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Quantifying the Dividends of Climate Adaptation and Resilience Interventions: The Case of the GARID Project in Ghana

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Abstract

In response to the challenges and impact of climate change, governments and development organisations are investing heavily in climate adaptation and resilience interventions. These initiatives aim to reduce the vulnerabilities of communities and ecosystems to climate change while enhancing their capacity to respond. However, several key questions arise: what are the benefits of such adaptation and resilience interventions? how can these benefits be quantified? And, when compared to the costs, are such interventions justified? Answers to these questions enable governments and development partners to justify investments in adaptation and resilience and to monitor and evaluate interventions before, during, and after the implementation. This study applies the Triple Dividend of Resilience (TDR) to the Greater Accra Region (GAR) Resilience and Development (GARID) project, which encompasses interventions aimed at improving flood risk management and solid waste management in the Odaw River Basin of the GAR, home to a population of 2.5 million people. The analyses compare benefits and costs of the interventions. Findings indicate that the GARID project will generate total benefits ranging from US$451.97 to US$6,269.50 million, with costs estimated between US$317.97 million and US$350.83 million, depending on the assumptions made around discount rates and carbon pricing. This results in Net Present Values (NPVs) ranging from US$134.00 million and US$5,918.67 million, and Benefit-to-Cost Ratios (BCR) between 1.42 and 17.87. The study validates the TDR framework as a robust, evidence-based tool for decision making and investment planning in a developing country context. Furthermore, it demonstrates that accounting for broader benefits-the three dividends - rather than only avoided losses in traditional cost-benefit analysis can significantly improve the BCR metric (by 6% and 1,235% in the case of GARID).

Keywords: climate adaptation; resilience; cost-benefit analysis; triple dividend of resilience; Ghana

JEL classification : Q54; Q56; Q51; H43; O13

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About the Resilience Adaptation Mainstreaming Program (RAMP) and the RAMP University Network

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At the heart of RAMP's approach to capacity-building is its University Network for Strengthening Macrofinancial Resilience to Climate and Environmental Change ('the RAMP University Network'). Launched in 2022, the RAMP University Network consists of leading universities in vulnerable countries that seek to develop and deliver high-quality multi-disciplinary teaching and research on adaptation economics and climate risk management, train public officials, and serve as centres of expertise that ministries of finance and other public institutions can rely on. This approach ensures that skills and knowledge are embedded locally, strengthening partner countries' ability to integrate climate risks into economic decision-making.

Co-founded by the Centre for Sustainable Finance (CSF) at SOAS University of London and the World Resources Institute, RAMP is currently managed by the CSF, which also acts as Secretariat for the RAMP University Network. For more information visit: https://www.soas.ac.uk/university-network

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1. Introduction

The threats of climate change are already being felt through the global rise in temperatures, changes in the physico-chemical properties of oceans, and an increase in extreme environmental risks such as wildfires, droughts, floods, hurricanes, and tropical storms. Studies (e.g. Chinowsky et al., 2011; Mutume, 2002) indicate that a significant proportion of these threats affect the developing world - particularly those countries least equipped to adapt to the associated risks. This necessitates that governments in developing countries adopt policies, programmes and projects that promote effective adaptation and resilience within their development agendas. Studies have shown that climate change can undermine economic growth, increase the prevalence of poverty, and exacerbate social inequalities. In response to these challenges, governments and development organisations across the globe have begun to invest in climate adaptation and resilience interventions, which aim to reduce the vulnerabilities of communities and ecosystems to climate change, while strengthening their capacities to respond to and recover from climate-related shocks and stresses.

The impact of climate change has driven a range of community-level efforts focused on adaptation and resilience building. Various studies have attempted to quantify the dividends resulting from such interventions. One example is the GARID project (see Wamsler et al. 2019), a five-year initiative aimed at enhancing the resilience capacities of vulnerable communities in selected African and Asian countries. The project's interventions concentrated on promoting sustainable agriculture, improving water availability and access, and scaling up of renewable energy. However, studies evaluating the dividends of these interventions remain limited. Those that are available tend to highlight only partial or isolated benefits.

Climate change interventions require substantial financial investment, which poses a significant challenge, particularly for governments in developing countries that are often limited by fiscal constraints. The African Development Bank has estimated that nearly USD40 billion per year will be needed over the coming decades to support climate-related initiatives across African countries (Kaberuka, 2009). In light of these considerable financial requirements, an important question arises: how can climate interventions be framed in ways that enhance their attractiveness to stakeholders and thereby mobilise the necessary support and funding? Heubaum et al. (2022) propose that the TDR approach offers a compelling and innovative framework for addressing such challenges. The TDR framework identifies three categories of benefits arising from adaptation measures: first avoid losses; second, induced economic or developmental gains; and third, additional social and environmental co-benefits. By emphasising the multiple and cross-cutting advantages of adaptation – particularly when these can be quantified and shown to exceed intervention costs- the TDR framework enhances the appeal of climate investments to a broader set of stakeholders, both public and private.

This study seeks to quantify the dividends of climate adaptation and resilience interventions within a developing country context, using the GARID project as a case study. In doing so, it validates the TRD framework and contributes to establishing a credible basis for designing and justifying climate change intervention investments. The study also advances evidence-based decision- making and investment planning in relation to climate and flood risk mitigation (World Bank, 2020). Moreover, it responds to the observation by Mechler and Hochrainer-Stiegler's (2019) that, despite growing interest in the TDR framework among academics and practitioners, relatively few case studies provide robust and comprehensive evidence across all three dividends.

The study is structured into six sections. The first provides the introduction and outlines the motivation for the research. The second examines the climate change and resilience context of the case study area – Greater Accra Region of Ghana – including background information on the GARID project. The third section presents an overview of the TDR framework. The fourth details the study's methodological approach. The fifth section presents and discusses the results, while the sixth concludes with key findings and policy recommendations.

2. The TDR Concept

Adapting to and building resilience against the impacts of climate change can yield a range of benefits. These benefits – conceptualised as "dividends"-are encapsulated in the TDR. Specifically, the TDR identifies three categories of benefits: avoided losses (the first dividend); induced economic or developmental gains (the second dividend); and additional social and environmental co-benefits (third dividend) (ODI and DFID, 2015, Heubaum et al., 2022).

The first dividend -avoided losses- refers to the savings realised as a result of investments in climate change adaptation. These include the preservation of lives and assets, protection of livelihoods, and the mitigation of negative impacts on education, health, and social welfare resulting from climate-related disruptions (Heubaum et al., 2022). The second dividend - induced economic or development benefits -, captures the gains generated by climate interventions even in the absence of realised risk. Various studies have demonstrated the economic value of such interventions across different contexts. For example, the Thames Barrier in the UK provides protection to over 1.4 million inhabitants and half a million properties valued at more than £321 billion, representing substantial economic and developmental benefits (UK Environment Agency 2021). In the US, resilient landscaping, design, and construction practices have led to reduced exposure to storm and flood damage, lower insurance premiums, improved access to investment due to reduced risk, enhanced marketability, and reputational advantage for companies (McCormick and Marshall, 2015). Additionally, climate change interventions can yield long-term economic benefits such as reduced operational and maintenance costs for infrastructure and other assets. Improvements in quality-service, sustainable revenue streams and acceptable returns on investment over assets lifespans are also recognised as a second dividend outcomes (Heubaum et al., 2022). Moreover, investments in resilience can stimulate entrepreneurial activity and economic growth along various supply chains. For instance, resilience-focused infrastructure development can drive innovation and expansion within the construction sector.

The third dividend-social and environmental benefits-, captures the gains accruing to society and the environment as a result of investments in climate change interventions. Although many of these benefits are difficult to monetise, several methodological approaches have been explored within the field of economics to estimate their value. Adaptation and resilience interventions often generate substantial social dividends, including improvements in health and well-being, reducing mortality and morbidity, and strengthening social cohesion. For example, a study by Mensah et al. (2019) assessed the social benefits of enhanced water and sanitation infrastructure in the GAR and found that such interventions significantly improved health outcomes through increased access to clean water and sanitation services. From an environmental perspective, investments in climate adaptation can yield benefits such as improved ecosystem health, enhanced biodiversity, reduced land degradation, and increased carbon sequestration, all of which contribute to broader climate mitigation goals. Additionally, such interventions may support the restoration of green spaces and urban gardens, thereby promoting recreational opportunities and improving the quality of urban life.

