Food and Agriculture Organization of the United Nations

Disaster risk reduction at farm level:

Multiple benefits, no regrets

Results from cost–benefit analyses conducted in a multi-country study, 2016–2018

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Food and Agriculture Organization of the United Nations
Rome, 2019

REQUIRED CITATION
FAO. 2019. *Disaster risk reduction at farm level: Multiple benefits, no regrets.* Rome. 160 pp.
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ISBN 978-92-5-131429-6

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Contents

Highlights

- The farm-level use of practices and technologies intended to reduce disaster risks provides farmers with economic and social benefits that are significantly higher than the benefits they gained from previously used practices.

- Disaster risk reduction (DRR) good practices in agriculture are highly context- and location-specific. Not all have the potential for wider upscaling; rather, targeted upscaling – driven by evidence – should be pursued.

- To truly qualify as a good practice, DRR measures must offer added value in both hazard and non-hazard situations – that is, they must increase agricultural productivity even in the absence of hazards.

- On average, the DRR good practices analysed in this study generated benefits 2.2 times higher than practices previously used by farmers under hazard conditions. The average observed benefit–cost ratio (BCR) was 3.7 in hazard cases – under non-hazard conditions this rose to 4.5. Benefits included both increases in agricultural production as well as avoided hazard-associated damage and loss.

- Prevention and DRR measures in agriculture are especially useful in avoiding or reducing damage and loss from high- to medium-frequency events – which occur with low or medium intensity. Greater emphasis in agriculture sector strategies is needed on farm-level DRR as an effective and relatively low-cost way to prevent and mitigate the types of disasters that most frequently affect vulnerable smallholders.

- Agricultural development policy, planning and extension work should treat DRR as a priority. Farm-level DRR should not only be mainstreamed in a deliberate manner, but widely promoted and implemented at much larger scales.

- The upscaling of good practices can considerably increase farm productivity and enhance the resilience of smallholder farmers to natural hazards, bring broader benefits at regional and national levels, and contribute to the achievement of the global development agenda articulated by the Sustainable Development Goals, the *Sendai Framework for Disaster Risk Reduction 2015–2030*, and the Paris Climate Agreement.

- There are two suitable but different paths for upscaling farm-level DRR good practices in agriculture. The first is at a smaller- and incremental scale, through farmer-to-farmer replication, which requires lower investment and institutional support. The second path is through larger-scale efforts in which government or private sector support are needed to promote uptake of good practices at scale. Crucially, both pathways depend on good infrastructure as well as an enabling environment. This means that new initiatives and investments aimed at meeting those critical needs for upscaling are necessary.

Foreword

> So far, little evidence has been assembled regarding the economic benefits of investing in preventive small-scale disaster risk reduction measures in agriculture. With this study, FAO seeks to help fill this knowledge gap.

In recent years multiple disasters have imposed devastating consequences on agriculture, food security and the livelihoods of millions of farmers, pastoralists, fishers and forest-dependent communities. From the 2015/16 El Niño and resulting hazards worldwide to the exceptionally strong 2017 hurricane season in the Caribbean to the devastation wrought in southern Africa this year by Cyclone Idai, across the globe agriculture is bearing the burden of disaster impacts.

With global food security dependant on a productive and resilient agriculture sector, protecting agriculture from the impacts of disasters triggered by natural hazards is of paramount importance – especially as the planet's population continues to grow, demands on productive resources increase, and climate-related shocks become more frequent and more intense.

Recent studies by the Food and Agriculture Organization of the United Nations (FAO) have shown that disasters have an outsized impact on the agriculture sector, leading to large-scale economic losses and causing physical damage to the lands, resources and livelihood assets that the planet's most vulnerable people rely on to get by.

But agriculture represents much more than a mere means of subsistence; rather, it lies at the heart of development, providing important opportunities for poor communities to enhance their standard of living through the sustainable intensification of production. Yet efforts to harness the power of agriculture as an engine for sustainable development are being repeatedly – and increasingly – challenged by disasters. Importantly, it is not only high-impact disasters that cause this damage: low- to medium-level disasters – which occur more frequently – also significantly hinder smallholder farmers in realizing their full potential.

So far, little evidence has been assembled regarding the economic benefits of investing in preventive small-scale disaster risk reduction (DRR) measures in agriculture. With this study, FAO seeks to help fill this knowledge gap, by systematically analysing the costs and benefits of farm-level DRR practices across sub-sectors, countries and continents.

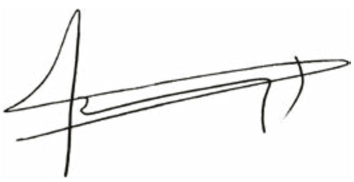
This report assesses and identifies solutions with special relevance for smallholder farmers: DRR good practices that work at farm-level and which, with small investments, can have significant positive impact on the resilience of their livelihoods. It evaluates the cost-effectiveness and socio-ecological suitability of different specific DRR interventions, with the intention of providing decision-makers and farmers both with reliable assessments that can guide their decisions around DRR investment. For smallholder farmers and development actors alike, the study findings can help prioritize options among a multitude of available DRR interventions, taking into account local contexts and specific needs. For policy-makers,

this study is particularly valuable, as it offers cost–benefit figures for individual good practices as well as for combined interventions that are based on actually-observed impacts. The report also estimates the costs and benefits of upscaling selected good practices, thus providing insights to decision-makers on the relevance of establishing enabling conditions for replication beyond study sites.

Enhancing the resilience of agriculture-based livelihoods in the face of hazard-induced disasters and climate change lies at the core of FAO's commitment to tackle hunger, food insecurity and extreme poverty and to help build a world with Zero Hunger. This goes hand in hand with FAO's work to promote a shift to the sustainable management of the natural resources on which all food production – and the livelihoods of millions of people – depend. Preventive action is needed to support smallholder farmers as key agents in building resilience and as the frontline custodians of large swathes of the Earth's ecosystems. National and international DRR efforts must facilitate and support action at all scales – but above all, by smallholder farmers.

This study makes clear that in most cases, DRR efforts on the farm make good economic sense: that investing in DRR early can save many dollars that would otherwise be spent on post-disaster rehabilitation. Moreover, farm-level DRR good practices are often "no-regret" measures – meaning that they prove effective in providing added benefits even in the absence of hazards.

Three major agreements adopted by the international community in 2015 provide a global framework for increasing the resilience of agriculture-based livelihoods to disasters. The *Sendai Agreement for Disaster Risk Reduction 2015–2030*, the 2030 Sustainable Development Goals (SDGs) and the Paris Agreement on Climate Change all call for joint, preventive action. This study represents an important contribution to better informed, evidence-based implementation of those agreements at the local level, and aims to catalyse further research and analytic assessment of farm-level DRR impacts. Not only does the study show that prevention pays, it highlights the significant role that small scale, farm-level interventions can play in increasing peoples' resilience and advancing sustainable development.



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Acknowledgements

This report on the benefits of farm-level DRR practices in agriculture is the result of cross-departmental and cross-country collaboration within FAO.

Its lead authors were Niccolò Lombardi, Lisa Murken, and Sophie Charlotte von Loeben, working under the overall coordination of Stephan Baas and with contributions from co-authors Camille Touzé and Jiwon Rhee.

The study results offer an important strategic as well as technical contribution to the Organization's work on disaster risk reduction under FAO's Strategic Programme 5: "Increase the resilience of livelihoods to threats and crises". The Strategic Programme provided overall guidance and financial support to this study. A number of FAO country offices contributed invaluable assistance and support with data collection during project implementation and analysis, namely: FAO Bolivia (Plurinational State of), FAO Cambodia, FAO Colombia, FAO Guyana, FAO Haiti, FAO Jamaica, FAO Lao People's Democratic Republic, FAO Pakistan, FAO Philippines, and FAO Uganda (as did their national implementation partners). In addition, the FAO Regional Office for Latin America and the Caribbean supported with coordination and project follow-up.

Special thanks for the substantive country and regional office-driven support goes to: Einstein Tejada (Plurinational State of Bolivia), Kimhian Seng and Sophary Long (Cambodia), Teresita Gongora, Maria Consuelo Vergara and Carlos Arango Dominguez (Colombia), Onika Baptiste, Reuben Robertson and Felix Girard (Guyana), Jean Robert Rival and Gianluca Gondolini (Haiti), Gillian Smith and Claudia Ennis (Jamaica), Satendra Singh and Olayvanh Singvilay (the Lao People's Democratic Republic), Kennedy Igbokwe and Emmanuel Zziwa (Uganda), Muhammad Hussnain, Fahim Ahmed and Banaras Khan (Pakistan), Roberto Sandoval (the Philippines), Anna Ricoy and Marion Khamis (Regional office for Latin America and the Caribbean), and Daniele Barelli (Subregional Office for the Caribbean). Without the continued effort of colleagues in country and regional offices this report would not have been possible, and the coordinators would like to express their special gratitude for this engagement over several years.

Technical inputs and advice were provided by the respective Ministries of Agriculture in the target countries as well as by several divisions and units within FAO, including the Emergency and Resilience Division, the Climate and Environment Division, the Agricultural Development Economics Division, the Agriculture and Consumer Protection Department's Research and Extension Unit (AGDR), and the Fisheries and Aquaculture Policy and Resources Division.

The authors greatly appreciate the in-depth technical review and assistance in fine-tuning the text provided by the team managing FAO's Technologies and Practices for Small Agricultural Producers platform (TECA, housed in AGDR). Thanks for continuous feedback and the final peer-review goes to Shukri Ahmed, Anne De Lannoy and Selvaraju Ramasamy.

George Kourous edited the final report and provided input on content and messaging. Graphic design and data visualizations were done by Anneta BouSaleh under the guidance of Diane Prince.


CUL PAL-0157-06

Acronyms

AGDR	Research and Extension Unit, Agriculture and Consumer Protection Department, FAO
BCR	Benefit–cost ratio
CBA	Cost–benefit analysis
DRR	Disaster risk reduction
ECONADAPT	Economics of Climate Change Adaptation Project of the European Union
FAO	Food and Agriculture Organization of the United Nations
GSR	Green Super Rice
IFRC	International Federation of Red Cross and Red Crescent Societies
IMP	Integrated pest management
IUCN	International Union for Conservation of Nature
ODI	Overseas Development Institute
NPV	Net present value
SDGs	Sustainable Development Goals
TECA	Technologies and Practices for Small Agricultural Producers Platform, FAO

Introduction

Currently 2.5 billion people worldwide depend on agriculture for their livelihoods. At the same time, agriculture is highly vulnerable to the impacts of recurrent disasters and other types of crises.

Over the last decade, the number of disasters caused by natural hazards has steadily increased, along with the number of people affected and the scale of economic losses generated – including in agriculture. A recent FAO study found that between 2006 and 2016, the agriculture sector absorbed approximately 23 percent of all damages and losses caused by natural hazard-induced disasters in developing countries (FAO, 2018). If not prevented, or significantly reduced or counteracted, these impacts will continue to have major negative implications for poverty and food security, worldwide (The State of Food Security and Nutrition in the World, 2018).

There are multiple pathways to reduce the impacts of natural hazard-induced disasters on the agriculture sector, at different levels – including farm level. The *Sendai Framework for Disaster Risk Reduction 2015–2030* establishes four lines of priority action that, together, can effectively address the risk of natural hazards: 1) understanding disaster risks; 2) strengthening disaster risk governance to manage risk; 3) investing in disaster risk reduction for resilience; and 4) enhancing disaster preparedness to enable "building back better" during recovery, rehabilitation and reconstruction.

The third priority, which focuses on investment in disaster prevention and non-structural measures to enhance the economic, social and cultural resilience of communities, is the entry point for this study.

Investing in disaster risk reduction (DRR) measures at farm level is a crucial way to proactively reduce risk exposure at local level and enhance, from the bottom up, the resilience of farming families to natural hazards. Also, the fact that many DRR good practices add value to production even in non-disaster contexts provides an additional incentive to incorporate greater consideration of risks from natural hazards into existing agronomic and natural resources management practices on farms.

