The Malawi Priorities Project

Cost Benefit Analysis of Stimulating Farmer Uptake of Irrigation in Malawi - Techincal Report

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

COPENHAGEN CONSENSUS CENTER

NATIONAL PLANNING COMMISSION

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Malawi Priorities: Background

Malawi Priorities is a research-based collaborative project implemented by the National Planning Commission (NPC) with technical support 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.

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Acknowledgements

The National Planning Commission would like to thank the following individuals for helpful comments throughout the research process: Lameck Fiwa (LUANAR), Vessall Nourani, Travis Lybbert (University of California, Davis), Geoffrey Mamba (Ministry of Agriculture, Irrigation and Water Development), Wilkson Makumba (Ministry of Agriculture, Irrigation and Water Development), Munyaradzi Mutenje (International Maize and Wheat Improvement Center), Kenneth Wiyo (LUANAR), Grivin Chipula (LUANAR), David Kamchacha (Mtalimanja Holdings Limited), Ignatious Majamanda (Malawi Mangoes), Flora Nankhuni (Feed the Future Innovation Lab for Food Security Policy), Christone Nyondo (Mwapata Institute), Joseph Kanyamuka (International Institute for Tropical Agriculture), and participants at the Malawi Priorities webinar held on 27 November 2020. Amit Sharma provided research assistance.

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1. Introduction

Irrigation plays an integral role in the quantity, quality and sustainability of Malawi's agriculture sector, helping farmers to produce a sustainable supply of good quality food, while contributing to water conservation strategy. With such a large part of the population dependent on rain-fed agriculture, the increasing vulnerability to climate shocks and drought, and the recognition that structural transformation of the economy will be difficult without increasing farm productivity, policy makers across Malawi have recognized the importance of irrigation as a development priority. For example, out of 31 flagship projects listed in MDGS III (the Malawi Growth Development Strategy), four of them relate to irrigation, including the Green Belt Initiative, the Small Farms Irrigation Project and the Shire Valley Transformation Project. The National Irrigation Policy and the National Agricultural Investment Plan (2018) lay out important aspects of irrigation policy for Malawi. Irrigation plays a prominent part in the recently released Malawi 2063 vison document with the hope that irrigation infrastructure ***"caters for national food security needs, supports agriculture commercialization and promotes exports"*** (NPC, 2021).

However, recent experience with irrigation investments in Malawi has been mixed. Irrigation has increased substantially for smallholder farmers, quadrupling from 15,988 ha in 2011 to 61,977 ha by 2019 (Nhamo et al. 2016; Malawi Department of Irrigation, 2019). However, in the same period, the irrigated area of privately owned smallholder estates grew only from 48,360 ha to 56,856 ha (Nhamo et al., 2016; Deininger and Xia, 2017; Malawi Department of Irrigation, 2019).

Overall, there is still ample scope for increased irrigation investment. Malawi's overall irrigation potential is estimated at 408,000 hectares of which only about a third (118, 833 ha) has been developed (Malawi Department of Irrigation, 2019). Both the National Irrigation Policy and the National Agricultural Investment Plan (2018) target an increase in the irrigated area by 43,700 ha in the medium term.

Encouraging farmers to take up and use irrigation is a challenge. Perhaps the most important constraint is cost – irrigation projects are expensive, requiring economies of scale, consistent water supply, credit or grants, and available markets for produce to reduce or justify costs. For example, as noted by Schuenemann et al., (2018), the Irrigation Master Plan estimated an upfront cost of irrigation infrastructure at USD 18,500 per hectare, and ongoing costs of USD 2,400 per hectare. To put this in perspective, an analysis of irrigation returns in Malawi estimated revenue per hectare of between USD 330 and USD 1400 depending on the crop irrigated (Kadyampakeni et al., 2015). Schuenemann et al., (2018) note that using figures presented in the Irrigation Master Plan, the economy wide benefits from irrigation are unlikely to exceed the costs. Besides cost, additional challenges include lack of knowledge about how to use and maintain irrigation technology, as well as vandalism and theft (Nhamo et al., 2016).

However, the promise of irrigation is large as noted above in the Malawi 2063 vision: farmers can both ensure water availability during the normal cropping season reducing the impact of climate variability (insurance benefit), while expanding cropping during the dry-season. This should improve farm incomes and food security. Surplus produce arising from irrigation can catalyze an agricultural commercialization drive that boosts overall economic growth (NPC, 2021). A key question is whether these benefits outweigh costs. Based on consultations with stakeholders this paper examines the costs and benefits of two interventions to expand irrigation with analyses separated for smallholder and estate farms for financing. These interventions are:

1. 1. Reorient extension workers to provide better and more market orientated information on irrigation usage for smallholder farmers
2. a. Provide financing and grants to smallholder farmers for solar irrigation pumps

   b. Provide financing and grants to estate farms for solar irrigation pumps

We also study the effect of crop choice on each intervention. Noting that one major constraint is market access, we focus on a set of crops for which data indicates the presence of a pre-existing market with potentially unmet domestic or export demand. In line with the PRIDE baseline report, we assume that the presence of irrigation enables smallholder farmers to expand the area under cultivation during the dry season from an average of 0.27 ha to 0.98 ha, and estate farms to expand their area of cultivation to 90% of potential area (up from 48%).

The results of this analysis show that the range of benefit-cost ratios (BCRs) span 0.1 to 6 depending on the crop and irrigation technology under consideration, meaning that expansion of irrigation has to be well focused to work cost-effectively. Some key messages that arise from the analysis include:

- The choice of irrigation technology has a large bearing on the BCR. We assume, in line with consultations, the first intervention uses relatively inexpensive gravity technology, which yields BCRs consistently above 1. On the other hand, BCRs are typically not above 1 for the more expensive option of solar-powered irrigation pumps. It should be noted that we assume costs for solar irrigation pump that are significantly less expensive than the costs presented in the Irrigation Master Plan (USD 5,700 per hectare compared to USD 18,500).
- Another key driver of the BCR is the choice of crop. This is because the largest marginal costs and benefits are typically farm inputs and outputs respectively. Crops that have higher gross margins, and for which yields are more susceptible to water availability, are better able to cover the costs of irrigation and supporting interventions. Promising crops in Malawi are tomato and cassava which have higher BCRs (and BCRs > 1 even under solar

pump irrigation). This highlights the importance of increasing crop diversity, simultaneous with irrigation promotion, to maximize benefits.

- Because the largest costs and benefits are variable in nature, with relatively lower fixed costs, the actual uptake resulting from the interventions does not alter the BCR much. Of course, uptake rates affect the net benefits of the intervention.
- To ensure positive returns for gravity irrigation requires that farmers increase area under farming during the dry winter months substantially. The government should ensure policies are in place so that the necessary inputs are available and affordable for those who need them.

2. Policy Context

Creating wealth through agriculture has been a long-running development goal in Malawi. The Greenbelt Initiative (GBI), launched in 2011, aims to increase agricultural production, to facilitate enterprise development and increase exports. Specifically, the GBI aims to increase agricultural exports, improve value chain linkages and operations, and increase private sector participation in the sector. The geographic scope coincides with that of this analysis: targeting about one million hectares of land along Lake Malawi and Malombe, the Shire River and the perennial rivers right from Chitipa to the Shire Valley. The target is to have irrigated land extending for 20 kilometers from the water sources. The targeted food crops include maize, rice, cassava, potatoes, pulses, millet and sorghum whilst the cash crops will include cotton, sugarcane and wheat. Specific horticultural crops to be promoted under the program include fruits like citrus fruits, mangoes and bananas; vegetables and tomatoes; and spices. Government will also pursue niche markets for commodities such as cotton, vegetables, paprika, chilies and fruits for which it has a comparative advantage.

The GBI also envisions an integrated package of extension services. This will involve supporting all stakeholders along various commodity value chains by providing technical information from relevant institutions through front line staff, lead and peer farmers. In its overlapping National Resilience Strategy (2018-2030), the Government of Malawi will, among other things, prioritize the creation of an enabling environment for private sector investment in commercial agricultural production, processing, and value addition, particularly on private estates and smallholder farmers that are organized into cooperatives, and through efficient contract farming arrangements, in line with the government's Contract Farming Strategy. It also recognizes sustainable irrigation development is an important strategy for increasing crop production and mitigating the negative effects of climate change related disasters (floods, drought/dry spells) that contribute to food insecurity.

In alignment with the National Resilience Strategy is the Malawi National Export Strategy (2013-2018) prioritizing three clusters of exports: (1) oil seed products like cooking oil, soaps, lubricants, paints, varnishes, meals and flours, bio-fuel, animal feed, fertilizer, snacks and confectionery derived from sunflower, groundnuts, soya and cotton (2) sugar cane products like a range of sugars, sugar confectionery, sweeteners, ethanol, spirits, cane juice, fertilizer, animal feed, and cosmetics; (3) manufactured products such as beverages, value-added agricultural products (including horticulture, dairy and maize, wheat, and pulses), plastics and packaging and assembly. Urgent attention is to be given to policies affecting infrastructure to ensure affordable and reliable access to energy and water/irrigation. It also recognizes that technical support is essential to improve the quality of export products, particularly those relating to technology transfer, R&D and technical training.

The National Irrigation Policy (2016) adds precision to the policy framework on irrigation regarding the components of sustainable irrigation development. Among its desired outputs are the development of farmer organizations, the exploration of alternatives to current handling and marketing of farmers' produce for maximum profitability, and the strengthening of extension services for irrigated agriculture through awareness and outreach of irrigation technologies.

