics

The cross-sectional study interviewed a total sample of 183 households producing maize, beans or sweet potatoes. The study revealed that farming was mostly dominated by male headed households with 161(88%) being Males and 22 (12%) females. The median age in years for the household head (HH head) was 37, minimum 27 whilst the oldest surveyed was older than 75 years. The median age of the household heads is within the economically active age as such are able to adopt and cultivate the biofortified crops.

One hundred and sixty-nine (92.3%) of HH heads were married whilst 7 (3.8%) each are either divorced or widowed. One hundred and seventy-four (95%) of household heads had attended school whilst 9 (4.9%) had never attended school. The majority 93 (50.8%) of those that had attended school reached a highest grade of secondary school, 80 (43.7%) primary school whilst only 1 (0.5%) of had reached tertiary level. Most HH heads had basic education enough to comprehend new agricultural innovations and make informed decisions thereof concerning adoption and production.

The most frequent household size realized in the study was 5, whilst the minimum and maximum were 1 and 11 respectively, were revolving between 3 and 8 family members whilst 11 was an outlier. Most households' livelihood activity was centered on agriculture 140 (76.5%), followed by self-employment 18 (9.8%), casual labour off-farm 7 (3.8%), small scale mining 6 (3.3%) whilst on-farm casual labour constituted 5 (2.7%). Handicraft and formal employment constituted the least livelihoods 2% each amongst the HH heads surveyed.

Table 2 Proportion of household head by sex, age and marital status

Variable	Category	N	Percent
Sex			
	Male	161	88
	Female	22	12
Age			
	Median	37 years	
	Minimum	21 years	
	Maximum	> 75 years	
Marital Status			
	Married	169	92.3
	Divorced	7	3.8
	Widowed	7	3.8
School Attendance			
	No	9	4.9
	Yes	174	95.1
Highest Grade			
	Primary	80	43.7
	Secondary	93	50.8
	Tertiary	1	0.5
Household size			
	Median	5	
	Mode	5	
	Minimum	1	
	Maximum	11	
Livelihood Activity			
	Farming (crop + livestock)	140	76.5
	Salaried employment	4	2.2
	Self-employed off-farm	18	9.8
	Casual labourer on-farm	5	2.7
	Casual labourer off-farm	7	3.8
	Handcraft/weaving/basket	3	1.6
	Small-scale mining	6	3.3

4.3.2 Household Economy

Agricultural implements are essential tools of trade in farming, during the study 175 (95.6%) of households owned of a hoe, 99 (54.1%) an ox drawn plough and 97 (53%) a shovel. The least possessed tools comprised a pick 67 (36.6%), rake 44 (24%), wheelbarrow 25 (13.7%) and a spade 16(8.7%). Findings from the survey clearly showed that a higher percentage 142 (77.6%) of households had access to draught power whilst 41 (22.4%) used other means in their agricultural activities due to lack of access to draught power. The average number of draught animals owned by a household was five, minimum and maximum being two and fourteen respectively. The study showed that the average amount of money earned by a household monthly was USD 25.64, the median being USD 6.00 with most households having no earnings in monetary value. All the households (183) that participated in the study had access to markets where agricultural inputs are bought and produce sold. Thirty two percent of households asserted that biofortified seeds were available at the market whilst the majority 124 (68%) said otherwise.

4.3.3 Agricultural production

Study findings showed that all the households (183) had access to agricultural land suitable for crop production. On average a household had access to 2.3 hectares (ha) of arable land, the least accessing a minimum of 0.25 ha as compared to a maximum 8 ha. At the time the survey was conducted a lesser proportion of households 32 (17.5%) had adopted and were cultivating biofortified crops whilst a greater proportion 151 (82.5%) had not adopted. A greater proportion of households 26 (78.8%) that had adopted biofortified crops were producing orange fleshed sweet potatoes followed by 14 (42.4%) producing high iron beans whilst only 3 (9.1%) were producing orange maize. A lower proportion of farmers producing maize could be attributed to resistance by farmers to produce orange maize considering it fodder and fear of its possible negative interaction with conventional white varieties (Jena *et al.*, 2018). The majority 99 (54.1%) of the farming households had been in contact with the agricultural extension services in the agricultural season 2021-2022, whilst 84 (45.9%) had not been in contact with extension services.

Figure 4 below shows that the most frequent reasons why households were growing biofortified crops was attributed to their high nutritional value 22 (69%) and desired health benefits 20 (63%) whilst reasons such as influence from social networks, readily available seed, good agronomic performance and yield were not frequently mentioned during the study as evidenced by an average frequency of 9 (28%) each.

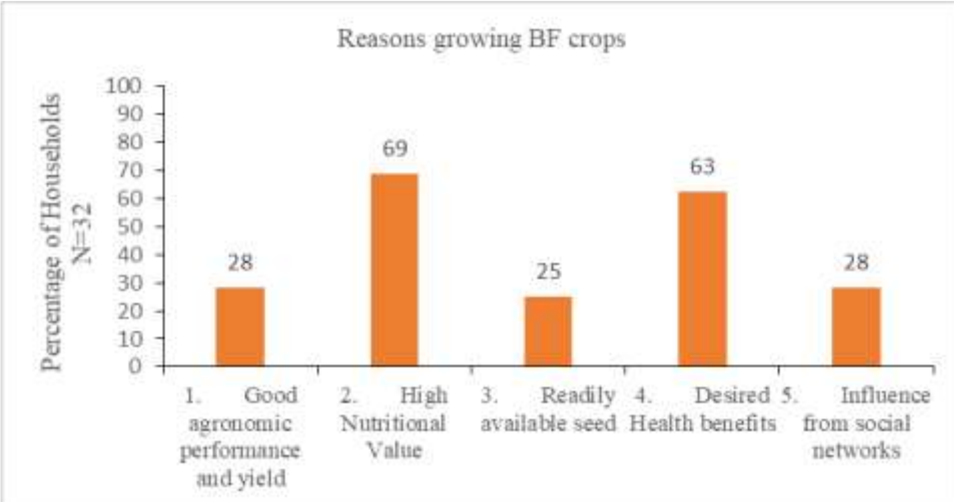
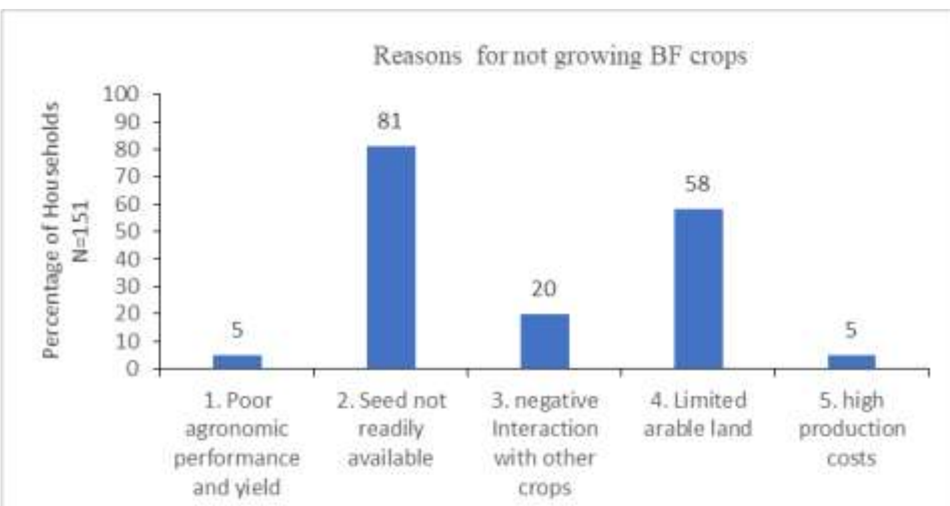