A key data gap, up to now, has been a lack of evidence regarding the amount of disaster-induced losses in agriculture that could be avoided by investing in preventive DRR good practices on farms.

The present study makes a significant contribution to answering this question, by analysing the benefits that improved farm-level DRR good practices offer farmers versus technologies and approaches they used in their fields previously.

> This study developed and applied a systematic methodology to quantify, on a case-by-case basis, how much damage and loss can be reduced through the implementation of disaster risk reduction good practices at farm level.

This analysis is based on comprehensive data collected from ongoing and completed FAO field projects in multiple countries, in various world regions. The study developed and applied a systematic methodology to quantify, on a case-by-case basis, how much damage and loss can be reduced through the implementation of DRR good practices at farm level. Various types of hazards were considered (mainly floods, dry spells/

drought, and storms). The performance of DRR good practices under both hazard-induced stress and in non-hazard conditions was examined, when both scenarios could be recorded during the study period.

Study outcomes point to a number of specific DRR good practices that have high potential to reduce the exposure and vulnerability of households and communities to natural hazards. These outcomes are intended to support policy-makers, national and local governments, development actors, the private sector, DRR practitioners, and others in making good, evidence-based decisions on how to best reduce the risk exposure of agricultural producers and their communities.

As the results strongly suggest, much wider use of farm-level DRR interventions and more extensive upscaling of these approaches should be treated as a priority in disaster risk reduction and development-related policymaking.

Study rationale and innovation

> Disaster risk reduction measures in agriculture hold vast potential for improving damage prevention and impact mitigation at the local level, with immediate and palpable benefits to the lives of billions of people.

Considerable evidence about the benefits of preventive action to avoid disaster losses has already been created in both DRR and climate change adaptation literature (Coughlan de Perez *et al.* 2014; Pappenberger *et al.* 2015; Costella *et al.*, 2017). But missing from the mix has been a cost-benefit study that systematically assesses, in different hazard-contexts, the performance of farm-level DRR practices that can be implemented by the world's food producers themselves. Given that the 2.5 billion people on the planet whose livelihoods rely on agriculture play a central role in feeding the global population, quantifying the benefits and costs of DRR technologies for agriculture, especially at farm-level, is clearly a worthwhile goal.

The rationale for this study is therefore not just to further consolidate evidence that prevention pays, but to make the case that disaster risk reduction measures in agriculture hold vast potential for improving damage prevention and impact mitigation at the local level, with immediate and palpable benefits to the lives of billions of people.

As a particularly innovative feature, the study distinguishes between benefits of DRR practices in hazard versus non-hazardous situations. This allows for the identification of "no-regret" options, where implementation makes good economic sense even when natural hazards are not at play. Considering the high uncertainty of future climate change and natural hazards occurrence, there is compelling reason to identify no-regret options for disaster risk reduction on farms. It is worth stressing that most of the good practices presented and evaluated in this study can be implemented by farmers themselves with limited external support (for example, training).

This study in the context of the international development agenda

Three global landmark agreements adopted in 2015 – the *Sendai Framework for Disaster Risk Reduction 2015–2030*, the Sustainable Development Goals (SDGs) and the Paris Agreement on Climate Change – recognize the importance of disaster risk reduction and resilience. They also acknowledge the crucial role of agriculture for risk sensitive, sustainable development.

SDG target 2.4 stresses the need to “ensure sustainable food production systems and implement resilient agricultural practices (…) that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters”, while SDG target 13.1 sets as a goal “strengthen(ing) resilience and adaptive capacity to climate-related hazards and natural disasters in all countries”.

For its part, the Paris Agreement, in Article 7, calls for actions to strengthen resilience and reduce vulnerability via various means, *inter alia*, building the resilience of socioeconomic and ecological systems, including through economic diversification and sustainable management of natural resources.

And the Sendai Framework, in Priority 3, emphasizes the need to invest in disaster risk prevention and reduction through structural and non-structural measures to “strengthen the protection of livelihoods, as these measures are cost-effective and instrumental to save lives, prevent and reduce losses and ensure effective recovery and rehabilitation”. Under the same priority, the Framework highlights the need to improve measures aimed at protecting livelihoods and productive assets, including livestock, working animals, tools and seeds.

Common to these three agreements is an implicitly articulated demand to shift away from *post facto* management of disasters induced by natural hazards towards proactively reducing their risks, lowering vulnerability, and enhancing resilience before they hit.

The present study directly contributes to the internationally-agreed priority of working to enhance the resilience of the planet’s most vulnerable communities to natural hazard-related disasters, and specifically to Priority 3 of the Sendai Framework. It creates a sound evidence-base and argument for investing more in disaster risk reduction in the agriculture sector, as opposed to exclusively investing in disaster response. With its focus on farm-level measures, it highlights the critical importance and high added-value of local action for achieving the 2030 Sustainable Development Agenda.

Structure of the study

The study starts with a comprehensive literature review critically analysing existing evidence and previous economic evaluations of DRR practices. Research relevant to the agriculture sector is assessed in detail, with a view to informing the present study's methodology and focus. Research gaps and the contribution of this study to filling those gaps are highlighted. A subsequent section explains in detail the methodology employed, including the quantitative and qualitative approaches used to conduct field level assessments, and the potential benefits of upscaling select good practices.

The study's core findings (starting on p. 26) provide a detailed analysis of field-level data from 924 farms covering 36 different DRR practices in ten countries. For each location where practices were implemented and monitored, the hazard context is explained in Annex III. This provides a qualification of hazard contexts- and intensities under which each practice's performance was assessed. Alongside descriptions of select examples of good practices and their cost–benefit analyses (CBAs),[1] results from farmer interviews are also included, to highlight the social and environmental co-benefits observed.

Next, the potential for upscaling or increasing the use of good practices is discussed. This potential was assessed using a system dynamics model. Select case studies are showcased, including the introduction of the green super rice variety in the Philippines, the implementation of a good practice package for improved banana cultivation in Uganda, and the use of a good practice package for protecting camelids from harsh temperatures in the Bolivian Andean region.

The report closes by situating the results in the broader context of ongoing efforts to assess the economic benefits of DRR measures, followed by a conclusion summarizing the results and providing an outlook on future research and other follow-up actions in the realms of policy and practice. ◂

[1] For the purposes of brevity and to avoid repetition, this study employs the acronym CBA and the term cost-benefit analysis interchangeably, generally on an alternating basis. CBA as used here should not to be confused with "community-based adaptation." A glossary of all acronyms used herein can be found in Appendix IV.

Cost–benefit analyses of DRR interventions: Insights from the literature

To make a strong case that greater upfront investment in anticipatory DRR measures represents a better use of resources than costly post-disaster spending on reconstruction and recovery, a sound evidence base regarding the economic benefits and costs associated with DRR measures is required. An existing body of research on the subject exists that can offer valuable insight to investment decisions; this study seeks to build on and advance that knowledge, filling some important gaps along the way.

To embed the present study within the existing body of research, an in-depth literature review was conducted. A considerable body of work on the economic advantages of disaster preparedness and risk management – including cost benefit analyses of DRR in general – has evolved in recent years. This study's review examined three primary threads of the relevant literature: theoretical guidance for cost benefit analyses of DRR interventions; overview studies on DRR costs and benefits across sectors, and; empirical cost–benefit studies in the agriculture sector.

The main sources of reference were materials published online by international organizations, government agencies, civil society organizations, academia and individuals. A large share of the literature is grey literature – that is to say, not peer-reviewed. Empirical studies were reviewed in greater depth, as they contained interesting case studies of specific project interventions or DRR measures. Particular attention was given to three specific areas of focus: cost benefit analyses, disaster risk reduction, and agriculture.[2] The review shows that CBAs of DRR interventions have been undertaken for a range of projects at different scales and addressing different hazards. Of note are Mechler (2016), Shreve and Kelman (2014), Savage (2015) and Cabot Venton (2018), who give a good overview on the recent state of the art in cost–benefit assessments of DRR measures. Chadburn *et al.* (Tearfund, 2013) look exclusively at community-based measures. In the most comprehensive such review so far, the EU-funded ECONADAPT project (Chiabai *et al.*, 2015) analysed over 500 climate change adaptation projects with regard to their costs and benefits. The OECD (2015) also dedicated a chapter to adaptation cost-efficiency in an analysis of climate-related risks.

In contrast, the cost–benefit literature on DRR measures in agriculture is relatively limited. According to the inclusion criteria employed for this work, 23 of the studies reviewed are strictly identifiable as agriculture-specific DRR CBAs; however, they exhibit varying levels of quality and methodological rigour. Within the agriculture sample, most studies look at subsectors such as crops and livestock; only a few consider

[2] Depending on the purpose of the studies reviewed and the entities who conducted them, diverse terminologies were used to describe these three key foci. Thus, studies were assessed with a view to their wider thematic treatment and relevance for this analysis, especially regarding the description of DRR measures, which are often similar to climate change adaptation interventions. Although only a few studies exist that directly include all three terms cost benefit analysis, disaster risk reduction and agriculture, an in-depth review allowed for the identification of many relevant case studies and rendered their findings useful for this literature review.

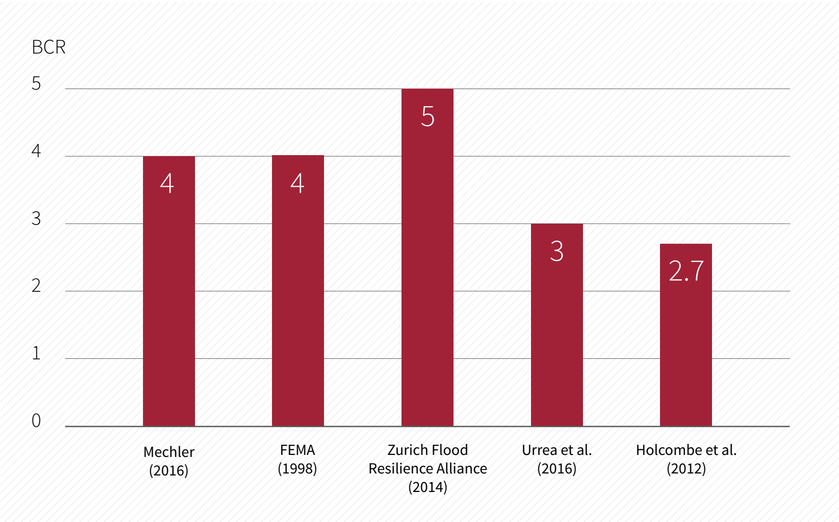
fisheries and forestry (e.g. Baig *et al.* 2016; FAO and UNHCR, 2018). Additional research focusing on climate change adaptation measures in the agriculture sector provided interesting insights as well, with the practices examined often similar to the ones assessed in this study.

Cost–benefit methods used to assess DRR interventions

A wide array of cost–benefit methods for analysing DRR interventions exist. It is important to understand them, as differences in DRR cost–benefit assessment methods and study designs help explain the differences in their results. On the most basic level, all aim to evaluate the costs of the intervention versus their benefits. However, there are significant differences between them, including:

- methodological approach: quantitative, qualitative or combined
- timing of the analysis: analysis conducted *ex-ante* or *ex post*
- the consideration and calculation of risk: deterministic or probabilistic; differences in risk factors due to different hazards; the consideration for potential change of risk over time; the consideration of climate change
- the discount rate used and the timeframe of the analysis
- the inclusion of benefits and costs: short-term economic and vulnerability benefits and costs; inclusion of longer-term non-monetary costs and benefits
- the type of comparison or counterfactual: no comparison; comparison with non-intervention cases; comparison of hazard and non-hazard cases

Figure 1. Differing cost–benefit ratios from select CBA analyses of DRR measures



Given the wide range of methodologies employed and interventions examined by other studies, it is not surprising that quite different results appear in the literature (see Figure 1). The unit of measurement employed influences how results are understood and communicated, with the most

common measurements typically being Benefit–Cost Ratios (BCRs), Net Present Value (NPV) and Internal Rate of Return (IRR). In general, it is useful to report not just one indicator, but several, to give a fuller picture of results.

Common trends and lessons learned

> The overarching conclusion that clearly emerges from the different assessments reviewed is that disaster risk reduction pays.