Guided by this policy framework is the flagship irrigation development programme - the Programme for Rural Irrigation Development (PRIDE), which aims to develop climate-smart land and water management systems for small-scale farmers engaged in rain-fed agriculture and cultivating on irrigated land. Specifically, PRIDE will establish and strengthen the capacity of the Water Users' Associations to manage, operate and maintain irrigation schemes for appropriate land and water governance. It will establish farmer business schools to improve business management capacity. It will also promote market linkages through value chain analysis to identify suitable crops and commodity platforms to bring together all actors in the value chain. The Programme is being implemented in 15 irrigation schemes in eight districts of Malawi (Chitipa, Karonga, Rumphi, Nkhatabay, Machinga Zomba, Chiradzulu and Phalombe) to develop 5,200ha of irrigated land and 12,300ha of rain-fed land to benefit 19,500 households representing a population of about 950,000. Nine of the 15 irrigation schemes fall under the districts that are under analysis here.

3. Research Context and Selection of Interventions

The National Planning Commission (NPC), with technical assistance from the African Institute for Development Policy (AFIDEP) and the Copenhagen Consensus Center (CCC), has carried out a cost-benefit analysis across a wide range of policy areas, to assist the Government of Malawi in its prioritization of spending across sectors.

The project, 'Malawi Priorities', and its research agenda takes its starting point in the NPC's existing research agenda, which is structured around the six thematic areas of Sustainable Agriculture, Sustainable Economic Development, Human Capital and Social Development, Sustainable Environment, Demography, Governance, Peace, and Security. Furthermore, a Reference Group of 24 experts from a variety of sectors were polled to identify the most pertinent research questions and potential interventions for study. The following research question is the result of these two processes:

What are the most effective ways to increase irrigation uptake in places with abundant water supply especially along the shores of Lake Malawi or around the Shire River?

It is first useful to examine the constraints to improved irrigation uptake. Four factors which affect farmer adoption of irrigation are the affordability of irrigation equipment, access to financing, the quality of extension services and access to water. The importance of these challenges is confirmed by the National Irrigation Policy (2016), which identifies inadequate financial resource mobilization and high development costs (i.e. US$ 9,000 to US$15,000 per hectare) among the primary constraints.

There are several studies which attempt to identify the determinants of irrigation uptake by farmers. Osewe et al. (2020) sought to determine factors that influence adoption of farmer-led irrigation in Tanzania. Membership to water user group affected the adoption of farmer-led irrigation positively. The authors speculated that generally membership to a social group enhances social trust, information, capital, and idea exchange. Christian et al. (2019) found that, in South Africa, access to credit had a positive and statistically significant effect on adoption at the 10% significance level, suggesting that farmers who could easily access credit have a greater likelihood (96%) of adopting. Furthermore, the distance to irrigation schemes significantly influences the decision to adopt: the farther the households are from the scheme, the less likely (34%) they are to participate as compared to households that are located within a close proximity. This is a factor unlikely to affect the farming households concerned here, which are located along Lake Malawi and the Shire River. Mango et al. (2018) studied the determinants of farmer adoption of irrigation in the Chinyanja Triangle (Zambia, Malawi, and Mozambique) and found that the odds of irrigation uptake when the farmer has access to irrigation equipment are 2.027 (p value 5%); and access to a reliable water source are 18.564 (1%). Furthermore, the authors found that irrigation farming increased income by 205% (5% significance) and extension services increase income by 170% (10% significance).

To build on this background knowledge, consultations were held in August 2020 with local agricultural economists and irrigation experts: Kenneth Wiyo, Grivin Chipula, David Kamchacha, and Ignatious Majamanda. The points below synthesize their perspectives on the factors affecting farmer uptake of irrigation technology:

1. Limited access to finance for investment in irrigation infrastructure and the lack of resources to maintain irrigation systems were key constraints to the lack of uptake and/or the abandonment of schemes.
2. Current irrigation scheme designs are production-oriented, as opposed to being market-oriented. Farmers understand that irrigation will significantly increase yields yet are not left with a surplus or be obliged to sell to exploitative agents because they have made the wrong choice of crop.
3. Extension workers are essentially social workers for rural areas, whereas farmers require technical support for irrigation farming, as well as other inputs; extension workers currently don't have sufficient training to assist with farm and water management. Three of the functions that extension workers should take on are (1) the formal organization of farmers to reduce transaction costs by traders and millers and (2) quality control of harvests, particularly for export commodities, and (3) the promotion of high value crops.
4. Lack of input subsidies Traditionally, farmers do not cultivate their land during the winter months (May to October). This practice is reinforced by the fact that the Farm Input Subsidy Program (FISP) only supplies farmers with fertilizer and seed during the rainy season. Thus, dry season farming, which requires irrigation technology, does not benefit from input subsidies.
5. The pervasiveness of donors and NGOs in the sector has engendered a lack of ownership by farmers. Crop choices and irrigation technology are determined by these outside agencies and most irrigation schemes are fully financed, without requiring contributions from farmers. However, maintenance remains the burden of the farmers, who cannot afford diesel/electricity operated irrigation systems, compromising the sustainability of irrigation projects.

3.1 Interventions considered for cost-benefit analysis

To address the above factors, the following measures for improving farmer uptake of irrigation were considered:

3.1.1. Increase extension services (workers, demonstrations, communication) for improved irrigation technology adoption and application

Extension services are indispensable to irrigation technology adoption. Leaving farmers with their traditional practices does not necessarily result in the best farm management practices. Fanadzo et al. (2010) found that, for South Africa, farmer management with regards to crop production falls far short of expectations, and that poor crop yields are caused by poor basic cultural practices such as planting density, nutrient and water management, and inadequate crop protection. Irrigation may be inefficient if farmers are unfamiliar with the importance of respecting the correct timing, frequency of irrigation and cleaning of filters (FAO, 2014). In an application of various small-scale irrigation technologies in bean cultivation in Malawi, Kadyampakeni et al. (2013) found that when farmers were allowed to determine and handle water application without training and based on indigenous knowledge only, water deliveries were inadequate. Makarius et al. (2017) also studied farmers in Tanzania, and found that lack of knowledge of irrigation and other practices as a main constraint on growing certain crops. Lastly, in a study of bean farmers in Malawi, Banda et al. (2010) discovered that the mean depths of water applied for all the irrigation technologies studied (water can, gravity, and treadle pump) were lower than the irrigation requirement. The farmers over-irrigated the crop at the early growth stage but under-irrigated at the mid growth stage when the water requirement was highest.

3.1.2 Reorientation of the FISP

Another suggestion arising from consultations, based on the premise that one of the main impediments to irrigation uptake for dry season farming is the lack of inputs, is to reorient the FISP so that farmer allocations of seed and fertilizer are distributed just before the dry season.

Receiving subsidized inputs is associated with an increase in yields. In a collaborative study, the FAO, ILO and UNICEF (2019) find that FISP beneficiaries experienced a 23.9% increase in predicted yields. Also, Hemming et al. (2018), in a systematic review of the literature on farm input subsidies, found that in low- and middle-income countries, these subsidies lead to an average 9% increase in yield and a 17% increase in farm revenue.

3.1.3 Facilitating access to solar-powered pumps for estate and remote farms

The irrigation sector is venturing into solar powered pumping systems. Despite their relatively heavy initial investment cost, solar pumps make it possible for water resources to be accessed in remote rural locations, require no fuel, and minimal maintenance. Furthermore, the falling costs of photo-voltaic panels used by solar pumping systems makes them increasingly affordable (Chafuwa, 2017).

3.1.4 Bulk marketing of irrigated crop output

Farmers will only make high up-front capital investments in irrigation systems if they can expect positive returns on their investments. Hence, improved access to reliable markets where farmers can sell their produce at higher prices may lower risks and incentivize them to make the necessary investment for irrigation (IFPRI, 2018).

Mango et al. (2018), in a study of over 300 farmers in Zambia, Malawi, and Mozambique, discovered that the distance traveled to access input and/or output markets had a significant negative influence on the adoption of irrigation farming. Odds of adoption decreased by about 18% with a one-kilometer increase in distance to the nearest input or output market for the farmer.

Most agricultural produce is sold at the farm gate, as looking for an alternative buyer entails marketing costs. Furthermore, the majority of farmers do not use cooperatives to market their rice due to delays in payment from the rice buyers. Finally, in the same study, the author discovered that cooperative irrigation schemes increase incomes by 65% (p=0.1) and per capita daily caloric intake by 10% (p=0.01). Nkhata (2014) proposes contracted relationships with local institutions like schools, prisons, hospitals in ensuring steady markets for irrigated products.

3.1.5 Fuel subsidies to offset operational costs for farms

Moving from a manual lift technology (like the water can or treadle pump) to a motorized pump represents significant time savings for the farmer. However, the fuel and maintenance costs of motorized technologies are considerable, given the revenues realized at harvest. FAO (2014) estimates that energy costs for diesel pumps range from $500-$700 per hectare over the pump's lifespan of five to eight years. Experts consulted also cited the travel time to buy fuel and fuel costs as one of the principal reasons for abandoning irrigation projects.

3.1.6 Matching grants for irrigation investment

A matching grant is a one-off, non-reimbursable transfer to project beneficiaries, provided that the recipient makes a specified contribution for the same purpose. Grants and matching contributions can be either in cash or in kind, or a combination of both. They may or may not be provided together with other financial services, such as loans, or linked to them (IFAD, 2012).