Figure 4 Proportion of Household by reasons for growing biofortified crops

Source: (survey data, 2022)

Study findings showed that most households were not growing biofortified crops citing reasons such as lack of readily available seed 122 (81%), limited arable land 87 (58%), 30 (20%) were skeptical due to alleged possible negative interaction with other crops in the field and a lesser percentage 8 (5%) citing poor agronomic performance and high cost of production respectively as shown in figure 5 below.



Source: **Own data 2022**

Figure 5 Proportion of households by reasons for not growing biofortified crops

4.3.3.1 Factors affecting the adoption of biofortified crops by smallholder farmers

Table 3 below shows the results of a binary regression analysis of factors that influenced the adoption of biofortified crops in the study. The analysis showed that only three independent variables affected adoption of BF crops and were statistically significant ($P<0.05$). A unit change in farmers' contact with agricultural extension influenced adoption of biofortified crops by 4 times in the positive direction, a unit change in area of arable land a household had access to influenced adoption by one factor in the positive whilst a unit change in knowledge of biofortified crops influenced adoption of BF crops by 0.836 in the negative direction. These three factors increased BF crop adoption rate averagely five times in the positive direction as opposed to six times in the negative without any predictor variable.

The survey findings are similar to other studies that showed that access to arable land positively influenced adoption in farming, meaning that as the area of arable land that a farmer has increases the probability of adopting new technology also increases (Brauw *et al*., 2015; Gezimu *et al*., 2019; Haregu, 2018; Djibo and Maman, 2019). From the study there is less likelihood for a farmer with limited arable land to adopt biofortified crops an assertion that concurs findings by (Okello *et al.*, 2017; Obayelu, 2017). There was a strong positive relationship between participation in agricultural extension activities and adoption of improved crop varieties as shown by the findings. Extension services capacitated farmers on the importance and processes followed to produce and maintain improved crop varieties resulting in increased rate of adoption, corroborating Muthini et al. (2019) findings.

This shows that there is an awakening effect induced to farmers through the agricultural extension sessions which drives the adoption of improved varieties (De Groote *et al.,* 2010; Beshir and Wegary, 2014; Haregu, 2018). Knowledge of BF crops by households had a negative influence on adoption, this is similar to De Brauw *et al.* (2018) BF crop adoption study findings in Mozambique. Muvhuringi and Chigede (2021) revealed that in Mazowe district most households could not empirically distinguish the difference between yellow maize and orange maize a gap that could have affected adoption. Furthermore, the survey findings showed that sex, age and marital status and education level of household head, income, agronomic performance, access to markets and agricultural implements had no effect on the adoption of BF crops as opposed to other study findings on adoption of agricultural technology (Gezimu *et al*., 2019; Haregu, 2018; Kairiza *et al*., 2020; Djibo and Maman, 2019; Ragasa *et al*., 2016).

Table 3: Factors affecting Adoption Binary Logistic regression results

Variables in the Equation

		B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
								Lower	Upper
Step 1[a]	Age of HH head	.004	.020	.037	1	.848	1.004	.965	1.044
	HH head Marital Status	-.580	1.556	.139	1	.709	.560	.027	11.823
	Sex of HH head	-.114	2.091	.003	1	.956	.892	.015	53.707
	HH size	.220	.145	2.305	1	.129	1.246	.938	1.655
	Access to Farm machinery	18.782	5443.609	.000	1	.997	143534071.848	0.000	
	Number of draft animals	-17.817	5443.609	.000	1	.997	.000	0.000	
	Amount of income earned by a household monthly	-.002	.005	.139	1	.709	.998	.989	1.008
	Availability of biofortified crop inputs	-.026	.699	.001	1	.970	.974	.248	3.830
	hectares of arable land a household had access to 2021/22 crop season	1.051	.239	19.345	1	.000	2.861	1.791	4.571
	Knowledge of BF crops	-.888	.375	5.590	1	.018	.412	.197	.859
	Contact with agricultural extension services	4.107	.996	16.987	1	.000	60.743	8.617	428.175
	Constant	-6.179	2.214	7.790	1	.005	.002		

a. Variable(s) entered on step 1: Age of HH head, HH head marital status, Sex of HH head, HH size, Access to farm machinery, Number of draught animals, Amount of income earned by a household monthly, Availability of biofortified crop inputs, Hectares of arable land a household had access to 2021/2022 crop season, Knowledge of BF crops, Contact with agricultural extension services.

Source: (survey data, 2022)

4.3.3.2 Factors affecting the intensity of production of biofortified crop varieties

The findings showed that there was a strong positive correlation (0.78) between area under BF crop production and amount of income that a household earned monthly and number of hectares of arable land they have access to. From the analysis, 60% of the variation in area under biofortified crop production was explained by income and area of arable land a household had access to whilst 44% of the variation was because of other factors not included in the model.

Table 4 below shows all the predictor variables included in the model, with only two variables statistically significant ($P<0.05$). A unit change in area of arable land a household had access to influenced the intensity of production of BF crops by a factor of 0.254 whilst income earned by a household influenced production by a factor of 0.004.

These findings correspond to other researchers perspectives, for example availability of disposable income at household level had a positive influence on the intensity of production of BF varieties (Issa, 2016), meaning that households with lack of access to income channels find it difficult to increase the intensity of productivity as they cannot afford to purchase the scarce BF crop seeds that are not distributed using the conventional methods (Gilligan, 2012; Muvhuringi and Chigede, 2021). The larger the area of arable land a farmer had, the more s/he was likely to increase area under biofortified crop production and the survey results supports Bryan (2014) findings. As opposed to Vaiknoras and Larochelle (2018), the survey findings showed no relationship between yield and intensity of production.

