Multiple benefits of DRR investment

Reducing risk and building resilience in Sub-Saharan Africa

Zambia

UNDRR
UN Office for Disaster Risk Reduction
UN Office for Disaster Risk Reduction

Building Disaster Resilience in Sub-Saharan Africa

An initiative of the African, Caribbean and Pacific Group of States funded by the European Union

Funded by the European Union

Cover photo: Tatsiana Hendzel/Shutterstock.com

Design and layout: hofergrafik°
Printing: United Nations Office at Nairobi
Publishing Services Section

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Executive Summary

This study aims at quantifying the multiple benefits of disaster risk reduction (DRR) investments and building a knowledge base for risk-informed decision-making on DRR investment in target countries including Zambia. The present report describes the methods of direct and indirect benefit assessment and their application to flood and drought risk management and is released as part of the project 'Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities'.

For the direct benefit assessment, a multi-model analysis showed that the existing multi-purpose dams have flood regulating benefits, reducing the annual average losses (AAL) of floods by approximately US$7.3 million in the country. When combined with the additional benefit of power generation, the indicative benefit cost (BC) ratio was estimated at 1.13 using a discount rate of 7%. Additional direct benefits included drought tolerant and shorter-cycle varieties of Maize, with

the potential of reducing drought AAL from the original level of US$ 8.5 million to US$ 0.07 million and US$0.5 million, respectively. Indicative costs of insurance against agricultural drought risk (covering the risk of 5 to 50 year drought events) were also estimated in which the reduction in the cost of premium are estimated at US$9.8 million (drought tolerant) to US$9.3 million (shorter cycle) when adopting improved crop varieties.

Within the indirect benefit assessment, DRR investment implied multiple benefits beyond a mere reduction of disaster damage. When compared to the reference scenario, the DRR policy scenario (in which additional multi-purpose dams are constructed) reduced the damage to productive capital while fostering a safer environment that promoted savings and investment, leading to the creation of more productive capital such as buildings and machinery. When taking into account the co-benefits in terms of additional power production and better access to water, DRR investment is estimated to accelerate GDP growth. The Total Growth Effect (TGE) of this DRR investment is estimated at 7.6% of GDP in period 30. Similarly, the indirect benefit assessment of improved crop varieties underscored the potential for DRR investment to foster national economic growth. The TGE of drought risk reduction policy is estimated at 2.2 % at period 30 for the 40% improved variety scenario and 2.9% of GDP for the 60% improved variety scenario. The indirect benefit analysis provides substantial evidence that in addition to reducing the immediate impact of disasters (e.g., loss of lives and destruction of capital assets), DRR investment helps cultivate a safer environment where undamaged infrastructure and productive assets enable future earnings and promote further investment.

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Citation: UNDRR (2020), Multiple benefits of DRR investments – Reducing Risk and Building

Resilience against Floods and Droughts in Sub-Saharan Africa, Zambia.

Acknowledgements

UNDRR wishes to express profound appreciation for the work provided by IIASA and the support provided by the National Authorities for disaster risk reduction/disaster risk management and by the United Nations Country Teams in the respective countries.

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Published in March 2020

1. Introduction

In 2013, the European Union (EU) and the African, Caribbean and Pacific Group of States (ACP) signed an agreement focused, amongst others, on strengthening the ACP Member States' regional integration and inclusion in the global economy. Furthermore, the agreement addressed challenges related to climate change, agriculture and rural development.

Under this agreement, a programme entitled 'Building Disaster Resilience to Natural Hazards in Sub-Saharan African Regions, Countries and Communities' was launched in July 2015. Its aim has been to provide a comprehensive framework for disaster risk reduction (DRR) and disaster risk management (DRM) and its effective implementation across Sub-Saharan Africa.

To support DRR in Sub-Saharan Africa, the EUR 80 million programme covered a period of five years and focused on five key results: strengthening regional DRR monitoring and coordination; enhancing DRR coordination, planning and policy advisory capacities of Regional Economic Communities; improving the capacity of National and Regional Climate Centres for weather and climate services; improving risk knowledge through disaster databases for future risk modelling; and developing disaster risk financing policies, instruments and strategies at the regional, national and local levels.

This study aims at contributing to broader efforts geared at assisting African countries in building capacity in investment planning and supporting initiatives to increase public investment in disaster risk reduction. In line with the Sendai Framework for Disaster Risk Reduction (2015-2030), the program seeks to assist countries in estimating potential disaster impacts, including economic losses. Furthermore, it provides tools for countries to optimize their investment plans in order to address disaster risk and reduce future losses.

The UNDRR supported this study in demonstrating that disaster risk reduction (DRR) investments not only protect productive assets and lives but, if implemented appropriately, also yield a number of additional benefits that can enhance the well-being and resilience of countries such as Zambia. A plethora of DRR investment options – both structural and non-structural - are available for disaster risk management, necessitating that decision-makers and relevant stakeholders work together to formulate appropriate DRR investment strategies. Quantifying the costs and benefits associated with investment options allows for the transparent evaluation of alternative DRR options.

Globally, economic appraisals of DRR investment options are becoming increasingly commonplace practices. Based on National Progress Reporting under the Hyogo Framework of Action (HFA), the number of countries stating that studies on the economic costs and benefits of DRR were available increased from 23 during the 2009-11 reporting period to 41 in the 2013-2015 reporting period. However, HFA monitoring also revealed that, in many parts of the world, including Zambia, there is a profound knowledge gap and lack of capacity when it comes to economic cost and benefit studies conducted on a regular basis within the country. In order to close this knowledge gap and to encourage active discussions of future DRR investment in Zambia, this technical report describes the concepts and methods for conducting an economic appraisal. We evaluate selected examples of flood and drought risk management options, evaluated based on both a direct and indirect (i.e. macroeconomic and co-benefits) cost and benefit analysis

