The Malawi Priorities Project

A Cost-Benefit Analysis of Environmental Management and Disaster Risk Reduction 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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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.

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Contents

1. INTRODUCTION

Malawi has faced continual and compounding disasters over the last few decades, with The Intergovernmental Panel for Climate Change's (IPCC) Fifth Assessment Report (AR5) identifying the country at high risk to the adverse effects of climate change. Malawi's high level of vulnerability can further be attributed to other geo-climatic factors such as the influence of El Niño and La Niña phenomena on climate variability along with the variability in water levels in the country's three major lakes. Other contributing factors which add to its susceptibility to disasters include rapid population growth, poverty, unsustainable urbanization, climate variability and change, and environmental degradation. The wide variety of natural hazards that the country is exposed to includes floods, strong winds, dry spells, cyclones, earthquakes, and landslides.

The impacts of the extreme weather events have been substantial – hindering people's lives, livelihoods, the country's economy and damaging infrastructure. The floods of 2015 resulted in losses estimated at US $335 million, while the drought that followed in 2016 resulted in an estimated loss of US $365 million, severely impacting the Malawian economy and increasing the poverty rate by almost one percentage point. (World Bank, 2018). In 2019, physical damage to the country was estimated at US$ 220 million as a result of Cyclone Idai.

Over the past five decades, Malawi has experienced more than 19 major flooding incidents and seven droughts. Mean annual temperatures have been consistently increasing, going up by an average of 0.9 degrees Celsius over the period from 1960 to 2006 (Vincent et al. 2013). There is a high level of variation between average annual rainfalls. While there were very high levels of rainfall in 1989, 1997 and 2015, by contrast, 1992, 2005, 2008 and 2016 were very dry. These fluctuations add to the issue of disaster management and relief planning given the wide spectrum of activities needed to build resilience.

This paper conducts cost-benefit analyses on two interventions that sector experts in the country noted are critical to improving Malawi's resilience to the two main disasters (namely floods and drought) that befall the country:

1. Early Warning Systems (EWS) Improvements
2. Expanding the use of climate smart agriculture practices to address drought and floods

For the first intervention we make use of a recently completed World Bank assessment of gaps in Malawi's disaster risk response framework following the 2019 floods associated with Cyclone Idai. The approach adopts a real-option analysis framework that considers not only the expected losses, but also the tail risk of outcomes. For the second intervention we update existing reports that have recently examined the costs and benefits of climate smart agriculture in Malawi which showed CSA options that combined soil and water conservation management practices based on the principles of conservation agriculture (CA), improved varieties were economically viable and worth implementing for risk averse smallholder farmers (Mutenje et al. 2019).

The results suggest that both interventions have high Benefit-Cost Ratios (BCRs) indicative of their cost-effectiveness. Early warning system improvements in Malawi yields a BCR of 15.8 indicating that this intervention is an excellent investment, triggering early action and enabling better disaster preparedness. Climate smart agriculture interventions combining integrated conservation agriculture with crop diversification, drought tolerant varieties and rice intensification yield a BCR of 3.0.

Overall, the results indicate that out of the two options, improvements in EWS are a more effective use of marginal resources compared to climate smart agriculture strategies. This is not to say that CSA should be overlooked, just that out of the two, EWS improvements should be prioritized by a welfare-maximizing decision maker with limited resources. The logic behind this finding is that successfully integrating CSA policies requires engaging and changing the behaviour of millions of smallholder farmers in the face of an important, but relatively slow acting disaster (drought). The scale of engagement required renders this intervention particularly costly. In contrast, EWS improvements require only modest additional costs, since the base infrastructure of EWS is already established. The scale of engagement required to enact change is large, but can leverage community level structures at much lower cost. The relatively acute and obvious nature of the disaster (flood) also lends itself to more rapid behaviour change, if sufficient warning is provided.

1.1. Disaster Profile

Malawi has one of the highest flood risks in the world, with risk (expected welfare losses from river floods) estimated at 1.2% of GDP (Hallegate et al. 2016). The concentration of population and economic activities along the great African Rift Valley explains its high exposure to flood damage. In 2015, Malawi experienced its worst floods in 50 years, followed by a drought in 2016 due to the strongest El Niño event in 35 years. Just these two successive events resulted in annual estimated losses of US$500 million across all sectors in the country and pushing many of Malawi's poor into food insecurity. During the El Niño-induced drought, nearly 6.7 million people (40 percent of the population), were affected and eventually classified as food insecure, of which 3.6 million were children. The poverty rate increased almost one percentage point, from 50.7 percent in 2010 to 51.5 percent in 2016. Estimates using the international poverty line of US$1.90 per day indicate that 69.2 percent of the population was classified as being poor in 2017, a higher proportion than in 2010. (World Bank, 2018).

More recently, in early 2019, the country was struck by Tropical Cyclone Idai which led to heavy rains and strong winds severely affecting 15 of Malawi's 28 districts, 2 of the 4 major cities, and an estimated 975,000 Malawians. Based on the Government's Post Disaster Needs Assessment (PDNA), physical damage to the country's capital stock totaled US$220 million. The input needed for recovery and reconstruction needs totaled US$370 million. Together this represented 5.8 percent of Malawi's gross domestic product. The scale of damage caused by Cyclone Idai can be estimated by the fact that a total of 109,000 hectares of crops were washed away impacting almost 2.3 million farm families. Climatic projections and models suggest that the severity and frequency of climatic shocks will continue to increase (Future Climate for Africa brief, 2017).

The impact of recurrent natural shocks has a direct and significant effect, increasing food insecurity, poverty, malnutrition and public health disease outbreaks. Disasters play an important role in increasing poverty of rural and urban households and can explain larger geographical distribution of poverty in the country. For example, the southern region of Malawi has the highest concentration of poor people and at the same time experiences most severe forms of disasters, such as flooding and droughts. Major disasters have had substantial budgetary impacts, resulting in additional unplanned expenditure, widening fiscal deficits and increased domestic borrowing and thus, in rising domestic interest rates and additional inflation (Benson and Mangani, 2008).

1.2 Underlying Factors

Vulnerability to weather-related shocks in Malawi is aggravated by poor access to timely and accurate climate and weather forecasts and early warnings. Limited resources including finances and lack of capacity affect the quality of weather forecasts in Malawi. Weather forecasts and early warnings are mainly produced in English, and not in the local dialects, and broadcast through selected communication channels, not always reaching a significant share of communities and decision makers. Farming decisions such as seeding, fertilizing, and pest control measures are all weather-dependent and can result in the full loss of the crop if, for example, seeding is not followed by rain. Flood early warnings are not issued systematically, and frequently fail to reach communities, with most flood victims taken by surprise. In spite of these structural systemic weaknesses, Malawi has advanced in some part building capacity in real time monitoring networks and higher resolution rainfall and flood forecasts.

Unplanned urbanization and poor building and infrastructure construction standards are also underlying factors of vulnerability. Although only 15.3% of Malawi's population live in urban areas, and its rate of urbanization is modest when compared with other African countries, Malawi's urban population is expected to almost triple, from 2.2 million in 2015 to 6.3 million by 2040. Urbanization is concentrated in four major cities—Blantyre, Lilongwe, Mzuzu and Zomba—where growth is mostly informal and unregulated, largely because of lack of adequate and affordable housing for the urban poor, lack of enforcement capacity, and weaknesses in land use planning and building codes. Public infrastructure, mainly transport infrastructure and schools, is affected almost every year during the rainy season resulting in closure and repairs. In rural areas, construction of schools is mainly done by local artisans with limited technical skills and lack of guiding manuals, regulation and standards. In parallel, transport infrastructure designs and construction methods lack risk-sensitive guidance and standards.

1.3 DRR Policy Framework

Malawi's Disaster Risk Management (DRM) policy landscape has been shaped by international frameworks, including the Sendai Framework and the African Strategies for Disaster Risk Reduction. These frameworks have informed the formulation of Malawi's overarching development planning document, the Malawi Vision 2063. The Malawi Vision 2063 acknowledges the recurring natural disasters and climate adversities that the country faces. It aims to develop systems to break the cycle of environmental degradation and increase resilience. These include integration of disaster risk reduction and financing into sustainable development and planning as well as the promotion of climate change adaptation, mitigation, technology transfer and capacity building for sustainable livelihoods through Green Economy measures.

DRM is defined as a cross-cutting theme which aims to reduce vulnerability and to enhance the resilience of Malawi's population to disasters and socioeconomics shocks. The National Resilience Strategy (draft) is intended to inform the implementation of the DRM activities under MGDS III, with a particular focus on breaking the cycle of food insecurity.

Additionally, the National DRM Policy (2015) provides strategic guidance for the effective mainstreaming, implementation and coordination of DRM programming at all levels of sustainable development policy and planning. This policy highlights a set of key priority areas and strategies to increase Malawi's resilience to disasters. However, the absence of the DRM Bill has paralyzed the implementation of the policy especially in relation to financing for preparedness and response. This is a significant gap which needs to be addressed by the policy makers.