3.1.7 Supplemental Irrigation + Agricultural insurance

Supplemental irrigation (SI) is defined as the application of additional water to rain-fed crops, when rainfall fails to provide essential moisture for normal plant growth; irrigation allows farmers to plant and manage crops at the optimal time, without being at the mercy of unpredictable rainfall. All sources of water can be used for SI systems, including runoff harvested water, surface water, underground water, and treated industrial waste water. Kameze (2018), in a three-year randomized controlled trial experiment on the impact of drought index insurance on the demand for supplemental irrigation (SI) among smallholder farmers in Northern Ghana, found a significant increase in the demand for SI among drought-insured farmers compared to uninsured farmers. This is because farmers perceive drought index insurance as a tool to hedge against the high cost of irrigation in drought years.

3.2 Intervention selection process

The intervention selection process starts with a wide universe of potential interventions drawing from the literature and stakeholder interviews. From there, the prioritization of interventions takes in a number of considerations. Though there is no mechanical formula for selection, several important factors include:

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. Due to the relatively limited cost-benefit literature on irrigation, and the fact that many point towards fair BCRs (defined as BCR < 5), this factor was not particularly critical in the choice of investments at this stage of the analysis.
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, triangulated by expert consultation. 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. Table 1 presents the intervention screening process.

Table 1: Intervention screening process

Intervention considered	Sector expert priority	Addresses a problem of sufficient size	Significant gap in current coverage levels	Availability of data	Chosen for further analysis
Extension workers	Yes	Yes, there is an insufficient number, untrained in irrigation agriculture.	Current ratio extension officer: farmer is 1900; government target is 1000. Only half of households received extension advice in the last 12 months	Yes	Yes
Solar-powered irrigation systems for estate and remote farms	Yes	Yes, irrigation coverage is 1/20 of cultivated land.	Less than 60,000 ha among estate farms irrigated of the 1.35 million ha in total	Yes	Yes
Matching grants	Yes	Yes, as per IHS4, 68% of rural respondents expressed a need for credit.	Not currently a policy instrument for irrigation	Yes	Yes
Reorientation of FISP	No	Most farmers do not farm during the dry and winter seasons.	No	Yes	No
Bulk marketing	Yes	Yes, the lack of guaranteed buyers is widely cited as one of the reasons for refusing to irrigate during dry/winter seasons.	Only one example could be identified in practice in Malawi, concerning the rice sector.	No	No
Fuel subsidies	No	Yes, roughly 40% of irrigated hectarage utilizes motor pumps, but irrigated lands are only 2% of total cultivated lands.		Yes, but not to stimulate irrigation uptake	No
Supplemental irrigation, drought insurance	No	Doesn't address the constraints related to dry season farming	Not currently a policy instrument	Yes	No

Based on the above two interventions were chosen for further cost-benefit analysis, with analysis split on the second intervention for smallholder and estate farms

1. 1. Reorient extension workers to provide better and more market orientated information on irrigation usage for smallholder farmers
2. a. Provide financing and grants to smallholder farmers for solar irrigation pumps

   b. Provide financing and grants to estate farms for solar irrigation pumps

4. Choice of Crops for Analysis

The benefits to irrigation are realizable only if increased produce can be sold. Farmer access to markets, as well as private investment to promote value addition, are critical to irrigation uptake. However, bulk purchasing is in its infancy in Malawi, for a variety of reasons. Some of which include limited capacities by agricultural extension officers on agricultural markets and marketing. Agricultural extension officers can create an appropriate environment for private investors and for forward contract markets; their critical role in this is discussed in more detail in the next section.

Matching crops with the appropriate irrigation technology is essential to maximizing profitability; it is not a profitable route to take for all crops. Wiyo and Kamwamba (2017), found that: (1) conservation agriculture technology is profitable for most crops; (2) watering-can technology is not viable given the current policy targets; (3) treadle pumps and river diversions are suitable for medium to high value crops, and (4) solar and motorized pumps are suitable for medium to high value crops but not suitable for legumes and grain maize. Among the crops that do well under higher-cost technologies are spices (ginger and garlic) and vegetables (tomatoes, onions, and cabbage).

The identification of existing markets (local and external) plays a role in the motivation for investing in irrigation. Supplying domestic markets carries a lower risk than exporting, due to the numerous international standards that must be met. Also, commodities for which imports are significant imply a local demand that could be met from the increased output and regularity of output from irrigation.

Another risk factor is the perishability of produce and whether the appropriate harvesting and treatment facilities are in place in order to reach markets.

To put these two features into consideration we create a perishability-marketability matrix (Table 2). This matrix classifies the array of commodities produced by Malawian farmers by perishability and market potential. The former is measured by the percentage of post-harvest losses. While precise post-harvest loss (PHL) estimates are unavailable, there is consensus concerning which crops are considered highly perishable and/or delicate. The top exports and imports, obtained from FAOSTAT, can be used to identify promising local or international market opportunities.

Table 2: Perishability-marketability matrix

Consumption	PHL: Low (<20%)	Medium (20-40%)	High (>40%)
Imports	GRAINS: wheat (143,068); maize flour (6,000); maize (465); rice (3712) TOBACCO (13,852) OILSEEDS: Palm oil (37,700); soybean oil (12863); sunflower oil (1461) SUGAR: Molasses (21,515); confectionary sugar (6493) COTTON: cottonseed (1700)		FRUITS: bananas (1240); apples (948); oranges (451); watermel-on (211); grapes (144); pears (144) ROOTS/TUBERS: potato (633) VEGETABLES: dry onions (250); fresh vegetables (229)
Exports	GRAINS: maize (1910) OIL SEEDS: soybeans (25714); sunflower seed (2530); soybean oil (1109); sesame seed (454) COTTON: seed (4576); lint (4009)	PULSES: dry peas (39141); shelled groundnuts (31213); dry beans (3627); chick peas (1200) SPICES: paprika (17); chillies (70)	

Source: Ambler et al. (2017); Tsusaka et al. (2017); APHLIS; Affognon et al. (2015). Import and export volumes in parentheses are expressed in tonnes, for the year 2018 and were obtained from FAOSTAT.

Generally, it is assumed that low PHL imported and exported commodities should be most suitable for irrigation, given that viable markets have already been established and the produce is not sensitive to pests and handling and/or a post-harvest chain is already in place in Malawi.

Based on the above information, irrigation is best paired with commodities which have shorter growing periods (to maximize the output per annum), lower perishability, local demand and/or growing export potential.

Table 3 sets out the general selection criteria for the commodities analyzed. Both the GBI and the National Export Strategy (NES) prioritize certain commodities. Also contributing to the selection of commodities analyzed is the National Smallholder Farmer Association of Malawi (NASFAM). Their commercial division NASCOMEX works directly with associations to support the development and implementation of a coordinated marketing programme at local and national levels. NASCOMEX currently trades groundnuts, rice, soya, chilies and maize. Commodities that are considered to have low post-harvest losses also merit consideration, given existing road and transport conditions in Malawi. Finally, from the 2019/2020 production estimates from the MoAIWD, the crops having the largest hectarage, greatest yields, and highest market prices were also considered.

Table 3: Selection criteria for commodities analyzed

						S	E	S	E	S	E
Commodity	**NES**	**Low PHL**	**Market > 5,000t**	**GBI**	**NASCOMEX**	**Largest ha**		**Highest yields**		**Highest prices**	
Maize (short)		X	X	X	X	X	X		X		
Sorghum		X		X							
Millet (pearl)		X		X							
Wheat	X	X	X	X							
Cassava				X		X		X			
Irish potato								X			
Sweet potato								X			
Common bean		X		X							
Groundnut	X	X	X		X					X	
Pigeon pea	X	X		X		X	X			X	
Sunflower	X	X									
Soyabean	X	X	X		X						
Cotton	X	X	X	X						X	
Tobacco		X	X				X				X
Rice		X		X	X						
Chilies				X	X				X		X
Paprika				X					X		X
Onion				X							
Tomato		X		X							
Sugar	X		X	X							
Tea											

Coding: S-smallholder, E-estate. NES-National Export Strategy, GBI-Green Belt Initiative. Source: Growing periods were taken from Benson et al. (2016); Production estimates are from the MAIWD; NASCOMEX information from NASFAM website

Based on the above, the crops selected for dry season farming under irrigation are: maize, wheat, rice, groundnut, pigeon pea, soybean, tobacco, cotton, paprika, chilies, cassava and tomato.

4.2 Yield, cost and prices of selected crops

Table 4: Main crop parameters

Commodity	Rain-fed, MT/ha	Irrigated, MT/ha	Producer Price MWK/MT	Total variable cost, MK/ha	Post Harvest Loss
Maize	1.7	3.0	200,000	526,000	15%
Groundnuts	0.9	3.1	300,000	432,200	25%
Pigeon pea	1.6	2.0	240,000	166,300	25%
Tobacco	1.2	2.1	720,000	486,000	15%
Soybean	0.9	3.0	300,000	265,200	15%
Cotton	0.6	1.2	310,000	239,760	15%
Chillies	0.3	0.6	900,000	180,021	25%
Wheat	1.2	3.2	390,000	526,000	15%
Cassava	23.4	37.6	100,000	513,500	40%
Rice	1.8	3.5	280,000	523,000	15%
Paprika	0.4	3.0	700,000	227,640	25%
Tomato	20.0	29.0	300,000	678,900	40%

Conducting this analysis requires data related to the different yields associated with rain-fed and irrigated agriculture, the price of produce, the variable costs of production, and post-harvest losses. These are summarized in Table 4 above.