Table 4 Factors affecting the intensity of production results

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-.100	.736		-.135	.894	-1.641	1.442
	Number of draught animals	-.054	.047	-.184	-1.150	.264	-.153	.045
	HH size	.053	.063	.209	.840	.412	-.080	.186
	Amount of income earned by a household monthly	.004	.002	.407	2.221	.039	.000	.008
	Availability of biofortified crop inputs	-.203	.229	-.156	-.888	.386	-.683	.276
	Contact with agricultural extension services	-.028	.164	-.023	-.173	.864	-.367	.310
	hectares of arable land a household had access to 2021/22 crop season	.254	.095	.620	2.690	.014	.056	.452

a. Dependent Variable: Size of land under biofortified crops

Source: (survey data, 2022)

4.4 Recommendations

In view of the survey findings there is need to impart knowledge of the benefits acquired from BF varieties crops to facilitate adoption and production thereof. Closing the knowledge gap calls for awareness campaigns at national and subnational level so that farmers are capacitated, agricultural extension services need to revitalize platforms such as demonstration plots and field days where farmers learn through physical observations. According to the study findings economic strengthening is dire as farmers needs a source of income that can support and help improve the intensity of production of biofortified crops. At policy level there is need to mainstream and incorporate the biofortified crops in the educational curriculum so that people are informed from grassroot level upwards. A market gap in terms of seed availability exists, and there is need distribute biofortified inputs through the conventional market channels and in-cooperate them in the presidential input scheme a platform that is key in increasing the intensity of adoption and production.

4.5 Conclusion

In view of the study findings, it is evident that most surveyed households were male headed and agriculture was the major livelihood activity in the district. The major factor that influenced the intensity of adoption and production of biofortified crops was area of arable land at the disposal of the household. The likelihood for a household with more space of arable land to adopt and produce crops was higher compared to those with limited space. The findings show that farmer's knowledge on the importance of biofortified crops has a positive influence on adoption concurring with Gonzalez *et al.* (2011), and a source of income at household level would increase productivity. It is key for households to have a revolving fund that will help in boosting agricultural production activities at household level. The availability of BF crop inputs and knowledge on their health advantages are two of the most critical drivers of biofortified crop acceptance and uptake. Because of the variability of respondents' preferences, most research shows that segmented tailored communication techniques are required to influence increased adoption and production of these crops.

Chapter 5

Results and Discussion

Assessment of Factors Affecting the Intensity of Consumption of Biofortified Crops in Mazowe District

Abstract

Genetic improvement of staple food crops is a promising technique for improving human health by enhancing the nutrient density of diets through biofortification. One of the key underlying causes leading to poor dietary quality is that current food systems do not provide minerals and vitamins in sufficient quantities at affordable prices for the poor. In non-emergency situations, poverty is a major factor that limits intake of adequate, nutritious food, which must be available, accessible, and affordable to the poor. Therefore, agricultural investments and policies that improve the availability and affordability of more nutritious foods, such as biofortification, must be made an important part of the solution. Consumer and producer acceptance of novel crop varieties will determine if biofortification can be implemented successfully. What people eat depends on many factors, including cultural, geographical, environmental, and seasonal factors. Most studies on biofortified crops have focused on adoption leaving a gap on consumption hence this study aims to bridge the gap. The study was conducted in Mazowe district with focus on ward 12. From a sampling frame of 300 households, 183 randomly selected farming households were interviewed through administration of a household questionnaire.

Descriptive statistics, linear regression model was used in analysing survey data on factors affecting consumption of biofortified varieties. The findings showed that key drivers for consumption of biofortified crops were their nutrition profile, flavour, and health benefits. Consumers are now health conscious and particular about what they eat, the change in sensory properties in biofortified crops can be a crucial component in influencing acceptance for consumers. There is a change in hue and flavour in provitamin A–rich crops as OFSP, orange maize, and yellow cassava which consumers needs to embrace as evidenced by the study findings. SBCC platforms and social networks should be used to cascade information and influences an increase in consumption of biofortified crops.

Keywords: biofortified, health, consumption, micronutrient, Mazowe

5.1 Introduction

Malnutrition especially micronutrient deficiencies are of public health importance regarding under 5 years children and women of childbearing age. In most African countries these deficiencies are diet-related due to poverty and food insecurity problems that have seen households failing to consume a balanced diet (FAO, 2015; IFPRI, 2016). Household diets in rural settings are dominated by staples such as cereals and tubers, which are largely grown on the homestead, while availability and price limit intake of other foods that might increase dietary quality, such as legumes, vegetables, fruits, and animal source foods. For a long time, vitamin A deficiency has been a hazard to human existence, and the world has taken numerous efforts to address this threat. According to Rice *et al.* (2004), for a long time, international organizations such as the United States Agency for International Development (USAID), the United Nations Children's Education Fund (UNICEF), and the World Health Organization (WHO), among others, have been working tirelessly on how to improve this threat. Vitamin A deficiency (VAD) has been linked to blindness and to an increased risk of children suffering and dying from childhood diseases including measles and diarrhea and is the leading cause of night blindness in pregnant women and contributes to the risk of maternal death (Adekambi *et al*.,2020). In Zimbabwe the prevalence of VAD is 22% averagely across all the age groups and iron deficiency 65% confirming that most households are vulnerable to morbidities triggered by food insecurity and in fear of death.

In underdeveloped African countries, efforts to address hidden hunger has seen numerous unique intervention initiatives been implemented. Biofortification a word used to describe a breeding technique aimed at increasing the micronutrient content of basic food crops is one of these intervention (Nestel *et al*., 2006). The emergence of food systems approaches to address hidden hunger through biofortified crops which include orange maize, high iron beans and orange fleshed sweet potatoes has resulted in the development of staple food crops that are high in beta-carotene, a precursor to vitamin A in the body (Kolapo and Kolapo, 2021). Food-based approaches encourages people to eat biofortified staple foods high in beta-carotene, a precursor to Vitamin A, that are readily available in their area to help prevent VAD.

Africa has prioritized raising awareness through market sensitization and demand generation efforts, as well as nutrition education and training. These activities were targeted at persuading households to grow and consume biofortified varieties in the long run. Furthermore, mass media efforts were launched to inform the general farming community about the financial and nutritional benefits of producing biofortified cultivars (Adekambi *et al*.,2020). Several attempts are underway in Africa to promote the cultivation of these cultivars due to the limited adoption of these varieties and the desire to increase their consumption to combat VAD. Consumer and producer acceptance of novel crop varieties will determine if biofortification can be implemented successfully. Due to scarce information available on factors affecting consumption of biofortified crop varieties, the researcher closed the gap by contributing to the board of knowledge existing on biofortified varieties. This chapter focuses on analysis and presentation of factors affecting the intensity of consumption of biofortified crops in Mazowe district.