The National Resilience Strategy (NRS, 2018-2030) facilitates a paradigm shift, with greater emphasis on a multisectoral perspective to build resilience to break the cycle of food insecurity and to facilitate the provision of other humanitarian support in the event of disasters. It is centered around four pillars, including: (i) resilient agricultural growth; (ii) risk reduction, flood control, early warning and response systems; (iii) human capacity, livelihoods, and social protection; and (iv) catchment protection and management.

Climactic projections and models suggest that the severity of frequency of climactic shocks will continue to increase – however, lack of capacity and resources make risk reduction, preparation and response against drought and extreme rainfall events more challenging. Given the multiple challenges Malawi faces in terms of disaster risk, the range of effective measures to improve disaster preparedness, reduce disaster risk and mitigate the effects of climate change is also extremely large.

Some measures to mitigate the impact and severity of flooding would include improved infrastructural guidelines, proper management and enforcing of zones and buffer zones, enhanced solid waste management, enforcement and constructions of proper water pathways and channels, especially in urban areas.

Risk assessment of districts which are geographically prone to floods is necessary so that the disaster response is more proactive than reactive. Community level disaster preparedness capacity also needs to be enhanced and improved – possibly by training and establishing local structures as primary responders to disasters, Including appropriate infrastructure and equipment for timely response such as purposively built evacuation centres and search and rescue equipment. Specifically, the capacity of district and community civil protection committees needs to be improved.

The other major issue is of existing early warning systems. The EWS in Malawi is under-resourced and under-utilized with the data not widely available or accessible to communities. While data are transmitted daily from staffed stations, these data are only incorporated into the central database once per month, limiting their real-time utility. While the DCCMS does try to relay information to the public via different media, it is not adequate, timely and often the quality of information is poor.

Seasonal forecasts, which help farmers plan their crops, are available but only used to a limited degree. Hydrological monitoring and forecasts have recently been improved for the Shire river basin but remain unavailable for much of the country. The main forecasting system is based on a 1D model which is supplemented by a 1D/2D model, and very often the results are not easily accessible to the stakeholder in real-time. Further, due to frequent changes of the basin, there is a need to update the system to conform to the geomorphic changes. Challenges in forecast verification exist since the hydromet network that the system was modelled with does not fully cover the entire basin and critical forecast locations. There is a significant need for the forecasting system to be well understood at the community level since they are the primary response during flooding period.

2. RESEARCH PROCESS

The National Planning Commission (NPC), with technical support from AFIDEP, and the Copenhagen Consensus Center (CCC) are conducting the Malawi Priorities project – 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.

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. As a first step, Malawi Priorities drew questions from the NPC research agenda that could be answered by CBA. 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 research questions. The validation process finished in July 2020.

2.1 Interventions Considered and Researched

The project team completed a scan of all potential interventions which were beneficial in reducing the risk of disasters as part of the process of narrowing down on interventions for cost-benefit analysis. A thorough literature review of DRR interventions was undertaken in order to ascertain the extent to which Malawi had integrated the intervention in its strategic plan; based on previous Copenhagen Consensus research, whether the interventions were considered high social return on investment, and whether there were similar country examples, pilot/demonstration projects, and/or the results of randomized trials that could inform the selection and design of the interventions to be analyzed. We also interviewed several local experts, including:

- **Samuel Gama,** *Principal Mitigation Officer, Department of Disaster Management Affairs (DoDMA)*
- **Fyawupi Mwafongo,** *Chief Relief and Rehabilitation Officer, Department of Disaster Management Affairs*
- **Patrick Likongwe,** *Project Manager (Leadership for Environment and Development (LEAD) Southern and Eastern Africa*
- **Malawi Priorities Reference Group**

The intervention selection process starts with a wide universe of potential interventions drawing from literature, stakeholder interviews and advisor input. From here, the prioritization of interventions takes in a number of considerations. Though there is no mechanical formula for selecting interventions, 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.
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 Disaster risk reduction interventions 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 above.

The interventions selected for cost benefit analysis are noted below:

- Early Warning System Improvements – this combines last mile enhancements with overall improvements as noted by the PDNA
- Climate Smart Agriculture facilitated by extension workers – this intervention combines the two agriculture focused high priority interventions noted above

Table 1: Intervention Screening Process

Interventions considered	Sector expert priority	High BCR or cost-effectiveness	Addresses a problem of sufficient size	Significant gap in current coverage of intervention	Availability of data	Overall
Improving community-based "Last-Mile" disaster management and response	Yes, noted by sector experts	Literature review suggest BCR of 3.5 in Nepal (White and Rorick, 2010).	Village Civil Protection Committees are poorly trained in disaster management practices	Only around 40% of the communities are involved in communication and dissemination of weather and climate information.	Yes	High
Enhancing Early Warning systems capability	Yes, noted by sector experts	Literature review suggests BCR of 15 in Kenya (Barrett et al. 2021) while previous research by CCC indicates BCR of 20.8 in India.	EWS in Malawi is under-resourced and under-utilized with the data not widely available or accessible to communities.	According to the 2017 comprehensive baseline study of EWS in Malawi, only 42.74% of the population has access to improved weather forecasts and warnings.	Yes	High
Environmental management (Afforestation and land use)	Yes, damage to the environment and loss of protection by natural ecosystem due to deforestation was noted by sector experts.	Literature review suggests BCR of 4.3 (Kirui, 2018).	Yes, land degradation hotspots cover about half - 41 % (MoNREM, 2017) of the land area in the country			
	Around 7.7 million ha of degraded land (80% of Malawi's total land area) requires restoration.	Yes	Medium			
Climate Smart Agriculture (Provision of alternative crop types, early-maturing seed varieties, livestock)	Yes noted by sector experts	Literature review suggests BCR of 24 to 35 (Venton et al. 2010).	More than half of the districts in Malawi had more than 40% observable signs of soil degradation in the farmlands with low uptake of other crops such as pigeon peas, groundnuts and legumes.	Yes, only 53% of fields in Malawi use intercropping techniques.	Yes	High

Irrigation management	Yes, noted by sector experts (is being researched in another paper)	Research by CCC in Malawi indicates BCRs of between 1 and 5 depending on the crop.	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 (with DRR) for resilience	Noted by Sector Expert	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
Flood mitigation through catchment conservation	Yes, catchment degradation noted by sector experts in flood prone districts	Literature review suggests BCR of between 1 and 5 (Price, 2018).	With catchment degradation, large volumes of sediments washed down from catchments get deposited in rivers and lakes, thereby clogging the flow and leading to water flow disruptions especially in the Shire and its tributaries.	Nkula Dam, which is located in the middle section of the Shire River, is under massive siltation causing reduction of the capacity of the Dam reservoir from 14 m to about 1.5 m.	Yes	Low
Construction of dykes, river gauges etc	Yes, noted by sector experts	Literature review suggests low BCR of 0.7 (Burton and Venton, 2009).	To be completed	To be completed	Yes	Low

3. Intervention 1: Early Warning System Improvements

Malawi is highly vulnerable to the impacts of extreme weather events. On average, floods constitute about 75% of annual average losses estimated at $68M.[1] Floods of a different magnitude are happening almost every year. The 2019 flood was the most devastating in recent history, with damage estimated at $220M.[2] Using the modern terminology, the 2019 flood could be characterized as a "gray rhino": events that are obvious and highly probable (Wucker, 2016). Despite a random occurrence, extreme weather events are not random surprises like "black swan events" and can be predicted in time to prevent some of the flood damage.

The Early Warning System (EWS) plays an essential role in the mitigation of damage from natural disasters. According to Ferguson (2021), any natural disaster results from a combination of natural factors and the vulnerability of society. While the natural courses constitute a hazard, society's response to a natural disaster determines the exposure. Risk is a combination of hazard and exposure. Building resilience of the economy and society to natural disasters significantly reduces exposure to extreme weather events. Climate change amplifies hazards (frequency and intensity) of extreme weather events.

Thus, resilient rebuilding after the 2019 flood and continued adaptation to climate change should be a key element of any development strategy. It mitigates the long-term effect of changing climatic conditions. The EWS addresses an acute impact of extreme weather events and provides an essential but marginal reduction in exposure. The ultimate role of EWS is to help potentially exposed communities better prepare for the upcoming event: protect property, leave the potential exposed area for shelter, move livestock to the high ground, etc. In other words, EWS improves the last mile of disaster response on a community level.

Droughts and earthquakes are responsible for the remaining damage from natural disasters and were not included in the BCA of EWS. The mechanism of response to the risk of droughts is different. While the timely response to a flood warning is measured in hours, a timely response to droughts is measured in weeks. The soil moisture analysis plays a key role in drought risk assessment. The soil moisture index (SMI) is an important indicator to predict both droughts and floods. Use of remote sensing[3] for SMI and other relevant indices to better predict droughts and floods is an essential next step to reduce cost and increase the reliability of early warning systems.

