The Malawi Priorities Project

Cost-Benefit Analysis of Food and Nutrition Security in Malawi - Technical Report

National Planning Commission Report with technical assistance from the Copenhagen Consensus Center and the African Institute for Development Policy

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AFIDEP
African Institute for Development Policy

Report Contributors
Munyaradzi Mutenje, Ph.D., Agricultural Economics independent consultant
Brad Wong, Ph.D., Chief Economist, Copenhagen Consensus Center
Saleema Razvi, Ph.D., Research Economist, Copenhagen Consensus Center
Charles Jumbe, Ph.D., Professor of Economics (Academic Advisor, Malawi Priorities Project), Lilongwe University of Agriculture and Natural Resources, Malawi
Jabulani Nyengere, Research Officer, Malawi National Planning Commission
Sipho Billiat, Senior Development Planning Officer, Malawi National Planning Commission

www.copenhagenconsensus.com
www.npc.mw
www.afidep.org

This work has been produced as a part of the Malawi Priorities project.

Malawi Priorities: Background

Malawi Priorities is a research-based collaborative project implemented by the National Planning Commission (NPC) with technical assistance from the African Institute for Development Policy (AFIDEP), and the Copenhagen Consensus Center (CCC) to identify and promote the most effective interventions that address Malawi's development challenges and support the attainment of its development aspirations. The project seeks to provide the government with a systematic process to help prioritize the most effective policy solutions so as to maximize social, environmental and economic benefits on every kwacha invested. Cost-benefit analysis is the primary analytical tool adopted by the project. Cost-benefit analysis will be applied to 20-30 research questions of national importance. Research will take place over the course of 2020 and 2021.

Research questions were drawn from the NPC's existing research agenda, developed in September 2019 after extensive consultation with academics, think tanks, the private sector and government. This sub-set was then augmented, based on input from NPC, an Academic Advisory Group (AAG) of leading scholars within Malawi, and existing literature, particularly previous cost-benefit analyses conducted by the Copenhagen Consensus Center. The research agenda was validated and prioritized by a Reference Group of 25 prominent, senior stakeholders. The selection of interventions was informed by numerous consultations across the Malawian policy space, and one academic and two sector experts provide peer review on all analyses.

Cost-benefit analyses in Malawi Priorities consider the social, economic and environmental impacts that accrue to all of Malawian society. This represents a wider scope than financial cost-benefit analysis, which considers only the flow of money, or private cost-benefit analysis, which considers the perspective of only one party. All benefit-cost ratios (BCRs) reported within the Malawi Priorities project are comparable.

The cost-benefit analysis considered in the project is premised on an injection of new money available to decision makers, that can be spent on expanding existing programs (e.g. new beneficiaries, additional program features) or implementing new programs. Results should not be interpreted as reflections on past efforts or the benefits of reallocating existing funds.

Inquiries about the research should be directed to Salim Mapila at smapila@npc.mw.

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1. Introduction and Context

Malawi has a significant problem with food security and is calorific deficient as a whole. Gelli et al. (2020) show that 36 percent of all Malawian households consume less than 1,800 calories per capita per day in the postharvest season, rising to 46 percent of households in the lean season.[1] The Fifth and latest Integrated House Survey (IHS5, 2019-2020) results indicate that 62.9% of households struggle with severe food security, barely unchanged since 2016, and almost double that of 2010 (where severe food insecurity was at 32.5%). More than half of the households surveyed (55%) reported that adult members ate 2 or fewer meals per day, while 49% households reported similar meal intake of 2 or fewer meals in children in the age group of 6-59 months. A very high number of rural households (70%) and 45% of urban households reported that they did not have sufficient food over the last 12 months. (IHS5, 2019-2020).

Food insecurity and undernourishment have negative effects that ripple from the household, to the broader economy and to future generations. Sub-optimal calorific and micronutrient intake in adults has been linked to poorer subjective well-being (Mwene-Batu et al. 2020), lower wages (Thomas and Strauss, 1997; Strauss and Thomas, 1998; Horton and Ross, 2003) and lower economic growth (Arcand, 2001). Undernourishment also impacts health outcomes, leading to higher mortality and morbidity. In the context of Malawi, this has been particularly problematic for those living with HIV and AIDS, where poor nutrition increases the risk of mortality by 18% (Kendi et al. 2013). A raft of literature also demonstrates a negative link between child malnutrition, particularly stunting, and childhood survival (Olofin et al. 2013), adult wages (Hoddinott et al. 2008), asset accumulation (Victora et al. 2008), and education attainment (Nandi et al. 2015).

Food insecurity is also a drain on government resources, with the share of population in need of food assistance increasing from an average of 2 million in 2012-13 to 2015-16 to almost 7 million in 2016-17. This reflects in part restricted per capita agricultural resources due to population growth, coupled with crop production shocks (Ministry of Agriculture, Malawi, 2016-17).

The causes and correlates of food insecurity in Malawi are multi-faceted and include over-reliance on rain-fed agriculture, low agricultural productivity, climate-related shocks, environmental degradation, poverty and endemic gender inequalities (Mutenje et al 2019, WFP, 2016). Because the arena of food security is so multi-dimensional, no one paper can hope to examine all the potential levers to mitigate it. The focus of this paper is on **sustainable farming models**. Current evidence shows that maize-legume intercropping has agronomic benefits, increases productivity, and reduces crop income variability (FAO 2019). Strategies to encourage increased intercropping, including maize-legume intercropping, should be pursued by the government, donors, and research institutions.

Following consultations with sector experts, a review of academic and grey literature, as well as careful consideration of national policy documents, this paper conducts a cost-benefit analysis of four intercropping / crop diversification strategies - one for each unique agro-ecological region in Malawi as well as a novel technology for reducing post-harvest losses: the Purdue Improved Crop Storage (PICS) bags. We present results of both interventions at the national level, and crop diversification results at the regional level. Crop diversification in this technical report is defined as cultivating more than one crop belonging to the same or different species in a given area. It involves moving away from traditional cropping systems to high value, nutrition sensitive cropping systems. The results indicate that both of these interventions have the potential to meaningfully impact food security at a national level with PICS bags having the higher benefit-cost ratio (BCR) but lower absolute impact.

The results suggest that a comprehensive government engagement and information campaign to encourage crop-diversification, would require an investment of MWK 200 billion to MWK 350 billion (USD 270 million to USD 470 million) annually in terms of increased extension costs, cultivation costs and breeder seed production. This figure assumes 60% uptake of crop diversification approaches after 10 years. The strategy would yield MWK 1,160 billion (USD 1.6 billion)[2] in additional farm output per year at steady state. Over a 10-year period the BCR of this strategy is 2.0. While the BCR is relatively modest, it would have a large absolute impact on the Malawian economy.

By 2030, the extra farm income net of cultivation costs obtained through crop diversification techniques would be equivalent to 7% of counter factual GDP. Sub-results indicate that some strategies have higher BCRs such as focusing on potato in the mid-elevation region of Malawi, where the region has a comparative advantage, providing direction to Malawian authorities about where to start efforts. Sensitivity analyses examine the importance of various parameters, which suggest results are most sensitive to assumed uptake rates. Nevertheless, BCRs remain within a relatively narrow range of 1.6 to 2.3.

The second intervention examined in this study is the promotion and expanded use of PICS bags. PICS bags, developed by Purdue University, are a simple and durable hermetic home storage method that has been shown to reduce post-harvest losses compared to conventional methods (Singano, Munvi and Stathers (2019). The analysis for PICS bags indicates that an investment of MWK 81 billion would yield benefits of MWK 236 billion over 10 years, resulting in a BCR of 2.9 (8% discount rate).

Avoided grain loss would increase substantially from 26,000 tonnes with 5% of farmers using the intervention to almost 320,000 tonnes at 60% usage. In steady state the net benefit of the intervention is estimated at MWK 46 billion, equivalent to 0.4% of counterfactual GDP. This is extremely important for Malawi given the potential the extra grain reserves have for reducing food

[1] Definition of Calories per Capita: The household average dietary energy consumption per capita is an indicator that estimates calorie consumption based on the total amount of food acquisition or consumption by the household.

[2] Since this report is designed for Malawian decision makers, we do not continue to put USD equivalent figures throughout the text. The assumed MWK to USD exchange rate is 745 MWK per USD.

insecurity and poverty. The results of the PICS bags analysis are most sensitive to assumptions around the cost of bags and the extent of post-harvest losses avoided.

While we have determined the total social costs of these interventions, it is beyond the scope of the study to estimate the exact subsidization pathways, and therefore government contribution that would be required. We only note a few salient features for consideration by policy makers. For crop-diversification, the government would likely be required to put up 100% of the marginal extension costs, and around 60% of extra cultivation costs if historical subsidization rates continued. For PICS bags, the government outlay would likely include 100% of the promotion costs plus 80% of the PICS bag cost per year. This level is based on a study by Masters and Alvarez (2018), which found that less than 1% of the farmers were willing purchase a PICS bag without subsidies, with a mean willingness to pay of MWK 312 (USD 0.42), just more than a fifth of market price. Over time, it may be possible to reduce the subsidization rates if farmers can be convinced that the private benefits substantially exceed the private costs of these interventions.

We then tie the result of crop diversification to potential changes in the calorific and micronutrient basket relative to continual traditional farming practices. This analysis suggests that this intervention has immense potential to significantly add to the food grain reserves available in the country. With the proposed set of changes, Malawi would have a surplus of calories, protein and zinc that could be consumed, exported, or used in agro-processing, a key pillar of the country's Vision 2063. This does not mean that these deficiencies would be eliminated at an individual level, since it is uncertain how such gains would be distributed across the population. Nevertheless the results provide hope that Malawi can achieve the required food security at a national level to help meet its goals. Additional scenario analyses show that **at a maximum** any additional health impacts flowing from improved food security would increase benefits by roughly MWK 300 billion annually. This is a large absolute figure but as a percentage equates to 25% of benefits, an amount that would only change the baseline BCR at the first decimal place. Furthermore, this is a substantial overestimate since it assumes that illnesses and mortality from nutrition deficiencies and child wasting are eliminated, and that the price of food does not embed any health benefits. The likely missing health benefits, if they exist, are therefore unlikely to change the BCRs or policy implications of the report substantially.

1.1 The Importance of Agricultural Diversity

The links between Agri-food systems, diets, nutrition and health are manifold and complex, involving a range of direct and indirect effects (Turner et al 2018). At a farm level, agricultural diversity plays a role in "environmental services" that have a positive influence on food production, including adaptation to climate change, soil protection, crop pollination, and pest control (Snapp et al., 2014). Diversity in agricultural production systems minimizes vulnerability to existing and emerging stresses that are experienced in monocultures (Snapp et al., 2014, Thierfelder, et al 2017), allowing for longer term sustainability in production. All the services contribute to longer term farm well-being, food supply stability, food security, and ultimately, nutrition.

Adequate human nutrition involves regular intake of a wide range of nutrients, a number of which must be consumed on a frequent basis, even if in small quantities (Coates et al., 2007). Growing a range of local crops supplemented by livestock products helps provide such diversity in the human diet, especially of poor rural families in Malawi, and complements the nutrition provided by staples such as maize, rice and cassava. Balanced nutrition in the human diet depends not just on growing a diversity of crops but also crop variety diversity (Jones et al 2014). For example, beta-carotene content can differ by a factor of 60 between sweet potato cultivars while the protein content of rice varieties can range from 5 to 13 per cent (Kennedy and Burlingame, 2003).