5.2 Material and Methods

A household survey questionnaire was used to solicit information from the respondents and key informant interviews conducted with officers at district level.

5.2.1 Description of study area

The survey was conducted in Mashonaland central province, Mazowe district and Ward 12, a detailed account was provided in chapter 3.

5.2.2 Research Design

A cross sectional quantitative study design with reference to previous adoption studies was adopted, details are given in chapter 3.

5.2.3 Sampling procedure

As described in chapter 3, a multistage cluster sampling procedure was used to come up with the target sample. Simple random sampling was utilized to eliminate respondent bias in line with previous studies.

5.2.4 Data collection procedure

A detailed account concerning primary data collection for the study is detailed in chapter 3. Questions on household consumption of biofortified crops were asked using a 30-day reference period.

5.2.5 Data analysis procedure

As described in chapter 3, linear regression analysis was used in analysis of factors affecting the intensity of consumption of biofortified crops at household level.

5.2.5.1 Factors affecting the intensity of consumption of biofortified crops

To determine factors affecting the intensity of consumption of BF crops a linear logistic regression model was used. The dependent variable was the frequency of consumption of BF crops, a continuous metric variable measuring the number of times a household consumed BF crops. The predictor variables were continuous (HH size, Amount of income earned monthly by a household, and knowledge of BF crops) whilst the remaining are dichotomous variables (nutritious, texture, source of vitamins, flavour, taste and healthy). The linear regression model used for the analysis was as below.

Model Specifications:

$$y = \alpha + \beta_{1HHS} + \beta_{2NUT} + \beta_{3HIN} + \beta_{4KBF} + \beta_{5TEX} + \beta_{6SOV} + \beta_{7FV} + \beta_{8TST} + \beta_{9HT} + e$$

Where,

Y= the dependent variable, intensity of production of biofortified crops

α = constant variable

β1…...β9 = coefficients of factors affecting adoption of biofortified crops

$_{HHS}$ = HH size

$_{NUT}$ = Number of draft animals

$_{HIN}$ = HH monthly income

$_{KBF}$= Knowledge of biofortified crops

$_{TEX}$= Texture

$_{SOV}$ = Source of vitamins

$_{FV}$ = Flavour

$_{TST}$= Taste

$_{HT}$= Healthy

e = is an error term which captures all other factors neglected but affecting intensity of consumption of BF crops.

5.2.6 Challenges encountered during data collect

Data collection for the study coincided with the political campaigns and the by-election polls for the councilors and parliamentarians. Gathering people wasn't possible during the period with participants scared of being alienated with political factionalism thus the researcher had to compromise and deflect on the focus group discussions.

5.3 Results and Discussions

5.3.1 Household Food Consumption

From the study findings a lesser proportion of households 59 (32.2%) were consuming biofortified crops whilst 124 (68%) were not. High iron beans (NUA45) were the most frequently consumed by households 52 (88%) followed by orange fleshed sweet potatoes 9 (15%) and orange maize rarely consumed. Most crops biofortified crops consumed 86.4% were coming as gifts to the households whilst 13.6% were from own production. In opposition to Petry et al., (2020), the survey findings showed that the majority of households consuming BF varieties did not produce. The study findings supports the notion from other researchers which cites that availing and flooding the market with these varieties boosts the intensity of consumption (Woods et al., 2020).

5.3.2 Factors affecting the intensity of consumption of biofortified crop varieties

The study findings showed a very strong positive correlation (0.91) between frequency of consumption and the predictor variables. The results revealed that 81% of the variation in frequency of consumption was explained by the model whilst 19% was accounted for by other factors not included in the model.

The independent variables included in the model are shown in the table below, with 4 variables statistically significant ($P<0.05$). The findings showed that intensity of consumption was positively influenced by nutrition composition, flavour, nutrition and health benefits a crop had. A unit change in nutrition composition influenced the intensity of consumption by a factor of 0.604 in the positive direction, source of vitamins by a factor of 0.37, flavour by 0.422 whilst health aspect of the crop by 0.53. The predictor variables influenced a significant increase in the consumption of BF as compared to rate of consumption without any external variables.

The findings are in agreement with other studies where the populace is now health conscious and consuming functional foods which have health benefits in a bid to combat hidden hunger and other diseases of age (Mack, 2018; Nathan and Soekmawati, n.d.; Victor *et al*., 2021; Rizwan *et al*., 2021), whilst aroma and flavor also had an effect on stimulating consumption agreeing with Mahboob *et al*., (2020) and Woods *et al*., (2020) findings. Nutrition is key to address micronutrient challenges that Zimbabwe is facing and the findings showed that most people were consuming biofortified crops because of their nutritional content (Loizou, 2009). These findings agree with Obayelu (2017), that consumer preferences in terms of flavour and sensory properties are key drivers to adoption and consumption of biofortified crops.

As opposed to Issa (2016), the findings did not show any association between income and consumption of BF crops neither household size. There was no relationship between knowledge of biofortified crops and intensity of consumption an assertion that concurs with other studies (Obayelu, 2017). The tolerance level and Variance inflation factor (VIF) are indictors of multicollinearity in a regression model. Literature explains that the average VIF value should not exceed the value of 10 and it exceeds, it means the model has a high degree of collinearity (Simpson and Lord, 2015). The findings showed VIF values less than 10 meaning there is no collinearity between the predictor variables as shown in table 5 below.

Table 5: Factors affecting the intensity of consumption of biofortified crops results

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B		Collinearity Statistics	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)	-.034	.078		-.442	.659	-.188	.119		
	Nutritious	.604	.045	.529	13.530	.000	.516	.692	.673	1.487
	Texture	-.017	.095	-.006	-.176	.860	-.204	.170	.789	1.267
	Source of Vitamins (protein)	.370	.146	.082	2.535	.012	.082	.658	.978	1.023
	Flavour	.422	.058	.288	7.238	.000	.307	.537	.650	1.538
	Taste	.022	.086	.010	.252	.801	-.147	.190	.595	1.682
	Healthy (good for health)	.539	.043	.427	12.448	.000	.453	.624	.876	1.142
	Knowledge of BF crops	.016	.017	.032	.957	.340	-.017	.050	.914	1.094
	Amount of income earned by household monthly	-1.589E-05	.000	-.002	-.066	.948	.000	.000	.973	1.028
	Household size	.001	.001	.020	.626	.532	-.001	.003	.977	1.023

a. Dependent Variable: Frequency of consumption of BF crops

Source:(survey data, 2022)

5.3.3 Reasons for not consuming biofortified crop varieties

During the study two thirds of the households interviewed were not consuming biofortified crops citing reasons that they were not available on the market 69 (56.1%), 31 (25.2%) choosing not to eat them, or considered them not part of their regular diet 22 (17.9%) whilst 20 (16.3%) were citing health risks that may be associated with the novel varieties. Concern is of a lesser proportion of the interviewed households that cited that these varieties were expensive to purchase 10 (8.1%) and not readily available 3 (2.4%). Table 6 below shows the results.