Despite differences, the overarching conclusion that clearly emerges from the different kinds of assessments reviewed is that disaster risk reduction pays.

And as regards diverse types of intervention options in agriculture, some common trends related to cost-effectiveness and performance can be detected in the literature (for more detailed information, see Annex I).

For instance, combined interventions tend to bring higher BCRs than single interventions (e.g. dual pond and river improvement in ODI, 2013; three combined interventions in Yargon, 2017; irrigation plus insurance in Mechler *et al.*, 2008).

Interestingly, nature-based solutions, such as planting mangrove to protect coastal areas from floods, appear to offer higher BCRs and overall benefits than hard infrastructure measures (see Daigneault *et al.*, 2016 and IUCN, 2016). This could be due to lower input costs for nature-based solutions, as compared with "grey infrastructure" measures.

Similarly, generally high BCRs are reported for people-centred approaches due to the low costs they incur; this makes them no-regret options in most scenarios – and particularly well-suited for smallholder farmers (see Chadburn *et al.*, 2013, Shongwe, Masuku and Manyatsi, 2013 and Seekao and Pharino, 2018).

Such findings are mirrored in the cost–benefit literature for climate smart agriculture. Climate smart agriculture studies do not always fall directly under the DRR focus of this study, but the practices they evaluate are sometimes the same as – or similar to – a number of DRR interventions. Generally, infrastructure measures look to be less profitable than use of improved crop varieties or other people-centric, agronomic measures (see Sain *et al.* 2017, Ng'ang'a *et al.* 2017, Mishra and Rai, 2013).

Early warning systems can be a useful addition alongside other DRR measures; however, the literature also suggests that it is difficult to assess them as a stand-alone measure, with results revealing comparatively lower benefits compared with hands-on interventions (see, for instance, Kull *et al.* 2013). However, in a study on a flood early warning system in Fiji, a BCR of 3.7–7.1 was estimated (Holland, 2008), highlighting the value that early warning can have. In a literature analysis, Urrea *et al.* (2016, cited in Costella *et al.*, 2017) estimated a BCR of 3:1 in beneficiaries' savings, outweighing the cost of cash transfers released upon flood early warning in Bangladesh.

Farm-level interventions in agriculture provide low cost, bottom up options for disaster risk reduction, but have been neither studied sufficiently nor considered systematically in national strategies.

Recent FAO assessments have measured the return on investment of early actions triggered by early warnings that are intended to prevent or mitigate the impact of disasters on vulnerable farmers and herders. These have found that for every dollar invested by FAO in early action, farmers and herders obtained between USD 2.5 and 7.1 in added benefits and avoided losses, depending on location and hazard context. In Mongolia, for instance, feed and cash distribution ahead of forecasted harsh winter helped significantly reduce negative impacts on livestock (the BCR was 1:7.1; FAO, 2018a).

Another interesting thread that emerges from the literature relates to agricultural risk insurance. A study of drought risk management in India (Kull *et al.*, 2013) finds that, depending on the frequency of events, either traditional irrigation or insurance solutions can be more economically efficient. For high-frequency events, irrigation is better suited, whereas for low-frequency events with higher intensity, as a risk transfer mechanism, insurance can help buffer dramatic income shocks (Kull *et al.* 2013). Mechler (2016) adds that insurance solutions are better suited in costly, less frequent high-risk contexts where risk cannot fully be mitigated. In coping with typhoon impacts in China, Ye *et al.* (2016) find that insurance should be the preferred option to share risk, ahead of risk reduction measures like the costly windproof retrofitting of buildings. Agricultural insurance can motivate farmers to invest more, leading to increased income (Dinesh *et al.*, 2017). However, the insurance needs to be carefully designed, so as to avoid incentivizing risky behaviour and poor agricultural practices.

When it comes to “non-tangible” results that are difficult to quantify, namely environmental and social benefits, the literature has been largely silent.

The DRR environmental co-benefit most frequently-mentioned is greenhouse gas mitigation – agroforestry measures in particular, but also conservation agriculture, which sees trees and healthy soils removing atmospheric CO2 and storing carbon. Other reported co-benefits include improved soil fertility, reduced pressure on water resources and reduced chemical pollution on farms.

Few studies explicitly mention social co-benefits, but positive benefit–cost ratios and improved economic efficiency often translate into higher household income levels and improved savings, at least when families bear the costs (and benefits) of DRR interventions themselves. In turn, higher household income may lead to increased investments in education, health, and bring social dividends in terms of enhanced well-being.

A key general lesson from across the studies reviewed is that long-term engagement pays off, especially in a community context (see for instance IFRC, 2010). The more time a DRR project is given to develop, the more its

benefits become manifest. This is because the one-off costs which must be paid at the beginning of an intervention take time to be compensated by the resulting, long-term benefits.

Following off the above observation is that it is important to measure benefits over multi-year spans. Where BCRs and NPVs are calculated for several years in a row, both increase considerably over time (for one example, see Fassina, 2015). It is useful therefore to not only assess a project's outcome directly after completion, but to either measure benefits in subsequent years, or project them. Follow-up studies can be useful in evaluating a measure's longer-term effects (IFRC, 2012; Chadburn *et al.*, 2013).

Conclusions from the literature review

Based on this study's literature review of cost benefit analyses of DRR interventions in the agriculture sector, the following conclusions can be drawn:

- Comparisons of different CBA studies should be done with care, since evaluation methods can vary considerably. To reach meaningful results that can reveal the pros and cons of diverse preventative actions, thorough assessments and a better harmonization of CBA approaches are needed.
- Multiple entry points for reducing communities' disaster risk and exposure to damage and loss exist.
- Diverse DRR good practices are often most effective when deployed in combination, as mutually reinforcing measures.
- Farm-level interventions in agriculture provide low cost, bottom up options for DRR but have not yet been studied sufficiently, nor have they been considered systematically as part of national DRR strategies.
- People-centred approaches are frequently no-regret options, and well-suited for smallholder farmers – as are lower-cost nature-based interventions.
- Early warning systems add value, but their benefits are difficult to quantify as a stand-alone measure. And clearly, when early warnings trigger early actions, high benefits are achieved.
- DRR measures in agricultural settings can yield environmental and social co-benefits but such outcomes are difficult to measure, and better data are needed
- DRR in agriculture is a "long game" – interventions should remain engaged with communities and not be limited to up-front, one-off investments and actions. ◂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How this study breaks new ground

Effective measures of the costs and benefits of DRR remains challenging to establish; a great level of detail and complexity is needed to thoroughly assess the pros and cons of preventive action. None of the studies reviewed manages to comprehensively cover all critical aspects. (For a more in-depth analysis on this point, see Annex I).

Still, the extant literature provided a good entry point to inform the design of this study, since it has already assembled evidence for the value added of disaster risk reduction measures in general. Works that particularly influenced the research design of this study include Dinesh *et al.* (2017), the International Federation for the Red Cross (2016a, 2016b) and the "From Risk to Resilience" series (Moench *et al.*, 2008).

The following section situates in greater detail the present study in the wider context of economic evaluation of DRR measures. It shows that this new study is unique and adds significant value to existing knowledge in a number of ways, including (but not exclusively) through its:

- focus on agriculture and more specifically on farm-level interventions
- evaluation of clusters of similar DRR good practices across countries and continents
- assessment of the impacts of low to medium-scale hazards
- assessment of and comparison between good practices' performance in both hazard stress and non-hazard conditions, which helps to identify no-regret options

Methodology and approach

Evaluated against the literature, the methodology used in this study exhibits a number of strengths, addressing most of the challenges and shortcomings in approaches discussed in the preceding literature review. This positions the FAO methodology as an effective means for conducting robust assessments of the costs and benefits of agriculture-specific DRR interventions, with a particular focus on the needs and challenges specific to smallholder producers.

Regarding the time-scale of the analysis, this CBA calculates the benefit–cost ratio *ex post*, with data being collected over several seasons and the BCR then being computed for an 11-year appraisal period. Thus, actually-observed data is utilized to project costs and benefits over the appraisal period, as opposed to assumed inputs used in *ex-ante* assessments. This increases the validity of the findings. The 11-year appraisal period allows an understanding of whether longer term benefits compensate for the capital investment made at the start of the intervention. A relatively short period of time was chosen to reduce uncertainty associated with longer term analyses, because no major capital outlays were involved in the farm-level good practices analysed by the study.

With its implementation and assessment of similar practices in different regions, this methodological approach aims to shed light on geographic differences and scales of possible replication from place to place.

To provide a useful counterfactual, a distinction is made between hazard and non-hazard scenarios, as well as between intervention and non-intervention cases within each hazard- and non-hazard scenario. Only one study examined in FAO's literature review – IFRC, 2012 – attempts this. This distinction permits some interesting conclusions, perhaps the most noteworthy being the fact that all interventions show positive benefit-cost-ratios (BCRs) even in non-hazard scenarios, indicating that their adoption would be a no-regret option for farmers. In addition, comparing between DRR good practices adopted for the study and the practices that were previously used by farmers on the same plots yields detailed insights into the benefits brought by the good practices.

This study also uses different methodological approaches, combining quantitative assessments with qualitative interviews and upscaling simulations to assess costs and benefits of farm-level DRR interventions from a variety of angles. This contributes to a more holistic evaluation of applied good practices, producing important evidence for policy formulation and further guidance for DRR practice.

With its implementation and assessment of similar practices in different regions, this methodological approach aims to shed light on geographic differences and scales of possible replication from place to place. A qualitative component is included to identify environmental and social co-benefits or costs, which were not monetized in the quantitative assessment.

Calculations for the upscaling potential of good practices represent an additional innovation in this work versus conventional cost–benefit analyses, which often only consider a measure's potential for wider implementation qualitatively, if at all. This study's emphasis on identifying particularly well-performing practices and assessing their wider replicability highlights the policy-relevance of its findings and goes beyond mere assessment to ensure that the farm-level perspective is adequately represented at the governance level.

Cost–benefit analyses at higher level – for example, the national scale – are often criticized for not considering distributional effects of DRR interventions, which may unequally benefit people or groups (Vorhies and Wilkinson, 2016; Shreve and Kelman, 2014). With its farm-level focus, this study does not disguise distributional effects but rather allows them to be scrutinized, as household-level, disaggregated data are collected and analysed. By evaluating the smallholder farmer level and not communities or villages as a whole, this study automatically explores how individuals can benefit from a range of interventions, in different ways. While primarily aggregated results are presented here, qualitative interviews gave additional space for farmers to highlight their individual perspectives and perceptions, some of which are shared in the subsequent chapter.

The discount rate and timeframe of analysis employed are consistent with mainstream approaches in the literature, and the sensitivity analysis

conducted with different discount rates enhanced the validity of findings. As regards the type of evaluation chosen, it is noted that cost–benefit analyses are by no means the only tool for assessing the success and impact of DRR projects. However, the CBA design as evaluation method gives clear answers to the most pressing questions related to making the case for upscaling farm-level DRR measures – namely economic returns.

It should be noted that the cost–benefit methodology is also valuable beyond the mere economic assessment: participatory CBA processes like those utilized in the framework of this study also help to inform local communities about good practices and their benefits, as well as to share experiences and knowledge (Price, 2018; Shyam, 2013; IFRC, 2010).

Targeted data gaps

As articulated in the previous section, this study sought to push the envelope in number of ways.

Key innovations in its approach include: its focuses on farm-level interventions and small-scale, people-centred interventions;[3] its examination of a range of interventions, including practices in the crop, livestock, forestry, fisheries and aquaculture sub-sectors; its consideration of multiple hazard types; its analysis of good practice performances under hazard versus non-hazard conditions; its coverage of multiple locations across continents, and last but not least; the fact that it covers this ground using a systematic, multi-disciplinary, and harmonized methodology.

Thanks to this approach, the findings yielded by this study fill a number of critical knowledge gaps. Indeed, when systematically comparing the non-sector specific DRR CBA research reviewed in the literature survey with the agriculture-specific findings of this study, a series of new, value-added results stand out.