Producer prices are from official government data (either farm gate prices or estimates from district level gross margin data). Variable cost data is also sourced from government provided gross margin data with the exception of tomato, which was sourced from PRIDE (2020). Post-harvest losses are approximations based on expert consultation regarding the extent of perishability of each crop.

Rain-fed and irrigated yield data are from government provided gross margin data for districts around Lake Malawi and Shire Valley. Where government data is limited, data has been sourced from literature within Malawi, and failing that outside of Malawi. Table 5 (next page) documents the source of yield estimates.

Table 5: Summary of yield estimates and sources

Commodity	Rain-fed yield	Irrigated Yield
Maize	1.7MT / ha (government gross margin data)	Multiple data sources suggest a lower bound range of 3.0 MT / ha 2.84 MT / ha (government gross margin data) 4.09 to 4.73 MT (Schuenemann et al., 2018) 3.0 MT / ha (Nhamo et al., 2016)
Groundnuts	0.9 MT / ha (government gross margin data)	2.9 to 3.22 MT / ha (Schuenemann et al., 2018)
Pigeon pea	1.6 MT / ha (government gross margin data)	20% increase applied based on (Praharaj et al., 2017) from India 13 to 30% increase in yields from (Schuenemann et al., 2018) for pulses in general
Tobacco	1.2 MT / ha (government gross margin data)	2.1 MT / ha (government gross margin data)
Soybean	0.9 MT / ha (government gross margin data)	4.5 MT / ha yield potential from agricultural best practice, including irrigation (United Nations Conference on Trade and Development, 2020) Used 3 MT / ha to be conservative and following experience in Egypt (Cornelius and Goldsmith, 2019)
Cotton	0.6 MT / ha (government gross margin data)	1.2 MT / ha based on yields of large farms across Africa, assumed to be irrigated (Sabesh and Prakash, 2019)
Chillies	0.3 MT / ha (Makoka, Chitika and Simtowe, 2010)	0.6 MT / ha (government gross margin data)
Wheat	1.2 MT / ha (government gross margin data)	3.2 MT / ha (government gross margin data) Around 3 MT / ha (Kadyampakeni et al., 2015)
Cassava	23 MT / ha (government gross margin data)	37.6 to 49.1 MT / ha (Odubanjo, Olufayo and Oguntunde, 2011) from Nigeria 45 MT / ha yield potential from best practice including irrigation (Kanyamuka, Dzanja and Nankhuni, 2018)
Rice	1.8 MT / ha (government gross margin data)	Just under 4 MT / ha (Kadyampakeni et al., 2015) 3.6 MT / ha (government gross margin data)
Paprika	0.4 MT / ha (Makoka, Chitika and Simtowe, 2010)	2.3 MT / ha (Makoka, Chitika and Simtowe, 2010)
Tomato	20 MT / ha (PRIDE, 2020)	37% increase in yields applied from (Kadyampakeni et al., 2015)

5. Cost Benefit Analysis: Extension Officer Reorientation

5.1 Background

The existing extension system is not very effective. Agricultural Extension Development Officers (AEDOs) have limited knowledge of crop management systems in general and irrigation systems in particular. In addition, their mobility is limited, making it difficult to reach all farmers, their focus is on maximizing farmers' yields rather than profits, and demand for their services is low (strongly suggesting farmers do not find it valuable). Ragasa and Niu (2017) and Ragasa (2017) have produced a more detailed picture summarizing the above challenges. Each AEDO is responsible for 30-50 villages or more, with one extension worker serving in the region of 2,500 to 3,000 individual farmers. To increase their impact, Malawian extension workers use the Lead Farmer (LF) approach. Theoretically, there should be one LF for 23 farmers, but Ragasa (2019) found that only 13% of households reported having any advice from a Lead Farmer in the past two years and that only 34% knew a LF in the local community in 2018 (down from 44% in 2016). Lead Farmers used bicycles or walked to reach other farmers in their community and all used cell phones.

A key finding of Ragasa et al. (2019) is that the current extension service has had no effect on the adoption of most agricultural technologies being promoted by the government. Given that a network of AEDOs and LFs already exists and that this could in principle reach all farmers on a regular basis, this is clearly a major missed opportunity to improve farmers' productivity and incomes. Beamon et al. (2020) reported a field study in 200 villages in Malawi using Lead Farmers to encourage a specific technology (pit planting). Over three years, this practice grew by 11%, showing the importance of targeted use of local networks created by the Lead Farmers themselves. Investment in more and better trained extension workers plus revitalization of the existing Lead Farmer network could have a significant impact on the use of cost-effective irrigation techniques.

5.2 Intervention Scope and Design

Given this current situation, the intervention proposed is:

1. **To increase the number of agricultural extension workers for better coverage.** This intervention seeks to decrease the ratio of farmers to AEDOs to 1500:1, whereas the government's desired ratio is 1000:1 (Government of Malawi, 2018). This would put it approximately in line with Uganda or Ghana in terms of extension worker intensity. See Table 6 below.

Table 6: *Extension worker to farmer ratios in selected African countries*

Country	Coverage of 1 extension worker by no. of farmers	Country	Coverage of 1 extension worker by no. of farmers
Nigeria	3,333	DRC	540
Tanzania	2,500	Kenya	950
Ethiopia	480	Ghana	1,300
Guinea	10,000	Mozambique	787
Uganda	1,800		

Sources: *Davis et al. (2010); Tetteh Anang et al. (2020), Feed the Future (2018), Ragasa (2018).*

2. **To reorient the work of AEDOs towards farm income growth** rather than yield maximization
3. **To improve their mobility** by purchasing motorcycles for every 4 AEDOs
4. **To revive the Lead Farmer (LF) model**, by using LFs for last-mile extension services and to offer them financial incentives for their organization of demonstration days and outreach.

In particular, an expanded body of better-trained AEDOs should focus on advising farmers on the benefits of cultivating during the dry season (according to the IHS4, only 14.5% of farmers work during the dry season) and giving information on the range of crops that can be grown in the respective regions and in the dry season; organizing farmers into formally-registered cooperatives, who can, in turn, negotiate with buyers; giving technical advice on water use efficiency, soil fertility management, and the efficient application of farm inputs; undertaking quality control and grading of harvest, and any other relevant information like impending weather patterns and government or financial instruments. Organizing farmers is critical for private sector engagement, as processors require volumes and can access these by directly engaging with farmer organizations (FO). Farmer organizations would also reduce the transaction costs of investors: rather than having to contract with individual farmers, they can directly engage with the FO for quantity and quality needs.

Part of the reform of agriculture extension services includes the adoption of performance criteria for AEDOs. Their evaluation should include indicators measuring the increase in formal FOs/cooperatives/water user associations; the number of farmers who seek financing for irrigation adoption, and the number of farmers who register in irrigation schemes. Supporting the idea that a significant portion of AEDO time should be spent organizing farmers, Osewe et al. (2020) found that smallholder farmers who were members of a water user group were 30.9% (significance 1%) likely to use farmer-led irrigation practices. Another important performance measurement outcome for AEDOs should include indicators which measure quality control and grading of produce.

This reorientation of agriculture extension services would better align service delivery to the National Irrigation Policy's (2016) objectives of increasing land under sustainable irrigation farming; facilitating crop diversification and intensification; creating an enabling environment for irrigated agriculture; optimizing investment in irrigation development taking into account climate change; enhancing capacity for irrigated agriculture, and promoting a business culture in the small-scale irrigated agriculture sector.

Using mobile technology to alert farmers and share critical, technical, and timely information will complement the Lead farmer model and also compensate for the lack of access of AEDOs to remote farms (the last mile of extension services). Malawi had more than 30 publicly- and privately-run radio stations and about three-quarters of these had farming-related programs (Sigman et al., 2014). There is also an existing mobile phone-accessible system (Mchikumbe 212) that gives access to information on livestock production and marketing. Such platforms can be used also to spread and reinforce messages about the benefits of appropriate irrigation.

5.3 Impact of Reorientation

We assume two main impacts associated with the intervention:

- Five percent of farmers exposed to the intervention will invest in irrigation technology: about 56,300 of the total of approximately 1,125,000 in the target districts. This meets the targets of the National Irrigation Policy (2016) and the National Agricultural Investment Plan (2018) to increase the irrigated area by 43,700 ha in the medium term.
- During the dry season area under cultivation will expand from an average of 0.247 ha to 0.981 ha, as observed in the PRIDE project following adoption of irrigation. For the analysis, we assume (simplistically) that farmers switch completely from the average dry season cropping patterns to one of the crops as documented in section 4. Lack of data precludes a more complex analysis, but this simplified approach also enables us to highlight which crops may be more valuable under irrigation.
- There is no change to cropping pattern or area cropped during the wet season

The first parameter used (5% of uptake) requires further examination. While there is limited evidence specifically on the impact of extension workers on irrigation, literature broadly on the impact of technology adoption from extension points towards 5% being a plausible, if not lower bound value (see Table 7).

It is anticipated that the revamped extension services will stimulate farmer uptake of irrigation technology. LUANAR (2019), in a study of solar-powered irrigation systems in Karonga, Mchinji, Dedza, Chiradzulu and Chikwawa districts, found that sixty-six percent of the households participating in the irrigation schemes reported that they joined the schemes on their own while 20% joined after being encouraged by Government extension workers. Also, Mangisoni et al. (2019) studied the determinants of farmer uptake of rainwater-harvesting technologies and found that the frequency of extension visits explained approximately one third of the rate of adoption. These results are supported by Fisher et al. (2017) who concluded that Lead Farmers have a strong influence on follower farmers, when they themselves are familiar with and have adopted a technology. Based on a household survey in four districts (Lilongwe, Kasungu, Machinga and Zomba) in Malawi on the familiarity and adoption of conservation agriculture technologies via Lead Farmer, their adoption of minimum tillage is associated with a 15.7% higher likelihood that the followers were familiar with minimum tillage (1% significance), with similar results found for other interventions.