Due to the inherently stochastic nature of the damage from natural disasters, the cost-benefit analysis relies on a probabilistic model with multiple uncertainties, including natural factors and the community responses to the EWS advisories. Therefore, the next sections that describe the methodology and the model are highly technical. A non-technical audience may find it productive to skip sections 3.1-3.4 and proceed to section 3.5 that summarizes results and provides sensitivity analysis.

3.1. Description of Methodology (Real options analysis)

The benefit-cost analysis of the early warning system (EWS) in Malawi applies the cutting-edge methodology for environmental risk calculation using the real options (RO) approach. This methodology provides estimations of risk-adjusted benefits and costs of the EWS and, therefore, calculates the benefit-cost ratio of EWS that is risk-adjusted. The methodology is described by Anda et al. (2009) and has been applied in some EWS BCA studies, including "Cost-Benefit Analysis of Adaptation Strategy in Bangladesh" and "Andhra Pradesh Priorities: Early Warning System" (2018) . (see also Golub et al. 2015, Golub et al. 2017, Golub, Brody, 2017, and Cooke, Golub 2020) .

When considering mitigation of disasters, policy makers are concerned with both the mean and the variance of potential damage. Obviously, the higher the mean (expected value) of damage, the more value there is in mitigation. While sometimes ignored, the same relationship holds for variance. Highly variable outcomes also increase the value of mitigation because of the reduced risk of low probability but very high impact events. Therefore, considering only the expected value of damages understates the potential value from EWS. The expected value needs to be 'risk-adjusted', i.e. the expected value of damages is augmented such that a risk-neutral policy maker would be indifferent to experiencing either probability distribution – the one with a lower expected value and positive variance or the one with a higher expected value and no variance.

Real options analysis estimates the value of the risk by applying approaches used for valuing options in financial markets. Specifically, the risk-adjusted probability distribution are equal to the sum of the expected value and the option value of avoided damage where the latter accounts for the risk (Golub and Brody, 2017; Golub and Golub, 2015; Anda et al. 2009). The value of the option is estimated by the equilibrium value that a hypothetical counterpart would require to issue an at-the-money call option to avoid all damages from the disaster in question (in this case floods). If we know the probability distribution of the damage, we can

[1] According to the knowledge platform for disaster risk reduction in 2014 the annual average damage from flood was $24.11M. The damage was recalculated for 2020 (scaled up proportionally to per capita GDP growth) (see: https://www.preventionweb.net/countries/mwi/data/)

[2] https://reliefweb.int/report/malawi/malawi-2019-floods-post-disaster-needs-assessment-report

[3] See, for example, Peter, B.G., Messina, J.P., Carroll, J.W., Zhi, J., Chimonyo, V., Lin, S., and Snapp, S.S., (2020).

compute the value of the option. We also can use an actual market price of a call option on an asset with a similar distribution of the historical price.

Disaster risk management includes three essential elements: hazard analysis, exposure and vulnerability (resilience) assessment, and benefit-cost analysis of available management options. In the case of floods, both hazard and exposure are described by the probability distribution. The mean and option value are calculated using a probabilistic model for flood damage described in the next section. The quantitative part of the EWS BCA has been carried out using existing studies that describe the past damage attributed to floods and expert estimates of the implied cost of the EWS.

3.2. The Model Description

Random occurrence of floods requires the application of a probabilistic risk model. The Malawi flood risk assessment model (FRAM-M) treats annual flood occurrences as independent events. This approach considers unlikely but still possible situations like two major floods happening at five years interval or at two consecutive years. The model better accounts for fat tail risk in this formulation and does not ignore "gray rhino" events.[7]

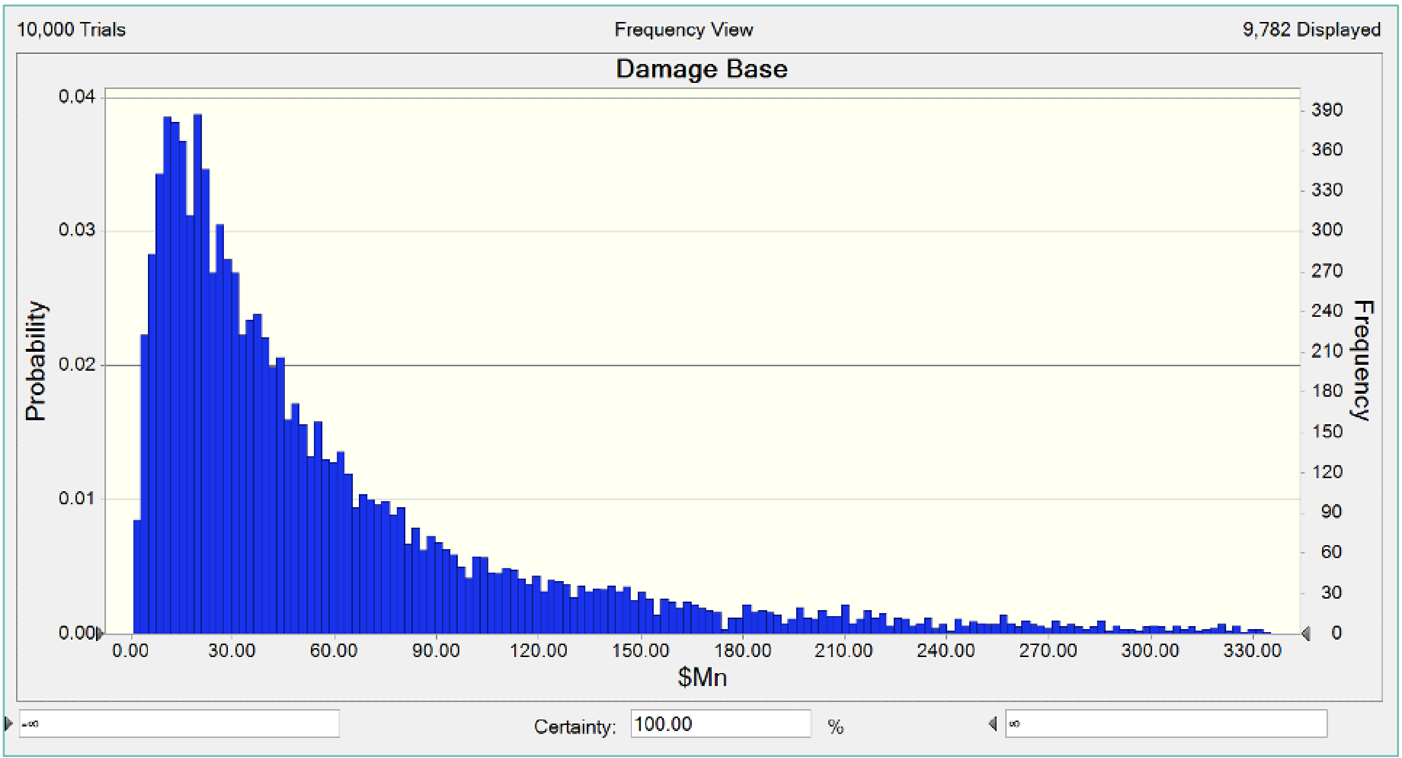
The base value of flood risk is calculated for 2020. The flood risk is a combination of flood hazard and exposure to flood. For the forward-looking analysis, we consider a continuous transformation of natural hazards associated with climate change. We apply an adjustment coefficient to the damage calculated on historical data using the same parameters as in (Golub and Golub, 2015; and Golub and Golub, 2018). The hazard adjustment coefficient ((1+k)t where k denotes an annual increase in hazard intensity) was calculated taking into account uncertain climate sensitivity and uncertain cumulative GHG emissions. For numerical analysis, we linked FRAM-M with DICE-2016 (for DICE description see: Nordhaus, 2013).[8]

Exposure and fragility of population and property could change over time. The index of exposure is calculated as a percent of an average value of the underlying parameter over the observed period. The annual increase of the exposure (the exposure coefficient) is calculated using a projection of population and GDP growth provided by the Copenhagen Consensuses Center.

3.2.1 Fitting Damage Distribution

Construction of the Probability Distribution Function (PDF) for damage from floods is a critical element of the technical analysis. The 2019 flood risk is treated as a 20-years return event that is equal to damage in the 95th percentile. The moving average of the flood risk is used as a proxy for the mean value. The moving average was available for 2014. It was recalculated for 2020 using GDP per capita growth as a scaling coefficient (see Table A.2 in the annex). The Probability Distribution Function is presented in Figure 1.