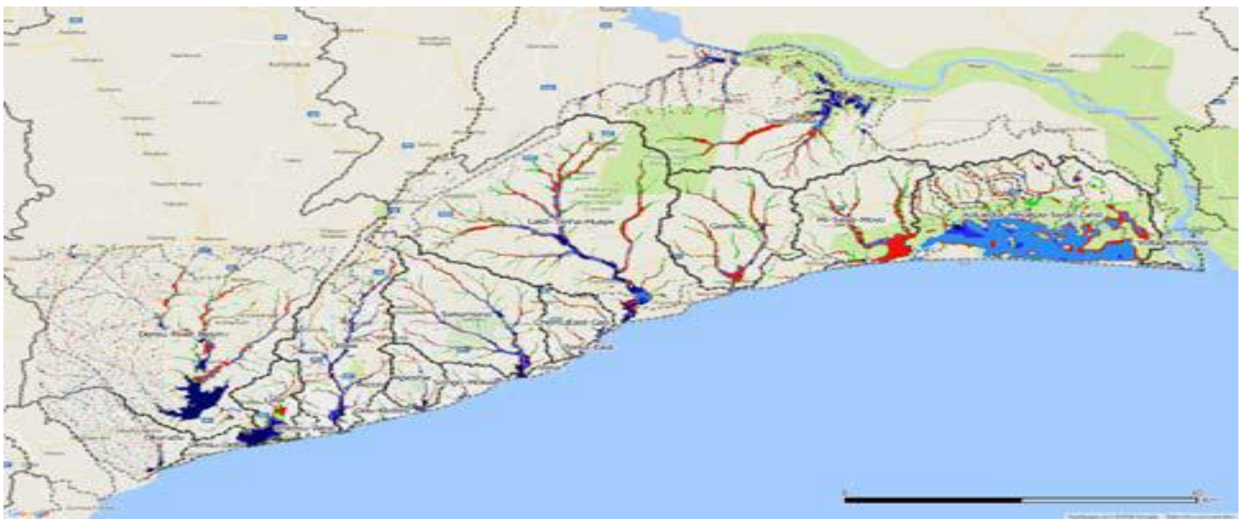
3. Case Context

Ghana has a tropical climate characterised by two main seasons: a dry season, from November to February, and a wet season, from March to September. The hottest period occurs in February and March.

Average temperatures range between 21°C and 34 °C in the coastal region, and from 25°C and 40°C in the northern part of the country. Ghana also experiences two distinct rainfall regimes: the coastal region follows a double maxima, both major and minor rainy seasons, while the northern region exhibits a unimodal rainfall pattern (Environment Protection Agency, 2013).

Impacts of climate change are already apparent in Ghana. Research by the Ministry of Environment, Science, Technology & Innovation (MESTI) indicates that the country's average temperature has increased by 1.0°C in the past century, with projections suggesting a continued upward trend. Ian Ross, a climate scientist at Ghana's Council for Scientific and Industrial Research (CSIR), has warned that temperatures in Ghana could rise by 3.0°C by 2100. Such an increase is expected to contribute to sea level rise and exacerbate flooding, particularly in low-lying areas such as the GAR.

Figure 1: Hazard Map for the Greater Accra Region (Source: World Bank, 2020)



Elevation in Ghana ranges from sea level to approximately 800 meters above sea level. The capital city, Accra, is situated along the coast and is characterised by low-lying areas, which are prone to flooding (see Figures 1, 2 and 3). The region's geology – dominated by rocky lower hills composed of hard sandstones, phyllites and shales- presents challenges for the construct of effective drainage systems, thereby exacerbating flood risk during the rainy seasons. Moreover, the region's high population density, estimated at 4.01 million, places a considerable pressure on natural resources such as water and land. These pressures are likely to intensify with the projected impact of climate change (Ministry of Environment, Science, Technology, and Innovation, 2015).

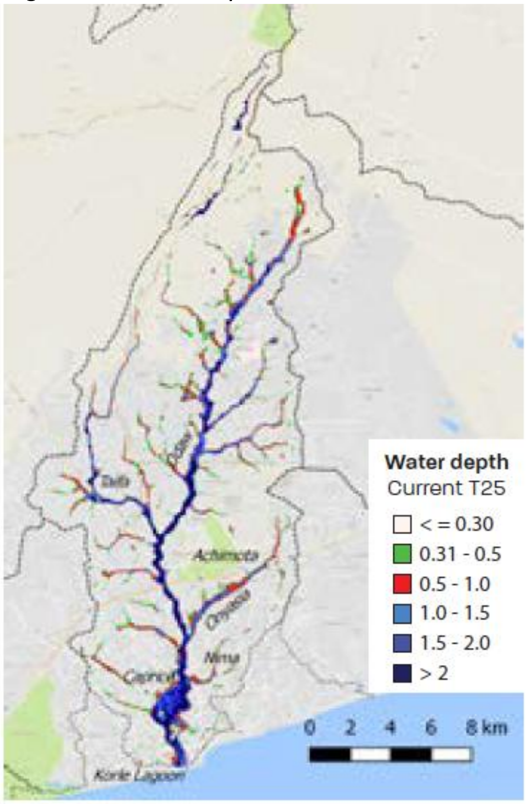


Figure 2: Water Depth Risk-Odaw River Basin

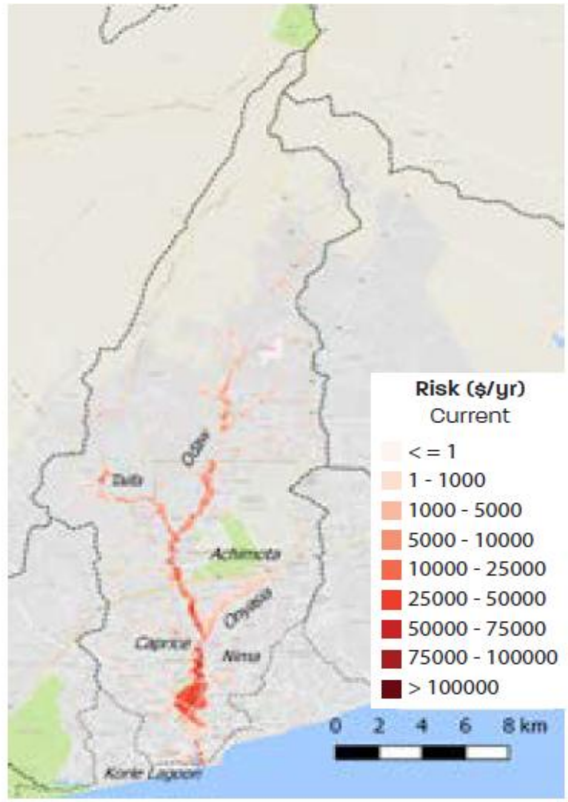


Figure 3: Damage Risk-Odaw River Basin

GAR is home to approximately 18 percent of Ghana's population and contributes around 35 percent to the national gross domestic product (GDP). Its population is projected to reach nearly 11 million people by 2050, up from 5.5 million in 2021 (GSS 2021). Flooding remains a significant are a major challenge in the region, with both urban and rural areas regularly affected. Urban flooding is particularly severe due to unplanned urbanisation, combined with inadequate infrastructure, such as storm drains and retention basins. Key drainage systems in the region – including the Odaw River, Korle Lagoon, and the Sakumo Lagoon, have been heavily encroached by human activities, increasing their vulnerability to flooding. Rural flooding, meanwhile, typically affects communities located next to rivers and other water bodies. Ghana's Environmental Protection Agency (EPA) predicts that by 2025, both urban and rural flooding will extend into areas previously unaffected (Environment Protection Agency, 2013).