Table 7 presents a summary of uptake rates of irrigation and other technologies after exposure to extension services.

Table 7: Irrigation and technology uptake from extension exposure

Country	Stimulus, technology	Uptake rate	Reference
Tanzania, Mozambique, Zimbabwe	Extension officer, irrigation	4%	Wheeler et al. (2016)
Tanzania	Extension officer, irrigation	6.5%	Osewe et al. (2020)
Malawi	Lead farmer, mulching	9.4%	Ragasa (2019)
Malawi	Lead farmer, organic fertilizer	8.9%	Ragasa (2019)
Malawi	Lead farmer, inter-cropping	35.2%	Ragasa (2019)
Malawi	Extension officer, solar powered irrigation	20%	LUANAR (2019)
Malawi	Extension officer, Rainwater harvesting	34%	Mangisoni (2019)
India	Mobile extension services, irrigation	60%	Cole and Fernando (2016)

5.4 Costs

Costs fall into three broad categories: 1) the costs associated with the intervention changing and increasing the number of extension workers, 2) irrigation infrastructure and maintenance, 3) the marginal change in costs associated with greater area of cultivation.

5.4.1. Extension Worker Costs

The costs incurred for increasing the number of AEDOs and their mobility include training and salaries of new AEDOs, and a sufficient number of motor vehicles (motorcycles) to provide one for every 4 AEDOs. Seven hundred and fifty extra AEDOs will be hired, at a monthly salary of MK 79,440 (NAIP, 2018). They are expected to be trained at a cost of USD 2150 per AEDO (NAIP, 2018). Retraining takes place every five years.

Motorbikes are priced at USD 3000 (NAIP, 2018), and 34% are assumed to already have access to one (Government of Malawi, 2018). These are replaced every five years. Maintenance and repair has been costed at 15% of total cost and occurs in the third year following a purchase.

The costs incurred for intensification of extension services include incentives for LFs, which is an extra allocation of the FISP subsidy. According to the NAIP (2018), a voucher for legume seed costs USD 7.20/farmer; a voucher for maize seed USD 2.50/farmer, and a voucher for fertilizer USD 41.50/farmer. LFs receive one bag of each, totaling USD 51.20.

The annual cost of this category is relatively small, around MWK 580 million every year, except for every five years where new vehicles are procured where costs are MWK 978 million.

5.4.2. Irrigation Costs

With regards to the irrigation infrastructure, FAO (2014) estimates the fixed cost for a gravity system at USD 700/ha and operation and maintenance costs at USD 140/ha annually. The estimated lifespan of gravity-fed system is 12 years. Although irrigation raises yields, water use efficiency is very poor in most cases. Approximately ten times the amount of water actually consumed by the crop is used in gravity systems, for example, while motorized pump and treadle pump systems deliver 3-4 times the volume of water actually needed (Kadyampakeni et al., 2013). However, there is currently no incentive to use water efficiently, since it access to water that is priced, at a flat fee of MKW 1,000 per farming season, regardless of crop area. Total upfront investment is substantial, estimated at MWK 28 billion with ongoing maintenance costs of MWK 5.9 billion.

5.4.3. Cultivation costs of expanded area

This is typically by far the largest cost component of the intervention, though not in all cases. For this we use the data noted in the Table 4, in Section 4.2 to estimate the total costs for each crop. From this, we subtract the estimated costs of cultivation in the baseline scenario from the PRIDE report.[1] The net cost of expansion is then MWK 6.6bn (with a baseline area of 0.274ha without irrigation). The marginal cost per crop varies substantially from MWK 2,906 million for pigeon pea to MWK 31.2 billion for tomato per year.

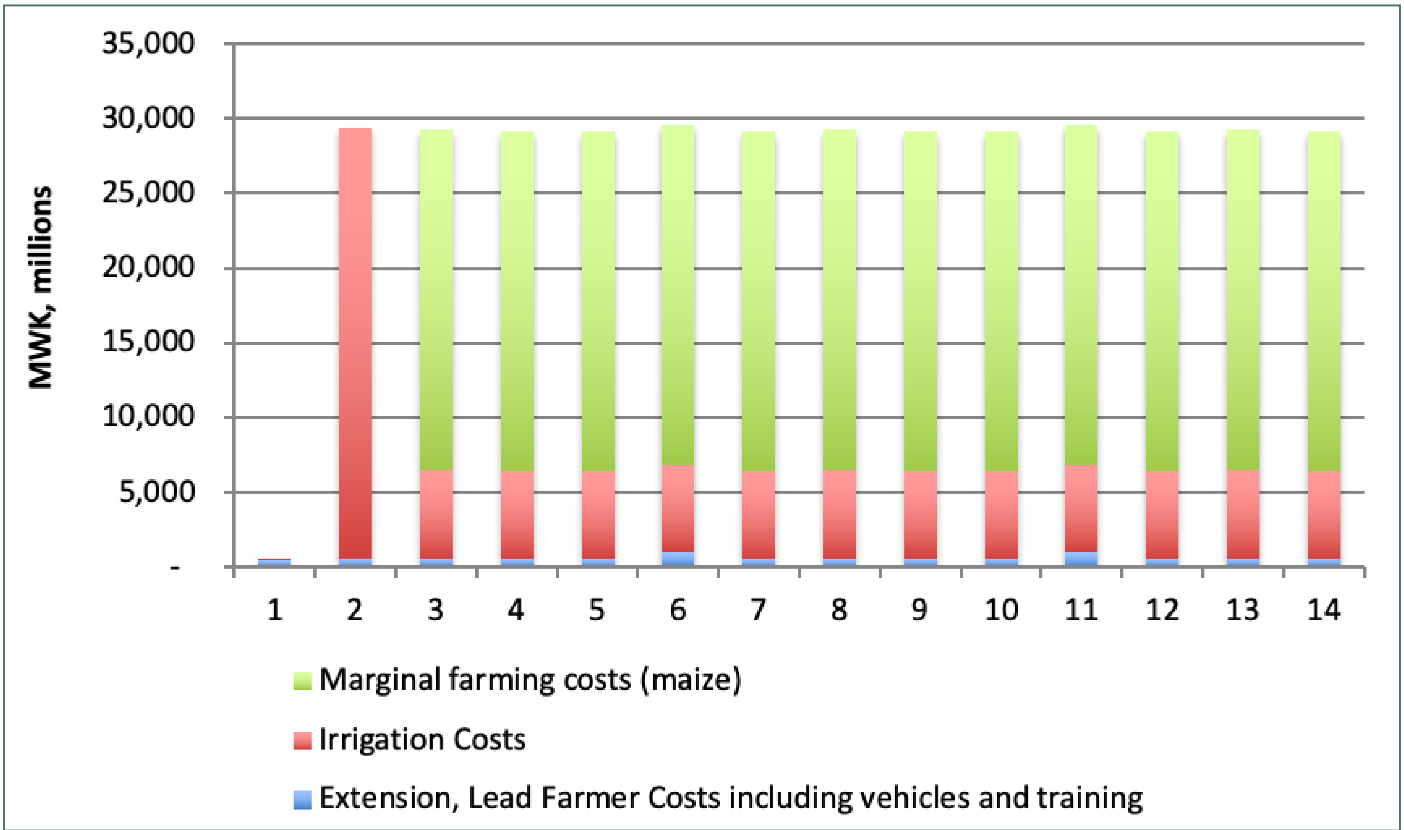
[1] The baseline crop mix is assumed to be 55% maize, 16% tomato, 11% mustard, 8% rice, 7% sweet potato with the remaining in rape and beans. The weighted average cost of cultivation for this mix is MWK 428,000 per hectare.

Table 8: Marginal costs of cultivation by commodity

Commodity	Marginal cost of cultivation per year (MWK, millions)
Maize	22,763
Groundnut	17,584
Pigeon Pea	2,906
Tobacco	20,554
Soybean	8,365
Cotton	6,961
Chillies	3,663
Wheat	22,763
Cassava	22,073
Rice	22,597
Paprika	6,292
Tomato	31,203

A profile of costs is depicted below assuming a complete movement towards maize. It is clear that the primary cost is the cost of cultivation associated with increased cropped area of maize. A substantial investment cost is also required for irrigation in year 2. In contrast, the additional cost of improving extension workers, including lead farmer incentives, is relatively small.

Figure 1: Costs of extension officer reorientation with a focus on maize



Sources: Estimates by the authors

5.5. Benefits

There are two anticipated benefits of irrigation uptake. First, there is the marginal change in output associated with change in cropping pattern during the winter season. On average, baseline crop area per farm during the winter season is 0.274 (PRIDE, 2020). The average cropping pattern across all farmers for this area is 55% maize, 16% tomato, 11% mustard, 8% rice, 7% sweet potato with the remaining in rape and beans with estimated revenue of MWK 1,254,000 per hectare at farm gate prices. As discussed above, irrigation allows farmers to expand the area of cultivation to 0.981 hectares. The marginal benefit is estimated as the new output for a given crop (marginal yield x farm gate price x 0.981 hectares) less the baseline output. Finally, we adjust output by the estimated extent of post-harvest losses (see Table 4).