Figure 1: Probability Distribution for a base value of the annual flood risk (proxy for an annual flood damage)



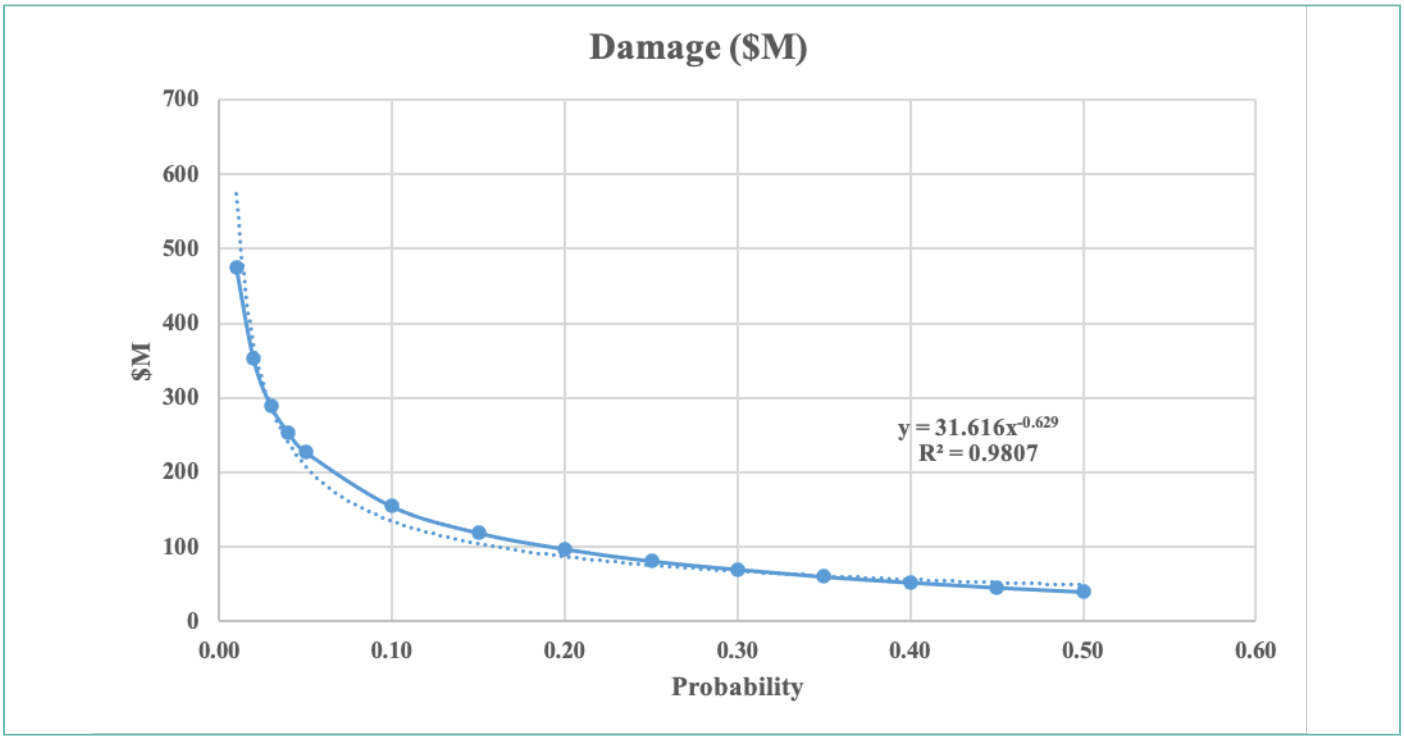
3.2.2 Exceedance Curve

The exceedance curve (Figure 2) is a common way of risk presentation. The vertical axis presents damage, and the horizontal axis presents the probability of its occurrence. The exceedance curve could be built by transposition and rotation of the reversed probability

[4] http://www.copenhagenconsensus.com/sites/default/files/golub_climate_change_adaptation.pdf
[5] https://www.copenhagenconsensus.com/publication/andhra-pradesh-priorities-early-warning-system-golub
[6] Golub, Brody (2017) provides a refined concept of application of the real options methodology for benefit-cost analysis.
[7] A "gray rhino" is a highly probable, a high impact, yet neglected threat.
[8] Coefficient k represents permanent shocks. Therefore, it is time invariant. For simplified calculations (without linking FRAM-M with DICE, k could be approximated with lognormal distribution with mean value 0.003 and SD about 0.0027).

of damage distribution (in other words it presents the same information as the PDF in Figure 1). The exceedance curve describes the probability that various levels of damage will be exceeded. For example, if we simulate 100 years of floods, the highest damage of about $500 million will have a 1% chance of being exceeded and happens once every 100 years, the damage of about $20 million has a 50% chance of being exceeded and happens every 2 years.

Figure 2: The Exceedance Curve



The Exceedance curve (EC) is a "derivative" of the PDF and plays the same role in risk analysis. The EC is a better tool for risk communication, while PDF is more practical for Monte-Carlo simulations.

3.3. Intervention Description and Costs Estimation

The 2019 flood devastated the Malawi economy and caused significant damage. The Malawi 2019 Flood Post Disaster Needs Assessment - PDNA Report, (GoM, 2019) formulates a reconstruction plan to restore and rebuild the DRM system. Strengthening of DRM should ensure resilient recovery by "building back better". The cost of rebuilding and strengthening is summarized in Table 13 of the PDNA report (Annexure: Table A.1).

Not all the cost calculated however, in Table 13 of the report is associated with the EWS. This analysis uses cost estimates adopted from the PDNA Report for both short term and midterm actions.

Short Term Costs

The total recovery and reconstruction needs for the DRM and EWS is US$ 10.9 Million. Priority is given to the following activities in the short term:

i. Conducting a gender-responsive disaster risk assessment (including capacity building for stakeholders) and zoning in 15 district and two city councils;

ii. Reviewing the implementation of the NDRF to ensure its alignment with the 2019 PDNA recovery framework;

iii. Monitoring the implementation of the National Disaster Recovery Framework, with particular reference to the incorporated 2019 PDNA recommendations;

iv. Supporting the development of evacuation plans in areas susceptible to disaster; and

v. Reviewing the disaster impact and needs assessment and reporting to include recovery needs (including building the capacity of stakeholders at national and local level).

These short-term recovery strategies are costed at MWK 1,937 million or US$ 2.6 million.[9] To be on the conservative side, for BCA, we consider all interventions listed as short-term recovery needs in Table A.1 as EWS improvements (Table 2). Actual cost directly related to the EWS improvements could be lower and the corresponding BCR will be higher.

[9] The exchange rate used is 1 USD = 745 MWK.

Table 2: Short-Term Actions (Adopted from PDNA Report)

Short term	Intervention	MWK (Million)
DRM high-risk sectors	Conduct hazard, vulnerability and risk assessments (including capacity building of stakeholders) and zoning of 15 district and 2 city councils	1117.5
DRR &EWS	Review the National Disaster Recovery Framework (NDRF) to incorporate 2019 PDNA issues	260.8
	Review the disaster impact and needs assessment and reporting to include recovery needs (including building capacity of stakeholders at national and local level; and from short to medium to long term	186.3
	Provide a return package to households in displacement sites	372.5
Total Cost		1937

Midterm cost

To meet medium-term recovery needs, the following strategies would be implemented:

i. The establishment and strengthening of a community-based flood early warning system, with particular consideration to the needs of women, children, the elderly and PWD;

ii. Establishing and training Civil Protection Committees (CPCs) in DRM;

iii. Training and strengthening local search and rescue teams and provide necessary equipment for males and females;

iv. Training contractors to conduct activities in accordance with the principles of building back better and smarter;

As well as potentially (only included in sensitivity analysis):

v. Conducting a comprehensive Building Damage Assessment (BDA) to inform the construction/rehabilitation of damaged infrastructure with on the-job training of contractors in resilient reconstruction (BBB) and improved construction when reconstruction schools; houses; health-posts or other infrastructure

These interventions cost MWK 1378 million ($1.850 million) (Table 3). The selection was done based on an expert review of improvements proposed in GoM/WB 2019 based on one of the authors' experience with other EWS assessments and literature. An annual operation cost was assumed at 15% of the cost of intervention.