2. Types of DRR Benefits

Disasters are known to affect the economy, society and the environment in a number of ways. In addition to the immediate destruction of assets, lives and livelihoods, disasters have medium and longer-term consequences which include adverse health effects and implications for educational attainment (Noji 2005; Watson et al. 2007; Mochizuki et al. 2014; Salazar et al. 2016; Cadag et al. 2017; Wang et al. 2017; Takasaki 2017), poverty and inequity effects (Karim and Noy 2016; Hallegatte et al. 2017) and negative macroeconomic outcomes (Raddatz 2007; Noy 2009; Cavallo et al. 2013). By investing in DRR, individuals, communities, and countries are able to reap a multitude of benefits by averting these negative consequences and their associated feedbacks. The various types of such DRR benefits may be conceptualized using the concept of 'triple dividends' (Tanner et al. 2015) which include:

- The 1st dividend – **avoiding direct impact.** DRR investments – whether they are structural (e.g. green and gray infrastructure such as retention areas, dikes and dams) or non-structural measures (e.g. land use planning, early warning and building codes) contribute to reducing immediate impacts of disasters in terms of human and direct economic losses.[1] As less people are affected and less buildings, crops and other properties are destroyed, the reduction of such direct impacts constitutes the first dividend (i.e. direct benefit) of DRR.

- The 2nd dividend – **enhancing economic potential.** Perception of disaster risks are known to affect people and firms' economic decisions including savings and investment behaviors (Chantarat et al. 2015; Stephane 2016). Lacking appropriate safety nets, for example, low income farmers may be reluctant to adopt higher yielding (yet higher cost) crop varieties. Likewise, firms may be less likely to invest in regions with higher perceived disaster risks, out of fear that their futures earnings may be affected. As communities, regions and countries become safer to invest in, enhanced economic activities constitute the second dividend (i.e. indirect benefit) of DRR.

- The 3rd dividend – **generating development co-benefits.** DRR investments can be designed for multi-purpose uses – such as dams which provide flood mitigation, power generation, and water access benefits or cyclone shelters which can also be used as school and community buildings. As people, communities and countries profit from them, co-benefits constitute the third dividend (i.e. indirect benefit) of DRR.

We outline below the methods for quantifying these multiple benefits.

[1]Economic valuation of human lives lost is a still debated topic in the literature and comprehensive discussions of this topic are beyond the scope of the present report.

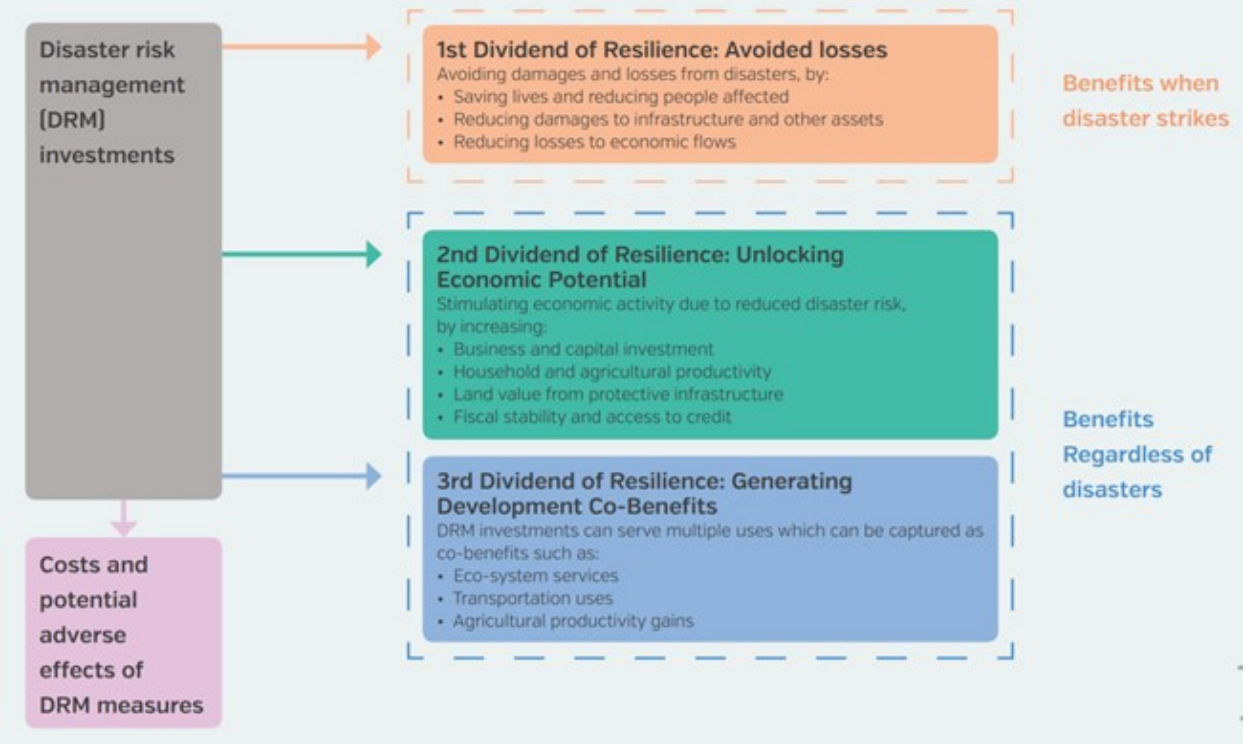


Figure 1: The tree types of dividends of DRR investments (copyright clearance pending)

3. Direct Benefit Assessment

The direct benefit of DRR will be estimated in terms of a reduction in disaster damage. The quantification of economic values will be based on a standard accounting-based method using the replacement costs of assets as a measure of disaster damage. In case of buildings and infrastructure, the replacement cost is equivalent to the cost necessary to rebuild damaged structures, while damages to agricultural crops, for example, may be valued at the cost necessary to produce the equivalent amounts of crop lost. The extent of disaster damage before and after DRR investment may be estimated with the use of probabilistic disaster risk models that incorporate hazard, exposure and physical vulnerability information.

