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Adaptation strategies to enhance climate-smart food systems by smallholder farmers and rural communities in Zimbabwe

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Abstract

Food and nutrition security in sub-Saharan Africa is under threat from climate change, extreme events (e.g., drought, heat waves, cyclones) and climate variability. This paper reviews possible adaptation strategies that can be adopted by smallholder farmers to increase resilience in food systems in sub-Saharan Africa, using Zimbabwe as a case study. Climate-smart agriculture technologies such as conservation agriculture and legume technologies have the technical potential to contribute to food security and adaptation to climate change. When the climate-smart technologies are coupled with early planting, grain yields can exceed household food self-sufficiency thresholds. The rising temperatures expected with climate change effects will shorten the crop growth period meaning more diversified diets that include drought tolerant crops such as traditional grains and vegetables (such as Spider plant and Amaranth) and Non-Timber Forest Products such as indigenous fruits and edible insects can be adopted. The diversified diets have the potential to augment the nutrient composition of family diets, contributing to household food security and the alleviation of hidden hunger. Edible insects are an alternative protein source as they are high in protein content depending on insect species. However, due to the increased frequency of drought, there is need to explore rearing technologies so that edible insect consumption can become sustainable. Despite the reported benefits of the strategies discussed in this paper, adoption of some strategies has not followed. More multidisciplinary studies are needed to investigate the sustainability of the adaptation strategies being proposed, and relevant policies to support the adoption and sustainability of the adaptation strategies need to be explored.

Key words: *Adaptation strategies; Climate change; Climate-smart technologies; Smallholder farmers; Food and nutrition security.*

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1. Introduction

Adapting Africa's food system to climate change will be crucial if Africa is to achieve food security and eradicate food insecurity. About 277 million of Africa's population (22%) are undernourished, and the number could increase to 350 million by 2050 if appropriate adaptation measures are not taken (Braimoh, 2020). Climate change impacts will continue to deepen existing vulnerabilities and low capacities, leading to poverty, fragility and conflict (Bhatasara, 2015). For Africa to be prepared for this troubling and uncertain future, it is vital that resilience be built into its food systems (Braimoh, 2020). Climate-induced water stress intensifies pre-existing problems including declining agricultural and economic productivity coupled with poverty and insecurity (Brown et al., 2012). Extreme weather conditions (such as droughts, heatwaves and cyclones), loss of biodiversity, and accelerated desertification (Tabbo et al., 2016) are also some of the negative effects of climate change.

Zimbabwe is among the countries most severely affected by climate change and variability. The impacts have led to water shortages, declining yields, and periods of food insecurity, accompanied by economic downturns. In particular, the country's agricultural sector, which is mostly comprised of smallholder rain-fed systems, is at great risk of drought (Mavhura, 2019). Every district has been affected by drought during the past thirty years, with varying levels of severity and frequency. Severe drought episodes have been observed in 1991–1992, 1994–1995, 2002–2003, 2015–2016, and 2018–2019 (Frischen et al., 2020). Drought vulnerability and exposure vary substantially in the country, with the south-western provinces of Matabeleland North and South showing particularly high levels. Variable seasonal rainfall, frequent droughts and flash floods characterise semi-arid areas in southern Africa (Spear et al., 2018). The region is highly vulnerable and predicted to be impacted by extreme negative impacts of climate change; temperatures are predicted to increase in this region by between 1 and 4 ºC by 2050 with the substantial multi-decadal variability in rainfall predicted to continue, without certainty in the direction of the change (Bhatasara, 2015). The climate change effects, where rainfall patterns have become irregular and continue to shift, have resulted in adverse effects on food and nutrition security given that the economy of Zimbabwe is largely agro-based.

Climate change affects the four dimensions of food security namely: food production and availability; access to food; stability of food supplies; and food utilization (Adams et al., 1998). Studies indicate that smallholder farmers in sub-Saharan Africa (SSA) are particularly vulnerable to the effects of climate change (Phiiri et al., 2016; Chepkoech et al., 2020) and the impacts of climate change are felt disproportionately among different socio-economic groups (Nelson et al., 2010). The impact may be greater for smallholder farmers in many developing countries because they are predominantly dependent on rain-fed agriculture for their farming activities and are increasingly being exposed to extreme events, in addition to their general widespread poverty and marginalisation (Chepkoech et al., 2020). It is against this background that most smallholder farmers in Zimbabwe are being encouraged to adopt different adaptation strategies to circumvent the devastating effects of climate change. Agricultural adaptations need to embrace several options that include macro and micro-level options. Examples include; crop diversification, altering timing of operations and market responses (Smit & Olga, 2001). Other options include developing meteorological forecasting capability to enhancing farmers' adaptive capacity, improvement in agricultural markets and information provision; and technological developments, e.g. promotion of new crop varieties and integrated water management (Smit & Olga, 2001; Smit & Skinner, 2002). It will entail a lot more innovation than just enhancing agricultural production to prevent susceptibility to the anticipated negative climate change impacts and adapting food systems to enhance both food and nutrition security.

Based on this background, the aim of this paper is to review two adaptation strategies for smallholder farmers and rural communities in Zimbabwe to circumvent the devastating impact of climate change. These adaptation strategies are; (i) the introduction of drought tolerant crops and cropping systems to sustainably intensify food and feed production and improve soil fertility and (ii) the utilisation of Non-Timber Forest Food Products (NTFPs) to mitigate the negative impact of climate change. The main research question in on whether these two adaptation strategies can contribute towards food and nutrition security in Zimbabwe.

