Food and Agriculture Organization of the United Nations

Economic assessment of **drought risk management**

A two-tier framework for cost–benefit analysis of proactive versus reactive drought management

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by
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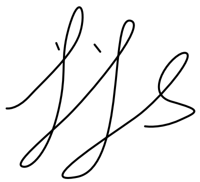
Foreword

Drought is among the costliest natural hazards, generating significant economic losses and damages across sectors, especially in agriculture. Accordingly, the paradigm shift from reactive to proactive drought management approach is more important than ever with the intensifying and the rising frequency of drought events, coupled with anticipated worsening conditions due to climate change. However, even with the urgency of implementing proactive action, the constantly encountered economic challenge – of allocating scarce or limited resources – hinders progress in the decision-making process. Identifying alternative courses of action and selecting the fitting option to address drought entail complex and risk-informed decision-making. Decisions should serve the communities' goals, and thereby, improve social welfare.

Economic decisions, however intricate, will always involve benefits and cost factors. Decision-makers are concerned with determining the losses and damages they will incur and the resources they have to invest, as well as the returns, which will provide better conditions than those anticipated in the absence of the proposed intervention. Under this setting, the fundamental considerations for economic decision-making cover: the extent of benefits and costs, the timing of action, and the risks of the decision. Given the uncertainty surrounding the occurrence of drought in terms of timing and intensity, all three decision-making factors are vital. Thus, the crucial question is: "how do we undertake proactive investments"?

The "Economic Assessment of Drought Risk Management" report is prepared by the Food and Agriculture Organization of the United Nations (FAO) under the framework of the project "Enabling Activities for Implementing UNCCD COP Drought Decisions", funded by the Global Environment Facility (GEF), and implemented in collaboration with the United Nations Convention to Combat Desertification (UNCCD) and other partners. The project is designed to support the operationalization of national drought plans according to the principles of integrated drought management. The report investigates the broad concept of the economics of drought management, provides a conceptual, two-tier framework for the assessment of proactive and reactive actions, and disseminates case studies for the implementation of the framework in decision-making processes.



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Abbreviations

BACI – benefits of action and costs of inaction

CCA – climate change adaptation

CSA – climate-smart agriculture/al

DRR – disaster risk reduction

FAO – Food and Agriculture Organization of the United Nations

GDP – gross domestic product

HMNDP – High-level Meeting on National Drought Policy

IDMP – Integrated Drought Management Programme

MAR – managed aquifer recharge

USD – United States dollar

Highlights

Drought is considered one of the costliest and most destructive among natural hazards. With the threat of higher frequency and greater intensity of future drought events due to climate change, the debate in drought management has evolved from whether to implement reactive or proactive drought management approaches – in other words, whether to invest or not in proactive drought actions – to how to invest in proactive drought action.

Proactive actions or drought risk management actions are rational economic investments that provide benefits during both the periods with and without drought. There is a need to adjust the mindset that perceives proactive actions to address only concerns related to minimizing drought impacts, and to not reap returns during non-drought periods. This is required to break the vicious cycle of the so-called 'hydro-illogical cycle' that characterizes the myopic behaviour of drought-affected stakeholders. The previous mindset allows for investment intentions on proactive action to be overshadowed by other issues during non-drought periods, thereby facilitating reallocation of funds and re-prioritization of investments from drought mitigation to other urgencies. An adjusted outlook on proactive action should be promoted. That is, investments in proactive drought measures can avoid losses and save costs when a drought disaster occurs, while providing rapid stimulus to the economy and producing co-benefits in the absence of drought.

The decision to undertake proactive action and invest in the most rational proactive measures is a complex process. There are a number of factors to be taken into account, one of which is the economic rationality of the investment decision. While economic elements are not the only consideration, an economic assessment, such as a cost–benefit analysis, is a critical step in this decision-making process. This kind of assessment can methodically evaluate the viability of a drought risk management measure and can help prioritize measures in a suite of options. With this is the significance of effectively capturing both the cost and benefit items in an economic assessment.

In relation to costs, intangible costs are significant factors to consider in assessing the total costs of inaction. Whereas a variety of intangible costs is recognized as part of the costs of droughts, these factors are yet to be incorporated as a regular cost item in assessments due to the challenge in quantifying them. These intangible costs include environmental costs such as damages to wildlife and fish habitat, animal disease, loss of biodiversity, loss of wetlands, etc. These costs may likewise be in the form of social costs manifested through the inconvenience or hardship experienced in accessing and acquiring water, and in some cultures where provision of water is considered to be women's responsibility, additional burden to women in searching for water. Hence, there is a need to improve the intangible cost's comparability against monetized cost in economic assessments. Enhancement in accounting costs of proactive action is also warranted. Along with the direct costs, the indirect, intangible and transaction costs incurred in adopting or implementing proactive measures should be considered. Transaction costs, in particular, can be substantial and may be a vital consideration in selecting a proactive drought measure to implement.

All types of benefits of proactive actions need to be incorporated in economic assessments. Overlooking a benefit item renders the assessment incomplete and the results to be misleading. Such benefit items include avoided costs, cost savings, unlocked economic potential, and the economic, environmental and social co-benefits. Distinguishing between the benefits received when drought strikes and the benefits accrued without drought provides a more systematic analysis of benefits. The distinction allows for the investment gains during non-drought years to be outlined better.

A framework that incorporates both monetized and intangible factors in comparing benefits of action and costs of inaction is a helpful tool in drought investment decision-making. Such framework enables an in-depth understanding of the benefits and costs of proactive action, and the costs of inaction. Under this premise, this report proposes a two-tier framework based on the cost-benefit analysis tool that is set in a broader multicriteria analysis framework. This tool promotes a two-level assessment of proactive measures, with the first level emphasizing evaluation of the economic viability of the measures. Meanwhile, the second level allows for prioritization of economically viable options, enabling combinations of measures that will maximize benefits and minimize costs to be selected. Thus, economic assessments can provide decision-makers, planners, and project managers the opportunity to consider both monetary and non-monetary decision criteria in planning and designing the proactive drought risk management measures to implement.

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1 Introduction

As drought is the most complex of all natural hazards, predicting the onset and the foreseen impacts is difficult, thus creating uncertainties when investment risks are identified. Drought is a slow-onset event whose beginning and end of cycle periods are difficult to identify. Because of this, and without preparedness, such as availability of early warnings, drought incidents are typically recognized when communities, economies, and societies begin to feel the phenomenon's consequences (Vogt *et al.*, 2018; Logar and van den Bergh, 2013; Ndayiragije and Li, 2022). Another, drought is a recurrent event, whose duration can vary from a few months to several years, making it possible to last longer than any other hazard. Also, drought can occur in any part of the world, irrespective of precipitation or temperature regimes, though with varying frequencies, severities, and implications (Jenkins, 2012). Drought is characterized by variable spatial propagation through different subsystems, from the meteorological subsystem to the agricultural, ecological, and hydrologic subsystems (Gil *et al.*, 2013; Fuentes *et al.*, 2022). The complexity of drought events is a major cause of the uncertainty in investment risk perceptions. Different and evolving drought events can be mitigated with varying measures, but the best trade-off between the efficacy and the profitability – be it a financial or an economic profit – must be targeted.

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Drought has no universally applicable definition, and this contributes to the difficulty in addressing and managing drought impacts. Meteorological drought relates to rainfall deficit from average conditions, as well as to temperature anomalies resulting to dry weather patterns. Propagation from meteorological drought to other drought types depends on many factors. For example, hydrological drought involves depletion in surface and sub-surface water supplies such as rivers, reservoirs, lakes, ponds, and aquifers from average conditions, causing low water supply. On the other hand, agricultural drought is linked to the deficiency in soil moisture, thereby, affecting crop growth. Finally, ecological drought relates to water unavailability resulting to the reduction in the health of forests, wetlands, and wildlife habitat (Jenkins, 2012; Ndayiragije and Li, 2022). Distinguishing the different types of droughts is often not possible, as the different systems are interdependent.

Due to its unique characteristics, drought can cause extensive short- and long-term economic, social, and environmental impacts and cascading effects over different time horizons. Consequently, drought is considered one of the costliest and most destructive among natural hazards (Logar and van den Bergh, 2013; Freire-González *et al.*, 2017; Vogt *et al.*, 2018; Ndayiragije and Li, 2022; Reichhuber *et al.*, 2022). This is because drought has direct and indirect impacts, and even though the associated costs of indirect impacts are not immediately apparent, knock-on effects on other sectors can entail significant costs. For example, irrigation from groundwater can reduce the risk of drought in agriculture sector, but declining water tables increase the cost of pumping and affect the energy demand. The same characteristics that contribute to the complexity of drought also define the reasoning for its strengthened management, especially with the threat of higher frequency, longer duration, and greater severity (Jenkins, 2012; World Meteorological Organization and Global Water Partnership, 2017; Garcia-Leon *et al.*, 2021; United Nations Office for Disaster Risk Reduction, 2021). Drought management can be classified as pre-drought - or proactive measures which cover mitigation and preparedness, and post-drought - or reactive measures which ultimately build up the drought recovery process (Ndayiragije and Li, 2022). Many proactive measures, in reality, are taken during the onset or early phases of declared drought events. Under the impact-horizon categorization prepared by the Food and Agriculture Organization of the United Nations (FAO), pre-drought measures involve those that improve resilience of the system, including the measures that improve the ability of systems to withstand and adapt to drought (Horizon 1). Examples of these measures include construction of climate-smart irrigation systems, construction of post-harvest facilities, land and ecosystem restoration practices, and adoption of drought-tolerant varieties. Pre-drought actions also include the measures that mitigate the potential impacts when the onset of drought is already declared (Horizon 2), such as early information to agricultural stakeholders (e.g. farmers, pastoralists), destocking of livestock, introducing micro credit and crop insurance schemes for farmers at very low interest rate, estimation of loss and damage to measure the impact on food security, and identification of priority interventions to determine areas where loss and damage is expected, among others. Horizons 1 and 2 differ in a sense that impact mitigation during an ongoing drought event has a limited window to take action due to the time constraints. Consequently, the timelines of the financial transactions are shortened to an extent that not all types of proactive measures can be implemented. Meanwhile, post-drought measures fall under the recovery and restoration category, wherein activities to recover from drought events after impacts and measures to restore systems are primarily implemented (Horizon 3). Examples of these measures include emergency food assistance and drinking water provision to affected populations, relief funds, subsidies for restoring livestock population, indemnity insurance compensations, tax reliefs, and rehabilitation/recovery programmes (Pek and Salman, 2023).

The complexity of drought translates to the challenge in its economic assessment. The economics of drought management goes beyond discussions of monetary costs and returns of drought resilience measures. It encompasses the assessment of the measures' economic costs and benefits that affect societies' well-being in a sustainable manner. Drought resilience measures vary from simple and less expensive practices, such as adopting water conservation practices, to large-scale constructions like installing water harvesting infrastructures or setting-up irrigation systems.

The broad menu of potential interventions suggests that drought impacts can be mitigated through alternative measures, thus giving ample opportunities to select the best-fitting measures that are economically rationale. Distinct measures can address the same or similar drought impacts, though, to different extents and on different timelines. The flexibility of the selection is precisely the advantage that can inspire lucrative investment approaches in drought management. Nevertheless, understanding of drought, its impacts, and the monetized value of impacts is fundamental for constructing such approaches. Based on these premises, the question left is **how an economic assessment of integrated drought management can be conducted in support of the dual objectives of making rationale investment decisions and building drought resilience**.

Box 1. Drought management terminology

This report uses "drought management" as the general term when referring to both the proactive and reactive drought management approaches. Drought "risk" management, on the other hand, specifically refers to the proactive approach. Fundamentally, proactive drought management is a risk-based approach which mitigates drought risks and minimizes the scale and severity of drought impacts.

Source: Authors' own elaboration.

Call for a paradigm shift in drought management

Due to the failings and shortcomings of the traditional drought management being implemented, a shift from reactive to proactive drought management approach is being called for, but the financial viability of its implementation is often called into question. The prevailing structure of drought management is the reactive, post-hazard or post-impact management. They are also called crisis-based or crisis-driven approaches, as relief to impacted sectors and individuals are provided when drought has reached a crisis state. Most countries engage in reactive drought management, such that these measures have been considered the default course of action for natural hazard-related disasters such as drought. However, this approach has been criticized to:

- incur high human, social, ecological, and economic costs;

- be less efficient, less effective, and largely untimely;
- trade off self-reliance; and
- be often poorly coordinated and fragmented (Logar and van den Bergh, 2013; World Meteorological Organization and Global Water Partnership, 2017; Augenstein *et al.*, 2022).

Moreover, the reactive management approach has been assessed to fail in reducing future vulnerability to drought. In fact, some contends that providing relief to those vulnerable to drought may have acted as an incentive for systems to stay in a vulnerable state. As a result, continued vulnerability makes reactive management more costly to society than proactive investments that mitigate and prepare for drought risks by building resilience (World Meteorological Organization and Global Water Partnership, 2017). In response to these shortcomings, a call has been raised for a "paradigm shift from reactive and crisis-based approach towards a more proactive drought management approach" (Tsegai and Bruntrup, 2019).

Despite the advantages of a change, the shift from reactive to proactive drought management has been protracted and moving at a slow pace even in the most affected countries. Proactive drought management is a risk-based approach which mitigates drought risks and minimizes the scale and severity of drought impacts. As a risk-reducing approach, it decreases vulnerability, builds capacities, and thus, strengthens resilience to drought. Proactive drought measures have been argued also to be socially optimal compared to reactive drought measures (World Meteorological Organization and Global Water Partnership, 2017; Farr *et al.*, 2022; United Nations Convention to Combat Desertification, 2022). With these, the support for the transition – from reactive to more strategic proactive risk-based approach to drought management – is becoming stronger (FAO, 2019; Venton *et al.*, 2019; United Nations Office for Disaster Risk Reduction, 2021; Augenstein *et al.*, 2022; United Nations Convention to Combat Desertification, 2022). Even though this shift has already gained strong political commitment and its advantages have been proven, progress for implementation of proactive action has been protracted and halted often due to economic reasons (Sayers, *et al.*, 2016; Venton, *et al.*, 2019).

The challenges

Current empirical evidence on the economic viability of engaging in proactive actions are lacking. One of the reasons for such slow development is economics, particularly, the allocation of scarce or limited resources and the 'uncertainty' of positive returns on investments. Governments and the private sector, alike, are yet to be convinced to significantly invest and allocate funds to proactive measures, especially to drought mitigation as this typically involves high levels of investments in hard or structural measures. To date, there is a lack of economic assessments, specifically, on the costs and benefits of mitigation and preparedness investments against reactive measures. There is a shortage of empirical evidence on the greater economic efficiency – allocation of resources to their most valuable uses – of drought risk management compared to the reactive drought management approach (Ding *et al.*, 2010; World Meteorological Organization and Global Water Partnership, 2017).

Proactive actions are typically seen as addressing concerns only related to drought events and are yet to be recognized as rational economic investments under conditions without drought. The avoided costs from droughts are the most acknowledged benefits of proactive investments. Accordingly, there are hesitations on the returns on investments during non-drought periods. In essence, there is doubt on the economic gains in investing, given the uncertainty in drought occurrence. Proactive investments are perceived to be sunk costs (i.e. costs incurred that cannot be recovered) if drought does not occur (Overseas Development Institute and World Bank, 2015). Under this state of uncertainty, individuals, governments, and society, in general, will "delay irreversible investments until their net benefits exceed a positive critical value" (Venton *et al.*, 2019, p. 10). Consequently, countries tend to continue with the traditional reactive path of addressing drought than venture into the direction of proactive drought risk management.

Proactive measures can be turned into appealing investment opportunities under scenarios with and without droughts if investment in resilience is well designed to contribute to development objectives. In disaster risk reduction (DRR) and climate change adaptation (CCA), the above issues are addressed by measuring the additional economic potential and the co-benefits of proactive action investments or the "triple dividend of investments" in resilience (Overseas Development Institute and World Bank, 2015). The same is true in drought management; thus, it is crucial that economic potential and the co-benefits of investments in proactive management are identified, enhanced, and communicated. Information on the clear positive net benefits and extensive co-benefits of proactive drought risk management actions are foreseen to incentivize decision-makers in undertaking such investments. Fundamentally, good sets of costs and benefits information and extensive economic assessments are vital for an informed drought management decision-making (Meyer *et al.*, 2013; Vorhies and Wilkinson, 2016; Freire-González *et al.*, 2017).

The benefits from a proactive measure can be enhanced if its design is based on a 'multi-risk approach for integrated management of hazards'. The advantages of a proactive measure are amplified if it does not only address the impacts of drought but responds to further development needs such as agricultural productivity or answers DRR or CCA concerns. To illustrate, constructing an integrated or multi-functioning reservoir, as part of an integrated approach for flood and drought management, magnifies the benefits gained from the infrastructure. The integrated reservoir can protect assets from flood damages and can be resupplied to avoid yield failure during droughts. In this sense, the co-benefit is not in a form of revenue generation (i.e. economic benefit), but is manifested through avoiding costs that can be brought about by other natural hazard related disasters.

Objectives and scope of the report

The provision of a framework for decision-making can help repurpose the question "should the proactive investment be undertaken?" to "how should the proactive investment be undertaken?". Investment in drought resilience should not be a mere financial question, as an investment decision based on profitability would easily exclude the most vulnerable. Investment in drought is not yes-or-no question as resilience-building is necessary in all conditions and environments. The question is rather **how investment should be designed to maximize the economic benefits for all**.

Efforts to narrow the knowledge gaps are being implemented to support the adoption of proactive measures, but resources are still scarce. One such endeavour is the World Bank and Integrated Drought Management Programme's (IDMP) methodological framework for the assessment of the benefits of action and costs of inaction (BACI) for drought mitigation and preparedness. The present report is a parallel effort to the BACI assessment tools utilized in accomplishing the 10-step methodology for developing a drought risk management policy proposed in the World Bank and IDMP report. The present report complements the BACI assessments through:

- further exploring the cost and benefit elements for economic assessments;
- developing typologies of costs of drought and benefits of proactive drought risk mitigation and preparedness actions;
- investigating possible indicators to represent the costs and benefits of drought; and
- stocktaking on possible data sources.

Given the limited financial funds and existing economic constraints of many countries, the efficient use of resources is of vital importance. Moreover, with the unique characteristics of drought, which sets it apart from other hazards, proactive drought measures would need to address not only the consequences of drought, but also would require to function effectively during periods without drought. Hence, this report goes further by developing a two-tier framework on how to effectively use the sets of information from BACI assessments for drought decision-making.

Economic assessments of drought are best conceptualized within the integrated framework of drought management, disaster risk reduction, climate change adaptation and development. Some contends that to be successful, the economic argument for drought mitigation and preparedness should be founded within the wider disaster risk management framework and should be embedded within existing local and national development processes (Venton *et al.*, 2019). This report supports this notion, and it expands this line of thinking by arguing for an assessment of benefits of action and costs of inaction within an integrated framework of drought management, disaster risk reduction and management, and climate change adaptation. Thus, while the report primarily focuses on drought, it will borrow economic concepts, arguments, and ideas from their literature and frameworks. This strategy promotes the reasoning that drought management is not an independent, self-contained, or stand-alone issue, but is a concern that spans across sectors and systems. Whereas the report will incorporate economic costs, benefits, and other valuation concepts from various fields, it limits itself economic assessment related to drought.

This report aims to assist decision-makers, policymakers, planners, and national authorities responsible for planning and programming to conduct an exhaustive economic assessment related to drought. With the knowledge gained from the report, a critical step in drought investment decision-making process can be effectively undertaken. Furthermore, the report is a useful tool for policymaking and for formulating drought plans at all levels, in view that the development of a drought plan requires the identification and assessment of resources to implement it.

Report outline

The report is structured to guide the readers through the decision process flow. It depicts the various stages towards attaining a proactive action decision, along with the additional steps in selecting a proactive measure to implement among a suite of options. The report is structured in two parts, one to set the theoretical background for an economic assessment of drought management, and the other to provide a practical framework to conduct the economic assessment.

The first part of the report includes the following sections:

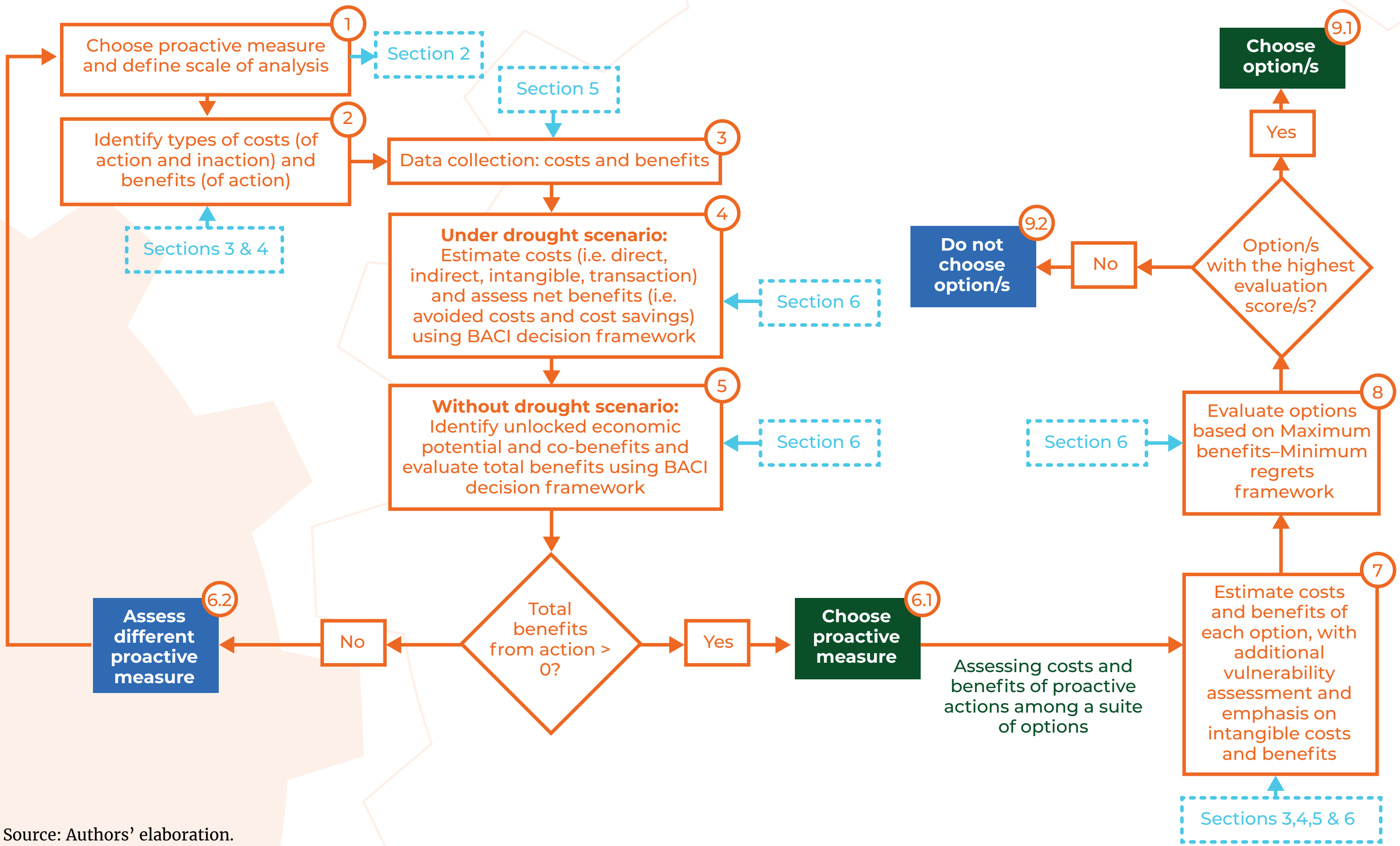
- Section 2 explores drought management measures under the reactive and proactive actions to drought.
- Section 3 discusses cost, where a typology of costs is proposed and each type of costs is investigated.
- Section 4 presents benefit discussions and focuses on the benefits of actions.
- Section 5 presents information that can assist in identifying cost and benefit items, such as compilations of cost and benefit indicators from different case studies, and sets of possible data sources.

The second part of the report includes the following sections:

- Section 6 describes and illustrates the proposed framework for evaluating monetized and non-monetized benefits and costs of drought inaction and action, and for selecting proactive measures among a suite of options.
- Section 7 recommends actions on the way forward.

The structure is visualized in Figure 1 to reveal the logical relationships among chapters. While the proposed framework is ready-to-use, the chapter contents are fundamental for putting the definitions into the right context.

Figure 1. Report outline in decision process flow for cost–benefit assessment



Source: Authors' elaboration.

2 Drought management measures

Drought management can be classified in many ways, but a particular aspect of it is the timing-based classification that distinguishes measures taken before or after the impacts occur. Post-drought measures fall under the reactive approach, while pre-drought actions comprise the drought risk management approach, also called the proactive approach. Reactive drought management is triggered during droughts and implemented within and after the drought event's timeframe. Thus, it covers relief, late or rescue response, recovery, and restoration measures. On the other hand, proactive drought management encompasses mitigation and preparedness actions. Proactive actions primarily aim to reduce vulnerabilities and strengthen resilience of systems to droughts; therefore, these are measures that can be operated even during the absence of drought (Figure 2 and Table 1) (Logar and van den Bergh, 2013; FAO, 2019; Ndayiragije and Li, 2022). The notion here is to demonstrate the diversity of drought measures, thus supporting the assumption that even if a specific measure is not financially viable, other economically justified measures can replace it to address the same impact. Drought is among the very few disasters that lend themselves to be managed in various ways, and like this, enable the optimization of the cost–benefit ratio of its management.

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Table 1. Approaches to drought management

Approaches	Investment types	Timing of occurring costs
1. Reactive drought response	Assistance to vulnerable populations: water, food, health care	During droughts
	During drought: emergency water wells, water trucking, emergency water transfer After drought: restoration of lost assets, re-establishment of livestock production, distribution of seeds as compensation	Triggered during and after droughts
2. Proactive drought mitigation and preparedness policies, plans, and measures	Preparedness or contingency plans, programmes; drought policy institutions	Continuing
	Mitigation measures such as hydraulic infrastructure: wells, aqueducts, dams, irrigation, water, and sanitation systems Investment in farm-level good practices such as drought-resistant seeds, soil and water management practices, etc.	Continuing, especially in non-drought years
	Proactive drought policies as part of sustainable development planning, integrated water resources management, environmental policy, drought and environment as part of sectoral and regional policies, institutional development and capacity building, participation and civil society role, water demand management (irrigation efficiency improvement, water allocation, leakage reduction)	Continuing

Source: Authors' elaboration based on **FAO**. 2019. *Proactive approaches to drought preparedness: Where are we now and where do we go from here?* Rome, Food and Agriculture Organization of the United Nations. http://www.fao.org/3/ca5794en/ca5794en.pdf.

Figure 2. Impact-horizon categorization of drought financial instruments

	HORIZON 1 **Improved Resilience**	HORIZON 2 **Early response**	HORIZON 3 **Recovery and restoration**
(i)	Building long-term resilience to improve the ability of systems to withstand, adapt to, transform and recover from drought, including the preservations and restorations of basic functions	Taking actions on and mitigating the direct impacts of already forecasted drought, and ensuring safety and basic needs of affected systems	Recovering from drought events after impacts occurred and restoration of systems by building back their basic functions
(clock)	Time-neutral, but before a successive drought event would be forecasted and priority actions should be taken	Before the full-scale impacts of a forecasted or ongoing drought event occur	Post-drought event, when impacts occurred
(scale)	Large scale, for example infrastructure, large equipment, programmatic interventions, systematic and transformative capacity building	Small to medium, for example small-scale and easy to-distribute equipment, fast-track practices, temporary relocation, safety measures	Small to large, for example rehabilitation and reconstruction, insurance pray-out and compensation transter, provision of stocks, distribution of productive assets
(institution)	Monitoring and early warning, impact and vulnerability assessment, mitigation and preparedness	Impact and vulnerability assessment mitigation and preparedness	Impact and vulnerability assessment, mitigation and preparedness

Source: Authors' elaboration based on the work of **Pek, E. & Salman, M.** 2023. *Enabling pathways for drought finance in agriculture*. Rome, FAO. https://doi.org/10.4060/cc7453en

In conventional terms, financing drought measures can be considered as investment if any sort of benefits (e.g. added value or profit) is generated overtime. This definition makes the economic assessments of reactive and proactive measures distinct. If investment in proactive measures bring benefits, for example development-related targets or avoidance of predictable losses, measuring the economic viability is straightforward. Nevertheless, new-generation emergency projects qualify as investment too. If post-disaster measures are implemented in the spirit of "building back better", reactive actions can incorporate proactive measures to reduce the risks, and therefore, contribute to build resilience to future drought events. Thus, the definition of timing is often blurred by the timeline and the extent of the investment impact. Timing associated with the impact can help overcome the dilemma. It can also serve as a basis for the decision whether an economic assessment can be conducted in a meaningful way or not.

Under the impact-horizon categorization, pre-drought actions fall under Horizons 1 (improved resilience) and 2 (anticipatory action and early response) categories, while Horizon 3 (recovery and restoration) fits under post-drought activities. FAO developed a classification for drought finance which is based on three impact-horizon categories (Pek and Salman, 2023). This horizon-categorization incorporates four parameters:

1. definition of expected drought impacts;
2. timing of the action;
3. investment scale/horizon; and
4. identified instruments per the three pillars of the integrated drought management (i.e. monitoring and early warning; vulnerability and impact assessment; risk mitigation, preparedness and response).

The categorization is applicable, not only to drought financing, but also to the classification of drought management measures. Particularly, Horizon 1 instruments, which aim to build resilience of systems and improve the ability to withstand, adapt to, transform, and recover from drought are covered under the risk mitigation measures. Meanwhile, Horizon 2, which encompasses actions to address impacts of forecasted drought are included under the preparedness measures. It is important to note that Horizon 2 is a transition between Horizon 1 and 3, but it is still considered as the phase for proactive measures. The identification of the occurrence of the first impacts is often difficult, especially if their magnitudes are low enough to be neutralized. Therefore, Horizon 2 covers the window where an existing drought event is managed in a proactive manner to avoid irreversible losses and damages. Lastly, Horizon 3 refers to the phase when drought management is reactive, after the full-scale impacts of drought have occurred and are geared toward recovering from drought events and restoring the basic functions of systems (Figure 2). Such categorization forms a basis for the decision on how a drought measure counts as investment.

The costs and benefits of drought measures are among the primary deciding factors for the selection of proactive measures. A good comprehension of the purposes, characteristics, properties, and capabilities of drought measures will assist in effectively identifying cost and benefit items. This section explores pre- and post-drought measures with the objective to better understand the various drought management options that can be implemented before, during, and after drought events. Knowing better how proactive drought actions work, their impacts on the agriculture sector, and the linkages of their effects to other sectors or systems, can assist in:

- distinguishing various benefits reaped through the proactive measures' implementation;
- realizing the economic opportunities that may unfold due to reduction of system risks; and
- identifying system linkages, thereby, realizing the possible additional economic, environmental, or social benefits that measures can deliver.

First and foremost, it is important to review and understand which drought measures qualify as a proactive or resilience-building measure.

Reactive drought management approach

The timing of the implementation distinguishes proactive drought management approaches from the reactive ones, but depending on the nature of the measure, reactive can turn into proactive measure. Since reactive drought actions are initiated when drought is occurring, or when the intensity of drought impacts has reached a crisis state, reactive approach is also referred to as crisis management. The reactive approach has two distinct types of measures to alleviate the crisis. Those that are the immediate responses, and those that deal with recoveries. This is the prevailing approach in many countries, and thus, is considered the traditional action for drought (Logar and van den Bergh, 2013; Vogt *et al.*, 2018). In general, national and local governments, or local communities take the responsibility for response actions; and under extreme conditions or intense severity of drought impacts, international organizations, likewise, intervene (Ndayiragije and Li, 2022). A third type of measures are the ones that are implemented in the post-drought period but serve long-term objectives related to resilience building. Given that the reactive approach is conceptualized in this report as a crisis-based or crisis-driven approach, and that response is initiated when drought has reached a crisis state, and for pragmatic reasons, this report shifts this third type of measures under the proactive category.