The World Bank estimates that assets worth nearly US$1.7 billion in the GAR are at risk of flood damage, with this figure projected to rise to US$3.2 billion by 2050 due to population growth and an increase in assets accumulation (World Bank, 2020). In response, the government of Ghana t recognised the need for a comprehensive approach to strengthening climate resilience in the region. The GARID project, implemented by the government of Ghana, aims to enhance the region's resilience to climate-induced shocks and stresses. GARID forms part of a broader national effort to adapt to climate change and build the resilience of vulnerable communities and ecosystems. Specifically, project focuses on improving flood risk management and solid waste management within the Odaw River Basin of GAR, as well as expanding access to basic infrastructure and services in targeted communities throughout the basin. Approximately 2.5 million people live within the Odaw River catchment area, alongside numerous commercial and industrial entities (World Bank, 2019). The drainage system of much of Accra, including the central business district and the main industrial area, discharges into the Odaw River. Among the nine drainage basins in the GAR, the Odaw River Basin presents the highest levels of flood hazard and risk, particularly in its downstream, low-lying and densely populated central business area (World Bank, 2020). For this reason, GARID project interventions are concentrated within the Odaw River Basin, which has been identified as a strategic entry point due to its high flood exposure, population density, and economic importance (World Bank, 2019). The GARID project comprises three components World Bank, 2019, World Bank, 2020):

Component 1: Climate Resilient Drainage and Flood Mitigation - This component focuses on improving drainage and flood management within the Odaw River Basin through a combination of structural and non-structural intervention Structural measures include the construction of retention basins, tidal gates, drainage infrastructure, and dredging activities. Non-structural measures involve the development of early warning and emergency response systems to enhance preparedness and reduce the impact of flooding events.

Component 2: Solid Waste Management Capacity Improvements - This component aims to strengthen solid waste management capacity in the Greater Accra Region through a range of target interventions. These include the promotion of community-based solid waste collection initiatives, the construction of waste transfer stations, and the implementation of a city-wide public educational campaign to raise awareness and encourage responsible disposal practices.

Component 3: Participatory Upgrading of Targeted Flood Prone Low-income Communities - This component seeks to support the most flood-vulnerable communities through participatory upgrading processes. Interventions include limited (voluntary) resettlement through participatory planning and land re-adjustment.

4. Methodology

This study adopted a case study approach, focusing specifically on the GARID project as the case, and sought to quantity the costs and dividends of the project's interventions across the three categories of dividends (see section 2.0). As noted by the World Bank (2019), in addition to direct benefits, the "investments are expected to bring indirect benefits to the approximately 2.5 million people, residing in the catchment area of the Odaw River Basin, by lessening interruptions to businesses, commercial entities and transport corridors [second dividends], and improving public health through a more sanitary environment [third dividends]" (p. xx).

Prior to the quantification, a comprehensive literature review was conducted to identify the categories of costs and dividends that can be attributed to GARID project interventions. As Heubaum et al. (2022) observe, certain costs and dividends are not commonly quantified, while others lack sufficient data and analysis. Given the time constraints and the current stage of the GARID project, a desk-based study was conducted using documentary analysis to capture relevant costs and dividends. In some cases, the data was drawn from ex ante project appraisals or monitoring documents produced during implementation; in others, they sourced from ex post project evaluations (Heubaum et al., 2022). Where necessary, dividends were projected based on available data. Discussions and clarifications were also sought from key project personnel to better understand the types and categories of costs and dividends the interventions generated – or are expected to generate. Due to the nature of the data available, it was not possible to quantify dividends by specific interventions or group interventions within the GARID project. Rather cumulative or collective benefits of all interventions.

Drawing on the standardised assumptions from the Ghana Priorities project, discount rates of 3%, 5%, and 8% were applied in the analysis of benefits (Wong and Dubosse, 2019; Lomborg, Annim and Nordjo, 2021). Lower discount rates are particularly appropriate for long-term projects such as the GARID interventions (2018 -2050), as they ensure that the long-term benefits are adequately valued, thereby promoting sustainable and equitable decision-making. This approach aligns the project's evaluation with broader societal goals, including sustainability, intergenerational equity, and inclusive economic growth. In developing economies like Ghana, future cash flows are expected to increase due to economic growth. Applying a lower discount rate captures this expected growth more accurately, resulting in a higher Net Present Value (NPR) and a more favourable Benefit Cost Ratio (BCR) for long-term projects. For public sector projects, the opportunity cost of capital is generally lower than that of the private sector. Therefore, using a lower discount rate aligns more closely with the cost of public funds and provides a more accurate reflection of the project's economic value. Furthermore, lower discount rates place greater emphasis on the value of future cash flows. This is especially relevant for long-term projects, where the benefits may not materialise for many years. Using a higher discount rate in such contexts would substantially reduce the present value of these future benefits, potentially leading to an undervaluation of the project's long-term impact. Lower discount rates also reflect society's time preference- typically assuming a lower rate in order to assign greater value to benefits accruing to future generations. Long-term projects also face heightened uncertainty- economic, political, and environmental. A lower discount rate helps to mitigate the risk of undervaluing future outcomes by not disproportionately discounting future cash flows, thus offering a more balanced assessment of the project's potential value. Moreover, such an approach supports intergenerational fairness, ensuring that future generations are not disadvantaged by present-day valuation methods. Bramby and Cloutier (2022) even argue that a zero-discount rate may be appropriate for many investment projects – particularly those that are climate-sensitive -precisely to ensure that long-term benefits are not unjustly minimised.

The approaches to quantifying the costs and the three categories of associated dividends are outlined below.

Quantifying Costs of Interventions - The GARID project encompasses three broad thematic areas: *Climate Resilient Drainage and Flood Mitigation*, *Solid Waste Management Capacity Improvements* and *Participatory Upgrading of Targeted Flood Prone Low-income Communities*. Based on a review of relevant literature, interviews with key project personnel, and analysis of project documents a, the cost components required to deliver e. These costs include investments in, or expenses related to both structural non-structural interventions. Structural interventions comprise stormwater retention, tidal gates, drainage infrastructure, and dredging activities, non-structural interventions include early warning and response systems; solid waste management initiatives (such as waste collection programmes and the construction of transfer stations); public awareness campaigns (both community-based and city-wide), participatory community upgrading; and limited (voluntary) resettlement. The cost parameters considered in the analysis include construction costs, operations and maintenance costs, contingencies, costs for design studies and supervision, land acquisition (where applicable), and resettlement expenses. Given the high and often uncertain land acquisition costs, project personnel advised that it is preferable to present cost estimates both with and without these costs included. Due to data constraints, costs were estimated at the level of broad intervention categories rather than for were determined rather than individual sub-components. The costing period spans from 2018 to 2050, with major investments expected to occur in the initial years of implementation, followed by recurring operations and maintenance costs over the long term.

Quantifying Dividend I: Avoided Losses - Avoided losses refer to the portion of potential losses expected to be prevented through the implementation of proposed interventions (Heubaum et al., 2022). Globally, there is growing recognition that investing in disaster prevention is more cost-effective than responding to disasters after they occur. One estimate suggests that for every US$ 1 spent on prevention, up to US$ 6 in future disaster-related costs can be saved (NIBS, 2018). One of the most severe flood-related disasters in the case study area occurred on June 3, 2015, when extensive flooding triggered a fire incident. The disaster affected approximately 53,000 people, caused the death of 150 individuals, and resulted in the in the full or partially destruction of around 77,0000 buildings. The total damage was estimated at US$ 55 million, with a further US$ 115 required for repairs (World Bank, 2020). The World Bank (2020) estimates the average annual loss from flooding in GAR at US$48 million, with and estimated at US$ 34 million attributed to the Odaw River Basin alone. Additionally, the present value of flood-related damage is projected at US$ 1.7 billion for GAR and US$ 1.2 billion for the Odaw River Basin. These figures are expected to quadruple by 2050 in the absence of mitigation measures. For the GARID project, analysis of projected documentation and interviews with key personnel indicate that avoided losses primarily stem from the direct economic benefits of reducing flood damage. The main beneficiaries include households, businesses, and offices located within the Odaw River Basin. Currently, approximately 2.5 million people reside within the Basin, with an estimated 161,000 people considered to be at high risk of flooding from a 1-in-10-year flood event (World Bank, 2020).