2. Selected climate change adaptation strategies for smallholder farmers in Zimbabwe

2.1 Introduction of drought tolerant crops and cropping systems to sustainably intensify food and feed production and improve soil fertility

2.1.1 Climate-smart agriculture (CSA) technologies

To meet the challenge of ensuring sustainable food and nutrition security in the face of climate change, farmers in smallholder areas of Zimbabwe can adopt different climate-smart agriculture (CSA) technologies. Climate-smart agriculture is premised on achieving three objectives: a) climate change adaptation to enhance resilience into the system; b) mitigate greenhouse gas emissions and increase both above and below ground carbon sequestration, and c) sustainably enhance productivity and profitability to meet food and nutrition security (Campbell et al., 2014; Lipper et al., 2014). Climate-smart agriculture is not one single practice but an array of practices integrated in an agricultural system (Thierfelder et al., 2017). Conservation agriculture (CA) and legume technologies such as intercropping have been put forward as promising CSA options in semi-arid Zimbabwe (Mupangwa et al., 2007; Mazvimavi & Twomlow, 2009; Masvaya et al., 2017b, 2017a). The effective application of these CSA options, as reported in these studies, results in increased food production per unit land, while maintaining or rebuilding soil fertility.

(a) Conservation agriculture

Conservation agriculture (CA) is a technology founded on three principles: a) minimum soil disturbance, b) mixing and rotating crops and, c) a semi-permanent or permanent soil cover (FAO, 2014). It has been promoted to smallholder farming systems in sub-Saharan Africa to reverse the effects of declining soil fertility as it allows for crop yield stabilisation and increases drought resilience (Hobbs et al., 2008). The advantages linked with CA in comparison with conventional tillage include intensification of cropping sequences (Brouder & Gomez-Macpherson, 2014), early planting which allows for improved utilisation of the cropping season (Hobbs et al., 2008; Nyagumbo et al., 2017), soil organic carbon sequestration (Rusinamhodzi, 2015), and improved soil water holding capacity, resulting from reduced run-off, soil erosion, and lower surface soil temperatures (Thierfelder & Wall, 2009; Nyamadzawo et al., 2012; Mupangwa et al., 2016b). Comprehensive practice of CA results in enhanced productivity and profitability and meeting food and nutrition security in the future (Rusinamhodzi et al., 2011; Sithole et al., 2016). Conservation agriculture practices have been tested extensively in smallholder Zimbabwe in the last decade with, however, variable responses in crop yields ranging from positive, no effect to negative effects (Mashingaidze et al., 2012; Nyamadzawo et al., 2012; Nyamangara et al., 2014b; Mupangwa et al., 2016a; Masvaya et al., 2017b; Nyagumbo et al., 2017; Kodzwa et al., 2020). In addition, CA has been shown to improve soil quality for example conserving soil moisture by reducing runoff and increasing infiltration, building soil organic carbon, enhancing soil aggregation and below-ground fauna (Chivenge et al., 2007; Nhamo, 2007; Nyamadzawo et al., 2009; Nyamadzawo et al., 2012; Nyamangara et al., 2014a).

Despite the reported benefits of CA in view of climate change impacts, the adoption of CA has not followed (Pedzisa et al., 2015). Major impediments have been the high labour demand associated with operations such as manual land preparation and weeding (Giller et al., 2009; Mashingaidze et al., 2012). With CA, as promoted in Zimbabwe, farmers with no draught power are encouraged to carry out land preparation in the off season using hand hoes (digging pits for fertilizer/manure and seed placement) to reduce the labour requirement at the start of the season therefore encouraging early planting (Twomlow et al., 2008; Nyamadzawo et al., 2012). Early planting in combination with CA, is important in managing production risks in regions of high rainfall variability (Nyagumbo et al., 2017; Masvaya et al., 2018). Masvaya et al. (2018) showed that planting with the first rains in semi-arid Zimbabwe resulted in maize (*Zea mays* (L.)) grain yields under CA exceeding the food self-sufficiency thresholds at household level.

(b) Legume-based technologies

Incorporating food (cowpea, groundnuts, common bean, etc.) or forage (mucuna, lablab, leucena, sun hemp etc.) legumes into cereal-based cropping systems, characteristic of Zimbabwean smallholder farming systems, either in rotations or intercrops or improved fallows is a means of achieving crop diversification whilst simultaneously rebuilding soil fertility (Snapp et al., 1998; Thierfelder et al., 2012). Legume production results in high N in the root zone during the growth of the legume from biological N fixation (Mapfumo et al., 2005). However, maize is the main crop produced in subsistence households and small areas of land are allocated to legumes (Nhemachena et al., 2003; Mubaiwa et al., 2018) resulting in minimal returns from the legume associations (Ncube, 2007). Therefore, the current cropping systems characterized largely by continuous monocropped maize degrade the natural resource base and are not sustainable (Ngwira et al., 2013; Thierfelder et al., 2016). In addition to the prioritisation of maize, the lack of improved seed and produce markets and low yields from the use of retained seed are some reasons why smallholder farmers are not inclined to practise rotations or intercrops involving legumes (Mazvimavi & Twomlow, 2009; Ngwira et al., 2012).

(i) Multi-purpose legumes

Multi-purpose legumes have the advantage of intensifying productivity whilst conserving the soil and therefore their adoption in smallholder cropping systems may be key to achieving food, nutrition and income security (Snapp & Silim, 2002). Apart from soil fertility restoration, these legumes increase the quantity and quality of fodder and reduce soil erosion (Masikati et al., 2014). Enhanced availability of livestock feed can reduce pressure on pastures therefore reduce degradation of the grazing lands. Production of livestock is an important source of livelihood in semi-arid areas of Zimbabwe and therefore provision of opportunities for diffusion of forage technologies which lead to alternative feed sources will lead to profitability in livestock enterprises and therefore food and nutrition security. Figure 1 depicts the use of multi-purpose legumes in smallholder integrated crop-livestock systems.