Secondly, there are the avoided losses in yield variability resulting from inadequate rainfall during the wet season. The crops with the greatest area under cultivation during the rainy season are maize, pulses, and cassava. The difference in the downward variability from average output per hectare was used to calculate the avoided losses from the normalization of harvest that results from irrigation adoption. Table 9 presents crop yield variability in the wet season.

Table 9: Crop yield variability

Crop	Wet season variability	References
Maize	46.9%	Tamene et al. (2015)
Pulses	21.9%	ICRISAT (2013)
Cassava	14.6%	Moyo et al. (2004)

Table 10: Benefits of extension reorientation by crop

Commodity grown during dry season	Value of additional produce during dry season (MWK, millions per year)	Annual yield variability benefit during wet season (MWK, millions per year)	Total benefits (MWK, millions per year)
Maize	17,579	3,670	21,249
Groundnut	36,852	3,670	40,522
Pigeon Pea	16,349	3,670	20,019
Tobacco	59,331	3,670	63,001
Soybean	30,952	3,670	34,622
Cotton	10,013	3,670	13,682
Chillies	10,855	3,670	14,525
Wheat	47,688	3,670	51,358
Cassava	113,327	3,670	116,996
Rice	35,304	3,670	38,974
Paprika	75,667	3,670	79,337
Tomato	276,556	3,670	280,225

5.6 Summary of results

Assuming a 5% adoption rate for irrigation, the BCRs for a range of crops are shown in Table 11, using a discount rate of 8% with a time horizon of 14 years.

We can see that irrigation of both tomato and paprika would be beneficial, with BCRs of around 5-6 in both cases. Cassava, a staple crop, also sees a good yield increase and fairly good BCR of 3.3, but it must be born in mind that post-harvest losses of this crop are high and the growing season is relatively long. The returns to irrigated maize do not appear to pass a benefit-cost test.

BCRs are not scale-dependent, as costs and benefits per hectare are essentially constant (although the cost of extension workers per hectare does decline with scale, albeit this being a minor part of the overall cost). However, there is a degree of sensitivity to other factors, particularly commodity prices, as Table 12 shows.

Table 11: Summary of results

Commodity	Benefit, MWK millions	Cost, MWK millions	BCR
Maize	143,985	242,070	0.6
Groundnuts	274,583	204,175	1.3
Pigeon pea	135,654	96,753	1.4
Tobacco	426,906	225,910	1.9
Soybean	234,604	136,708	1.7
Cotton	92,714	126,430	0.7
Chillies	106,084	102,296	1.0
Wheat	348,010	242,070	1.4
Cassava	792,793	237,020	3.3
Rice	264,094	240,858	1.1
Paprika	567,696	121,534	4.7
Tomato	1,898,868	303,841	6.2

Table 12: Sensitivity analysis

Commodity	Base Case	Uptake Rate 40%	Increased area from irrigation 0.35ha (50% reduction)	Increase in irrigation costs by 50%	Increase in commodity prices by 20%
Maize	0.6	0.6	0.4	0.5	0.8
Groundnuts	1.3	1.4	1.1	1.1	1.7
Pigeon pea	1.4	1.5	0.9	1.0	1.8
Tobacco	1.9	1.9	1.6	1.6	2.3
Soybean	1.7	1.8	1.3	1.4	2.2
Cotton	0.7	0.8	0.4	0.6	1.0
Chillies	1.0	1.1	0.6	0.8	1.4
Wheat	1.4	1.5	1.2	1.3	1.8
Cassava	3.3	3.4	3.0	2.9	4.1
Rice	1.1	1.1	0.9	1.0	1.4
Paprika	4.7	4.9	3.9	3.6	5.7
Tomato	6.2	6.4	5.8	5.6	7.5

6. Cost Benefit Analysis: Irrigation Financing

6.1 Background

Financing for irrigation schemes is largely constrained on the supply side. In a systematic review, Merrey and Lefore (2018) examined financial services, i.e., credit, insurance, and savings products, aimed at supporting farmers' investments in small-scale irrigation (SSI) technologies. Credit from official sources is rare, and informal sources are expensive. Many studies also find that the lack of financial means to purchase equipment such as pumps is the most critical gap for several smallholders. For example, Otoo et al. (2018) in a study on solar pump systems in Ethiopia confirmed that there is a large gap between the size of agricultural loans generally available (mean loan size is $18.40) and the cost of a solar PV pump (smaller pumps range between $400 and $650). Lending terms for irrigation financing also tend to be unreasonable. Merrey and Lefore (2018) found that when microfinance institutions finance irrigation equipment, loans are repayable in 6 months and the interest charged works out to 30-50% per year. Otto et al. (2018) found interest rates from microfinance lenders are between 15 and 24% in Ethiopia.

Therefore, it can be concluded that in designing an irrigation financing instrument, the amount of credit being offered needs to be large enough to purchase the technology; it needs to be longer term than credit offered for seasonal agricultural supplies. It also needs to be affordable: the high cost of credit is frequently cited in the literature as a major deterrent.

Generally, there is a paucity of studies evaluating the effectiveness of financial instruments for irrigation, despite a wide variety of instruments being piloted by donors and NGOs, such as pay as you go, credit to cooperatives, renting of mobile pumps, rent to own, etc. What emerges from the literature, on solar-powered irrigation systems in particular, is that, owing to its cost structure, the upfront costs are prohibitive for smallholder farmers (those farming on 1 ha or less) and that risks can better be hedged by cooperatives or larger farms, with returns on investment realized in a shorter period of time.

Although the number of newly registered cooperatives has increased, they have been found to be unsustainable (FUM Diagnostic Study, 2016). The lack of access to finance contributes to the instability of Farmer Organizations (FO). The NAIP (2018) recognizes that access to finance remains a key constraint facing both small and estate farms. High interest rates, demanding collateral requirements and complex loan application procedures are the main access barriers as identified by the NAIP (2018).

The Farmer Organization Development Strategy (FODS), 2018 recognizes FOs as critical to agricultural commercialization. Among the strategic pillars in FODS is capacity-building in agribusiness and cooperative management; the promotion of irrigation development and agricultural zoning schemes based on ecological comparative advantages; the revitalization of advisory and extension service delivery and a move to market-oriented services; the promotion of land aggregation, agro-processing and value addition among FO members. The NAIP has allocated $15 million for strengthening FOs.

FOs play an important role in the marketing of agricultural produce. They can conduct market surveys. They link farmers to buyers and also undertake collective bargaining on behalf of members. They could also provide storage services and quality control for a fee (Me-Nsope and Nankhuni, 2018). They also can play an important role in the expansion of irrigation by helping small farmers overcome the financing barrier and spreading the risk.

The National Irrigation Policy (2016) recognizes the need to facilitate financing for farmers and the NAIP (2018) includes a policy target for 50 matching grants for irrigation investments. The Government of Malawi has had previous experience with matching grants and irrigation financing, namely for the treadle pump. There is also currently a matching grant program with AGCOM, a World Bank financed initiative, targeting cooperatives. The objective is to provide producer organizations with financing for capital investments with an aim of increasing productivity, quality and sale of agriculture products, improving post-harvest storage and processing capability in particular. The ratio of the matching grant is 30 (cooperative):70 (government).

There is evidence of the beneficial use of financing of irrigation projects in other developing countries. Of the 106 matching grant agricultural projects financed by the World Bank (up to 2017), one was just recently completed in India in 2015. This matching grant for irrigation development in the form of shallow tub wells (STW) was set at 50% to address the key constraint of a lack of capital to invest in irrigation and farm mechanization. A total of 100,000 STWs were installed in the project area exceeding its target by 11%. An additional 281,706 ha of land were placed under irrigation (World Bank, 2015).

Mullally and Chakravarty (2017) undertook a review of a matching grant program in Nicaragua supported by the Millennium Challenge Corporation for plantain producers. The program offered matching funds covering up to 30% of the cost of two years of inputs, extension services, and diesel-powered micro-sprinkler irrigation for individual farms. They found that the program increased plantain revenue by an average of 44% among beneficiaries, while expanding irrigated production area by 42%. However, the net economic benefit of the program was negative under most scenarios, and was only large when disregarding the fixed costs of irrigation equipment.

In a randomized experiment to estimate demand for solar-powered irrigation systems (SPIS) under three financial models – 'grant'; 'grant-loan' and 'grant-pay as you go' in Nepal, Mukherji et al. (2017) estimate that 20% of demand was for the grant model, 46% for the grant-loan model, and 34% for the grant-pay as you go model. Another notable finding was that, of the 65 applications, only one application was from a group, showing that the majority preferred to apply as single applicants. However, this seems to be a culturally-specific finding for Nepal and, since the Malawi experts consulted expressed the sentiment that farmers tend to work collectively, the organizational requirement will remain.

The Government of Malawi has in the past offered credit to farmers with a view to encouraging irrigation uptake. In 2002/2003, the Malawi Government distributed 908 Ajay treadle pumps to 908 smallholder farmers at the price of US$73.77. To allow farmers to afford the pumps, the government introduced a loan scheme under which the farmers were allowed to repay the loan in 3 instalments over a period of 3 years. The number of farmers increased to 1,133 and 1,272 in 2003/2004 and 2004/2005, respectively, indicating an average uptake rate of 18.5%. Sixty-seven percent were individual owners, and 36% acquired the treadle pump via loan, which was less than 10% interest. Fifty-four percent used the pump during the winter season; 31% during the dry season (Mangisoni, 2006).