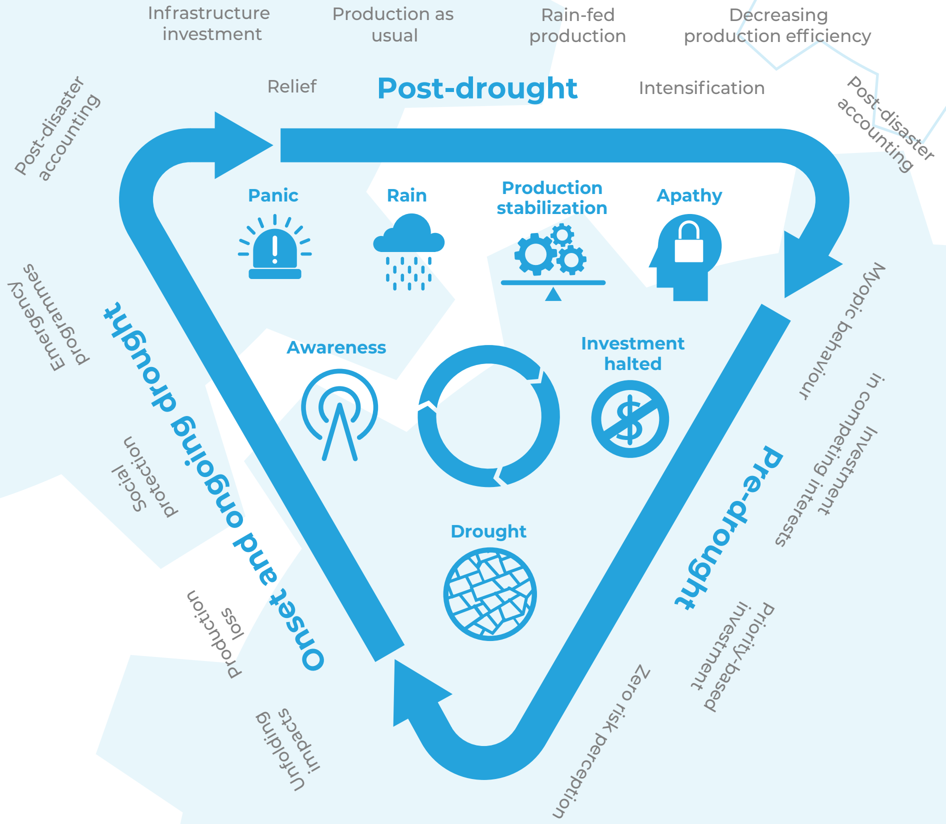
Box 2. Recovery actions to build back better

Ideally, recovery measures need to contribute to building back better, and to enhancing the resilience of people and systems in view of future drought events. However, reactive measures are often based on an emergency rather than on a strategic framework, hence, designs of measures to ensure building better conditions than before are often not achieved. A post-drought recovery measure, whose effectiveness is assessed, planned, and designed before drought strikes but implemented during or after drought occurs, can be considered more of a proactive rather than a reactive measure. In this sense, timeline of action is continuous, beginning pre-drought and completing post-drought.

Source: Authors' own elaboration.

There is lack of acknowledgement that drought can occur in any part of the world – even in areas which are traditionally not drought-prone – and that drought can return again and again, albeit occurrence in terms of timing is with uncertainty. Consequently, there is the absence of recognition that drought is a normal part of the climate (Jenkins, 2012; Wilhite, 2019). Under these circumstances, Wilhite (2015; 2019) described the perseverance of the reactive approach as a hydro-illogical cycle. According to Wilhite, at the beginning of a drought event, awareness of drought is the prevailing condition. This initial reaction is trailed by concern and panic as drought intensifies. Then intentions for reducing drought vulnerability emerge. However, when regular rainfall patterns return, plans to develop proactive drought strategies in preparation for the next drought event are usually set-aside, and the system moves to the apathy stage. And then, as the next drought event is experienced, the cycle continues. Applying this idea on investment behaviour in relation to drought, awareness of the hazard is the initial stage of the cycle. Applying this idea on investment behaviour in relation to drought, awareness of the hazard is the initial stage of the cycle. When drought intensifies, damages are incurred, and investment behaviour enters the concern stage. When drought reaches a crisis level, reactive response is triggered – relief programmes are implemented, investments in infrastructures to alleviate drought impacts are applied, and plans for reducing drought vulnerability emerge. But when precipitation patterns return to normal (i.e. agriculture recovers and production starts to increase), the concern over drought becomes overshadowed by more pressing issues of the moment. Given the limited resources, both the public and private sectors alike, reallocate funds and re-prioritize investments from drought mitigation and preparedness to other urgencies. Accordingly, proactive drought investments are halted. Thus, when the next drought arrives, the system is unable to prepare for and mitigate the impacts of drought, and the cycle begins again (Figure 3).

Figure 3. Hydro-illogical cycle: Reactive approach to drought



Source: Authors' elaboration based on the work of **Wilhite, D.A.** 2015. Chapter 7.1: Drought-management policies and preparedness plans: Changing the paradigm from crisis to risk management. In: I. Chabay, M. Frick & J. Helgeson, eds. Land restoration: Reclaiming landscapes for a sustainable future, pp. 443–462. Elsevier.

Box 3. Risk assessment as instrument to overcome the hydro-illogical cycle

Under the Sendai Framework for Disaster Risk Reduction, the first priority of action is understanding disaster risk in all its dimensions of vulnerability, capacity, and exposure of persons and assets. This understanding is achieved through an effective risk assessment. In relation to the hydro-illogical cycle of drought management, risk assessment facilitates improved knowledge of disaster risk at the awareness stage. Next, risk assessment brings up-to-date information on the vulnerabilities, capacities, and exposures of areas, people, and assets, thereby providing better understanding of the need for drought risk management measures when the cycle reaches the concern stage. Lastly, risk assessments enable targeted solutions at the crisis stage. In essence, risk assessment can be an important instrument to overcome the hydro-illogical cycle in drought management.

Source: Authors' own elaboration.

The primary objectives of response are to cover the basic needs of drought victims and avert extreme drought consequences such as loss of lives, while recovery contributes to returning systems to pre-drought conditions. Carrying out response measures under the reactive approach chiefly involves making immediate decisions and actions regarding people from severely impacted areas. Accordingly, most reactive actions are in the form of emergency programmes that provide relief, in terms of basic needs. Examples of these efforts include public aid to compensate loss of revenue, drought relief funds, food/feed programmes and provision of drinking water supply. In particular, providing monthly allowance to the low-income people can assist families to afford their basic needs, especially those who suffered from loss of revenues. Meanwhile, recovery actions offer support in building back pre-drought or normal conditions. They are comprised of measures that aim to reduce the burden of drought impacts, and to move toward restoration and recovery. These actions are expressed through, for example, subsidies or lower prices for livestock transportation and feeds, insurance compensations, tax reliefs, rehabilitation/recovery programs, moratoria on loan, or low-interest loans (Wilhite, 2015; Water Research Foundation, 2015; FAO, 2019; Ndayiragije and Li, 2022).

The reactive approach has been criticized as flawed, with serious limitations and shortcomings. The reactive approach chiefly deals with the symptoms of drought and not the causes such as vulnerability or exposure to drought (Logar and van den Bergh, 2013; Wilhite, 2015). One shortcoming of the approach is its tendency to increase vulnerability and reduce coping capacity of systems to drought in the long-term due to the probable reliance of communities and individuals on relief and recovery assistance. High dependence on reactive measures has further consequences on the ability to build resilience for future events. The severe impacts of drought are likely to suppress or compromise people's capacities to recover, and relief and recovery assistance, when implemented under an emergency framework, will not be sufficient. In other words, losses and damages suffered by communities can further increase their vulnerability, which would, in optimal case, require additional measures to restore only the baseline levels. For this reason, response and recovery measures may need additional resources that are often not available or provided by post-disaster interventions. Reactive measures are likewise considered to be effective short-term remedies, but not long-term solutions. They typically do not result to changes in behaviours, or operation and management practices. Thus, after the assistance has been extended, those affected by drought return to business as usual. To illustrate, provision of water through tanks may reduce severe water scarcity during a specific drought event, but it cannot be a stable solution to the default water scarcity problem. Another limitation of the reactive approach is the timing. Assistance often arrives beyond the time they are most needed or after the period when relief is most valuable (Wilhite, 2015; Bandyopadhyay *et al.*, 2020).

The following list of limitations of the reactive drought approach is compiled from global references (Logar and van den Bergh, 2013; Wilhite, 2015, 2019; Vogt *et al.*, 2018; Bandyopadhyay *et al.*, 2020):

- Given that measures are applied under emergency situations, there is minimal time for evaluating best options and for conducting stakeholder consultations. Accordingly, there is limited stakeholder participation in the decision-making process.
- As carried out without consultations and under time-pressure, implementation of reactive measures often results in inefficient technical and economic solutions, and efforts are typically uncoordinated and untimely.
- They are often focused on treating symptoms of impacts instead of causes. Hence, the approach reinforces the continuation of past management practices that contributed to forming system vulnerabilities to drought.
- Placing little attention on reducing drought risks in view of future drought events, actions are effective for a short period, typically within months or only for one season or a single drought event.
- Actions can increase vulnerability to future drought episodes and decrease the coping capacity of individuals and communities by reducing self-reliance and increasing dependence of people on governments and donor organizations.

With the limitations of reactive drought management, and the trend of continued system of reliance on humanitarian aid, the call for transition to proactive drought management is gaining ground. For one, humanitarian aid was not designed, nor resourced, to address cyclical and predictable shocks at immense scales (e.g. drought crises in the Horn of Africa) (Farr *et al.*, 2022). Another, since reactive measures focus mostly on the impacts of current drought event and pays little attention to efforts geared toward reduction of future drought impacts, people remain vulnerable and continue to experience extreme impacts from the hazard.

Box 4. Recent events on reactive drought

Limitations and shortcomings of reactive measures continue to manifest in recent drought crisis events. The fading drought awareness and the identified failings in the preceding discussions are evident in the drought experiences of the people in the Horn of Africa (i.e. Ethiopia, Kenya and Somalia) during the last decade. Farr *et al*. (2022) reported that, in 2011, even with constant warnings of an imminent drought crisis in the Horn of Africa region, drought response (e.g. assistance) was not received on time. Consequently, Somalia suffered serious famine due to severe drought, causing the death of over a quarter of a million people. Following the disaster, leaders in the region committed to end drought emergencies by 2022. Likewise, the international community strived to guarantee that the failures that led to the 2011 famine will not be repeated. However, the 2021–2022 drought revealed that full commitment for proactive action was not activated at full scale. Nearly half a million people across Somalia and parts of Ethiopia again faced famine-like conditions due to drought; and in Kenya, around 3.5 million people suffered crisis levels of hunger.

Source: **Farr, E., Finnegan, L., Grace, J. & Truscott, M.** 2022. *Dangerous delay 2: The cost of inaction*. London, Save the Children International and Nairobi, Oxfam International. https://www.oxfam.org/en/research/dangerous-delay-2-cost-inaction

Proactive drought management approach

The transition from reactive to proactive drought approach is still in the nascent stage, although the recognition of the strengths of the proactive drought risk management approach is steadily growing. The call for a paradigm shift in drought management was primarily motivated by the outcome of the High-level Meeting on National Drought Policy (HMNDP) held in Geneva, Switzerland, in March 2013. The fundamental goal of the HMNDP was to build drought resilient societies, characterized with food security and sustainable natural resource systems. By addressing multiple components of drought management, such as disaster risk reduction, national water policies, or land policies and planning, the integrated drought management framework promotes mitigation of drought risk, reduction of system vulnerabilities, and strengthening of system resilience to drought (Crossman, 2018; Wilhite, 2019). Another vital outcome of the HMNDP is the encouragement of adopting national drought management policies whose key elements are comprised of proactive mitigation and planning measures, risk management and public outreach. These policies, likewise, are envisioned to:

- improve public understanding of and preparedness for drought;
- develop greater collaboration among institutions and enhance the observation networks and information delivery systems at all levels (national, regional and global);
- promote inclusion of governmental and private insurance and financial strategies into drought preparedness plans;
- develop a safety net of emergency relief based on sound stewardship of natural resources and self-help at diverse governance levels; and
- foster effective, efficient and customer-oriented coordination of drought programmes and response (Sivakumar *et al.*, 2014).

Box 5. Benefits of proactive measures in the case of Gujarat, India

Proactive drought actions can address the shortcomings of reactive drought measures, reduce the impacts of drought, and attend to the needs of individuals, communities, and society as a whole. Bandyopadhyay *et al.* (2020) analyzed drought management in Gujarat, India and showed that the existing management heavily relies on the reactive or post-disaster actions, with minimal proactive action measures. As a result, conditions sometimes worsen rather than improve. For example, the 2019 drought relief expenditures created a heavy burden on the Gujarat State's budget expenditures, which could have been utilized for development activities.

Bandyopadhyay *et al.* (2020) emphasized that implementation of mitigation measures would have reduced the severity of drought impacts, as well as increased crop production, and therefore, would have resulted in savings in resources spent on relief. Another, with high dependence on relief, the only choice of affected people is to wait for rations of food, water, and other needs, which may be delayed or be insufficient. If work relief is available, women, older and disabled people tend to be at a disadvantage, especially if only hard manual jobs are offered. Hence, vulnerable people – poor, children, women, elderly, and disabled people – experience the heavy impacts of drought the most. With such findings, it was concluded that improvements in drought management can be achieved by reducing vulnerability and strengthening resilience of people to drought, specifically, by implementing drought risk management measures. Suggested risk management measures are:

- **Prediction and early warning**: investment in improved seasonal climate forecasts, communication of information to grass root level communities regarding the status of monsoon, forecast temperature information along with rainfall, use of region-specific meteorological parameters for declaring drought, use of appropriate drought index for a particular region.
- **Preparedness**: preparing district, village, and household level drought plans; preparing checklist of all the measures to be taken before monsoon, during monsoon and post monsoon; sharing of database for drought preparedness and planning between drought hit states; introducing micro credit and crop insurance schemes for every farmer at very low interest rate.
- **Mitigation**: identifying vulnerable groups and mapping their location for planning, water storage structure, advanced water conservation strategies, region specific impact assessment methodologies, better monitoring networks, creating awareness about early warning and predictions issued, involving local communities in water harvesting techniques, reuse of irrigation water and minimization of wastage of water.

Source: **Bandyopadhyay, N., Bhuiyan, C. & Saha, A.K.** 2020. Drought mitigation: Critical analysis and proposal for a new drought policy with special reference to Gujarat (India). *Progress in Disaster Science, 5*: 1–13.

Water management is at the centre of proactive approaches, and proactive actions can be short- or long-term measures towards reducing water demand, increasing water supply, or minimizing the impacts of drought. It is no exaggeration to say that all investment in water sector is investment in drought management, but not all drought measures are related to water sector. The continuum of proactive management incorporates measures that have impacts before, during and after the drought event. However, their implementation is based on a strategy rather than within an emergency framework. Measures undertaken before the occurrence of drought are typically the long-term structural and institutional endeavours that aim to reduce the vulnerability of systems to drought and to strengthen the dependability of the systems to address future demands under drought scenario. Examples include increasing the capacity of storage facilities, improving water use efficiency, and applying integrated water resource management. On the other hand, measures implemented after the projection or start of a drought are short-term measures that attempt to confront an incoming drought event within the existing framework of infrastructures and management policies. These cover measures such as contingency or emergency plans, or conservation measures implemented in severe drought conditions (Rossi *et al.*, 2005; Integrated Drought Management Programme and Global Water Partnership, 2015; Water Research Foundation, 2015; FAO, 2019).

A proper analysis of the costs and benefits requires a thorough stocktaking of drought measures, but stocktaking must be routinely updated to keep pace with technology development. An all-inclusive stocktaking is certainly not possible and is not a one-off event. Nevertheless, the identification of alternative measures that serve the same objectives is of great importance if the economics of drought management is investigated. Under the assumption that all drought impacts should be somehow addressed, the economic decision is more about the selection of optimal measure that is based on socio-economic and environmental arguments. While retaining the principle that the stocktaking is a dynamic and continuous process, existing information portals and studies such as the Drought portal by FAO, the Drought Toolbox by UNCCD, or the HelpDesk of the IDMP are useful instruments to kick off the process.

Annex 1 includes a non-inclusive list of proactive measures, aggregated under FAO's results framework on integrated drought management (FAO 2023, Integrated Drought Management Programme, 2023, United Nations Convention to Combat Desertification, 2023).

Proactive drought measures are manifold and can target the same objective, so the selection must be based on multiple criteria, including the availability of resources, the desired scale of impact, and the economic feasibility. Implementation of proactive drought measures has a relatively large opportunity cost, but the concern can be dispelled if alternative measures are taken into account. For example, declining availability of renewable water resources can be compensated through the development of alternative sources, improvement of conveyance system deficits, or controlled water demand. Even if the option of alternative sources is selected, there is a broad menu of techniques including seawater desalination, water reuse, or non-conventional water harvesting. At the macro level, proactive drought activities typically involve institutional and policy measures; at the micro-level, efforts encompass structural and non-structural measures involving households, communities and individual businesses (World Meteorological Organization and Global Water Partnership, 2017; Vogt *et al.*, 2018; Tsegai and Bruntrup, 2019: United Nations Secretariat of the International Strategy for Disaster Reduction, 2007; Ndayiragije and Li, 2022; Water Research Foundation, 2015; Integrated Drought Management Programme, 2021). Nevertheless, sustainability is jeopardized if proper economic assessment is not carried out before the selection. **As rule of thumb, economic assessment must be reiterated until the sum cost of the measure, or the combination of measures, is lower than the cost of inaction**.

3 Costs of drought management

One of the critical but challenging areas in the economic assessment of drought is estimating the costs of drought impacts and of drought measures. Cost assessments provide crucial information for drought decision-making. The BACI assessment stated that "the costs and benefits of [a proactive drought risk management policy] must be weighed against the losses that are likely to result if no plan is in place (i.e. the cost of inaction)" (Venton *et al.*, 2019). Based on the World Bank and IDMP's BACI framework, the costs of inaction are comprised of the damages or losses incurred due to the occurrence of drought. Meanwhile, costs of action are classified as impact mitigation costs, preparedness costs and drought relief costs. Mitigation and preparedness costs comprise the costs of proactive drought action, while relief costs compose the costs of reactive drought action. A large share of the literature conveys that the costs of inaction are typically higher than the costs of actions, but setting up this assumption is not a linear process.

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Taking proactive drought action versus not taking action or taking a different action entails complex decision-making. Empirical evidences are necessary requirements and valuations of damages and losses to drought are helpful decision support mechanisms to this process. Given the limited resources for investments in drought management, cost estimates serve as guides in setting disaster assistance levels, developing risk management strategies, deciding on the appropriateness of mitigation, determining suitable levels of mitigation, and assessing trade-offs with different management options, among others (Bouwer *et al.*, 2011; Jenkins, 2012; Logar and van den Bergh, 2013; Freire-González *et al.*, 2017; Cravens *et al.*, 2021).

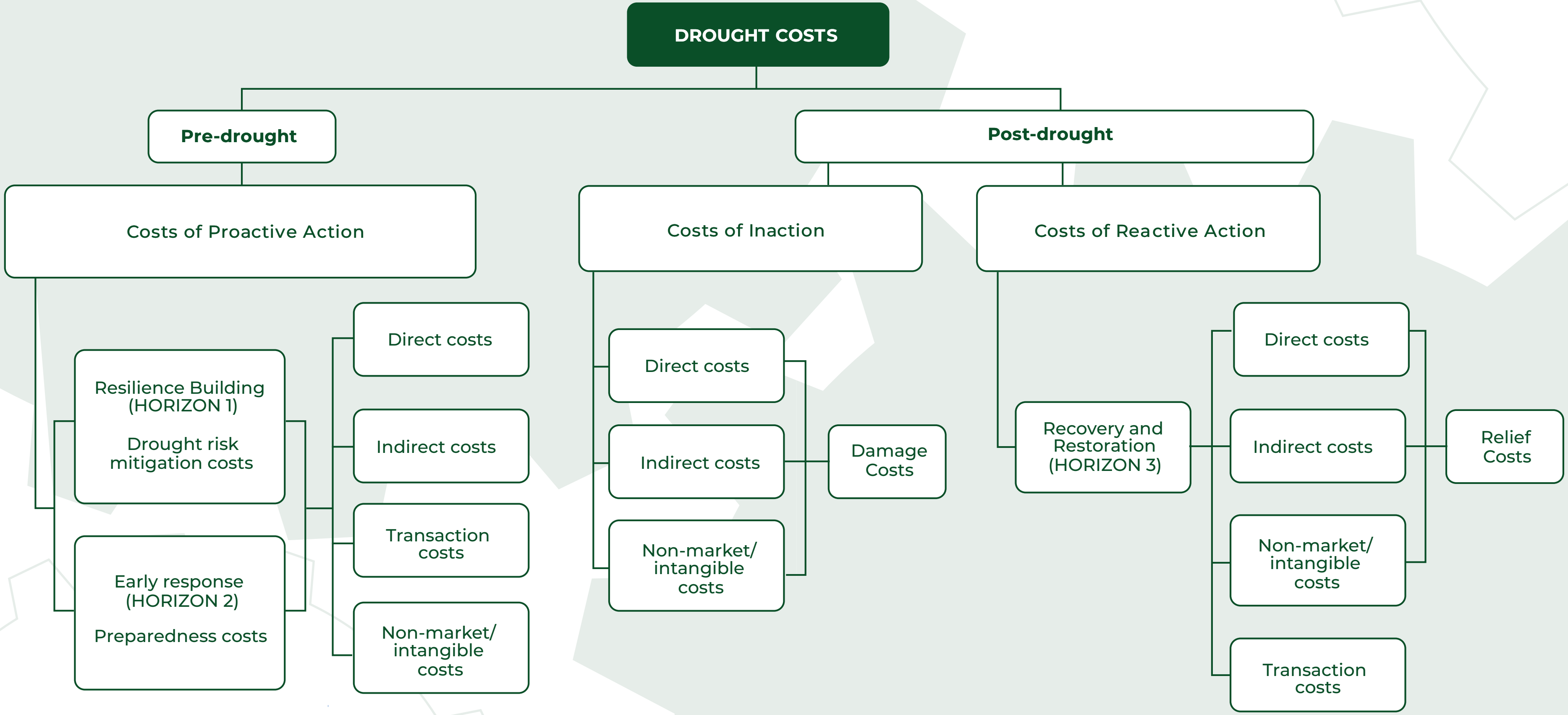
Cost estimation is a challenging exercise, and a number of factors contribute to the difficulty in effectively conducting this activity, most important of which is the interdependency of involved systems that absorb far-reaching and spillover effects of drought impacts. For damages and losses, these factors include the lack of consistent and systematic approaches for calculating economic costs. There is also the bias of cost assessments towards the direct costs of drought against indirect and intangible costs, little understanding on the compounded and cascading impacts of droughts, uncertainties in cost estimates, and a shortage of methodologies in quantifying the social and economic effects of drought. Consequently, costs, in most instances, are underestimated (Ding et. al, 2010; Jenkins, 2012; de Brito, 2021). Similar difficulties are encountered in cost calculations for proactive drought management. However, additional challenges are identified, such as the need for better estimation of non-structural measures, the lack of methodologies for comparative analysis of reactive and proactive drought management costs, and the lack of tools that could support the integration of cost assessments into the decision-making process (Meyer *et al.*, 2013; Naumann *et al.*, 2015; World Meteorological Organization and Global Water Partnership, 2017; Venton *et al.*, 2019). This section addresses some of these knowledge gaps by proposing a typology of costs that goes beyond the cost categories generally identified in literature. It also clarifies cost terminologies for a better understanding of concepts. This understanding enables a more effective identification of costs to include in the estimation process, thereby, minimizing underestimation.

Typology of costs: Pre-drought and post-drought costs

Costs of drought are distinguished as pre- and post-drought costs, where pre-drought cost refers to the cost of the implementation of proactive actions, and the post-drought cost is categorized as either the cost of inaction or the cost of reactive actions. This report proposes a classification of costs based on the timing or timelines by which costs are incurred. The costs of inaction and costs of reactive actions, which are both classified as post-drought costs, are considered to be very closely linked, almost synonymous, but not equal. The cost of inaction is the cost incurred by loss of functions or assets in a system, while the cost of reactive action is the cost of recovering or restoring the system to a state closest to its original condition. Examples of costs of inaction are the crop loss and the systemic impacts on health and nutrition due to water deficit brought by drought. Meanwhile, an example of the cost of a reactive action is the distribution of third-season seeds to compensate households and food markets for the loss of harvest.

The typology works under the assumption that the reactive action is triggered by the impacts of drought, and that the magnitude of the cost of reactive action is influenced by the extent of inaction. That is, the greater is the level of inaction, the higher is the cost of reactive action to recover or restore the system. On the other hand, proactive action is operationalized before drought takes place. Its implementation is not activated by the degree by which a current drought event is affecting economies, societies and environments. Rather, proactive action is based on experiences from historical drought occurrences – and (possibly now) on the basis of climate projections – and has been designed using strategic rather than emergency framework. Proactive action aims to minimize both the damage costs and the recovery and restoration costs by reducing vulnerabilities and strengthening resilience of systems to future drought events. Figure 4 displays a stylized diagram of a proposed typology concept that provides a basis for the development of an assessment framework.

Figure 4. Typology of drought costs



Source: Authors' elaboration.

It is vital to consider all cost items in accounting for the costs of drought, but no agreed vocabulary has been established to create a basis for a common understanding, and such missing baseline is a detriment to the development of economic assessment methods. Along with the typical costs identified with droughts, namely, direct costs, indirect costs, and non-market or intangible costs, this typology includes transaction costs incurred for taking proactive drought mitigation and early response measures, and reactive recovery and restoration activities. In order to effectively account for the proactive and reactive action costs, a good understanding of the cost concepts is required. Such understanding enables better identification of costs to include in the estimation process (Figure 5).

Figure 5. Definition of costs

Direct costs

	Proactive action (pre-drought)	Cost of inaction (post-drought)
Direct costs	Primary costs: cover all fixed and variable inputs in researching and designing, setting-up, operating, and maintaining drought early response and resilience building measures; typically have market values and are monetized	Primary damage costs in economic production: incurred due to the interruption in water supply as key input, losses and reductions in income flows, and decline in productivity from economic activities that utilize water; typically have market values and are monetized
Indirect costs	Secondary costs, externalities, or negative consequences: incurred by other stakeholders due to the activities incited by the investments in, or by the adoption of, drought management measures; consequences of systems linkages; can be monetized or qualitatively assessed.	Secondary costs: characterized by cascading upstream and downstream costs in production and compounded costs in the consumption market; consequences of systems linkages; can be monetized or qualitatively assessed.

In-tangible costs

Proactive action (pre-drought) / **Cost of inaction (post-drought)**

Non-market damages and losses: difficult to assess in economic terms due to their lack of market values; primarily qualitatively assessed but can be quantitatively analyzed using non-monetary unit of measure; largely generated by the social, environmental, health, and cultural impacts of drought or drought risk management measures; can be caused by direct or indirect impacts of drought; affect welfare of individuals and society

Trans-action costs

Proactive action (pre-drought)

Costs: incurred by engaging in transactions such as

- (re)allocation of resources;
- transfer of property rights in relation to goods and services;
- transfers of information, knowledge, and ideas;
- activities associated with public policies and government decision-making;
- the undertakings that define, establish, maintain, use, administer, and change institutions and organizations;
- the actions needed to define the problems that these institutions and organizations are intended to address.

Can be monetized or quantitatively assessed, but typically qualitatively analyzed

Source: Source: Authors' elaboration based on the works of **Ding, Y., Hayes, M. J. & Widhalm, M.** 2010. Measuring economic impacts of drought: A review and discussion. Papers in Natural Resources. Nebraska, University of Nebraska–Lincoln. https://digitalcommons.unl.edu/natrespapers/196. **Bouwer, L. M., Poussin, J., Papyrakis, E., Daniel, V., Pfurtscheller, C., Thieken, A.H., & Aerts, J.C.J.H.** 2011. Methodology report on costs of mitigation. CONHAZ Report. Leipzig, Helmholtz Centre for Environmental Research UFZ. https://research.vu.nl/en/publications/methodology-report-on-costs-of-mitigation-conhaz-project-delivera. **Jenkins, K.L.** 2012. Modelling the economic and social consequences of drought under future projections of climate change. Cambridge, United Kingdom, University of Cambridge. PhD dissertation. https://doi.org/10.17863/CAM.16425. **Meyer, V., Becker, N., Markantonis, V., Schwarze, R., van den Bergh, J.C.J.M., L. M. Bouwer, L.M. *et al.*** 2013. Review article: Assessing the costs of natural hazards – State of the art and knowledge gaps. Natural Hazards and Earth System Sciences, 13: 1351–1373. Cuevas, A.C. 2014. Transaction costs of exchange in agriculture: A survey. Asian Journal of Agriculture and Development, 11(1): 21–38. **Hallegatte, S.** 2015. The indirect cost of natural disasters and an economic definition of macroeconomic resilience. World Bank Policy Research Working Paper 7357. Washington, D.C, World Bank. https://elibrary.worldbank.org/doi/abs/10.1596/1813-9450-7357. Jahn, M. 2015. Economics of extreme weather events: Terminology and regional impact models. Weather and Climate Extremes, 10: 29–39. **Freire-González, J., Decker, C. & Hall, J.W.** 2017. The economic impacts of droughts: A framework for analysis. Ecological Economics Volume, 132: 196–204. World Meteorological Organization and Global Water Partnership. 2017. Benefits of action and costs of inaction: Drought mitigation and preparedness – a literature review. Integrated Drought Management Programme Working Paper 1. Geneva, World Meteorological Organization and Stockholm, Global Water Partnership. https://library.wmo.int/doc_num.php?explnum_id=3401. **Shahab, S., Clinch, J.P. & O'Neill, E.** 2018. Accounting for transaction costs in planning policy evaluation. Land Use Policy, 70: 263–272. **Loch, A., Santato, S., Pérez-Blanco, C.D. & Mysiak, J.** 2020. Measuring the transaction costs of historical shifts to informal drought management institutions in Italy. Water, 12(7): 1866–1885.

Damage costs pertain to the negative economic and socio-economic impacts affecting production and consumption streams, as well as the reduction in economic and social well-being of people in the affected areas (i.e. welfare loss). Fundamentally, the concept of damage cost covers all types of costs of inaction, namely direct cost, indirect cost and intangible cost. In agriculture, these include, for example, revenue, sale and production losses from irrigated and rainfed farms and livestock farms, increase in production costs and irrigation costs, increase in poverty incidence due to lower household incomes, farm households' welfare losses due to water use constraints and worsened water quality, or conflicts in the agricultural community over access to water.

Technically, damage also relates to the complete or partial destruction of physical or capital assets in the areas affected by drought (Naumann *et al.*, 2015). This encompasses agricultural infrastructures such as irrigation canals, dams and water reservoirs, wells, or storage sheds (Hallegatte and Przyluski, 2010). However, droughts typically do not directly damage or cause very minimal damage to physical assets (e.g. buildings or equipment). In fact, this is one factor that distinguishes impacts of drought from impacts of other natural hazards like earthquakes, hurricanes, or floods (Freire-González *et al.,* 2017). Unlike these natural hazards, drought is detrimental to vital natural resources such as land and water stocks. As regeneration of natural resources is a complex bio-physical process with a very limited possibility and little control by human intervention, preserving natural resources is a safer way to build resilience. This is among the many reasons why the proactive approach should be preferred over the reactive approach.

Proactive measures are economic investments regardless to which pillar they belong to. The pre-drought or proactive action costs are investment costs for the structural and non-structural measures implemented to build long-term resilience (Horizon 1) and mitigate predicted impacts (Horizon 2). Thus, the inclusion of return on investments and the rate of return are among the factors affecting decisions on which proactive measure should be implemented. This decision factor is true not only in relation to droughts, but also with respect to other disasters, natural hazards and climate change adaptation (Damania *et al.*, 2017; World Meteorological Organization and Global Water Partnership, 2017; Venton *et al.*, 2019; Williams *et al.*, 2020). Proactive action costs also refer to the costs of risk management as measures for reducing vulnerability and strengthening resilience to drought are implemented (World Meteorological Organization and Global Water Partnership, 2017). Examples of these costs include research and development, engineering and construction of drought-proof infrastructure, purchase of new technology, or awareness-raising (Logar and van den Bergh, 2013; Sayers *et al.*, 2016; Carfagnam *et al.*, 2018).