Masikati et al. (2014) showed that the use of multi-purpose legumes such as mucuna (*Mucuna pruriens*) improved maize productivity in a rotation system and soil fertility in smallholder farming systems in semi-arid Zimbabwe. Mucuna is a high protein livestock supplementary feed (Maasdorp & Titterton, 1997) that is also drought tolerant with low aphid susceptibility (Nyambati et al., 2006). Mucuna has been shown to be able to fix more than 50 kg N ha^{-1} $year^{-1}$ on a sandy loam soil (Giller, 2001) while maize yields of 3–6 t ha^{-1} were observed under mucuna as green manure without adding mineral N fertilizer (Kumwenda and Gilbert, 1998).

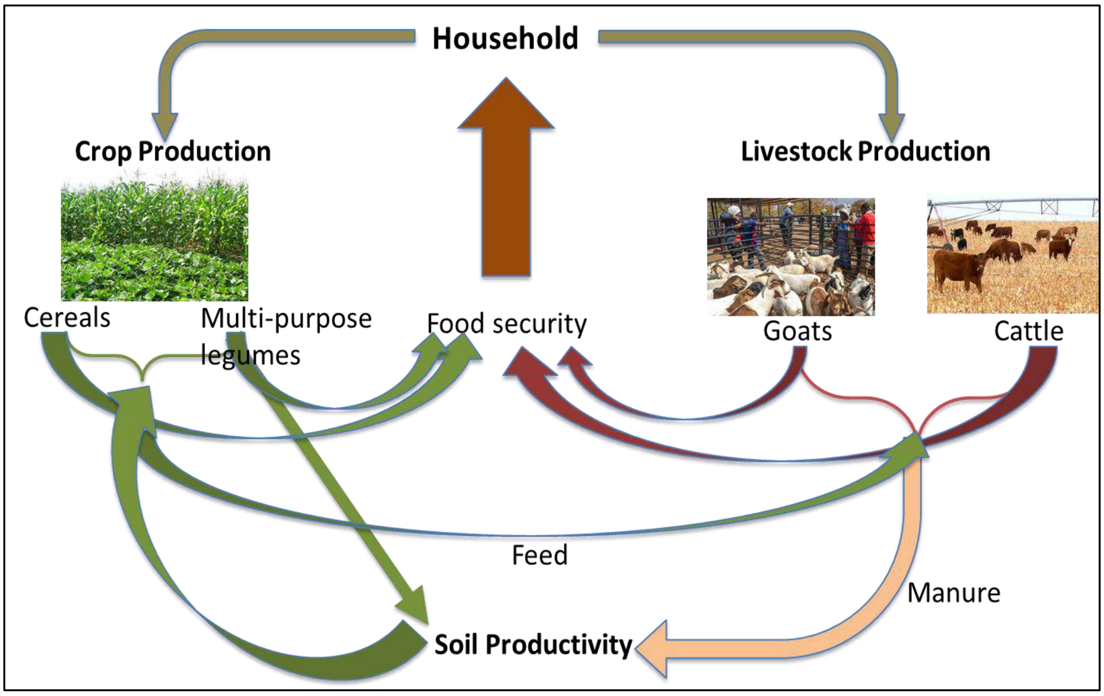

Figure 1: Use of multi-purpose legumes in smallholder integrated crop-livestock systems

(ii) Intercropping

In intercropping systems, multiple crop species or genotypes coexist for a time (Brooker et al., 2014). This allows for an intensification of the cropping system. The complementary utilization of water, nutrients and solar radiation (Rusinamhodzi et al., 2012; Li et al., 2014) enhances the efficiency of land use whilst decreasing the risk of complete crop failure (Carlson, 2008). This cropping system therefore provides a high level of production stability compared with monocropping. Intercrops produce more biomass than monocrops, and therefore can help mitigate climate change through C capture in biomass and soils. The performance of intercrop systems is dependent on the crop species interactions (interspecific relations) and the interaction between the crops and the soil environment. Each of these interactions is influenced by management and the local climate (Gou et al., 2016).

Ideal intercrops are characterised by a complementary resource utilisation and spatial and temporal niche differentiation (Figure 2), ensuring an optimal resource use efficiency as well as optimal crop yields (Li et al., 2014). Figure 2 shows intercropping of a maize crop with cowpea (*Vigna unguiculata* (L.) Walp). In semi-arid southern Zimbabwe, shading of cowpea by maize in intercrops has resulted in poor cowpea yields occurring when both crops are planted simultaneously (Jeranyama et al., 2000). It has been suggested that the interspecies competition in intercrops can be controlled by altering the plant populations of the crop species (Vandermeer, 1992) or by separating the dates of planting the different crop species in relay cropping (Rusinamhodzi et al., 2012; Masvaya et al., 2017a). However, knowledge on the mechanisms that result in advantages or risks in intercrops is limited (Li et al., 2014).