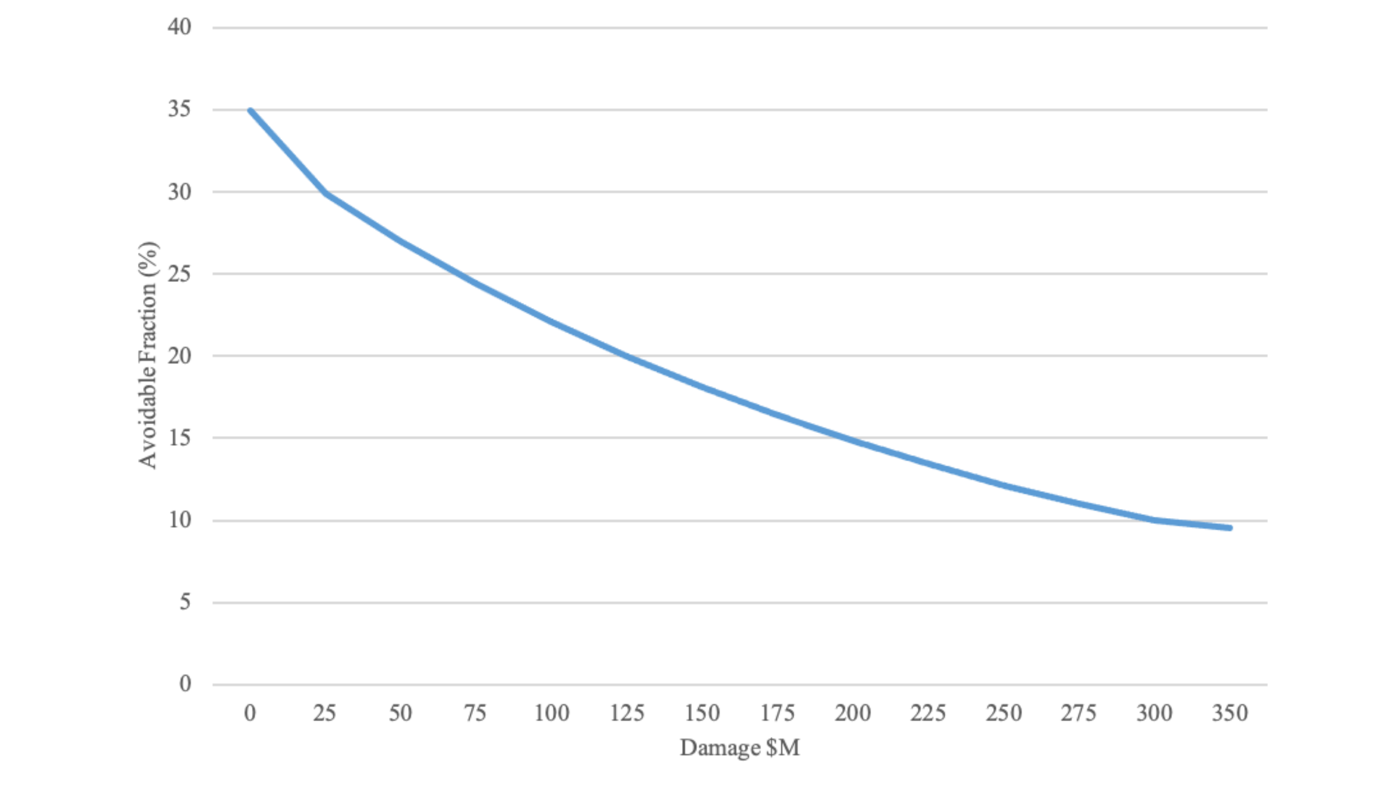
Table 3: Mid-Term Actions (Adopted from PDNA Report)

Mid term	Intervention	USD $ (Million)
DRR	Rehabilitate, establish and strengthen automated community-based flood early warning systems with consideration for the needs of women, children, the elderly and PWD	373
	Establish, revamp and train CPCs in DRM	261
	Train and strengthen local search and rescue teams for males and females and provide necessary equipment	745
Total Midterm Cost (base case)	Essential mid-term DRR requirements	1378
DRM and Infrastructure ***(Included for sensitivity analysis)***	Conducting a comprehensive Building Damage Assessment (BDA) to inform the construction/rehabilitation of damaged infrastructure with on the-job training of contractors in resilient reconstruction (BBB) and improved construction when reconstruction schools; houses; health-posts or other infrastructure	1490
Total Midterm Cost (base case plus DRM)		2868

3.4. Benefits

For a major flood like in 2019 (20-year flood), we estimate that about 10% of housing and property damage 70% of livestock and 80% of health damage could be avoided with proper response to EWS advisory (Rogers and Tsirnkov, 2011). For the minor event (2-year flood), a larger fraction of damage could be avoided. For example, up to 25% of total damage from the minor event (which has 10% of 2019 flood damage) could be prevented from responding to EWS advisory. For numerical analysis, we use the avoidable damage function presented in Figure 3. The figure presents an avoidable fraction of the total damage (vertical axis) as a function of the total flood damage (horizontal axis).

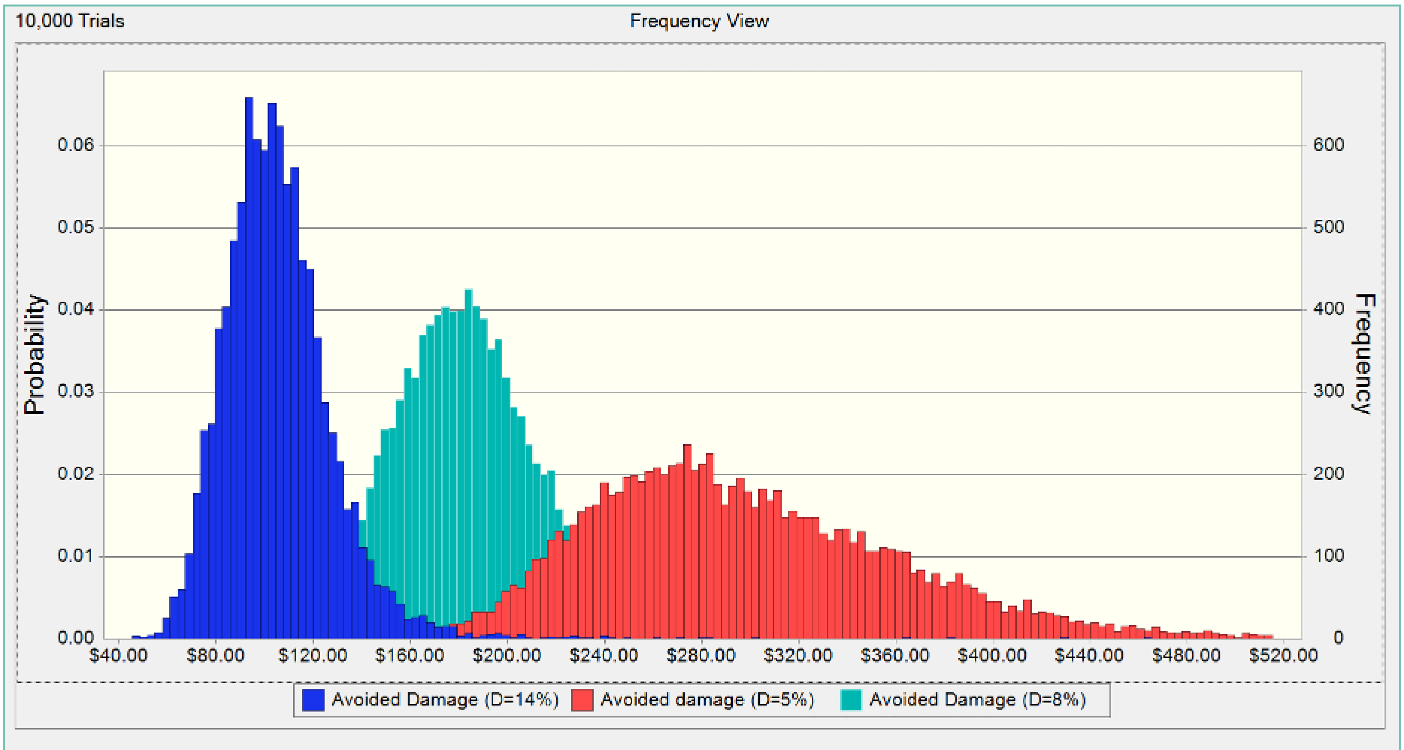
Figure 3: Avoidable Damage Fraction.



The avoidable damage could not be higher than 35% (optimistic estimate) and could not be lower than 10% (conservative estimate)

The last step of the benefit analysis is Monte-Carlo simulations to compute avoided damage probability distribution using FRAM-M.[10] The output is presented in Figure 4. It is easy to see that avoided damage is highly sensitive to discount factors. Higher discount rate results in lower expected avoided damage, mainly because extreme weather acts on long term horizons (decades). Higher discount rates essentially minimize the significance of these long run events, lowering the overall avoidable damage function. For each discount rate, the standard deviation is between 20 and 25% of the mean value, and a lognormal distribution could approximate the avoided damage distributions.

Figure 4: Probability distribution of avoided damage calculated with different discount rates



[10] The hazard increase is also uncertain. For the Monte-Carlo simulation, we use the annual average rate of 0.3% (mean value) described by lognormal distribution with a standard deviation equal to the mean.

To calculate the risk-adjusted benefits of EWS (the benefit equals the preventable damage – Table A.3) we use ROA, as explained in section 3.1. According to Anda et al. (2009), Golub, and Golub (2015), and Golub and Brody (2017), risk-adjusted benefits could be calculated as a sum of expected value and the option value. One should apply the Gram-Charlier option pricing formula in case of events with a significant tail risk (Anda et al. 2009).

3.5 Summary of Results

The BCR calculation is the next step of cost-benefit analysis. The result of the BCA is summarized in Table 4. The central estimate BCR is 15.8 indicating the high socio economic efficiency of the EWS improvements for Malawi.

Table 4: Results of Cost-Benefit analysis of EWS improvements in Malawi Time period of analysis: 2021-2100

Discount Rate	PV Cost (MWK Millions)	PV Benefits (MWK Millions)	BCR
5%	13,120	248,085	**18.9**
8%	9,429	149,073	**15.8**
14%	6,569	84,739	**12.9**

3.6 Sensitivity Analysis

For sensitivity analysis, the study considered an additional cost of EWS improvements that focus on disaster risk management. The actual effectiveness of the EWS will be revealed over time after required adjustments. For example, it may be necessary to implement some additional DRM infrastructure improvements that cost another $2 million: on-the-job training of contractors in resilient reconstruction (BBB) and improved construction when reconstructing schools, houses, health posts, or other infrastructure.[11] The BCRs obtained with this increased cost are given in Table 5 below.