Direct costs

Direct cost of inaction is a type of damage cost incurred from the primary effects of drought on economic production, thus, it is considered the immediate consequence of drought. As a primary cost of inaction, direct costs manifest as losses, such as output or production losses, declines in productivity, and reductions in income flows from economic activities that utilize water as a vital input in the production processes. Fundamentally, drought is a shock that interrupts the supply of water, a key input, thereby resulting in negative impacts on production (Ding *et al.*, 2010; Hallegatte, 2015; Freire-González *et al.*, 2017). Direct costs can also be incurred from the agricultural production for own-consumption or own final use. More known as subsistence agriculture, this kind of production has been an integral part of non-market household production (Organisation for Economic Co-operation and Development, 2002). Direct costs are the most tangible costs, and they take the form of market impacts, hence, are easy to monetize and quantitatively measure. Consequently, most cost estimation on drought impacts focuses on the direct costs. With this, they are considered to be a good indicator to determine the extent or severity of a drought event (Markantonis *et al.*, 2012; Meyer *et al.*, 2013; Frame *et al.*, 2018; Ciasca *et al.*, 2023).

Direct costs of proactive drought actions involve costs of producing the goods or services that will mitigate the impacts of and prepare for a drought event. The direct costs of a proactive action are primary costs that cover all fixed and variable costs incurred in researching and designing, setting-up, constructing, establishing, and operating and maintaining drought early response and resilience building measures. These costs may be one-time, straightforward investments or recurring costs. Similar to direct costs of inaction, this type of costs has market price and is simple to estimate. It relates to the actual costs of measures, and accordingly, dominates the cost assessments of drought management efforts (Bouwer *et al.*, 2011; Meyer *et al.*, 2013; Logar and van den Bergh, 2013; Water Research Foundation, 2015). An often-overlooked aspect of direct costs is the operating expenses, which are the costs to operate and maintain the proactive measure. For example, the construction of an irrigation system is a critically important strategy to mitigate the impacts on crop production. Nevertheless, an ill-designed system that entails high operating costs can lead to the abandonment of infrastructure. Economic assessment is not about the upfront or investment cost but rather about the justification of the feasibility of the measure during its entire life cycle.

Indirect costs

Indirect costs are secondary costs by spillover effects that cover both production and consumption markets. Like direct costs, indirect costs are viewed differently for proactive and post-drought or inaction settings. Indirect costs are more difficult to quantify, less understood, hence, are often excluded from economic accounting of costs (Jenkins, 2012; Meyer *et al.*, 2013; Water Research Foundation, 2015; Vogt *et al.*, 2018). Fundamentally, indirect costs are consequences of system linkages, whose cause originates from either the impacts of drought or impacts of drought management efforts.

Foundations of the concept of indirect costs of inaction can be traced from the input-output theory in economics, which depicts the linkages and interconnections of industries and sectors. That is, the output of one industry or sector may be an input in another. Primarily, they result from the cascading impacts of the direct costs and the interactions among systems. For example, a direct cost stemming from the decline in crop production will affect the industries which use this crop as an input for their own production. Production in the second sector will either decline or all together discontinue, depending on the importance of the crop as input in the production line, or other alternatives to consider. The level of output produced by the second sector, will then affect the third sector which utilizes this secondary output as an input, and so on. Therefore, the indirect cost is a secondary cost, typically resulting from the direct costs, which can spillover to the multitier levels, depending on extent of production linkages.

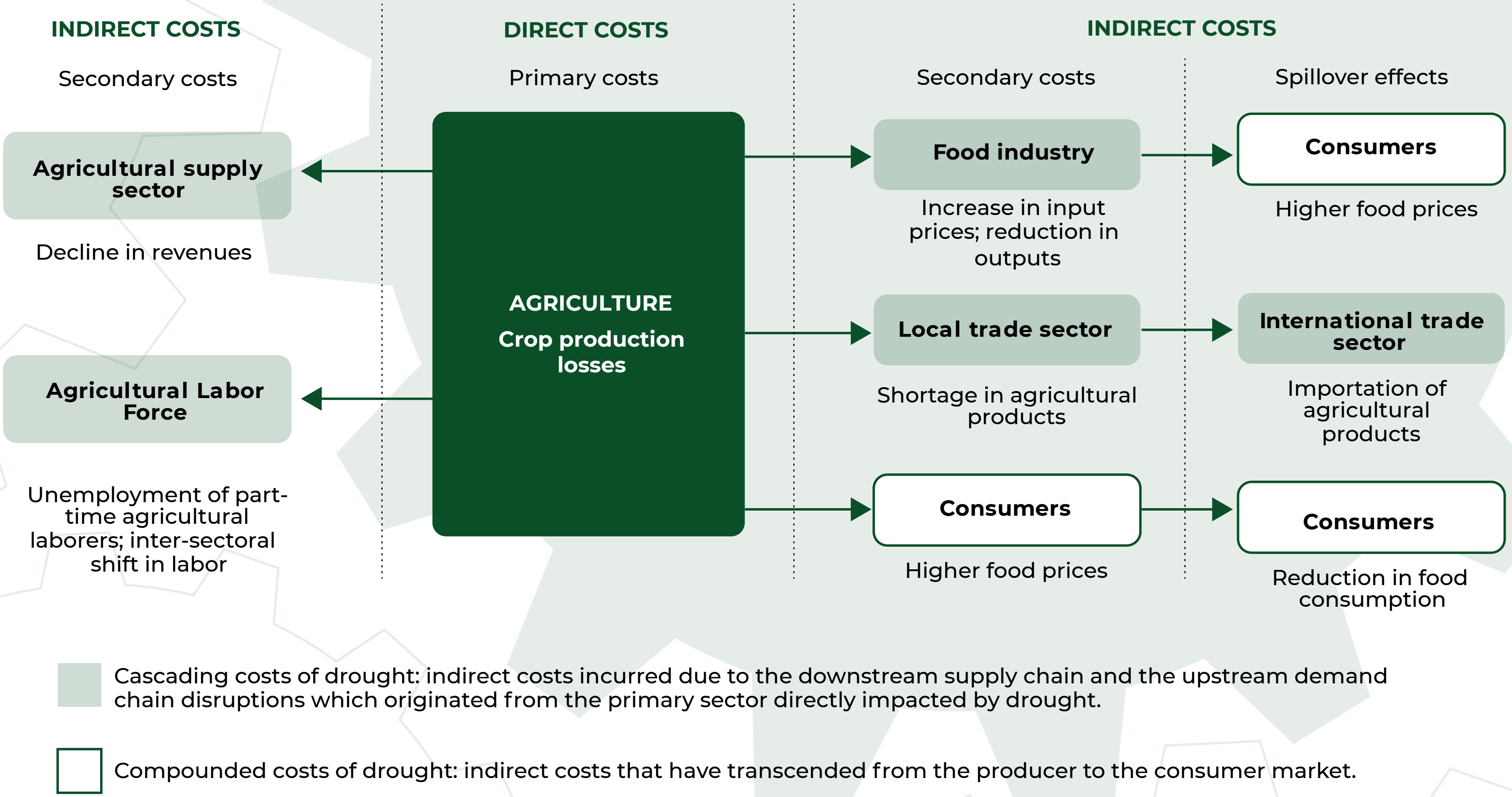
Essentially, the direct costs' inter-industry or inter-sector impact is spread through the upstream or downstream linkages of the primary sector, in this case agriculture, to others (Hallegatte, 2015; Jahn, 2015; Freire-González, *et al.*, 2017). To continue the example in agriculture, crop production losses will reduce the supply to downstream industries such as food processing and food manufacturing. Due to the supply shortage, the food sector producers will need to either bid a higher price for the crop inputs in order to maintain the same level of output, or reduce their production due to the lower level of inputs. On the other hand, due to the decline in crop outputs, farmers may have reduced their use of other inputs in production such as fertilizers and pesticides from upstream suppliers (Ding *et al.*, 2010). In this example, the costs to the food industry are the downstream indirect costs, while the costs to the agricultural supply sector are the upstream indirect costs.

Downstream supply-chain and the upstream demand-chain disruptions generate indirect cascading costs of drought. Indirect costs can also transpire within the primary sector impacted by drought. An example of which is the upstream indirect cost on agricultural labour. Literature is torn on whether labour is affected by drought. Gil *et al.*'s (2013) work showed that some studies, which used econometric modelling, found no significant relationship between water availability and agricultural employment. However, other research, particularly those that analysed the linkages through input-output and computable general equilibrium models, concluded otherwise. In their work, Gil *et al.* (2013) determined that agricultural employment, "at least formally hired labour, is hardly affected by water scarcity, though informal, family or seasonal labour might have been impacted". This may be true especially for small-scale farms. To illustrate, the 2020 drought in Nghe An, Viet Nam had caused water levels in the province to be 35-45 percent lower than the levels during the same period the year before. The water shortage resulted in farmers skipping double-cropping, thereby, reducing the demand for labour. Consequently, some farmers were forced to abandon their fields (VietNamNet, 2020). The above examples show the downstream supply-chain and the upstream demand-chain disruptions originating from the primary sector directly impacted by drought. These situations illustrate the cascading costs of the hazard and should be accounted in the economic analysis as part of the indirect costs.

Consumer-borne costs define the indirect compounded costs of drought. Costs induced by drought are not only shouldered by producers but are also carried by consumers through the increase in prices of goods and services. By law of supply and demand, when demand exceeds supply - in this case due to supply shortage - prices will rise. The greater are the price increases, the higher are the costs borne by consumers (Ding *et al.,* 2010; Logar and van den Bergh, 2013; Reichhuber *et al.,* 2022). When this occurs, the economic impacts of drought are intensified and compounded. Thus, the compounded costs of drought, which are the indirect costs that have transcended from the producer to the consumer market. These costs may be transmitted to distant market, depending on what stage the final good or service is bought by consumers (Figure 6).

There is scarcity in literature regarding the indirect costs of proactive drought measures, in particular, and of drought management, in general. Thus, this report also explored climate change adaptation and disaster risk reduction literature. Specifically, the concept of maladaptation – the condition where adaptation strategies fail, creating worse conditions before the adaptation measure was implemented –closely relates to the concept of indirect costs of proactive drought measures. Moreover, like the concept of indirect costs, maladaptation is a function of system linkages and interconnectedness (Schipper, 2020; Niggli *et al.*, 2022). In this sense, maladaptation relates to indirect costs under the field of economic assessment and cost accounting. Accordingly, considerations regarding maladaptation can be incorporated in the economic assessment. An advantage of this accounting is that as proactive measure designs are adjusted to minimize indirect costs, the occurrence of maladaptation is similarly addressed.

Figure 6. An example of indirect costs of drought impact on agriculture



Source: Authors' elaboration.

The indirect costs of proactive drought measures are secondary costs, externalities, or negative consequences incurred by stakeholders due to the activities incited by the investments in drought management measures. These may manifest in different forms such as:

- additional unplanned or unintended costs experienced as the mitigation measure is operationalized;
- costs of interruptions in regular operations by the implementation of measures;

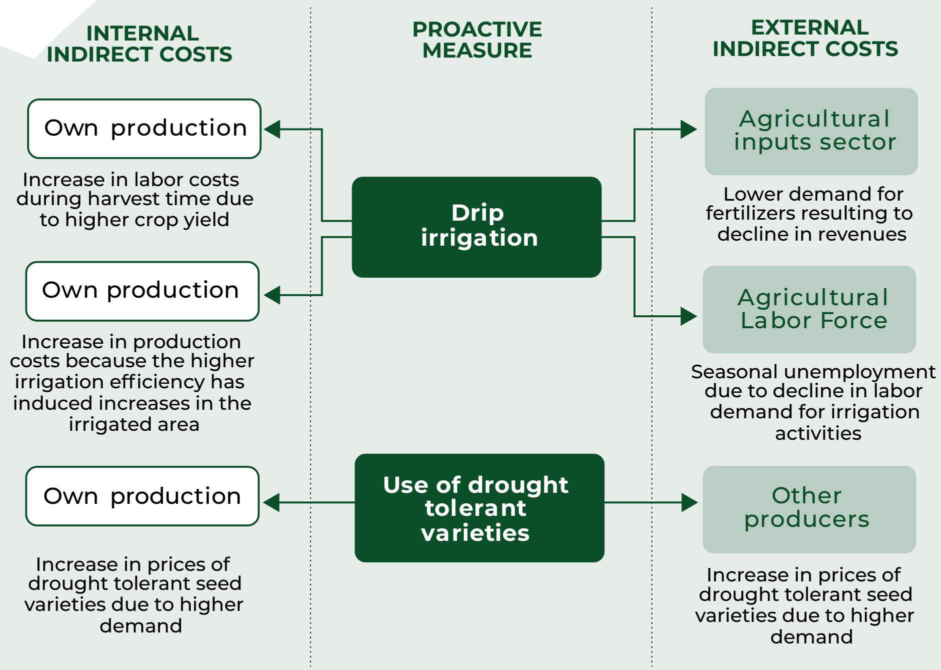
- induced production or revenue losses of suppliers or extra costs to consumers affected by the measure; or
- added demand on existing resources from the post-adoption effects (Bouwer *et al.*, 2011; Meyer *et al.*, 2013; Asplund and Hjerpe, 2020; Kori *et al.*, 2021).

Indirect costs may be shouldered either by the implementers of the proactive measure or by other stakeholders. Based on the definition above, the following examples demonstrate the two options of taking indirect costs:

- Adopting a new cropping pattern or drought-resilient varieties might result in the infestation of other or new pests not previously detected in the area, which may require distinct pest management practices. The resulting increase in the costs of pesticides is the indirect cost of the proactive measure. In extreme cases, this indirect cost may take the form of an investment in new channels to specific pesticide markets. Meanwhile, the use of drought tolerant varieties may drive-up the prices of seeds especially in areas where these varieties are not readily available. This price increase is also an indirect cost, because of the rise in demand from farmers who implemented the mitigation measure (Kori *et al.*, 2021).
- The adoption of drip irrigation has several benefits including, reduction in fertilizer use and lower labour inputs for water delivery, weeding and application of fertilizers (Niyazmetov and Rudenko, 2013; United States Agency for International Development, 2020). However, these reductions in production inputs may have negative consequences on the suppliers. Revenues of fertilizer sellers may decline, and seasonal unemployment for informal agricultural workers may rise. One of the benefits of the technology is the increase in yield due to the more efficient and effective transmission of water (directly) to crops. Consequently, more labour than normal may be hired during harvest times to accommodate the increase in crop production (World Bank, 2021).

Looking at these examples, it can be surmised that indirect costs may be shouldered either by the implementers of the proactive measure or by other stakeholders. Costs assumed by the implementers are the internal indirect costs that compound the total costs for adopting the drought management measure. Meanwhile, the costs borne by other stakeholders are the external indirect costs that cascaded or spilled over to other activities, businesses, industries, sectors, or markets as proactive drought measures are adopted (Figure 7).

Figure 7. An example of indirect costs of proactive measures in agriculture



Source: Authors' elaboration.

Intangible or non-market costs

Intangible costs are largely generated by the social, environmental, health and cultural impacts of drought (i.e. for costs of inaction) and impacts of drought management actions. The general characteristics of intangible costs are the same for pre- and post-drought cost classifications. First, intangible costs are losses or damages to non-market goods and services, therefore, they have no market price. Consequently, they are difficult to monetize or quantify. Second, if or when they are quantitatively estimated, non-market valuation exercises are costly and time-consuming. They also require a high level of economic expertise and specific estimation methods and entail specialized data collection and modelling activities. Subsequently, it is typical for non-market or intangible costs and losses to be excluded from economic assessments (Ding *et al.*, 2010; Bouwer *et al.,* 2011; Meyer *et al.,* 2012; Freire-González *et al.,* 2017; Blauhut *et al.,* 2021).

There have been few attempts on quantifying intangible costs, specifically of natural hazard-induced disasters. For example, in Australia, it was estimated that the social costs of natural hazard-induced disasters in 2015 were at least equal to the physical costs, if not higher. The same study theorized that with the exclusion of intangible costs in economic assessments, the economic cost of natural hazard-induced disasters may be underestimated by at least 50 percent (Deloitte Access Economics, 2016). With this, the failure to incorporate intangible costs in the total cost estimation is likely to result in misrepresentation of assessments. Thus, it is crucial to integrate intangible costs into economic analysis (Markantonis *et al.,* 2012; Kori *et al.*, 2021).

Intangible costs depict the direct and indirect damages which are difficult to be price-tagged, or the price tag would not correlate with the social reality. Intangible costs of inaction can be incurred from non-provision of public goods, such as the case of direct drought impacts on natural resources. They can likewise be generated from the negative externalities of the direct impacts of drought (Jahn, 2015; Deloitte Access Economics, 2016). In relation to environmental impacts, intangible costs include damages to wildlife and fish habitat, animal disease, loss of biodiversity, loss of wetlands, deteriorated water quality, loss of soil nutrient, intensified soil erosion, and loss of aesthetic impacts (Freire-González *et al.,* 2017; Venton *et al.,* 2019). Costs generated by social impacts encompass inconvenience or hardship experienced in accessing and acquiring water, forced migration, social welfare losses due to water use constraints among households, community conflicts from competing for water, or changes in income distribution (Logar and van den Bergh, 2013; Ciasca *et al.,* 2023). Health costs cover the rise in diseases, malnutrition, famine due to the reduction in food supply, and mental illnesses due to the experience from drought events. Lastly, cultural costs can be borne from the loss of ancestral land and from forced relocation, and damages to cultural or natural heritage sites, among others (Markantonis *et al.,* 2011; van der Geest *et al.,* 2019). An example of the latter are the possible damages of drought to the rice terraces of the Philippine Cordilleras. These are the high rice fields carved by the Ifugao tribe in the contours of the mountains, and have existed for 2 000 years (United Nations Educational, Scientific and Cultural Organization, 2023). While intangible costs have no market prices, thereby cannot be monetized, some can still be quantitatively analysed using indicators such as number of people with compromised food consumption, number of people with reduction in number of meals per day, and cases of malnutrition, among others (Venton *et al.*, 2019)

Intangible costs of proactive action are direct and indirect non-market social, environmental, health and cultural impacts of drought risk mitigation measures. As such, intangible cost, as non-market indirect cost, also relates to the concept of maladaptation. Examples of intangible costs include environmental damages due to the incorporation of new technologies into the construction of water infrastructures or from the adoption of new techniques and practices to mitigate the impacts of drought. This has been experienced in the case of drip irrigation. Studies have provided evidence that the higher irrigation efficiency brought by the measure has changed the water consumption behaviours of farmers. Particularly, the higher yields from the efficient use of water have led to users increasing their irrigated area or shifting to crops with higher water-use requirements, and consequently, intensifying the volume of water consumed. Such incidents further exploit water resources, especially the aquifers (Meyer *et al.*, 2013; Grafton *et al.*, 2018). Proactive measures can also generate social cost, such as conflicts among community members if new assets are not fairly distributed. On the other hand, the construction of new dams and water reservoirs may change the landscape or the natural environment of the construction site, and therefore, generate loss in the aesthetic value attached to the area (Bouwer *et al.*, 2011; Asplund and Hjerpe, 2020). Discussions on intangible costs are more extensive regarding costs of inaction; this topic is rarely included in the conversations concerning drought risk management. Consequently, intangible costs of proactive action are seldom, if not at all, incorporated in economic assessments.

Considerable intangible costs can be incurred from reactive drought actions, whereas the expectations on rapid interventions can compromise the results even if the most possible parameters are taken into account. Post-hazard operations are usually limited within tight timeframes and draw upon existing or tested resources and solutions. This also means that post-hazard operation is not always optimal or all-inclusive. While intangible costs are difficult to monetize, reserved estimations in the context of costs of inaction show that intangible costs can surpass tangible costs. For this reason, a proper economic assessment is needed in accounting for both pre- and post-drought costs. At the minimum, stocktaking of possible intangible costs of proactive and reactive drought measures is a move in the right direction.

Box 6. The intangible costs of emergency operations in Chirumanzu, Zimbabwe

In a climate change adaptation research, Kori *et al*. (2021) illustrated the costs incurred from unplanned measures implemented "out of desperation in order to restore the losses" from the impacts of drought. The work was conducted through a case study in the resettlement areas in Chirumanzu district in Zimbabwe. Specifically, the research investigated the intangible costs associated with measures implemented after substantial costs from drought already had been experienced. Under the drought management classification, the measures examined fall under the restoration and recovery (HORIZON 3) category. These measures included changing planting dates, use of drought tolerant varieties, good crop establishment practices, conservation farming, wetland farming and crop diversification. It should be, however, noted that upon intensive examination, some costs identified by Kori *et al*. (2021) fits better under this study's classification of transaction costs (which is discussed in the next section).

Source: **Kori, D.S., Francis, J. & Zuwarimwe, J.** 2021. Intangible and indirect costs of adaptation to climate variability among maize farmers: Chirumanzu District, Zimbabwe. In N. Oguge, D. Ayal, L. Adeleke & I. da Silva, eds. African Handbook of Climate Change Adaptation, pp. 397–422. Springer.

Drought management measure	Problems, dangers, challenges experience in implementing measures	Intangible costs incurred
Conservation farming	Tedious and labour intensive	Reliance on child labour leading to violation of children's rights
		Extra burden on members of the family
	Lack of mechanical equipment	Setbacks in implementing
	Forced to borrow equipment	Embarrassment associated with borrowing
		Ridicule and stereotyping associated with borrowing
		Availability and access of equipment not guaranteed
	Forced to hire equipment	Effort put in hiring equipment
		Availability of equipment not guaranteed
	Complications in hiring equipment	Effort put in negotiating deals
	Lack of mulch material	Setbacks in implementing
	Forced to travel long distances in search for mulch	Less time to rest
		Wellbeing concerns
	Forced go to unsafe places	Safety concerns
		Encounters with snakes
Use of drought tolerant varieties	High cost of drought tolerant varieties	Effort spent looking for better priced drought-tolerant varieties
	Scarcity of drought-tolerant varieties	Effort spent looking for drought-tolerant varieties

Drought management measure	Problems, dangers, challenges experience in implementing measures	Intangible costs incurred
Changing planting dates	Risk of falling behind schedule and difficulties catching up while waiting for effective rains	Worry, anxiety and uncertainty
		Extra burden
	Possibility of replanting associated with dry planting as seed fail to germinate due to insufficient moisture	Pain and suffering due to poor germination
		Threatened emotional wellbeing

Frameworks for environmental and social governance are getting into the forefront to ensure that investment is effective, efficient and sustainable. Investment is guided by a suite of criteria that touch upon economic, social, environmental, technical, and other aspects. A powerful instrument to address intangible costs is the compliance with the principles of environmental and social governance. Although such frameworks vary from one organization to another, they share the same objective. Even if intangible costs cannot be monetized, thus no budget is allocated to recover them, environmental and social principles can help in mitigating these costs. For example, using groundwater as strategic reserve during drought can lead to overexploitation. If groundwater monitoring service is activated as an environmental safeguard, the intangible cost of water resources degradation can be reduced.

Transaction costs

Transaction cost conversations in the economics of drought management are very scarce, but the missing foundation must be restored to avoid the underestimation of costs. Given the very limited transaction costs discussion in drought management, this investigation relies heavily on other literature, specifically, climate change adaptation. Still, while adaptation literature is more advanced than drought literature on the topic, information is also scant. It should be, however, noted that while this report accounts for transaction costs, monetary valuation will not be provided, and analysis is limited to qualitative evaluations of the costs. The extent of research needed to quantify transaction costs is expansive, which cannot be covered by the scope of this report.

In practice, transaction costs are traditionally neglected in empirical assessments of environmental or natural resource policies. Similar conditions exist in climate change adaptation and drought management efforts. Transaction cost concerns are yet to be effectively captured in the economic analysis (Watkiss, 2015; Loch *et al.*, 2020). This is an important concern since climate change adaptation and droughts are "wicked problems" (Termeer *et al.*, 2013; Vogel and van Zyl, 2016; Cuevas, 2018), and "wicked environmental and natural resource issues are likely to entail high transaction costs" (McCann, 2013, p. 253). In the case of climate change, costs consist of the cost of explicit adaptation measures plus the residual impacts of climate change, and the transaction costs of implementing adaptation. In general, adaptation options incur substantial costs not covered by the direct technical or engineering costs that the current adaptation cost estimates chiefly evaluate (Parry *et al.,* 2009).

Because transaction costs are not typically incorporated in evaluations of options in adaptation or drought measure options, actual costs are likely greater than the presented estimates. To fully compare the benefits of action and costs of inaction, transaction costs should be considered along with direct, indirect and intangible costs. In particular, accounting for transaction costs strengthens economic assessments through the following:

- improving preliminary comparisons and screenings across policy options and drought management measures;
- enhancing design and implementation of drought management options;
- evaluating existing policies, governance arrangements, institutions, and management options to improve their effectiveness; and
- assessing budgetary impacts of proactive options over their life cycles (McCann *et al.*, 2005; Watkiss, 2015; Marshall, 2017).

A barrier to the assessment of transaction cost is the lack of a unified definition of the concept. The definition of transaction cost is not explicit and distinct definitions are used by various stakeholders, allowing for different interpretations of the concept. This plasticity of the definition requires the context-specific meaning.

As per the traditional definition, transaction costs are generated in situations involving any kind of contractual arrangement among various stakeholders, in any kind of human interaction and activity, and in any type of institutional action. Transaction cost has assumed varying meanings, depending on how the concept has been applied. In the context of this type of cost, transaction is the unit of analysis (Whittington and Young, 2013; Cuevas, 2014; Das and Roy, 2023). Transaction can be defined as either the exchange transpiring between the production or distribution chain as products change in form, or transfer of property rights in relation to goods and services, such as the exchange of ownership rights. Transactions can likewise be the transfers of information, knowledge and ideas, activities associated with public policies and government decision-making, undertakings that define, establish, maintain, use, and change institutions and organizations, and actions in governance and management. Engagement in such transactions creates transaction costs (Driesen and Ghosh, 2003; Marshall, 2013; Cuevas, 2014; Shahab *et al.,* 2018).

Transaction costs may account for a considerable proportion of the total costs of investments, or a substantial part of the overall costs of environmental management initiatives and designs of policy instruments. Various estimates of transaction costs' magnitude suggest that they can range from 8 to 38 percent of total project costs (McCann *et al.,* 2005; Marshall, 2017). To illustrate, costs are incurred in coordination, governance, management of institutions, researching relevant prices, information flow, acquiring knowledge of materials and production, and negotiating, concluding, monitoring and enforcing policies or activities. Also, initiatives and various actions may incur costs involving trainings, new forms of behaviour, interaction with technical systems, interacting with insurance companies and developing emergency management response plans contracts (Araral, 2013; Watkiss, 2015; Asplund and Hjerpe, 2019). All these cost concerns fall under the broad category of transaction costs. To better identify transaction costs, some studies devised typologies (Table 2); and others identified various types, depending on how the concept of transaction costs is applied (Table 3).

Table 2. Typology and determinants of transaction costs in mechanisms for water exchange and allocation

Type of transaction cost	Major determinants of increased transaction costs
Research and information	Hydrological and climatic uncertainty; lack of system storage; water transferred out of agriculture and/or out of the basin; significant third-party effects including environmental effects; dependence on return flows; lack of clear water rights.
Enactment or litigation	Significant third-party effects; dependence on return flows; duration of the transfer; riparian water rights; lack of clear water rights; complexity of water law; concentrated incidence of costs; lack of water users' associations; lack of familiarity with markets; lack of social capital; weak government.
Design and implementation	Water transferred out of agriculture and/or out of the basin; infrastructure not suited to transfers of water; significant third-party effects; existing institutional and administrative structure not designed for water marketing; riparian water rights; lack of clear water rights; complexity of water law; lack of water users' associations; lack of familiarity with markets; lack of government will.
Support and administration	Larger areas; increasing number of people involved; increased precision of contracts required with respect to quantity, quality, time, and place; lack of effective water users' associations; lack of familiarity with markets.
Contracting	Lack of rule of law; lack of social capital; increased precision of contracts; lack of water users' associations; lack of familiarity with markets; lack of system storage; lack of water rights registry.
Monitoring/ detection	Lack of social capital; poor monitoring technology; increased precision of contracts; lack of water users' associations; disagreement about initial distribution of water rights; high transportation and communication costs.
Prosecution/ enforcement	Hydrological uncertainty; lack of water users' associations; lack of conflict resolution and contract enforcement mechanisms; weak government; high potential for violence.

Source: **MMcCann, L. & Easter, K.W.** 2004. A framework for estimating the transaction costs of alternative mechanisms for water exchange and allocation. *Water Resources Research*, 40(9): 1–6.

Table 3. Types of transaction costs in projects and institutional frameworks

Coverage	Type of costs	Descriptions
Projects	Search costs	Costs incurred by investors and hosts as they seek out partners for mutually advantageous projects.
	Negotiation costs	Includes those costs incurred in the preparation of the project design document (e.g. baseline determination and monitoring rules) that also documents assignment and scheduling of benefits over the project period. It also includes public consultation with key stakeholders.
	Validation Costs	Review and revision of project design document by operational entity.
	Approval costs	Registration and approval by authorities.
	Monitoring costs	Costs needed to ensure that participants are fulfilling their obligations.
	Verification costs	Verification activities by authorities.
Institutional Frameworks	Static transaction costs	Incurred in operating under an institutional option; cover costs related to support and administration, contracting, monitoring and detection, and prosecution and enforcement.
	Institutional transition costs	Incurred in effecting change from existing institutional arrangements to a new institutional option; cover costs related to research and information, enactment or litigation, and design and implementation transactions.
	Institutional lock-in costs	Relates to adaptation or replacement; the additional institutional transition costs incurred by 'successor' institutional options (e.g. those eventually chosen as adaptations, transformations or replacements of the option under consideration) due to the impact on institutional path dependencies of the institutional option under consideration.
	Static transformation costs	The transformation costs incurred in operating under the technologies or practices that are adopted subject to the influence of the institutional option under consideration.
	Technological transition costs	The transformation costs incurred in effecting change from existing technologies or practices to those adopted subject to the influence of the institutional option under consideration.
	Technological lock-in costs	The additional technological transition costs incurred by 'successor' technologies or practices (e.g. those chosen under the influence of 'successor' institutional options) due to the impact on technological path dependencies of the institutional option under consideration.

Sources: **Stronzik, M., Hunt, A., Eckermann, F. & Taylor, T.** 2003. The role of transaction costs and risk premia in the determination of climate change policy responses. ZEW Discussion Papers, No. 03-59. Mannheim, Leibniz Centre for European Economic Research. https://ideas.repec.org/p/zbw/zewdip/1381.html. **Marshall, G.R.** 2013. Transaction costs, collective action and adaptation in managing complex social-ecological systems. Ecological Economics, 88: 185–194.

Further typology assessment can be found in Annex 2.

From the perspective of water exchange and allocation, the category 'research and information' carries common and significant transaction costs, because drought as hazard is not fully explored and can manifest in many different forms. Different contexts have distinct mixes of transaction costs, but there is one category that applies to all cases. Integrated drought management is technology-dependent, as measures are best designed if they are based on accurate monitoring and early warning systems. Furthermore, monitoring and early warning systems must be connected to water resources monitoring systems that provide real-time information. For example, parametric insurance products are popular proactive measures, but insurance companies must operate early warning systems to receive triggers. This also involves a near continuous research on geo-specific drought indices. Another example is the managed aquifer recharge (MAR) to store and preserve strategic resources. Even though aquifer recharge can be done through relatively simple technologies such as earth dams to sophisticated infrastructure such as injection wells, a good understanding of the condition of aquifers is required. This entails the involvement of experts to map out and characterize the aquifers.