Quantifying Dividend II: Induced Economic or Development Benefits - Reducing flood risk can stimulate economic activity by encouraging investment, lowering insurance premiums, and minimising disruptions to businesses. According to Erman et al. (2018), flood management can generate greater benefits than typically estimated by creating an enabling environment for investments in addition to reducing direct losses. Moreover, reducing disaster-related 'background risk' is known to facilitate forward-looking planning, long-term capital investments, and entrepreneurial activity (ODI and GFDRR, 2015). In the case of the GARID project, analysis of project documents, interviews with key personnel, and a review of relevant literature indicate that t induced economic and development benefits are primarily realised, through reduced disruptions to transport and business operations, increased tourism, and enhanced employment opportunities resulting from the interventions (Mensah et al., 2019; Oteng-Ababio, Ablo and Wong, 2020).

Quantifying Dividend II: Social and Environmental Benefits - Assigning a monetary value to social and environmental benefits can be challenging or, in some cases, inappropriate (Heubaum et al., 2022). For the GARID project, analysis of project documentation, interviews with key personnel, and a review of relevant literature indicate that social and environmental benefits are likely to arise from improvements in living conditions and access to basic environmental services -including solid and liquid waste management -reduction in water-borne diseases, and a decline in poverty resulting from reduced exposure to disaster and climate risks. These outcomes contribute to an overall improvement in quality of life in the most vulnerable (Awuah et al., 2020; Oteng-Ababio, Ablo and Wong, 2020). For example, Labite et al (2010) conducted a bacteriological study in Accra and estimated that 60% of all diarrhea-related Disability-Adjusted Life Years (DALYs) are attributable to open, unclean drains. The GARID project solid waste management interventions are therefore expected to generate comparable and environmental benefits.

5. Findings from Case

Costs of GARID Interventions - The costs of the GARID programme interventions are categorised under the following components:

- Climate Resilient Drainage and Flood Mitigation
- Solid Waste Management Capacity Improvements
- Participatory Upgrading of Targeted Flood Prone Low-income Communities

The costs encompass construction, O&M, contingencies, design studies and supervision, and resettlement. The determine the economic costs, financial costs were converted, using shadow pricing, applying a standard conversion factor of 0.83 for capital investments and 0.71 for O&M, in accordance with World Bank guidelines (World Bank, 2019). The total economic cost of the project, comprising the components listed above, is estimated at US$276 million (see Table 1) (World Bank, 2023). This figure excludes land acquisition costs, as the land is owned by the Government of Ghana (World Bank, 2020).

Table 1: Costs of GARID Interventions

Item	**Category**	**Estimated Costs (Initial Investments)**
1	Climate Resilient Drainage and Flood Mitigation	US$162 million[1]
2	Solid Waste Management Capacity Improvements	US$55.2 million[1]
3	Participatory Upgrading of Targeted Flood Prone Low-income Communities	US$58.8 million[1]
	Total	**US$276 million**

[1]Estmated from GARID Project Implementation Status & Results Report (World Bank, 2023)

Feasibility studies conducted by the World Bank (2023) estimate that the O&M costs of the GARID interventions will average 1.33% of the initial investment cost. Based on this estimate, the annual O&M cost amounts to approximately US$3.67 million. As shown in Table 2, the discounted O&M costs for the periods 2018 and 2050 are estimated at US$41.97 million, US$58.00 million and US$74.83 million, using discount rates of 8%, 5% and 3% respectively. Consequently, the total discounted costs -combining capital and O&M – are estimated at US$317.97 million (at 8%), US$334.00 million (at 5%), and US$350.83 million (at 3%).

Table 2: Discounted O&M Costs

Item	Category	O&M Costs per year (1.3%)[1]	Discounted O&M Costs[2]	Total Discounted Costs[3]
1	Scenario 1 - 8% discount	US$3.67 million	US$41.97 million	US$317.97 million
2	Scenario 2 - 5% discount	US$3.67 million	US$58.00 million	US$334.00 million
3	Scenario 3 - 3% discount	US$3.67 million	US$74.83 million	US$350.83 million

[1]This is calculated as 1.3% of total initial investment cost of US$276.00 million.[2]This is calculated as the discounted present value of US$3.67 million per year between 2028 and 2050. [3]Total Discounted Costs = Discounted O&M Costs (Total from Table 1) + Discounted O&M Costs (from Table 2).

Costs and Avoided Losses (Dividend 1) Arising from GARID - To estimate the avoided losses on the GARID project, we relied on analysis of simulated flood damage under scenarios with and without, the project interventions, based on varying flood return periods and future years (World Bank, 2020). The estimates indicate that the GARID interventions are projected to mitigate approximately 48.5% of the potential flood damage in the Odaw River Basin by 2050 (World Bank, 2020). Oteng-Ababio, Ablo and Wong (2020) further estimate that 40% of economic assets in the basin are currently at risk of flooding. The total avoided losses attributable to the GARID interventions- calculated using the simulated flood damage data (World Bank, 2020), annual flood loss estimates, and flood damage projections by Oteng-(Ababio, Ablo and Wong, 2020) – over the period 2018 to 2050 are estimated at:

- **US$370.48 million** at an **8%** discount rate
- **US$938.65 million** at a **5%** discount rate
- **US$1,770.60 million** at a **3%** discount rate

These avoided losses yield Net Present Values (NPVs) of:

- **US$52.51 million** at **8%**
- **US$604.65 million** at **5%**
- **US$1,419.77 million** at **3%**

The corresponding BCRs are:

- **1.17** at **8%**
- **2.81** at **5%**
- **5.05** at **3%**

(see Table 3).

Table 3: Costs and Avoided Losses of GARID Interventions

No.	Category	Scenario 1 - 8% discount	Scenario 2 - 5% discount	Scenario 3 - 3% discount
1	Project Costs	US$317.97 million[1]	US$334.00 million[1]	US$350.83 million[1]
2	Avoided Losses (Dividend I)	US$370.48 million[2]	US$938.65 million[2]	US$1,770.60 million[2]
3	Net Present Value (NPV) = (2-1)	US$52.51 million	US$604.65 million	US$1,419.77 million
4	Benefit-to-Cost Ratio: = (2 ÷ 1)	1.17	2.81	5.05

[1]This is the Total Discounted Costs = Discounted O&M Costs (Total from Table 1) + Discounted O&M Costs (from Table 2). [2]Estimated from reports of simulated damage averted, estimates of annual loss from floods, flood damage estimates and Cost Benefit Analysis of investment options for the year range of 2018 to 2050 (World Bank, 2020; Oteng-Ababio, Ablo and Wong, 2020)

***Costs and Induced Economic or Development Benefits (Dividend 2) Arising from GARID* -** The induced economic or development benefits arising from GARID project interventions are based on Oteng-Ababio, Ablo and Wong's (2020) estimates of the indirect economic gains resulting from reduced transport and business interruption. These benefits are calculated by considering avoided reductions in economic activity, loss of trading time and market demand, and decreased disruptions to both businesses and commuters (World Bank 2020).

Based on this methodology, the induced economic or development benefits from the GARID interventions over the period 2018 to 2050 are estimated as follows:

- US$59.17 million at the 8% discount rate
- US$149.91 million at the 5% discount rate
- US$282.78 million at the 5% discount rate.

These figures resulting the following Net Present Values (NPVs):

- US$258.80 million at 8%,
- - US$184.09 million at 5%
- - US$68.05 million at3%

The corresponding Benefit-to-Cost Ratios are:

- 0.19 at 8%,
- 0.45 at 5%
- 0.81 at

(see Table 4).

These results reinforce the argument in favour of using lower discount rates for long-term climate adaptation investments as advocated by Bramby and Cloutier (2022). Lower discount rates better reflect the long-term nature of such projects and improve their viability in cost-benefit analysis.