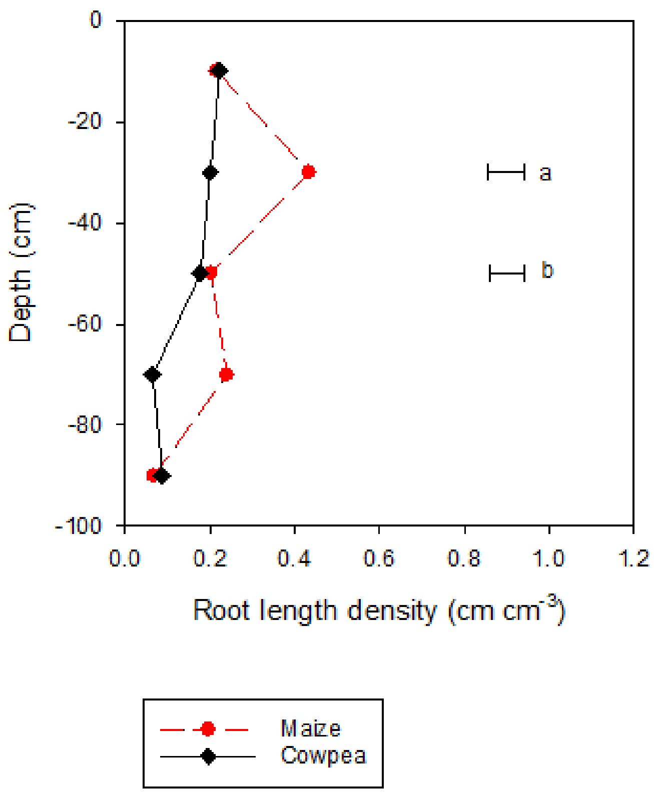

Figure 2. Root length densities of maize and cowpea in a maize-cowpea intercrop showing the spatial distribution of roots. Error bars represent standard error of the difference of the means of factors (a) Depth and (b) Intercropping. (Adopted from: Masvaya et al. (2017a))

In recent times, some work has been done to understand the underground mechanism in intercropping systems and whether these may explain crop yields in a maize-cowpea intercrop in semi-arid Zimbabwe (Figure 3) (Masvaya et al., 2017a). The study showed that only minimal below-ground complementarity existed in the intercrops as there was no spatial difference in terms of root growth. As such, it was perceived there was high nutrient and water competition between the two crops. However, there remains a dearth of information on below-ground processes. It remains important to carry out more research to understand intercropping systems to enable the determination of intercropping strategies that give the best returns on investment in semi-arid areas of Zimbabwe especially in poor fertility soils.

Figure 3. Maize intercropped with cowpea in semi-arid southern Zimbabwe (Photo: ICRISAT-Zimbabwe 2009 - 20 39.58'S, 28 15.58' E)

2.1.2. Adoption of drought tolerant crops

The rising temperatures expected with climate change effects in Zimbabwe will shorten the crop growth period potentially reducing plant production meaning shorter duration and more drought tolerant crops should be produced (Springate & Kover, 2014). Rurinda et al. (2015) suggested that increasing temperatures would result in a decrease in yields for maize in Zimbabwe meaning that rainfed maize production, in the future, may prove risky. Important interventions will include farmers embracing proven drought tolerant crops which may not necessarily be entirely new but may be newly grown to the region. Sorghum (*Sorghum bicolor*

L.) and millets (Figure 4) are believed to be drought tolerant and therefore environmentally well-suited with dry areas compared with maize (Phiri et al., 2019). A study identifying climate analogues in smallholder areas of Zimbabwe, based on 30 years meteorological data, showed that sorghum and cowpea, yields at the hotter site remained high implying that these crops are more tolerant to warmer temperatures predicted for 2050 (Nyamangara et al., 2015). At the drier sites, yields for all crops were significantly lower at the hotter site implying that crop production in the 2050s climate of the present cooler site will be more difficult.

Figure 4. Drought tolerant (from left) sorghum, pearl millet and finger millet crops in semi-arid southern Zimbabwe

A study identifying climate analogues in smallholder areas of Zimbabwe showed consistently high sorghum and cowpea yields at warmer sites inferring that these crops would be tolerant to the hotter temperatures anticipated for 2050 (Nyamangara et al., 2015). However, at the low rainfall receiving sites, crop yields were significantly lower at the warmer sites implying that productivity of crops in the drier 2050s climate will be more difficult. This implies that farmers in currently cooler and wetter climates may, in the future, have to grow drought tolerant crops that include but are not limited to sorghum, pearl millet (*Pennisetum glaucum* (L.)), groundnuts (*Arachis hypogaea* (L.)) and cowpea.

2.2 Utilisation of Non- Timber Forest Food Products (NTFPs) as an adaptation strategy to mitigate the negative impact of climate change in Zimbabwe

The world population is projected to reach 9 billion in 2050 (Prusky, 2011) and this population growth necessitates the need for alternative food sources that are sustainable and able to meet the demand for food and nutrition security (FAO, 2010). The potential role of Non-Timber Forest Food Products (NTFPs) in improving nutrition and health and reduction of poverty in the face of climate change has been recognized in recent years. NTFPs provide an essential mitigation measure towards addressing climate variability and change as they serve as livelihood resources in the face of climate stresses (Balama et al., 2017). NTFPs continue to be an important source of household food security, nutrition, and health and form an integral part of the livelihood strategy of rural communities and continue to be an important component of household nutrition and health in Africa (Arnold & Pérez, 2001; Shackleton & Shackleton, 2004b). More so, NTFPs provide livelihood benefits by assisting households to cope in times of adversity manifested as sudden changes in the economic, social or bio-physical environments in which households exist and function (Shackleton & Shackleton, 2004a). In these situations the increased use of NTFPs is typically a coping strategy, with the products providing a 'safety' or 'emergency' net (Ahenkan & Boon, 2011).

NTFPs are also vital for supplementing agricultural production (Taru & Chazovachii, 2015) and have significant subsistence and sociocultural importance and are commonly one part of multifaceted, adaptive livelihood strategies (Shanley et al., 2016). NTFPs are accordingly critical in building household resilience, a factor that is likely to become even more important, given the dire predictions around climate change (Shackleton et al., 2011). Due to prolonged droughts as a result of climate change, some communities in Zimbabwe have intensified the use of NTFPs for improved food security. The key characteristics of NTFPs are as follows (Shumsky et al., 2014):

(i) They are locally available and their use is based on traditional ecological knowledge.
(ii) They are a low-input, low-cost option for increasing nutrition and reducing the need to spend limited cash resources.
(iii) They provide greater benefits to vulnerable populations (poorer households, women, and children) who are often disproportionately affected by climate events.
(iv) They contribute to livelihoods and are available during times of drought or conflict-driven famine.
(v) They tolerate water stress better than their domesticated relatives possessing an "innate resilience to rapid climate change, which is often lacking in exotic species".