Capacity development in relation to effective implementation of proactive drought measures can incur considerable transaction costs. To illustrate, monitoring and early warning systems depend on information capacity. Firstly, their operation and accuracy are contingent upon the availability of and access to information. The sets of information, then, need to be effectively communicated and interpreted to stakeholders. Specifically, active, iterative and inclusive communication between climate experts, stakeholders and decision makers is a necessity. Furthermore, meteorological and other scientific information need to be translated in manners that will be useful to the diverse data users and stakeholders (e.g. planners, decision-makers, farmers, grassroots women's group). All activities to address and strengthen information capacity, therefore, will generate transaction costs. In essence, transaction costs are like devil in the details and if not properly assessed, they can jeopardize the financial feasibility of measures.

4 Benefits of drought management

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Investments in proactive measures remain low despite the disadvantages of drought inaction and in the face of rising awareness and support for proactive action. The transition from reactive to proactive drought management has been sluggish, and a crucial factor in the discussion of drought management investments is the benefits accrued from such endeavours. A large part of such slow development is how the benefits from proactive actions are perceived (Overseas Development Institute and World Bank, 2015; World Meteorological Organization and Global Water Partnership, 2017; Venton *et al.*, 2019). Typically, benefits from investing in proactive measures are assessed as the avoided damages or losses from reducing vulnerability and from strengthening resilience to drought. This concept results in a belief that in the absence of the event, investment seem unnecessary (Helgeson and O'Fallon, 2021; European Environment Agency, 2023). This idea, however, is faulty. Whereas avoiding losses is the general incentive for investing in vulnerability reduction and in resilience building, considering this as the only benefit from such investments underestimates the total benefits to the economy and society.

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Proactive drought measures that stimulate resilience building can make essential contributions to development, poverty alleviation and economic growth through the additional economic, social and environmental benefits they generate. That is, benefits can be accrued irrespective of whether or not a disaster or severe hazard occurs (Overseas Development Institute and World Bank, 2015; Global Commission on Adaptation, 2019; United Nations Office for Disaster Risk Reduction, 2020). However, it is quite challenging to shift from a traditional line of thinking to a new set of ideas. Hence, such discussions increase the demand for information and empirical evidence on the total benefits generated for managing risks, reducing vulnerability, building resilience, and overall, supporting proactive action (Mechler and Hochrainer-Stigler, 2019).

A discussion on the typology of the benefits of actions will assist in achieving a better appreciation of proactive measures. This section contributes to this conversation by exploring the benefits of proactive drought risk management. It presents a typology of benefits and clarifies benefit terminologies for better understanding of the concepts. The section will further assist in identifying benefits of adopting proactive drought risk management measures, and in understanding how each type of benefit fits in the estimation process. By the end of this section, the benefits of proactive action with or without the occurrence of drought are explained, and their (benefits') significance in building resilience is illustrated. Clarity on the extent of benefits from investing in proactive action is a crucial step in breaking from the current notion that these kinds of investments are only significant in avoiding damages and losses. Rather, the complete picture is that they are rational and smart investments under any scenario.

Typology of benefits

Benefits can be distinguished between with and without drought scenarios, and these benefits are accrued simultaneously the moment proactive drought measures are adopted. Overall, the typology of benefits identifies four types of benefits (Figure 8).

Figure 8. Definitions of the benefit types of proactive drought risk management

Avoided costs

This type of benefit is classified under the benefits generated when drought strikes. It is comprised of the direct, indirect, and intangible costs or simply the damage costs avoided due to the implementation of proactive measures. They are direct benefits of proactive drought risk management due to reduced vulnerability and strengthened resilience of systems to drought. They can be produced through the reduction of the immediate costs by the drought impacts, or benefits generated when the costs of inaction are greater than the costs of action.

Co-benefits

This also comprises the benefits regardless of drought events, but can be one or combinations of economic, environmental and social benefits. Co-benefits do not result from the resilience building function of proactive measures, but are generated through system linkages.

Unlocked economic potential

This type is derived from the reduced drought risk effect of the proactive drought measure. It comprises the benefits accrued regardless of drought events. This benefit is created from the economic activities stimulated or generated by the reduced drought risk effect of proactive drought action

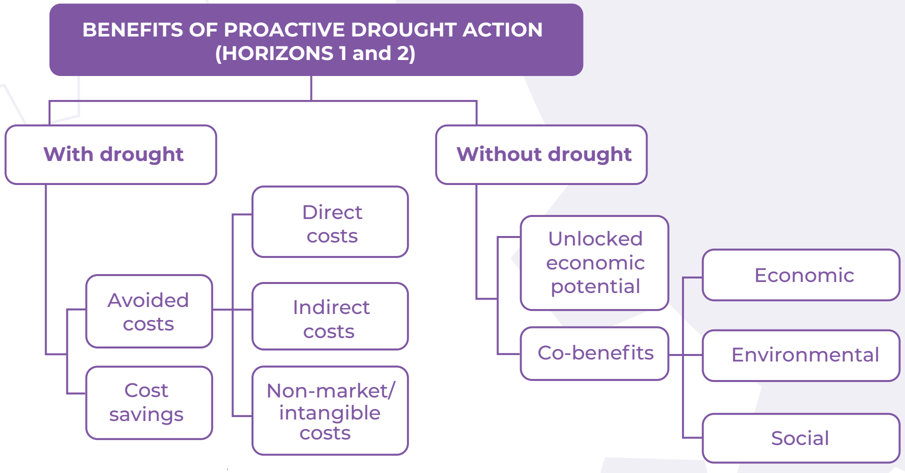
Cost savings

This covers the recovery and restoration costs saved under post drought scenario. These benefits with drought scenario can be considered as direct effects of the reduced vulnerability or strengthened resilience of systems to drought. In other words, cost saving produces indirect benefits of proactive drought risk management in the form of reduced expenditures from reactive action, or avoided higher expenditure on restoration and recovery measures.

Source: authors' elaboration based on the works of Overseas Development Institute and World Bank, 2015; World Meteorological Organization and Global Water Partnership, 2017; Weingärtner *et al.*, 2017; Venton, 2018a; United Nations Office for Disaster Risk Reduction, 2020; Helgeson and O'Fallon, 2021

This typology also stresses the importance of recognizing not only the monetized direct and indirect costs in analysing the avoided costs, but also of identifying the non-monetized or non-market indirect and intangible costs (Figure 9).

Figure 9. Typology of benefits from proactive action



Source: Authors' elaboration based on the work of Overseas Development Institute and World Bank, 2015

The typology highlights how proactive drought investments can avoid losses and save costs when a drought disaster occurs, while simultaneously stimulating the economy and producing co-benefits in the absence of drought. This typology caters to the needs of a cost-benefit analysis type of economic assessment for investment planning. Thus, the classification of benefits is primarily for the purpose of economic accounting, and is structured in a manner that will avoid double counting of benefit items. This typology borrows concepts from the triple dividend framework for disaster risk reduction developed by the Overseas Development Institute, the London School of Economics, and the World Bank. The primary components of the triple dividend framework are the avoided losses, unlocked economic potential and co-benefits. While fairly new, as it was developed in 2015, this framework now is being considered in climate change adaptation, and also is currently discussed in drought management conversations (Overseas Development Institute and World Bank, 2015; Vogt *et al.*, 2018; Global Commission on Adaptation, 2019).

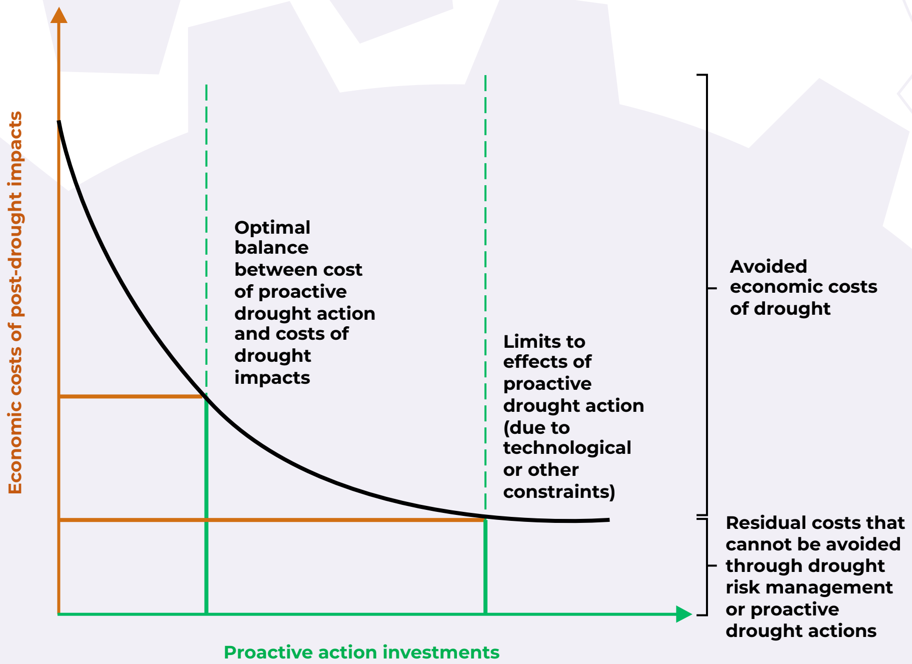
Like costs, proactive action benefits can be fixed or variable. They can also be realized once or can repeat over time, can be short-run or long-run benefits, and can relate to production and consumption of goods and services, utility of consumers, or the welfare of society as a whole (Water Research Foundation, 2015). The triple dividend framework has initiated the interest in investments that generate multiple dividends, prevent loss of life and livelihoods, unlock development, and create economic, social, and environmental co-benefits (Overseas Development Institute and World Bank, 2015; Global Commission on Adaptation, 2019; Mechler and Hochrainer-Stigler, 2019; United Nations Office for Disaster Risk Reduction, 2020). Through better understanding of the benefits' concepts in the context of drought management, the same kind of interest can be triggered in relation to the proactive approach in drought management.

Avoided costs

Engaging in proactive measures aims to lessen the risks and avoid the direct impacts from drought by reducing vulnerability and strengthening resilience of systems to droughts. The structural and non-structural measures promote the reduction in the immediate impacts of drought in terms of direct economic losses, indirect damages, and the social, environmental, health and cultural impacts of drought. Avoided costs, therefore, are primary or direct benefits of drought risk management (Vorhies and Wilkinson, 2016; Weingartner *et al.*, 2017; United Nations Office for Disaster Risk Reduction, 2020). Assessing the monetary economic benefits of drought risk management measures entails quantifying the damage costs of a drought event (i.e. direct and indirect costs) and determining the monetary value of costs reduced by implementing the approach. Based on a rational economic decision-making process, proactive investments reduce the losses and damages from drought. Essentially, effective proactive measures improve the capacity of systems to withstand and recover from the impacts of drought, thereby they likely lower the post-drought costs. It should be, however, noted that not all costs of drought impacts can be reduced; some damages from the residual drought impacts will remain. Thus, these residual damages or costs that persist even after the adoption of proactive actions, or those costs that drought risk management measures cannot alleviate, need to be taken into account in the economic analysis (Figure 10) (United Nations Framework Convention on Climate Change, 2011; Ciasca *et al.*, 2023; European Environment Agency, 2023).

In assessing the avoided costs, it is imperative that all costs are considered. When the costs of inaction are greater than the proactive action, this indicates that avoided costs are positive in early response or mitigation. Under these circumstances, proactive action should be among the priority investments (Venton *et al.*, 2019; Ciasca *et al.*, 2023). It should be, however, noted that not all avoided costs can be monetized since they also cover non-market or intangible costs. Hence, qualitative assessments or non-monetary quantitative indicators are also relevant in determining both the costs of inaction and action, and in evaluating the avoided costs.

Figure 10. Avoided economic costs and residual costs of drought



Source: Authors' elaboration based on the work of European Environment Agency, 2023

Cost savings

Proactive actions lessen the amount or level of assistance needed to respond to drought impacts, and to recover and restore what has been damaged by the drought event. Cost savings as type of benefit is founded on the notion that proactive drought measures, such as drought-related monitoring, communication, and planning endeavours, can result in lessened drought impacts on communities and systems, thereby potentially reducing the costs of drought. In other words, their implementation will eventually reduce the drought relief costs or generate savings from reactive drought expenditures. To illustrate, the Multihazard Mitigation Council in the United States of America computed that for every dollar spent by the Federal Emergency Management Agency on hazard mitigation grants, an estimated four dollars in future benefits are realized (Water Research Foundation, 2015; World Meteorological Organization and Global Water Partnership, 2017). Hence, distinguishing proactive (in other word pre-drought measures categorized under Horizon 1 and 2) and reactive (in other words post-drought categorized under Horizon 3) actions is relevant in the case of cost savings discussion. Cost saving suggests that the overall costs of proactive action are less than the combined costs of inaction and costs of reactive action. Such statement, obviously, does not apply to all situations, especially if proactive action is not based on proper selection of measures. Nevertheless, it is assumed that proactive action is based on the most optimal combination of measures with the highest possible impacts. Thus, assuming effective implementation of proactive action, a portion of the reactive action expenses is saved due to the reduced damages and losses in drought impacts, as systems remediate their vulnerabilities and improve their resilience to drought (Venton, 2018a; World Meteorological Organization and Global Water Partnership, 2017). Numerous studies have already proved that substantial cost savings can be achieved if proactive action, such as early humanitarian response, safety nets and resilience building measures, are implemented (Moench *et al.*, 2007; Venton, 2018a, 2018b, 2018c; National Planning Commission, 2021).

Box 7. Cost savings benefit of the early humanitarian response in the Horn of Africa

The studies of Venton (2018a, 2018b, 2018c) in Ethiopia, Kenya, and Somalia best illustrate the cost savings benefit. In Ethiopia, around USD 965 million costs of late response would be saved in a 15-year period, if early humanitarian response measures are implemented. Likewise, savings from costs of a late response is estimated at USD 1.2 billion, if safety net programming, at a transfer level of USD 245-262 per household, is applied. Lastly, a resilience building scenario, which involves an additional increase in income of USD 120 per household, will save approximately USD 1.2 billion over the cost of a late response (Venton, 2018a). In Kenya, an early humanitarian response and a resilience building scenario (e.g. increase in income of USD 450 per household) can save an estimated 381 million and 73 million, respectively, over the cost of a late response, in a 15-year period (Venton, 2018b). Lastly, in Somalia, an estimated USD 220 million on cost of late humanitarian response over a 15-year period can be saved by implementing early humanitarian response; while a safety net programming, at a transfer level of USD 270 per household, saves about USD 115 million of late response costs, over 15 years (Venton, 2018c). Other studies arrived at the same conclusion that in every dollar spent on mitigation action, benefits in terms of avoided disaster relief or rehabilitation and restoration expenses are generated (i.e. cost savings) (Moench *et al.*, 2007; National Planning Commission, 2021).

Sources: **Moench, M., Mechler, R. & Stapleton, S.** 2007. High level dialogue information note no. 3: Costs and benefits of disaster risk reduction. Global Platform for Disaster Risk Reduction, First session, 5-7 June 2007. Geneva, United Nations Office for Disaster Risk Reduction. Cited 17 April 2023. https://www.unisdr.org/files/1084_InfoNote3HLdialogueCostsandBenefits.pdf. Venton, C.C. 2018a. Economics of resilience to drought: Ethiopia analysis. Washington, D.C., United States Agency for International Development Center for Resilience. https://2017-2020.usaid.gov/sites/default/files/documents/1867/Ethiopia_Economics_of_Resilience_Final_Jan_4_2018_-_BRANDED.pdf

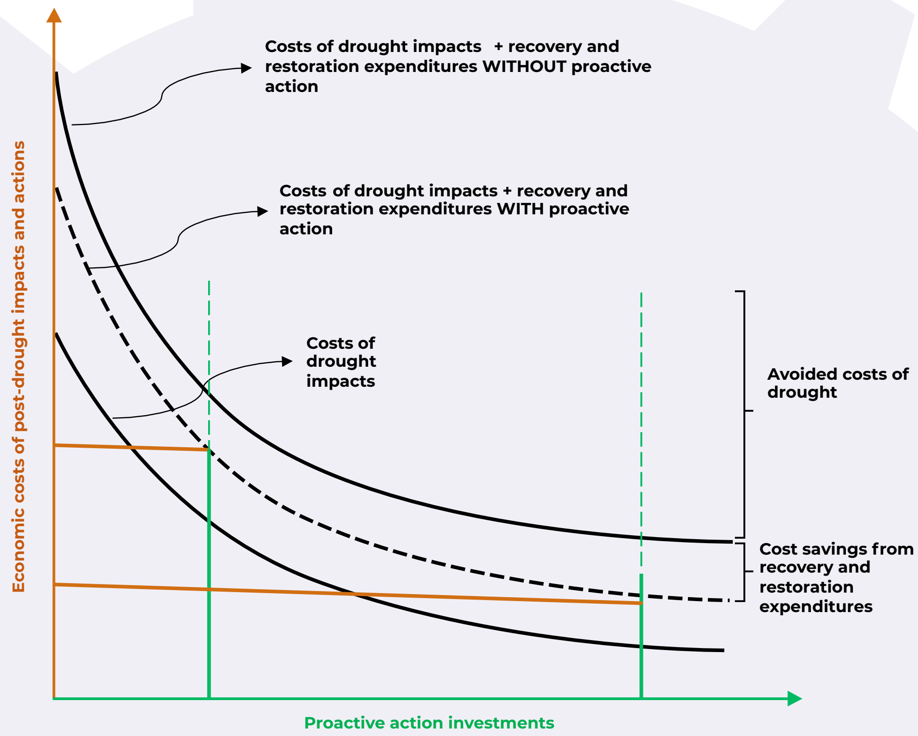
Venton, C.C. 2018b. Economics of resilience to drought: Kenya analysis. Washington, D.C., United States Agency for International Development Center for Resilience. https://2017-2020.usaid.gov/sites/default/files/documents/1867/Kenya_Economics_of_Resilience_Final_Jan_4_2018_-_BRANDED.pdf

Venton, C.C. 2018c. Economics of resilience to drought: Somalia analysis. Washington, D.C., United States Agency for International Development Center for Resilience. https://www.alnap.org/system/files/content/resource/files/tor/SOMALIA.pdf. National Planning Commission. 2021. A cost-benefit analysis of environmental management and disaster risk reduction in Malawi – Technical report, Malawi priorities. Malawi, National Planning Commission, USA, Copenhagen Consensus Center and Malawi, African Institute for Development Policy. https://www.afidep.org/publication/a-cost-benefit-analysis-of-environmental-management-and-disaster-risk-reduction-in-malawi-technical-report/

Effective management of natural hazards such as droughts can be costly but can also result in significant cost savings, and developing well-constructed drought plans, including detailed action plans, is a useful strategy to maximize cost saving. Drought-related monitoring, communication and planning efforts can help alleviate drought impacts on communities, thereby potentially reducing the costs of drought (Svoboda *et al.*, 2011). Each drought can present different climatic, social, economic and political conditions, requiring a utility to assess and respond to the current event rather than solely rely on practices that were effective in a previous drought. Drought risk management plans guide decision-making before, during and after a drought, and include critical information for managing drought events, such as descriptions of drought stages, triggers, monitored indicators and responses (Fontaine *et al.*, 2014; Water Research Foundation, 2015).

Engaging in proactive drought investments not only avoids drought damages and losses – falling within the avoided costs – but also lowers drought expenditures from restoration and recovery measures, thus generating cost savings. Figure 11 illustrates the relationship between proactive drought investments and cost savings. As previously suggested, cost of drought impacts (cost of inaction) and costs of reactive action are closely linked. That is, for unit cost of drought impact, there is an accompanying cost of reactive action with the purpose of recovering losses and damages or restoring systems into their pre-drought state. Accordingly, with the additional expenditures for restoration and recovery activities, the overall cost of drought impacts increases. However, with every proactive investment, the vulnerability to drought of the system lessens, and the losses and damages from drought impacts are reduced. Therefore, the costs needed to recover losses and restore systems, similarly, are less than what could have been required under conditions without the proactive investments. This implies that proactive actions can positively change the cost–benefit ratio by simultaneously reducing the cost of drought impacts and cost of recovery, rehabilitation and reconstruction measures.

Figure 11. Cost savings from proactive drought action



Source: Authors' elaboration.

Box 8. Conceptualizing intangible cost savings

Cost savings concept is not limited to costs that can be monetized. Intangible cost savings can be illustrated through the case study on practicing reactive responses in Zimbabwe by Kori *et al.* (2021). The case study showed various intangible costs associated with the reactive measures. Here, it is suggested that some of the intangible costs may not have been experienced if proactive actions were implemented. That is, if drought management measures have been planned, designed, and initiated before the drought event took place, the intangible costs from reactive measures may have been avoided. Some proposed proactive actions for each intangible cost are also presented. This benefit is conceptualized as the cost minimization effect of proactive actions, which translates to cost savings. Given that implementing proactive actions incur transaction costs, the accompanying transaction costs are likewise provided for each proposed proactive action.

1. Conservation farming

Intangible costs incurred from reactive measures	Proactive actions that may have minimized intangible costs	Transaction costs of proactive measures
Challenges: Tedious and labour intensive		
Reliance on child labour leading to violation of children's rights	Planned scheduled labour rotation among community members based on community cooperation and collective action	Costs of persuading community members to agree on labour rotation scheme; coordination costs; scheduling costs; costs of enforcing schedule arrangements
Extra burden on members of the family		
Challenges: Lack of mechanical equipment, forced to borrow equipment, forced to hire equipment, complications in hiring equipment		
Setbacks in implementing	List of possible suppliers of equipment prepared; prior lending-borrowing or use arrangements (with compensation clauses and schedules, whether monetary or in-kind) between suppliers and users of equipment; adopting measure at small scale in between drought years to establish practices and procedures	Costs of persuading farmers to adopt measure; costs for generating a formal or informal arrangement/ contract between suppliers and users of equipment; negotiation costs; costs of enforcing contract arrangements
Embarrassment associated with borrowing		
Ridicule and stereotyping associated with borrowing		
Availability and access of equipment not guaranteed		
Effort put in hiring equipment		
Availability of equipment not guaranteed		
Effort put in negotiating deals		
Challenges: Lack of mulch material, forced to travel long distances, forced to go to unsafe places		
Setbacks in implementing	Generating maps for possible locations and sources of mulch with details on distances and travel costs/time, presence of dangers (e.g. animals) and other information to ensure the safety and well-being of farmers; adopting measure at small scale in between drought years to establish practices and procedures	Costs of persuading farmers to adopt measure; research costs for generating maps
Less time to rest Wellbeing concerns		
Safety concerns Encounters with snakes		

2. Use of drought-tolerant varieties

Intangible costs incurred from reactive measures	Proactive actions that may have minimized intangible costs	Transaction costs of proactive measures
Challenges: High cost of drought tolerant varieties, scarcity of drought tolerant varieties		
Effort spent looking for better priced drought tolerant varieties Effort spent looking for drought tolerant varieties	Preparing list of sources of drought tolerant varieties seeds with details on distances, travel costs/time, and drought tolerant varieties prices; adopting measure at small scale in between drought years supplemented with arrangements with private sector, specifically with drought tolerant seed suppliers, and arrangements with government for support/subsidy on drought tolerant seed supply	Costs of persuading farmers to adopt measure; research costs for preparing list of sources of drought tolerant seeds; costs for generating a formal or informal arrangement/ contract between suppliers and users of drought tolerant seeds; negotiation costs; costs of enforcing contract arrangements

3. Changing crop calendar

Intangible costs incurred from reactive measures	Proactive actions that may have minimized intangible costs	Transaction costs of proactive measures
Challenges: Risk of falling behind schedule and difficulties catching up while waiting for effective rains, possibility of replanting associated with dry planting as seed fail to germinate due to insufficient moisture		
Worry, anxiety and uncertainty Extra burden Embarrassment associated with borrowing Threatened emotional wellbeing	Support mechanisms in place such as standard operating procedures for various types of challenges encountered; techniques to induce or help seed germination implemented with the changing of planting dates; trainings for adoption of practices to implement along with changing of planting dates completed; adopting measure at small scale in between drought years to establish practices and procedures	Costs of persuading farmers to adopt measure; costs of designing individual or collective planting schedules

Source: **Authors' own elaboration based on the work of Kori, D.S., Francis, J. & Zuwarimwe, J.** 2021. Intangible and indirect costs of adaptation to climate variability among maize farmers: Chirumanzu District, Zimbabwe. In N. Oguge, D. Ayal, L. Adeleke & I. da Silva, eds. African Handbook of Climate Change Adaptation, pp. 397–422. Springer.

Unlocked economic potential

Unlocked economic potential is the benefit from the economic activities stimulated by the reduction of drought risk as proactive measures are employed. They can be received irrespective of whether drought occurs or not. Fundamentally, the perception of risk affects economic decisions, including savings and investment behaviours. Economic benefits are stimulated when investment decisions are adjusted with the change in risk perception due to the resilience building effects of proactive drought measures; thereby "unlocking the economic potential" (Tanner *et al.*, 2015). Perhaps the most salient case is the unlocked economic potential by improved financial inclusion. In case of agriculture, if drought risk is mitigated, farmers have a better risk profile in the eyes of financial institutions. Consequently, their access to financial products, such as microloans or savings, is improved, and the financial inclusion can be translated into investment. At a larger scale, out of concern that if earnings are negatively affected by drought, investors are hesitant to invest in areas. With the reduced risk, areas and communities become safer to invest in, and economic agents are encouraged to engage and economic gains can be attained from positive risk taking. Unlocked economic potential benefit is also manifested through investments in productive assets (e.g. in small-scale agriculture), extended planning horizons (e.g. for building up savings) and rise in land values after engaging in proactive drought investments.

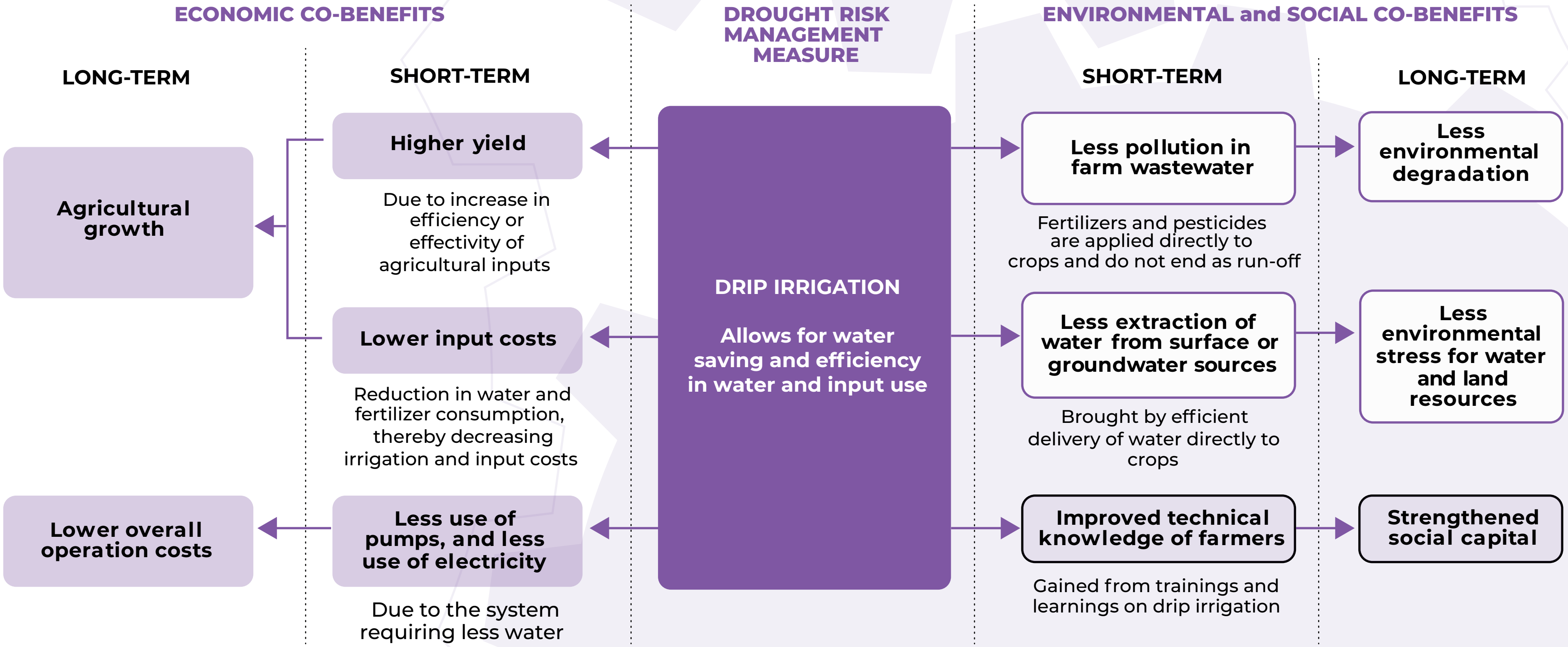
Managing drought risk as a business risk is a good approach to understand how investments can be safer for both investors and recipients. In essence, by managing the background risk of potential future disasters, proactive actions allow forward-looking planning, long-term investments and entrepreneurship, even if drought does not occur (Overseas Development Institute and World Bank, 2015; Tanner *et al.*, 2015; United Nations Office for Disaster Risk Reduction, 2020).

Co-benefits

Co-benefits are are not bound to the occurrence of drought and can be generated in between drought years by simultaneously responding to development needs or building resilience to other types of disasters. Beside drought management, co-benefit discussions are significant in various domains including disaster risk management, climate change adaptation and sustainable development (Vorhies and Wilkinson, 2016). Some regard co-benefits to be those that are received by third parties to the investments, while others consider them to be externalities or spillover effects of investments. They may also be benefits that are not directly related to the planned primary objective of the investment. Co-benefits can be tangible or intangible benefits linked to the various systems in which proactive measures interact with. Hence, in this report, co-benefits refer to the positive economic, environmental and social indirect benefits that did not result from the resilience building function of proactive measures, but rather, were generated due to the proactive measure's design or through system linkages (Overseas Development Institute and World Bank, 2015; United Nations Office for Disaster Risk Reduction, 2020; Helgeson and O'Fallon, 2021).

The economic co-benefits are the direct and indirect benefits from the proactive measure, generated through the interactions of the design, features and attributes of the proactive measure with the production or consumption markets. For example, early warning systems have the potential to bring extra revenue due to the value of information they offer. By reducing uncertainties of future conditions, provision of weather information can help in agricultural decision-making, in relation to predicting potential yields. Such decisions include undertaking planting and other farming activities to take advantage of favourable weather conditions (Bouwer *et al.*, 2011; Apergi *et al.*, 2020). Meanwhile, the design of the drip irrigation technology allows for water saving and efficiency in water use. Thus, drip irrigation is a water conservation technology to better distribute and save water for drought-prone periods. On the other hand, drip irrigation can significantly increase the yield if fertilizer use is more precise, or agrochemical leaching does not occur. In some cases, where the extent or maximum level of water consumption is regulated, the water saved by drip irrigation can be, eventually, transferred to non-irrigated areas, thus increasing the yields of previously rainfed lands (Figure 12). Another example is the case of emergency reservoirs. While additional storage facilities are at the forefront of drought resilience measures, reservoirs have multiple benefits to other industries such as aquaculture or tourism. Economic co-benefits are more visible than the other types, they can also be quantitatively measured or monetized.

Figure 12. An example of the co-benefits of drip irrigation



Source: Authors' elaboration.

Box 9. Economic benefits of drip irrigation systems in Uzbekistan

Semi-arid and arid areas are exposed to default water scarcity, and drought events can exacerbate the situation. Drip irrigation is a water conservation measure that can serve resilience-building objectives while producing a range of co-benefits. Such studies were carried out in Uzbekistan, whereas the intensification of agriculture involves increase in water use (Niyazmetov and Rudenko, 2013; Djumaboev *et al*., 2019; United States Agency for International Development, 2020).