Figure 2: Analytical Steps for Direct Benefit Assessment

Different types of DRR investment options have different channels through which they affect hazard, exposure or physical vulnerability, thereby reducing disaster risk. For example, constructing dikes and dams may directly alter the flow of water thereby affecting the extent and frequency of flood hazards in certain geographic areas. Likewise, the introduction of land use zoning will alter the spatial pattern of settlements, thereby reducing exposure to hazards in various locations as well as prompting the retrofitting of buildings and subsequent reduction of structural physical vulnerability. Depending on the DRR investment options of interest, one evaluates probabilistic risk using models based on alternative assumptions of hazard, exposure and vulnerability. As will be shown below, to estimate the case of DRR effectiveness pertaining to multi-purpose dams, alternative runs of hydrological models are compared to estimate how water discharge levels change with and without dams. Similarly, in the case of improved crop varieties, alternative runs of a crop model are compared to how yields change with and without improved seeds. Physical damage (such as the number of buildings destroyed or tons of crops damaged) is multiplied by the amount of physical damage per unit cost (such as the construction cost of buildings and production cost of crops), yielding the economic value of damage.

The difference in economic values of damage before and after DRR investment – typically evaluated using the differences in Annual Average Losses (AAL) – can then be considered as the direct benefit of DRR investment. Once estimated, the direct benefit of DRR can be compared to the cost of DRR investment to determine whether DRR investment is economically efficient (i.e., a country can gain more from investing in DRR than not investing). Here we apply this methodology on two DRR investment options in Zambia.

Illustrative Example 1: Direct Benefit of Multipurpose Dam for Flood Risk Management

Flood is a recurrent hazard in Zambia estimated to affect approximately 20,000 people (roughly 0.11% of the total population) on average annually, causing direct economic losses of about US$ 25 million (equivalent to 0.06 % of the country's total capital stock value) (CIMA, UNDRR 2019). Flood risk hotspots are concentrated in the north east part of the country. Multi-purpose dams are typically used for

hydropower generation and water storage but, when managed properly, they have the additional benefit of improved flood regulation downstream. By increasing the water storage capacity, multi-purpose dams mitigate flood hazard either by reducing the peak discharge or flood volume or by delaying peak time.

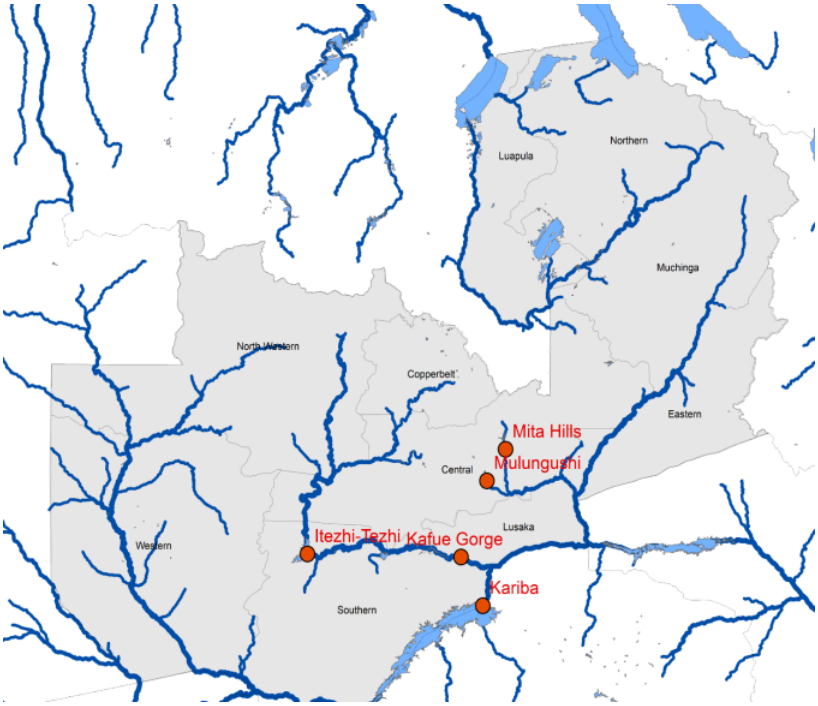


Figure 3: Existing Multi-Purpose Dams analyzed in Zambia

A multi-model analysis of water discharges with and without dams[2] was used to estimate how flood risk can be mitigated. Figure 3 shows the locations of dams currently in operation that were analyzed for Zambia: Mita Hills on the Lunsemfwa river, Mulungushi on the Mulungushi river, Itezhi-Tezhi and Kafue Gorge on the Kafue river[3].

Based on CIMA/UNDRR (2019), the AAL due to floods is estimated at US$ 25 million in Zambia with the larger share of losses accounted for in the housing and services (commercial) sectors. If we were to assume that the above five dams did not exist (i.e. no human intervention), the hydrological model analysis shows that the AAL would have been higher by US$ 7.3 million, with an additional US$ 4.5 million, US$ 0.9 million and US$ 1.9 million in costs estimated for the downstream areas of Southern, Lusaka and Central.

[2]The study uses the framework of ISI-MIP 2a (Inter-Sectoral Impact Model Intercomparison Project – Historical validation for impact analysis) – https://www.isimip.org (Warszawski et al., 2014), comparing hydrological simulation without human intervention (Nosoc) and with human interventions including dams (Varsoc). The ensemble averages of the following four models are used: H08 (Hanasaki et al., 2008, 2018); Matsiro (Pokhrel et al., 2012); · DBH (Tang et al., 2007);·LPJmL (Bondeau et al., 2007; Rost et al., 2008).
[3]The effect of Kariba dam on the Zambezi river are excluded in the analysis.