The following graphic gives an indication of how the present study is situated in the agriculture-specific DRR CBA landscape, compared to the 23 studies that the literature review placed in the same category.[4] Individual icons represent the hazard types evaluated by both pre-existing work and by the present study. The x-axis indicates the type of studied DRR intervention, while the y-axis characterizes the scale of the intervention. Finally, the focus of FAO's study – covering multiple hazard types at farm level in multiple regions – is outlined in green.[5]

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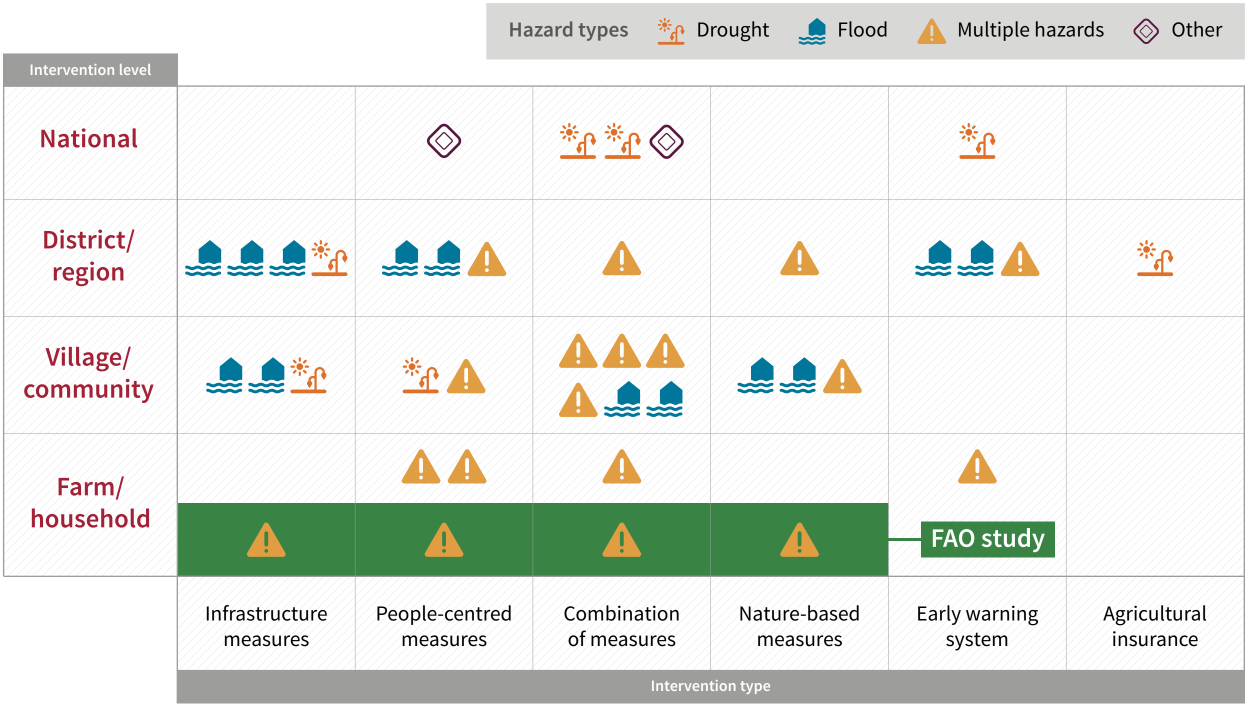
[3] Importantly, as used here, farm-level means that in this study data was collected on individual farms, as opposed to being aggregate data (or estimates) from a larger project spanning multiple farms.

[4] See Appendix III for a reference table listing all studies.

[5] Some studies appear more than one time, because they evaluated several interventions or projects separately. Projects which combined different types of interventions and which only calculated one BCR for the intervention bundle were only listed once. The studies were assigned to levels based on the authors' judgement; the individual studies themselves may self-report different intervention levels.

Figure 2. CBAs of DRR interventions in agriculture: FAO's study vs. the literature



The most conspicuous contribution of this study, apparent in the graphic, is the new evidence yielded by its focus on the farm level. Studies that look only at the overall capital or production BCR of DRR interventions overlook the actual impact on vulnerable and marginalized communities and do not fully capture the value of DRR interventions for small scale farmers, herders and fishers.

Another notable gap in the literature that the present study fills relates to its analysis of practices in the livestock sub-sector; in particular its consideration of pests and diseases in the context of livestock interventions. However, its analysis of other intervention types also contributes to the evidence base. For instance, worth highlighting are a small number of practices implemented and analysed during this study that are "nature-based," such as the agronomic practices related to the production and application of botanical pesticides and liquid compost, cattle raising in silvopastoral systems, and the use of guano fertilizer. And while the main hazards discussed consist of drought and floods – which echoes the general trend in the literature – this study nonetheless adds a further component via its analysis of DRR practices in the context of storms and animal and plant pests and diseases.

It is important to note that the present study does not include any singular high-intensity disaster, but rather focusses on low-intensity–high frequency types of events. A characteristic of the small to medium-scale events covered herein, which do not have the same destructive dimensions of high-intensity disasters, is that while they represent deviations from the

norm in intensity, they notably occur more frequently than high-impact disasters, posing recurring challenges to the livelihoods of farmers.

These new findings on small- to medium-scale disasters are important, as they are largely overlooked in the literature even though prevention measures implemented with such disasters in mind potentially yield even higher economic benefits than those responding to major disasters, as Mechler (2016) argues. This could be because prevention for high-impact disasters is much more costly than it is for more frequently occurring, lower-intensity events. Generally, high-impact events receive more attention, and consequently their handling receives more evaluation. This has important implications for DRR investments, and highlights the urgent need for more studies on higher frequency, lower impact disasters, where DRR measures are actually more effective and can prevent larger damage from happening, whereas high impact disasters require different means of preparedness.

The small to medium-scale events covered in this study, while lacking the destructive dimension of high-intensity events, occur with greater frequency and so pose recurring challenges to the livelihoods of farmers.

Finally, with its unique collection of case studies in different world regions and across three continents, this study gives important regional depth. It adds to the DRR cost–benefit evidence base notably for South and Central America, as so far, most CBA studies for DRR measures in agriculture have focused on Asian and sub-Saharan African countries (Chadburn *et al.*, 2013). With constantly expanding the scope of this study and adding further country case studies, this advantage may be built on in the future, potentially also to include more countries from the Near East and North Africa region, for which a literature gap exists as well.

Research design

A total of 36 good DRR practices were monitored between 2015 and 2018 on farms in the Plurinational State of Bolivia, Cambodia, Colombia, Guyana, Haiti, Jamaica, the Lao People's Democratic Republic, Pakistan, the Philippines, and Uganda. Their performance was tested and benchmarked against practices previously used on the farms. When conditions permitted, testing was done in contexts of both hazard stress exposure (including dry spells/drought, floods, frost, hailstorms, strong winds, pests and diseases) as well as in the absence of hazards. Doing so made it possible to compare the tested practices' performance in both scenarios. Study sites were selected from among the most hazard-prone developing countries where FAO is actively implementing DRR good practices field projects.

This study did not aim to develop new practices *per se*, but rather to assess the effectiveness of existing agricultural practices in the context of disaster risk and risk reduction. Many were already being used by – or at least known to – farmers. Others had previously been promoted by national extension services as agricultural good practices in general (i.e. not as DRR-specific). And all had already been validated in the past by national or international research institutes as contextually-appropriate agronomic practices.

Key criteria used to select existing technologies and farming practices as potential DRR good practices included:

- Agro-ecological suitability: the practice is suitable under existing and near future climatic, edaphic and topographic conditions for specific site and also, in general, for use in same agro-ecological zones elsewhere.
- Socio-economic feasibility: the practice is economically and socially beneficial and contributes to livelihood improvement even in the absence of extreme events.
- Increased hazard-specific resilience: the practice increases the resilience of agricultural livelihoods against the impacts of climate hazards.
- Environmental co-benefits: the practice brings environmental co-benefits and contributes to sustainable agricultural development.

For the purposes of this study, to rate as a DRR good practice tested practices and technology options had to satisfy all four criteria. It is important to note that this study did not assume that previously applied agricultural practices were bad practices. In fact, local knowledge is often invaluable for the successful reduction of disaster risks at farm level.

Figure 3. Analytical framework

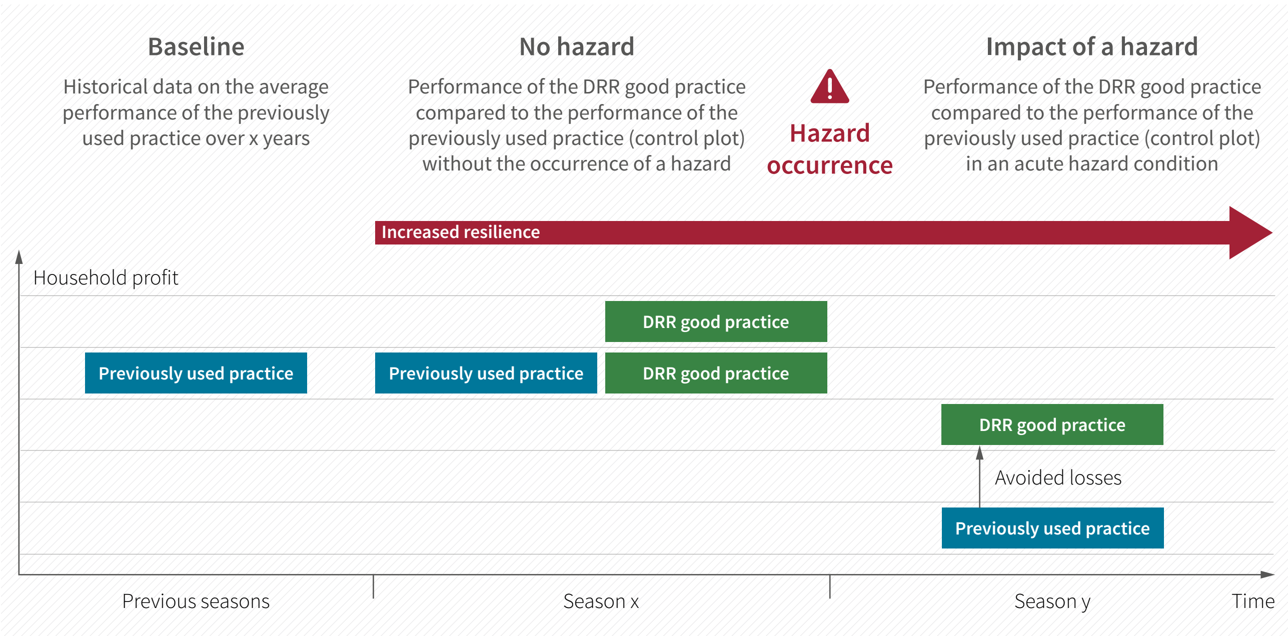
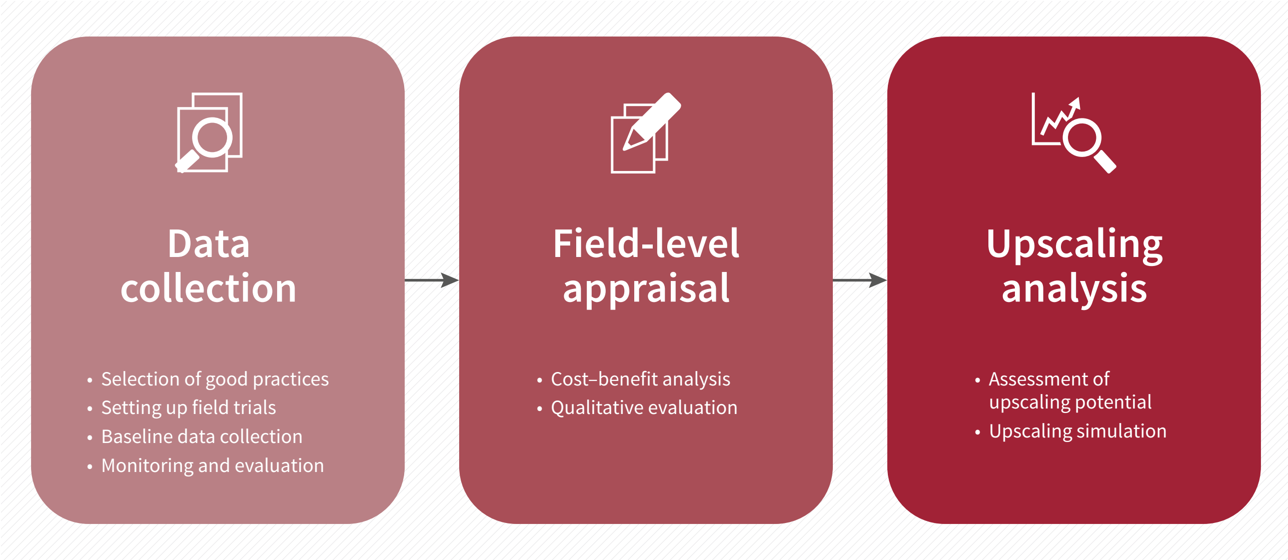


Figure 3 shows the general analytical framework used by this study. Once baseline production data is obtained, the performance of a proposed DRR good practice under both non-hazard and hazard conditions is assessed. Possible outcomes include improved profit and resilience under both scenarios; however, the looked-for result needed to validate a good practice is that it brings at least the same profit as previous practice under non-hazard conditions, and higher profits (also from reduced damage and losses) under hazard conditions.