Economic Benefits	Details
Water saving/ reduction in water consumption	• Saves up 50-65 percent of water consumption in cotton growing and up to 54 percent in horticulture and vegetable growing. • Can generate water savings equivalent to 11.7 thousand m³/ha of cotton, 6.6 thousand m³/ha of wheat, and 11.4 thousand m³/ha of other crops.
Improvements in application of agricultural inputs	• From a maximum of 70 percent of fertilizers ending up in runoff, 100 percent of the inputs can be applied directly to the crops. • Reduces fertilizer application in cotton farms by 30-40 percent compared to conventional irrigation.
Increase in agricultural production	• Can increase cotton yields by 10-19 percent compared to furrow irrigation; 12 percent against gated pipe irrigation; and 31 percent than traditional irrigation scheduling. • Possible to harvest 3 800 kg of cotton from one hectare, compared to 1 500 to 2 100 kg/ha harvest using traditional irrigation scheduling method. • Can increase crop yield by 30-70 percent compared to conventional irrigation.
Increase efficiency of infrastructure/ facility	• Higher water use efficiency (kg/m³); drip irrigation water use efficiency (kg/m³) is 1.41 compared to traditional irrigation scheduling's 0.51 kg/m³ and gated pipe irrigation's 0.74 kg/m³.
Decrease in operation or input costs	• Can reduce labour costs, by 1.3-3 times (e.g. water delivery, weeding, and application of fertilizers). • Can incur 58 to 60 litres less fuel per hectare for farm machinery use compared to costs using conventional irrigation methods.

Sources: **Niyazmetov, D. & Rudenko, I.** 2013. Drip irrigation – A necessity in Uzbekistan. GEF Small Grant Programme Newsletter No. 4. Tashkent, Global Environment Facility's Small Grants Programme. **Djumaboev, K., Manthrithilake, H., Ayars, J., Yuldashev, T., Akramov, B., Karshiev, R., & Eshmuratov, D.** 2019. Growing cotton in Karshi Steppe, Uzbekistan: water productivity differences with three different methods of irrigation. Proceedings of 9th International Micro Irrigation Conference (9IMIC), 16–18 January 2019. Bangalore, Ivy League. United States Agency for International Development. 2020. Ending the wait for water. In: United States Agency for International Development. Washington, D.C. Cited 29 May 2023. https://www.usaid.gov/uzbekistan/news/ending-wait-water

Other co-benefits, particularly the environmental and social co-benefits, are intangible, hence, they typically do not have market prices. Accordingly, measuring these types of co-benefits is difficult. With this, they are usually overlooked and are likely to be excluded in benefit-cost analyses. Under this situation, benefits are undervalued against aggregate costs (Vorhies and Wilkinson, 2016; Global Commission on Adaptation, 2019). Environmental co-benefits are linked to ecosystems and natural resources. To illustrate, environmental co-benefits from crop diversification, and applying mixed cropping or intercropping practices, include improvement in biodiversity, prevention against pest and disease infestations, and soil erosion control by preventing excess nutrients and chemicals from leaching away (Williams *et al*., 2020). Meanwhile, aside from economic benefits, employment of drip irrigation produces environmental co-benefits such as less pollution from farm water waste due to the reduction in water runoff. Likewise, given the increased efficiency in delivery of water to crops, less water is used and extracted from the surface and underground water sources (Niyazmetov and Rudenko, 2013; United States Agency for International Development, 2020). In the long run, these continued benefits in the area will contribute to the reduction of environmental degradation, and generate less stress for water and land resources, respectively.

Social co-benefits are the positive impacts of proactive action on the capacities, conditions and welfare of individuals, communities and society as a whole. To illustrate, the usage of early warning systems, along with the training that comes with the establishment of the system, strengthen planning and decision-making capacities of farmers. Likewise, community participation, as the early warning system is installed or drought preparedness planning is set up, can strengthen community cooperation and collaboration. Moreover, due to limited resources, many local governments rely on the community for knowledge, communication systems, labour and other inputs. Accompanying capacity building activities of proactive measures, therefore, have the potential to strengthen community cohesion even in the absence of a drought disaster. In the same manner, the technical training that farmer communities undertake in relation to drip irrigation systems improves the technical knowledge and capacities of participants. In the long run, such capacity building activities can strengthen social capital. Therefore, along with building system resilience, proactive drought measures can contribute to the welfare and inclusiveness of the communities they operate in (Overseas Development Institute and World Bank, 2015; Vorhies and Wilkinson, 2016; Yaron and Wilson, 2019; Apergi *et al.*, 2020).

An emerging aspect of the social co-benefits is the positive impact of proactive measures on health. Drought impacts health in many ways, among many are the heat-stress, negative impacts on nutritional status, the consequences of poor accessibility of water, or the declining water quality. Proactive drought measures, such as the creation of water storages, groundwater conservation, and shading structures such as agroforestry systems can achieve significant co-benefits to the health of individuals and communities. Such social co-benefit can be monetized or intangible. If drought-induced health problems put additional burden on the health service system, monetary health benefits can be drawn from proactive measures.

5 Crafting a two-tier framework for economic assessment of drought

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There is no standard methodology or data source for the economic assessment of drought, as even relatively unified approaches must be adapted to specific situations. Assessments of drought impacts in the fields of drought management, disaster risk reduction and climate change adaptation have employed diverse methodological approaches, including computable general-equilibrium modelling, input-output analysis, econometric modelling, risk-based methodology, hydro economic modelling, welfare analysis, and cost–benefit analysis, among others (Mechler *et al.*, 2008; Martin-Ortega and Markandya, 2009; Gil *et al.*, 2013; Montaud, 2019; Arfanuzzaman *et al.*, 2021; Garcia-Leon *et al.*, 2021; Medellin-Azuera *et al.*, 2022; Sawadogo, 2022). Examinations of the costs and benefits of drought, disaster risk, and climate change adaptation measures, likewise, have utilized various tools such as the AQUATOOL decision support model (Ruperez-Moreno *et al.*, 2017), Household Economy Approach Model (Venton, 2018a, 2018b, 2018c), and Climate Smart Agriculture Programming and Indicator Tool (Akinyi *et al.*, 2022). Combinations of primary and secondary data sources have also been used.

Examining various economic assessments of drought and drought management measures provides a better insight on how costs and benefits have been accounted. Thus, this chapter presents a compilation of studies that have carried out economic assessments of drought. It describes and examines the cost and benefit indicators used in these assessments. Costs and benefits information are classified according to the typologies presented in the previous chapters. To assist in data collection, various databases, as possible sources of indicators and data for assessments, are also presented in this section. The chapter, finally, crafts a two-tier framework for economic assessment of drought.

The database of case studies

Although the evidences on the implementation of economic assessments of drought management are still short, the baseline for assessment methodologies has been progressing in leaps and bounds. Real-term case studies of economic assessments are few, but there is a growing interest in accurately evaluating the costs and benefits of drought management. This is even more urgent, as the drought community is now calling for the contribution of the private sector. Nevertheless, private sector requires strong evidences that investment in drought resilience is profitable. The review of the endeavours shows successful approaches but also the shortcomings. Therefore, 10 case studies are collected, analysed and framed into the terminologies introduced by this report (Mechler *et al.*, 2008; Niyazmetov and Rudenko, 2013; Rupérez-Moreno *et al.*, 2017; Venton, 2018a; Montaud, 2019; Williams *et al.*, 2020; Arfanuzzaman *et al.*, 2021; National Planning Commission, 2021; Akinyi *et al.*, 2022; Sawadogo, 2022).

The information extracted from the case studies is examined based on the different types of costs and benefits in this report's typologies. The goal is to understand to what extent costs and benefits are assessed. Above all, the objective is to prove that not only can proactive measure investments be recovered, but they can produce substantial benefits as well, and therefore generate returns. The analysis does this in a way that it recognizes the costs entailed by proactive measures, including the intangible ones. The case studies are grouped into three databases:

- Case studies presenting the costs and the impacts of drought;
- Case studies presenting the costs of the proactive measures; and
- Case studies presenting the benefits of the proactive measures.

The summary table of the case studies is presented in Annex 3.

Outcomes of the case studies: observations on the costs and the impacts of drought

The most common type of cost assessed is the direct cost, as this cost type is the most apparent and straightforward to investigate. Some studies included indirect costs, and others also examined the intangible costs. Meanwhile, the works of Mechler *et al.* (2008), Montaud (2019), Garcia-Leon *et al.* (2021), and Sawadogo (2022) covered all three types of costs. Analysis of the studies suggests that the process of accounting for the costs and impacts of drought is quite extensive, with considerations on inter-sectoral or inter-system linkages and connections, and non-market losses and damages. In general, the direct costs refer to production impacts, such as crop losses and damages, decreases in agricultural outputs, reductions in agricultural productivity, and increases in costs of agricultural inputs, particularly water and irrigation related costs (e.g. water pumping costs, electricity costs, etc.). Some studies also presented direct losses to farmers, like farm livelihood income declines. Others cited implications of the damages such as increases in agricultural prices. Droughts typically do not damage physical capital stocks such as machinery and tools, or capital structures like buildings, irrigation structures, dams or reservoirs. While damage is possible in the long run, like most analyses, these cost items also were not covered in the case studies.

Analysis of indirect costs opens a fresh perspective, with a number of case studies identifying cascading costs cutting across multiple systems and tiers, while others tracing linkages that lead to compounded costs to consumers. Secondary costs generally pertain to the impacts within agriculture, and to the downstream and upstream costs and losses to other sectors and industries directly connected to agriculture. Examples of costs "within" included informal and farm family employment losses, increases in debts of farmers, higher costs and lower feed crop availability for livestock productions, reduced profits from livestock from higher cost of feed crops, and decreases in agricultural market activities. Downstream costs were manifested through reductions in trade with outside markets, production declines in food processing and manufacturing, and gross revenue losses in food processing. On the other hand, upstream costs covered losses and damage connected to inputs of production such as reduction in intermediate agricultural inputs' revenues. Meanwhile, spillover effects encompassed damages and losses to the succeeding sectors or industries or the overall impacts of drought to the subnational or national economies. Such costs included production damages from services linked to agricultural outputs, such as wholesale, accommodation, and restaurant services, reduction in agrifood industrial gross value added, gross domestic product (GDP) losses, increases in agricultural imports, employment losses in other linked sectors, and reductions in non-farm wages. Some studies covered indirect compounded costs such as increases in national and food prices, declines in real household consumption, and weakening purchasing power of the consumers.

Recognizing intangible cost is crucial in an economic assessment of drought, and overlooking intangible cost leads to an incomplete analysis. This type of cost can be extensive. A number of case studies identified socio-economic costs, while others determined the social, health or environmental costs. Some registered combinations of the different kinds of intangible costs. The socio-economic costs included the rise in poverty incidence and rates, general decline in standard of living, and costs that increase food insecurity. Meanwhile, some reports incorporated social welfare losses due to reduction of household water supply, rural migration due to lower purchasing power and reduction in opportunities in rural areas, lack of community social cohesion for accessing water for agricultural purposes and drinking, and the disproportionally worsening living standards for women as social costs. Examples of health costs included increases in cases of malnutrition and the psycho-social stress brought by seeking water. Lastly, environmental costs were illustrated as, damage to biodiversity, declining groundwater levels, land desertification and soil fertility losses.

There is a need to adjust the perception or assumption that intangible costs have lower values compared to monetized direct and indirect costs, and to improve the comparability of the cost items in economic assessments. In terms of impacts on vulnerable households and communities, intangible costs can be equivalent to monetized direct and indirect costs. However, this cost item receives less attention in the overall economic assessments. To illustrate, Sawadogo (2022) estimated that in the short term, intense and moderate droughts can increase rural poverty in Burkina Faso by 6.5 and 2.9 percentage points, respectively. Long-term (i.e. year 2040) poverty impacts are worse with estimated increases of more than 10 percentage points in both drought scenarios. Results of analysis likewise suggested that droughts worsen the standard of living of women, compared to men, especially of those in the rural areas. Meanwhile, Melcher *et al.* (2008) stated that during droughts in Uttar Pradesh, India, the affected households who were unable to find alternative sources of living during the drought event, eventually experienced malnutrition and exploitation at the hands of local moneylenders. Still, even with the seriousness of intangible cost impacts, evidences suggest that the prevailing collective perception considers intangible costs to be secondary considerations against the monetized direct costs of drought. To illustrate, Bahinipati's (2020) work in Gujarat State in India, showed that the affected households of drought "give lower value to intangible losses that occurs over a period than the immediate tangible loss and damage which directly affect their total wealth".

Outcomes of the case studies: observations on the costs of proactive actions

Accounting the costs of proactive drought actions is not as extensive compared to identifying the costs or impacts of drought, with all case studies covering only the direct costs incurred in adopting or implementing the proactive measures. None of the case studies included the indirect, intangible and transaction costs associated with proactive action. The direct costs generally pertained to the project investment costs, specifically, the costs of installation, construction, establishment, and set-up of the early response and mitigation measures, including operation and maintenance costs. This does not mean that proactive actions do not entail intangible or transaction costs. Just the opposite, they may incur high transaction costs to the extent that this value may discourage the adoption of proactive measures. For example, promoting water conservation practices that are not attuned with cultural norms will incur high costs in convincing people to adopt the practices and in implementing the programme efficiently. Insufficient recognition of costs associated to proactive measures is counterproductive, as it embraces the unrealistic hope that any proactive measure fits all situations. Consequently, the economic assessment does not support the identification of alternative measures that can address the same impacts but with more favourable economic conditions. The more rigorous stocktaking and the elimination of biases is important to construct an objective picture about the economics of proactive management.

In general, transaction costs can comprise a considerable proportion of the total costs of a project, yet they are not included as a regular cost item in economic assessments of proactive drought measures. Various estimates on the magnitude of transaction costs imply that they can range from 8-38 percent of the total costs of a project or programme (e.g. climate change adaptation project, technical assistance programme, management agreement schemes, etc.) (McCann *et al.*, 2005; Marshall, 2013). Thus, transaction costs are relevant considerations in analyzing the costs and benefits of any project. Accordingly, due to the potential sizable level of transaction costs, reducing them can increase the benefits received. For example, soft measures to mitigate the costs of drought, such as the implementation of regulations concerning surface water market, incur considerable transaction costs. Lowering transaction costs of surface water trading – by streamlining the approval process of trading or centralizing information – are said to improve the adaptive capacity of the surface water market. In the United States of America, possible benefits of eliminating transaction costs in the wholesale market for surface water were estimated to range from USD 86 million to USD 278 million per year (Bruno, 2021). Still, even with the significance of transaction costs in project costing, none of the case studies in the compilation covered transaction costs, either in quantitative or qualitative form. This implies that the importance of transaction costs in economic assessments is yet to be reflected.

Identifying intangible costs of proactive drought measures is uncommon. As mentioned in section 3, discussions on intangible costs in the context of costs of inaction are more extensive. This type of cost is rarely included in drought risk management conversations. This notion is supported by analysis of the case studies, as none included this cost item in the assessments. Given this, the extent of intangible costs in relation to total costs of proactive action is difficult to presume. In addition, due to the very limited studies on the topic, information on intangible cost of proactive action is challenging to collect from secondary sources. Thus, primary data collection may be necessary to incorporate this type of cost in the analysis.

Outcomes of the case studies: observations on the benefits of proactive measures

Current identification of proactive action benefits typically does not distinguish between the benefits under scenarios with and without drought. Analysis of the benefit items identified in the case studies showed no distinct pattern of accounting for the benefits of proactive actions. Each study examined different combinations of benefits, with some highlighting the avoided costs, cost savings and economic co-benefits (Mechler *et al.*, 2008; Venton, 2018a; National Planning Commission, 2021); and others featuring only the avoided costs and co-benefits (Montaud, 2019; Arfanuzzaman *et al.*, 2021; Sawadogo, 2022). Meanwhile, Niyazmetov and Rudenko (2013) and Ruperez-Moreno *et al.* (2017) identified the unlocked economic potential and co-benefits, and Williams *et al.* (2020) and Akinyi *et al.* (2022) presented only the co-benefits of proactive measures. Avoided costs are comprised of:

- reduced hazard or drought impacts on general prices, rural food prices, rural food availability, food security;
- avoided income and revenue losses from livestock, crops, rural income, and GDP; and
- reductions in food deficits.

On the other hand, cost savings were in the form of reduced government relief expenses and expenditures, and decreased or avoided humanitarian aid.

Though not particularly classified as unlocked economic potential benefit, some studies acknowledged benefits arising from the reduced risk in the system. Specifically, according to Niyazmetov and Rudenko (2013), drip irrigation systems allow for slopes or areas with complex topography to be irrigated without the need for special facilities. Moreover, the system does not cause erosion. Thus, without the risk or with minimal risk of erosion, and with the possibility of irrigating strongly intersected plots, the adoption of drip irrigation system opens economic opportunities. Meanwhile, Ruperez-Moreno *et al.* (2017) indicated that implementing MAR system for irrigation preserves the ecological status of the aquifer and the groundwater-dependent ecosystems. With this, Ruperez-Moreno *et al.* (2017) included the bequest value of properties or environmental assets among the benefits of the measure. Thus, the reduced risk of environmental damage allowed for the natural resources and the surrounding areas to have economic value for future generations.

Economic co-benefits may manifest either from the input or output aspects of production as direct benefits, and also may emerge from the linkages and interdependencies of systems, as indirect benefits. Economic co-benefits of proactive actions are the most recognized among the co-benefits, with all 10 case studies presenting a range of economic co-benefits of proactive measures. A number of economic benefits relate to the improvements in agricultural production such as increases in harvests, yield gains, and rise in profitability from applying irrigation interventions (e.g. drip irrigation, MAR, deep groundwater irrigation, shallow groundwater irrigation), adopting drought resistant crop varieties, implementing climate smart agricultural (CSA) practices, and from employing intercropping, mixed cropping, or crop rotation practices. On the other hand, some economic co-benefits are linked to the inputs of production. For example, the use of drip irrigation results in savings from the reduced water use and lessened fertilizer and pesticide application. Meanwhile, implementing alternate (to rice) maize cropping can produce maize residue that can be used as livestock feed. Other case studies identified benefit items that arose from system linkages or that transcended from the production to consumption sectors. These can be considered as "cascading" or "compounded" economic co-benefits. To illustrate, Sawadogo (2022) identified the long-run benefits of adopting drought tolerant varieties to include, improvements in purchasing power and food consumption of consumers, increases in food access and food availability, reduction in poverty rates, and increases in GDP. Meanwhile, Ruperez-Moreno *et al.* (2017) considered the water use value for industrial consumption and for recreational use of wetlands and springs in the area to be among the benefits from the MAR system for irrigation. Lastly, Venton (2018a) identified surplus to the food deficit and surplus incomes, as benefits of early humanitarian response.

Environmental benefits from proactive drought measures can be substantial, though overall impacts of benefits are realized only after a longer period of time. Environmental benefits can be in the form of avoided harm to the environment such as the maintenance of soil structure and non-generation of secondary salinity from drip irrigation system, and slow water runoff from intercropping, mixed cropping, and crop rotation practices. Other benefits featured in the case studies include the enhancement or development of environmental conditions from proactive measures, for example:

- improvement of groundwater resources from MAR irrigation;
- increases in plant species per unit area from intercropping and mixed cropping practices;
- better soil fertility from crop rotation; and
- increased biodiversity, minimized greenhouse gas emission, and improved water quality from CSA practices.

Proactive drought measures have extensive benefits with or without drought. None of the case studies identified a complete set of benefits that reflects the typology of benefits proposed. However, there were studies that illustrated the benefits with drought (i.e. avoided costs and/or cost savings) and those without drought – though not presented under such classification. The economic co-benefits were the most commonly highlighted and extensively accounted co-benefit item (Mechler *et al.*, 2008; Venton, 2018a; Arfanuzzaman *et al.*, 2021; National Planning Commission, 201; Sawadogo, 2022). Still, the works of Niyazmetov and Rudenko (2013), Rupérez-Moreno *et al.* (2017) and Williams *et al* (2020) showed that the other co-benefits may likewise be substantial or that the proactive measure may unlock economic opportunities. Thus, considering and systematically investigating all types of benefits under drought and without drought scenarios is envisioned to produce a more complete account of the total benefits of proactive actions.

Box 10. Social benefits arising from the overall design of proactive drought measures

Social benefits cited in the case studies included the availability of water use for drinking as a result of MAR irrigation, higher social welfare estimated through increased farmer incomes from using drought resistant crop varieties, and the availability of alternative fuel for cooking from the maize dried plants by implementing alternative cropping, particularly, maize over the traditional rice crop. However, there are benefits which resulted from the design of the measure itself. In the case of alternate maize cropping practice adoption in Bangladesh, the buyer-seller arrangement of the measure benefited poor and marginal farmers since the latter can avail of the seeds and fertilizers at due price, and can pay the seller after harvesting (Arfanuzzaman *et al*., 2021). This suggests that additional co-benefits can be accrued by customizing the design of the proactive measure to the prevailing conditions in the system. Particularly, incorporating arrangements or design details that will address existing issues and concerns in the system.

Source: **Arfanuzzaman, Md., Hassan, S.M.T. & Syed, Md.A.** 2021. Cost–benefit of promising adaptations for resilient development in climate hotspots: Evidence from lower Teesta basin in Bangladesh. *Journal of Water and Climate Change*, 12(1): 44–59.

Stocktaking of potential data sources for the identification of costs and benefits

Quantitative economic methods are used more frequently for assessing the inaction, while pre-drought assessments of proactive measures rely on financial, often qualitative, evaluation methods. There are sophisticated methods, such as general equilibrium models or matching techniques, to assess the impact of drought, but the downside of these methods is the detailed and quantitative data requirement. Moreover, data must be controlled and validated to obtain robust results. If data are not properly handled, the explanatory power of these methods drastically drops and results are subject to many caveats. Assessment of drought management has further complexities, as datasets must be layered to distinguish the directly associated factors and the compounding factors. For example, a minor drought event can cause significant losses to communities with high vulnerability, by leading to a certain yield failure. Members of communities with poor farming practices might experience even higher relative losses. In the latter case, however, the yield failure can be attributed to the drought event only to a certain extent. Otherwise, these methods bring very accurate and reliable results, but data scarcity is stereotypical problem. First, if pre-drought assessment of proactive measures is carried out, the assessment must build on estimates and projections, thus making the application field of quantitative methods bound to assumptions. Furthermore, if implemented measures are assessed, data must be obtained from the right sources. Data collection related to financial issues is arguably one of the most delicate exercises, thus, data must undergo a reality check. Undoubtedly, economic assessments require public data sources to comply with the above-mentioned requirements.

Comparing the benefits of action and costs of inaction entails combinations of primary and secondary data sources. Primary data sources include project and online surveys, shared learning dialogues, focus group discussions, key informant, expert, and key resource interviews, public consultations, and workshop results. Meanwhile, secondary data may come from outputs of other studies and related literature, government and private sector databases, published and unpublished reports, project reports and national surveys. As evidenced by the data used in the case studies, a number of data sources may be needed in order to collect the data required for the assessment. Usually, a single data source is not sufficient, even if this source provides primary data. On the other hand, not all data can be obtained through primary sources due to their specific nature. Table 4 summarizes the normal data requirements of an economic assessment.

Table 4. Types of data needs to complete economic assessment of drought

Elements at risk	Data requirements
Economic	The value of losses associated with economic sectors (crop, dairy and livestock, timber and fishery production, and tourism). The assessment should consider not only the direct economic losses but also any indirect impacts such as the inability to plant the following year, loss of milk production for food consumption, or recovery time for fisheries to return to their predrought state.
	The cost of increased food prices can be measured by the increased cost and the number of people affected, or by valuing the cost of providing a substitute source of food. If no substitute is available, and those affected have less food as a result, data will be required on the decrease in food supply, as well as resulting malnutrition rates and costs.
	Lost revenue to water supply firms can be quantified by estimating the number of days that service is interrupted and the average revenue per day.
Environmental	Data will be required to quantify the extent of the damage for example, number of plant species damaged, areas of wetlands lost, quantity of water bodies affected, and so on.
	Monetizing environmental losses requires the use of willingness to pay or other contingent valuation techniques. It may be possible to monetize some of these losses by tracing the environmental impact to its outcomes - for example, by determining the lost revenue to tourism as a result of environmental impacts, loss in crops as a result of water or wind erosion of soil, or increased flooding damage to houses as a result of loss of wetlands.
Social	Data will be required to quantify the number of people affected by social impacts for each different type of impact. Monetizing social impacts can be difficult; therefore, it may be helpful to give the impacts a qualitative ranking - for example, from minimal to severe damage.
	It may be possible to monetize some of these losses by tracing the social impact to its outcomes. For example, where stress leads to health outcomes, it may be possible to gather data on the number of people affected and the cost of treating those health outcomes. Increased conflict may incur a cost through loss of life and property and through the deployment of peacekeeping forces. Monetizing losses such as damage to cultural sites, loss of aesthetic value, or reduced quality of life requires the use of willingness to pay or other contingent valuation techniques.

Source: **Venton, P., Venton, C.C., Limones, N., Ward, C., Pischke, F., Engle, N., *et al.*** 2019. Framework for the assessment of Benefits of Action/Cost of Inaction (BACI) for drought preparedness. Washington, D.C., World Bank. https://www.droughtmanagement.info/literature/WB-Framework-for-the-Assessment-of-Benefits-of-Action-or-Cost-of-Inaction-BACI-for-Drought-Preparedness-2019.pdf

For pragmatism, accuracy and cost–efficiency purposes, secondary datasets are good complementary options instead of the full-scale collection of primary data. Primary data is inevitable to view and plan assessments in local conditions. Drought can take any shape, depending on the geographical area of the affected system. Therefore, *in situ* data collection is a backbone of a fair and complete assessment. However, secondary data should not be considered as a worst-case option but rather as a complementary resource to primary data. This is because primary data is not always available or affordable at full-scale. In the past decades, information systems have greatly improved, with facilities that are user friendly and easily accessible. Table 5 presents some of the databases and knowledge-sharing platforms that have been developed and are currently operational. They can be useful sources of data in estimating or identifying the costs of drought and benefits of proactive drought actions.

Table 5. List of possible data sources for economic assessments of drought

Description	Descriptions and/or examples of data, indicators, information available	Publicly available for free?
FAOSTAT database (https://www.fao.org/faostat/en/#data) Data level: Country/national level Coverage: Global		
Database developed and maintained by the Food and Agriculture Organization of the United Nations (FAO). It provides country level data on a wide range of indicators on agricultural production, food security and nutrition, food balances, trade, prices, investments, food value chain, climate change, and other macroeconomic data. Structural data from agricultural censuses, reported by country members, are also displayed. Data from these censuses are collected at holding level, and present information regarding the agricultural structure of a country or a territory (e.g. size and number of holdings, land tenure, legal status, and holder gender). Data are available in time-series, from 1961 to 2020s (most recent data).	Production (by primary crops/livestock, processed crops/livestock, live animals): area harvested, yield, production quantity, stocks, producing animals, slaughtered animals. Prices (producer price by crop, by aggregated items [agriculture, cereals, citrus fruits, etc]: producer price per tonne, producer price index. Agricultural structure (by holdings, by parcels): area, average number of parcels per holding, percentage of total area, average persons per holding.	Yes

Description	Descriptions and/or examples of data, indicators, information available	Publicly available for free?
AQUASTAT (https://data.apps.fao.org/aquastat/?lang=en) Data level: Country/ national level Coverage: Global		
AQUASTAT database comprises FAO's global information system on water resources and agricultural water management. Data are available in time series (from 1960 to 2020), for around 180 variables and indicators. AQUASTAT draws on national capacities and expertise with an emphasis on Africa, the Near East, countries of the former Soviet Union, Asia, and Latin America and the Caribbean.	Area under agricultural water management: percentage of agricultural water managed area equipped for irrigation, percentage of area equipped for irrigation actually irrigate, percentage cultivated area equipped for irrigation. Irrigated crop area and cropping intensity: harvested irrigated permanent crop area, by crop; harvested irrigated temporary crop area, by crop; total harvested irrigated crop area. Irrigated crop yield: ratio between rainfed and irrigated yields.	Yes
International Emergency Disaster Database (https://public.emdat.be/) Data level: Regional, country/national, subnational level Coverage: Global		
International Emergency Disaster Database contains crucial data on the occurrence and effects of global mass disasters, including droughts, from 1900 to the present day. Supported by the Centre for Research on the Epidemiology of Disasters, World Health Organisation and the Belgian Government, data in the database are compiled from a wide range of sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies.	Data on drought: associated disaster; specific subnational areas affected; drought years, by country; total deaths; number of affected; reconstruction Costs (thousand USD); insured Damages (thousand USD); total Damages (thousand USD).	Yes / Registration needed
DesInventar, Disaster Information Management System (https://www.desinventar.net/DesInventar/index.jsp) Data level: Country/ national, subnational level Coverage: Global		
DesInventar database provides information on disaster impacts, including drought, in aid of analysis and better understanding of the effects of many types of disasters that occurred in the country. DesInventar is hosted by the United Nations Office for Disaster Risk Reduction.	Data on drought (available at the province, district, and commune levels): number of people directly and indirectly affected; crop damages; number of animals lost.	Yes

Description	Descriptions and/or examples of data, indicators, information available	Publicly available for free?
Asian Disaster Reduction Center's Disaster Information (https://www.adrc.asia/latest/index.php) Data level: Country/ national level Coverage: Regional		
The Center collects and disseminates information on disasters, including droughts, and provides an overview of the events and the damages of impacts. Links to relevant information (e.g. news articles, publications, etc.) are provided.	Sri Lanka: Drought: 2020/03: situation reports. Viet Nam: Drought: 2016/01: reports, articles Djibouti: Drought: 2011: situation reports	Yes
Famine Early Warning Systems Network (https://fews.net/) Data level: Country/ national level Coverage: Global		
The Famine Early Warning Systems Network provides timely early warning and vulnerability information on emerging and evolving food security issues. Its main activities are focused on monitoring and analysing relevant data and information in terms of its impacts on livelihoods and markets to identify potential threats to food security. It is a United States Agency for International Development-funded activity, in collaboration with international, regional and national partners. The Famine Early Warning Systems Network Data Platform provides data on: population and demography, relief needs estimates and actual deliveries, market prices, agricultural production, nutrition, cross border trade, and livelihoods	Acute Food Insecurity Population Estimates: Integrated Food Security Phase Classification (IPC) Food-insecure Population Estimates data which provides phase and scenario indicators of food-insecure populations. Acute Food Insecurity Classifications: IPC Food Insecurity Classification data which provides scale and scenario indicators on food-insecure populations globally or for specific geographic locations. Prices: Product and product market information (e.g. product source and product cost data at market and country level). Nutrition: Health and nutrition indicator information (e.g. mortality rate, disease prevalence, death rate).	Yes / Registration needed

Description	Descriptions and/or examples of data, indicators, information available	Publicly available for free?
OCHA Financial Tracking Service (https://fts.unocha.org/home/2023/donors/view) Data level: Country/ national level Coverage: Global		
Financial Tracking Service data repository hosts reports of humanitarian funding, including aid to address drought, to affected countries. Country data include: funding to meet the requirements of an internationally coordinated response plan in that country; funding outside of plan requirements (such as Red Cross/Red Crescent activities and bilateral funding to the affected governments); and humanitarian contributions in countries which do not have coordinated response plans/ appeals.	Ethiopia: The aim of the project is to make a contribution to strengthening resilience to future extreme weather events in selected drought-prone communities in Afar, Somali and Oromia. Lifesaving Health Services to Drought Affected communities in selected woredas in Somali and Oromia Regions of Ethiopia.	Yes
National surveys and census Data level: Country/ national; subnational Coverage: National		
Surveys conducted by country's national statistical offices. Some useful census and surveys include (among many others): Census of Agriculture, National Survey on Household Living Conditions, National Survey of Household Income and Expenditure, National Labour and Employment Survey.	Census of agriculture: farm size, tenure of holdings, land use and area planted to crops, inventory of livestock, and poultry, distribution and number of households engaged in farming, fishing, and related activities. National Survey on Household Living Conditions: household resources, housing, labour, education, pensions and health. National Survey of Household Income and Expenditure: income, expenditure and spending, food and non-food consumption, number of family members employed for pay or profit (or as wage, salary, or own-account workers), occupation, age, and educational attainment of household head; and other housing characteristics.	Varies depending on country Data policies

Description	Descriptions and/or examples of data, indicators, information available	Publicly available for free?
Country Drought Plans Data level: Country/ national; subnational Coverage: National		
With the support of the United Nations Convention to Combat Desertification (UNCCD) and its partners, many countries signified their commitment in developing national drought plans as part of the UNCCD 'Drought Initiative'. At present, 34 national drought plans are available and can be accessed on the UNCCD website.	Data varies depending on the content and design of the drought plan. Philippines: list of droughts experienced by the country; major impacts of listed droughts; damage losses of the most recent droughts, by sector. Montenegro: drought impacts by sector; intangible costs/impacts of droughts.	Yes
Knowledge base sharing platform of the United Nations Office for Disaster Risk Reduction PreventionWeb (https://www.preventionweb.net/knowledge-base) Data level: Regional, national, subnational Coverage: Global		
PreventionWeb, is the global knowledge sharing platform for disaster risk reduction and resilience of the United Nations Office for Disaster Risk Reduction. It provides disaster-related news, information, and publications filtered by year, content type, location, theme, and hazard, including droughts and heatwaves. Examples of theme groupings include disaster risk management, early warning, economics of disaster risk reduction, critical infrastructure, food security and agriculture, water, recovery planning, among others.	Assessment of agricultural drought vulnerability based on crop growth stages: A case study of Huaibei Plain, China (2023). Madagascar: Improved Early Warning to promote community-led anticipatory action: Protecting livelihoods from drought and floods for food security (2022).	Yes
Post Disaster Needs Assessment reports Data level: Country/ national, subnational Coverage: Global		
Post-Disaster Needs Assessments reports are conducted by disaster affected country governments under the Standby Recovery Financing Facility. These reports are prepared with the support of the Global Facility for Disaster Reduction and Recovery and the international community. Reports are generated for various types of disasters, including droughts.	Reports containing cost estimates on the damages and losses from drought by sector; cost needs by sector, profile of populations affected by drought/vulnerable groups.	Yes

Source: Authors' elaboration.