Nutrition is closely linked to agriculture in two ways (1) the agriculture sector produces food, and (2) many of the undernourished people in Malawi are smallholder farmers (Frelat et al 2016). For a long time, the Malawi agricultural policy response to under nutrition was to strengthen staple food production through price incentives and promoting improved farm technologies. The focus was primarily on a narrow range of cereal crops, maize, sorghum, millet and rice (Jones, et al. 2014, Makate et al 2016). While this strategy has clearly helped to reduce hunger, it has also contributed to lower levels of crop species diversity (Jones, et al. 2014, Makate et al 2016). Low levels of dietary diversity are associated with higher rates of micronutrient deficiencies, child stunting, child deaths and other negative health consequences (Jones, et al. 2014, Makate et al 2016).

More diversified agricultural and food systems may help to improve dietary quality and nutrition (Njeru, 2013). Agricultural diversification scale is determined by economic/ policy incentives, markets, and socio-cultural factors. Studies in Southern Africa have shown that diverse farm production promotes diverse food consumption in the farm household. This is especially common in developing countries, where smallholder farms are often subsistence-oriented (Njeru, 2013). Agricultural diversity will be an appropriate strategy to enhance food and nutritional security for two main reasons: firstly, Malawi is poor with high rates of under-nutrition (UNICEF, 2018). Secondly, farm households in Malawi are primarily subsistence-oriented.

Under-nutrition remains a huge health burden in Malawi. Approximately 3.4 million people are undernourished in Malawi, most of them living in rural areas (UNICEF, 2018). Nutritional deficiencies impair physical and mental human development, increase the susceptibility to infectious diseases and contribute to premature deaths. Women and children suffer the substantial impact. An estimated 34.4% and 64% of reproductive women and children under 5 years of age suffer from deficiencies in particular micronutrients, such as iron, zinc or vitamin A (UNICEF, 2019 and FAOSTAS, 2020). Thirty-seven percent of children in Malawi are stunted (UNICEF 2019). Twenty - three per cent of all deaths of children under 5 years of age are linked to under-nutrition (UNICEF, 2019). Childhood under-nutrition also decreases adult productivity and entails substantial economic losses.

Improvements are necessary therefore, in not only the quantity but also the quality of people's diets (Ragasa et al. 2019). Diet and nutritional status are influenced by the types of foods that households can either produce themselves or purchase from markets. The variety of crops grown on farms has been shown to be positively related to household dietary diversity and intakes of calories and protein in Malawi (Koppmair et al. 2017). Studies also link crop diversity with households' access to important micronutrients: iron, folate, vitamin A, and zinc (Jones 2017; Mazunda et al. 2018). In some contexts, access to markets for buying and selling food and produce influences dietary diversity more than crop choice does (Koppmair et al. 2017).

1.2 Existing Policies and Government Measures Affecting Food Security and Nutrition

Malawi is committed to reducing food insecurity and the Government of Malawi has expressed its strong commitment to improving food and nutrition security through a variety of policies and institutional arrangements (NPC, 2020). The Hunger and Nutrition Commitment Index (HANCI) also ranks Malawi second-best out of 45 African countries based on an evaluation of the political commitment to tackling hunger and undernutrition (IDS 2017). Malawi has also been a member of the Scaling Up Nutrition (SUN) movement since 2011 (Babu et al. 2016). Some of the key documents that pertain to Malawi's food security goals and plans are summarized below.

- Malawi's constitution includes the right to adequate nutrition, stating, "The State shall actively promote the welfare and development of the people of Malawi by progressively adopting and implementing policies and legislation aimed at achieving the following goals... Nutrition: To achieve adequate nutrition for all in order to promote good health and self-sufficiency" (WIPO 1998, 3).
- The country's third national development strategy, the Malawi Growth and Development Strategy (MGDS3) (2017–2022), includes improved nutrition as a stated goal, describes the causes and implications of under-nutrition in Malawi, and delineates the necessary strategies to overcome under-nutrition (GoM 2017).
- The National Multi-Sector Nutrition Policy (NMNP) (2018–2022), to be operationalized through the National Nutrition Strategic Plan (2018–2022), is a revision of the National Nutrition Policy and Strategic Plan 2007–2012. The Department of Nutrition, HIV and AIDS is the lead department responsible for the policy, but the roles of many other governmental and nongovernmental institutions are enumerated in the policy (GoM 2018b).
- The goal of Malawi's National Agriculture Policy, adopted in late 2016, is the following: "To achieve sustainable agricultural transformation that will result in significant growth of the agricultural sector, expanding incomes for farm households, improved food and nutrition security for all Malawians, and increased agricultural exports" (GoM 2016, 10). The policy explicitly acknowledges that Malawi has "over-concentrated" on maize and tobacco production in the past (GoM 2016, xi).
- The National Agricultural Investment Plan (2017/18–2022/23) is the implementation and investment framework for the National Agriculture Policy (Mpaso 2018). It includes a detailed budget for each of the 16 intervention areas, including food and nutrition security.
- Other policies with the potential to provide support to the country's nutrition objectives are the National Health Policy, the National Education Policy, the National Gender Policy, the National Resilience Strategy, the National Irrigation Policy, the Malawi National Social Support Programme II, and the Decentralization Policy.

While the Government of Malawi has expressed a strong commitment to food and nutrition security and has taken important steps to that end, more must be done to ensure effective multi-sectoral coordination and prioritization of resources to meet the challenges at hand (Ragasa et al. 2019).

As Malawi's National Agriculture Policy acknowledges, the agricultural sector has an important role to play in achieving nutrition security in Malawi (GoM 2016). Enabling low-income and smallholder farmers to pursue agricultural diversification will require not only public support to ease household resource constraints, but also public-private partnerships to strengthen input and output marketThe

2. Research Context

National Planning Commission (NPC), with technical assistance from AFIDEP and the Copenhagen Consensus Center (CCC) are conducting the Malawi Priorities project across 2020 and 2021. The project is a research and advocacy exercise to identify the most effective ways to address the nation's challenges using the framework of cost-benefit analysis. The aim is to inform both short and long term development priorities for the country, acknowledging that there are insufficient resources to address all of Malawi's challenges and that maximizing outcomes requires careful, evidence-based consideration of the costs and benefits of all policies.

The starting point of all research questions is the NPC's existing research agenda, structured around the six thematic areas of Sustainable Agriculture, Sustainable Economic Development, Human Capital and Social Development, Sustainable Environment, Demography, Governance, Peace, and Security, and Human Capital and Social Development.

The NPC's research agenda was developed by the Commission in September 2019 after extensive consultation with academics, think tanks, the private sector and government. Consequently, the Commission's research agenda, prima facie, contains questions of national importance.

This paper seeks to address the question:

"What interventions most effectively deliver sustained food and nutrition security, as well as greater dietary diversity within sustainable farming models?"

The paper aligns with the pillar of agriculture productivity and commercialisation of the Malawi 2063 V ision which seeks to impact poverty and hunger by increasing production and achieving greater output per unit of land used and producing large farm surpluses. Crop diversification and using PICS bags for storage contribute greatly to building grain reserves and thereby help in attaining these objectives of the Malawi 2063 Vision.

As a first step, Malawi Priorities drew questions from the NPC research agenda that could be answered using a cost-benefit methodology. Then, additional research questions were added based on input from NPC, an Academic Advisory Group (AAG) of leading scholars within Malawi, and existing literature, particularly previous cost-benefit analyses conducted by the Copenhagen Consensus Center. This process of identifying research questions for investigation generated a total of 38 potential research questions across all 6 thematic areas.

The research agenda was validated and prioritized by a Reference Group of 25 prominent, senior stakeholders from government, civil society and the private sector. The outcomes of the Reference Group exercise were used to inform which research questions to prioritize and which interventions to focus on within those 38 potential research questions. The validation process was completed in July 2020.

2.1 Research Process

The intervention selection process started with a wide universe of potential interventions drawing from literature, stakeholder interviews and advisor input. The project team completed a scan of all potential interventions by means of a rigorous literature review. Several experts were interviewed including:

- Jacob Ricker-Gilbert, Dept. of Agricultural Economics, Purdue University
- Joseph Kanyamuka, Centre for Independent Evaluations, Lilongwe
- Travis Lybbert, Agricultural & Resource Economics, UC Berkeley
- Malawi Priorities Reference Group

The prioritization of interventions then took in a number of considerations including:

1. **Sector expert priority** – An intervention is accorded higher priority if sector experts note that it is important. There are several avenues from which experts provide input into our process such as the Reference Group questionnaire, direct interview, inferences from the NPC research agenda, and via our academic advisory group.
2. **High benefit-cost ratio or cost-effectiveness in similar previous research** – The purpose of the Malawi Priorities project is ultimately to identify interventions of outsized benefits relative to costs. Input into this factor is determined from the economics literature, particularly previous research conducted by the Copenhagen Consensus Center. In the Center's experience BCRs above 15 are among the highest across all interventions. Due consideration is given to contextual differences between previous research and the current situation in Malawi in determining the effect of this criterion.
3. **Addresses a problem of sufficient size** – some interventions could be considered highly effective but only address a small percentage of a given problem, limiting the overall net benefits of the approach. To avoid focusing on solutions that are too small, each intervention must have the potential to address a problem that is significant.
4. **Significant gap in current coverage levels of intervention** – all analysis conducted in Malawi Priorities focuses on marginal benefits and costs. Therefore, if an intervention already has high coverage rates, then additional resources provided towards that

intervention are unlikely to be effective or will suffer from the 'small-size' problem.

5. **Availability of crucial data or credible knowledge of impact** – due to time and resource constraints, all analyses conducted by Malawi Priorities are based on secondary data. No primary research is conducted, such as field experiments or trials. Therefore, each intervention is constrained by the availability of data. In many cases, one key constraint is knowledge concerning the impact of a given intervention. It is typical to formally deal with uncertainty via sensitivity analyses. However, in some cases the uncertainty is so great that it precludes even researching the intervention at all.

The universe of potential interventions impacting food security also draws from previous Copenhagen Consensus projects conducted in other developing countries, which analyzed multiple interventions. The process of screening and prioritizing interventions is summarized in Table 1, drawing on the factors described a below.