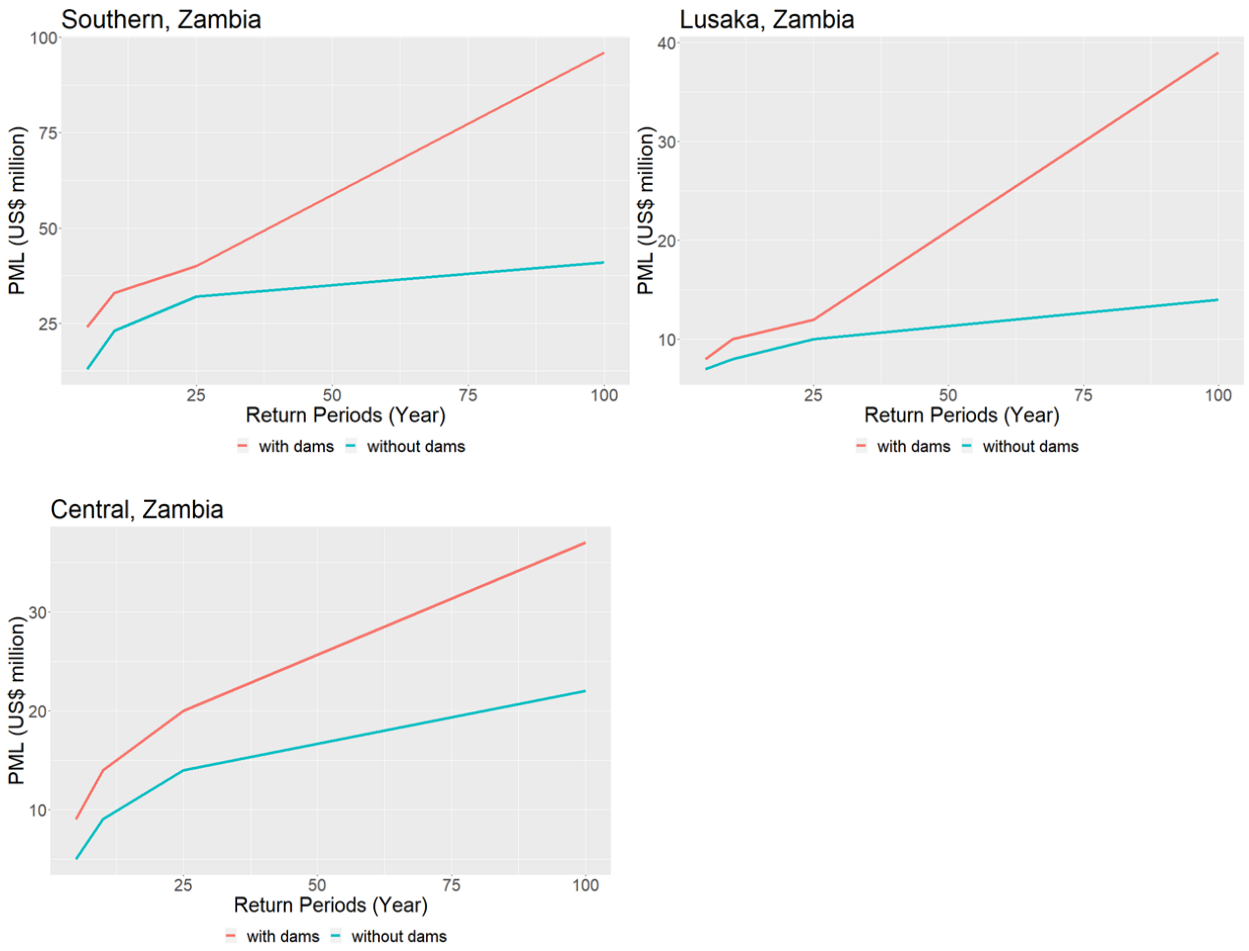


Figure 4: Flood Risk Reduction Effects Estimated for Selected Sub-Regions in Zambia

While a detailed project-level analysis of costs and benefits are beyond the scope of this study, the direct benefits in terms of a reduction in AALs and co-benefits of power generation can be compared to the construction and maintenance costs in order to broadly understand the economic efficiency of such investment. Assuming that other negative and positive externalities (such as environmental impacts) do not exist, the BC ratio of multi-purpose dam investments are estimated to be approximately 1.43, under a discount rate of 5%, for a policy scenario under which dams with similar DRR effectiveness are expanded across Zambia.

Table 1: Indicative Costs and Benefits of Multiple Purpose Dams

	5% discount rate	**7% discount rate**	**10 % discount rate**
Total Discounted Benefit (of which flood reduction)	US$ 2,936 million (US$ 102 million)	US$ 1,509 million (US$ 80 million)	US$ 1,110 million (US$ 59 million)
Total Discounted Cost	US$ 1,353 million	US$ 1,336 million	US$ 1,320 million
BC Ratio	1.43	1.13	0.84
Net Present Value	US$ 583 million	US$ 173 million	US$ -210 million

Note: Authors' calculation based on a policy scenario in which 3 additional dams with a total generation capacity of 513 MW will be constructed over the project lifespan of 40 years.

Illustrative Example 2: Direct Benefit of Improved Crop Varieties for Drought Risk Management

Droughts frequently occur in Zambia routinely exposing households to food security risk. On average, droughts affect 7.19 million people (or approximately 41% of the total population) with an estimated direct economic loss of approximately 75 million USD per year from the agricultural and productive sector (CIMA, UNDRR 2019).

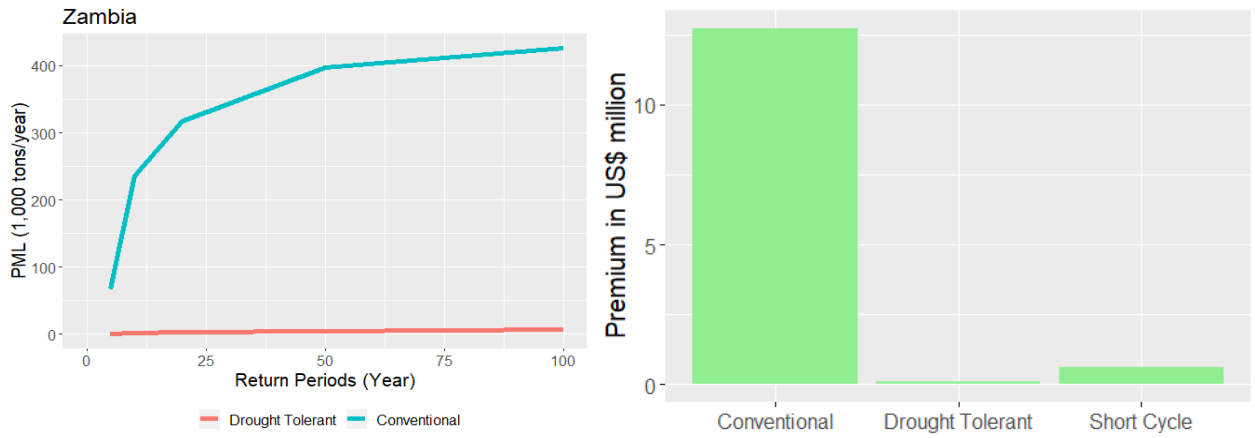


Figure 5: Reduction in Drought Risk (left: Drought Tolerant Variety) and Premium Cost (right) in US$ million