The two-tier framework: the economic assessments of drought as first tier

The conduct of economic assessments of drought impacts is faced with challenges in terms of availability of methodologies and data, and of quantifying non-market or intangible benefits and costs. Thus, assessments typically focus on monetized variables, and oftentimes, exclude intangible benefits and costs from the analysis (World Meteorological Organization and Global Water Partnership, 2017; Garcia-Leon *et al.*, 2021; Sawadogo, 2022). In cases wherein non-market variables are included, systematic comparison is lacking. However, the significance of non-monetized benefits and costs cannot be ignored. Hence, there is a need for existing decision-making tools to be modified or new ones to be developed to help evaluate the costs and benefits of drought management measures more exhaustively.

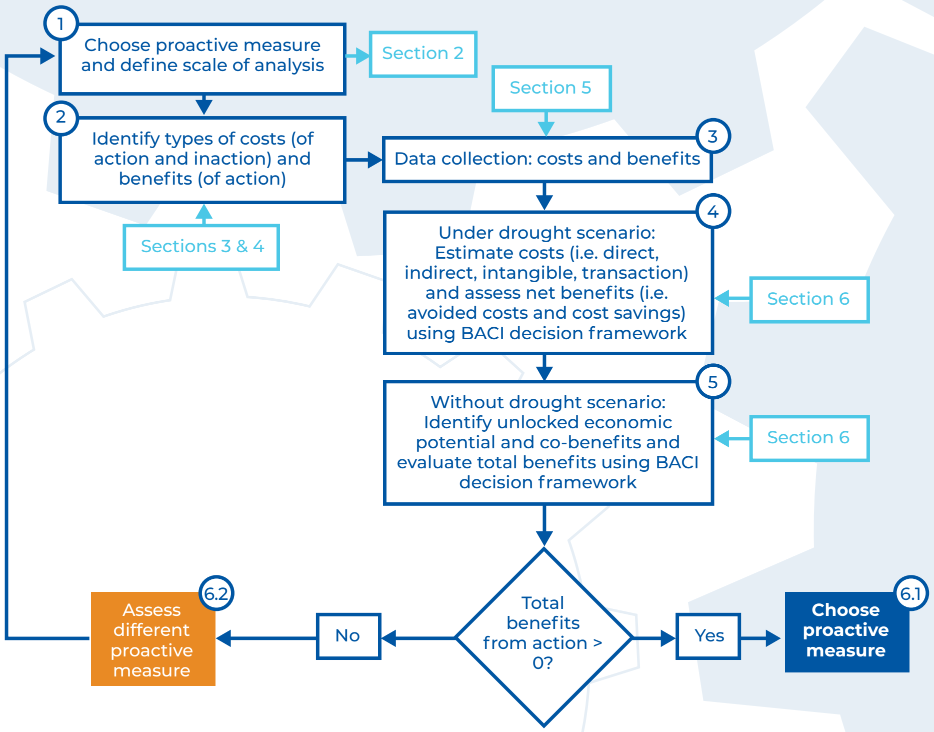
Benefits of proactive measures with and without drought are vital considerations in the benefit and cost comparisons. It is important for BACI assessments to demonstrate the co-benefits of drought risk management (Venton *et al.*, 2019). This can be achieved by distinguishing the benefits accrued under scenarios with and without drought, and by illustrating such benefits are generated simultaneously the moment proactive drought measures are adopted. However, a substantial amount of these benefits has no market prices, making comparative analysis difficult. Therefore, a framework which can transform qualitative assessments into quantitative forms is needed. With this in mind, this section introduces a two-tier framework that can assess monetized and intangible benefits of action and costs of inaction (first-tier), and selecting proactive drought measures among suite of options (second-tier). Examples are also provided to demonstrate the utility of the two-tier framework and to clarify how to conduct the analyses.

A framework that incorporates both monetized and intangible factors in comparing benefits of action and costs of inaction is a helpful tool in drought investment decision-making. The proposed two-tier framework is based on a cost–benefit analysis tool, set in a broader multicriteria analysis. The multicriteria analysis approach combined with scoring methodologies enables quantitative comparisons of benefits of action and costs of inaction. Specifically, the framework is a two-level assessment of proactive measures. The first level entails using the BACI decision framework, which is essentially, a cost–benefit analysis of adopting the proactive measure.

The succeeding discussions show how the sets of information presented in previous sections, which clarified costs and benefits concepts and presented case studies on cost–benefit assessments of proactive actions, can be effectively utilized. The BACI decision framework is designed to allow for qualitative assessments to be transformed into quantitative forms, thereby enabling a more simple and effective way of incorporating these variables into the decision-making process. If the resulting assessment in the first-tier is net benefits > 0, then analysis proceeds to the second-tier which is the called the proactive maximin option framework. In this context, the term "maximin" pertains to maximum benefit, minimum regrets. If net benefits < 0, this signifies that the measure is not an economically viable investment, and an assessment of a different proactive measure is warranted. Thus, the utility of the BACI decision framework is an iterative process, with the goal of generating a suite of proactive options that will be further examined for prioritization. This suite of proactive options is then assessed in the proactive maximin option framework. The second tier can provide an assessment of combinations of options to implement which will best maximize benefits and minimize costs.

The BACI decision framework operates under the assumption that proactive action will be undertaken, and assessments are conducted to determine which proactive measure is an economically viable investment, thus providing an iterative assessment that is repeated until the most optimal design of investment is achieved. This first-tier of the framework is divided into two stages. The first stage assesses the benefits when drought strikes, namely the avoided costs (i.e. costs of inaction minus costs of proactive action) and cost savings (i.e. from reactive drought action, particularly, relief cost savings). Thus, it primarily involves the costs of inaction and costs of proactive action variables, as well as the recovery and restoration costs. The costs of proactive action are comprised of not only the direct costs, but also the indirect, intangible and transaction costs. Assessment of the net benefits with drought – the difference between costs of inaction and costs of proactive action (deducted with cost savings) – comprises stage 1 of the framework (Figure 13).

Figure 13. Decision process stage for using BACI decision framework



Source: Authors' elaboration.

Stage 1 of the framework focuses on the costs under the scenario with drought. Stage 1 has four main components namely, total monetized costs of inaction and proactive action, monetized recovery and restoration costs, intangible costs, and transaction costs (Table 6 and Table 7). The total monetized costs variables are further classified into direct costs and indirect costs for both costs of proactive action and inaction, relief costs for restoration and recovery costs, and transaction costs for costs of proactive and reactive actions (i.e. if quantitative assessment of transaction costs is available to the evaluators). The comparison of damage costs of inaction with the costs of proactive action leads to the avoided costs. Comparisons are enabled for both monetized and non-monetized types of costs. Meanwhile, cost savings, which can be computed in monetary terms, are added to avoided costs, to arrive at the net monetized benefits with drought. Assessment of the cost savings is easier in situations where budgets for relief costs are available (e.g. international, national, and to some extent, subnational budgets for restoration and recovery). At the farm level, estimation of this variable is difficult unless primary data collection is conducted (e.g. surveys and interviews).

Table 6. Summary description of component costs in

Stage 1

Costs of Action and Inaction		Cost Categories	Cost Market			Notes
			Production	Consumption	Welfare	
Post-Drought Costs	Costs of Inaction/ Damage costs	Monetized direct costs	X			Primarily incurred in production chain
		Monetized indirect costs	X	X		Incurred in both the production (cascading costs) and consumption (compounded costs) markets
		Intangible costs	X	X	X	Direct and indirect costs with no market price; qualitative assessment
	Recovery and restoration costs (HORIZON 3)	Monetized relief costs	X	X		Comprise the recovery and restoration costs if monetized transaction costs are included
		Transaction costs	X	X	X	Qualitative assessment
Pre-Drought Costs	Drought risk mitigation costs (HORIZON 1) AND Preparedness costs (HORIZON 2)	Monetized direct costs	X			Fixed and variable costs of proactive measures; overall (proactive) project costs
		Monetized indirect costs	X	X		Negative externalities of proactive investments
		Intangible costs	X	X	X	Direct and indirect costs with no market price; qualitative assessment
		Transaction costs	X	X	X	Qualitative assessment

Source: Authors' elaboration.

Table 7. Stage 1 – BACI decision framework components

Cost item	Description		Possible scores
	Inaction	With Action	
Monetized net benefits with drought (monetized avoided costs + monetized cost savings)	Sum of all costs of inaction	Sum of all costs of action (minus cost savings)	-10 ≤ n ≤ 10
Direct costs Indirect costs Transaction costs Relief costs	Identify all possible monetized costs and compute for the total monetized costs using estimation methodologies at the evaluators' disposal. Note that cost savings, if computed, should be deducted from the total costs of proactive action. Transaction cost, if can be monetized, applies to proactive action only. Afterwards, evaluate costs based on the framework's scoring methodology		
Intangible costs	Identify all possible costs based on experience, expert opinions, literature review, stakeholder consultations, surveys, interviews. Afterwards, evaluate costs based on the framework's scoring methodology.		-5 ≤ n ≤ 5
Transaction costs			-5 ≤ n ≤ 0
Net benefits with drought	Sum of component scores		-20 ≤ n ≤ 15

Source: Authors' elaboration.

The assessment process uses both quantitative and qualitative data. Resulting monetized net benefits with drought are then evaluated based on the framework's scoring methodology. Assessment of the non-monetized intangible costs and transaction costs is based on qualitative assessments and non-monetized quantitative data (e.g. number of avoided malnutrition cases, hectares of land with improved soil quality, etc.). Data are gathered from evaluators' experiences, expert opinions, literature review, stakeholder consultations, surveys, interviews and other data collection means available to the evaluators. Costs are identified for both inaction and with action scenarios, and data are compared. Comparative analysis results are quantified based on the framework's scoring methodologies.

The corresponding scoring methodology is more precisely presented in Annex 4.

Stage 2 incorporates a scenario without drought. Accordingly, this stage involves the benefits from proactive action when drought strikes (i.e. net benefits with drought) and the benefits in between drought periods (i.e.

benefits regardless of drought). It covers four components, namely, net benefits with drought (results of Stage 1), monetized economic co-benefits, unlocked economic potential benefits and intangible co-benefits (Table 8). The net benefits with drought variable represents the resulting score from stage 1 of the BACI decision framework. Meanwhile, the monetized economic co-benefits are those with market prices such as increase in yield, savings in production inputs (e.g. labour, fertilizers, electricity consumption, etc.), among others. Resulting total monetized economic co-benefits value is then evaluated based on the framework's scoring methodology. Assessments of the unlocked economic potential benefits and the non-monetized or intangible co-benefits follow the stage 1 process. That is, evaluation is based on qualitative and non-monetized quantitative data, and benefits are then quantified based on the framework's scoring methodologies. If the total benefits score is positive, then proactive action path is chosen. Otherwise, the path towards assessing another proactive measure is selected. The path undertaken when total benefits score is negative illustrates the iterative course in the BACI drought decision making process. This stresses the notion posited at the beginning of the document. That is, the **provision of a framework for decision-making can help repurpose the question "should the proactive investment be undertaken?" to "how should the proactive investment be undertaken?" Specifically, the framework promotes the principle that investing in proactive drought measures should undergo an iterative decision-making process to determine economically viable options.**

Table 8. Stage 2 – BACI decision framework components

Benefit item	Description	Scores
Net benefits with drought	Resulting net benefits from assessing monetized and non-monetized costs of inaction and action.	$-20 \le n \le 15$
Monetized economic co-benefits	Compute for monetized economic co-benefits from action and evaluate against the monetized value of net benefits with drought. Afterwards, evaluate benefits based on the framework's scoring methodology.	$0 < n \le 10$
Unlocked economic potential	Identify all possible unlocked economic potential benefits and economic environmental and social co-benefits based on experience, expert opinions, literature review and evaluate co-benefits based on the framework's scoring methodology.	$0 \le n \le 5$
Intangible co-benefits		
Economic		$0 \le n \le 5$
Environmental		$0 \le n \le 5$
Social		$0 \le n \le 5$
Total benefits	Decision condition: If total benefits score is positive, then choose proactive measure; otherwise assess another proactive measure.	$-20 \le n \le 45$

Source: Authors' elaboration.

Each case among the hypothetical examples of the framework's utility highlights the significance of each classification of costs and benefits in the assessment (Annex 5). The hypothetical cases illustrate that:

- assessment may not solely depend on the monetized costs of inaction and proactive action;
- accounting for the indirect, intangible and transaction costs of proactive action are important in the decision-making process; and
- economic, environmental and social co-benefits are likewise significant components in the assessment.

The hypothetical cases also highlight the notion that analysis should be conducted for both scenarios with and without droughts. Some cases demonstrated that assessments should not stop at the results with negative net benefits scores under the scenario with drought. At first glance, such investments may seem to be unattractive. However, a negative net benefit score under drought scenario only shows part of the story. Environmental benefits may be sizable, and significant economic and social co-benefits may also exist. Therefore, resulting total benefit from proactive action may be positive, even with a negative net benefit score under drought scenario.

The two-tier framework: proactive drought measures based on maximum benefits and minimum regrets as second tier

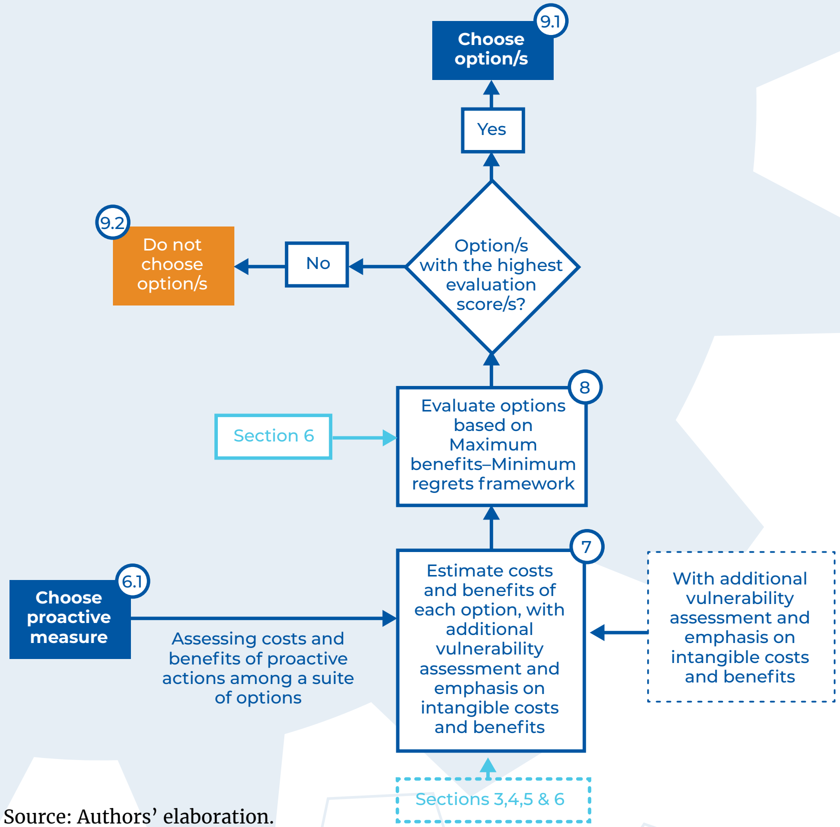
Another challenging aspect of drought management is selecting the suitable measure to implement among several proactive drought risk management options, given the limited available resources. This report acknowledges the difficulty in comparing costs and benefits of alternative measures due to the ambiguity in monetizing or quantifying costs (e.g. indirect, intangible and transaction) and benefits (e.g. unlocked economic potential and co-benefits). In fact, the BACI decision framework presented in this report enables analyses that use combinations of both quantitative and qualitative data. Similarly, the proposed proactive maximin option framework for the comparative analysis of proactive drought risk management options also adheres to the same principle. The second-tier framework is designed in such a way that it has the potential to:

- provide an extensive consideration of benefits and costs of proactive measures;
- offer a quantitative comparative analysis of linkages and cascading effects of options using combinations of quantitative and qualitative data; and
- consider vulnerability reduction impacts of proactive management actions.

The rationale behind adding the second-tier to the framework design is the notion that, **whereas it may be unlikely to identify one best proactive management option, it is possible to select the alternative that can maximize the benefits and minimize the probability of regret**. Hence, the maximin (i.e. maximum benefit, minimum regrets) assessment is an optimal approach to evaluate the alternative proactive actions. In this context, regrets take the form of damages – revenue losses or missed opportunity to increase revenues – due to not selecting the best option (Cervigni *et al.*, 2015). Regret may also materialize in the form of negative consequences of not selecting the best option for the future condition that have unfolded. Rather than setting conditions for identifying the best measure, the design of the framework aims to strike a balance between the risk of inaction and the risk of taking the wrong or worst action. Thus, it factors in the costs and benefits of the proactive measure under scenarios with and without drought, while considering the system's level of vulnerability under the scenario of the proactive measure. Moreover, it incorporates costs and benefits incurred in implementing the proactive measure due to system linkages (co-benefits and cascading and compounded costs).

The second-tier, proactive maximin option framework, considers the linkages and cascading effects of drought management measures to significant factors in determining the rationality of investments. Accordingly, these linkages are accounted in comparing options. Also, it is important to ensure that drought risk mitigation, and early response and preparedness measures are relevant not only during drought events but are likewise useful in between drought years. In the context of adaptation, this way of thinking is referred to as a "no regrets" action (Callaway, 2003). Applying this to drought, a no regret action refers to one that is undertaken for purposes other than avoiding drought damages, but still lessen the impacts of drought when it occurs. This is due to the lower vulnerability and higher coping capacity to drought of systems after the implementation of the action. It also accounts for the measure's effect on the system's exposure and sensitivity to drought. Moreover, by maximizing benefits and minimizing regrets of not selecting the best response, the uncertainty surrounding a drought event is incorporated in drought management appraisal. The framework is considered to be best utilized for micro-analyses at the subnational scale or project level. However, it has the potential to be used for national scale assessments, depending on the available information that can represent factors at a macro-level.

Figure 14. Decision process stage for using proactive maximin option framework for proactive action options



Source: Authors' elaboration.

The proactive maximin option framework incorporates both quantitative and qualitative data and information in the assessment. It has five main components namely, monetized net benefits or the combined avoided costs and cost savings, monetized economic co-benefits, transaction costs, change in vulnerability or re-evaluated system vulnerability, and the system linkages factors (co-benefits and cascading and compounded costs). The scoring methodologies for the monetized net benefits, monetized economic co-benefits, and transaction costs are the same as those of the BACI decision framework. Thus, the scores of these factors from the first-tier can be plotted in the second-tier (Table 9). A scoring methodology for the other factors was also formulated (Annex 4). The framework is flexible, such that users can consider other factors and devise their own scoring methodology for each factor. For example, subfactors of the system linkages can be modified, or weights of factors can be adjusted. Likewise, if other kinds of assessments are available, such as water accounting, water evaluation analysis, and the like, these can be incorporated as additional criteria or conditions, with their own sets of scoring methodologies.

Table 9. Description of factors comprising the proactive maximum option framework

Factors	Description
Monetized net benefits with drought	Combined monetized avoided costs and cost savings Difference between the costs of inaction and the costs of proactive action = monetized avoided costs. Add the monetized cost savings to the monetized avoided costs. Alternatively, cost savings can be deducted from the total costs of action early on. Same score as registered in the BACI decision framework
Monetized economic co-benefits	Compute for monetized economic co-benefits from action and evaluate against the (absolute) value of monetized net benefits with drought. Same score as registered in the BACI decision framework
Transaction costs	Non-market or not calculated into quantitative values due to various constraints. Same score as registered in the BACI decision framework
System Vulnerability	Reassessment of system vulnerability with proactive drought measure applied. The proactive measure may affect or change any one of the vulnerability components, hence, a change the vulnerability assessment is expected. The framework has a flexible design such that whether the vulnerability methodology used generates quantitative or qualitative evaluations, the framework's scoring methodology can be applied to normalize the resulting values.
System linkages: Co-benefits	Assessment of the intangible co-benefits of drought proactive measure
System linkages: Cascading or compounded costs	Assessment of the intangible costs of drought proactive measure

Source: Authors' elaboration.

The scores for each proactive measure are summed up to arrive at the maximin drought mitigation option score. The higher the maximin score value, the better option is the mitigation measure. The same kind of assessment can be conducted for the preparedness options. It should be noted that the co-benefits and cascading or compounded costs identified in the system linkages are essentially intangible benefits and intangible costs, respectively. With this design, the framework highlights the importance of comparing the intangible benefits and costs of each measure, and the significance of incorporating these factors in the investment decision-making process. The framework hypothesizes that by knowing the intangible costs of the proactive measure's adoption, the implementation of the measure can be re-designed to minimize these costs or negative consequences. Likewise, implementation can be (re)designed to maximize the benefits.

6 The implementation of the two-tier framework: drought in 2015–16 in the Philippines – case study

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The framework application for generating an economic case

Case study limitations

The BACI decision framework can aid in proactive action decision-making as it enables comparison of costs under scenario with drought and allows for the incorporation of benefits under the scenario without drought in the assessment. The framework's utility is tested in the case of the Philippines, specifically, the comparison of benefits from adopting drip irrigation system and the costs of inaction. It should be noted that the figures presented are estimates that can be influenced by internal or external factors, such as the ongoing polycrisis and its economic implications. Thus, while the estimates are based on actual data (i.e. as against hypothetical figures), the nominal values must be used with caution. **To put differently, the monetized values presented, as well as the scores of the other factors (intangible costs and transaction costs) are for illustrative purposes only, particularly, to demonstrate the potential of the framework as a tool for decision-making.** With this, a more exhaustive estimation of costs and benefits is recommended, along with the re-evaluation of the qualitative assessments (and their associated scores) based on opinions of local experts. Succeeding discussions show how the framework can be utilized, and they illustrate the possible types of analyses that can be conducted.

Box 11. BACI decision framework: Weights

The current version of the framework assumes equal weights across components or categories. This approach was selected given this study's limitations, and the information constraints concerning the possible magnitude of components to the totality of the net benefits. First, the extent of research needed to quantify transaction costs is expansive in itself, which cannot be covered by the scope of this report. Thus, assigning weight for this component was deemed premature with the available information. Next, there is a possibility the weight assignment may be project or context specific. The suite of proactive measures is expansive, covering institutional, behavioural, financial, capacity building, and structural measures, among others. The framework will need to be tested extensively to determine a more conclusive weighting assignment. The framework's design is flexible such that adjustments in its features, like component weights, are possible without changing the framework's overall integrity. Finally, weights are also subject to national policies and priorities. Therefore, weights will be set only as indicative values in the future by giving freedom to users to adjust them to the local context.

The background of the case study

Estimates on the impacts of drought or the costs of inaction are provided for three drought severity scenarios: high, medium, and low. Stage 1 analysis compares costs of inaction and proactive action to arrive at the avoided costs and cost savings benefits. Meanwhile, Stage 2 analyses the benefits of proactive action under the scenario without drought. The most recent severe drought event in the Philippines, which occurred in February 2015 to July 2016, was the reference of the severe drought impact estimates. The drought occurrence caused damages to 16 of the 18 regions in the Philippines (85 percent of the country) and triggered a state of calamity declaration to nine provinces and one city. Around 400 000 farming households were affected and about 556 721 ha of agricultural land were impacted (National Drought Plan of the Philippines, 2019; Alampay and dela Torre, 2020).

Case study assumptions

- Drought is an extremely complex hazard, and this complexity makes estimation of the costs difficult to carry out. Unlike other hazards, drought can span across weeks, months, or even years, and its duration is challenging to predict. Thus, the timeline of estimation period is complicated. This challenge affects both the computation of the costs of drought (costs of inaction) and the costs of the drip irrigation system (cost of proactive action).

- Given this, the analysis of the case study was structured by drought severity scenarios, with the severe drought representing the 2015-2016 drought event in the Philippines. That is, the estimates for the high drought severity scenario are based on the direct and indirect impacts of this months-long drought event. Meanwhile, the medium and low severity scenarios were computed as 50 percent and 20 percent, respectively, of the costs of severe drought. For comparability of the costs of drip irrigation system and the costs of drought, estimates were adjusted to reflect the 2022 prices. Adjustments were applied to both the costs of inaction and costs (and benefits) of proactive action.

- The total cost of drip irrigation system is comprised of fixed costs of setting-up and construction of the system, and the variable costs incurred for operation and maintenance (O&M). Given the single period structure of the case, the total O&M cost, which was discounted for the expected lifetime of the system assumed to be 10 years, was lumped as a one-time cost together with the fixed costs.

- On the other hand, the monetized economic co-benefits, which are the benefits without drought, were computed for a single period. This is due to the uncertainty on when drought will occur. Moreover, studies on the annual increase in production or annual reduction in irrigation costs due to the adoption of drip irrigation system is very limited. Most studies are based on a single production cycle. Thus, while historically, droughts in the Philippines are far apart, the lack of information on the long-term economic benefits of drip irrigation prompted the decision to have undervalued than overinflated monetized economic co-benefits.

- Technically, the co-benefits and unlocked economic potential are also incurred under drought conditions because these benefits are present during the lifespan of the proactive measure, regardless of drought occurrence. However, since the estimation is structured for a single period, the co-benefits and unlocked economic potential are incorporated in the framework under the "without drought" layer to avoid double counting.

- Through the scoring methodology, the various estimates were adjusted to a common scale, thereby allowing comparisons across cost and benefit categories. Hence, the scoring methodology of the framework is the tool used to normalize the estimates.

Showcasing the framework for benefit of actions and cost of inactions

For better representation of costs under the drought scenario, computation of monetized costs should not be limited to direct costs. To illustrate, in addition to direct crop damages, indirect costs were likewise included in the analysis (Table 10). Specifically, indirect compounded costs and indirect cascading costs were estimated. Indirect compounded costs were represented by losses from the reduced consumption of rice. During the drought event, families were living on 1–2 meals a day for several months. These meals were typically comprised of root crops, banana and wild yam (Alampay and dela Torre, 2020). Indirect cascading costs, on the other hand, were in the forms of income losses from lower wage hike of agricultural workers, and employment losses, particularly that of the informal wage workers.

Meanwhile, the monetized direct costs of adopting drip irrigation system were calculated for 278 361 hectares, which is 50 percent of the total land area impacted during the severe drought in 2015–2016. It is assumed that this area coverage of drip irrigation system will have a considerable effect in mitigating the impacts of severe drought events. With regard to indirect costs of drip irrigation system, it was assumed that the lower revenues of fertilizer industry are cancelled out by the lower input costs of production. Both are results of the lower demand for fertilizer with drip irrigation use. Similarly, the labour reductions from higher input productivity are assumed to be cancelled out by the increase in labour demand for additional harvesting work due to higher production. Meanwhile, the cost savings, whose value represents the percentage reduction in relief and response costs, were deducted from the costs of adopting the drip irrigation system. Comparison of costs showed that monetized net benefits with drought is positive only under the high drought severity scenario. Still, this net benefits value is considered to be very low. On the other hand, under the medium and low levels of drought severity, the costs of drip irrigation are much expensive compared to the costs of drought impacts (Table 10).

Table 10. STAGE 1 – Comparison of monetized costs with drought: Inaction versus proactive action (in thousands USD)

Monetized costs of inaction			
Cost items	Drought Severity		
	High	Medium	Low
Crop damages	379 995	189 998	75 999
Losses from reduced rice consumption	380 853	190 426	76 171
Income losses from lower wage hike during drought	2 129	1 065	426
Employment losses in agriculture (informal wage workers)	1 728	864	346
Total costs	764 705	382 353	152 941
Monetized costs of proactive action			
Cost items	Drought Severity		
	High	Medium	Low
Costs of drip irrigation for 278 361 ha (50% of total area damaged in severe drought)	664 250	664 250	664 250
(Deduct) Cost savings from government relief and response aid from international community	5 472	2 736	547
Total costs	658 778	661 514	663 703
Stage 1 monetized net benefits assessment			
Monetized net benefits with drought (monetized avoided costs + monetized cost savings)	105 927	**-279 161**	**-510 762**
Scores of monetized benefits with drought	1	**-2**	**-4**

Source: Authors' own computations.

Intangible and transaction costs are significant factors to consider in comparing total costs of inaction and costs of proactive action under drought scenario. There is a very high level of intangible costs of inaction under the high severity drought scenario. These costs cover the:

- negative effects of drought to 400 000 farming households;
- groundwater depletion;

- prevalence of diseases due to malnutrition, reduced access to potable water, and lack of hygiene and sanitation;
- occurrence of forest fires resulting to biodiversity losses; and
- increases in erosion and river siltation.

According to Alampay and dela Torre (2020), civil unrest also resulted as food became scarce. Some farmers began to picket in main highways of the worst affected areas (e.g. Mindanao Island), demanding assistance. In other accounts, depression due to the feeling of helplessness of feeding own family was experienced by farmers. Under the medium and low severity drought scenarios, intangible costs of inaction were evaluated to have moderate and low scores, respectively (Table 11).

Intangible costs of drip irrigation were also accounted in the economic assessment. Based on studies, there is a risk that the use of advanced irrigation technologies with high irrigation efficiency, such as drip irrigation, may increase on-farm water consumption, groundwater extractions, and water consumption per hectare. This is due to the change, specifically an increase, in water consumption behaviours of farmers (e.g. switching to more water-intensive crops, expanding irrigated areas for higher production revenues). The continuous increasing water consumption can lead to reduction in groundwater recharge and a decline in the aquifer resources, thereby generating environmental damages. Such intangible cost is evaluated to have a medium impact (particularly in relation to the social, environmental, and health costs of drought under severe drought scenario), thus, was given a score of 3. This score is made consistent in all drought scenarios since the intangible cost is not dependent on the level of drought severity. It is a cost incurred throughout the lifespan of the proactive measure. It should be noted, however, that such score was assessed under the assumption that institutional support mechanisms, such as water consumption regulations, are not in place (Table 11). Similarly, transaction costs were assessed to be medium under all levels of drought severity. These costs include:

- those incurred for encouraging and convincing farmer stakeholders in adopting drip irrigation given the expensive initial monetary costs;
- research costs for studying all the relevant factors needed for installation and operation of drip irrigation system like land topography, soil, water, crop and agroclimatic conditions and suitability of drip irrigation system and its components; and
- training stakeholders to operate and maintain system, among others.

Incorporating all the costs, the net benefit of adopting drip irrigation system is zero under the high drought severity scenario. Worse negative net benefits are recorded under the medium and low levels of drought severity, due to the effect of the intangible costs and transaction costs.