Behaviour change is a long process and as such socio cultural factors retards the intensity of consumption of BF varieties (Obayelu, 2017). Market dynamics are also key in influencing the consumption of these crops however lack of availability maybe an impediment, also taking note of the misconception between biofortified varieties and GMOs which may deter consumption of the improved varieties (Jena *et al*., 2018) .

Table 6 Proportion of Households by reasons not consuming BF

REASONS NOT CONSUMING BF	Percent	N=124
Do not like the texture	3.3	4
Do not like the flavour/ taste	3.3	4
Not readily available	2.42	3
Expensive	8.1	10
Not available in the market	56.1	69
Do not like them (unspecified)	13.8	17
Not a part of regular diet	17.9	22
Takes too long to cook/ inconvenience/ long preparation time	5.7	7
Health considerations	16.3	20
Choose not to eat them /Prefer other foods	25.2	31

Source: (survey data, 2022)

5.3.4 Promotion of biofortified crop varieties

Findings showed that social networks within the proximity of interviewed households were mostly promoting the consumption of biofortified crop varieties 168 (91.8%). There is need to leverage on social networks and SBCC strategies to boost the consumption of biofortified crops and lower the prevalence of hidden hunger in the vulnerable population (Birol *et al*., 2015; Oparinde *et al*., 2016).

According to the survey it was mostly health workers that were approving the consumption of BF crops as evidenced by mentions during the interviews 86 (52.1) village health workers and 69 (41.8%) health facility staff. Neighbors 40 (23.8%) and spouses 35 (21.2%) were second in the promotion of BF crop consumption. Health education by the health workers has proved to be one of the major driving forces influencing consumption of BF varieties in the district and needs to be strengthened to improve on this aspect (Muthini *et al*., 2019).

5.3.5 Promotion of biofortified crop varieties

Figure below shows study findings from a series of knowledge questions on biofortified crops that were asked to the households (N=183). The majority of households had knowledge about BF crops, 67 (36.6%) were very knowledgeable, 50 (27.3%) highly knowledgeable, 45 (24.6%) moderately knowledgeable whilst a lesser proportion 21 (11.5%) were not knowledgeable. There is still a knowledge gap in terms of BF varieties which could be leveraged on to increase the intensity of consumption of improved varieties and address hidden hunger in the general population with much emphasis at the household level (De Brauw *et al*., 2018).

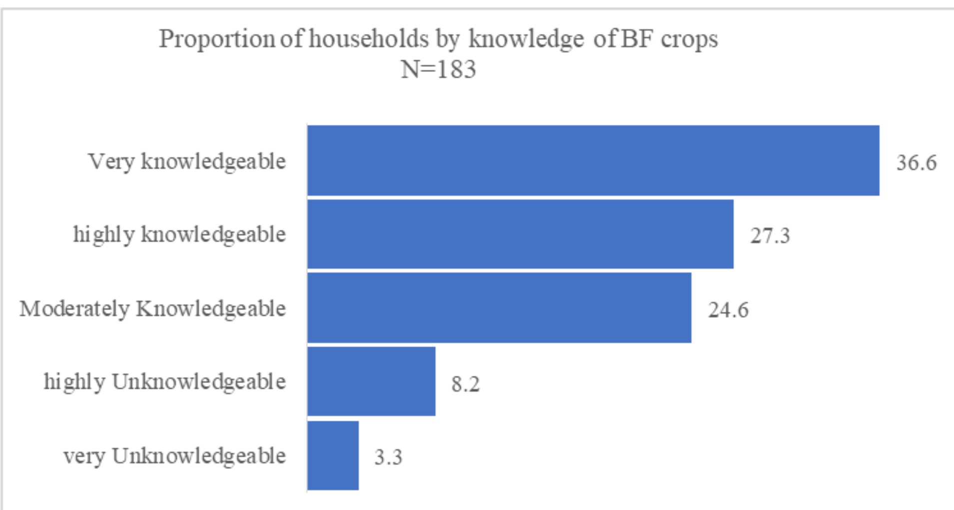


Figure 6 Proportion of households by knowledge of Biofortified crops

Source: (survey data, 2022)

5.4 Recommendations

The researcher proposed the following recommendations with reference to the study findings. The study revealed that the intensity of consumption was positively affected by the nutritional value, flavor, healthy aspect, and vitamins provided by the crops, as such there is need to educate consumers on the nutrition and health benefits of consuming BF crops, their nutritional composition, and sensory properties. The private sector should leverage on the sensory properties for example flavour and aroma of BF varieties by producing essentials oils that can be used to provide a vitamin A precursor to help combat hidden hunger. There is need to mainstream the health benefits of biofortified crops SBCC and mass media campaigns to boost adoption and consumption of BF varieties. At policy level there is need for inclusion of biofortification in educational curriculum and health sector to promote and inform behaviour change of the general population towards healthy diets. The findings showed that lack of availability was limiting consumption, as such there is need to promote production and marketing of these crops backed with consumer education to increase the intensity of consumption.

5.5 Conclusion

Chapter 5 was focused on the study findings and presentation of consumption patterns of biofortified crops at household level. The findings revealed that BF varieties are a good source of vitamins and are healthy options with the ability to reach the hard-to-reach population in remote areas. The general populace is now health conscious and seek to consume functional foods that are nutrient dense, it is of imperative importance to sensitize the consumers on the benefits of BF varieties to stimulate an increase in the intensity of consumption. Tastes and preferences are social behavioral change issues that takes time to happen (Muzhingi, 2008), as evidenced by the findings flavour had an influence on the intensity of consumption, thus social networks and SBCC platforms are key in their promotion.

Chapter 6
Summary, Conclusions and Recommendations

6.1 Introduction

This section aims to summarize and conclude on the factors affecting intensity of biofortified crop adoption, production, and consumption study findings from Mazowe district. The study was conducted using a cross sectional design with a randomly selected sample of 183 respondents participating in the study. Descriptive statistical analysis, binary logistic, linear regression and frequencies were used to analyse data with much detail and discussion presented in the results section. Finally, key recommendations that will be used to improve agriculture programming, inform policy formulation and areas that need to be further investigated will be presented.