Table 1: Intervention Screening Process

Intervention considered	Sector expert priority	High BCR or cost-effectiveness	Addresses a problem of sufficient size	Significant gap in current coverage levels	Availability of data	Overall
Crop diversification/ Intercropping/ Crop Rotation	Yes, noted by sector experts for agronomic benefits, improving food security and dietary diversity.	Previous research by CCC indicates BCR of around 1 for crop diversification and between 4 and 7[2] for inter cropping.	The agricultural sector in Malawi is highly undiversified, with maize and tobacco being the dominant staple and export crops, respectively.	Grains are grown on 50% farmland in Malawi, with legumes and oil seeds grown on only 30 %. Only 53% of fields in Malawi use intercropping techniques.	Yes	High
PICS (Hermetic) Storage Bags	Yes, noted by sector experts as important mechanism to reduce post-harvest losses for small holder farmers	Literature suggests BCR range of between 3 to 10.[3]	Yes, Malawian smallholder farmers suffer post-harvest loss of between 20 – 30% of their total harvest once in storage due to weevils, termites, fungi and other hazards	Uncertain	Yes	High
Irrigation management	Yes, noted by sector experts (is being researched in another paper)	Previous research by CCC indicates BCRs of around 1.5 in Gwhana and between 3.5 - 5 in India	Malawi's main crop producers are smallholder farmers, who occupy 70% of the country's arable land but depend mainly on rainwater.	Yes, though about 21% of the total land area has freshwater resources, only 3.5% of agricultural land in Malawi is irrigated.	Yes	High
Improved Agricultural Extension	Noted by Sector experts (is being researched in another paper)	Previous research by CCC indicates BCR of around 6 in India	Agricultural extension services in Malawi are plagued by high vacancy rates, poor coordination and infrastructure, limited coverage and training of existing staff.	The farmers per DAES (Department of Agricultural Extension Services) officer ratio in Malawi is estimated to be as low as 3000 to 1. 66% of households and 49% received extension services for crop production and fertilizer use respectively.	Yes	High

[2] https://cgspace.cgiar.org/bitstream/handle/10568/77786/AGORA_WP1_2018.pdf?sequence=4
[3] https://www.fanrpan.org/archive/documents/d02073/PHLM_CBA_Mozambique_Report-Mar_2017.pdf

Removal of Maize export Ban	Noted by sector experts (is being researched in another paper)	Uncertain	According to the last official estimates, an estimated 2.7 million people are assessed to be food insecure in 2020, of which 1.9 million live in rural areas and the remaining 800 000 people live in urban areas	Total cereal output is estimated at a well above-average level of 4 million tonnes for 2020 with Maize accounting for 93%. Due to excess market supply, Maize prices have seen a significant drop early this year (till May, 2020).	Yes	High
Flexible Vouchers in FISP	Yes, noted by sector experts as a way to improve farmer access to varied inputs.	Uncertain	Most smallholder farmers in Malawi cannot buy inputs due to lack of resources, credit borrowing, and access to markets. Flexible e-voucher would allow them to buy the farm inputs or equipment of their choosing – not just maize seed and fertilizer.	The fertilizer package is expected to benefit a total of one million (1,000,000) farmers.	Yes	Medium
Home gardening	Yes, noted as useful by sector experts in providing nutritious foods and improving dietary diversity in the household but considered too low scale for implementation.	Previous research by CCC in Ghana indicates BCR between 1.3 and 1.6.	Food insecurity is associated with unavailability of food, insufficient purchasing power, inappropriate distribution, or inadequate use of food, all linked to poverty.	Yes, only 22% households have backyard gardens established and only 39% of households practice integrated household farming.	Yes	Medium
Promotion of small livestock ruminants	Yes, noted by sector experts but there were apprehensions around the upkeep and sustainability of the intervention.	Previous research by CCC in Ghana indicates BCR between 1.3 and 1.6.	Food insecurity is associated with unavailability of food, insufficient purchasing power, inappropriate distribution, or inadequate use of food, all linked to poverty.	Around 62% of households own small livestock mainly goats, sheep, pigs and poultry, with non-poor house- holds were more likely to own animals than were poor households, as were male-headed compared to female headed.	Yes	Medium

2.2 Selected Interventions

The interventions considered for further research are noted below:

2.2.1 Crop Diversification

Description: Crop diversification has been identified amongst the most viable options for reducing the risks associated with food and nutritional insecurity and low incomes, proving to be a viable strategy to increase farm-level crop productivity (Jones et al 2014). It is also one way of developing climate and market resilient smallholder systems, especially as 75% of the rural population depend largely on agriculture for their livelihoods (Koppmair, et al 2017). The intervention targets 4.2 million farmers cultivating a total of 2.1 million hectares, providing inputs on extension services and breeder seeds. The adoption rate of bio-fortified beans would be scaled up from 5% to 60% over the course of ten years, while the intensity of extension services is pegged at 100% for the first three years. The desired bio-fortified beans adoption rate will be achieved through increased production of breeder and commercial seed.

Rationale: All the benefits of crop diversification contribute to improved yields for the smallholder farmers which translate to more and a variety of food for consumption and marketable surpluses from production. (The rationale for choosing this intervention is discussed in greater detail in Section 3).

2.2.2 Grain Storage through PICS Bags

Description: A new approach to post-harvest protection is hermetic storage, by which oxygen barriers limit the growth of insects or microbes inside the storage unit. The principal type of hermetic storage now being distributed to farmers in Africa through development assistance programs is the Purdue Improved Crops Storage (PICS) bags, developed at Purdue University in the 1990s and widely distributed across various African countries (Masters and Alvarez, 2018). The intervention seeks to increase usage of PICS bags in Malawi from 5% in the initial year (3 million PICS bags) to 60% (63 million PICS bags) over a ten-year period using intensified promotion plus an 80% subsidy. Avoided grain loss would increase substantially from 26 ,000 tonnes with 5% of farmers using the technology to 320 ,000 tonnes at 60% usage, thereby impacting food security levels significantly.

Rationale: Tefera (2012) suggests that 14-36% of household stored maize is lost after harvest, from the combination of insect or rodent damage and microbial contamination. Damage levels vary widely with humidity and temperature as well as grain handling practices that either protect or expose the stock to pests and mould (Kaaya et al., 2006; De Groote, 2016). A number of studies address the efficacy of hermetic storage bags, such as de Groote (2014) and Tefera (2012). The bags are reusable and do not require chemical treatments.

3. Crop Diversification Strategies

Before proceeding with the cost-benefit analysis, this section describes the rationale behind the choice of crop diversification strategies. Crop diversification in this technical report is defined as cultivating more than one crop belonging to the same or different species in a given area. It involves moving away from traditional cropping systems to high value, nutrition sensitive cropping systems.

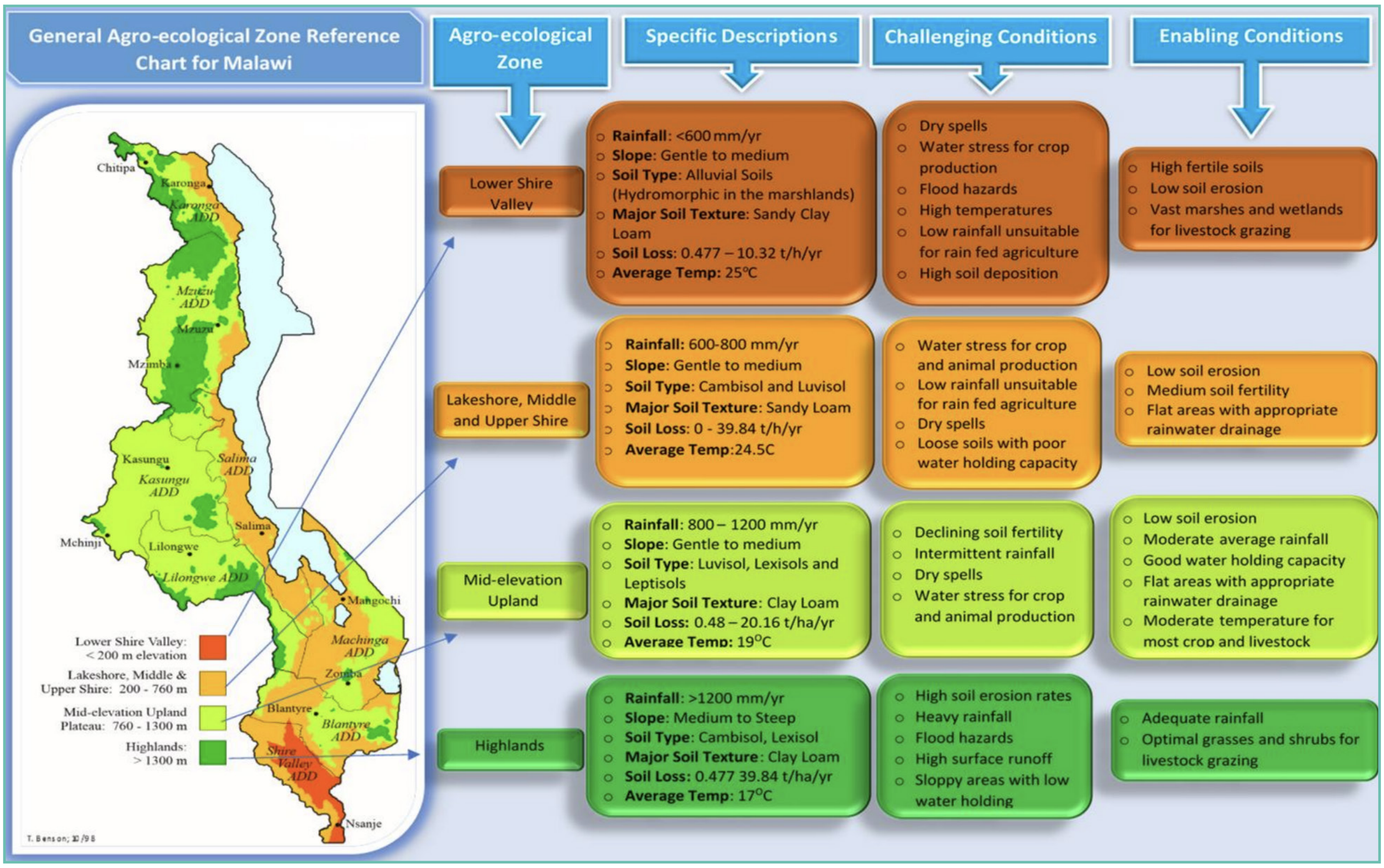
The proposed crop diversification options build on two specific objectives of diversification:

- diversification within traditional agricultural enterprises to take advantage of a wider range of output options for climate resilience; market risk reduction and improving food nutritional security
- diversification into non-traditional farm crops for improved farm income and nutritional security

Potential Crop diversification options by agro-ecological zones in Malawi

In Malawi, biophysical, topography, climatic and economic (such as input and output market access) factors are critical when selecting crop diversification options. The four major agro-ecological zones - Lower Shire V alley, Lakeshore, Middle and the Upper Shire, Mid Elevation Upland plateau and Highlands, recognised country wide by the Ministry of Agriculture (MoA), formed the bases for crop diversification options. (Figure 1).

Figure 1: Agro-ecological zones of Malawi (Benson 2020a and 2020b)



Four selection criteria were employed in the crop diversification option selection for each agro-ecological region. The first selection criteria is being grown by smallholder farmers at scale for food nutritional security and income. Production potential based on crop estimates and gross margins from the Ministry of Agriculture (MoAIWD, 2013-2017) as well as the water limited potential from agricultural researchers is the second criteria applied in the selection of crop diversification options. These were used to determine whether there is still room for improving productivity and production within the agro-ecological zone. The Integrated household survey (IHS4) also provided information on current land allocations and households producing the crop to estimate the potential adoption. Output market access, the third criteria, assessed whether domestic, international markets or both existed for the specific crop. The fourth criteria is based on Government priority. It looked at whether the crop is being promoted as a food and nutritional security and/or cash crop by the government and is mentioned as a priority crop in policy documents such as the Malawi Growth and Development Strategy (MGDS) (2017–2022), National Agricultural Investment Plan (2017/18–2022/23), National Multi-Sector Nutrition Policy (NMNP) (2018–2022.