It is important to note that these benefits are likely to be significantly underestimated, primarily due to data limitations. Potentially sizeable benefits – such as those derived from investments stimulated by improved infrastructure, reductions of insurance premiums, increased tourism, and enhanced employment opportunities- were not captured in the available data. (Erman et al., 2018).

Table 4: Costs and Induced Economic/Development Benefits of GARID Interventions

No.	Category	Scenario 1 - 8% discount	Scenario 2 - 5% discount	Scenario 3 - 3% discount
1	Project Costs	US$317.97 million[1]	US$334.00 million[1]	US$350.83 million[1]
2	Induced Economic/Development Benefits (Dividend II)	US$59.17 million[2]	US$149.91 million[2]	US$282.78 million[2]
3	Net Present Value (NPV) = (2-1)	- US$258.80 million	- US$184.09 million	- US$68.05 million
4	Benefit-to-Cost Ratio: = (2 ÷ 1)	0.19	0.45	0.81

[1]This is the Total Discounted Costs = Discounted O&M Costs (Total from Table 1) + Discounted O&M Costs (from Table 2). [2]Estimated based on less transport and business interruption (Oteng-Ababio, Ablo and Wong, 2020)

Costs and Social and Environmental Benefits (Dividend 3) Arising from GARID - There is relatively little research on the environmental dividends of the GARID program compared with its social and economic dividends. Maund and Anyidoho (2019) underscore the need for ecosystem-based approaches in GARID's climate change response strategy to enhance biodiversity conservation in the region. The interventions under the GARID project -such as drain widening- are estimated not only to reduce the extent of potential flood damage but also to lessen disease burden (including reductions in diarrhoeal diseases and associated mortality) over the period of 2018 to 2050 (Oteng-Ababio, Ablo and Wong, 2020). The expected reduction in diseases is around 30% with the corresponding averted productivity losses forming part of the overall social and environmental benefits anticipated from the project (Oteng-Ababio, Ablo and Wong, 2020). Community-led solid waste management interventions are also expected to yield additional benefits through the creation of cleaner community environments (Oteng-Ababio, Ablo and Wong, 2020). Furthermore, the World Bank (2019) estimates that welfare effects associated with improved access to services and infrastructure will generate further benefits from 2018 to 2050. Environmentally, the project is projected to achieve a net emissions reduction of 24,940,903 tCO2e over its economic lifetime (World Bank, 2019). The global average carbon price is estimated at $3 per tonne (Parry, 2021); however, the World Bank's State and Trends of Carbon Pricing Dashboard shows that carbon pricing can fluctuate considerably, currently ranging between US$0.46 to US$167 per tonne, with an average of US$83.73 per tonne. Notably, the only carbon pricing mechanism available in Africa is in South Africa, where the price is currently US$10.09 per tonne. Consequently, this South African pricing level may be used as a proxy for the carbon prices in Ghana. The considerable variability in carbon pricing presents challenges when determining the benefits resulting from reduced carbon emissions. It is therefore advisable to consider four scenarios – namely, South Africa, World Bank Low, Average and High carbon prices- to assess their effects on the total social and environmental benefits.

Table 5a: Costs and Social and Environmental Benefits of GARID Interventions for South Africa Carbon Price

No.	Category	Scenario 1 - 8% discount	Scenario 2 - 5% discount	Scenario 3 - 3% discount
1	Project Costs	US$317.97 million[1]	US$334.00 million[1]	US$350.83 million[1]
2	Social and Environmental Benefits (Dividend IIIa, using South Africa Carbon Price @US$10.09 per ton)	US$262.32 million[2]	US$278.68 million[2]	US$302.64 million[2]
3	Net Present Value (NPV) = (2-1)	- US$55.65 million	- US$55.32 million	- US$48.19 million
4	Benefit-to-Cost Ratio = (2 ÷ 1)	0.82	0.83	0.86

[1]This is the Total Discounted Costs = Discounted O&M Costs (Total from Table 1) + Discounted O&M Costs (from Table 2).[2]Estimated based on reduction in disease burden and cleaner environment, welfare improvements and net carbon emission reductions (Oteng-Ababio, Ablo and Wong, 2020; World Bank, 2019). Estimated also based on reduction in disease burden and cleaner environment (Oteng-Ababio, Ablo and Wong, 2020). Estimated, further based on net emissions reduction over the economic lifetime of the project (World Bank, 2019).

The social and environmental benefits arising from the GARID project interventions include multiple components. The reduction in disease burden is estimated to yield total benefits of approximately US$ 78.96 million (Oteng-Ababio, Ablo and Wong, 2020). Additional benefits from a cleaner environment and associated health improvements are valued at US$ 8.51 million (Oteng-Ababio, Ablo and Wong, 2020). Welfare effects linked to improved access to services and infrastructure are expected to generate further benefits of up to US$ 44.8 million. In addition, the reduction in carbon emissions is estimated at US$ 251.65 million, using the carbon price of US$10.09 per tonne, resulting in total social and environmental benefits of US$262.32 million over the period 2018 to 2050, applying an 8% discount rate. At lower discount rates, the total social and environmental benefits are estimate at US$278.68 million (at a 5% discount rate) and US$302.64 million (at a3% discount rate). These yield Net Present Values (NPVs) of - US$55.65 million, - US$55.32 million and - US$48.19 million at 8%, 5% and 3% discount rates, respectively. The corresponding Benefit-to-Cost Ratios are 0.82, 0.83, and 0.86, (see Table 5a). These findings reinforce the case for adopting lower discounts rates in project appraisal. As Bramby and Cloutier (2022) argue lower discount rates support better selection of climate adaptation projects by giving greater weight to long-term benefits.

Table 5b: Costs and Social and Environmental Benefits of GARID Interventions for Low World Bank Carbon Price

No.	Category	Scenario 1 - 8% discount	Scenario 2 - 5% discount	Scenario 3 - 3% discount
1	Project Costs	US$317.97 million[1]	US$334.00 million[1]	US$350.83 million[1]
2	Social and Environmental Benefits (Dividend IIIb, using Low World Bank Carbon Price @US$0.46 per ton)	US$22.14 million[2]	US$38.50 million[2]	US$62.46 million[2]
3	Net Present Value (NPV) = (2-1)	- US$295.83 million	- US$295.50 million	- US$288.37 million
4	Benefit-to-Cost Ratio = (2 ÷ 1)	0.07	0.12	0.18

[1]This is the Total Discounted Costs = Discounted O&M Costs (Total from Table 1) + Discounted O&M Costs (from Table 2). [2]Estimated based on reduction in disease burden and cleaner environment, welfare improvements and net carbon emission reductions (Oteng-Ababio, Ablo and Wong, 2020; World Bank, 2019). Estimated also based on reduction in disease burden and cleaner environment (Oteng-Ababio, Ablo and Wong, 2020). Estimated, further based on net emissions reduction over the economic lifetime of the project (World Bank, 2019).

If the reduction in carbon emissions is valued using the low World Bank carbon price of US$0.46 per tonne, the total social and environmental benefits fall significantly to US$22.14 million over the period 2018 to 2050 at an 8% discount rate, and US$38.50 million and US$62.46 million, respectively, at 5% and 3% discount rates. This results in NPVs of - US$295.83 million, - US$295.50 million and - US$288.37 million, at the 8%, 5% and 3% discount rates, respectively. The corresponding BCRs are 0.07, 0.12, and 0.18, respectively (see Table 5b). These results further highlight the value of applying lower discount rates in the economic appraisal of climate adaptation projects. As Bramby and Cloutier (2022) note, lower discount rates support improved selection of projects by more appropriately accounting for long-term benefits.