The analysis of drought tolerant and shorter-cycle varieties shows that AAL of drought for maize can be reduced from the current level of US$8.5 million to US$ 0.07 million when adopting drought tolerant varieties, and when using shorter-cycle varieties AAL may be reduced to US$ 0.5 million. While the premium costs for agricultural drought risk insurance are a function of the level of risk that a country faces, this reduction in drought risk is equivalent to approximately US$9.3 million (shorter cycle) and US$ 9.8 million (drought tolerant) saving in premium of drought insurance covering risks between 5 - 50 year return period.

4. Indirect Benefit Assessment

In addition to quantifying the reduction in disaster damage using a simple accounting method of the replacement cost of capital, the indirect benefit of DRR also includes a quantification of the value of future earnings, which includes the economic value that safeguarded productive capital - such as buildings and machinery - is expected to yield. In addition to quantifying the monetary value of disaster damage, a dynamic macroeconomic model can estimate the additional benefits that would be expected from changes in the saving and investment behaviors of firms and individuals over time, along with other "co-benefits" of DRR investments, such as better access to services like water, electricity, and enhanced environmental protections. Dynamic macroeconomic modeling allows one to evaluate the degree of economic benefits a country would be expected to gain in the future if houses, productive assets, and public infrastructure were safeguarded.

Figure 6 shows analytical steps involved in the indirect benefit assessment. Instead of comparing disaster risk before and after DRR investment, an indirect assessment compares a set of macroeconomic variables before and after DRR investment. Within an indirect benefit assessment, the dynamic macroeconomic model captures a forward-looking rational expectation of a representative household and firm[4], whose perception of future earnings and losses will be affected by the prevailing levels of disaster risk and DRR investment. The changes in expected utility of households and expected profit of production sectors will then affect other aspects of economic activities such as the optimal levels of savings and investment, demands for labor and capital, shares of import/export and ultimately the GDP growth trajectory.

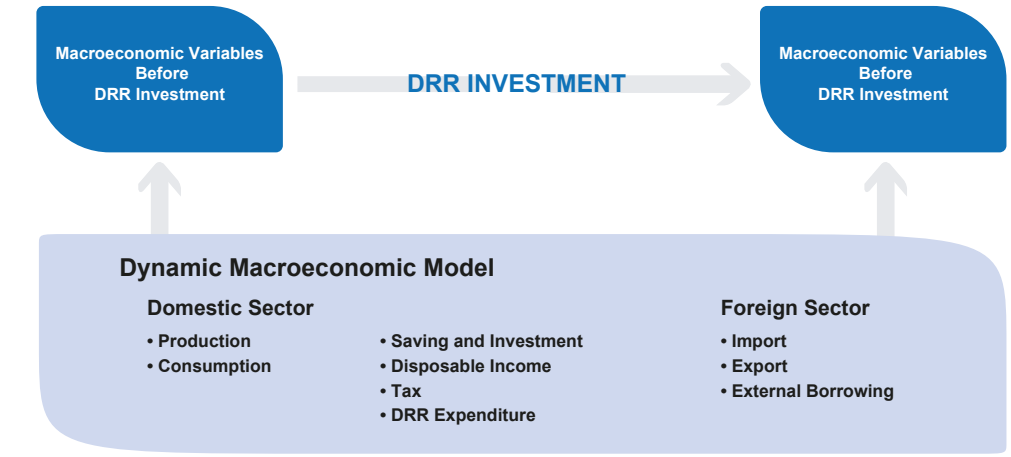
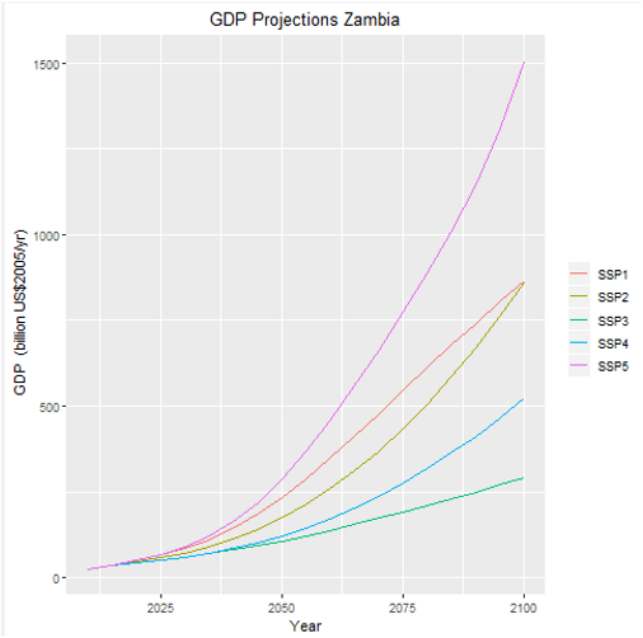


Figure 6: Analytical Steps for Indirect Benefit Assessment

[4]This generally means that a household considers the prospects of future income and risk when making a current decision.



Shared Socioeconomic Pathways (SSPs) are projections that show possible socioeconomic global trends over the course of the 21st century (O'Neill et al., 2014). SSPs do not take into account new climate policies so as to allow for standardized assessments of the effectiveness of current policies under various socioeconomic conditions. So far, the following five different pathways have been put forward: SSP1–sustainable pathway, SSP2–moderate pathway, SSP3–rocky road, SSP4–regional pathways and SSP5–taking the fast road (Moss et al., 2008).