Table 2: Potential Crop diversification options by Agro-ecological zones in Malawi

Ago-ecological Zones	Traditional farming practices				Proposed cropping systems			
	Major crops	Cropping system	% households practicing	Current Yield (Kg/ha	Major crops	Cropping System	Estimated Yield (Kg/Ha)	Potential adoption rate
Lower Shire valley	Sorghum & Pearl Millet	Ridge & farrow tillage system, Maize/sorghum pigeon pea intercropping	57%	500	Bio-fortified sorghum/ Pearl millet (summer)	Conservation agriculture, stress tolerant crop varieties, cereal –legume intercropping/rotation	1500	60%
	Maize		100%	1154	Maize (winter & summer)		1800	
	Groundnuts		13.2	350	Groundnuts (summer)		2000	
	Pigeon pea		11.9	550	Pigeon Pea)		1500	
	Rice		8.2%	800	Summer rice	Relay cropping	1900	
	Sweet potatoes		6%	4530	Sweet potatoes		8000	
	Cotton		22.1%	450	Summer cotton	Rotation	1000	
Lakeshore, Middle and Upper shire	Maize		100%	1982	Maize (drought tolerant, pro-Vitamin A)	Conservation agriculture Maize/cassava pigeon pea/ bean intercrop rotated with groundnuts/ cow pea pigeon pea intercropping or cotton. Rice – bean/ sweet potatoes relay -cropping	2500	60%
	Pigeon pea		85%	350	Pigeon Pea		1500	
	Ground nuts		25%	750	groundnuts		2300	
	Sweet potatoes		7.4%	8640	Bio fortified sweet potatoes		25000	
	Rice		33%	1350	Rice (improved)		1900	
	Beans		23%	250	Bio-fortified beans		800	
Mid-elevation upland	Maize	Ridge & farrow tillage system Maize common bean intercropping, Mono-cropping of groundnuts, sweet potatoes, Irish potatoes,	100%	2184	Maize (bio –fortified Protein & Vitamin)	Intensification of maize-legume systems Maize bean intercropping rotated with soya-bean-groundnuts intercropping	3500	60%
	Common beans		33%	900	Bio- fortified (Iron & Zinc) beans		2000	
	Soya beans		33%	1600	Soy beans		2000	
	Irish/sweet potatoes		13%; 21%	12450	Bio-fortified sweet / Irish potatoes		25000	
	groundnuts		21%	1250	groundnuts		2500	
	tobacco		8%	1200				

Highlands	Maize	Ridge & farrow tillage system Maize common bean intercropping, Mono-cropping of groundnuts, sweet potatoes, Irish potatoes	100%	2800	Maize (bio –fortified Protein & Vitamin)	Intensification of maize-legume systems Maize bean intercropping rotated with soya-bean-cowpea –ground nuts intercropping	4000	60%
	Common beans		29%	1200	Common beans		2000	
	Soya beans		25%	1600	Soya beans		2500	
	Irish/sweet potatoes		21% ; 14%	15300	Bio-fortified sweet potatoes		25000	
	Groundnuts		23%	750	Groundnuts		2500	
	Cowpeas		28%	550	Cowpea		1000	
	Rice		12%	1350	Rice		1900	

Table 2 shows the potential Crop diversification options for the four agro-ecological zones of Malawi. Detailed crop suitability maps and Agro-Ecological Zone Reference designed by IFPRI and IFAD respectively guided the explicit selection of crop diversification crops and agronomic practices for each agro-ecological region (Bension et a 2016 and IFAD, 2019) The proposed crop diversification options for each agro-ecological region will be complimented by: (i) best agronomic practices, (ii) use of commercial inputs, and (iii) post-harvest management to achieve the set outputs and outcomes. The major changes in all the agro-ecological regions are in cereal – legume land allocation both at farm and national level. Based on the MoAIW (2013-2017) crop forecast data and IHS 4 on average 65% of the land is allocated to Maize, 18% groundnuts,16% common beans 13% pigeon pea, cassava 11%, 9% soya bean and 3% rice.

The proposed crop diversification options included reducing Maize land allocation to 50% at farm scale, increasing land allocation under legume to at least 25% of the cultivated land. According to Ngwira et al 2012 and Thierfelder et al 2016 and van Vugt et al 2018 use of improved legume varieties, increased legume plant population and application of fertiliser and inoculants increased productivity per unit area. Smith et al 2016, Chikowo and Snapp, 2016 recommended intercropping of two grain legumes with different growth habits to increase land productivity for resource constrained smallholder farmers of Malawi. Based on these research findings two cropping patterns were proposed:

1. Increased plant populations to full population for legume intercrops and
2. Intercropping of two grain legumes.

To increase legume populations from the current traditional cropping patterns double plant rows per ridge will be adopted, inter row spacing for legume for legume will be promoted as part of good agronomic management.

Based on the current traditional cropping and the four set criteria above, **Lower Shire** focused on climate resilience crop diversification options. This will include conservation agriculture, stress tolerant maize, sorghum, groundnuts, cotton varieties. Conservation agriculture, stress tolerant crop varieties, m aize/ sorghum pigeon pea intercropping in rotation with ground nuts or cotton in summer identified as the best bet crop diversification option for the upland fields (Table 2). Whilst rice relay cropped with bio-fortified sweet potatoes will be cultivated in the S hire R iver flood plains (FEWS NET, 2015) This region is very prone to dry spells and severe droughts (WFP, 2016), thus require tillage and cropping systems that have higher water use efficiency such as conservation agriculture.

A number of on-farm trials have reported improved maize and legume yields of 20 to 125% increase in conservation agriculture plots relative to the traditional cropping systems in similar environments (Ngwira et al 2013; Thierfelder et al 2016). Maize pigeon pea/ cowpea intercropping was also identified as the best crop diversification option for winter flood plan cultivation. Since the zone also has the highest rate of malnutrition and poverty incidence (UNICEF, 2018; WFP, 2016), the selected crop diversification intervention also concentrated on developing nutrition sensitive agricultural value chains aimed at reducing poverty and enhancing participation of smallholder farmers. These include the iron and zinc bio-fortified sorghum, improved rice varieties and pro-vitamin A maize.

The Lakeshore, Middle and the Upper Shire crop diversification interventions also focused on climate resilience cropping system. Promotion of drought tolerant varieties/crops or adaptive cropping patterns that minimizes the impacts of the frequent in season dry spells were considered. According (FEWS NET, 2015) droughts occur more frequently in this zone once every 3 years, therefore soil and water conservation strategies are very important. This agro-ecological zone also has the highest population densities and poverty incidence. According to Ngwira et al. 2013 and Thierfelder et al 2016 sustainable intensification cropping practices such as conservation agriculture tillage practices with maize pigeon pea intercropping rotating with groundnuts pigeon pea/ soya bean intercrop are the best bet options to address the key challenges highlighted in Table 2. Maize yield increase of 20% to 125% in conservation agriculture systems relative to traditional cropping systems were observed, based on farm trials in some of the districts (Ngwira et al 2013; Thierfelder et al 2016). Groundnut pigeon pea intercrop were recommended for middle and upper shire zone as they are the main food legumes. For the Lakeshore, groundnuts and beans were the main grain legumes recommended based on the selection criteria.

Mid-elevation upland represents the high potential zone for Malawi, the key challenge to crop production is declining soil fertility, high population densities and output price volatility (FEW NET 2015; IFAD, 2019). Designing and promotion of market resilient adaptive sustainable crop intensification practices are crucial for this zone. Chikowo and Snap (2016) emphasised the importance of high value nutrition sensitive agricultural value chains such as improved maize varieties intercropped with bio fortified beans rotating with groundnuts soybean intercrop. Intensification of maize-legume systems which included maize beans intercropping rotated with soya-bean-groundnuts intercropping augmented with Irish / sweet potatoes in rotation with either soya-bean-groundnuts intercropping, or maize beans intercropping were recommended for this agro-ecological region based on literature and expert interview (Benson 2020a and 2020b).

Land fragmentation and soil erosion are the main challenges taken into consideration in designing crop diversification options in the Highlands agro-ecological zones. Promotion of sustainable crop intensification such as improved maize-legume and root crop intercropping are considered very important in this zone. Table 2 shows the main crop diversification options proposed for this agro-ecological zone. Based on the study findings from Ngwira et al. (2013) and Thierfelder et al (2016) Intensification of maize-legume systems in particular Maize bean intercropping rotated with soya-bean-cowpea –ground nuts intercropping was ranked as the most economically feasible crop diversification strategy for this zone.

4. Cost-Benefit Analysis

The three discount rates: 5%, 8%, and 14% applied in all analyses in the Malawi Priorities series were adopted in this technical report. The population data weights used to estimate the agro-ecological zone contribution were also calculated using data obtained from the 2018 Census (NSO, 2019).[4] The number of smallholder farmers used in this report were obtained from the World Bank Malawi Agricultural Commercialization Project (World Bank, 2017). The Ministry of Agriculture and food security 2019/2020 minimum farm gate price document was the main source of commodity price. This data was complemented by the IFPRI Malawi monthly maize market report.[5] A review of different agricultural technology adoption studies in Malawi revealed adoption rates ranging from 5% to 80% (Kazembe, 2021; Ward et al., 2018) (Holden et al. 2018; Mutenje et a 2016). A logistic model based on the IHS4 data showed the highest adoption ceiling of 55.7% and 75.8% for soil water conservation technology and maize varieties respectively. Collectively this evidence and Feder et al. (1985)'s adoption pathway prediction model was the basis for the 60% adoption level assumed in this technical report.

4.1 Crop Diversification

Costs

There are three costs associated with the intervention 1) marginal cultivation costs associated with the crop diversification strategies compared to traditional methods 2) extension costs to promote crop diversification 3) breeder seed costs for bio-fortified bean. The third cost is required due to a current lack of capacity to develop bio-fortified bean (Dr. Roland Chirwa, personal communication).

Cultivation costs are built bottom up for both traditional and crop diversification strategies by consulting various sources including government data, literature and expert estimation. The calculations for the costs are based on changes in land, labour allocations and quantity of commercial inputs (seed, fertilizer). A summary of traditional and intervention costs per hectare are presented in Table 3 below. Detail of the parameters used are presented in the appendix. The difference in traditional and intervention cropping strategies is considered the marginal cost of the intervention. The magnitude of this cost depends on the uptake of the cropping strategies per year and is therefore a variable cost.

Table 3: Cultivation Cost and Revenue per hectare

	Lower Shire	Lakeshore	Highlands	Mid-elevation	National
Cost per hectare (MWK)					
Intervention	546,053	491,221	404,000	686,915	548,285
Traditional	254,015	282,718	241,286	414,081	320,980
Incremental	**292,038**	**208,503**	**162,714**	**272,834**	**234,022**
Revenue per hectare (MWK)					
Intervention	1,351,405	1,963,758	2,321,172	4,414,363	2,935,711
Traditional	320,697	904,506	1,047,942	1,281,125	1,044,385
Incremental	**1,030,708**	**1,059,252**	**1,273,230**	**3,133,238**	**1,891,326**

Agricultural extension costs are sourced from (Van Campenhout, et al 2017; Masters & Guevara Alvarez, 2018; Ministry of foreign Affairs Denmark, 2019). Van Campenhout et al (2017), examined the effectiveness of using information and communication technology-based extension services providing the basis for calculating the cost of such extension approach. Masters & Guevara Alvarez, (2018) evaluated the wiliness of smallholder farmers to purchase PICS bags where different extension approaches have been used including farmer field schools.