Table 5: Sensitivity Analysis

Discount Rate	PV Cost (MWK Millions)	PV Benefits (MWK Millions)	BCR
5%	18,431	248,085	**13.4**
8%	13,143	149,073	**11.3**
14%	9,020	84,739	**9.4**

A high value of information justifies a relatively high BCR for EWS improvements. Even a rather conservative analysis presented in this paper yields very high BCR estimates. According to the literature, the BCR of EWS could reach a 500 mark (See Hallegatte, 2012; Subbiah et al. 2008). However, the lower estimate of the BCR could be 0.9 (Hallegatte, 2012). The BCR for EWS improvements in Andhra Pradesh, India was 20.9 at a 5% discount rate[12] - just slightly higher than in Malawi. However, information could be less useful if the population ignores it, or has no means to act using this information (no shelters, no evacuation routes, etc.). Therefore, the value of EWS should be considered as a part of a bigger picture that includes all sets of actions that must happen after the warning is issued.

Finally, EWS is not a substitute for a wide range of adaptation measures that should be embedded into the long-term economic development strategy (Golub and Toman, 2016). Even a relatively small but permanent productivity shock attributed to a negative impact of extreme weather events could tip the balance and hold up a district or the entire country in a development trap.

[11] See Table 13 from the "Malawi 2019 Flood Post Disaster Needs Assessment Report".
[12] https://www.copenhagenconsensus.com/publication/andhra-pradesh-priorities-early-warning-system-golub

4. Intervention 2: Climate Smart Agricultural Technologies (CSA)

4.1 Description of the best bet CSA technology for each region and the rationale

Climate-smart agriculture (CSA) includes farming practices that improve farm productivity and profitability, help farmers adapt to the negative effects of climate change and mitigate climate change effects (FAO, 2013), In Malawi, CSA practices are grouped under seven categories, namely: soil management, crop management (which includes use of drought tolerant crop/varieties and crop diversification), water management, livestock management, forestry, fisheries and aquaculture, and energy management (World Bank, 2018). Integration of soil, water and crop management CSA practices at farm scale is much more common in Malawi (Mutenje et al. 2019).

CSA technologies and practices considered in this paper are those that enhance food security, and at least one of the other pillars of CSA (adaptation and/or mitigation) (Mutenje et al. 2020; Hunter et al. 2020). The analysis of CSA practices and technologies is shaped around the agro-ecological zones emphasizing that CSA practices are not universally applied and that their application depends on a broader set agro-environmental variables and expected climate change and variability (Mutenje et al. 2020; World Bank, 2018).

In this paper, we analyse a combination of CSA strategies at farm scale which will be applied as the most proficient way of sustainably increasing adaptation and intensifying productivity in smallholder farming systems. The analysis builds on prior research (Mutenje et al. 2019) which conducted a cost benefit analysis of climate smart agriculture options in Southern Africa. It uses recent data which was then further updated and adjusted to ensure that it aligned to the Malawi Priorities research project for comparability. The basis for the calculations used in this analysis are from the above peer reviewed research paper published in the journal of Ecological Economics, 2019. Building on the above model, components including extension costs, and avoided tail risk and humanitarian aid costs were added to strengthen the analysis.

Table 6 below provides the description of the CSA practices that have been validated, agro-ecological regions they are most suitable and their potential adoption rates.

Table 6: Selected CSA technologies and practices and technologies for Agro-ecological zones key for food security in Malawi

CSA Practice & Technologies	Description	Adoption Rate	Region
Conservation Agriculture	Reduced tillage; (basins, ripping) crop residue management and intercropping; crop rotation with cereals and legumes	30%	Lower Shire Valley Lakeshore, Middle and Upper shire
Integrated soil fertility management	Fertiliser micro-dosing, Compost and manure management	60%	All
Small-scale irrigation	Manual irrigation using treadle pumps	30%	Lower Shire Valley Lakeshore, Middle and Upper shire
Crop diversification	Drought tolerant cropping systems	60%	All
Drought tolerant varieties	Drought tolerant crop varieties	60%	All
Rice intensification	Improved varieties, proper plant spacing, recommended fertilizer	60%	Lower Shire Valley Lakeshore, Middle and Upper shire
Agroforestry	Cultivation and use of trees and shrubs with crops	30%	All
Improved goat production	Improved goat breeds through hybridization and management	30%	Lower Shire Valley Lakeshore, Middle and Upper shire
Improved poultry production	Improved poultry breeds through hybridization and management	30%	All
Natural forest regeneration on farms, along rivers and streams	Natural tree regeneration on farms, along rivers and streams	30%	All

Source: *Adapted from CIAT; World Bank. 2018.*

Therefore, the CSA practices selected for cost-benefit analysis relate to agro-ecological zones and commodities focusing on the current production system and the most vulnerable food commodities to climate change impacts (in terms of impacts on quantity harvested and area suitability). Selection of the CSA practices builds on the previous research in the country. The selection process and evaluation process involved 4 important steps.

- Step 1: Desk review of the CSA being promoted in the four agro-ecological regions, listing the commodities, and cropping systems to which these practices have been applied their effectiveness in terms of loss reduction and adoption.
- Step 2: Validation of the identified CSA technologies by the in-country agronomist and other stakeholders promoting these technologies. The validation also involved evaluation of the smartness of the practices based on the three pillars of CSA (productivity, adaptation, and mitigation)
- Step 3: Participatory validation with farmers in the different communities where these have been implemented for at least five years. Different types of farmers (adopters, dis-adopters and non-adopters) were involved in the validation process to capture the opportunities and constraints in the uptake of the identified CSA practices).
- Step 4: Based on the on-farm trial data from experts and literature cost–benefit assessment of the identified combinations of CSA technologies was done.

Based on the above, the integrated CSA strategy including conservation agriculture, recommended fertilizer management, crop diversity, drought tolerant crop varieties and rice intensity was selected for analysis.

4.2 Integrated CSA Strategy

Description

This combination included Conservation Agriculture (CA), recommended soil fertility management (ISFM), crop diversity (CD), drought tolerant crop varieties (DT) and rice intensity (RI). The CSA technology and practices combinations were selected based on specific agro-ecological zones challenges (Benson, 2020) focusing on the current production systems (in term of cultivated area) and vulnerability to climate change impacts (Hunter et al. 2020). According to Mutenje et al. (2019) and Hunter et al. (2020), this strategy is more appropriate for all agro-ecological regions except the Highlands, where climate change impacts are increasing the risks of crop failure as a result of inadequate or erratic rainfall during the establishment of rain fed crops as well as increased frequency of in-season dry spells.

This CSA intervention entails production of drought tolerant staple grains varieties (maize, groundnuts, and beans) under minimum tillage using recommended spacing and fertiliser rates (Thierfelder, et al. (2017); Smith et al. (2016); Snap et al. (2014) as well as rice intensification. The adoption rate of this CSA strategy would be scaled up from 10% to 60% over the course of ten years, while the intensity of extension services is scaled up from 25% to 90% in the first three years, reducing back to 25% over the next two years (% represent number reached with extension as a function of all smallholder famers). The conservation agriculture adoption rate will be achieved through a combination of extension strategies such as field schools, on farm demonstrations, information, and communication technologies (ICT) and training & visits. All the benefits of this CSA contribute to reduced yield loss due to drought and flood impacts for smallholder farmers. This CSA strategy is also supported by the National Climate change Management Policy 2016 which emphasizes the importance of conservation agriculture, drought tolerant crop species and varieties for building resilient smallholder farming systems.

4.3 Cost Benefit Analysis

The projected climate change impacts for 2030 and 2050 on different production systems and crops was adopted in this technical paper (CIAT World Bank, 2018; Hunter et al. 2020). The overall effect of increased mean temperature decreased annual rainfall and erratic onset of the rainfall season in all the 4 agro-ecological zones of Malawi is reflected in the reduced yield (Hunter, 2020). According to CIAT-World Bank (2018), climate change is likely to reduce the yields of maize, groundnut, beans, cassava and potato by 2030 by 5.4%, 3.1%,0.6%, 2.1% and 8.1% respectively.

Based on these predictions, current area under production, current productivity the reduction in production for each crop and agro-ecological region was calculated over the ten-year period (from 2021 to 2030). The 2020 production year served as the base/ reference period. The Ministry of Agriculture and food security 2019/2020 production, area, productivity minimum farm gate price for each agro-ecological zone was used to calculate the economic value of the loss in yield due to climate change. Economic discount rates are set at 5, 8 and 14 percent.