2.2.1 Contribution of edible insects to food and nutrition security and resilience building

Edible insects are amongst the NTFPs that can help in mitigating food and nutrition insecurity challenges (Tao & Li, 2018) and previous studies have revealed that insects can contribute to food and nutrition, especially in developing countries where they are mostly consumed (van Huis, 2015; Tao & Li, 2018). Wild harvested edible insects are one example of NTFPs that are widely consumed in Zimbabwe and can contribute to nutrition security (Manditsera et al., 2019a). More so, their consumption is one of the many examples of adaptation strategies to food and nutrition securities adopted by rural communities in Zimbabwe to circumvent challenges brought about by climate change (Manditsera et al., 2019a; Matiza Ruzengwe et al., 2022). Moreover, consumption of edible insects is an integral component of human survival and have been consumed since the existence of the early man (Chavunduka, 1975). At least 40 species of edible insects are consumed in Zimbabwe, and some are specific to geographical locations. Figure 5 shows some of the commonly consumed edible insects in Zimbabwe. Results from the recent rural livelihood assessment conducted by the Zimbabwe Vulnerability Committee (ZimVAC, 2020) revealed that *Ishwa* (flying termites; *Macrotermes spp.*) (43%) and *Hwiza* (43%) are the most commonly consumed edible insects in Zimbabwe. However, consumption varies per province, for examples *Hwiza* (migratory locust; *Locusta migratoria*) is commonly consumed in Mashonaland Central (80%) and *Madora* (mopane worm; *Gonimbrasia belina spp.*) mainly consumed in Matabeleland North (76%) and Matabeleland South (83%).

Figure 5. Some of the commonly consumed edible insects in Zimbabwe**:** **A** - Soldier termites (Eng); Majuru (Sh); Amagenga (Nd), **B** - Edible Stink bug (Eng); Harurwa (Sh); Umtshipela (Nd), **C** - Mopane Worm (Eng); Madora (Sh); Icimbi (Nd), **D** - Monster Cricket, King cricket (Eng); Jenya (Sh)

Numerous studies have proved that edible insects are a valuable food product that can provide the required for nutrients by human beings (Musundire et al., 2014; van Huis, 2015; Tao & Li, 2018; Manditsera et al., 2019a; Manditsera et al., 2019b; Matiza Ruzengwe et al., 2022). Table 1 shows the nutritional content of some popularly consumed edible insects in Zimbabwe (Adapted from Musundire et al., 2016). In general, the majority of the edible insects are high in protein content (ranging from 20 to 60% depending on insect species) thus; insects are referred to as an alternative protein source (Rumpold & Schluter, 2013). Not only that the protein is high but the amino profile of some insects can contribute towards the essential amino acids requirements (Rumpold & Schluter, 2013). The edible insects' amino acids can complement the limiting amino acids in the cereal staple diets (van Huis et al., 2013). For example, maize, a staple cereal in Zimbabwe is limited in lysine and tryptophan and edible insects are a potential source of tryptophan if incorporated in the meal (Manditsera et al., 2019b; Ruzenewe et al., 2023). Fat is another important nutrient that makes up the bulk of insects nutrients and the content can be as high as to about 60% for some species e.g. termites (Bukkens, 1997; Musundire et al., 2014). Thus, fats of edible insects significantly contribute to the caloric value of edible insects thus contributing to the required energy intake. In terms of the fatty acid profile, edible insects are a rich source of unsaturated fatty acids (Musundire et al., 2014; Zielińska et al., 2015).

Table 1. Proximate constituents (percentage composition on dry matter basis) of selected edible insects of Zimbabwe (adapted from Musundire et al. (2016))

Insect species	**Constituents (mean %) ± standard error**					
	Protein	Fat	Ash	Carbohydrate	Crude fibre	Energy (kcal/100g)
Brachytrupes membranaceus	53.4±0.19	15.8±0.23	6.0±0.12	5.0±0.30	5.0±0.30	454.7±2.25
Carebara vidua	43.6±0.13	38.2±0.64	8.6±0.16	9.1±0.26	9.1±0.26	519.8±6.43
Encosternum delegorguei (without alarm pheromones)	43.3^{a}±1.30	45.0^{a}±0.95	1.3^{a}±0.06	5.0^{a}±0.61	5.3^{a}±0.54	597.4^{a}±3.12
E. delegorguei (with alarm pheromones)	31.6^{b}±1.26	38.9^{b}±0.62	3.8^{b}±0.12	3.7^{b}±0.41	22.0^{b}±0.65	490.4^{b}±2.54
Eulopida Mashona	46.3±0.11	11.8±0.26	10.9±01.12	16.2±0.12	14.8±0.15	352.2±2.34
Gonimbrasia belina	55.4±0.22	16.4±0.36	8.3±0.17	8.2±0.45	16.0±0.17	329.1±5.21
Gonanisa maia	51.1±0.70	10.9±0.01	7.7±0.29	14.1±0.99	16.2±0.13	355.3±0.89
Gryllotalpa Africana	22.0±0.86	10.8±1.24	12.6±0.97	47.2±0.32	7.4±0.24	362.3±2.34
Loba leopardine	25.8±1.54	12.6±0.88	6.6±0.37	40.2±0.44	14.7±0.33	367.5±4.52
Macrotemes natalensis (winged reproductives)	37.1±0.29	41.6±0.08	35±0.15	0.4±0.05	4.9±0.12	542.5±0.4
Omithacris turbida	42.7±2.34	29.4±1.26	4.5±0.21	18.2±0.52	2.0±0.01	5.3.9±3.41