Ministry of foreign Affairs Denmark, (2019) examined the cost-effectiveness of farmer field school per farmer and at community level in Bangladesh. The cost per farmer field school participant was $32 according to this study. Building on these studies we calculated the cost of extension per farmer when 3 complementary approaches were implemented. The cost incorporates a breadth of extension approaches such as the training-and-visit approach, the farmer field school and information and communication technology-based extension services. It is assumed that each farmer targeted costs USD 67 per year (MWK, 49,915), which covers staff costs, fuel, training, inputs for field schools and infrastructure to communicate via SMS and integrated voice recording. All 4,200,000 farmers are targeted for crop diversification, regardless of uptake and this is therefore a fixed cost of the intervention. Over time we assume the intensity of extension services for crop diversification reduces as the practices become saturated. For the first three years it is set at 100%

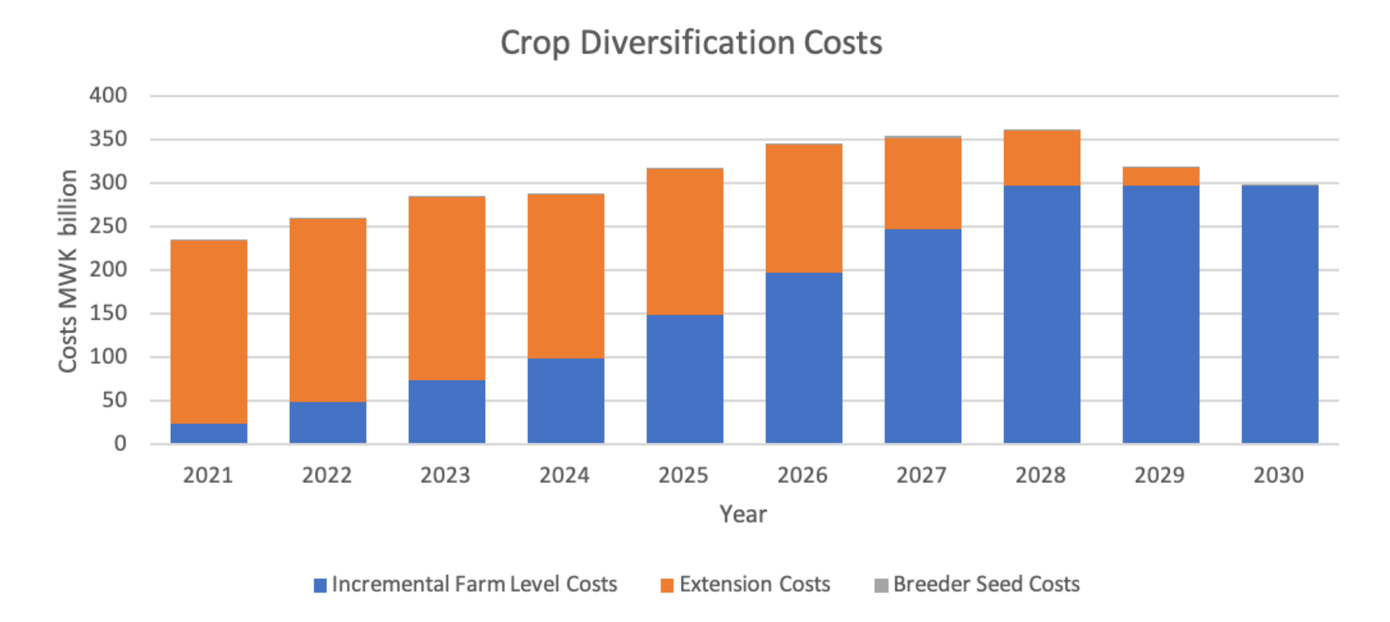
[4] NSO, (2019). 2018 Malawi Population and Housing Census, Main Report. National Statistical Office, Government of Malawi.
[5] https://massp.ifpri.info/resources/maize-market-report/

(i.e all farmers), then reduces by 10 percentage points per year for the next three years, then 20 percentage points per year for the three years after that before falling to zero relative to baseline by 2030.

The last cost component is that required for bean bio-fortified commercial seed production. One hundred kilograms of commercial seed is required per hectare given that all the 3 bio-fortified bean varieties, released in Malawi, are large seeded (Dr. Roland Chirwa personal communication). A multiplication ratio of 1:10 is adopted to calculate the amount of basic seed that would be required to produce the commercial seed for the land area allocated to bio fortified beans. We assume a unit cost of USD 2.50 (MWK 1490) per breeder seed.

The profile of costs is depicted below and suggest total societal costs in the range of 200 to 350 MWK billion every year, with 30% of costs for extension, and 69% for incremental farm costs. Breeder seed costs are negligible.

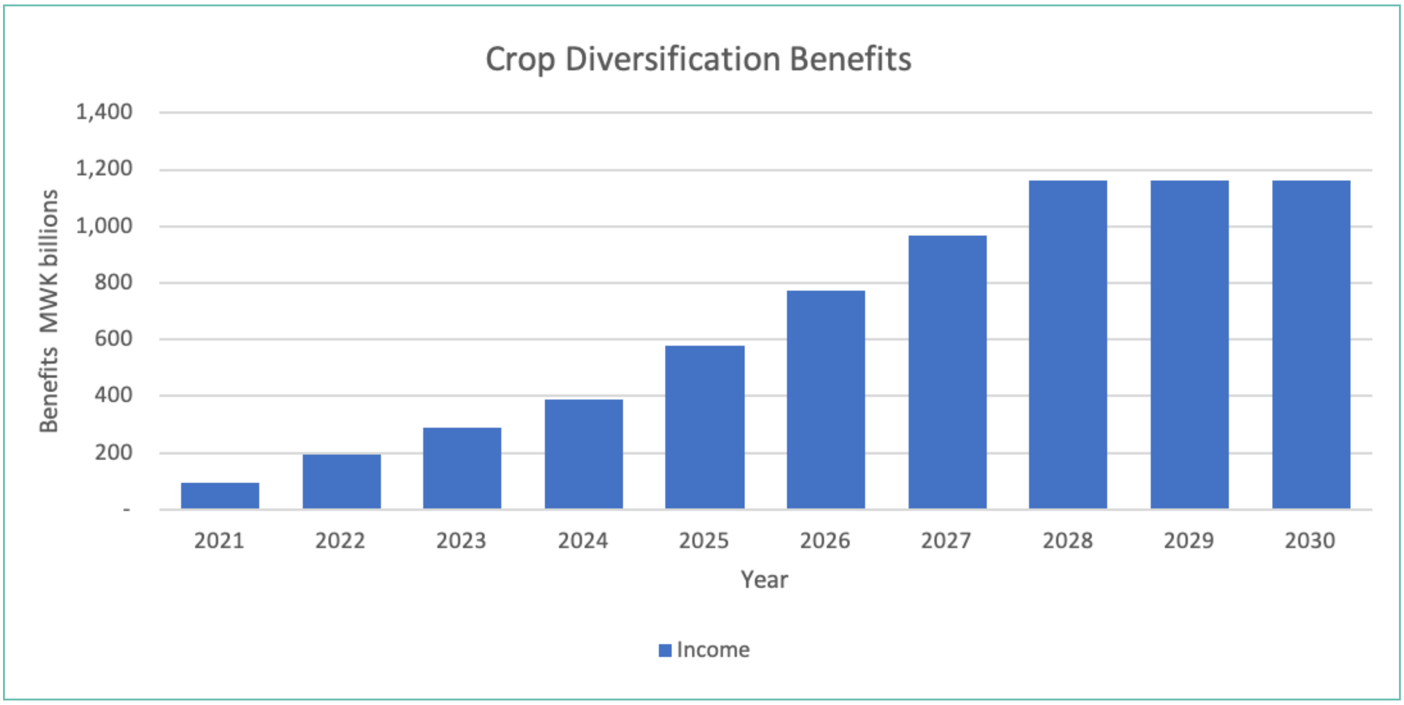
Figure 2: Crop Diversification Costs



Benefits

Changing cropping patterns have a raft of effects on soil, yield and crop damage. For example, increase in soil fertility and nutrient content due to the use of different crop species such as nitrogen fix legume will lead to increased productivity (Kafesu et al. 2018). Crop diversity can also lead to biological control of pest and diseases (Han-ming et al. 2019). These are all accounted for as change in total production. The total change in value of crop produce at the average market price is used to compute the net benefit resulting from crop modification. The analysis suggests that income benefits increase over time rising to MWK 1,160 billion at steady state. By 2030, net farm income is equal to 7% of counterfactual GDP suggesting that these strategies could have a significant impact on wealth creation in the country, if adoption rates reach the levels assumed in this analysis.

Figure 3: Crop Diversification Benefits



Results

The costs, benefits, benefit-cost ratios of the intervention are presented in Table 4 below, with results presented at the national and agro-ecological region level.

Table 4: Cost Benefit Analysis of Crop Diversification

	Benefits (MWK, billions)	Cost (MWK, billions)	BCR
NATIONAL	3,963	1,983	2.0
Lower Shire	275	139	2.0
Lake Shore	1,015	622	1.6
Highlands	611	397	1.5
Mid-elevation	2,063	826	2.5

Notes: Benefits and costs represent net present values from 2021-2030 using an 8% discount rate

Over a 10-year period, the net present value of benefits is equal to MWK 3,963 billion, with a cost of MWK 1,983 billion for a BCR of 2.0. Across the zones, the mid-elevation region has the highest BCR at 2.5, while the Highlands has the lowest at 1.5. Examining the data more closely indicates that the reason Mid-Elevation has a higher BCR is due to the potential for substantial yield improvements on potato, where the region has a comparative advantage. This provides an indication of where the government may consider prioritizing first in a nation-wide scale up.

Sensitivity Analysis

We alter several of the main parameters to assess sensitivity of results. The results are presented below. The range of BCRs is 1.6 to 2.3. The assumed level of uptake has the greatest bearing on results, with only 30% uptake yielding a BCR of 1.6, while 90% uptake generates a BCR of 2.3.

Table 5: Sensitivity Analysis

	BCR
Base	2.0
Increase extension cost by 25%	1.8
Decrease extension cost by 25%	2.3
Uptake reaches 30%	1.6
Uptake reaches 90%	2.3
Marginal cultivation costs increase by 25%	1.9
Marginal cultivation costs decrease by 25%	2.1

4.2 PICS Bags

This analysis is conducted assuming a counterfactual where currently 50% of farmers use polypropylene (PP) bags, and 50% use polypropylene bags with actellic super (PP + AS), a type of insecticide partially subsidized by the Malawian government. As with the crop diversification intervention, the assumed uptake of PICS bags is 60% in steady state with a gradual increase from 5% over 7 years. This is based on promotion plus a level of subsidization equivalent to 80% of the cost of the PICS bag. This level is based on a study by Masters and Alvarez (2018), which found that less than 1% of the farmers were willing purchase a PICS bag without subsidies, with a mean willingness to pay of MWK 312 (USD 0.42), just more than a fifth of market price.

The intervention assumes 4,200,000 farmer households each store 0.75 tonnes annually for personal consumption. This is based on Ecker and Qaim's (2011) estimate of 382g per capita consumption of maize per day, with a modest increase to account for increased production and wealth since 2004-2005, the source of data for their estimate. Each bag is assumed to cater for 50kg of grain. The main parameters for this analysis are shown below.