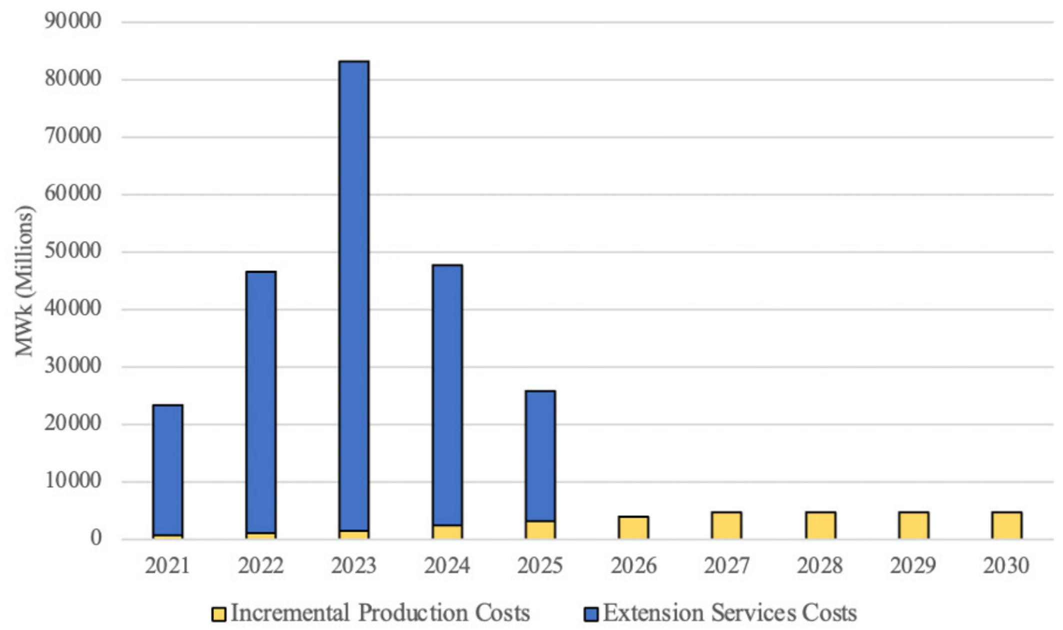
4.3.1 Costs

There are two costs associated with the intervention – firstly, marginal production costs associated with the CSA strategies relative to current traditional conventional practice and secondly extension costs to promote this CSA strategy. The information to calculate the marginal production costs are obtained from both published and unpublished sources including government data, literature, and expert estimation (Mutenje et al. 2019). Changes in quantity of commercial inputs particularly seed and fertilizer are the main components of the marginal production cost.

While farmers in Malawi commonly adopt fertilizer micro-dosing using a combination of fertilizer and manure known as Mbeya manure, it gives sub optimal yields compared to the recommended fertilizer rates. Further, most of the manure is made from various products and tends to be labour intensive particularly for women. Given these circumstances it becomes counterproductive to continue such practices. As a result we expect fertiliser costs to increase by 200% as farmers increase their application rate of both basal and top dressing fertiliser from the current average of 50kg per hectare to the recommended rate of 250kg per hectare (IHS 2019/2020).

Figure 5 shows the marginal cost changes due to adaptation to climate change.

Figure 5: Integrated CSA Strategy Costs



The second cost, agricultural extension costs are sourced from a study based on farmer-to-farmer extension (F2FE) for promoting climate smart agriculture (Franzel et al. 2018). In the F2FE approach, farmer trainers are provided education through extension programs. They then in turn coach and educate other farmers, typically 17–37 per year. This approach is found to be effective in improving ability to reach a large number of farmers. Another advantage is that compared to extension programs that provide training directly to groups of farmers, F2FE can reduce the cost of training each farmer by more than 50%.

Franzel et al. (2018) calculated that in the conventional approach, an extension worker trains 100 farmers per year at a cost of USD 65 per farmer. In the F2FE approach, an extension worker trains 20 farmer-trainers per year, each of whom trains 20 farmers, amounting to 400 farmers at a cost of USD 29 per farmer (in 2010 figures). The cost per farmer trained in the F2FE model is thus 55% lower than the cost in the conventional approach. The cost per farmer field school participant in current prices was estimated USD 32 according to this study. About 77% of the 4.2 million smallholder farmers in the lower Shire Lakeshore, and mid–elevation are targeted for integrated conservation, agriculture, crop diversification, drought tolerant, and rice intensification. Due to the knowledge intensiveness of this CSA strategy the extension cost is scaled up from 25% to 90% in the first three years, reducing back to 25% over the next two years.

4.3.2 Benefits

The analysis quantifies two specific benefits. Adoption of integrated conservation agriculture practice reduces yield loss due to climate change impact following Thierfelder et al (2017) and Mutenje et al. (2019). We focus on four crops which will benefit from CSA technology: maize, groundnuts, rice and sweet potato. The overall revenue weighted yield gain is relatively modest at 6.4%. This is in line with the fact that CSA raises the floor as opposed to the ceiling of yields. The overall expected yield increase is relatively modest estimated at 3.4% for maize, 2.6% for groundnuts. These are all accounted for as change in total production. The incremental benefits due to adoption of this CSA strategy are obtained by subtracting the total production value without CSA Strategy from the total value of crop production with the CSA strategy. The total production value is found by summing the of value of each the crop produce at the prevailing average market price. The analysis suggests that income benefits increase over 5 years rising from MWK 8,025 million to MWK 48,151 million at steady state.

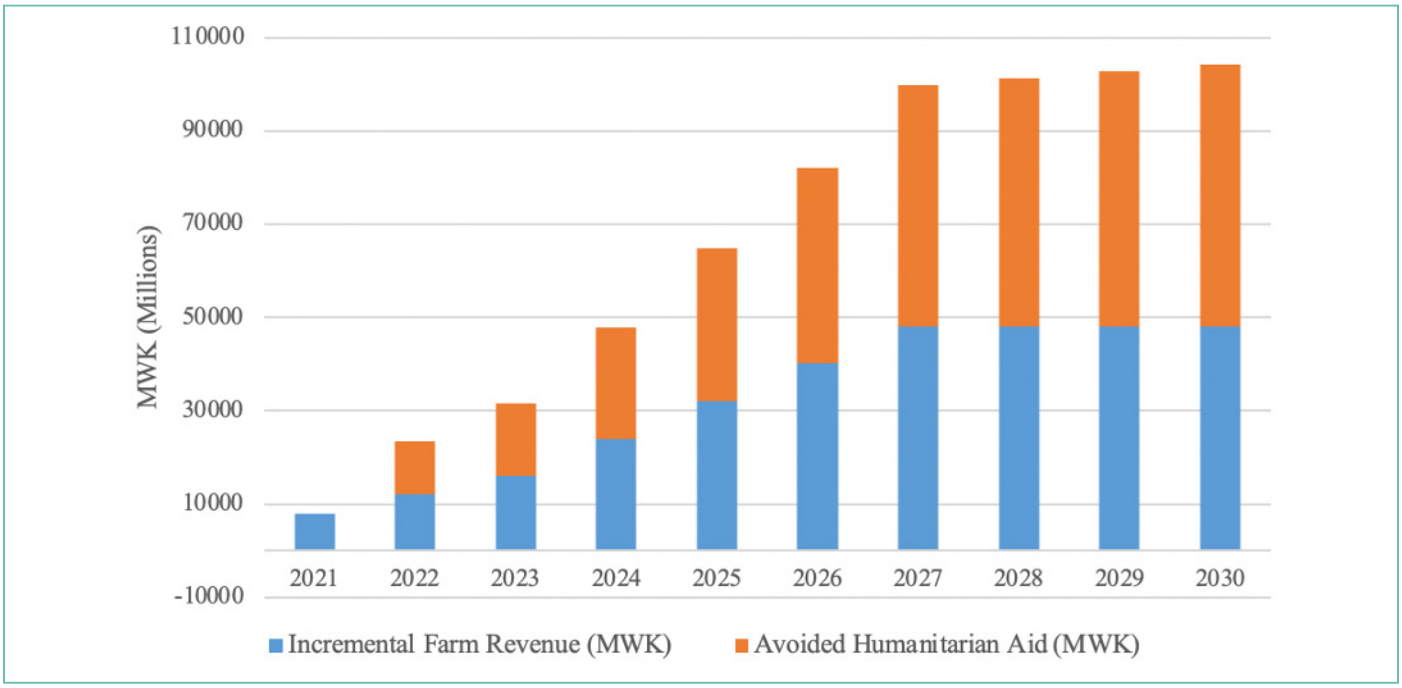
The second benefit is that of avoided humanitarian aid. CSA is essentially an insurance against droughts and floods and therefore it generates the greatest benefit when it is analysed as a response against some disaster (especially against a tail risk disaster such as severe drought). The probability of severe drought in Malawi is 20% or once every 5 years (Vulnerability Assessment Report, 2018). The socio-economic impact of droughts often leads to increased food insecurity causing the population to eat less, a general decline in living conditions and increased health issues. In the last 36 years, Malawi has experienced eight major droughts, affecting over 24 million people, the latest being the 2015-16 drought. The PDNA, conducted in May 2016, estimated the overall drought recovery needs for the country at about US$500.2 million, more than half of which are based on food security needs. It therefore stands to reason that the typical policy response of the Malawian government has been to supply humanitarian aid in the form of food aid and support.