6.2 Research summary

Micronutrient deficiency is referred to as "hidden hunger" since its symptoms are difficult to detect. Hidden hunger, which is caused by a lack of important micronutrients such as vitamin A, iron, and zinc, hinders the mental and physical development of children and adolescents, with long-term consequences for their livelihoods. Agricultural extension initiatives can promote biofortified crops based on their agronomic, and nutritional qualities, or both features. In a bid to assess the factors that affect the intensity of adoption, production and consumption of biofortified crops a cross sectional survey was conducted in Mazowe district.

A binary regression analysis was used to analyse the key drivers of adoption of BF crops whilst a linear regression model was adopted for analysis of factors influencing the intensity of production and consumption. Key factors that influenced adoption of BF crops were statistically proven ($P<0.05$) to be knowledge a household had concerning biofortified crops, area of arable land a household had access to, and farmers' contact with agriculture extension services. There was positive influence between contact with agricultural extension service and knowledge with adoption of biofortified varieties compared to a scenario without independent factors. The intensity of production was found ($P<0.05$) to be positively affected by the number of hectares of arable land at the disposition of the farmer and income that a household had access to monthly.

This shows that as the area of arable land increase the intensity of production increases on the pretext of readily available income to support production activities at household level. Health and nutritional benefits, flavour, and nutritional composition of BF crops were the key drivers affecting the intensity of consumption (Howarth Bouis *et al*., 2020; Muthini *et al*., 2019; Talsma *et al.,* 2013; Vaiknoras and Larochelle, 2018). Households that are health conscious are more likely to consume biofortified crops subject to their availability. Availability of the food product, its flavor, participation in participatory research, knowledge and understanding of nutritional health advantages were major factors that influenced adoption and production of biofortified crops. There is need to sensitize the general population on the benefits of these crops and demystify negative thoughts that may hinder the rate of adoption, production, and consumption.

Consumers and farmers willingness to adopt newly produced crop types is critical to the success of biofortification as a strategy. Producers' willingness to use biofortified crops will be influenced by characteristics such as yield, disease resistance, drought tolerance, and marketability. Overall, area of arable land, knowledge, geographical and consumer variables, as well as pricing are key in adoption, production, and consumption of biofortified varieties.

6.3 Conclusions

Based on the study results it is evident that farming is a major livelihood in Mazowe district and that there is great potential for the biofortified crops to be adopted, produced at scale, and consumed as a strategy to combat micronutrient deficiencies in the district. The health and nutrition benefits that are gained from biofortified crops should be leveraged on to improve rate of adoption and production of the crops. The researcher concludes that farmer's knowledge on the importance of biofortified crops has a positive influence on adoption concurring with Gonzalez *et al*. (2011), and a source of income at household level would increase productivity. It is key for households to have a revolving fund that will help in boosting agricultural production activities at household level.

The availability of BF crop inputs and knowledge on health and nutrition benefits are the most critical drivers of biofortified crop acceptance and uptake. Because of differing respondents' preferences, there is need for segmented food-systems approach that inform decision making processes and policy formulation. Adoption is a progressive and chronological decision-making process in which households collect new knowledge over time and decide whether to start, continue, quit, or restart the cultivation of a biofortified variety each farming season. Education is key in stimulating behaviour change and demystifying socio-cultural norms and myths *(*Bouis *et al.*, 2013), and needs to be prioritized so that the population is aware of recent innovations in the fight against hidden hunger. To a lesser extent, biofortified crops are not spared from the challenges and opportunities that other agricultural technologies encounter in Sub Saharan Africa which calls for strengthening of areas that are delimiting adoption, production and consumption rates in the district.

6.4 Policy implication and recommendations

Currently in Zimbabwe there are no standards that pertain to biofortified crops, orange maize and high iron beans a situation that distorts the pricing system on the market. According to SI 145 of 2019, GMB was rendered the sole trader of all grains (Statutory Instrument 213 of 2019, 2019), a predicament that may affect farmers' adoption and production due to incompetent pricing. The policy makers need to revise this statutory instrument and facilitate market liberalization through public private partnerships. There is need to include biofortification in the school curriculum to mainstream the importance of these crops at all education levels. The presidential input scheme and the Zunde ramambo should harness biofortified crops and narrow the gap on seed availability on the market.

6.4.1 Farmers and consumers

Knowledge of biofortified crops was shown to positively affect adoption of biofortified crops in the study. There is need to sensitize and inform the farmers, consumers, and the general population of biofortification and its health and nutrition benefits. The researcher recommends dissemination of biofortification information through mass media platforms and social networks to promote behaviour change towards biofortified crops. There is need to strengthen agricultural extension services through the revival of farmer-to-farmer groups, demonstration plots and field days where farmers are practically capacitated on new technologies resulting in a multiplier effect. There is need to economically strengthen farmers through trainings in income generating activities and or market linkages so that they have a revolving fund which is key in positively influencing the intensity of production of BF crops.

6.4.2 Government

The government must create and enhance current insufficient infrastructure, such as markets, and roads. Road network is of paramount importance and investment in it will help the expansion and reach of new technology through the agricultural extension services and non-governmental organisations. Efficient road networks will promote the distribution of inputs through the conventional market channels. There is need to incorporate biofortification within the presidential input scheme and pfumvudza intervention a move that can see adoption of the crops at scale. This will work as a strategy of addressing micronutrient deficiencies by provision of inputs at household step cushioning the food-based approach. The Government should strengthen public private partnerships a move that will promote expansion of biofortification at all levels.

6.4.3 Policy makers

Policy makers have a role to play also through main streaming biofortification as a strategy within the national development strategies. There is need to include biofortification in educational curriculum and health education colleges to promote behaviour change that will cause demand creation and an increase in adoption and consumption rates.

6.5 Areas for further research

The findings from the study are worth to ignite another inquiry on biofortified crops adoption, production and consumption at household level using a larger sample size to generalize the findings at national level. Assessment of the effect gender, age, household size and highest education level reached by the household head or decision maker on adoption is of interest at a larger scale and needs further investigation.

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6.7 Appendices

Appendix 1 Key Informant Interviews/ Focus Group Discussion guide

Factors influencing intensity of adoption, production, and consumption of biofortified crops

1. What are your perceptions towards biofortified crops?
2. What are the key enabling factors towards production, consumption and adoption of biofortified crops in this area?
3. What are the limiting factors towards production, consumption, and adoption of biofortified crops in this area?
4. What do you think should be done to improve adoption of biofortifed crops?