Table 6: Main parameters for analysis

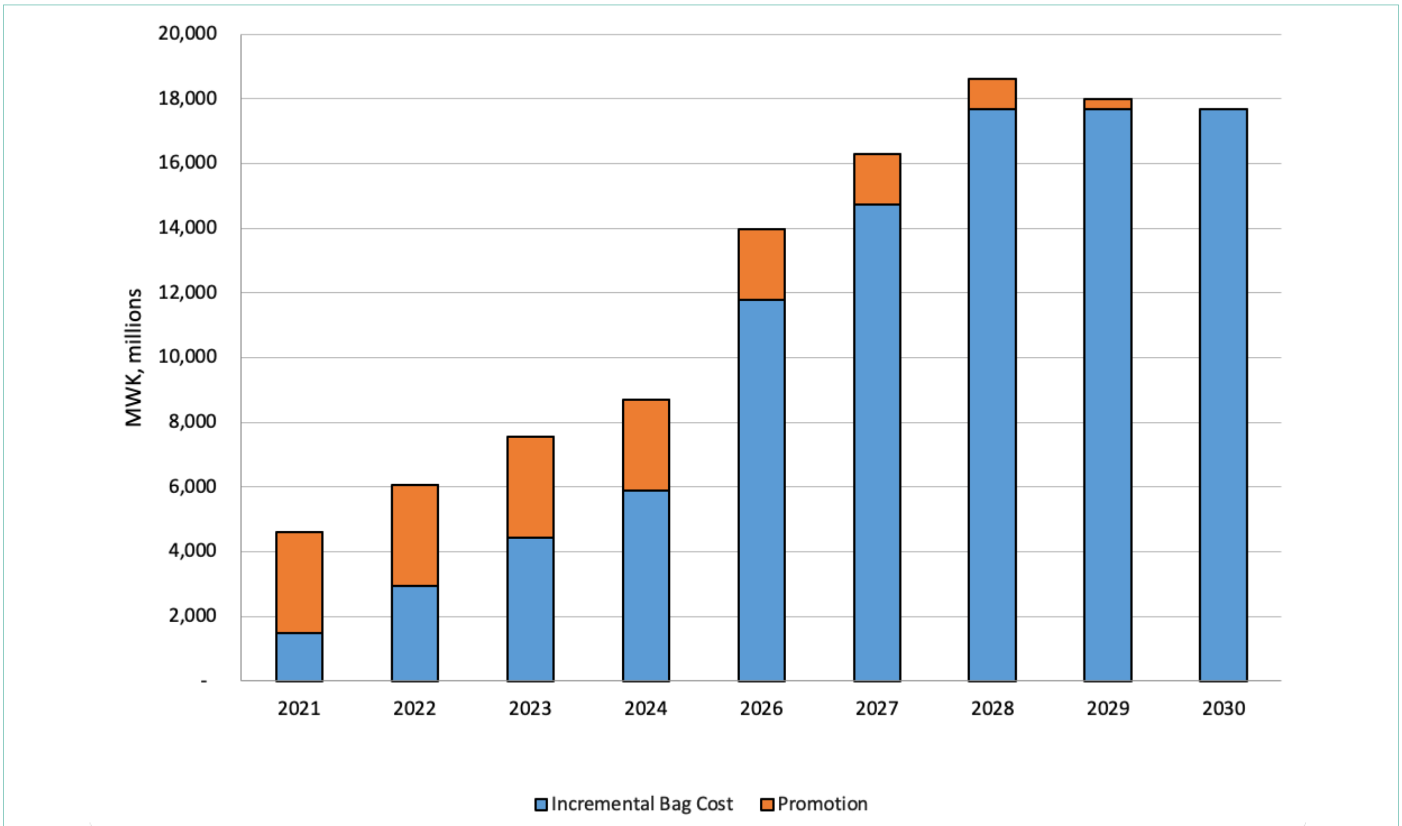
	Polypropylene bag	Polypropylene plus actellic super dust	PICS bag
Storage requirement per year (tonnes)	3,150,000	3,150,000	3,150,000
50kg bags required per year (millions)	63	63	63
Cost per bag per year (MWK)	246	308	745
% paid by government	0%	20%	80%
Losses associated with storage method	28%	24%	9%
Proportion of farmers using in baseline	50%	50%	0%
Proportion of farmers using in intervention scenario by 2030	20%	20%	60%

Costs

There are two types of costs associated with the intervention: the marginal change in the price of storage method, and the cost of promotion. The cost of promotion is set at MWK 745 per farmer based on authors' assumptions.

The cost of a polypropylene bag is assumed to be MWK 246 per year, while for PP+AS it is MWK 308 per year. Both of these figures were determined via expert interview and examination of current market prices. PICS bags are currently manufactured and distributed in Malawi, with retail prices of MWK 1490/bag. PICS bags are assumed to be used for two years, resulting in a MWK 745 annualized cost (Masters and Alvarez, 2018). The cost profile of the intervention for 4.2 million farmers is noted below. Most of the cost of the intervention is the marginal cost of the PICS bags. Total costs start at MWK 4,600 million and rise to approximately MWK 18,000 million in steady state when 60% of farmers are assumed to be using PICS bags. Essentially all of the marginal cost would have to be borne by the government if willingness-to-pay noted by Master and Alvarez, 2018 for PICS bags does not change. However, over time it may be possible to reduce the subsidy as farmers learn that PICS bags provide value in terms of avoid loss.

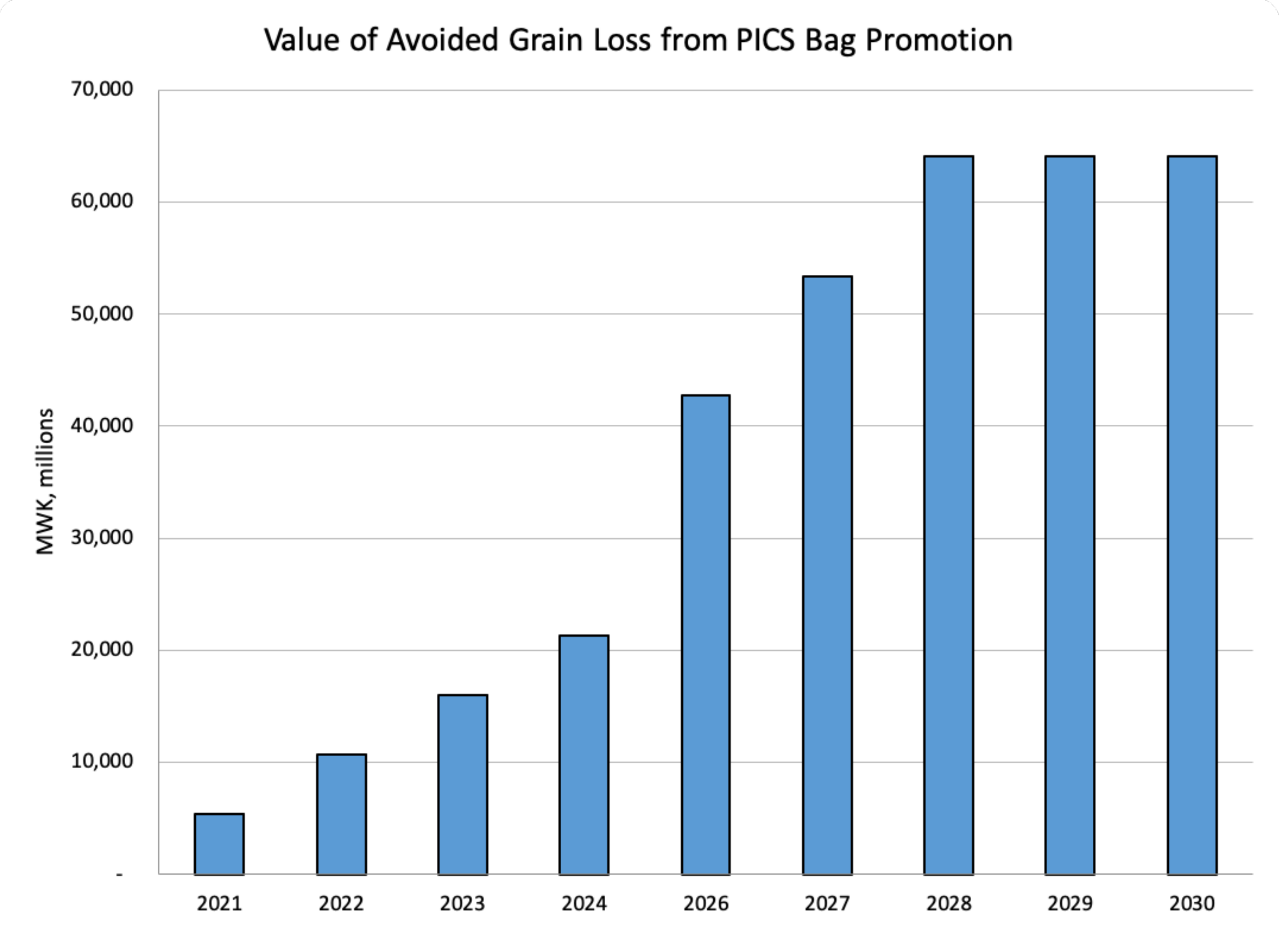
Figure 4: Cost of PICS Bag Promotion



Benefits

Benefits of post-harvest storage management is simply the incremental crop loss avoided at a market price of MWK 201 (USD 0.27) per kg. In steady state, the intervention would avoid almost 320,000 tonnes of crop loss with a market value of MWK 64 billion. Avoided loss figures for each of the three technologies are drawn from Singano, Munvi and Stathers (2019).

Figure 5: Benefits of PICS Bag Promotion



Results

The net present cost of the intervention is equal to MWK 81billion over 10 years to 2030, while the net present benefit is equal to MWK 236 at an 8% discount rate. The BCR is 2.9.

Sensitivity Analysis

We vary certain parameters to assess sensitivity of assumptions to results. The analysis indicates that the BCR is most sensitive to the cost of the PICS bags and the extent of post-harvest loss avoided with a BCR range from 1.5 to 8.1. In contrast, the uptake rate and promotion costs have minimal impact on the BCR.

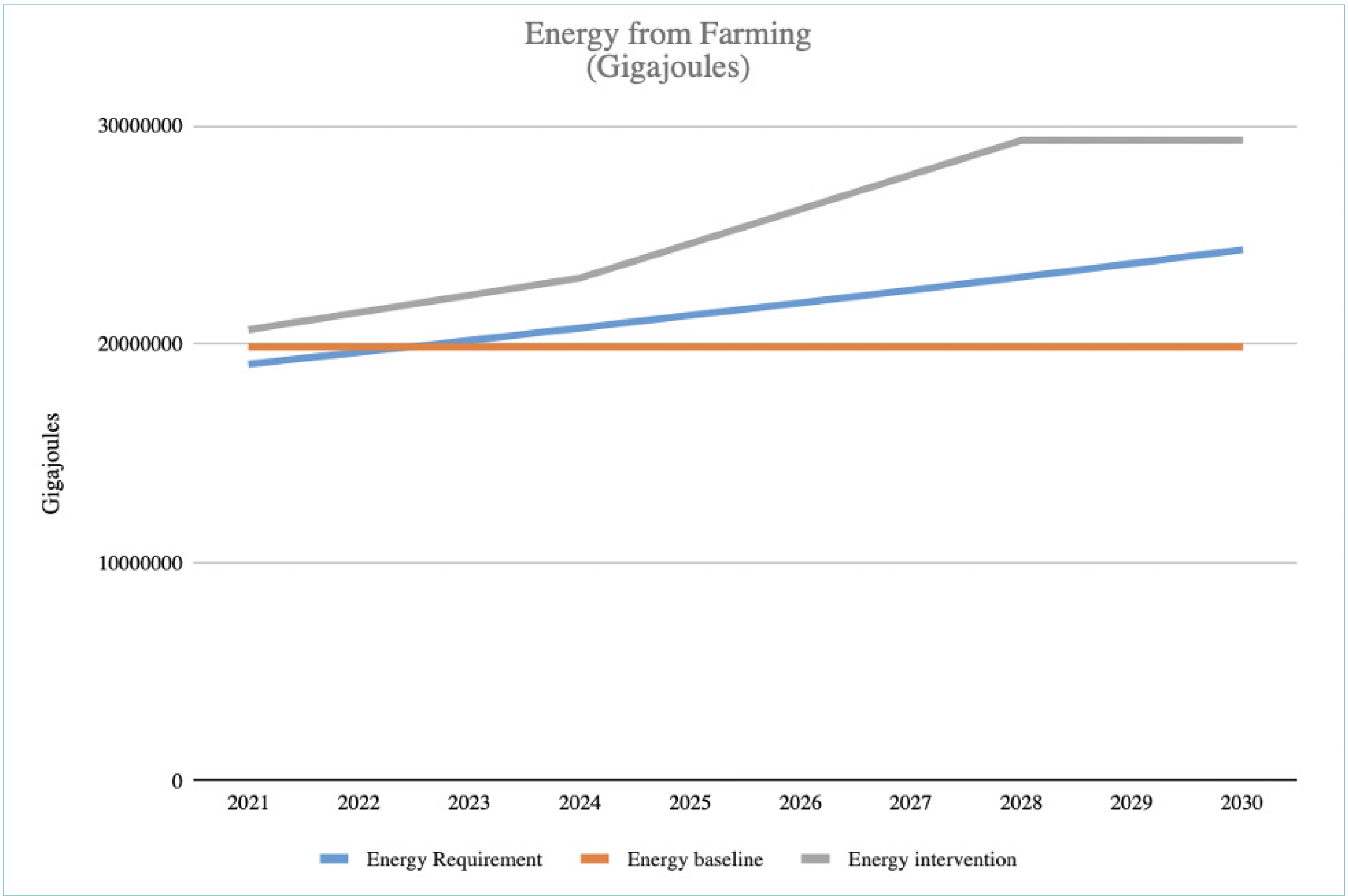
Table 7: Cost Benefit Analysis of PICS Bags and Promotion