However, there is not much development in the edible insect value chain, as these chains are mostly associated with traditional processing and at times the harvesting processes that are not sustainable (Manditsera et al., 2022). The edible insect value chain in Zimbabwe depends on wild harvested seasonal insects which affects their consistent availability for the local and regional markets. Furthermore, the over harvesting of wild edible insects presents great challenges: unreliability of supply and the potential for habitat destruction. For this reason, semi-domestication can be a solution to seasonality and geographical availability, which are a key factor that can limit the potential contribution of wild harvested insects to food and nutrition security (Manditsera et al., 2018). Whilst the semi-domestication and rearing of edible insects are still in their infancy in Zimbabwe as these are widely available in the wild. However, due to the increased frequency of drought, there is now need to explore rearing technologies. As a result, the adaptation strategy through edible insect consumption can become sustainable. Figure 6 shows a mopane worm rearing house constructed at Mutedzi homestead in Marange (19°15'0"S;32°16'0"E), Manicaland Province.

Figure 6. Mopane work rearing facility constructed using a shed net.

2.2.2 Contribution of indigenous fruits to food and nutrition security and resilience building

Non-Timber Forest Products (NTFPs) such as indigenous edible fruits are occasionally used to meet food shortages, complement staple food diets. Indigenous fruits are known to make important contributions to food baskets and livelihoods in the smallholder and subsistence farming communities of sub-Saharan Africa (Shumsky et al., 2014). As a result, protecting and promoting the sustainable use of indigenous fruits with more mainstream agricultural innovation efforts has the potential to build household resilience to food insecurity. Indigenous fruits remain a major option for coping with micronutrient deficiencies in diets of rural households during vulnerable times in the semi-arid areas of sub-Sahara Africa (Kasimba et al., 2019). The importance of the fruits is greatest in drought seasons because of the drought tolerance of the trees (Kadzere & Jackson, 1997). The harvesting, utilization and marketing of indigenous fruits has been central to the livelihoods of the majority of rural communities throughout Africa (Akinnifesi et al., 2008b) and can make a difference during period of famine and food scarcity. Market and financial analyses in southern Africa showed that indigenous fruits contribute to household income, and women and children are the major beneficiaries through value addition and fruit processing (Akinnifesi et al., 2008a). Nutrition wise, several indigenous fruit tree crops are vital source of fibre, vitamins, macronutrients, antioxidants, and can act as a 'safety net' when other fruits are scarce because the trees are well adapted to harsh condition (Neudeck et al., 2012).

Zimbabwe has a rich reserve of edible indigenous fruits and the indigenous fruits represent about 20% of the total woodland resources used by rural households in Zimbabwe (Campbell *et al*., 1997). Their importance in rural communities is seen by the collection of indigenous fruits for sale at roadsides and at the local markets when in season by collectors and intermediaries as an income-generating venture (Ramadhani et al., 2002). More so, frequent droughts in the country have seen food and agriculture experts turning to indigenous foods in efforts to ensure food security and the attainment of the United Nations' Sustainable Development Goals (SDG) of eradicating poverty and hunger (SDGs 1-3). The importance of indigenous fruits depends largely on their abundance, consumer liking and preference, thus having realised their high potential and availability in Zimbabwe, their value addition is deemed beneficial for the communities- income generating ventures for communities, commercialization and provision of health benefits. The diversity of indigenous fruits has the potential to augment the nutrient composition of family diets and may contribute to household food security (Ngadze et al., 2017) and the alleviation of hidden hunger which is a result of a lack of dietary diversity, usually linked to poor consumption of fruit and vegetables in general. Figure 7 show some of the most consumed indigenous fruits in Zimbabwe. Results from the 2020 livelihood assessment conducted by the Zimbabwe Vulnerability Committee (ZimVAC, 2020) showed that at national level, *Matohwe* (Snot apple; *Azanza garckeana*) (52%) in the most consumed fruit followed by *Matamba* (Monkey-orange; *Strychnos spp*) (39%) and then *Hubva*/*Tsubvu* (Chocolate berry; *Vitex payos*) (38%).