Appendix 2 Household Questionnaire

Ward	Ward Number	12
Village	Village	
resp_name	Name of Respondent	
Interviewer	Interviewer	
interview_date	Date of Interview	
Informed_consent	INFORMED CONSENT Greetings. My name is _________________________and I am a student at Bindura University of Science Education. I am conducting an assessment to know the factors that influence the intensity of production, consumption and adoption of Biofortified crops. I would appreciate your participation in this survey. The information you provide will help improve interventions to address micronutrient disorders. The interview will take about 30 minutes to complete. Whatever information you provide will be kept confidential and will not be revealed to other households. Participation is voluntary and you can choose not to answer any individual question or all of the questions. Do you want to ask me anything about the survey?	
consent	Do you agree to participate in this survey?	

MODULE A: HOUSEHOLD ROSTER

HOUSEHOLD LISTING FORM

First, please tell me the name of each person who usually lives here, starting with the head of the household. (*Nditaurireiwo zita reumwe naumwe wamunowanzogara naye pano, muchibika nekudya mupoto imwechete. Tangai neMusoro wemba ino)*

LIST THE HEAD OF THE HOUSEHOLD IN LINE 01. LIST ALL HOUSEHOLD MEMBERS (A02), THEIR RELATIONSHIP TO THE HOUSEHOLD HEAD (A003), AND THEIR SEX (A04).

*Then ask**: Are there any others who live here, even if they are not at home now? (These may include children in school or at work)**. (**PANE VAMWE HERE VANOGARA PANO ASI VASIPO PAMBA IYE ZVINO? AVA VANOSANGANISIRA VARI KUZVIKORO KANA KUBASA)** IF YES, COMPLETE LISTING.*

Then, ask questions starting with A05 for each person at a time.

T	SEX (MUNHUKADZI/ MUNHURUME)	AGE OF HH HEAD (ZERA)	MARITAL STATUS (*AKAROORA/KUROORWA)*	SCHOOL ATTENDANCE	HIGHEST LEVEL OF EDUCATION ATTAINED	NUMBER OF PEOPLE IN HOUSEHOLD	MAIN LIVELIHOOD ACTIVITY
A01	**A02**	**A03**	**A04**	**A05**	**A06**	**A07**	**A08**
Name of household head ***(Ndipeiwo zita remusoro wemba***	Is (*NAME)* male or female? ***(Uyu Munhukadzi / Munhurume ?)*** 0= MALE 1 =FEMALE	How old is (*NAME*)? ***(Ane makore mangani akazara ?)*** How old was (*name*) on his/her last birthday ? *Record in completed years* 98=DK	WHAT IS (NAME)'S CURRENT MARITAL STATUS? **(AKAROORWA /KUROORA HERE?)** *0 = MARRIED OR LIVING TOGETHER 1 = DIVORCED/ SEPARATED 2 = WIDOWED 3 = NEVER MARRIED AND NEVER LIVED TOGETHER*	Has Name ever attended school? (**Akambopinda da chikoro here?)** 0=No 1=Yes 98=DK	What is highest grade name has completed? **(Akanyatsopedza danho ripi redzidzo?)** 0=primary_ 1=secondary 2=Tertiary	WHAT IS THE TOTAL NUMBER OF PEOPLE STAYING IN THIS HOUSEHOLD?	WHAT WERE NAME'S MAJOR LIVELIHOOD ACTIVITY IN 2021? (NDEZVIPI ZVAAIITA ZVEKUMURARAMISA MUGORE RATABVA 2021?) 0. NONE 1. FARMING (CROP + LIVESTOCK) 2. SALARIED EMPLOYMENT 3. SELF-EMPLOYED OFF-FARM 4. CASUAL LABOURER ON-FARM 5. CASUAL LABOURER OFF-FARM 6. SCHOOL/COLLEGE CHILD 7. HERDING 8. HOUSEHOLD CHORES 9. HANDCRAFT/WEAVING/BASKET 888=OTHER (SPECIFY IN CORRESPONDING SPACE)

MODULE B: HOUSEHOLD ECONOMY			
. Does your household have access to any of the following agricultural implements that are in working condition? ***(Mune zvikwaniso zvinotevera here zvekushandisa pakurima zvichiri kushanda?)***	A	Hoe	0=No 1=Yes 98=DK
	B	Shovel	0=No 1=Yes 98=DK
	C	Rake	0=No 1=Yes 98=DK
	D	Spade	0=No 1=Yes 98=DK

	E	Pick	0=No 1=Yes 98=DK
	F	Wheel Barrow	0=No 1=Yes 98=DK
	G	Plough/ Ox Plough	0=No 1=Yes 98=DK
. Does your household have access to any of the following draught animals? ***(Mune zvipfuyo zvinodhonza zvinotevera here?)***		Mombe/ madhongi dzinodhonza	0=No 1=Yes 98=DK
. What is the number of draught animals your household own? **.**		_______________	
. What is the amount of income earned by your household monthly? ***(Munowana mari yakawanda zvakadii pamwedzi?)***		USD ____________	

MODULE C: MARKET ACCESS

C01.	*Do you have access to a market place?*		0=No 1=Yes 98=DK
C02.	Is there availability of biofortified crop inputs at the market place?		1=Yes 0=No 98=DK
C03.	Does your household face challenges to access inputs from the market? **Pane zvipingaidzo zvamunosangana nazvo here kana muchitenga kunzvimbo iyi?**		0=No 1=Yes 98=DK
C04.	What are the main challenges your household face to access inputs from the market? ***Zvipingaidzo zvamunonyanyosangana nazvo ndezvipi?***		A. Lack of product diversity B. Not enough supply (not enough inputs available on the market) C. High prices D. Unpredictable price changes E. Markets too far F. Bad road to market G. Poor quality products H. Other, specify: _________

MODULE D: AGRICULTURE PRODUCTION				
D01.	Does your household have **access to** land that can be used for agriculture? ***Mune nzvimbo here yamunokwanisa kurima?***		0 = No 1 =Yes 98 DK	If 0 or 98 skip to E01
D02.	How many hectares of arable land does this household had access to **2021/22 crop season**? ***Nzvimbo iyi yakakura zvakadii?***		_______ Ha	
D03.	Did this household produce any biofortified crops **2021/22** cropping season?		0 = No 1=Yes 98=DK	If 0 or 98 know skip to D05
D04.	What size of land was under biofortifed crops **2021/22** cropping season? ***Pane zvamakarima here mumwaka wapfuura uyo 2021/22?***		_______ Ha	

D05. Which biofortified crops did your household cultivate in the 2021/22 season? ***Makange makadyara mbesa dzipi mumwaka wapfuura, 2021/22?*** *0 = No 1=Yes*	Orange maize		Orange fleshed Sweet potatoes	Dry Beans	High Iron beans	Other ____
D06. Have you been in contact with /attended agricultural extension sessions on biofortified crops.	0 = No 1=Yes 98=DK					