	BCR
Base	2.9
Increase promotion cost by 100%	2.4
Uptake reaches 30%	2.7
Uptake reaches 90%	3.1
Increase PICS bag cost by 50%	1.8
Decrease PICS bag cost by 50%	8.1
Post-harvest loss avoided increases by 50%	4.4
Post-harvest loss avoided decreases by 50%	1.5

5. Impact on Available calories, protein, vitamins and minerals

Crop diversifying smallholder households will be able to produce and consume a diversified food basket. For this technical paper, the total annual energy and protein requirements contribution of the crop diversification intervention were analysed for the macro-nutrients, while total annual zinc requirements were measured for the micro-nutrients. We calculated calories in giga joules, protein, iron and zinc yield in kilograms from the total production data. Then energy content for maize and the legumes raw grains, root tubes and vegetables were obtained from Calorie calculator data base (https://www.caloriescalc.com/category/cereal-grains-and-pasta/) and the GeNUS database (http://projects.iq.harvard.edu/pha/genus) where kcal per 100g seed values of crops are reported. The same database also provided the protein, iron and zinc content in grams, milligrams and micrograms per 100g seed values of all the crops included in the analysis.

Figure 6: Energy Contribution from Crop Diversification



Further, we assessed how different cropping systems contributed to the human daily caloric requirements based on the projected basic dietary requirement of 2540 kcal/person/day by 2030 for sub–Saharan Africa as shown in the Green facts database (https://www.greenfacts.org/en/diet-nutrition/figtableboxes/table-1.htm) D'Odorico et al., 2014). Based on the projected population growth and basic dietary requirements the total annual macronutrient and micronutrient requirements were calculated. Surplus/ deficit caloric yield per year for the total population was calculated as the difference between the total crop diversification system macro/micronutrient yields and the caloric yield required for the whole population per year. We assumed no other trade-offs (such as selling for monetary income) of the harvested grain in our calculations although we recognize that there are competing needs and demands for this surplus amount. In this study we only consider the surplus caloric yield that could potentially be consumed.

Table 8: Nutritional impact of Crop diversification

	Estimated population level requirement in 2030	Traditional system in 2030	Crop diversification in 2030 at 60% uptake
Total energy per year (giga joules)	24,290,020	19,870,382	29,326,668
Total protein (metric tonnes per annum)	641,390	528,964	954,586
Total zinc (kg per annum)	133,882	109,439	166,219

The nutritional outcome of the crop diversification intervention is also shown in Table 8. The results revealed that with the current traditional practice, the total production is not able to meet the country's annual daily calorie and protein energy requirement. There is a deficit of 4,420,000 giga joules of daily energy requirement and 112,000 metric tons of protein energy. This suggests that and 18% deficiency in calories and protein by 2030 at the national level. The results also revealed that it requires about 30% adoption of crop diversification intervention to be able to meet the annual calorie and protein energy requirement for the whole population from crop production. If intervention succeeds at the rate we assume then Malawi will have surplus calories in 2030 which can be exported or used for agro-processing (see Figure 6).

To assess a plausible order of magnitude estimate for the flow-on health benefits of crop diversification, we note that Malawi experiences 1,494 disability-adjusted life years (DALYs) per 100,000 per year from nutritional deficiencies (including protein deficiency), and 2,449 DALYs per 100,000 per year from child wasting. If the status quo remains, in 2030 Malawi would experience roughly 1,000,000 DALYs from lack of sufficient nutrition and calories (IHME, 2019). At estimated 2030 value of statistical life year figures for Malawi, this cost is around MWK 300 billion annually. A precise assessment of the resulting distribution of extra calories, protein and nutrients is beyond the scope of this study. Instead, we present a range of estimated benefits based on the level to which crop diversification could reduce health impacts from under nutrition. At a maximum, if DALYS from nutrition deficiencies and child wasting were eliminated, the extra health benefits would equal around a quarter of the marginal increase in farm revenue. This is of course, a sizeable overestimate because it is unlikely that health impacts from these two illnesses would be eliminated. Additionally, it is likely that some of these health benefits are reflected in the market price of the commodities.

Nevertheless, this scenario analysis shows that the potential additional benefits from health impacts would only change the BCRs at the first decimal place, if at all. As a comparator, if Malawi were able to reach the same level of food security as Ghana (approximately 90%) from crop diversification, then DALYS from these two causes of illness would reduce by roughly 35%. These additional health impacts would be worth around 10% of extra farm revenue in 2030 or MWK 105 billion.

Table 9: Scenario analysis of additional health benefits from avoided child wasting and nutritional deficiencies resulting from crop diversification

Assumed reduction in DALYS from child wasting and nutritional deficiencies	Value of health benefits (MWK millions)	as % of extra farm revenue in 2030
100%	300,537	26%
75%	225,403	19%
50%	150,268	13%
25%	75,134	6%
10%	30,054	3%
5%	15,027	1%

6. Conclusion

The main objective of this technical report is to identify and prioritize agricultural interventions for Malawi that could most effectively deliver sustained food and nutrition security, as well as greater dietary diversity within sustainable farming models. Based on the literature review, expert interviews and cost benefit analysis, crop diversification and PICs bag were identified as the two main interventions that could potentially improve food and nutritional security at farm level. Crop diversification has been widely recognised as the most ecologically, feasible and cost-effective pathway to achieve household food and nutritional security in sub–Saharan Africa. This is especially important for Malawi, where smallholder farmers are often subsistence-oriented and are the most undernourished portion of the population (Pinstrup-Andersen, 2007 and Frelat, et al 2016). Crop diversification intensities and scales varies across agro-ecological zones.

Two approaches were used to identify the most feasible crop diversification options for the four agro-ecological zones of Malawi. The first approach involved analysing the current traditional cropping system to determine the potential for improving crop productivity and the enabling conditions. This included reviewing literature (both grey and published) to identify opportunities to diversify from current traditional cropping systems to high value, nutrition sensitive cropping systems. Information on current traditional cropping systems, productivity and production levels were also supplemented by analysis of IHS 3 and 4 data as well as expert interviews. Using four selection criteria, crop grown by smallholder farmers at scale, market existence for surplus production, production potential and government priority crops, crop diversification options for each agro-ecological region were identified. Cost benefit analysis of identified crop diversification options to determine their economic viability constituted the second approach.

Using these approaches, conservation agriculture, stress tolerant maize/ sorghum intercropped with pigeon pea/ cow pea rotated with groundnuts in winter and rice in summer was identified the most ideal crop diversification option for the Lower Shire agro-ecological zone. Conservation agriculture tillage practices with maize pigeon pea interloping rotating with groundnuts pigeon pea intercropping was prioritised as the best bet crop diversification option for the Lakeshore Middle and the Upper Shire. This is augmented with rice-beans sequential cropping in wetlands. In the Mid-elevation upland sustainable crop intensification practices of improved maize varieties intercropped with bio fortified beans rotating with groundnuts soybean intercropping is ranked as the most viable crop diversification option. Sustainable intensification of maize-bio fortified beans intercropping rotating with soybean-cowpea intercropping constituted the most feasible crop diversification for the Highlands. This is augmented with rice-sweet potatoes sequential cropping in wetlands.

If this intervention could be rolled out across the country with 60% of farmers adopting, it would deliver benefits of MWK 1,160 billion at steady state. While the intervention is very costly, requiring investment between MWK 225 billion to 350 billion per year, net farm benefits are equivalent to 7% of counterfactual GDP in 2030, a substantial improvement in economic growth. The BCR of the intervention is estimated at 2.0. Regional analysis indicates that the BCR is highest in the Highlands, with most of this driven by returns from potato.

In addition to crop diversification, PICS bags were also identified as an important intervention strategy to improve food and nutritional security. The cost-benefit analysis revealed that promoting and subsidizing PICS bags would avoid 320,000 tonnes of maize loss in steady state. The net benefit is equivalent to 0.4% of counterfactual GDP in 2030. The intervention would require investments of up to MWK 18,000 million in steady state, and has a BCR of 2.9.

Both of these interventions could be considered by the government for investment. While the impacts of both interventions are large, the BCRs are relatively modest. Given current levels of input subsidization and estimated willingness-to-pay for PICS bags, the resource requirement on government associated with both of these interventions would be substantial. However, it is possible that once farmers realize the benefits of these interventions they would be willing to gradually contribute more of the costs. A precise estimation of this dynamic is out-of-scope for the current study. We only note that the social benefits of both interventions exceed the costs which should theoretically allow for some cost share in the future.

Based on the technical report findings, we conclude that crop diversification and PICS bags are a viable option to improve household food and nutritional security. Such an approach may be preferred to policies that incentivize sole cropping as a path toward diversified diets and commercialization. Variations in the performance of crop diversification options supports the notion that optimal approaches for farmers will be heterogeneous and will include a suite of options to meet their spatial and temporal conditions. Providing extension support and training for producing high value dual crops (food and cash) will enhance food and nutritional security both at farm and national scale. Finally, policymakers must consider the enabling environment (macroeconomic, infrastructure, legal, and institutional environment) when prioritizing policy alternatives to ensure that incentives for changing agricultural practices are adequately supported and promote food and nutritional outcomes.