The methodological process for assessing field level DRR agricultural practices in an iterative manner is illustrated in Figure 4. This process was applied consistently across all participating countries and in the monitoring of all tested practices.

Figure 4. Measuring returns from DRR good practice implementation: the methodological process



Data collection

Selection of testing sites

Background data collection in target villages was conducted by teams of experts with good knowledge of both the practices to be assessed as well as local agro-ecological zones.

An important first step involved identifying households willing to participate in field tests. Initial pre-selected sites and test practices then had to be double checked and validated. Since the practices to be assessed for DRR applications were drawn from already known agricultural practices, as described previously, these follow-up visits by experts aimed to ensure that the testing of selected practices and field plots indeed conformed to the agro-ecological suitability criteria.

Additionally, background information was collected and reviewed if and when available, including good practice implementation guidelines, technical specifications, and results of previous assessments. This desk review offered another way to cross check the agro-ecological and socio-economic suitability of the practices selected for field level testing. It also created a repository of information that could be used to complement field level data and fill potential gaps.

A representative sample of households to be surveyed was identified for each good practice, randomly selecting among the households that had started implementing the good practice in the framework of FAO projects.

In Uganda, farmer Gorreti Asiimwe inspects her mushroom crop.

On-site testing parameters

Once farmers understood and agreed to the monitoring commitments, field trials began. A necessary condition was to divide the field where practices were being assessed into two plots of equal or similar size. One acted as the "test" plot, where a potential DRR good practice was introduced as an innovation. The other plot served as a "control," on which previously used farming practices were continued, unaltered.[6]

Conditions therefore on both the test and control plots were highly similar, and subject to the same general management practices – apart from those parameters modified as part of the DRR good practice package being tested. In a few cases where no control plot could be established (or the good practice was implemented on all available land), a control plot was instead established on an adjacent field, provided that site conditions and the management practices used on the field were the same as or very similar to those formerly applied on the DRR test plot.

[6] The terms "control" and "test" are used figuratively here and throughout the text of this report in the interest of simplifying language and improving readability. Given the field conditions in which the study occurred, it was not possible to perfectly control all variables. For the purposes of this study, "control" and "control plot" refer to the plot of land where the standard practices and technologies previously employed by a farmer were continued, without change. "Test" or "test plot" refer to the plot of land where a new DRR good practices was introduced as an innovation.

Monitoring data from field implementation

Data was gathered and analysed season by season separately for DRR practice test plots and control plots. Performance on both the test and control plots during non-hazard years (when no hazards occurred) was compared to performance under hazard conditions (when one or more hazards occurred). This made it possible to identify, under real field conditions, those practices that:

- perform best in the context of natural hazard exposure
- and in the absence of hazards, also perform at least as well as the conventional agronomic practices used previously (Figure 3).

The actual performance data of the field trials was collected and recorded by farmers and extension workers throughout the respective cropping seasons.

- A **baseline interview** was usually conducted before the start of monitoring. It collected three main pieces of information:
    1. Household profile: size of household, members' age, sex and role.
    2. Productive activities: land area, livestock types, average yields and production for all agricultural activities.
    3. Hazard exposure and extreme events: information on the frequency and intensity of extreme events and disasters that hit the farm/household over the last five years, including specific information on damage and losses to assets and production. Qualitative data was validated through satellite-based weather data.

    When collecting this information, interviewers also took advantage of the opportunity to explain to the farmer the process for collecting quantitative data on test and control plots.

- **Monitoring sheet:** all key information required to conduct a cost–benefit analysis and measure the returns from investing in the DRR good practice vs. usual practices was collected on this form. This included data on input use (e.g. fertilizer, pesticide, labour, seeds, fodder, feed, seedlings, and energy) as well as output (e.g. yields, production quantities). Farmers used the monitoring sheet to record input and output data during the monitoring period for both the good practice and the control plots. At the end of the season/productive cycle, the interviewer compiled all the information provided by the farmer, making sure to use consistent and measurable units.

- **Evaluation interview:** a post-testing follow-up interview focused on registering the perceptions of the farmer regarding the performance of the good practice. It focused in particular on the impact of hazards and extreme events (if any) on the good practice plot and the control plot; differences perceived by the farmer with regard to changes in livelihood resilience; overall benefits; and potential unintended consequences brought by the introduction of the good practice. The interview also

covered the perceived sustainability of continuing the good practice, and captured farmer suggestions on how the practice could be improved. Additionally, households' access to climate information and knowledge was assessed.

In addition, each season the research team compiled a price/costs sheet, listing the prices of all inputs, outputs and capital costs for each practice tested. Depending on the specific good practices monitored, prices included, among others: costs of seeds, fertilizers, pesticides, animal feed; costs of animal treatments and vaccines; capital costs of agricultural assets (such as machinery, tools or infrastructure); average salary of agricultural workers and; farm-gate sales value of agricultural output, including primary and secondary livestock products. A minimum and maximum price/cost was indicated for each item, referencing local prices in the areas where the good practices were implemented.

Table 1. Summary of key data needed to analyse DRR good practices

	Baseline data	Monitoring and evaluation data (for both the good practice and the previously used practice)
Data common for all practices	• Structure of the household • Farm profile (land area for each type of crop, number of livestock, area and volume of fish ponds, if any; data on other activities) • Yields obtained using the usual practice • Most common hazards that the household faced over the last 5 years, and their impact on agricultural production	• List of hazards that affected the farm during the monitored season, and their impact (quantitative and qualitative) • Access to climate information (early warning systems) • Climate data (rainfall, temperature, etc.) at the most granular level • Positive and negative impacts of the good practices (qualitative) • Knowledge acquired thanks to the implementation of the good practices • Sustainability of the good practices: replication during the following season even without external assistance • Maintenance costs
Crops	• Area of the cultivated land • Impact of hazards on production	• Output: number of bags/hectare (or other unit of measurement) + price • Inputs: seeds, fertilizer, pesticides, labour, water use + price
Aquaculture	• Area and volume of the fish pond • Impact of hazards on fish production	• Output: kg of fish harvested/month and size of the pond (or other measurement unit) + price • Inputs: fish fingerlings, feed, labour, water use + price
Livestock	• Number of livestock (per species) • Impact of hazards on livestock production	• Output: average kg/unit and number of units slaughtered/month (or other UM) + number of eggs and litres of milk (when relevant) + price • Inputs: vaccines, feed, labour, water use + price

Data analysis

Data analysis consisted of two components:

1. a CBA that quantitatively assessed the net benefits derived from the good practice as compared to the usual practice, under hazard and non-hazard conditions
2. a qualitative analysis of the social and environmental co-benefits reported by farmers as being associated with the good practice.

Benefit–cost Ratio (BCR)	The total discounted benefits are divided by the total discounted costs. Practices with a BCR greater than one have greater benefits than costs, hence they have a positive NPV. The higher the ratio, the greater the benefits relative to the costs.
Net Present Value (NPV)	The NPV represents the net benefit gained through the use of the good practice. The present (discounted) value of costs is subtracted from the present value of benefits over the appraisal period; the greater the net present value, the more justifiable the practice.

Cost–benefit analysis

This study evaluated the feasibility and effectiveness of new disaster risk reduction good practices versus the performance of formerly used practices, under both hazard and non-hazard conditions.

A cost–benefit analysis is a systematic process for calculating and comparing the benefits and costs of a given action, project or investment. It is derived by assigning a monetary value to all activities performed (either as inputs or outputs) and then comparing those total investments with potential returns. This study's CBA evaluated the feasibility and effectiveness of new DRR good practices versus the performance of formerly used practices, under both hazard and non-hazard conditions, in the following manner:

- **Hazard scenario:** Assessment in seasons/conditions when natural hazards occur; the performance of the DRR good practice in minimizing damage and losses was evaluated and compared to the performance of the practice recorded on the control plot. In the hazard scenario calculation, a hazard stress similar to that reported during the monitored season(s) was assumed to recur annually over the appraisal period; this assumption is acceptable in the framework of this study, given its focus on low-intensity, high frequency hazards.

- **Non-hazard scenario:** The analysis under non-hazard conditions sought to assess the economic feasibility of the good practice when climatic conditions in the analysed season corresponded to long-term averages in the study zone. A good practice that yielded positive net benefits under both hazard and non-hazard conditions was deemed a "no-regret" measure.

The occurrence and severity of natural hazards and stress periods was assessed through farmer interviews and qualified using secondary information and relevant climate data, as available, including satellite-based weather data (Earthmap). When possible, this was compared against 20-year average weather data timelines. The average recurrence period of stress periods and natural hazards was estimated based on historical data collected from questionnaires, as well as national and subnational statistics, or existing studies.

The CBA followed three steps:

1. **Baseline setting,** using historical household data on agricultural production and impact of natural hazards on agriculture and livelihoods over the previous five years. Data gaps were filled using relevant secondary data from analogue case studies, and country/province official statistics.

2. **Valuation**, a monetary value was assigned to the costs, added benefits and avoided costs associated with the implementation of both the good practice and the previously applied practice, under both normal and hazard conditions. Market and non-market-based approaches were used to estimate costs and benefits. In cases when no relevant control practice was available (e.g. when the good practice was totally new for the targeted households), an opportunity cost approach was used. Unpriced goods or services, such as family labour or open-access water resources, were valued using prices of marketed goods as substitutes. The types of costs and benefits varied depending on the type of practice, and included, *inter alia*, the following:

   Costs
   - Upfront capital costs (e.g. costs of machinery and materials, costs of installing equipment/structures)
   - Operations and maintenance (O&M) costs
   - Input costs (e.g. labour, energy, water, fertilizers, pesticides, seeds, feed)

   Benefits
   - Revenues from agricultural production
   - Value of agricultural assets, for instance, livestock

3. **Assessment of net returns.** The NPV of both the good practice and usual practice was calculated and compared to assess the added benefits (such as enhanced productivity) and avoided damage and losses achieved by the good practice. An appraisal period of 11 years was used, applying a 10 percent discount rate. In general, a positive NPV indicates that the present value of benefits outweighed the present value of costs over the assessed time period, and therefore that it is convenient to implement the practice. On the other hand, a negative NPV indicates that upfront- and running costs are not fully repaid by the benefits accrued over time. A practice is more profitable when its NPV is higher.

The second key indicator used to compare practices was a BCR. The BCR indicates how many monetary units (e.g. USD, Ugandan shillings) are obtained for each monetary unit invested, and it is calculated as the ratio of the discounted present value of benefits to the discounted present value of costs.

The cost–benefit analysis aimed to facilitate the identification of the DRR good practice technologies that were most cost-effective and to provide insight into the scope for upscaling them. Sensitivity analysis was done by switching values for the discount rate.