D07.	What are the main reasons for your household to grow biofortifed crops? (Nemhaka yeyi muchirima zvirimwa zvakawandudzwa?)	1. Good agronomic performance and yield 2. High Nutritional Value 3. Readily available seed 4. Desired Health benefits 5. Influence from social networks 6. Other (specify)	If D03 =1
D08.	What are the main reasons your household doesn't grow biofortifed crops? (Nemhaka yeyi muchirima zvirimwa zvakawandudzwa?)	1. Poor agronomic performance and yield 2. Seed not readily available 3. negative Interaction with other crops 4. Limited arable land 5. high production costs 6. Other (specify)	If D03 =0 or 98

MODULE E: HOUSEHOLD FOOD CONSUMPTION

CONSUMPTION OF BIOFORTIFIED CROPS AT HOUSEHOLD LEVEL

E01.	In the past 1 month did your household consume any biofortified crops? ***(Mumazuva manomwe adarika, mumba muno makambidyiwawo here zvirimwa zvakawandudzwa***	0=No 1=Yes 98 Don't know	If 0 or 98 skip to E06
E02.	What type/ variety of crop did your household members consume*)* ***(Mhando yezvirimwa zvamakadya ndedzipi, ndinokumbirawo kana zvichibvira mundiratidzewo?)***	1. Orange Fleshed Sweet potato 2. NUA 45 beans 3. Orange maize products	
E03.	About how many times in the last past month did your household eat biofortified crops? ***(Mungangodaro makazvidya kanokwana kangani mukati memazuva manomwe apfuura)***	1. Rarely 2. Seldom (1-3 days per month) 3. Sometimes (1-2 days per week) 4. Often (3-5 days per week) 5. Daily	______ Number of times
E04.	What was the MAIN source of biofortified crops your household consumed? ***(zvirimwa izvi maizviwanepi)***	1.Purchased (Dzakatengwa) 2.Own production (Vakarima vega) 3. Donation (Vakapiwawo nevaipa vanhu munharaunda iyi) 4. Remittance (Dzakabva kuhama kana vana vawo) 5. gift (Chakauya sechipo kwavari) 6. Other specify (Kumwewo, munditaurire)	
E05.	What are the main reasons for your household to consume biofortifed crops? ***(Nemhaka yeyi muchidya zvirimwa zvakawandudzwa?)***	A. Readily available (Inyaya yeuhwandu hwadzo/ nekuwanikwa kwadzo) B. Nutritious food (Dzine kudya kwakanaka) C. like the texture (Muto wacho wakakorera) D. Inexpensive/affordable (Hadzidhuri) E. Source of protein (Dzinotipa kudya kunovaka muviri) F. Adds flavour (Dzinowedzera kunaka kwekuyda kwatiinako) G. Tastes good (Dzinonaka kudya) H. Healthy/ good for health (Dzine utano/ uye dzakanakira utano hwedu) I. Don't Know (Handizive) J. None (hapana) K. Other (specify)____	If E01= 1
E06.	What are the main reasons why your household is not consuming biofortified crops? ***(Chikonzero neyi musingadyi zvirimwa zvakawandudzwa mazuva matatu kana kudarika pavhiki rimwe nerimwe, mugore rose?)***	A. Do not like the texture (Hatifarire kakukora kwemuto wacho) B. Do not like the flavour/ taste (Hatifariri manakiro adzo) C. Not readily available	

		(hazviwanikwe) D. Expensive (Dzinodhura) E. Not available in the market (Hadzinyanyowanikwe) F. Difficult to produce (Dzinonetsa kurima) G. Do not like them (unspecified) (Hatingodzifariri) H. Not a part of regular diet (Hatiwanzongodzidya hedu) I. Takes too long to cook/ inconvenience/ long preparation time (Dzinotora nguva yakareba kuti dziibve) J. Don't know how to cook/ prepare them/ no recipes (Handizivi kuti ndodzibika sei, hatina mabikiro akawanda wanda atinoziva) K. Health considerations (Tinotyira utano hwedu) L. Choose not to eat them /Prefer other foods M. None (Hapana) N. Don't know (handizive) O. Other (specify_____) (Zvimwewo, ndiudzei)	
E07.	Do most of the people that you know approve of you consuming biofortified? ***Vanhu vazhinji vamunoziva vanozvibvumira here kuti mudye zvirimwa zvakawandudzwa kwemazuva matatu pavhiki roga roga mugore rose?***	0=No 1=Yes 98=Don't know	**If 0 or 98, skip to E09**
E08.	Who are the people that approve of your household consuming biofortified crops at least 3 days a week throughout the year? ***Ndevapi vanowirirana nekudya zvirimwa zvakawandudzwa kwamunoita kwemazuva matatu pavhiki roga roga mugore rose?***	A. Friends B. Village Health workers C. Health facility staff D. Grand mother E. Grand father F. Spouse G. Religious leader H. Traditional leader I. Neighbours J. Other (specify)	

Knowledge and Perceptions about Biofortification

E09.	PLEASE INDICATE YOUR AGREEMENT OR DISAGREEMENT WITH THE FOLLOWING STATEMENT. ***MUNOBVUMIRANA KANA KUPOKANA NEZVINOTEVERA HERE?***	**Strongly agree**	**Somewhat agree**	**Neither agree nor disagree**	**Somewhat disagree**	**Strongly disagree**
A.	Biofortified crops are nutritious. ***zvirimwa zvakawandudzwa zvine kudya kwakanaka.***					
B.	Biofortified crops are an affordable source of micronutrients. ***zvirimwa zvakawandudzwa zvinotipa kudya kunovaka muviri nemutengo wakaderera.***					
C.	Biofortified crops are high in vitamins and minerals. ***Bhinzi dzakaoma dzine mavhitamini akawanda.***					
D.	Biofortified crops are free of fats and saturated fats. ***Zvirimwa zvakawandunzwa hazvina mafuta akawanda.***					
E.	Biofortified crops help reduce the risks of hidden hunger. ***Zvirimwa zvakawandunzwa zvinoderedza mukana wekubatira zvirwere.***					
F.	Biofortified crops are good for soil fertility and sustainable agriculture. ***Zvirimwa zvakawandudzwa zvinowedzera kudya nehutano hwevhu.***					
G.	Biofortified crops help control appetite. ***Zvirimwa***					

	zvakawandunzwa zvinobatsira kuti munhu anzwe kuda kudya.					
H.	Biofortified crops help reduce the risks of poor eyesight conditions. ***Zvirimwa zvakawandunzwa zvinobatsira kuderedza mukana wezvirwere zvemaziso.***					
I.	Biofortified crops help improve immunity. **Zvirimwa zvakawandunzwa zvinosimbisa masoja emuviri.**					

End of Questionnaire