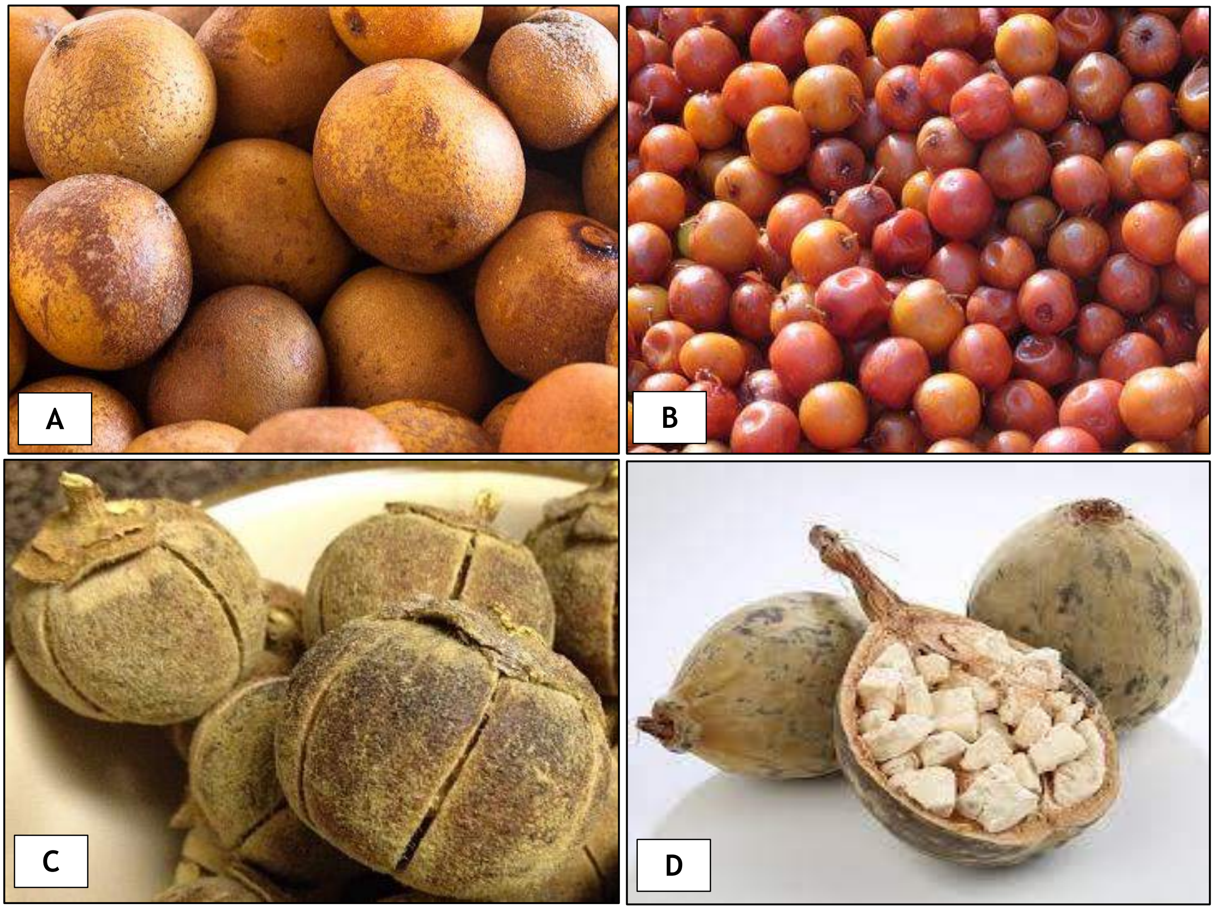

Figure 7. Some of the commonly consumed indigenous fruits in Zimbabwe. **A** - Wild Loquat (Eng); Mazhanje (Sh); Umhobohobo (Nd) *Uapaca kirkiana*, **B** - Jujube (Eng); Masau (Sh); Amasawa (Nd), *Ziziphus mauritana*, **C** - Snot apple (Eng); Matohwe (Sh); Uxakuxaku (Nd), **D** - Baobab (Eng); mauyu (Sh); Umkhomo (Nd), *Adansonia digitata*.

However, like most NTFPs, edible indigenous fruits are underutilised due to limited diet diversification, lack of infrastructure and resources for value addition, policies that do not recognize sufficiently the important role of these in promoting food security and nutrition, as well as limited research and knowledge dissemination of the health and economic benefits. Even though the consumption of edible indigenous fruits is on the rise in Zimbabwe, there is limited value addition with most focus being on the conventional exotic fruits. The fact that most edible indigenous fruits are underutilized and little attention has been given to their potential commercialisation presents a huge opportunity for value addition and commercialisation of the value-added products for improving human health and nutrition for all communities of Zimbabwe, and as income generating ventures for local community cooperatives (Cogill, 2015). There is need to domesticate the indigenous fruit trees to ensure availability and limit dependence on the wild harvested fruits.

2.2.3 Contribution of African Indigenous Vegetables to food and nutrition security and resilience building

African Indigenous Vegetables (AIVs) are promising vegetables crops which can resist the adverse effects of climate change (Capuno et al., 2015). Adoption of AIVs in mainstream agriculture and food systems has the potential to improve food and nutrition security as AIVs are mainly produced by resource-poor smallholders, are nutrient-denser than exotic vegetables, have various health benefits, contribute to identity and authenticity, and offer a range of agronomic advantages (Stöber et al., 2017). AIVs have been the mainstay of human diets for centuries, providing millions of consumers with important nutrients and energy needed to maintain health and promote immunity against infections (Bua & Onang, 2017; Kansiime et al., 2018). More so, these vegetables form a significant and inexpensive source of a balanced diet for the poor rural households in Africa, Zimbabwe included (Mazike et al., 2022). Many traditional or indigenous vegetables are characterized by a high nutritional value compared with global vegetables like tomato and cabbage (Keatinge et al., 2011). As sources of essential vitamins, micronutrients, protein and other phytonutrients, traditional vegetables and AIVs have the potential to play a major role in strategies to attain nutritional security (Ebert, 2014). AIVs, are rich in micronutrients (e.g. vitamins A and C, and iron) and can be part of the solution to hidden hunger (Stöber et al., 2017).

Apart from their commercial, medicinal and cultural value, traditional vegetables are also considered important for sustainable food production as they reduce the impact of production systems on the environment. Many of these crops are hardy, adapted to specific marginal soil and climatic conditions, and can be grown with minimal external inputs (Ebert, 2014). In Zimbabwe, consumption of indigenous vegetables is on the rise. The ZimVAC (2020) rural livelihood assessment survey (Figure 8) revealed that Nyevhe (Spider plant; *Cleome gynandra*) (89%) is the mostly consumed indigenous vegetable in the country followed by Mowa (Amaranth; *Amaranthus spp.)* (62%) and Munyemba (Cowpea leaves; *Vigna unguiculata*) (62%). These high consumption levels are an indication of the high acceptance of indigenous vegetables by consumers.