Table 11. Stage 1 – Comparison of total costs with drought: Inaction versus proactive action (drip irrigation)

Cost item	Inaction	With proactive action	Drought severity		
			High	Medium	Low
Monetized net benefits			1	**-2**	**-4**
Intangible costs	HIGH: Hundred thousand (at least 400 000) of farming households affected, groundwater depletion, prevalence of diseases due to malnutrition and reduced access to potable water, forest fires during droughts, leading to species loss, increased erosion and dam sedimentation, river siltation, and air pollution; high score (5) MEDIUM: 50% of costs under high severity scenario; moderate score (3) LOW: 20% of costs under high severity scenario; low score (1)	There is a risk that the use of advanced irrigation technologies with high irrigation efficiency, such as drip irrigation, may increase on-farm water consumption, groundwater extractions, and water consumption per hectare. This is due to the unregulated change, specifically an increase, in water consumption behaviours of farmers (e.g. switching to more water-intensive crops, increasing irrigated areas). Continuous increasing water consumption can lead to reduction in groundwater recharge and a decline in the aquifer resources, thereby generating environmental damages (3)	2	0	**-2**
Transaction costs		Costs incurred for encouraging and convincing farmer stakeholders in adopting drip irrigation with expensive initial costs, training stakeholders to operate and maintain system, additional care needed for water filtering and maintenance to avoid clogging, adjustments needed in production practice to accommodate drip irrigation design (e.g. modification of herbicides or top dressed fertilizers if sprinkler irrigation needed for activation), costs incurred in satisfying system requirements, careful study of all the relevant factors like land topography, soil, water, crop and agroclimatic conditions, and suitability of drip irrigation system and its components, costs for ensuring proper leaching (i.e. without sufficient leaching salts applied with the irrigation water may build up in the root zone), care needed for proper installation to avoid waste of time and water	**-3**	**-3**	**-3**
Net benefits with drought			0	**-5**	**-9**

Source: Authors' own computations.

Ending the assessment with the cost comparisons under the drought scenario (Stage 1) produces an incomplete analysis and misguided conclusion. The decision to choose investing in the proactive measure should consider the costs and benefits under the scenarios with and without drought. Stage 2 of the BACI decision framework incorporates the results of Stage 1 on top of the analysis of benefits without drought. The drip irrigation system is known to increase crop production and reduce water inputs in the initial level of agricultural production. These items were estimated as the monetized economic co-benefits from implementing the drought mitigation measure. An increase in rice production, of 29 percent, and a drop in water consumption, of 50 percent, were applied. The percentage increase in rice production used in the estimation is the average of the yield increases from various literature. Specifically, studies have recorded a wide range of increase in rice production with the use of drip irrigation system, namely, 12–45 percent (Bansal *et al.*, 2018), 29 percent (Parthasarathi *et al.*, 2018), 13–28 percent (Soman, 2021) and 50 percent (Netafim, 2023). Analysis showed very high monetized economic co-benefits. The ratio of monetized economic co-benefits to (absolute value of) net benefits with drought is 2:1 under the high drought severity scenario. Based on the scoring methodology of the framework (Annex 4), this translates to the total monetized benefit score of 10. Meanwhile, the economic co-benefits under the medium and low drought severity scenarios are 76 percent and 41 percent, respectively of the (absolute value) of the net benefits with drought. When converted into monetized economic co-benefit scores, medium drought scenario registers the score of 4, and the low drought scenario, 3 (Table 12).

Table 12. Stage 2 – Monetized economic co-benefits without drought (in thousands USD)

Stage 1 data entries			
Benefit item	Drought severity		
	High	Medium	Low
Monetized net benefits with drought	105 927	**-279 161**	**-510 762**
Stage 2 data Entries			
Benefit item			Monetary value of economic co-benefits
Increase in rice production with drip (29% increase)			111 404
Indirect economic co-benefits			99 206
Water cost savings (50% reduction in water usage)			1 344
Total monetized economic co-benefits without drought			211 953
Stage 2 monetized economic co-benefits assessment			
Benefit item	Drought severity		
	High	Medium	Low
Percentage of monetized economic co-benefits without drought to (absolute value) monetized net benefits with drought	200%	76%	41%
Monetized economic co-benefits scores	10	4	3

Source: Authors' own computations.

Intangible or non-monetized benefits are valuable components to consider in the comparative analysis, and the inclusion of intangible benefits can overturn a negative net benefits assessment into positive. To illustrate, the use of drip irrigation system allows for areas with irregular shaped fields and with various soil types to be irrigated. That is, levelling of fields is no longer a requirement to have an irrigated farm. This unlocks the economic potential of areas previously not qualified to be irrigated, to have irrigation. This benefit was assessed to be very low, with a score of 1 (for all drought severity scenarios). Meanwhile, even though economic co-benefits have already been estimated and monetized, some intangible benefits remain. These costs were classified under intangible costs. Their monetized equivalents were not estimated due to lack of information and data. These benefits include higher production efficiency, optimum usage of water, reduced water waste, and opportunity for diverse crop application. To avoid double counting with the monetized economic co-benefits, the intangible economic co-benefits item was given a score of 1 (very low). On the other hand, a score of 3 or moderate environmental co-benefits was evaluated. Particularly, the use of drip irrigation:

- results to minimized nutrient loss due to localized application and reduced leaching;
- allows for safe use of recycled (waste-) water;
- enables moisture within the root zone to be maintained at field capacity, thereby minimizing soil erosion;
- improves aeration;
- reduces greenhouse gas emission;
- increases available nutrients; and
- creates constant condition of water retention at low tension.

Lastly, very low social co-benefits score was assessed, as a result of the higher technical capacity of farmer stakeholders from the trainings and additional knowledge provided and imparted to them. Moreover, with equal opportunity to attend trainings, women are set to acquire additional skills and knowledge, thereby improving equity in human capital (Table 13). With the total benefit scores of 15, 6, and 0 under the high, medium and low drought severity scenarios, the analysis points to the decision to choose the proactive measure or adopt the drip irrigation system under the high and medium drought scenarios.

Economic assessments, such as the one illustrated using the BACI decision framework, aim to aid in the drought decision-making process by comparing the benefits of action and the costs of inaction, thereby, determining the economic viability of a proactive drought measure. However, drought risk management involves complex decisions based on a number of factors. In reality, decisions regarding investing in proactive measures are not made solely based on economic factors, but are conducted with varying priorities, motivations, influences, and considerations. Therefore, the resulting assessment under the low drought severity scenario (total benefits score under scenarios with and without drought equal to zero) can be supplemented by the following considerations:

- frequency of severe and moderate drought occurrence;
- level of risk decision-makers are willing to take concerning occurrence of low severity drought;
- existence of support mechanisms or enabling factors to assist in lowering costs of proactive action (e.g. institutional rules, whether formal or informal, that will regulate water consumption of drip irrigation users to lessen intangible costs);
- possibility of institutionalizing water consumption restrictions or cap to drip irrigation users to avoid over-exploitation of water resources; and

- willingness of decision-makers in establishing or improving water use measurement through water accounting to effectively monitor water withdrawals, among others.

However, at this point, decision-makers, planners, project managers, or project designers are expected to have a better understanding of the types and nature of the costs incurred in implementing the proactive drought measure assessed. Therefore, they will be able to foresee the institutional, information or design support mechanisms that will assist in minimizing the costs or, in the case of indirect and intangible costs, in avoiding maladaptation. These design adjustments or support mechanism considerations can be incorporated in the assessment in the second-tier of the framework – proactive maximin option framework – which is illustrated in the succeeding discussions.

Table 13. Stage 2 – Total benefits of proactive action with and without drought scenarios

Benefit item	Description	Drought severity		
		High	Medium	Low
Total net benefits with drought	Scores from Stage 1	0	**-5**	**-9**
Monetized economic co-benefits	The value of monetized economic co-benefits without drought is 2x, 76% and 41% the absolute value of the monetized net benefits with drought under high, moderate and low drought severity scenarios	10	4	3
Unlocked economic potential	Ability to irrigate irregular shaped fields, levelling of field is not necessary, soil type plays less important role in frequency of irrigation	1	1	1
Intangible co-benefits: Economic	Higher production efficiency, water supply is at an optimum level, highly uniform distribution of water (i.e. controlled by output of each nozzle, lessening water waste), usually operated at lower pressure than other types of pressurized irrigation thereby reducing energy costs, can be used for other crops other than rice	1	1	1
Intangible co-benefits: Environmental	Minimized nutrient loss due to localized application and reduced leaching, allows safe use of recycled (waste-) water, moisture within the root zone can be maintained at field capacity and minimized soil erosion, improves aeration, reduces greenhouse gas emission, available nutrients are increased, constant condition of water retention at low tension is created, reduces surface run-off	3	3	3
Intangible co-benefits: Social	Higher technical capacity of farmer stakeholders due to trainings and additional knowledge, if equal opportunity to attend trainings given to women, women acquire additional skills and knowledge, thereby improving human capital equity	1	1	1
Total benefits under scenarios with and without drought		16	5	0

Source: Authors' own computations.

Showcasing the framework for the selection of mitigation measures

Comparing the monetized and intangible benefits and costs, transaction costs, co-benefits and indirect cascading and compounded costs of proactive drought measures illustrate a better depiction of the advantages and disadvantages of each option. A hypothetical example of how to utilize the proactive maximin option framework is presented. Five drought mitigation options are defined namely, adoption of drip irrigation, construction of water harvesting structures, increase storage capacity of dams, application of water demand management practices and adoption of drought resistant crops. The framework illustrates the importance of non-monetized benefit and cost variables in comparing options. The framework works on the assumption that if identification of the benefit and cost components are not exhaustive, assessment will not be effective, and ranking of options will provide a misleading conclusion.

Box 12. Proactive maximin option framework for drought action plan development

By using the BACI decision framework, decision-makers, planners and project designers have a list of economically viable proactive options. However, with funding constraints, not all options can be implemented. The proactive maximin option framework can assist in the selection process by identifying those options which can provide the maximum benefit and minimum regrets. Moreover, modified designs of options can likewise be evaluated using the framework, thereby enabling a more thorough assessment of options.

Source: Authors' own elaboration.

Re-evaluation of system's vulnerability covers the proactive drought measure's effects on the system's sensitivity, exposure and adaptive capacity in relation to drought. Fundamentally, the re-evaluated system vulnerability factor strengthens the purpose of the framework in examining the possible maximum benefits and minimum regrets in implementing each option. Hence, the reference to the resulting score as the maximin proactive action option (i.e. maximum benefit–minimum regret proactive action option). A defining feature of the framework is that it employs multicriteria analysis. Therefore, regardless of the methodology used in analysing each component of the framework, results can be utilized in the assessment. One such methodology for vulnerability assessment is the International Centre for Environmental Management's Climate Change Vulnerability Assessment and Adaptation Methodology (Carew-Reid *et al.*, 2011). The methodology was adjusted to suit the needs of this hypothetical exercise. Particularly, the qualitative assessments provided by the methodology were transformed into quantitative forms by applying a (vulnerability) scoring approach (Table 14).

Table 14. Re-evaluated system vulnerability scores based on the implementation of proactive drought measures

Proactive drought measure	Exposure	Sensitivity	Impact level	Adaptive capacity	Vulnerability	System Vulnerability Score
Vulnerability scoring methodology: Very High (VH)=1; High (H)=2; Medium (M)=3; Low (L)=4; Very Low (VL)=5						
Adoption of drip irrigation	VH	M	H	H	M	3
Construction of water harvesting structures	VH	M	H	H	M	3
Increase storage capacity of dams	VH	H	VH	H	H	2
Apply water demand management	VH	M	H	M	M	3
Adopting drought resistant crops	M	M	M	H	M	3

Source: Authors' elaboration based on the work of **Carew-Reid, J., Ketelsen, T., Kingsborough, A. & Porter, S.** 2011. Climate Change Adaptation and Mitigation (CAM) Methodology Brief. Hanoi, International Centre for Environmental Management. https://icem.com.au/portfolio-items/cam-methodology/

The scoring methodology applied in the proactive maximin option framework is presented in Table 15. The scores for each proactive measure are summed up to arrive at the maximin drought mitigation option score. The higher the maximin score value, the more favourable option is the mitigation measure. The same kind of assessment can be conducted for the preparedness options. It should be noted that the co-benefits and cascading or compounded costs identified in the system linkages are disaggregated into intangible benefits and intangible costs. With this design, the framework highlights the importance of comparing the intangible benefits and costs of each measure, and the significance of incorporating these factors in the investment decision-making process.

The results of the hypothetical assessment show that adopting drought resistant crops is the most favourable option to maximize the benefits and minimize the probability of regret. This is followed by the construction of water harvesting structures and adoption of drip irrigation as the second and third favourable options, respectively. However, in the course of the assessment, specifically in the first-tier (i.e. BACI decision framework), evaluators will be able to better understand the costs of the proactive drought measures. Part of an effective assessment is determining how to address or minimize these costs. To illustrate this point, additional assessments are presented in Table 15, which are the drip irrigation with regulated water consumption and adopting drought resistant crops with seed seller–buyer arrangements. The additional assessment showed that the compounded costs incurred in the drip irrigation can be reduced by implementing a cap in water consumption. Moreover, this design has an improved vulnerability score. Regulating water consumption can be viewed as a form of water management, and has the potential to help users maximize the use of water without over-exploiting the water resources. Thus, a combined adoption of drip irrigation and water consumption regulation garnered a score of 7, making this design the second favourable proactive drought measure in the re-assessment. Meanwhile, establishing arrangements between sellers and buyers of drought resistant crops can lessen the indirect costs of increasing prices of seeds. Furthermore, this design is expected to decrease the transaction costs of buyers in looking for seed supply and in the search for better priced drought-resistant varieties. Hence, the measure of adopting drought resistant crops, accompanied by seller–buyer arrangements concerning seeds, is still the most favourable option after the re-assessment, with the score of 9. However, the score has considerably increased, meaning more benefits are to be gained with the new design of the proactive measure. Such kinds of assessments magnify the utility of the two-tier framework in supporting development designs of proactive drought measures.

Box 13. Modifying designs of proactive measures by incorporating support mechanisms or enablers

Various cost items have been identified using the BACI decision framework. By incorporating support mechanisms or enablers in the overall design of the proactive measures, some of these costs can be reduced. These enablers can be in the form of institutional arrangements that help contain intangible and transaction costs, or programmes that can influence behaviours of the population, such as water management. These modified proactive measures can then be assessed against the other available options.

Source: Authors' own elaboration.

Table 15. Assessment of drought mitigation options under medium drought severity scenario: Maximum benefits and minimum regrets

Drought management measure	Monetized net benefits with drought score (monetized avoided costs + monetized cost savings)	Monetized economic co-benefits score	Transaction costs score	Re- evaluated System Vulnerability	System linkages												Maximin Drought mitigation Option
					Co-benefits							Cascading or compounded costs					
					Food security	Poverty reduction	Income diversification	Improved environmental conditions (e.g. less soil erosion, improved biodivers ity)	Increase productivity	Mitigates impacts of hazards other than drought	Efficient use of resources	Creates social conflicts	Creates waste by-product	Negative impacts on environment or on biodiversity	Negative impacts on consumers	Negative impacts on health	
Adoption of drip irrigation	**-2**	4	**-3**	3	1			1	1		1			**-1**			5
Construction of water harvesting structures	**-1**	3	**-2**	3	1			1		1	1					**-1**	6
Increase storage capacity of dams	**-2**	2	**-2**	2	1				1	1	1						4
Apply water demand management	3	1	**-3**	3							1	**-1**			**-1**		3
Adopting drought resistant crops	2	4	**-4**	3	1		1				1			**-1**			7
Adoption of drip irrigation with regulated water consumption	**-2**	4	**-3**	4	1			1	1		1						7
Adopting drought resistant crops with seed seller-buyer arrangements	2	4	**-2**	3	1		1				1			**-1**			9

Source: Authors' own computations.

7 Conclusions and way forward

This report contributes to narrowing the knowledge gaps related to the economic assessments of adopting proactive measures. It builds on previous works that attempted to create an approach for the economic assessment of proactive drought risk management. It achieves its objectives through the following states:

- developing typologies of costs of drought inaction, and costs and benefits of proactive drought actions;
- examining how varying assessments represented the costs of droughts and benefits of drought risk management measures; and
- providing a framework to support decision-making in investment in proactive drought management.

The results of the investigation provide clarity on the classifications of costs and benefits and enable a better understanding of what compose each type of cost or benefit. With these, a more extensive coverage for comparing benefits of action and costs of inaction is envisioned.

Whereas the cost items of inaction are extensively identified in economic assessments, accounting those related to proactive drought measures needs improvement. The report proposes a classification of costs based on the timing or timelines by which costs are incurred.

The costs of inaction and costs of reactive action were combined in this topology, and were considered as post-drought costs. Conversely, proactive action measures were classified under pre-drought costs, since these are incurred before drought takes place. By reducing vulnerabilities and strengthening resilience of systems, they are actions that can reduce both the damage costs from drought, and can decrease the recovery and restoration costs after drought. The typology identifies the costs of inaction to be direct costs, indirect costs, and intangible costs. These are typically reflected in most economic assessments. Meanwhile, along with the direct, indirect and intangible costs, the typology also includes transaction costs under drought management measure costs. This cost item can be substantial, hence, is an important cost item in the assessment. Excluding transaction costs in the estimation process renders the analysis incomplete. Therefore, the report advocates for identifying and considering transaction costs of proactive action in the assessment, and simultaneously incorporating transaction cost minimization arrangements into proactive measure designs.

Proactive actions have more benefits than what are usually accounted for. Results from examining the case studies suggest that current economic assessments do not investigate all types of benefits. Thus, to better account for the benefits of action, various types of benefits should be examined, from avoided costs, to cost savings, to unlocked economic potential and to the range of co-benefits. Afterwards, assessments should determine which benefit type applies to the proactive action being considered. For a more systematic analysis of benefits, the report proposes to distinguish between the benefits received when drought strikes and the benefits accrued without drought. With this distinction, economic gains during non-drought years can be better outlined. Furthermore, through a better understanding of the concepts of each benefit item, exploring additional benefits not typically considered will be possible. As mentioned, some benefits, specifically social benefits, can arise from the design of the measure. Also, benefits can be boosted through cost savings.

Benefits of proactive action and costs of inaction are best illustrated through differentiating the benefits of proactive action under scenarios with drought and without drought. The avoided costs from droughts are the most acknowledged benefits of proactive investments. However, due to the perception that benefits from proactive action are received only when drought strikes, there are concerns on the returns on investments during non-drought periods, and on the economic gains in investing in proactive action given the uncertainty of drought occurrence. Thus, it is important to highlight how proactive drought investments can avoid losses and save costs, while simultaneously stimulating the economy and producing a range of co-benefits in the absence of drought. Economic co-benefits are the most recognized among the co-benefits, as they are also the easiest to monetize. This type of benefit may manifest as savings from or reduction in costs of production inputs, or as increases in yields, harvests or profits from adopting proactive measures. Likewise, they may also emerge from the linkages and interdependencies of systems. Hence, improvements in the outputs and production in agriculture may result in cascading and compounded benefits to other sectors, industries or systems. Environmental and social co-benefits may likewise be considerable, therefore, the significance of investigating and incorporating them in the benefits estimation.

Investing in proactive drought measures should undergo an iterative decision-making process to determine economically viable options possibly through comprehensive frameworks for all-encompassing assessments. The report strongly advocates for undertaking proactive drought risk management actions. However, it recognizes that not all proactive measures may be economically viable investments, especially with the limited available financial resources. Through an exhaustive economic assessment, decision-makers, policy-makers, and planners can identify measures that are economically practical in their country's context, and forgo those investments that are not (economically feasible). This iterative assessment process, thus, ensures economically rational investment decisions.

The next steps

Exploring the concept of opportunity cost can provide a more in depth understanding of proactive action costs and benefits. In some literature, opportunity cost is defined as a type of avoided cost, in the form of savings. That is, not allocating resources for reactive drought management measures, free up funds that can be utilized elsewhere (Beecher, 1996; Water Research Foundation, 2015). However, based on the defined typology and analysis in this report, the concept of opportunity cost may be better suited under the cost savings benefit grouping. Whether classified under avoided cost or cost savings, investigating the relevance of opportunity cost as a benefit of proactive action during drought events will be a good avenue to pursue. Conversely, other literature regard opportunity cost as a cost of proactive measures during periods without drought. When project investments are made, these resources cannot be used elsewhere. Likewise, given limited funds, an investment on one type of proactive measure reduces expenditures on another (Bouwer *et al.*, 2011). While maintaining the assumption that all drought impact must be mitigated, a more thorough investigation of opportunity cost can pave the way for the criteria-based selection of drought measures. In other words, opportunity cost can be incorporated among the conditions in the framework in assessing the measure to be selected.

For better accounting of drought impacts on vulnerable sectors and communities, examination of the costs of drought to the informal economy is recommended. The informal economy exists all over the world, and it is most predominant in low-income countries especially in developing Africa and Asia and the Pacific (International Labour Office, 2023). Agriculture is traditionally characterized by high level of informality, and the sector is believed to be among the chief drivers of the informal economy (Schneider *et al.*, 2021; Morkunas, 2022). In fact, globally, one in three workers in the informal economy works in agriculture, and nine in ten workers in agriculture are under informal employment (International Labour Office, 2023). Given the substantial impacts of drought on agriculture, the hazard, likewise, considerably affects the output and employment in the informal economy. For instance, Bastos *et al.*'s (2013) work showed that a higher frequency of drought lessens the local value added, employment and wages in the agricultural sector. Meanwhile, a special focus on the benefits of action to the informal economy can be incorporated in the assessment, thereby generating valuable information on the impacts of proactive action on vulnerable groups.

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Annex 1 – categorization of proactive drought measures

Drought resilient agrifood systems – monitoring and early warning

Natural resources and ecosystems

Terrestrial ecosystem

Area covered with environmental monitoring system(%)

- Development of monitoring system for natural resources

Aquatic ecosystem

Rate of water resources gauged and monitored (%)

- Equipment of water bodies with metering devices
- Equipment of irrigation systems with metering devices
- Development of monitoring systems for water resources
- Inventory of private wells

Food production systems

Crop production

Extent of cropped area covered by monitoring systems (ha)

Fishery

Rate of fish production areas gauged and monitored (%)

Livestock production

Extent of pasture area covered by monitoring systems (ha)

Post-harvest

Economy and livelihood

Households

Number of beneficiaries with access to weather services

- Development of early-warning systems
- Public information systems on weather and water
- Early information for pastoralists

Macro-economy

Drought resilient agrifood systems – impact and vulnerability assessment

Natural resources and ecosystems

Terrestrial ecosystem

- Inclusion of areas at drought risk (ha)
  - Environmental management system for minimizing natural resources degradation

Aquatic ecosystem

- Inclusion of aquatic systems at drought risk (ha)

Food production systems

Crop production

- Inclusion of cropped areas at drought risk (ha)
  - Geographical delineation of vulnerable areas
  - Impact assessment on projected vulnerabilities of cropped areas
  - Inventory of crop production practices in vulnerable areas

Fishery

- Inclusion of fish production areas at drought risk (ha)

Livestock production

- Inclusion of pastures at drought risk (ha)
  - Rangeland and pasture improvement programme

Post-harvest

Economy and livelihood

Households

- Number of beneficiary households from typical drought-prone area
  - Review of education curricula
  - Preparation of vulnerability and impact assessments
  - Designing social protection and cash transfer programmes
- Number of female beneficiaries from typical drought-prone area
  - Designing gender strategies and action plans
  - Gender-differentiated and targeted education programmes
- Number of vulnerable beneficiaries from typical drought-prone area
  - Designing strategies and action plans for reducing inequalities
  - Designing social inclusion programmes

Macro-economy

Drought resilient agrifood systems – mitigation, response and preparedness

Natural resources and ecosystems

Terrestrial ecosystem

Area with land and water conservation measures (ha)

- Land and ecosystem restoration practices
- Soil fertility practices

Area with green cover (ha)

- Land and ecosystem restoration practices
- Soil fertility practices

Aquatic ecosystem

Water abstraction rate per recharge capacity (%)

- Water reuse or recycling in industries
- Mandatory rationing Inter-basin water transfer
- Development of water desalination infrastructure
- Development of multiple water use infrastructure

Groundwater recharge capacity (m3/year)

- Water reuse or recycling in industries
- Mandatory rationing Inter-basin water transfer
- Development of water desalination infrastructure
- Development of multiple water use infrastructure

Food production systems

Crop production

Area under drought-smart practices (ha)

- On-farm practices for water demand control
- Soil moisture retention practices
- Shading practices
- Improvement of water use efficiency of water infrastructure
- Adapted cropping system
- Adjusted cropping calendar
- Water-efficient varieties

Water storage capacity, agricultural (million m3)

- Constructions of new reservoirs or water storage facilities
- Construction of farm ponds
- Introduction of water harvesting for water supply augmentation
- Other techniques for water supply augmentation

Fishery

Fish production areas equipped for water supply security

- Flow regulators for constant supply
- Water storage for pond recharge
- Temperature regulator

Livestock production

Number of herders with access to alternative forage sources

- Rapid inventory and map of grazing potential
- Alternative feed distribution
- Substitute feed distribution
- Navigation service to grazing areas

Livestock population with access to emergency shelter

- Livestock transfer
- Construction of protective shelter

Post-harvest

Number of farmers with access to emergency storage

- Construction of post-harvest facilities
- Construction of food storage facilities
- Construction of processing and packaging facilities
- Development of cooling facilities
- Distribution of refrigerators

Number of herders with access to processing facilities

- Destocking incentives
- Construction of meat processing facilities
- Construction of cooling facilities

Economy and livelihood

Households

Number of beneficiaries with new access to knowledge about drought

- Sensitization and awareness raising campaign

Macro-economy

Drought-resilient nonfinancial assets in GDP (%)

- Drought land banks
- Equipment service for construction of water infrastructure
- Development of infrastructure for intervention store

Value of drought-resil-ient non-produced non-financial assets (USD)

- Development of strategic water reserves
- Development of conservation areas
- Protection of vegetation on public areas

Drought resilient agrifood systems – mitigation, response and preparedness (continued)

Natural resources and ecosystems

Terrestrial ecosystem

Aquatic ecosystem

Food production systems

Crop production

Irrigated area size (ha)

- Development of irrigation infrastructure
- Localized on-farm irrigation techniques
- Development of nonconventional water sources Introduction of water harvesting structures for crop production
- Deficit irrigation Supplementary irrigation

Area cropped with drought-tolerant varieties (ha)

- Introduction of drought-tolerant crops
- Change of cropping pattern

Fishery

Livestock production

Number of animals with drought-proof and constructed drinking points

- Construction of water points
- Development of alternative drinking sources
- Development of multiple water use infrastructure for livestock service

Number of animals with drought-smart practices

- Ventilation techniques in stalls
- Cooling facilities

Post-harvest

Economy and livelihood

Households

Coverage of financial inclusion related to drought-specific products (%)

- Economic incentives for water saving
- Insurance products for drought hazard
- Tax reduction or credit holiday
- Establishment of relief funds

Macro-economy

Number of policies integrating drought management

- Reviewing and adjusting legal and institutional framework
- Regulation of water abstraction permits
- Review of water tariffs Regulation on water markets

Number of agricultural advisory services with drought curriculum

- Establishment of drought advisory service
- Integration of drought into the curriculum of extension services or farmers organizations

Spending on drought-related research and development (USD)

- Investment in drought-resilient crop breeding
- Investment in research on monitoring and early-warning

Drought resilient agrifood systems – mitigation, response and preparedness (continued)

Natural resources and ecosystems

- Terrestrial ecosystem
- Aquatic ecosystem

Food production systems

- Crop production
- Fishery
- Livestock production
- Post-harvest

Economy and livelihood

Households

Number of beneficiaries with new access to technology markets

- Market incentives for production of drought technologies
- Inventory of technology needs
- Public information about the brochure/menu of relevant technologies

Macro-economy

Number of patents related to drought-resilience

- Research and development in new water techniques
- Research and development in new cropping techniques

Annex 2 –
transaction costs related to policy designs and implementation

Table A1. Transaction costs related to policy design and implementation of Transferable Development Rights programmes

Policy stage	Category of activities, and examples of transaction costs creating transaction costs	Main parties involved
Policy Design	Agenda setting and policy selection: identifying issues and problems; proposing policy choices; evaluating alternative solution; selecting the preferred policy; calling for public meetings, hearings and votes	Planners, landowners and developers
	Policy design and preparation: specifying policy goals and objectives; designating preservation (sending) and development (receiving) areas; allocating Transferable Development Rights credits and ordinance for sending and receiving areas; receiving public input; enactment of enabling legislation; modifying existing zoning ordinance and downzoning if required	Planners, landowners, developers, and legislature
	Institutional arrangement: hiring and/or training staff; purchasing required equipment; designing the administration process and documents; public Transferable Development Rights educational programs and workshops	Planners and policy administrators
Policy Implementation	Support and administration: consulting with Transferable Development Rights sellers and buyers; reviewing preservation and development applications; determining eligibility and availability of Transferable Development Rights in sending sites; determining applicable number of Transferable Development Rights in development projects; maintaining a list of potential Transferable Development Rights sellers and buyers	Policy administrators
	Transferable Development Rights creation: hiring a land-use attorney; preparing title report; preparing land survey; applying for Transferable Development Rights certificate	Landowners and developers
	Contracting: finding a Transferable Development Rights seller or buyer; consulting with policy administrators, land-use attorneys, and brokers; hiring a broker and paying a brokerage commission; negotiating a Transferable Development Rights price; preparing a contract; payment	Landowners and developers
	Transferable Development Rights retirement: recording the contract in land record; applying the purchased Transferable Development Rights in development project; recording the contract, covenant, and other transfer documents	Developers and policy administrators
	Policy evaluation: evaluating the effectiveness of policy; monitoring the Transferable Development Rights market, and balance of Transferable Development Rights supply and demand; calling for public meetings and receiving public input; revising the policy design and institutional arrangement	Planners, landowners, and developers

Source: **Shahab, S., Clinch, J.P. & O'Neill, E.** 2018. Accounting for transaction costs in planning policy evaluation. *Land Use Policy*, 70: 263–272.