Figure 7 shows the projection of economic growth in billion US dollars (base year 2005) on a purchasing power parity (PPP) basis for Zambia for the five SSP storylines.

Figure 7: GDP projections (billion US$2005/yr) for five SSP storylines.

Illustrative Example 3: Indirect Benefit of Multipurpose Dam for Flood Risk Management

The indirect benefit of additional multi-purpose dam constructions was evaluated using the Dynamic Model of Multi-hazard Mitigation CoBenefits (DYNAMMICs) model. Compared to the reference scenario, the DRR policy scenario (in which an additional 3 multi-purpose dams with a power generation capacity of 205 MW each are constructed over the next three decades) reduces the damage rate of productive capital while fostering a safer environment conducive to greater savings and investment as well as the promotion of productive capital.

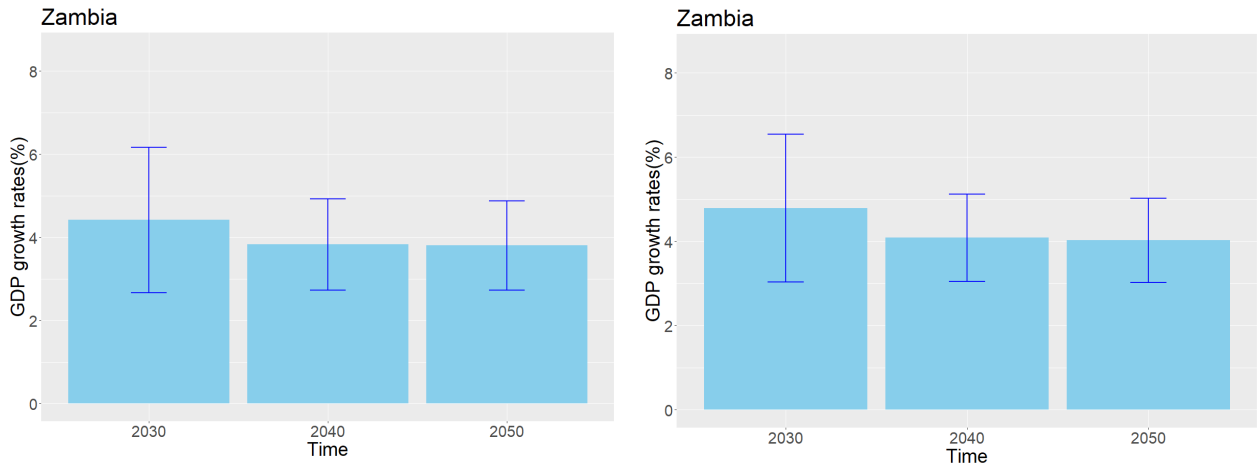


Figure 8: GDP growth rates under the reference (left) and DRR policy scenario for multi-purpose dams (right)

Such an investment is also expected to bring co-benefits in the form of additional power production and better access to water. As figure 8 shows, all of these benefits combined are projected to result in a GDP growth from 4.0% (reference policy) to 4.2% (DRR policy). The Total Growth Effect (TGE) of DRR investment is estimated as 7.6% of GDP in the period 30, as illustrated in figure 9 (right).

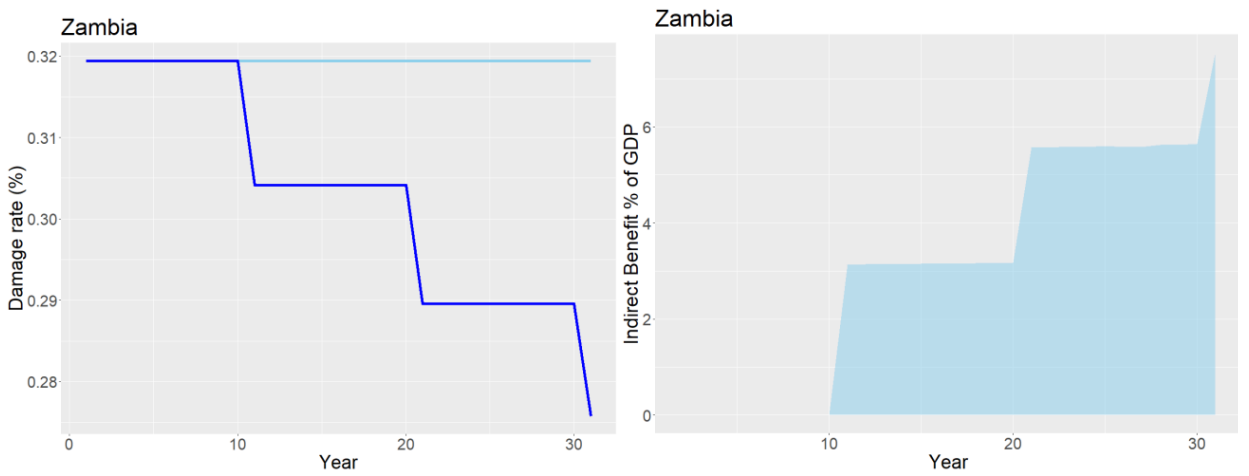


Figure 9: Flood damage reduction (left) and indirect benefit of multi-purpose dam (right)

Illustrative Example 4: Indirect Benefit of Improved Crop Varieties for Drought Risk Management

The indirect benefit assessment of improved crop varieties also shows that DRR investment enhances national economic growth potential. Compared to the business as usual of no DRR policy scenario, the introduction of improved crop varieties throughout the agricultural sector is expected to reduce the damage rate of agricultural production while a safer environment promotes savings and investment. All combined, the TGE of DRR investment is estimated as 2.2 % of GDP at period 30 for the 40% introduction scenario with insurance and 2.9% of GDP for the 60% introduction scenario with insurance[5].