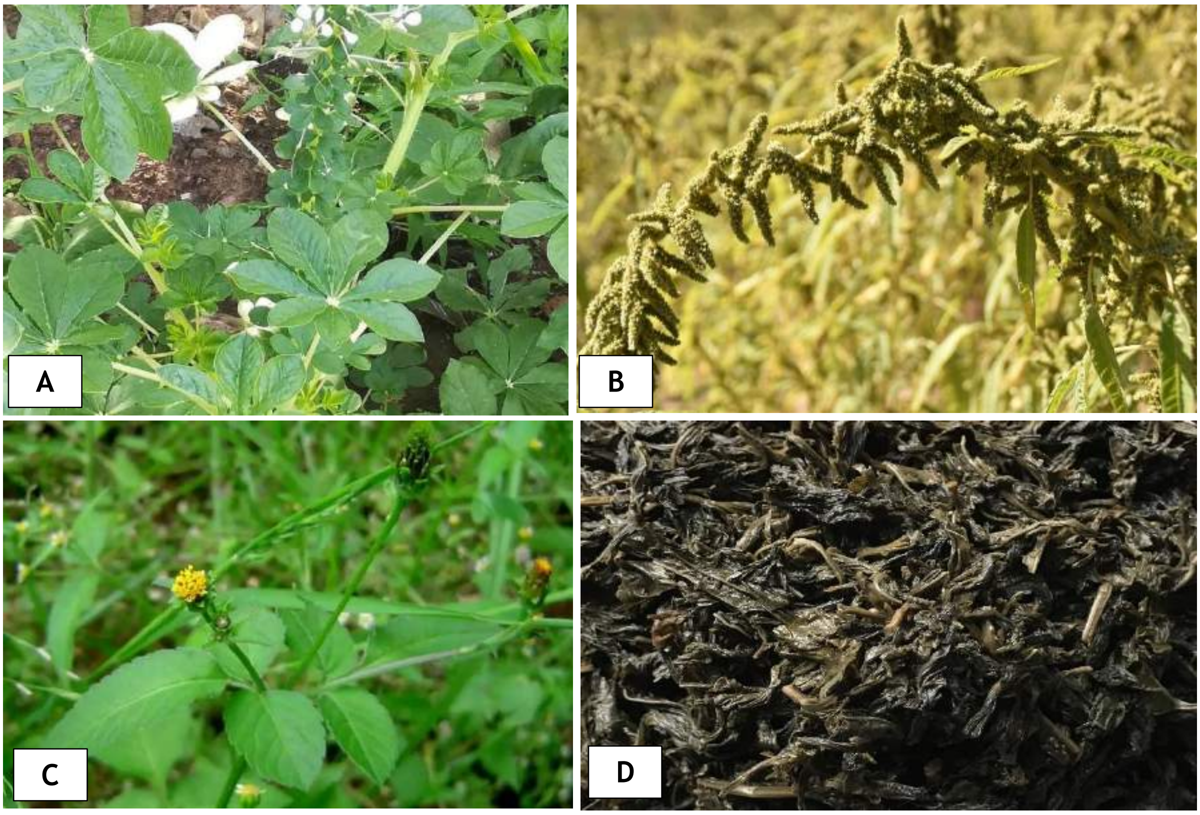

Figure 8. Top six commonly consumed indigenous vegetables in Zimbabwe. **A** – spider plant (Eng); Nyevhe (Sh); Ulude (Nd), **B** - Amaranth (Eng); Bonongwe/Mowa (Sh); Imbuya (Nd), **C**-Blackjack (Eng); Mutsine (Sh); Ucucuza (Nd), **D** - Cowpea leaves (Eng); Munyemba/Mutsotso (Sh); Imbida yendumba (Nd).

Despite their significant contribution to food security, nutrition, and sustainable livelihoods, NTFPs tend to be overlooked (Ahenkan & Boon, 2011). More so, the sustainability of these NTFP resources is threatened by deforestation, land degradation, and overexploitation (Adongo et al., 2019). Considering the importance of NTFPs, to household food security, it is essential that the social-ecological systems that make gathering these natural resources possible be appropriately protected, managed, and valued to avoid overexploitation and degradation (Shumsky et al., 2014). One important strategy that can be employed to ensure a sustainable use and reliance on NTFPs is their domestication. Because of their resistance to adverse climatic conditions, adaption to marginal soil and growth with minimal external inputs (Ebert, 2014), adoption of NTFPs into mainstream agriculture and food systems has the potential to improve food and nutrition security in the face of climate change and to increase resilience of rural household to climate change and its impact.

3. Conclusions

This paper explored two adapation strategies, i.e., enhanced cropping systems and the adoption of Non-Timber Forest Food Products (NTFPs), that smallholder farmers in Zimbabwe can adopt to mitigate the effects of climate change. Climate Smart Agriculture technologies such as conservation agriculture practices and the use of legume technologies may result in increased food production per unit land, while maintaining or rebuilding soil fertility in the face of adverse weather conditions as a result of climate change. Adoption of drought tolerant crops, such as Africa Indigenous Vegetables, may be a viable option for increased food and nutrition security, vis-à-vis the increased incidences and frequency of droughts in most parts of Zimbabwe. Moreover, the utilisation of other NTFPs such as indigenous fruits and edible insects can provide an essential mitigation measure towards addressing food and nutrition insecurities due to climate extremes and variability. Overall, this paper has provided some evidence that the two reviewed adaptation strategies can contribute towards food and nutrition security in Zimbabwe. However, there is need for a multisectoral approach to popularise the many available adaptation strategies to mitigate the impact of climate change, including the two strategies discussed in this paper. Furthermore, more multidisciplinary studies are needed to investigate the sustainability of the adaptation strategies being proposed. In addition, relevant policies to support the adoption and sustainability of the adaptation strategies need to be explored.

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