The analysis is based on the expectation of a similar response for future events too. Therefore the benefit of avoided exposure to drought is the avoided cost of humanitarian aid. It is necessarily a stochastic function – happening with different probabilities and therefore the analysis assesses the expected value of probability at annual time intervals. The benefits therefore in Figure 6 are not the actual value of benefits per year but the expected value of benefits per year.

Taking the annual risk of severe drought at 20% or once every 5 years (Vulnerability Assessment Report, 2018), and with 75% of the population requiring aid at a per capita cost of US$32 , the total benefit of avoided aid is obtained averaging MWK 43,412 million per year (over a time period of 15 years).

[13] Per capita cost of food aid calculated based on the USD$ 217 million disbursed for food aid targeting 40% of Malawi's population in 2016: https://news.un.org/en/story/2016/07/534912-un-agency-starts-food-aid-65-million-people-affected-severe-drought-malawi

Figure 6: Integrated CSA Strategy Benefits



4.3.3.Results

The costs, benefits, and benefit-cost ratios of the intervention are presented in Table 7 below, with results presented at the national level.

Table 7: Cost Benefit Analysis of Integrated CA+ISFM + CD+DT +RI

Discount Rate	Benefits (MWK millions)	Costs (MWK millions)	BCR
5%	811,719	235,911	**3.4**
8%	652,189	218,168	**3.0**
14%	442,108	190,452	**2.3**

Over a 10-year period, the net present value of benefits is equal to MWK 652,189 million, with a cost of MWK 218,168 for a BCR of 3.0 at 8% discount rate. This positive benefit cost ratio indicates that this CSA strategy is worth implementing for the smallholder farmers in Malawi prone to climate change impact.

4.3.4 Sensitivity Analysis

We alter several of the main parameters to assess sensitivity of results. The results are presented below in Table 8. The range of BCRs is 2.5 to 3.8. The extension cost has the greatest bearing on results, with decrease in the cost by 25% yielding a BCR of 3.8, while 25% increase generates a BCR of 2.5.

Table 8: Sensitivity Analysis

Parameters	BCR
Base	3.0
Extension cost increases by 25%	2.5
Extension cost decreases by 25%	3.8
Marginal production costs increase by 25%	2.7
Marginal production cost decreases by 25%	3.1

5. CONCLUSION & POLICY IMPLICATIONS

This report seeks to identify the most cost-effective interventions to address disaster risk reduction and prioritize agricultural interventions for Malawi that could most effectively build resilient smallholder farming systems least vulnerable to climate change and variability impacts.

The EWS benefit-cost analysis relies on the literature review and previous experience in countries with similar climatic and socioeconomic conditions. This approach provides a possibility to perform an initial screening and create a shortlist of potential priorities. The high estimated BCR suggests that EWS should be included in this shortlist for further consideration.

There are a number of critical policy recommendations that can be construed in management of DRR in Malawi. The analysis focuses on improving EWS and CSA. For EWS, there are a number of opportunities to improve the systems to effective level of operation. Prepositioning of emergency response materials like Food, Shelter equipment and evacuation equipment is crucial and critical for reducing the vulnerability of the population. Issuance of EWS protocols and channels is important as also financing for the disaster response. The institutional framework for strengthening the disaster response has to be improved with greater synergies between the three critical different departments – Department of Climate Change and Meteorological Services (DCCMS), Water Resources Department (WRD) and Department of Disaster Management Affairs (DODMA) for improving capacity, enhancing collaborations, and increasing resources and funds.

The actual effectiveness of EWS will be revealed and improved as a result of a permanent adjustment of interventions and behavioral transformations. The EWS creates an option to respond but does not guarantee proper actions automatically. Comprehensive action plans tailored to specific vulnerability assessment on a community level and specific measures well designed and explained will increase the probability of appropriate response to EWS advisories and increase resilience of local communities and entire countries to natural disasters.

Based on the literature review, expert interviews and cost benefit analysis integrated conservation agriculture with crop diversity, drought tolerant crops species/ varieties and rice intensification was found to be the best CSA option for the lower Shire, lakeshore and mid elevation projected to be most vulnerable to increased frequency of erratic onset of rain season and uneven distribution of rain. Whilst integrated soil fertility management with crop diversity and drought tolerant crop species/varieties as the best bet CSA option for some part of mid elevation and highlands agro-ecological zones characterised by reduced precipitation and increased mean temperature. These two CSA options are especially important for Malawi, where smallholder farmers are often subsistence-oriented and rely solely on rain fed agriculture (Mutenje et al. 2019; Hunter et al. 2020). The BCR of the integrated conservation agriculture with crop diversification, drought tolerant varieties and rice intensification intervention is estimated at 3.0. Sensitivity analysis revealed that the BCR of the CSA intervention is most sensitive to changes in the extension services costs.

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7. ANNEXURES

Table A1: Cost of rebuilding and strengthening of DRM

Annex Table 13: Recovery and reconstruction needs in the DRR and EWS

Sector	Program of activity value	US$	Responsible agencies
Short term recovery needs (one year)			
DRM and Infrastructure	Develop a suite of standards for improved retrofitting and reconstruction of infrastructures for all sectors (Housing, Schools, Health posts, Bridges, Dykes, Drainage, Water points and infrastructure, sanitation) to be used for immediate recovery	200,000	DoDMA and all sectoral agencies
DRM high-risk sectors	Conduct hazard, vulnerability and risk assessments (including capacity building of stakeholders) and zoning of 15 district and 2 city councils	1,500,000.00	DoDMA, DWR, and DCCMS
DRR/M	Document existing good resilient practices across the sectors, map data produced by projects, and ensure integration into sectoral planning and operations	80,000	DoDMA and all sectors
DRR &EWS	Review the National Disaster Recovery Framework (NDRF) to incorporate 2019 PDNA issues	350,000.00	DoDMA
DRR	Monitor the implementation of the revised NDRF	150,000.00	DoDMA and Sectors
	Support development of evacuation plans	350,000.00	DoDMA
	Review the disaster impact and needs assessment and reporting to include recovery needs (including building capacity of stakeholders at national and local level; and from short to medium to long term.	250,000.00	DoDMA
	Provide a return package to households in displacement sites	500,000.00	DoDMA
	Implement a national recovery and resilience public awareness program	500,000.00	DoDMA
Medium term recovery needs (two years)			
DRR	Rehabilitate, establish and strengthen automated community-based flood early warning systems with particular consideration for the needs of women, children, the elderly and PWD	500,000.00	DoDMA, DWR, DCCMS
	Establish, revamp and train CPCs in DRM	350,000.00	DoDMA
	Train and strengthen local search and rescue teams for males and females and provide necessary equipment	1,000,000.00	DoDMA, MDF, and MPS
DRM and infrastructure	On the-job training of contractors in resilient reconstruction (BBB) and improved construction when reconstruction schools; houses; health-posts or other infrastructure	2,000,000	DoDMA, NCIC, Engineers; Sectors
DRR	Conduct Comprehensive Building Damage Assessment (BDA) to inform construction/rehabilitation of Damaged infrastructure	100,000.00	DoDMA and Housing
	Support development of DRM plans	300,000.00	DoDMA
Long-term recovery needs (three to five years)			
DRR	Construct 4 evacuation centers one in each Phalombe, Nsanje, Chikwawa and Zomba districts	1,300,000.00	DoDMA
Long-term recovery needs (three to five years) (cont.)			
DRR	Promote ecosystem and cross-boundary disaster risk reduction (catchment management and capacity building of communities in catchment and riverbank management) with particular consideration for the needs of women, men, children, PWD	1,500,000.00	DoDMA
TOTAL		**10,930,000.00**	

Table A2: Recalculation of moving average for the annual flood damage

Indicator	Value	Source
Reported in 2014 ($Million)	24	https://www.preventionweb.net/countries/mwi/data/
Reported GDP per capita 2014 ($)	226	https://www.preventionweb.net/countries/mwi/data/
Population 2014 (Million)	16	https://www.preventionweb.net/countries/mwi/data/
GDP 2010 $	521	CC assumption file, and MER
Income elasticity	1.5	CC assumption file
Population in 2020 (Million)	20	CC assumption file
Recalculated to 2020		
Moving average flood damage 2020 (Million)	68	Excluding 2019 event
Intensity increase (per year) lognormal distribution SD 0.002	0.003	Golub 2018, DICE 2016, IPCC AR-6

Table A3: Calculation of an implied preventable damage

		Preventable (%)	Preventable $M
Housing			
Damage	82.7	10	8.27
Loses	23.9	10	2.39
Health			
Damage	0.2	80	0.16
Loses	2.4	80	1.92
Livestock			
Damage	0.5	70	0.35
Loses	7.7	70	5.39
Other			
Damage	74.3	10	7.43
Loses	28.5	10	2.85
Total			
Damage	157.7		
Loses	62.5		
Implied		13	28.76

The Malawi Priorities Project

2021

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