6.2 Intervention scope and design

Given the existing situation in Malawi with financing, the intervention considered is the provision of matching grants or preferential loans. This enables farmers, farmer organizations or estates to afford irrigation equipment while avoiding future interest payments. The need for beneficiaries to provide a proportion of the funding themselves demonstrates to government that farmers are committed to the success of the scheme.

The World Bank undertook a review of its matching grant programs in the agricultural sector. This found that market failures must be properly identified and described (e.g., lack of demand for or supply of business development services, limited supply of financial services, limited bankable demand for financial services, uncertainty of outcome, lack of adoption of technological innovation, lack of information) so that appropriate interventions can be made. In the case of Malawi, longer-term liquidity is lacking because banks and financial institutions focus on short-term working capital, which carries less risk. Furthermore, most farmers lack collateral. Finally, financial institutions suffer from asymmetric information about the borrowers' credit risk profiles. The matching grant should target a specific investment, the eligibility criteria, and include technical accompaniment. Beneficiaries' contribution must be set high enough to ensure ownership and to attract commercial credit. Finally, there should be a focus on the cost efficiency of the use of matching grants for example, by comparing the matching grant size to its operating costs, benefits generated, etc. (Varangis et al., 2017).

Therefore, the intervention proposed is a matching grant/credit combination of financial instruments to stimulate uptake of irrigation technology among both estate and smallholder farmers:

Instrument 1: Matching grant for estate farms

The contributions would be 30:70 (farmer: government) or 40:60, with the government portion being an interest-free line of credit. This instrument is only available to estate farms greater than 10 ha, and their contribution must be made at the start of the project. Finally, the farmer contribution could be in-kind (e.g. provision of land, borehole, tank, etc.).

Instrument 2: Matching grant for farmer organizations

The contributions would be 20:20:60 (farmer: government: loan). Also suggested by experts was 10:30:60. Instrument 2 is available only to formalized farmer organizations, water user groups or cooperatives. The first 20% is from the FO and can either be paid upfront or in monthly installments (pay-as-you-go) from the time of agreement. The second 20% is a government subsidy. The 60% is a line of credit at an interest rate of 13.5%, with monthly repayments delayed until the first irrigated harvest.

The pay-as-you-go (PAYG) option spreads out payments, while allowing smallholder farmers to begin benefiting immediately. They also minimize risk for lenders, because the irrigation technology serves as collateral (Merrey et al., 2020). The PAYG period does not exceed 5 years, and there is no interest to be paid.

These financial instruments specifically target solar-powered irrigation systems. These have a high capital cost (making them difficult to afford without such financial help) but have the benefit of low operating and maintenance costs.

6.3 Impact of financing

It is assumed that the interventions generate an uptake rate of 10% for estate farms and 15% for farmer organizations. These are considered plausible point estimates based on the limited available literature. As discussed with the first intervention, the BCR is relatively insensitive to the uptake rate.

For estate farms this translates into an additional 43,885 hectares under irrigation, while for farmer organizations this is 187,357 hectares. The counterfactual dry season area cropped is assumed to be 47% of total area for estate farms (Deininger and Xia, 2017), which increases to 90%. For smallholder farmers it is the same as the first intervention (0.27 hectares increasing to 0.98 hectares). As before, we do not assume any change to wet season cropping, and examine the costs and benefits by a single commodity grown in the dry season.

6.4 Costs

Costs fall into three broad categories: 1) irrigation infrastructure and maintenance 2) the costs associated with monitoring and management of the financing instrument, 3) the marginal change in costs associated with greater area of cultivation.

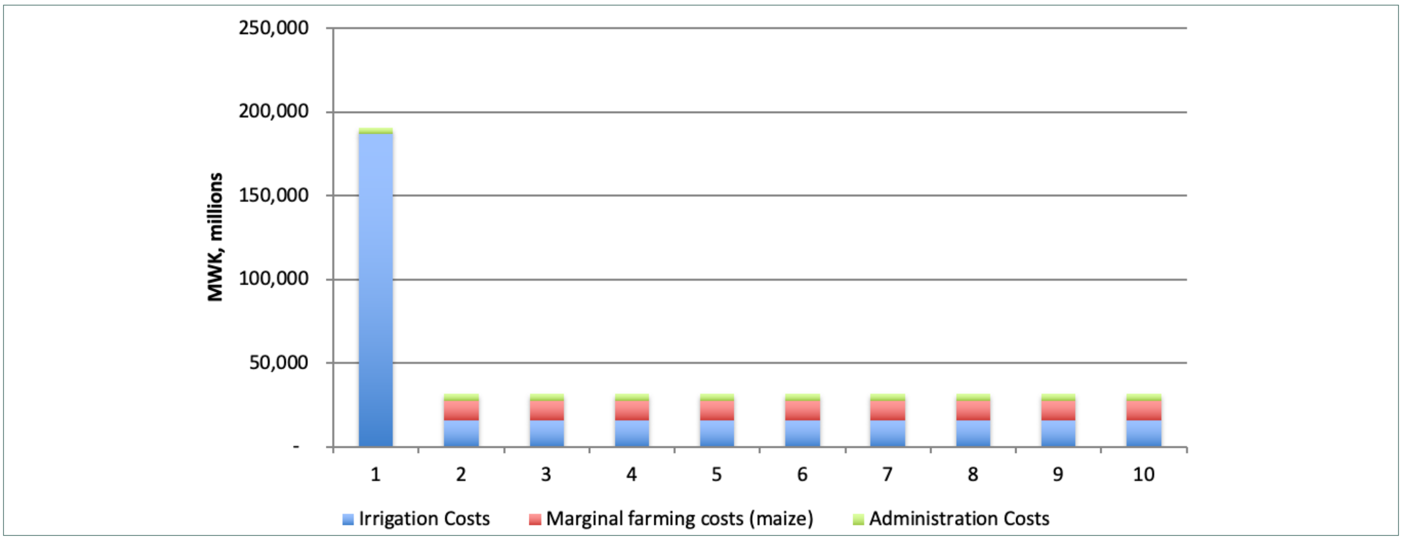
The average cost of a solar PV powered pumping system is $5,713 per hectare and includes a water storage facility (LUANAR, 2019). The cost could be higher or lower depending on water depth, but this was the average cost based on existing solar-powered irrigation systems (SPIS) in the region. Each scheme has an expected lifespan of 20 years, and therefore costs and benefits were calculated over the same period. The costs associated with maintenance and replacement of equipment has been estimated at 8.5% annually and includes the possibility of theft (LUANAR, 2019).

Rather than set up a new administrative structure for the matching grant scheme, it is proposed that the new functions be housed in an existing network like rural banks. There is nevertheless an administrative cost of the program, associated mainly with monitoring and auditing, as well as the cost of promotion/sensitization, which we assume is 2% of upfront investment costs annually.

The extra cultivation costs are as described above in Table 4. There are additional costs associated with promotion activities, water use fees and opportunity cost of dry season farming but these total less than 0.5% of the costs.

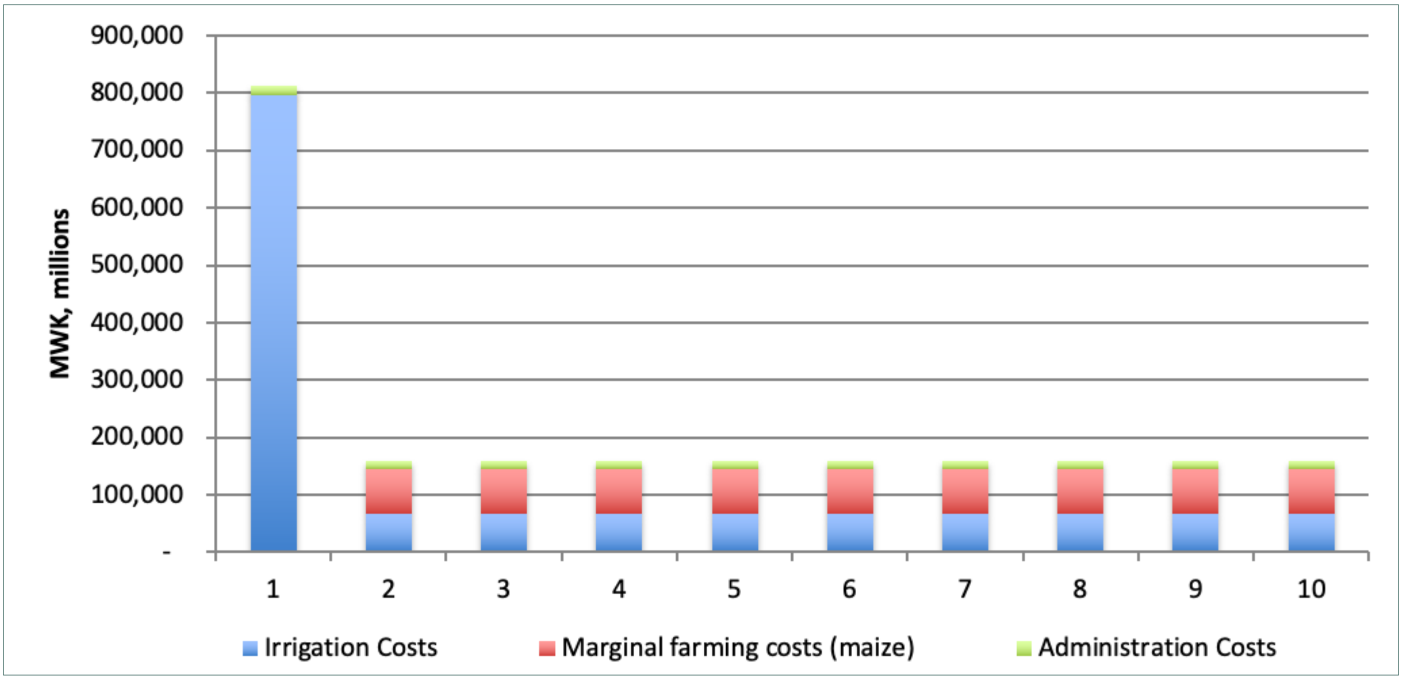
The cost profiles for these interventions are presented in Figures 2 and 3 for estate farms and farmer organizations respectively, assuming a complete shift to irrigated maize. While the absolute magnitude differs, the broad profile of both is similar. Irrigation infrastructure costs, particularly the initial investment, are substantial. This reflects the large assumed costs per hectare of solar irrigation, estimated at around USD 5,700 per hectare. Note that even this high cost is substantially lower than the upfront investment reported in the irrigation master plan of USD 18,500.