In addition to the case-by-case analysis, practices with similar characteristics have been categorized into five clusters to introduce an additional lens of analysis intended to facilitate strategic planning around DRR investments. These are:

- agronomic practices and livelihood diversification
- structural measures and equipment for improved resilience
- improved varieties and species
- combined application of several mutually reinforcing good practices involving crops
- combined application of complimentary practices involving livestock

In a separate step (discussed at length later), the upscaling potential of selected good practices was calculated. Customized models were used to simulate the potential impacts of upscaling three highly promising good practices. The simulations were based on results obtained from field-level appraisals and took into consideration context-specific potential barriers (for example, agro-ecological and socio-economic constraints).

Qualitative evaluation

Although the profitability of agricultural practices is a fundamental condition for their socioeconomic feasibility, this study considered a number of non-monetary impacts to offer a more integrated, holistic assessment. Various social and environmental benefits were qualitatively evaluated through semi-structured interviews and (when possible) focus group discussions with farmers, pastoralists and fishers. The interviews also helped to identify ‘hidden’ benefits and barriers that might have not been detected through quantitative monitoring.

> By considering non-monetary impacts, such as environmental co-benefits, this study offers a more holistic assessment of the kinds of gains possible through use of farm-level disaster risk reduction good practices.

Key potential benefits of DRR good practices assessed through qualitative interviews include, among others: reduced vulnerability; enhanced income and livelihood opportunities; reduced negative environmental impact; potential to reduce temporary food shortages during/after disasters and improve nutrition; potential to reduce greenhouse gas emissions.

Limitations of the methodology

A few methodological limitations should be considered when examining the results of this study. First, the CBA does not factor in the learning process: benefits are likely to increase incrementally over the years, as farmers become more adept at applying good practices. It was difficult to incorporate this into the analysis, given the variety of contexts and practices analysed. The projected benefits brought by the good practices should thus be considered as conservative.

Secondly, practices involving the use of local resources, such as water harvesting or the application of organic manure, may yield more – and more detectable – benefits over longer implementation and periods. More resources can be collected and used over longer time spans, to cope with high rainfall variability; that, however, necessitate greater planning and long-term balancing of resource use.

Thirdly, although the good practices assessed in this study covers several countries and continents, the samples of some of the cost–benefit analyses are still relatively small (on average 15–20 farmers tested per measure, with a control group of about the same size). Those samples are small, which poses some limitations in drawing broad, inductive, and generalizable conclusions (as also, surveyed farmers usually live and farm in close proximity to each other, under relatively similar conditions). Most other CBA studies focusing on DRR measures in the agriculture sector assess projects at community or project level. So, although the sample sizes used in this study would benefit by being increased, the approach is innovative as it allows direct comparison at farm level.

Finally, assumptions had to be used in some cases to fill season specific data and information gaps (e.g. missing prices, input quantities, animal weights) and calculate good practice costs and benefits. While the assumptions were based on a thorough literature review and expert judgement, they imply a certain degree of uncertainty which should be kept in mind when evaluating final results. ◄

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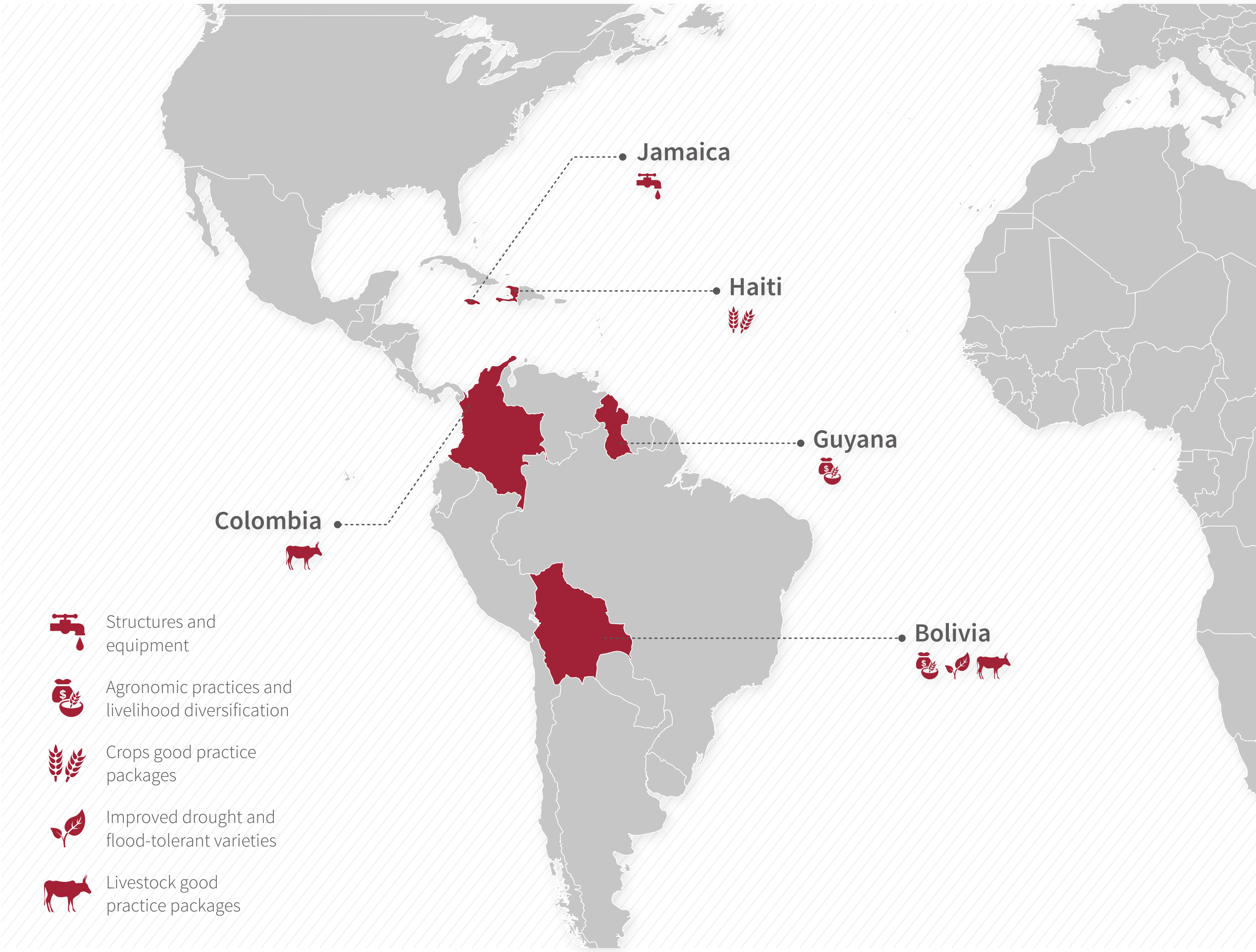
Benefits of DRR good practices at farm level: Evidence from developing countries

This chapter presents the results from FAO's cost–benefit analysis of DRR practices at farm level and includes an overview of all good practices analysed and the contexts in which they were tested. Five selected case studies demonstrating the diversity of DRR good practices covered by the study are featured to complement the analysis and illustrate the range of documented results. The case studies also provide background information that helps explain the how the consolidated CBA results were derived.

A more detailed discussion of the results then follows, comparing the performances of the different clusters of similar DRR good practices.

The chapter closes by looking at qualitative results related to non-quantifiable socio-economic and environmental co-benefits as well as farmers' perceptions of the tested DRR good practices.

Figure 5. World map indicating study sites and the types of DRR good practices implemented and monitored

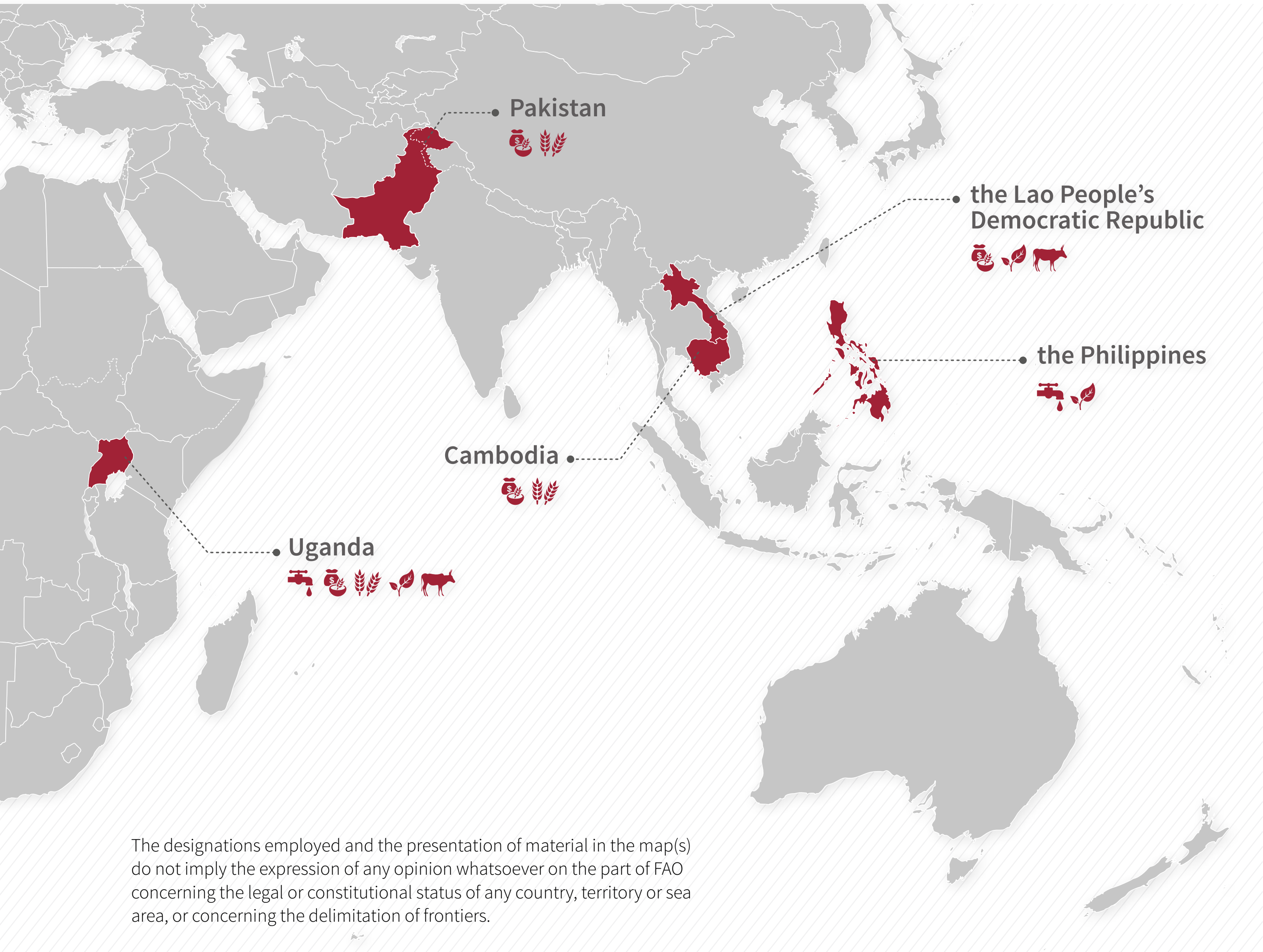


Source: FAO, 2019

Overview of analysed practices

A wide range of farm-level DRR good practices were assessed, including agronomic practices, livelihood diversification strategies, agriculture-related infrastructure interventions, the use of improved drought- and flood-tolerant crop varieties / species as well as diverse combinations of several mutually reinforcing good practices. Testing took place in different countries around the world and under both hazard stress and non-hazard conditions.

Table 2 summarizes all the DRR good practices selected and monitored and provides information on the convention practices with which the DRR practices were contextually compared. The table informs about the agricultural season of assessment and the main hazard addressed. Detailed information on each single practice, including precise guidance for field implementation/replication is available in the FAO TECA Database (see web links in the table). Figure 5 gives an overview on the geographical locations of the different study sites, as well as the types of good practices implemented. This highlights the regional diversity represented in this study.



The designations employed and the presentation of material in the map(s) do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal or constitutional status of any country, territory or sea area, or concerning the delimitation of frontiers.