Annex 3 –
summary tables of the case studies about cost identification

Table A2. Database of case studies presenting impacts and costs of drought management

Source	Scope of analysis	Methodology	Data sources	Costs of drought impacts		
				Direct costs	Indirect costs	Intangible costs
Mechler *et al.*, 2008	Subnational: Uttar Pradesh, India	Risk based methodology using the following approaches: global climate model downscaling; statistical relationship; survey analysis; stochastic modelling; microeconomic livelihood model; scenario-type simulation analysis	Primary data: survey; shared learning dialogues Secondary data: Special Report on Emissions Scenarios model runs; national statistics survey	Crops affected or destroyed; livelihood income decreases	Secondary costs: decrease in market activity; decline in trade with outside market; increase in debts	Poverty incidences rise; negative impact on food security; increase in cases of malnutrition; land degradation; negative impacts on water quality
Martin-Ortega and Markandya, 2009	Subnational: Catalonia region, Spain	Estimation done by Agència Catalana del'Aigua: input–output estimation methodology; value transfer of the estimates based on the application of stated preferences techniques; multinominal logit modelling; willingness to pay estimation methodology	Primary data for intangible costs: interviews Secondary data and cost estimates from: Agència Catalana del'Aigua report (report used data collected from River Basin Authority; water companies; published by the media); 6th European Framework Project AquaMoney	Production losses from irrigators and water suppliers	* Indirect costs computed by primary source Agència Catalana del'Aigua but not detailed in the case study	Welfare losses due to environmental/ecological damage (caused by low water flows and reduction of ecosystem services provision); social welfare loss due to reduction of household water supply
Gil *et al.*, 2013	Subnational: Ebro River basin, Spain	Econometric modelling; direct attribution model; indirect attribution model; inference procedure using chained elasticities	Secondary data from: Spanish Social Security; Spanish National Statistics Institute; Spanish Agricultural Guarantee Fund	Agricultural production losses	Secondary costs: informal and farm family employment losses Spillover effects: reduction in agrifood industrial gross value added	

Source	Scope of analysis	Methodology	Data sources	Costs of drought impacts		
				Direct costs	Indirect costs	Intangible costs
Montaud, 2019	National: Mali	Dynamic recursive computable general equilibrium model (standard PEP-1-t model)	Secondary data: FAOSTAT database; Climatic Research Unit of the University of East Anglia	Decreased agricultural production; increase in agricultural prices	Secondary costs: increases in processed food prices Spillover effects: increases in national and food prices; decreases in income per capita; reduction in agricultural gross domestic product	Migration due to lower purchasing power in rural areas; reduction in per capita supplies of foodstuffs; decrease in food access per capita; reduction in food availability per capita
Bahinipati, 2020	Subnational: Kutch district of Gujarat state	Contingent valuation method; willingness to pay valuation	Primary data: interviews and surveys	Crop and livestock losses; impact on assets and amenities; extra irrigation cost		Psycho-social stress, human mobility; dropout of children from school; lack of community social cohesion for accessing water for agricultural purposes and drinking; damage to biodiversity; declining groundwater level; land desertification
Arfanuzzaman *et al.*, 2021	Subnational: Teesta basin, Bangladesh	Extended cost–benefit analysis approach; welfare analysis of adaptation	Primary data: focus group discussion; key informant interviews Secondary data: surveys; statistical databases; scientific papers	Crop losses and damages; lower yield		Soil fertility loss

Source	Scope of analysis	Methodology	Data sources	Costs of drought impacts		
				Direct costs	Indirect costs	Intangible costs
Garcia-Leon *et al.*, 2021	National: Italy	Combination of statistical-agronomic modelling and computable general equilibrium modelling	Secondary data: Land use and agricultural production from Italian Council for Agricultural Research and Economics; Rete di Informazione Contabile Agricola database	Decrease in agricultural output; increase in agricultural prices	Secondary costs: production decline in food manufacturing Spillover effects: gross domestic product losses; increase in agricultural imports; production damages from services linked to agricultural outputs such as wholesale, accommodation and restaurants	Reallocation of land use between different crops
National Planning Commission, 2021	National: Malawi	Benefit–cost analysis	Secondary data: Malawi 2019 Flood Post Disaster Needs Assessment – Post-Disaster Needs Assessment Report; published and unpublished sources including government data, literature, and expert estimation	Damage losses to property and livestock		Increased food insecurity; general decline in living conditions and increased health issues

Source	Scope of analysis	Methodology	Data sources	Costs of drought impacts		
				Direct costs	Indirect costs	Intangible costs
Medellin-Azuera *et al.*, 2022	Subnational: California state, USA	Hydro-economic modelling	Primary data: informal surveys with various stakeholders Secondary data: remote sensing data on evapotranspiration; reported surface water deliveries and curtailments	Reduced surface and ground water availability; decline in irrigated areas; increased water pumping costs; increased capital costs for new wells; crop gross revenue losses; reduced value added from crops	Secondary costs: Reduced employment from farms; higher costs and lower feed crop availability for beef and dairies; reduced profits from livestock from higher cost of feed crops; reduced output from food processing sectors due to shortages in supply of some crops; gross revenue losses in food processing Spillover effects: strong commodity prices for beef and dairy products; decline in value added from food processing; employment losses in other sectors (e.g. food processing)	

Source	Scope of analysis	Methodology	Data sources	Costs of drought impacts		
				Direct costs	Indirect costs	Intangible costs
Sawadogo, 2022	National: Burkina Faso	Gendered dynamic computable general equilibrium model linked to a microsimulation model	Secondary data: 2013 Burkina Faso Agricultural Social Accounting Matrix; 2018/2019 National Survey on Household Living Conditions; World Bank development indicator data	Reduction in agricultural production and productivity	Secondary costs: reduction in intermediate agricultural inputs' revenue; decline in labour demand; price increases of agricultural products in the domestic market Spillover effects: reductions in gross domestic product, real household consumption, non-farm wages, purchasing power of the consumers	Migration of workers due to decline in economic opportunities in the rural areas (e.g. rise in unemployment); worsening standard of living for women (compared to men); increases in the poverty rate; reductions in food access per capita and food availability per capita

Source: Authors' elaboration.

Table A3. Database of case studies presenting the costs of proactive actions

Source	Scope	Methodology	Data sources	Proactive measure assessed	Costs of action
					Direct costs
Mechler *et al.*, 2008	Subnational: Uttar Pradesh, India	Risk based methodology using the following approaches: global climate model downscaling; statistical relationship; survey analysis; stochastic modelling; microeconomic livelihood model; scenario-type simulation analysis	Primary data: survey; shared learning dialogues Secondary data: Special Report on Emissions Scenarios model runs; national statistics survey	Irrigation; subsidized micro crop insurance	Construction of borehole and costs of pumping water for irrigation; premiums for insurance

Source	Scope	Methodology	Data sources	Proactive measure assessed	Costs of action
					Direct costs
Niyazmetov and Rudenko, 2013	Farm level: Namangan province, Uzbekistan	Cost–benefit analysis; comparative analysis	Primary data collection	Drip irrigation system	Cost of a drip irrigation system installation; cost of the acquisition of the film for covering the reservoir used to supply water to the drip irrigation system
Rupérez-Moreno *et al.*, 2017	Subnational: Hellin municipality, Spain	AQUATOOL decision support model	Primary data: survey; public consultations Secondary data: other studies; aquifer recharge data from Visual Balan	Managed aquifer recharge system for irrigation	Groundwater exploitation costs; investment and operating costs of installations for pumping and irrigation (e.g. piping and drilling, construction and installation work of pumping equipment, irrigation pond construction, and irrigation system installation)
Venton, 2018a	Subnational: Tigray and Somali regions of Ethiopia	Household Economy Approach model	Secondary data from following sites/sources: Famine Early Warning Systems Network (fews.net); www.adesoafrica.org; www.acted.org; kasmodev.com; www.fsnau.org; www.fews.net; World Food Programme	Early humanitarian response and resilience building on humanitarian outcomes: early response; safety net; resilience building	Costs of safety net and resilience building: cost of programming
Montaud, 2019	National: Mali	Dynamic recursive computable general equilibrium model (standard PEP-1-t model)	Secondary data: FAOSTAT database; Climatic Research Unit of the University of East Anglia	Drought tolerant crop varieties; extending drought early warning systems	Drought tolerant varieties: costs of using new varieties Early warning system: costs of full modernization
Williams *et al.*, 2020	Subnational: Keta and Nsawam Adoagyir municipalities in Ghana	Private profitability estimation	Primary data: field survey; workshop results; expert interviews	Intercropping; mixed cropping; crop rotation; mechanical irrigation; fertilization	Installation, maintenance and operational costs

Source	Scope	Methodology	Data sources	Proactive measure assessed	Costs of action
					Direct costs
Arfanuzzaman *et al.*, 2021	Subnational: Teesta basin, Bangladesh	Extended cost–benefit analysis approach; welfare analysis of adaptation	Primary data: focus group discussions; key informant interviews Secondary data: surveys, statistical databases, scien-tific papers	Application of short duration variety rice; alternate cropping (maize); deep tube well based irrigation; shallow tube well based irrigation	Short-duration variety/alter-nate cropping (maize): total production costs Deep tube well and shallow tube well: fixed cost (total installa-tion cost); cost of submersible pump/tube well pump, operation costs (labour, boring, pipe, and transport cost, electricity); total irrigation cost
National Planning Commission, 2021	National: Malawi	Benefit–cost analysis For early warning system: environmental risk calculation using the real options approach	Secondary data: Malawi 2019 Flood Post Disaster Needs Assessment – Post Disaster Needs Assessment Report; published and unpublished sources including government data, literature, and expert estimation	Early warning systems improvements; expanding the use of climate-smart agricul-ture practices	Climate-smart agriculture: marginal production costs asso-ciated with the climate-smart agriculture strategies relative to current traditional conventional practice (e.g. changes in quantity of commercial inputs particularly seed and fertilizer); extension costs to promote this climate smart agri-culture strategy
Akinyi *et al.*, 2022	International: Ethio-pia, Kenya, Malawi, Nigeria, and Zambia	Climate Smart Agriculture Prioritization Framework; Climate Smart Agriculture Programming and Indicator Tool	Primary data: online survey and interviews with key informants and key resource persons Secondary data: in-depth and systematic review of the literature from national and government ministries, research institutions, and non–governmental organizations	Climate-smart agricul-tural practices	Implementation, maintenance, and operations costs; machinery and equipment; inputs which includes costs of seeds, fertilizers, pesticides, storage bags; services including, greasing of equipment, transportation costs, sharpening of tools; increase in labour costs

Source	Scope	Methodology	Data sources	Proactive measure assessed	Costs of action
					Direct costs
Sawadogo, 2022	National: Burkina Faso	Gendered dynamic computable general equilibrium model linked to a microsimulation model	Secondary data: 2013 Burkina Faso Agricultural Social Accounting Matrix; 2018/2019 National Survey on Household Living Conditions; World Bank development indicator data	Expansion of the adoption of drought tolerant crops; adoption of integrated soil management; expansion of the irrigation capacity	Adaptation investment value

Source: Authors' elaboration.

Table A4. Database of case studies presenting benefits of proactive measures

Source	Scope	Methodology	Data sources	Proactive measure assessed	Benefits of actions					
					Avoided costs	Cost savings	Unlocked economic potential	Co-benefits		
								Economic	Environment	Social
Mechler *et al*., 2008	Subnational: Uttar Pradesh, India	Risk based methodology using the following approaches: global climate model downscaling; statistical relationship; survey analysis; stochastic modelling; microeconomic livelihood model; scenario-type simulation analysis	Primary data: survey; shared learning dialogues Secondary data: Special Report on Emissions Scenarios model runs; national statistics survey	Irrigation; subsidized micro crop insurance	Irrigation: reduces hazard impacts Insurance: reduced income diversion by the farmer from productive activities; compensates direct losses for insurance	Irrigation and insurance: reduce government relief expenses/ expenditure		Irrigation: smooths food supply, consumption, and income of farmers		
Niyazmetov and Rudenko, 2013	Farm level: Namangan province, Uzbekistan	Cost–benefit analysis; comparative analysis	Primary data collection	Drip irrigation system			Opens possibility of irrigating strongly intersected plots of the ground surface with different water infiltration of soils; allows the use of irrigation on slopes or areas with complex topography	Savings in: consumption of water from lesser irrigation frequency; energy (e.g. diesel fuel) for water pumps due to reduction of the number of agrotechnical activities (i.e. including cultivation and fertilization); reduction in use of mineral fertilizers; lower labour needs; increase in harvests; exemption from land tax	No secondary salinity; does not require the construction of drainage systems, hence underground waters and salts do not rise, and the structure of soil can be maintained	

Source	Scope	Methodology	Data sources	Proactive measure assessed	Benefits of actions					
					Avoided costs	Cost savings	Unlocked economic potential	Co-benefits		
								Economic	Environment	Social
Rupérez-Moreno *et al*., 2017	Subnational: Hellin municipality, Spain	AQUATOOL decision support model	Primary data: survey; public consultations Secondary data: other studies; aquifer recharge data from Visual Balan	Managed aquifer recharge system for irrigation			Bequest value	Water use value for agricultural irrigation, industrial consumption, and recreational use of wetlands and springs in the area; sustainability of agriculture	Improvement of the aquifer; support of the ecosystem associated with the aquifer; scenic beauty of the area	Water use for drinking
Venton, 2018a	Subnational: Tigray and Somali regions of Ethiopia	Household Economy Approach model	Secondary data from following sites/sources: Famine Early Warning Systems Network (fews.net); www.adesoafrica.org; www.acted.org; kasmodev.com; www.fsnau.org; www. fews.net; World Food Programme	Early humanitarian response and resilience building on humanitarian outcomes: early response; safety net; resilience building	Early response/ safety net response/ resilience building measures: avoided income and livestock losses Safety net response: reduction in food deficit	Avoided humanitarian aid		Early humanitarian response: surplus to the food deficit; surplus income		
Montaud, 2019	National: Mali	Dynamic recursive computable general equilibrium model (standard PEP-1-t model)	Secondary data: FAOSTAT database; Climatic Research Unit of the University of East Anglia	Drought tolerant crop varieties; extending drought early warning systems	Drought tolerant varieties: avoid negative impacts on agricultural gross domestic product; rural income and rural food security could be neutralized from a threshold level; offsets negative impacts of droughts on real income and food security Early warning system: reduction in negative impacts on agricultural production and consumption, agricultural gross domestic product, prices, rural income, rural food prices, rural food availability			Drought tolerant varieties and early warning system: Yield gains		

Source	Scope	Methodology	Data sources	Proactive measure assessed	Benefits of actions					
					Avoided costs	Cost savings	Unlocked economic potential	Co–benefits		
								Economic	Environment	Social
Williams *et al*., 2020	Subnational: Keta and Nsawam Adoagyir municipalities in Ghana	Private profitability estimation	Primary data: field survey; workshop results; expert interviews	Intercropping; mixed cropping; crop rotation; mechanical irrigation; fertilization				Intercropping/ mixed cropping/ crop rotation/ mechanical irrigation: high profitability Intercropping/mixed cropping/crop rotation: increase in farm labour employment	Intercropping and mixed cropping: enhanced water infiltration and slow run-off water; increased in plant species per unit area Mechanization of irrigation systems: increases soil moisture availability; increased in plant species per unit area Crop rotation: enhanced water infiltration; slow run-off water; increased in plant species per unit area; increased soil fertility Fertilization: Increased soil moisture availability; enhanced water infiltration; slow run-off water; increased in plant species per unit area; increased soil fertility	

Source	Scope	Methodology	Data sources	Proactive measure assessed	Benefits of actions					
					Avoided costs	Cost savings	Unlocked economic potential	Co–benefits		
								Economic	Environment	Social
Arfanuzzaman *et al.*, 2021	Subnational: Teesta basin, Bangladesh	Extended cost–benefit analysis approach; welfare analysis of adaptation	Primary data: focus group discussions; key informant interviews Secondary data: surveys, statistical databases, scientific papers	Application of short duration variety rice; alternate cropping (maize); deep tube well based irrigation; shallow tube well based irrigation	Short-duration variety/alternate cropping (maize)/deep tube well/shallow tube well: Avoided crop damages/losses			Short-duration variety/alternate cropping (maize): increase/higher production Alternate cropping (maize): increase/higher production; lower production costs (requires less irrigation); can also be cultivated simultaneously as a companion crop; crop residue of maize as livestock feed Deep tube well: increase in production; lower irrigation costs; higher economic lifetime; higher net revenue Shallow tube well: higher profit		Short-duration variety /alternate cropping (maize)/deep tube well/shallow tube well: higher social welfare estimated through increased farmer income Alternate cropping (maize): poor and marginal farmers can avail seeds and fertilizer at due price from the seller and can pay after harvesting; maize dried plants as fuelwood for cooking
National Planning Commission, 2021	National: Malawi	Benefit–cost analysis For early warning system: environmental risk calculation using the real options approach	Secondary data: Malawi 2019 Flood Post Disaster Needs Assessment – Post Disaster Needs Assessment Report; published and unpublished sources including government data, literature, and expert estimation	Early warning systems improvements; expanding the use of climate-smart agriculture practices	Early warning system: about 10% of housing and property damage 70% of livestock and 80% of health damage could be avoided with proper response to early warning system advisory Climate-smart agriculture: reduces yield loss due to climate change impact	Avoided humanitarian aid		Climate-smart agriculture: yield increase		

Source	Scope	Methodology	Data sources	Proactive measure assessed	Benefits of actions					
					Avoided costs	Cost savings	Unlocked economic potential	Co–benefits		
								Economic	Environment	Social
Akinyi *et al*., 2022	International: Ethiopia, Kenya, Malawi, Nigeria, and Zambia	Climate Smart Agriculture Prioritization Framework; Climate Smart Agriculture Programming and Indicator Tool	Primary data: online survey and interviews with key informants and key resource persons Secondary data: in-depth and systematic review of the literature from national and government ministries, research institutions, and non-governmental organizations	Climate-smart agricultural practices				Increased yields	Increased biodiversity; minimized greenhouse gas emission; improved water quality	
Sawadogo, 2022	National: Burkina Faso	Gendered dynamic computable general equilibrium model linked to a microsimulation model	Secondary data: 2013 Burkina Faso Agricultural Social Accounting Matrix; 2018/2019 National Survey on Household Living Conditions; World Bank development indicator data	Expansion of the adoption of drought tolerant crops; adoption of integrated soil management; expansion of the irrigation capacity	Drought tolerant varieties (short-run): slowdown of reduction in agricultural production; decline in negative impacts on agricultural crop productivity, employment, food consumption, food access, food availability Integrated soil management (long-run): contributes to the neutralization of the impacts of intense drought Increased irrigation capacity (short-run): fast reduction in drought effects			Drought tolerant varieties (long-run)/ integrated soil management (slow long-run)/ increased irrigation capacity (short-run): positive agricultural crop productivity; increases the agricultural production; improvements in purchasing power, food consumption, food access, food availability; reduction in poverty rates; increases in gross domestic product	Integrated soil management: soil fertilization and restoration	

Source: Authors' elaboration.

Annex 4 –
description of the scoring methodologies for economic assessment

Table A5. Analysing monetized and non-monetized costs of inaction and action

<table>
<tr><th>Cost item</th><th>Description</th><th>Scoring methodology</th></tr>
<tr>
<td>Monetized net benefits with drought

(Monetized avoided costs + monetized cost savings)</td>
<td>Identify all possible monetized costs, including direct, indirect, and transaction (if can be monetized).

Compute for the total monetized costs using estimation methodologies at the evaluators' disposal.

Get the difference between the costs of inaction and the costs of proactive action. This will be the monetized avoided costs.

Add the monetized cost savings to the monetized avoided costs. Alternatively, cost savings can be deducted from the total costs of action early on.

Evaluate net benefits based on the framework's scoring methodology.</td>
<td>Positive net benefits with drought scenario: Monetized costs of inaction is greater than monetized costs of action; the difference is the positive net benefits of action or positive combined avoided costs and cost savings. If values of monetized net benefits with drought (n) in relation to monetized costs of action ([monetized net benefits/monetized costs of inaction] x 100) are as follows, then:
<table>
<tr><th>Values of n</th><th>Score value</th></tr>
<tr><td>0% < n ≤ 20%</td><td>1</td></tr>
<tr><td>21% ≤ n ≤ 40%</td><td>2</td></tr>
<tr><td>41% ≤ n ≤ 60%</td><td>3</td></tr>
<tr><td>61% ≤ n ≤ 80%</td><td>4</td></tr>
<tr><td>81% ≤ n ≤ 100%</td><td>5</td></tr>
<tr><td>101% ≤ n ≤ 120%</td><td>6</td></tr>
<tr><td>121% ≤ n ≤ 140%</td><td>7</td></tr>
<tr><td>141% ≤ n ≤ 160%</td><td>8</td></tr>
<tr><td>161% ≤ n ≤ 180%</td><td>9</td></tr>
<tr><td>n > 180%</td><td>10</td></tr>
</table>
Negative net benefits with drought scenario: Monetized costs of inaction is less than monetized costs of action; the difference is the negative net benefits of action or negative combined avoided costs and cost savings. If absolute values of net benefits with drought (n) in relation to monetized costs of inaction ([- monetized net benefits/monetized costs of inaction] x 100) are as follows, then:
<table>
<tr><th>Values of n</th><th>Score value</th></tr>
<tr><td>0% < n ≤ 20%</td><td>-1</td></tr>
<tr><td>21% ≤ n ≤ 40%</td><td>-2</td></tr>
<tr><td>41% ≤ n ≤ 60%</td><td>-3</td></tr>
<tr><td>61% ≤ n ≤ 80%</td><td>-4</td></tr>
<tr><td>81% ≤ n ≤ 100%</td><td>-5</td></tr>
<tr><td>101% ≤ n ≤ 120%</td><td>-6</td></tr>
<tr><td>121% ≤ n ≤ 140%</td><td>-7</td></tr>
<tr><td>141% ≤ n ≤ 160%</td><td>-8</td></tr>
<tr><td>161% ≤ n ≤ 180%</td><td>-9</td></tr>
<tr><td>n > 180%</td><td>-10</td></tr>
</table>
</td>
</tr>
</table>

Cost item	Description	Scoring methodology
Intangible costs	Identify all possible intangible costs of inaction and costs of proactive action Information can be based on experience, expert opinions, literature review, stakeholder consultations, surveys, interviews. Evaluate intangible costs of inaction based on the framework's scoring methodology. Do the same for the intangible costs of proactive action. Get the difference between intangible cost of inaction and intangible cost of proactive action.	If intangible cost is: Very low = 1; Low = 2; Moderate = 3; High = 4; Very High = 5 If intangible costs of inaction > intangible costs of action, then score is positive. If the intangible costs of inaction < intangible costs of action, then the score is negative.
Transaction costs	Identify all possible transaction costs of proactive action Information can be based on experience, expert opinions, literature review, stakeholder consultations, surveys, interviews. Evaluate transaction costs of proactive action based on the framework's scoring methodology	Transaction costs score: No cost =0; Very low = -1; Low =-2; Moderate =-3; High = -4; Very High = -5
Net benefits with drought	**Sum of component scores**	

Source: Authors' elaboration.

Table A6. Stage 2 BACI decision framework components and scoring methodology

<table>
<tr><th>Benefit item</th><th>Description</th><th>Scoring methodology</th><th>Scores</th></tr>
<tr><td>Total net benefits with drought</td><td>Resulting negative total net benefits from assessing monetized and non-monetized costs of inaction and action</td><td>Score value of total net benefits with drought in Stage 1</td><td>-20 ≤ n ≤ 15</td></tr>
<tr><td>Monetized economic co-benefits</td><td>Compute for monetized economic co-benefits from action and evaluate against the (absolute) value of monetized net benefits with drought.</td><td>If values of monetized economic co-benefits (n) in relation to absolute value of monetized net benefits with drought ([monetized economic co-benefits/ |monetized net benefits with drought|] x 100) are as follows, then:
<table>
<tr><th>Values of n</th><th>Score value</th></tr>
<tr><td>0% < n ≤ 20%</td><td>1</td></tr>
<tr><td>21% ≤ n ≤ 40%</td><td>2</td></tr>
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<tr><td>161% ≤ n ≤ 180%</td><td>9</td></tr>
<tr><td>n > 180%</td><td>10</td></tr>
</table>
</td><td>0 < n ≤ 10</td></tr>
<tr><td>Unlocked economic potential</td><td rowspan="5">Identify all possible unlocked economic potential benefits and environmental and social co-benefits based on experience, expert opinions, literature review.

Evaluate co-benefits based on the framework scoring methodology.</td><td rowspan="5">Scores: No benefit =0; Very low = 1; Low = 2; Moderate = 3; High = 4; Very High = 5</td><td>0 ≤ n ≤ 5</td></tr>
<tr><td>Intangible co-benefits</td><td></td></tr>
<tr><td>Economic</td><td>0 ≤ n ≤ 5</td></tr>
<tr><td>Environmental</td><td>0 ≤ n ≤ 5</td></tr>
<tr><td>Social</td><td>0 ≤ n ≤ 5</td></tr>
<tr><td>Total benefits</td><td colspan="2">Decision condition: If total benefits score is positive, then choose proactive measure; otherwise assess another proactive measure.</td><td>-20 ≤ n ≤ 45</td></tr>
</table>

Source: Authors' elaboration.

Table A7. Scoring methodology of the proactive maximin option framework

<table>
<tr><th>Factors</th><th>Description</th><th>Scoring</th></tr>
<tr>
<td>Monetized net benefits with drought</td>
<td>Combined monetized avoided costs and cost savings

Difference between the costs of inaction and the costs of proactive action = monetized avoided costs.

Add the monetized cost savings to the monetized avoided costs. Alternatively, cost savings can be deducted from the total costs of action early on.</td>
<td>Positive net benefits with drought scenario: Monetized costs of inaction is greater than monetized costs of action; the difference is the positive net benefits of action or positive combined avoided costs and cost savings. If values of monetized net benefits with drought (n) in relation to monetized costs of action ([monetized net benefits/monetized costs of inaction] x 100) are as follows, then:
<table>
<tr><th>Values of n</th><th>Score value</th></tr>
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<tr><td>141% ≤ n ≤ 160%</td><td>8</td></tr>
<tr><td>161% ≤ n ≤ 180%</td><td>9</td></tr>
<tr><td>n > 180%</td><td>10</td></tr>
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Negative net benefits with drought scenario: Monetized costs of inaction is less than monetized costs of action; the difference is the negative net benefits of action or negative combined avoided costs and cost savings. If absolute values of monetized net benefits with drought (n) in relation to monetized costs of action ([- monetized net benefits/monetized costs of inaction] x 100) are as follows, then:
<table>
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<tr><td>n > 180%</td><td>-10</td></tr>
</table>
</td>
</tr>
</table>

<table>
<tr><th>Factors</th><th>Description</th><th>Scoring</th></tr>
<tr><td>Monetized economic co-benefits</td><td>Compute for monetized economic co-benefits from action and evaluate against the (absolute) value of monetized net benefits with drought.</td><td>If values of monetized economic co-benefits (n) in relation to absolute value of monetized net benefits with drought ([monetized economic co-benefits/ |monetized net benefits with drought|] x 100) are as follows, then:
<table>
<tr><th>Values of n</th><th>Score value</th></tr>
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<tr><td>161% ≤ n ≤ 180%</td><td>9</td></tr>
<tr><td>n > 180%</td><td>10</td></tr>
</table></td></tr>
<tr><td>Transaction costs</td><td>Non-market or not calculated into quantitative values due to various constraints</td><td>No cost =0; Very low = -1; Low =-2; Moderate =-3; High = -4; Very High = -5</td></tr>
<tr><td>System Vulnerability</td><td>Reassessment of system vulnerability with proactive drought measure applied. Measure may affect either one of the vulnerability components.</td><td>The framework has a flexible design. Whether the vulnerability methodology used generates quantitative or qualitative evaluations, the following scoring methodology can be applied to normalize the resulting values: Very high =5; High = 4; Moderate =3; Low =2; very Low = 1; No change = 0.0</td></tr>
<tr><td>System linkages: Co-benefits</td><td>Assessment of the intangible co-benefits of drought proactive measure</td><td>Binary scoring/evaluation: Value of 1 if the subfactor exists; otherwise, value of 0.</td></tr>
<tr><td>System linkages: Cascading or compounded costs</td><td>Assessment of the intangible costs of drought proactive measure</td><td>Binary scoring/evaluation: Value of -1 if the subfactor exists; otherwise, value of 0.</td></tr>
</table>

Source: Authors' elaboration.

Annex 5 –
hypothetical example of the baci decision framework

Case 1: BACI decision framework assessment, positive net benefits with drought with negative monetized costs

Stage 1 assumptions are the following:

1. monetized costs of inaction are less than monetized costs of action;
2. intangible costs of inaction are greater than intangible costs of action, difference is high;
3. there is very low level of transaction costs.

Table A8. Case 1 – stage 1 assessment

Cost item	Inaction	With Action	Scores
Total monetized costs	USD 15 000 000	USD 21 000 000	-2
Intangible costs	Inaction > Action = Difference is High		4
Transaction costs	Transaction cost is Very Low		-1
Net benefits with drought	Score of total net benefits with drought is positive (+)		1

Stage 2 assumptions are the following:

1. total net benefits score with drought is 1 from stage 1, case 1,
2. absolute value of monetized net benefits with drought is USD 6 000 000 and monetized economic co-benefits value is USD 5 000 000, monetized economic co-benefits is 83 percent of the total net benefits with drought;

3. unlocked economic potential not identified;
4. intangible economic benefit is moderate;
5. intangible environmental benefit is high;
6. intangible social benefit is very low.

Table A9. Case 1 – stage 2 assessment

Benefit item	Scores
Total net benefits with drought	1
Monetized economic co-benefits	5
Unlocked economic potential	0
Intangible co-benefits: Economic	3
Intangible co-benefits: Environmental	4
Intangible co-benefits: Social	1
Total benefits	14
DECISION: Choose proactive measure	

Case 2: Stage 1 BACI decision framework assessment, negative net benefits with drought with positive total monetized costs

Stage 1 assumptions are the following:

1. monetized costs of inaction are greater than monetized costs of action;
2. intangible costs of inaction are less than intangible costs of action, difference is low;
3. there is very high level of transaction costs.

Table A10. Case 2 – stage 1 assessment

Cost item	Inaction	With Action	Scores
Total monetized costs	USD 20 000 000	USD 11 000 000	5
Intangible costs	Inaction < Action = Difference is Low		-2
Transaction costs	Transaction cost is Very High		-5
Total net benefits with drought	Score of total net benefits with drought is negative (-)		-2

Stage 2 assumptions are the following:

1. total net benefits score with drought is -2 from stage 1, case 2;
2. absolute value of monetized total net benefits with drought is USD 9 000 000 and monetized economic co-benefits value is USD 2 000 000, monetized economic co-benefits value is 22 percent of the total net benefits with drought;
3. unlocked economic potential not identified due to lack of data;
4. non-monetized economic co-benefit is very low;
5. intangible environmental benefit is high;
6. intangible social benefit is very low.

Table A11. Case 2 – stage 2 assessment

Benefit item	Scores
Total net benefits with drought	-2
Monetized economic co-benefits	2
Unlocked economic potential	0
Non-monetized/ intangible co-benefits: economic	1
Non-monetized/ intangible co-benefits: environmental	4
Non-monetized/ intangible co-benefits: social	1
Total benefits	6
DECISION: Choose proactive measure	

Case 3.1: Stage 1 BACI decision framework assessment, negative total net benefits with drought with negative total monetized costs

Stage 1 assumptions are the following:

1. monetized costs of inaction are less than monetized costs of action;
2. intangible costs of inaction are greater than intangible costs of action; difference is moderate;
3. there is very high level of transaction costs.

Table A12. Case 3.1 – stage 1 assessment

Cost item	Inaction	With Action	Scores
Total monetized costs	USD 11 000 000	USD 20 000 000	-5
Intangible costs	Inaction > Action = Difference is Moderate		3
Transaction costs	Transaction cost is Very High		-5
Total net benefits with drought	Score of total net benefits with drought is negative (-)		-7

Stage 2 assumptions are the following:

1. total net benefits score with drought is -7, from stage 1 case 3.1;
2. monetized economic co-benefits are not identified/computed due to insufficient data and information (non-monetized economic co-benefits are identified instead);
3. unlocked economic potential not identified;
4. non-monetized economic co-benefit is very high;
5. intangible environmental benefit is moderate;
6. intangible social benefit is low.

Table A13. Case 3.1 – Stage 2 assessment

Benefit item	Scores
Total net benefits with drought	-7
Monetized economic co-benefits	0
Unlocked economic potential	0
Non-monetized/ intangible co-benefits: Economic	5
Non-monetized/ intangible co-benefits: Environmental	3
Non-monetized/ intangible co-benefits: Social	2
Total benefits	3
DECISION: Choose proactive measure	

Case 3.2: Stage 1 BACI decision framework assessment, negative total benefits

Stage 2 assumptions are the following:

1. total net benefits score with drought is -7, from stage 1 case 3.1;
2. absolute value of monetized avoided costs is USD 9 000 000 and monetized economic co-benefits value is USD 2 000 000, monetized economic co-benefits value is 22 percent of the avoided costs;
3. unlocked economic potential is very low;
4. non-monetized economic co-benefit is low;
5. no intangible environmental benefit;
6. no intangible social benefit.

Table A14. Negative total benefits with monetized economic co-benefits

Benefit item	Scores
Total net benefits with drought	-7
Monetized economic co-benefits	2
Unlocked economic potential	1
Non-monetized/ intangible co-benefits: Economic	2
Non-monetized/ intangible co-benefits: Environmental	0
Non-monetized/ intangible co-benefits: Social	0
Total benefits	-2
DECISION: Assess another proactive measure	

This report has been prepared by the Food and Agriculture Organization of the United Nations (FAO) under the framework of the project "Enabling Activities for Implementing UNCCD COP Drought Decisions", funded by the Global Environment Facility (GEF), and implemented in collaboration with the United Nations Convention to Combat Desertification (UNCCD) and other partners. The project is designed to support the operationalization of national drought plans according to the principles of integrated drought management. The report investigates the broad concept of the economics of drought management, provides a conceptual, two–tier framework for the assessment of proactive and reactive actions, and disseminates case studies for the implementation of the framework in decision-making processes.

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