Table 5c: Costs and Social and Environmental Benefits of GARID Interventions for Average World Bank Carbon Price

No.	Category	Scenario 1 - 8% discount	Scenario 2 - 5% discount	Scenario 3 - 3% discount
1	Project Costs	US$317.97 million[1]	US$334.00 million[1]	US$350.83 million[1]
2	Social and Environmental Benefits (Dividend IIIc, using Average World Bank	US$2,098.97 million[2]	US$2,115.33 million[2]	US$2,139.29 million[2]

	Carbon Price @US$83.73 per ton)			
3	Net Present Value (NPV) = (2-1)	US$1,781.00 million	US$1,781.33 million	US$1,788.46 million
4	Benefit-to-Cost Ratio = (2 ÷ 1)	6.60	6.33	6.10

[1]This is the Total Discounted Costs = Discounted O&M Costs (Total from Table 1) + Discounted O&M Costs (from Table 2). [2]Estimated based on reduction in disease burden and cleaner environment, welfare improvements and net carbon emission reductions (Oteng-Ababio, Ablo and Wong, 2020; World Bank, 2019). Estimated also based on reduction in disease burden and cleaner environment (Oteng-Ababio, Ablo and Wong, 2020). Estimated, further based on net emissions reduction over the economic lifetime of the project (World Bank, 2019).

If the reduction in carbon emissions is estimated using the Average World Bank carbon price of US$83.73 per tonne, the total social and environmental benefits rise significantly to US$2,098.97 million, US$2,115.33 million, and US$2,139.29 million at the 8% 5% and 3% discount rates, respectively, over the period 2018 to 2050. This results in NPVs of US$1,781.00 million, US$1,781.33 million, and US$1,788.46 million, respectively at the 8%, 5% and 3% discount rates. The corresponding BCRs are 6.60, 6.33 and 6.10, (see Table 5c).

Furthermore, if the reduction in carbon emissions is valued using the high World Bank carbon price of US$167 per tonne, the total social and environmental benefits increase substantially to US$4,175.80 million, US$4,192.16 million, and US$4,216.12 million at 8% 5% and 3% discount rates, respectively, over the period 2018 to 2050. This results in NPVs of US$3,857.83 million, US$3,858.16 million, and US$3,865.29 million, respectively. The corresponding BCRs are 13.13, 12.55, and 12.02 at the 8%, 5% and 3% discount rates, respectively (see Table 5d).

Table 5d: Costs and Social and Environmental Benefits of GARID Interventions for High World Bank Carbon Price

No.	**Category**	**Scenario 1 –** **8% discount**	**Scenario 2 –** **5% discount**	**Scenario 3 –** **3% discount**
1	Project Costs	US$317.97 million[1]	US$334.00 million[1]	US$350.83 million[1]
2	Social and Environmental Benefits (Dividend IIId, using High World Bank Carbon Price @US$167 per ton)	US$4,175.80 million[2]	US$4,192.16 million[2]	US$4,216.12 million[2]
3	Net Present Value (NPV) = (2-1)	US$3,857.83 million	US$3,858.16 million	US$3,865.29 million
4	Benefit-to-Cost Ratio = (2 ÷ 1)	13.13	12.55	12.02

[1]This is the Total Discounted Costs = Discounted O&M Costs (Total from Table 1) + Discounted O&M Costs (from Table 2).[2]Estimated based on reduction in disease burden and cleaner environment, welfare improvements and net carbon emission reductions (Oteng-

Ababio, Ablo and Wong, 2020; World Bank, 2019). Estimated also based on reduction in disease burden and cleaner environment (Oteng-Ababio, Ablo and Wong, 2020). Estimated, further based on net emissions reduction over the economic lifetime of the project (World Bank, 2019).

Costs and All Dividends of GARID Interventions - The analysis shows that the total discounted costs of the GARID interventions amount to US$317.97 million, US$334.00 million, and US$350.83 million at discount rates of at 8%, 5% and 3%, respectively (see Table 2). The total benefits of the GARID interventions range from US$451.97 to US$6,269.50 million, depending on the assumptions applied regarding discount rates and carbon pricing (see Table 6 and Figures 4 to 6). Based on these assumptions, the NPV of the GARID interventions- calculated by comparing total costs and total benefits- ranges between US$134.00 million to US$5,918.67 million, while the BCR ranges from 1.42 to 17.87. These findings indicate that, irrespective of the discount rate or carbon pricing assumptions used across the scenarios, the GARID project interventions demonstrate strong economic viability, with both NPV an BCR results confirming the value of the investment. However, as outlined in Section 4, lower discount rates are generally preferable for long-term projects, such as climate adaptation initiatives, as they lead to better project appraisal and selection (cf. Bramby and Cloutier, 2022).

Figure 4a: Benefits of GARID Project (8% Discount Rate and South Africa Carbon Price @US$10.09)

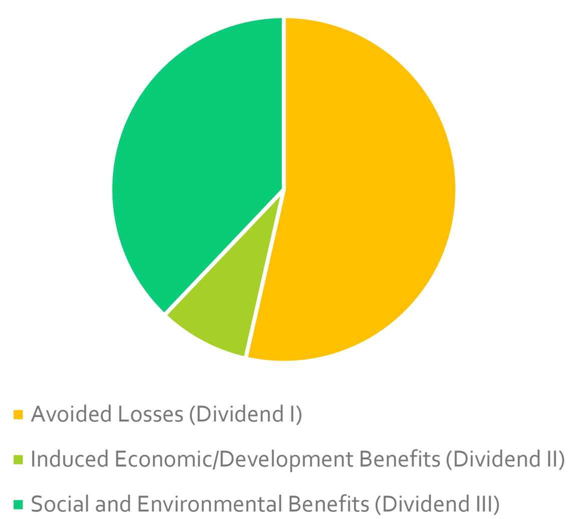


Figure 4b: Benefits of GARID Project (8% Discount Rate and Low World Bank Carbon Price @US$0.46)

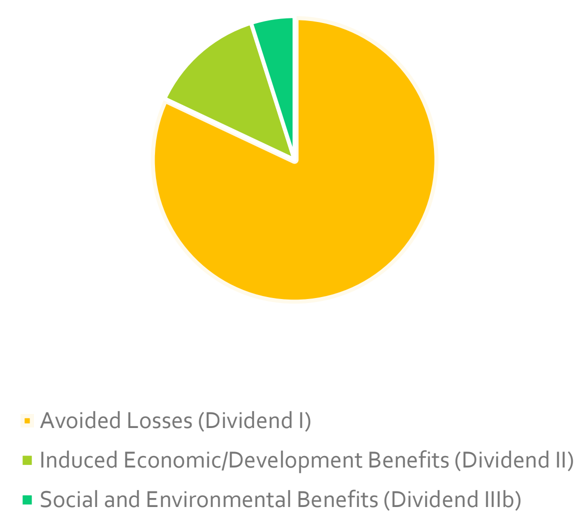


Figure 4c: Benefits of GARID Project (8% Discount Rate and Average World Bank Carbon Price @US$83.73)

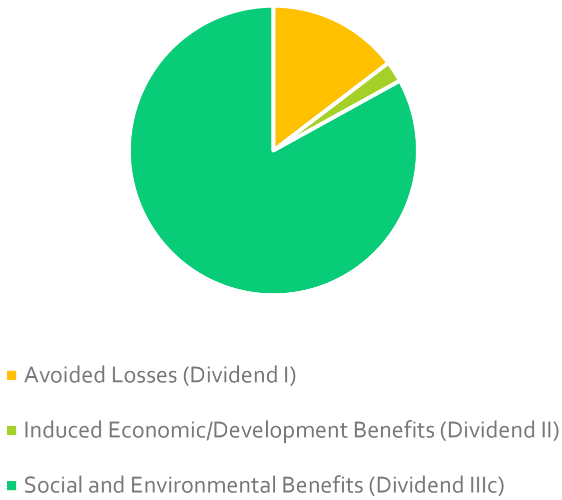


Figure 4d: Benefits of GARID Project (8% Discount Rate and High World Bank Carbon Price @US$167)