Table 2. List of good practices assessed by this study

Country	DRR good practice monitored	Previously used practice	Season	Hazard addressed
Bolivia (Plurinational State of)	Cattle raising in silvopastoral systems	Cattle raising without silvopastoral systems	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca3564en/ca3564en.pdf			
	Early-maturing cassava variety	Local cassava varieties	Dry season	Flood
	▸ www.fao.org/3/ca3900en/ca3900en.pdf			
	Camelid raising with livestock shelters (*corralones*) and veterinary pharmacies	Camelid raising with no shelters or veterinary pharmacies	Dry season	Frost and snow
	▸ www.fao.org/3/ca3729en/ca3729en.pdf			
	Cattle raising with livestock refuge mounds, deworming and preventive vitaminization	Cattle raising with no livestock refuge mounds, deworming or preventive vitaminization	Dry season	Flood
	▸ www.fao.org/3/ca3563en/ca3563en.pdf			
Cambodia	Home vegetable gardening with botanical pesticide and liquid compost	Home vegetable gardening with no botanical pesticide or liquid compost	Wet season	Pests, dry spell/ drought
	▸ www.fao.org/3/ca3727en/ca3727en.pdf			
	Home vegetable gardening with rooftop water collection, drip irrigation and plastic mulching	Home vegetable gardening with manual watering and with no plastic mulching	Wet season	Dry spell/ drought
	▸ www.fao.org/3/ca3730en/ca3730en.pdf			
Colombia	Sheep and goat raising with health care and improved corrals	Raising of free roaming sheep and goats, with limited or no use of animal treatment and vitaminization	Wet and dry season	Dry spell/ drought and related increase in animal disease incidence
	▸ www.fao.org/3/ca3954es/ca3954es.pdf			
Guyana	Poultry farming with Black giant chicken breeds for livelihood diversification	No poultry farming	Dry season	Dry spell/ drought, flood
	did not qualify as a good practice; not included in TECA database			

Country	DRR good practice monitored	Previously used practice	Season	Hazard addressed
Haiti	Bean cultivation with conservation agriculture and agroforestry	Bean cultivation with practices such as slash and burn, mounds	Dry season	Pests
	▸ www.fao.org/3/ca4033fr/ca4033fr.pdf			
	Pea cultivation on slopes with live barriers, conservation agriculture and agroforestry	Pea cultivation on slopes without live barriers, conservation agriculture practices, or agroforestry	Wet season	Strong wind, hurricanes
	▸ www.fao.org/3/ca4032fr/ca4032fr.pdf			
Jamaica	Tomato cultivation with rooftop rainwater harvesting and gravity drip irrigation	Tomato growing with manual watering using purchased water	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca4034en/ca4034en.pdf			
	Sweet pepper cultivation with rooftop rainwater harvesting and gravity drip irrigation	Sweet pepper cultivation with manual watering using purchased water	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca4034en/ca4034en.pdf			
the Lao People's Democratic Republic	Indoor mushroom production for livelihood diversification	No mushroom production	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca4450en/ca4450en.pdf			
	Rice cultivation with guano fertilizer to keep moisture and improve soil fertility in paddy fields	Rice cultivation with no application of guano fertilizer	Wet and dry season	Dry spell/ drought, cold wave
	▸ www.fao.org/3/ca3902en/ca3902en.pdf			
	Early maturing rice varieties	Local rice varieties	Wet and dry season	Dry spell/ drought, cold wave
	▸ www.fao.org/3/ca3904en/ca3904en.pdf			
	Flood-tolerant rice varieties	Local rice varieties	Wet season	Flood
	▸ www.fao.org/3/ca3903en/ca3903en.pdf			
	Drought-tolerant aquaculture species	Previously used aquaculture species	Wet and dry season	Dry spell/ drought
	▸ www.fao.org/3/ca4452en/ca4452en.pdf			
	Chicken raising with improved chicken breeds and vaccination	Chicken raising with local breeds	Wet and dry season	Disease, cold wave
	▸ www.fao.org/3/ca3562en/ca3562en.pdf			
	Goat raising in controlled areas and with vaccination	Free roaming goats	Wet and dry season	Disease
	▸ www.fao.org/3/ca3782en/ca3782en.pdf			

Country	DRR good practice monitored	Previously used practice	Season	Hazard addressed
Pakistan	Rice cultivation with line sowing and Alternate Wet and Dry (AWD) method	Rice cultivation with conventional sowing	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca4037en/ca4037en.pdf			
	Vegetable cultivation with ridge sowing, farm yard manure (FYM), multi-cropping and Integrated Pest Management (IPM)	Vegetable cultivation with multi cropping, but no ridge sowing, FYM and IPM	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca4035en/ca4035en.pdf			
	Wheat cultivation with levelling and IPM	Wheat cultivation with no levelling and no IPM	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca4040en/ca4040en.pdf			
	Cotton cultivation with laser levelling, ridge sowing, IPM and compost application	Cotton cultivation with no laser levelling, no ridge sowing, no IPM and no compost application	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca4039en/ca4039en.pdf			
	Wheat cultivation with FYM and compost	Wheat cultivation with no FYM and no compost	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca4038en/ca4038en.pdf			
the Philippines	Fish pots as passive fishing gear to prevent fish losses in case of extreme events	Bottom set longlines	Dry season	Typhoon, strong winds
	▸ www.fao.org/3/ca3907en/ca3907en.pdf			
	Multi-stress tolerant Green Super Rice (GSR)	Local rice varieties	Dry and wet season	Dry spell/ drought, flood, disease
	▸ www.fao.org/3/ca3781en/ca3781en.pdf			
Uganda	Tomato cultivation with rooftop water harvesting and water storage tanks	Tomato cultivation without rainwater harvesting and water storage tanks	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca3908en/ca3908en.pdf			
	Cabbage cultivation with rooftop water harvesting and water storage tanks	Cabbage cultivation without rainwater harvesting and water storage tanks	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca2566en/ca2566en.pdf			
	Ntula cultivation with rooftop water harvesting and water storage tanks	*Ntula* cultivation without rainwater harvesting and water storage tanks	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca2573en/ca2573en.pdf			

Country	DRR good practice monitored	Previously used practice	Season	Hazard addressed
Uganda	Indoor mushroom production for livelihood diversification	No mushroom production	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca2568en/ca2568en.pdf			
	Multi-stress tolerant bean varieties	Local bean varieties	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca2552en/ca2552en.pdf			
	Improved maize varieties	Local maize varieties	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca2545en/ca2545en.pdf			
	Coffee cultivation with mulching, digging of trenches for water retention, organic composting and planting of shade trees	Coffee cultivation with no mulching, no trenches, no organic composting and no shade trees	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca3728en/ca3728en.pdf			
	Banana cultivation with mulching, digging of trenches for water retention, organic composting and improved varieties	Local banana varieties, no mulching, no trenches, no organic composting	Dry season	Dry spell/ drought
	▸ www.fao.org/3/ca4451en/ca4451en.pdf			
	Cattle raising with zero grazing, improved cattle breeds and drought-tolerant fodder	Free ranging cattle, local breed	Dry season	Dry spell/ drought, disease
	▸ www.fao.org/3/ca2565en/ca2565en.pdf			
	Chicken raising in chicken houses and with improved chicken breeds	Free ranging chicken, local breed	Dry season	Dry spell/ drought, disease
	▸ www.fao.org/3/ca4453en/ca4453en.pdf			

Hazard contexts

The occurrence and severity of hazards affecting the monitored field plots were monitored and assessed on the basis of combined analysis of geospatial data and qualitative interviews with farmers. Sub-national level geospatial data of the monthly precipitation and temperature averages and deviations from the monthly average was attained using Earthmap, an FAO-Google tool integrating Google technologies and open-source datasets which makes possible historical analysis of environmental and climatic parameters. The precipitation and temperature data of each location and season monitored is presented in Annex 3. In addition, farmer perceptions about localized hazard patterns and intensities were collected through qualitative interviews.

For the purpose of this study, the combined analysis of climate data and farmers' perceptions led to the following hazard-type specific distinctions between seasons considered "normal" versus those considered to be "hazard impacted":

- Dry spell/drought
  This was the most commonly reported hazard context. All seasons classified as affected by dry spell/drought conditions were characterized by a) rainfall significantly below long-term average in the worst affected month of the season (on average 59 percent below the 37-year monthly average) and b) below average rainfall for at least two consecutive months. In specific cases, such as the Philippines, there was up to 89 percent less monthly rainfall in some districts compared to the 37-year monthly average.

- Flooding
  Farmers reported flooding impacts in two cases. In Camarines Sur, a province in the Bicol region of the Philippines, for one month of the season, a minimum monthly average rainfall that was 37 percent above the multi-year monthly average was observed. In the region of Bato, there was a peak of heavy rain 70 percent greater than the monthly 37-year average. In the Lao People's Democratic Republic, farmer-reported floods were not reflected in monthly sub-national level rainfall data, possibly because they were both localized and intense (according to farmer descriptions).

- Cold waves
  Farmers reported cold waves in three cases, all of which occurred in the Lao People's Democratic Republic during the dry season. Both provinces where cold waves were reported showed a drop in monthly temperature during the dry season ranging from 2.1°C up to -2.3°C, from -9 percent to -11 percent colder than the monthly 27-year average.

- Strong winds
  Farmers reported strong winds affecting agricultural production in Haiti and the Philippines. In the case of Haiti, the specific hazard was Hurricane Matthew, which hit the island with wind speeds up to 240km/h. In the case of the Philippines, no specific data could be collected on wind speed given the localized nature of the event.

- Plant pests and animal diseases
  Pests and diseases were reported during the monitored seasons by farmers in Cambodia, Colombia, the Lao People's Democratic Republic, the Philippines and Uganda and their presence was verified by FAO experts at national level.

Due to the often-localized nature of hazards, the occurrence and/or severity of hazards, as reported by farmers, were in some cases not equally reflected in the monthly average weather data attained through the Earthmap tool. In those cases, this study used information provided by farmers as the primary criteria for classifying a season as hazard affected or "normal".

Quantifying the benefits of DRR good practices – a spectrum of results

Results from field- and farm-level trials were analysed and compared using BCR and NPV as indicators. Since DRR good practice applications at farm level vary in nature and are dependent on the severity of season-specific hazard impacts, the study results must be viewed as being highly context- and location-specific; indeed, a wide range of results was obtained – as was expected. Still, some interesting findings and patterns did emerge, which offer valuable insights to inform DRR planning in agriculture.

Farmers in Pakistan seek to salvage their cotton crop following floods.

▷ CASE STUDY 1. Use of improved maize varieties in Uganda

Uganda's central cattle corridor is frequently affected by severe dry spells. Farmers participating in a Global Climate Change Alliance project, titled "*Agriculture Adaptation to Climate Change in Uganda*", raised concerns regarding the low average yields of local maize types, especially the *Munandi* variety.