[5]The 40% introduction scenario assumes that drought damage will be reduced at a rate equivalent to the effectiveness of shorter cycle variety maize for the 40% of agricultural sector production. The 60% introduction scenario assumes that the damage rate will be reduced for the 60% of sector production.

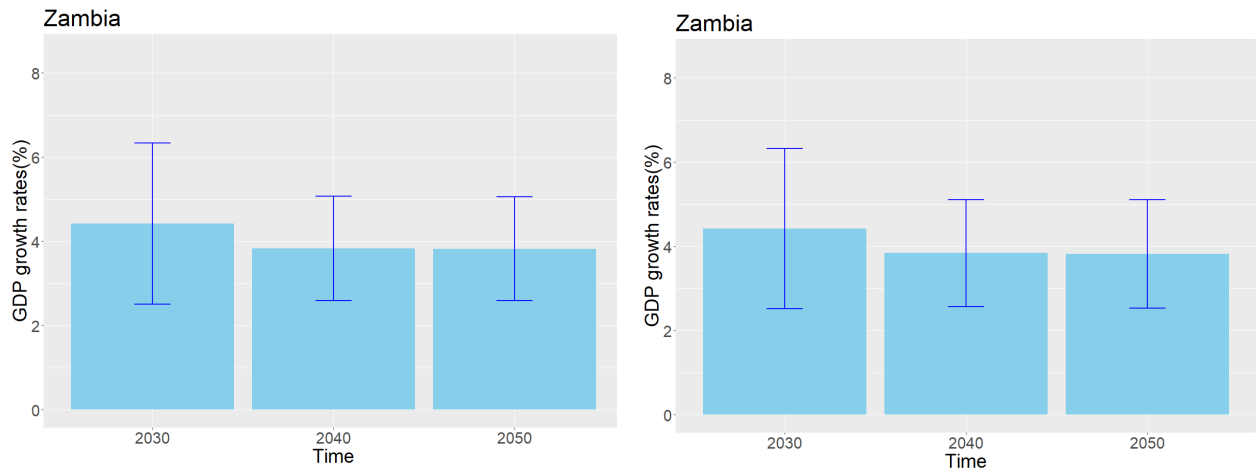


Figure 10: GDP growth rates under DRR policy plus agricultural insurance for improved crop variety showing 40% (left) and 60% (right) introduction scenarios.

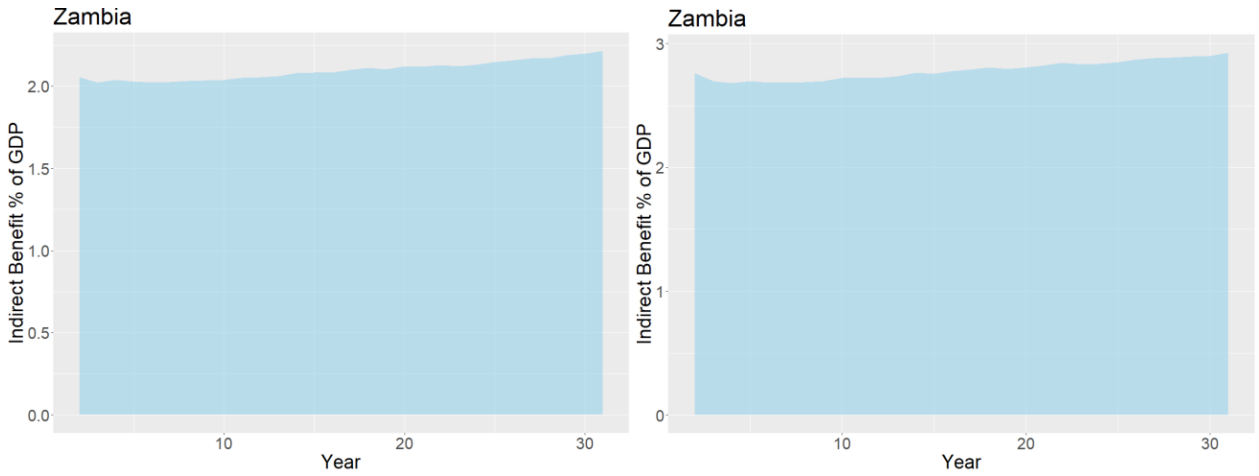


Figure 11: Indirect benefit of improved crop variety plus agricultural insurance under the 40% (left) and 60% (right) introduction scenarios.

5. Conclusions - the Case for Investing in Reducing Disaster Risk

As is evident in this analysis, DRR investment not only reduces the immediate impact of disasters such as the loss of lives and destruction of capital assets, but also increases future earnings and promotes further investment due to the presence of undamaged infrastructure and productive assets. Countries can thus benefit from disaster risk reduction investments, regardless of whether a disaster occurs or not. Multi-purpose dams typically used for hydropower generation and water storage, for example, can provide the added benefit of improved flood regulation downstream when managed properly. An evaluation of drought tolerant and shorter-cycle varieties of maize also indicates that the annual average losses for maize due to drought could be reduced significantly, while investment in disaster risk reduction measures over the next three decades will notably enhance agricultural production.

As has been demonstrated in the case of Zambia, the adoption of sovereign insurance options allows Zambia to follow a smoother growth path. Such an option is important for countries like Zambia, which face a number of additional internal and external risks including the impact of drought on hydropower output and uncertain international economic conditions (IMF 2019).

In addition to insurance and improved crop varieties investigated, a number of additional policy actions could be helpful in reducing further risk of drought in Zambia. These measures include the integration of projected spatial patterns of drought risk into agricultural sector development planning (UNDP 2010), increased investment in irrigation infrastructure and other water harvesting options. Sustainable groundwater management will also be an area of concern as increased number of pumping wells are being dug and this may lead to the lowering of groundwater levels in the future.

Africa's progress towards sustainable development requires that governments, development partners, private sectors and communities recognize the importance of investing in DRR. The methods described and demonstrated in this report can be applied to evaluate a wide range of additional DRR policy options and such analyses will help decision makers and relevant stakeholders evaluate the degree of economic benefits a country would be expected to gain if they were to invest in the safeguarding houses, productive assets and public infrastructure.