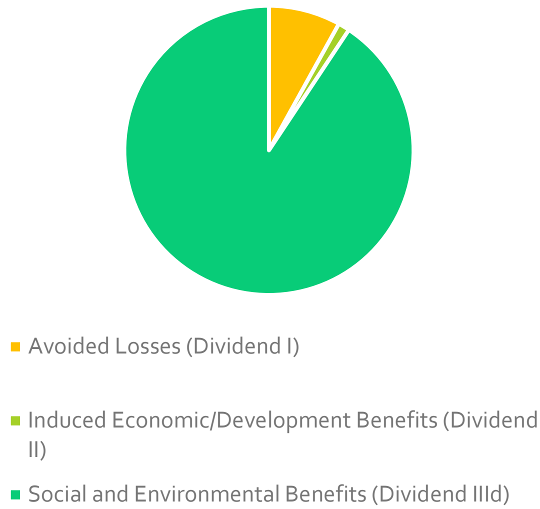


Figure 5a: Benefits of GARID Project (5% Discount Rate and South Africa Carbon Price @US$10.09)

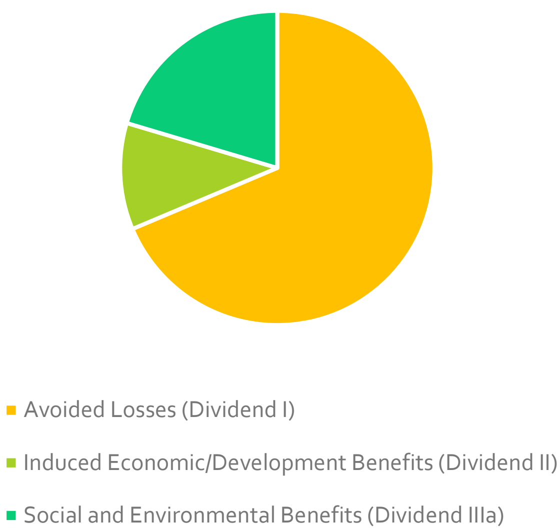


Figure 5b: Benefits of GARID Project (5% Discount Rate and Low World Bank Carbon Price @US$0.46)

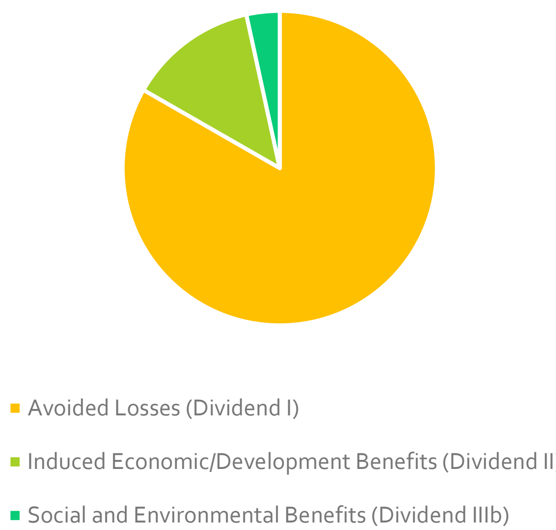


Figure 5c: Benefits of GARID Project (5% Discount Rate and Average World Bank Carbon Price @US$83.73)

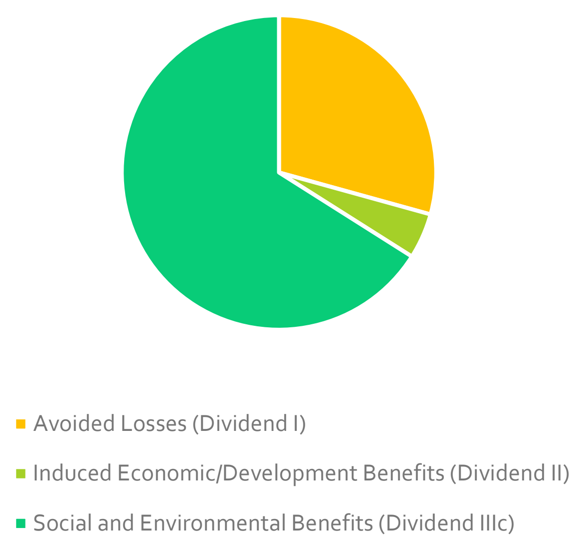


Figure 5d: Benefits of GARID Project (5% Discount Rate and High World Bank Carbon Price @US$167)

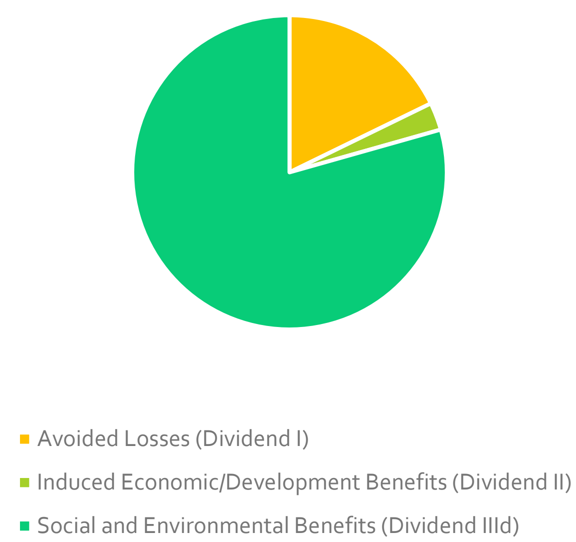


Figure 6a: Benefits of GARID Project (3% Discount Rate and South Africa Carbon Price @US$10.09)

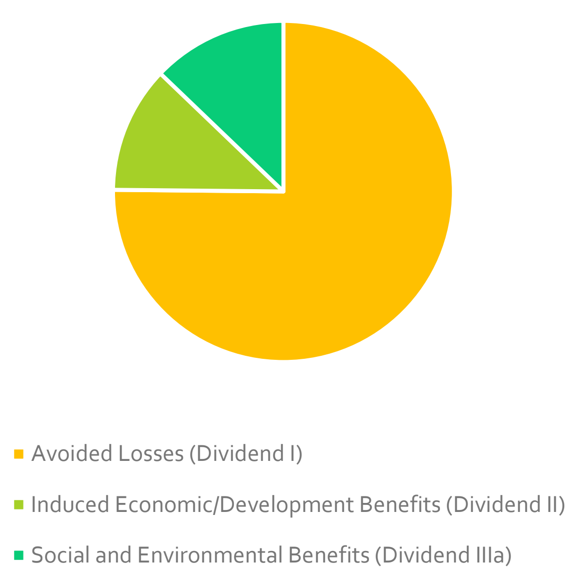


Figure 6b: Benefits of GARID Project (3% Discount Rate and Low World Bank Carbon Price @US$0.46

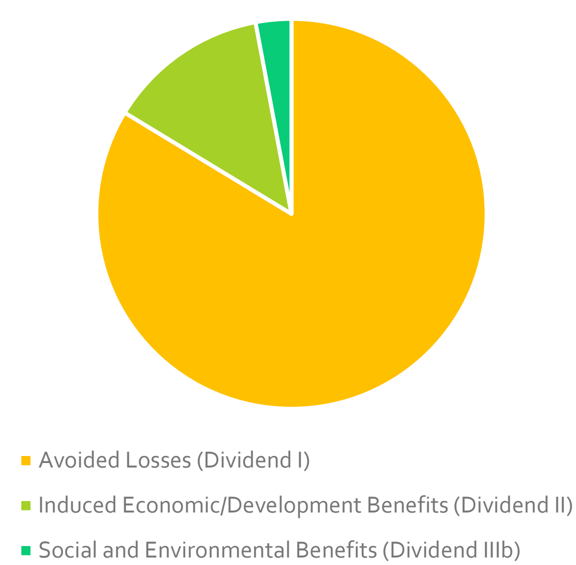


Figure 6c: Benefits of GARID Project (3% Discount Rate and Average World Bank Carbon Price @US$83.73)

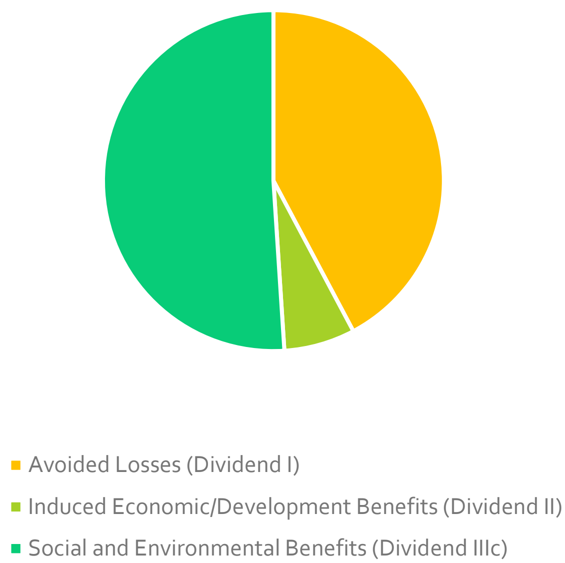


Figure 6d: Benefits of GARID Project (3% Discount Rate and High World Bank Carbon Price @US$167)