Figure 2: Cost profile for financing and matching grants for solar irrigation, estate farms



Note: cost profile is assumed to continue for 20 years, but is truncated at year 10 since the profile is the same each year

Figure 3: Cost profile for financing and matching grants for solar irrigation, farmer organizations



Note: cost profile is assumed to continue for 20 years, but is truncated at year 10 since the profile is the same each year

6.5 Benefits

The estimation of benefits is as per the first intervention: increase in output associated with irrigation during dry season, and reduction in variability during wet season. For estate farms the variability reduction is applied to maize, tobacco, pulses and groundnut. There is also a potential benefit from those who switch from currently diesel-powered irrigation system to a solar one. In the Mukherji et al. (2017) experiment in Nepal, 84% were already using irrigation technology (i.e. diesel and electric pumps). The authors concluded that the farmers who were attracted to these financial instruments were already knowledgeable about irrigation and its benefits, had already invested in irrigation schemes, and wanted to reduce the long-term costs of irrigation. Unfortunately, no evidence could be gleaned from the literature or government documents about speculative switching rates among Malawian farmers. Thus we ignore this benefit in further calculations. Table 13 presents the annual estimated benefits.

Table 13: Annual benefits of financing for solar irrigation

	Estate Farms			Farmer Organizations		
Commodity	Value of additional produce (MWK, millions per year)	Annual yield variability benefit (MWK, millions per year)	Total benefits (MWK, millions per year)	Value of additional produce (MWK, millions per year)	Annual yield variability benefit (MWK, millions per year)	Total benefits (MWK, millions per year)
Maize	5,334	2,950	8,284	58,528	12,218	70,746
Groundnut	19,124	2,950	22,073	122,696	12,218	134,914
Pigeon pea	4,455	2,950	7,404	54,435	12,218	66,652
Tobacco	35,207	2,950	38,157	197,540	12,218	209,757
Soybean	14,903	2,950	17,852	103,053	12,218	115,271
Cotton	(79)	2,950	2,871	33,337	12,218	45,554
Chillies	524	2,950	3,473	36,142	12,218	48,359
Wheat	26,877	2,950	29,826	158,774	12,218	170,992
Cassava	73,840	2,950	76,789	377,315	12,218	389,533
Rice	18,016	2,950	20,966	117,543	12,218	129,761
Paprika	46,895	2,950	49,845	251,929	12,218	264,146
Tomato	190,626	2,950	193,576	920,777	12,218	932,995

6.6 Summary of Results

The results of the analysis are presented in Table 14 below. Results are broadly consistent across both estate farms and farmer organizations. The main takeaway is that the high cost of solar irrigation pumps makes achieving positive NPV investments challenging. Tomato, paprika and cassava appear to be the only commodities that would yield more benefits relative to costs under solar irrigation pumps.

Sensitivity analyses are presented in Table 15 below, only for estate farms. The results from farmer organizations (unreported) are broadly similar. The results show that uptake rates do not affect the BCRs. However, other factors such as the expansion in cropped area, irrigation costs and commodity prices do have an influence on BCRs. The relative rank of crops does not change across the sensitivity analyses.

Table 14: Summary of Results for Financing Instruments for Solar Irrigation

	Estate Farms			Farmer Organizations		
Commodity	Benefits (MWK, millions)	Costs (MWK, millions)	BCR	Benefits (MWK, millions)	Costs (MWK, millions)	BCR
Maize	81,335	494,476	0.2	694,594	8,584,633	0.1
Groundnut	216,720	458,101	0.5	1,324,607	2,193,664	0.6
Pigeon pea	72,698	290,500	0.3	654,403	1,413,738	0.5
Tobacco	374,629	478,964	0.8	2,059,427	2,290,748	0.9
Soybean	175,276	393,341	0.4	1,131,746	1,892,304	0.6
Cotton	28,184	383,476	0.1	447,258	1,846,396	0.2
Chillies	45,627	360,310	0.1	528,428	1,738,594	0.3
Wheat	292,840	494,476	0.6	1,678,824	2,362,930	0.7
Cassava	753,930	489,628	1.5	3,824,491	2,340,373	1.6
Rice	205,848	493,312	0.4	1,274,011	2,357,516	0.5
Paprika	534,652	378,776	1.4	2,804,089	1,824,526	1.5
Tomato	1,900,557	553,768	3.4	9,160,278	2,638,845	3.5

Table 15: Sensitivity analyses of financing instruments of estate farms

Commodity	Base Case	Uptake Rate 30%	Total cropping area during dry season 65% of available land (instead of 90%)	Increase in irrigation costs by 50%	Increase in commodity prices by 20%
Maize	0.2	0.2	0.1	0.1	0.3
Groundnut	0.5	0.5	0.3	0.3	0.6
Pigeon pea	0.3	0.3	0.1	0.2	0.4
Tobacco	0.8	0.8	0.5	0.6	1.0
Soybean	0.4	0.4	0.2	0.3	0.6
Cotton	0.1	0.1	(0.0)	0.0	0.2
Chillies	0.1	0.1	(0.0)	0.1	0.2
Wheat	0.6	0.6	0.4	0.4	0.8
Cassava	1.5	1.5	1.0	1.1	1.9
Rice	0.4	0.4	0.2	0.3	0.6
Paprika	1.4	1.4	0.9	0.9	1.8
Tomato	3.4	3.4	2.4	2.6	4.2

7. Conclusions

Irrigation opens up the dry season for cultivation on a grand scale, comparable to rainy season harvests. It also stabilizes wet season cultivation, insuring yields against variable rainfall patterns. As such, it can provide a good opportunity for farmers – particularly the very large number of smallholders in Malawi – to increase their income and standard of living.

Two interventions were considered as ways to increase the area under cultivation near the lake shore and in the Shire river area:

1. Reorientation of extension services
2. Use of financial instruments, particularly matching grants, to help finance solar-powered irrigation schemes

Crops vary in their response to irrigation and therefore some are better choices than others for dry-season cultivation. However, this is not the only factor; unless the additional harvest is for direct consumption (highly unlikely), then it must have a high enough market value to justify its cultivation, and there must be a viable way to get it to market. An added complication is that many crops have very high post-harvest losses, further reducing their attractiveness.

Agricultural extension services in Malawi are currently inadequate. There are not enough extension workers to reach farmers, they need to be better trained and they also need more motorcycles to be able to travel to farms. They currently work through a network of Lead Farmers, a system which can be very useful and in this case needs to be revitalized. Improving these factors is assumed to increase the area under dry-season cultivation by 5%, which is likely to be the bottom of the actual range. The benefits which accrue will depend upon the crop cultivated. Improving extension services would of course also have other benefits to farmers, who would then receive better advice, but these additional benefits have not been estimated.

Irrigation financing is necessary in many cases because the preferred option of solar-powered pumps is unaffordable to many farmers. This is particularly true of the many smallholder farmers, who predominate, with an average plot size of approximately one hectare. Because it is often difficult for them to access funding and they may be unwilling to bear the risks, we consider the option of providing preferential from the government to Farmers Organizations that can spread the risk and help to get members' produce to market at favorable prices. The proposal is for a 20% farmer contribution (which can be in kind and on a pay-as-you-go basis) and 20% government subsidy and a 60% credit line at 13.5% interest, with repayments starting after the first harvest. This compares very favorably to commercial interest rates. At the same time, we consider a parallel intervention for estate farms, with the farm making a 40% contribution and the government providing interest-free credit for the other 60%. We assume a minimum take-up of 15% for FOs and 10% for estate farms.

The main takeaway from this cost-benefit analysis is that policy makers need to pay very close attention to costs of irrigation technologies and the choice of commodities promoted. Tomato, paprika and to a lesser extent cassava appear to fare well under irrigation, with gross margins large enough to cover the cost of irrigation investments studied in this report. The high returns to tomato in Malawi have been documented elsewhere in the literature, so it seems like this finding is relatively robust (Fandika, Kadyampakeni and Zingore, 2012; Kadyampakeni et al., 2015).

Different irrigation technologies have different costs and cost profiles. Our findings show, unsurprisingly, that relatively inexpensive gravity irrigation generates larger BCRs than more expensive solar. The types of irrigation schemes envisaged in the Irrigation Master Plan are substantially costlier, making it much less likely for them to achieve positive return on investment, given the current state of agriculture in Malawi.

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The Malawi Priorities Project

2021

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Stimulating farmer uptake of irrigation technology: a cost-benefit analysis