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Technical Annex

This annex presents major assumptions used in direct and indirect benefit assessments. For each assessment, flood and drought risk information was taken from each country's latest risk profile (CIMA/UNDRR 2019).

- **Multipurpose Dam:** The indicative CBA was based on the capacity and investment costs of a reference dam (i.e. the Kidatu dam) available from Payet-Burin et al. (2019), IRENA (2013), and Parker (2010). For cost estimation, we assume a dam's lifetime to be 40 years, and operation and maintenance costs equal 5% of the capital cost. Unless otherwise noted, for benefit estimation we assume that a unit of hydropower has a generation capacity of 205 MW, assumed to operate 8,760 hours (i.e. 24 hours times 365 days) per year at 40% efficiency. The price of power is based on the regional average taken from an industry database.
- **Improved Crop Varieties:** The indicative CBA was based on yield and cost information available from literature. For production costs, this study first refers to maize production costs available from the USDA (2019). This international reference cost was scaled to the region using each country's GDP. The production cost difference (i.e. a ratio) between conventional and improved seeds of 1.22 was taken from Shongwe et. al (2014). The yield improvement potential of 24% was taken from Kutka, F. (2011).
- **Macroeconomic variables:** For the indirect benefit assessment, a real business cycle model, incorporating the hazards and sectors of interest, has been developed. A locally hired technical consultant also communicated with relevant ministries to obtain necessary data including but not limited to: the Zambia Input Output Data, Net Investment Position Data and Premium Policy for the African Risk Capacity. The basic set-up of the model is shown below:

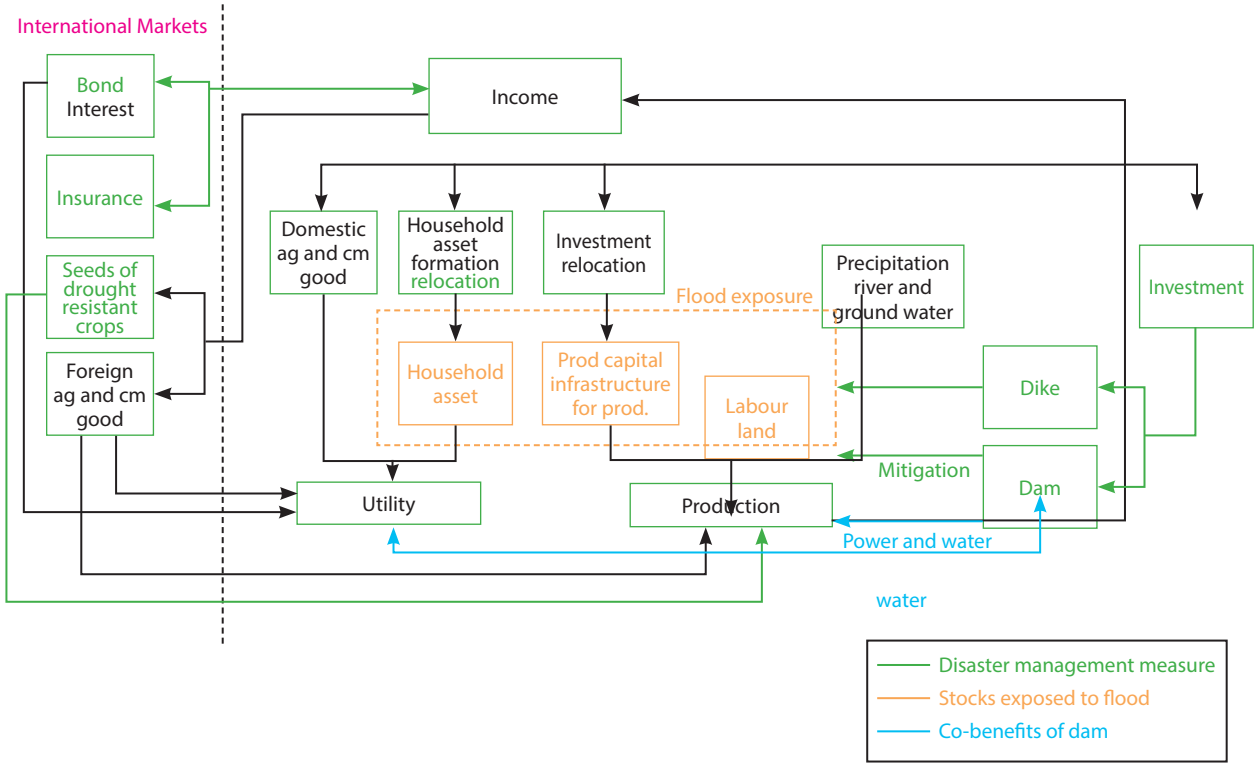

Figure 1: Schematic flow of macroeconomic growth model DYNAMMICs (Dynamic Model of Multi- hazard Mitigation CoBenefits)

Table A1: A list of major parameters used in the indirect assessment.

	Values and functional forms used	**References**
Disaster Damage functions		
Flood damage	% of damage per damage categories and disaster levels	Calibrated based on CIMA/UNDRR (2019)
Drought damage	% of reduction in agricultural production per disaster levels	Calibrated based on CIMA/UNDRR (2019)
Flood risk reduction policy options		
Initial number of multi- purpose dams	3	Lehner et al. (2011)
The number of newly dams to be built over time horizon	3	By assumption (policy parameter)
Flood risk reduction effectiveness of dams	Exponential functions per damage categories	Calibrated based on CIMA/ UNDRR (2019)
Power generation co- benefit	205MW (operation of 365days x 24 hrs @ 40% efficiency)	By assumption, based on expert input
Water access co-benefit	Power function per consumption categories	Calibrated based Lehner et al. (2011)
Drought risk reduction policy options		
Drought risk reduction benefit	Differences in the % of reduction in agricultural production in drought years between conventional and improved variety	Calibrated based on CIMA/ UNDRR (2019)
Percentage of improved varieties adopted	0.4 and 0.6	By assumption (policy parameter)

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