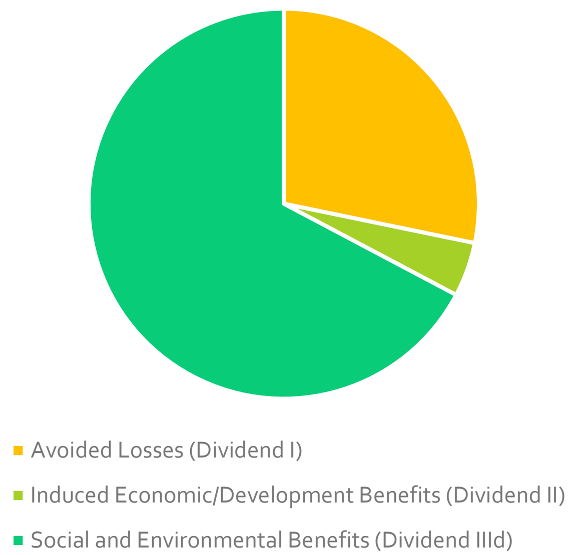


Table 6: Costs and All Dividends of GARID Interventions

No.	Category	Scenario 1 – 8% discount	Scenario 2 – 5% discount	Scenario 3 – 3% discount
1	Project Costs	US$317.97 million[1]	US$334.00 million[1]	US$350.83 million[1]
2	Avoided Losses (Dividend I)	US$370.48 million[2]	US$938.65 million[2]	US$1,770.60 million[2]
3	Induced Economic/Development Benefits (Dividend II)	US$59.17 million[2]	US$149.91 million[2]	US$282.78 million[2]
4	Social and Environmental Benefits (Dividend IIIa, using South Africa Carbon Price @US$10.09)	US$262.32 million[3]	US$278.68 million[3]	US$302.64 million[3]
5	Social and Environmental Benefits (Dividend IIIb, using Low World Bank Carbon Price @US$0.46)	US$22.14 million[3]	US$38.50 million[3]	US$62.46 million[3]
6	Social and Environmental Benefits (Dividend IIIc, using Average World Bank Carbon Price @US$83.73)	US$2,098.97 million[3]	US$2,115.33 million[3]	US$2,139.29 million[3]
7	Social and Environmental Benefits (Dividend IIId, using High World Bank Carbon Price @US$167)	US$4,175.80 million[3]	US$4,192.16 million[3]	US$4,216.12 million[3]
8	Project Benefits (Dividends I, II & IIIa) = (2+3+4)	US$691.97 million	US$1,367.24 million	US$2,356.02 million
9	Project Benefits (Dividends I, II & IIIb) = (2+3+5)	US$451.97 million	US$1,127.06 million	US$2,116.02 million
10	Project Benefits (Dividends I, II & IIIc) = (2+3+6)	US$2,528.62 million	US$3,203.89 million	US$4,192.67 million
11	Project Benefits (Dividends I, II & IIId) = (2+3+7)	US$4,605.45 million	US$5,280.72 million	US$6,269.50 million
12	Net Present Value (NPV): Dividend I, II and IIIa = ((2+3+4) -1)	US$374.00 million	US$1,033.24 million	US$2,005.19 million

13	Net Present Value (NPV): Dividend I, II and IIIb = ((2+3+5) -1)	US$134.00 million	US$793.06 million	US$1,765.19 million
14	Net Present Value (NPV): Dividend I, II and IIIc = ((2+3+6) -1)	US$2,210.65 million	US$2,869.89 million	US$3,841.84 million
15	Net Present Value (NPV): Dividend I, II and IIId = ((2+3+7) -1)	US$4,287.48 million	US$4,946.72 million	US$5,918.67 million
16	Net Present Value (NPV): Dividend II and IIIa only = ((3+4) -1)	US$3.52 million	US$94.59 million	US$234.59 million
17	Net Present Value (NPV): Dividend II and IIIb only = ((3+5) -1)	- US$236.66 million	- US$145.59 million	- US$5.59 million
18	Net Present Value (NPV): Dividend II and IIIc only = ((3+6) -1)	US$1,840.17 million	US$1,931.24 million	US$2,071.24 million
19	Net Present Value (NPV): Dividend II and IIId only = ((3+7) -1)	US$3,917.00 million	US$4,008.07 million	US$4,148.07 million
20	Benefit-to-Cost Ratio: (Dividends I, II & IIIa) = ((2+3+4) ÷ 1)	2.18	4.09	6.72
21	Benefit-to-Cost Ratio: (Dividends I, II & IIIb) = ((2+3+5) ÷ 1)	1.42	3.37	6.03
22	Benefit-to-Cost Ratio: (Dividends I, II & IIIc) = ((2+3+6) ÷ 1)	7.95	9.59	11.95
23	Benefit-to-Cost Ratio: (Dividends I, II & IIId) = ((2+3+7) ÷ 1)	14.48	15.81	17.87
24	Benefit-to-Cost Ratio: Dividend II and IIIa only = ((3+4) ÷ 1)	1.01	1.28	1.67
25	Benefit-to-Cost Ratio: Dividend II and IIIb only = ((3+5) ÷ 1)	0.26	0.56	0.98
26	Benefit-to-Cost Ratio: Dividend II and IIIc only = ((3+6) ÷ 1)	6.79	6.78	6.90
27	Benefit-to-Cost Ratio: Dividend II and IIId only = ((3+7) ÷ 1)	13.32	13.00	12.82

[1]This is the Total Discounted Costs = Discounted O&M Costs (Total from Table 1) + Discounted O&M Costs (from Table 2). [2]Estimated from reports of simulated damage averted, estimates of annual loss from floods, flood damage estimates and Traditional Cost Benefit Analysis of investment options for the year range of 2018 to 2050 (World Bank, 2020; Oteng-Ababio, Ablo and Wong, 2020) [3]Estimated based on reduction in disease burden and cleaner environment, welfare improvements and net carbon emission reductions (Oteng-Ababio, Ablo and Wong, 2020; World Bank, 2019). Estimated also based on reduction in disease burden and cleaner environment (Oteng-Ababio, Ablo and Wong, 2020). Estimated, further based on net emissions reduction over the economic lifetime of the project (World Bank, 2019).

6. Conclusion and recommendations

Despite widespread recognition of the increasing losses from disasters and climate-related risks, investment in ex-ante Disaster Risk Management (DRM) remains limited. This is partly due to the way in which decisions in DRM are made (ODI and GFDRR, 2015). This study has demonstrated that the TDR approach offers a credible, evidence-based framework for decision making and investment planning in climate change adaptation. It further shows that considering broader range of benefits- that is, all three dividends- rather than focusing solely avoided losses (Dividend I as in traditional cost-benefit analysis, can significantly improve BCR metrics and enhance the perceived viability of adaptation and resilience investments. In the case of the GARID project, the Induced Economic/Development Benefits (Dividends II) and Social and Environmental Benefits (Dividend III) significantly increased the overall BCR enhanced by -6% and 1,235% - compared to assessing avoided losses alone. Specifically, the lowest BCR when only Dividend I is considered 1.34, while the inclusion Dividend II and III increases the BCR to a range of 1.42 to 17.87, depending on the assumptions regarding to discount rates and carbon pricing. This analysis also confirms that lower discount rates are preferable for long-term projects, such as climate adaptation, as they result in more favourable project selection outcomes. These conclusions hold despite limitations in data availability and the potential underestimation of some benefits, particularly those relating to induced economic benefits and social and environmental gains benefits.

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