Table 10: Cost Benefit Analysis of Crop Diversification & PICS Bags

Intervention	Discount Rate	Benefit (MWK million)	Cost (MWK million)	BCR
Crop Diversification - NATIONAL	5%	4,803	2,300	2.1
	8%	3,963	1,983	2.0
	14%	2,777	1,518	1.8
Promotion of PICS Bags	5%	783	229	3.4
	8%	664	196	3.4
	14%	491	147	3.3
Crop Diversification - LOWER SHIRE	5%	333	162	2.1
	8%	275	139	2.0
	14%	192	105	1.8
Crop Diversification - LAKESHORE	5%	1,231	719	1.7
	8%	1,015	622	1.6
	14%	711	478	1.5
Crop Diversification - HIGHLANDS	5%	740	457	1.6
	8%	611	397	1.5
	14%	428	308	1.4
Crop Diversification - MIDELEVATION	5%	2,500	962	2.6
	8%	2,063	826	2.5
	14%	1,445	627	2.3

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8. Appendix

COMPARISON OF COSTS & BENEFITS OF TRADITIONAL SYSTEMS (TS) AND CROP DIVERSIFICATION (CD) FARMING MODELS IN LOWER SHIRE

BENEFITS	Summer Field 1 (TS)	Summer Field 1 (CD)	Summer Field 2 (TS)	Summer Field 2 (CD)	Wetland Field 3 (TS)	Wetland Field 3 (CD)	Winter cropping (TS)	Winter cropping (CD)	Whole Farm Income (TS)	Whole Farm Income (CD)
Maize yield (kg/ha)	807.80	900.0					577.00	900.0	373.90	486.0
sorghum yield (kg/ha)			500.00	750.0					145.00	217.5
legume 1 yield (kg/ha)	150.00	750.0	350.00	600.0			275.00	750.0	255.75	693.0
Legume 2 yield (kg/ha)	-	1,000.0	-				-	2,265.0	-	2,154.9
Cotton yield (kg/ha)			-	500.0					-	265.0
Rice yield (kg/ha)					600.00	1,900.0	200.00		656.00	1,558.0
Price maize ($/kg)	0.27	0.3	0.27	0.3	0.27	0.3	0.27	0.3		
Price sorghum ($/kg)	0.29	0.3	0.29	0.3	0.29	0.3	0.29	0.3		
Price Legume 1 ($/kg)	0.33	0.3	0.33	0.3	0.33	0.3	0.42	0.4		
Price Legume 2 ($/kg)	0.66	0.7	0.66	0.7	0.66	0.7	0.66	0.7		
Price cotton ($/kg)	0.53	0.5	0.53	0.5	0.53	0.5	0.53	0.5		
Price rice ($/kg)	0.82	0.8	0.82	0.8	0.82	0.8	0.82	0.8		
Gross benefits 1	267.61	1,151	260.50	681	492.00	1,558	271.29	2,053	1,291.40	5,442

Total labour days	105.00	132	90.00	148	85.00	140	90.00	132		
Labour unit price	1.93	2	1.93	2	1.93	2	1.93	2		
Labour costs	202.65	255	173.70	286	164.05	270	173.70	255	714.10	1,065
Maize seed price ($/kg)										
Maize quantity (kg)	20.00	13					20.00	13	25.00	25
Maize costs	6.60	33					33.38	33	66.75	67
Sorghum seed quantity			2.50	3					2.50	3
Sorghum seed sost			0.63	5						

COMPARISON OF COSTS & BENEFITS OF TRADITIONAL SYSTEMS (TS) AND CROP DIVERSIFICATION (CD) FARMING MODELS IN LOWER SHIRE

BENEFITS	Summer Field 1 (TS)	Summer Field 1 (CD)	Summer Field 2 (TS)	Summer Field 2 (CD)	Wetland Field 3 (TS)	Wetland Field 3 (CD)	Winter cropping (TS)	Winter cropping (CD)	Whole Farm Income (TS)	Whole Farm Income (CD)
Rice seed quantity (kg/ha)					65.00	65				
Rice seed cost					65.00	163			65.00	163
Legume 1 seed price ($/kg)	0.33	1	0.30	0			0.60	1		
Legume1 quantity (kg)	10.00	10	40.00	40			10.00	10		
Legume 2 seed price ($/kg)	0.66	1					1.00	1		
Legume2 quantity (kg)	-	40					-	40		
Legume costs	3.30	46	12.00	12	-	-	6.00	46	21.30	104
Fertilizer price (basal)	0.73	1	0.73	1	0.73	1	0.73	1		
Fertilizer quantity (basal)	50.00	100	-	100	-	250	50.00	100		
Fertilizer price (top dressing)	0.73	1	0.73	1	0.73	1	0.73	1		
Fertilizer quantity (top dressing)	50.00	100	-	100	50.00	200	50.00	100		

Fertilizer cost	73.00	146	-	146	36.50	329	73.00	146	182.50	767
pesticides price/Kg		23		23	-	-		23		
PesticidesQuantity (Kg)		1	0.50	1			0.50	1		
Pesticide cost		11	-	11	-	-	-	11	-	34
Total costs	285.55	491	185.70	455	265.55	761	286.08	491	1,022.88	2,199
Net benefits	-17.94	659	74.80	226	226.45	797	-14.79	1,562	268.52	3,243

COMPARISON OF COSTS & BENEFITS OF TRADITIONAL SYSTEMS (TS) AND CROP DIVERSIFICATION (CD) FARMING MODELS IN LAKESHORE

BENEFITS	price per kg	Field 1 yields (TS)	Field 1 yields (CD)	Field 2 yields (TS)	Field 2 yields (CD)	Field 3 yields (TS)	Field 3 yields (CD)	Whole farm analysis (TS)	Whole farm analysis (CD)
Maize yield (kg/ha)	0.27	1,387	1,250	1,387	1,250			749	675
pigeon pea (kg/ha)	0.33	105	1,500	105				69	495
ground nuts (kg/ha)	0.66	225	1,150					149	759
sweetpotatoes (Kg/ha)	0.21			2,160	6,250			454	1,313
cassava (kg/ha)	0.13			3,192	5,625			415	731
Rice yield (kg/ha)	0.82					1,350	1,900	1107	1,558
cow pea (kg/ha)	0.42				600				252
Gross benefits 1		558	1,592	1,243	2,633	1,107	1,558	2943	5,783
COSTS									
Total labour days		127	142	131	170	110	122		
Labour unit price	1.93								
Labour costs		245	274	253	328	212	235		
Maize seed price ($/kg)	2.67								
Maize quantity (kg)		18	13	18	13				

Maize costs		48	33	48	33				
Legume seed price ($/kg)									
Legume quantity (kg)									
Legume costs		14	46		25				
sweetpotatoes cutting(bundles/ha)	1.37			100	100				
sweetpotatoes vine price									

COMPARISON OF COSTS & BENEFITS OF TRADITIONAL SYSTEMS (TS) AND CROP DIVERSIFICATION (CD) FARMING MODELS IN LAKESHORE

BENEFITS	price per kg	Field 1 yields (TS)	Field 1 yields (CD)	Field 2 yields (TS)	Field 2 yields (CD)	Field 3 yields (TS)	Field 3 yields (CD)	Whole farm analysis (TS)	Whole farm analysis (CD)
sweet potatoes vine cost/ha				20	137				
Cassava cutting(bundles/ha)	0.8			20	200				
Cassava bundle cost/ ha				16	160				
Rice seed quantity (kg/ ha)						80	80		
Rice seed cost						66	200		200
Fertilizer price (basal)	0.73								
Fertilizer quantity (basal)		50	100	50	100	50	250		
Fertilizer price (top dressing)	0.73								
Fertilizer quantity (top dressing)		50	100	50	100	50	200		
Fertilizer cost		73	146	73	146	73	329		621
pesticides price/Kg	22.5								
Pesticides Quantity (Kg)		1	1	1	1				
Pesticide cost		16	11	16	11				
Total costs		382	510	406	704	351	764	1,138	1,978
Net benefits		176	1,081	838	1,930	756	794	1,769	3,805

COMPARISON OF COSTS & BENEFITS OF TRADITIONAL SYSTEMS (TS) AND CROP DIVERSIFICATION (CD) FARMING MODELS IN HIGHLANDS

BENEFITS	Price per kg	Field 1 yield (TS)	Field 1 yield (CD)	Field 2 yield (TS)	Field 2 yield (CD)	Whole farm analysis (TS)	Whole farm analysis (CD)
Maize yield (kg/ha)	0.27	1,960	2,000			529	540
bean yield (kg/ha)	0.62	360	1,000			223	620
Irish potato(kg/ha)	0.21	4,590	12,500			964	2,625
Rice yield	0.82			1,150	1,600	943	1,312
Gross benefits 1		1,716	3,785	943	1,312	2,659	5,097
COSTS							
Total labour days		160	160	144	144		
Labour unit price	1.93						
Labour costs		309	309	278	278	-	-
Maize seed price ($/kg)	2.67						
Maize quantity (kg)		20	13	-	-		
Maize costs		53	33	-	-		
Legume costs		24	48				
Rice seed quantity (kg/ha)							
Rice seed cost							

potato seed(bundles/ha)	0.8	550	1,000				
potatoes seed cost/ha		132	400			-	-
Fertilizer price (basal)	0.73						
Fertilizer quantity (basal)		75	200	50	250		
Fertilizer price (top dressing)	0.73						
Fertilizer quantity (top dressing)		50	100	50	200		
Fertilizer cost		91	219	73	329		
pesticides price/Kg	22.5						
Pesticides Quantity (Kg)		1	1				

COMPARISON OF COSTS & BENEFITS OF TRADITIONAL SYSTEMS (TS) AND CROP DIVERSIFICATION (CD) FARMING MODELS IN HIGHLANDS

BENEFITS	Price per kg	Field 1 yield (TS)	Field 1 yield (CD)	Field 2 yield (TS)	Field 2 yield (CD)	Whole farm analysis (TS)	Whole farm analysis (CD)
Pesticide cost		11	11				
Total costs		621	1,020	351	606	972	1,627
Net benefits		1,096	2,765	592	706	1,688	3,470

COMPARISON OF COSTS & BENEFITS OF TRADITIONAL SYSTEMS (TS) AND CROP DIVERSIFICATION (CD) FARMING MODELS IN MID-ELEVATION

BENEFITS	**price per kg**	**Field 1 (TS)**	**Field 1 (CD)**	**Field 2 (TS)**	**Field 2 (CD)**	**Field 3 (TS)**	**Field 3 (CD)**	**Whole farm analysis (TS)**	**Whole farm analysis (CD)**
Maize yield (kg/ha)	0.27	1,529	1750	1,529	1750	1,092		826	945
groundnuts yield (kg/ha)	0.82	1,250	1250				1250	1,025	2050
commonbean yield (kg/ha)	0.62	450	1000	450	1000			558	1240
soybean	0.41		1000						
tobacco	2					600			
swee/Irish pota-to(kg/ha)	0.21			2,790	12500		12500	586	5,250
Gross benefits 1	0.42	1,717	2528.459	999	3097.5	1,495	3650	4,210	9,276
COSTS									
Total labour days		160	160	170	170	212	165		
Labour unit price	1.93								
Labour costs		**309**	**308.8**	**328**	**328.1**	**409**	**318.45**		
Maize seed price ($/kg)	2.67								
Maize quantity (kg)		18	12.5	18	12.5	18			

Maize costs		48	33.375	48	33.375	48			
Legume seed price ($/kg)									
Legume quantity (kg)									
Legume costs		58	118	19	60	50	50		
sweetpotatoes cutting(bundles/ha)	1.37			100	100				
sweetpotatoes vine price									
sweet potatoes vine cost/ha				20	137				
potato seed(bundles/ha)	0.8			-	2000	-	2000		
BENEFITS	**price per kg**	**Field 1 (TS)**	**Field 1 (CD)**	**Field 2 (TS)**	**Field 2 (CD)**	**Field 3 (TS)**	**Field 3 (CD)**	**Whole farm analysis (TS)**	**Whole farm analysis (CD)**

COMPARISON OF COSTS & BENEFITS OF TRADITIONAL SYSTEMS (TS) AND CROP DIVERSIFICATION (CD) FARMING MODELS IN MID-ELEVATION

potato seed cost /ha									
potatoes seed cost/ha						-	800		
Fertilizer price (basal)	0.73								
Fertilizer quantity (basal)		50	200	50	100	150	250		
Cattle Manure									
Manure price									
Fertilizer price (top dressing)	0.73								
Fertilizer quantity (top dressing)		50	100	50	100	100	200		
Fertilizer cost		73	219	73	146	183	328.5	329	693.5
pesticides price/Kg	22.5								
PesticidesQuantity (Kg)		1	0.5	1	0.5				
Pesticide cost		**11**	**11.25**	**11**	**11.25**				
Total costs		**499**	**690.425**	**479**	**578.725**	**690**	**1496.95**	**1,667**	**2766.1**
Net benefits		**1,218**	**1838.034**	**520**	**2518.775**	**805**	**2153.05**	**2,543**	**6,510**

The Malawi Priorities Project

2021

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COPENHAGEN CONSENSUS CENTER

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