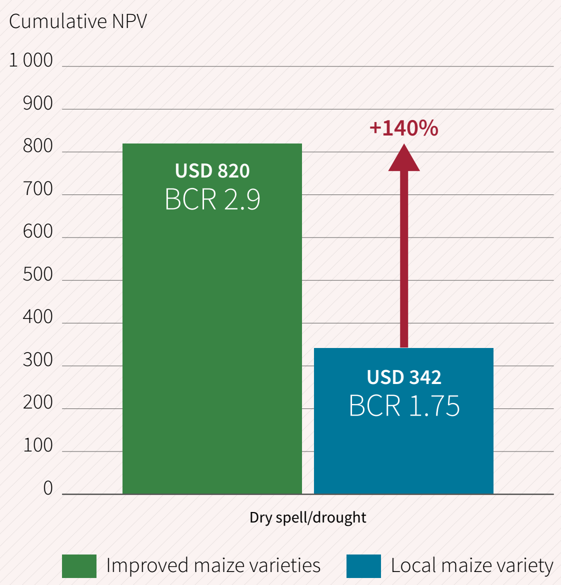
Although the use of local varieties means farmers do not have to buy seeds – they usually save them from one season to the next – those varieties are vulnerable to fluctuating rainfall patterns and prolonged dry periods. Through the project, farmers were introduced to improved maize varieties and trained in a set of good practices to

enhance the resilience of maize production to dry spell/drought conditions. The following varieties were used:

Variety	Attributes	Maturity
MM3	open pollinated, fast maturing, drought-tolerant	90 days
Longe 4	open pollinated, drought-tolerant	100 days
Longe 5	drought-tolerant, quality protein maize	115 days
Longe 7 H	hybrid, drought-tolerant, resistant to the maize streak virus (MSV), the grey leaf spot (GLS), the northern corn leaf blight (NLB) and Turcicum leaf blight	120 days
Longe 10 H	hybrid, drought-tolerant, resistant to MSV, GLS, NLB and Turcicum leaf blight	120 days

During the 2016 dry season (June to August), the performance of the improved maize varieties was monitored on 19 farms in the Kiboga (2) Mubende (3) and Nakasongola (14) districts. All farms were affected by dry spells during the monitoring period. The average rainfall during the season ranged between 5% and 17% below the 37-year average. The district of Mubende was particularly affected, experiencing up to 33 percent less rainfall in August 2016 versus the 37-year average for August.

Figure 6. BCR and cumulative NPV over 11 years under hazard conditions, DRR good practice vs. previously used practice(s) – USD/acre

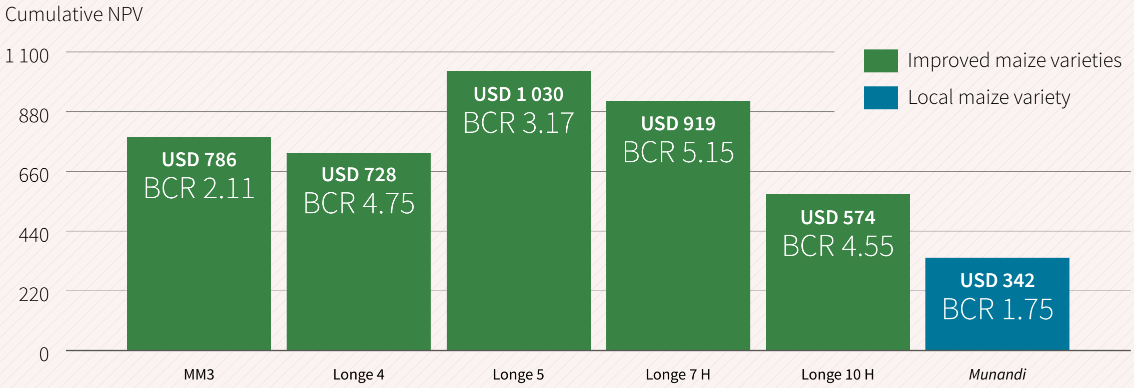


CBAs were conducted using quantitative data for the 2016 dry season collected during the monitoring period. Figure 6 shows that, under dry spell/drought conditions, the average NPVs brought by improved varieties over 11 years more than doubled those gained using the *Munandi* variety. Local varieties did involve higher labour costs than improved varieties did, which possess higher resistance to weeds, pests and diseases. On the other hand, higher seed and fertilizer costs associated with the cultivation of improved maize were more than compensated for by an increase in yields.

The BCR of improved varieties was 2.9 on average, compared to 1.75 for the local variety. Figure 7 shows that in the analysed dry spell scenario, Longe 5 and Longe 7 H were the varieties that brought higher net returns, followed by MM3, Longe 4 and Longe 10 H. The previously used *Munandi* variety yielded the lowest net benefits. The best performing variety (Longe 5) generated net returns almost three times higher than *Munandi*. Benefits under non-hazard conditions could not be analysed, as all farms were affected by a dry spell during the monitoring period. Farmers interviewed perceived the good practice (i.e. the use of the improved variety) positively. All indicated that they would like to replicate its use in the next season as it proved more productive, profitable and resistant to climate-related stresses.

Even improved maize varieties need to be managed properly; cultivation of maize of any variety can alter land fertility and quality – especially when inadequate soil management and the use of chemical inputs (herbicides, pesticides) is involved.

Figure 7. BCR and cumulative NPV over 11 years, DRR good practice vs. previously used practice(s), disaggregated by maize variety – USD/acre



In most districts in the test region where visits were conducted, communities were growing maize, which suggests the adoption of improved maize varieties in this part of Uganda holds great promise, given the observed high returns for farmers. However, because farmers often lack the financial means to buy improved seeds, replicating and upscaling this good practice requires measures to enhance farmers' access to those improved seeds. Furthermore, farmers will need training on soil and water resources management, sustainable maize productivity, and climate-change adaptation strategies.

The average BCR for disaster risk reduction practices was 3.7 in hazard scenarios, meaning that for every dollar invested in disaster risk reduction, the farmer achieved 3.7 dollars in terms of avoided loss/return. Under non-hazard conditions, this rose even further, to a BCR of 4.5.

The BCR of the DRR good practices that were monitored under hazard conditions was generally very satisfactory.

About two thirds of the good practices yielded economic benefits to farmers that were at least twice as high as their upfront investment and production costs. Not surprisingly, BCR values were typically lower for practices monitored under hazard conditions compared to practices monitored under normal conditions, due to the negative impact of hazards on production costs and yields.

The average BCR for DRR practices was 3.7 in hazard scenarios, meaning that for every dollar invested in DRR the farmer achieved 3.7 dollars in terms of avoided loss/return. Under non-hazard conditions, this rose even further, to a BCR of 4.5.

All the good practices analysed can be characterized as no-regret measures, meaning that they generate profit regardless if applied in hazard or non-hazard contexts.

Additionally, the BCR was generally lower for good practices that required relatively high capital investment, such as the purchase and installation of technologies and structures. This reiterates the importance finding ways to appropriately support vulnerable farmers who are willing to invest in

DRR, via for example measures aimed at improving their access to credit, targeted subsidies, or other actions that would need to be determined by local conditions and contexts.

The range of results is quite wide across the various practices assessed.

The highest BCR under hazard conditions was 6.8, obtained in Pakistan through vegetable cultivation that incorporated ridge sowing, farm-yard manure, and integrated pest management. This DRR good practice proved particularly effective in mitigating the impact of dry spells and pests on crop yields, at the same time as it reduced the cost of fertilizers and pesticides. The highest BCR under non-hazard conditions was 32, associated with the use of early maturing cassava varieties introduced in Bolivia's Beni River watershed eco-region. This high return was due to various factors, in particular the high yields and high market prices achieved using the introduced cassava variety.

In some cases, BCR results were lower – yet overall benefits still outweigh the costs for all good practices studied. One exception was in the case of bean cultivation combined with conservation agriculture and agroforestry in Haiti, which had a BCR of 0.5. There, while the good practice did prove more effective in mitigating the impact of pests on bean production than the previous practice, the absolute drop in yields due to pests wiped out the already limited profits gained under normal conditions. A fairly low BCR (1.35) was noted in Uganda for multi-stress tolerant bean varieties, due to the impact of dry spells on yields in combination with the low profitability of beans on local markets.

It is important to highlight that BCR only provides a relative measure of benefits versus costs, and that low BCR figures may still correspond to significant absolute monetary benefits, especially in the case of low-income farming households.

> The average NPV of studied disaster risk reduction good practices was 2.2 times higher than that of previously used agricultural practices, under hazard conditions.

Comparing the NPV of the introduced good practices with the NPV of practices previously used by farmers provides an important indication of the absolute added benefits and avoided losses associated with the use of the new practices. The average NPV of studied DRR good practices was 2.2 times higher than that of previously used agricultural practices, under hazard conditions. This important finding confirms the effectiveness of context-specific, farm-level DRR measures in preventing and or mitigating the negative effects of climatic stress and extreme events on the profitability of cropping, livestock rearing, and fisheries activities.

For some of the instances analysed, the NPV of good practices was significantly higher than the NPV of previous practices, particularly under hazard conditions. For example, in Uganda the use of drought-

resistant banana varieties alongside the adoption of good water and soil management practices (i.e. mulching, contour trenches, organic composting) resulted in net benefits about ten times higher than those of previously applied practices. Another outstanding case was the use of fish pots, instead of bottom set longlines, as a way to mitigate the impact of strong winds on fish capture in the Philippines: the NPV was more than five times higher due to avoided fish losses.

In only a few cases the gap in NPV between good practice and previous practice was narrow. The use of early-maturing rice varieties in the Lao People's Democratic Republic, for instance, only brought 6 percent additional monetary benefits as compared to traditional rice varieties; since the impact of expected cold waves on rice production did not fully materialize in the monitored season, early maturing varieties did not make a difference in that specific case. In only one case the NPV of the tested practice was lower than that of the previous practice: poultry farming for livelihood diversification in hazard prone areas of Guyana. Limited grass availability and high feed prices hindered chicken growth and ultimately net benefits were lower than those gained through casual agricultural work. Accordingly, the practice did not qualify as a DRR good practice according to the criteria used by this study.

Overall, however, a significant positive difference in NPV was found in the large majority of the analysed practices.

The analyses of both BCR and NPV showed that DRR good practices proved successful in reducing the impact of hazards on agricultural production. In some cases, however, the NPV differential and BCR results provided opposite results, due to differences between the two indicators: the former is a difference between absolute values of benefits and costs, while the BCR is a ratio of benefits and costs, thus more sensitive to high upfront investments.

The combined analysis of BCR and NPV results provides insights into the potential for replication and upscaling of the analysed practices. In cases when the BCR of the good practice is lower than that of the previous practice, farmers may be discouraged to uptake the good practice, given the relatively higher upfront investments involved, despite the fact that the absolute monetary benefits (NPV) derived from adoption would be higher. This highlights the importance of providing farmers with comprehensive support by creating an enabling environment for transitioning to improved, hazard-resistant agricultural practices. Improving access to credit (including through micro-credit, savings-and-loan associations etc.) providing continued guidance and capacity building and informing farmers regarding the expected increase in profits will be crucial to overcoming initial barriers to good practice uptake.

One example of the above was provided by a study plot in Uganda, where the BCR of vegetable cultivation was lower for plots where a rainwater harvesting system had been installed than for plots with no rainwater harvesting. Nevertheless, the net absolute benefits obtained using rainwater harvesting were higher than those obtained with only rain-fed production. The lower BCR for the good practice option can be explained as a factor of the high absolute costs involved – in particular the high capital costs of purchasing and installing rainwater harvesting systems. This reinforces the idea that in order to sustain the initial costs of switching from previously used practices to DRR good practices farmers may need financial support. Also: for some good practices, such as infrastructure measures, benefits will increase significantly over the long-term, as the upfront costs are one-off and only maintenance costs need to be accounted for throughout the lifespan of the infrastructure.

A disaggregated analysis shows that, on average, the overall costs of the DRR good practices examined by the study were higher than the costs of previously applied practices.

The increase in input costs was largely due to the purchase of improved crop varieties and animal breeds, as well as additional expenditures on fertilizers and pesticides (mostly organic) and animal treatment and vaccines. A slight increase in labour costs primarily stemmed from the additional time needed by farmers to become acquainted with the new practices. Nonetheless, most of the analysed good practices are expected to contribute to reduced labour efforts over time. Finally, the largest increase in costs was associated with the purchase, installation and maintenance of equipment and structures required for implementation of the DRR good practice. Unlike recurrent costs, upfront investment in structures and equipment are one-offs: for all the analysed DRR good practices, capital investments were more than compensated by added benefits and avoided losses in relatively short time.

All the good practices resulted in higher value of agricultural production compared to previous practices. These benefits – derived chiefly from reduced animal mortality, higher yields, and better-quality produce with an increased sales value – outweighed the elevated costs involved in implementing the good practices.

▷ CASE STUDY 2.
Goat raising in controlled areas and with vaccination in the Lao People's Democratic Republic

Allowing the free roaming of goats may increase their vulnerability to disease, which in turn may lead to lower animal productivity and increased mortality. Floods or dry spells/drought can heighten their vulnerability to illness, due to poor health and body conditions.

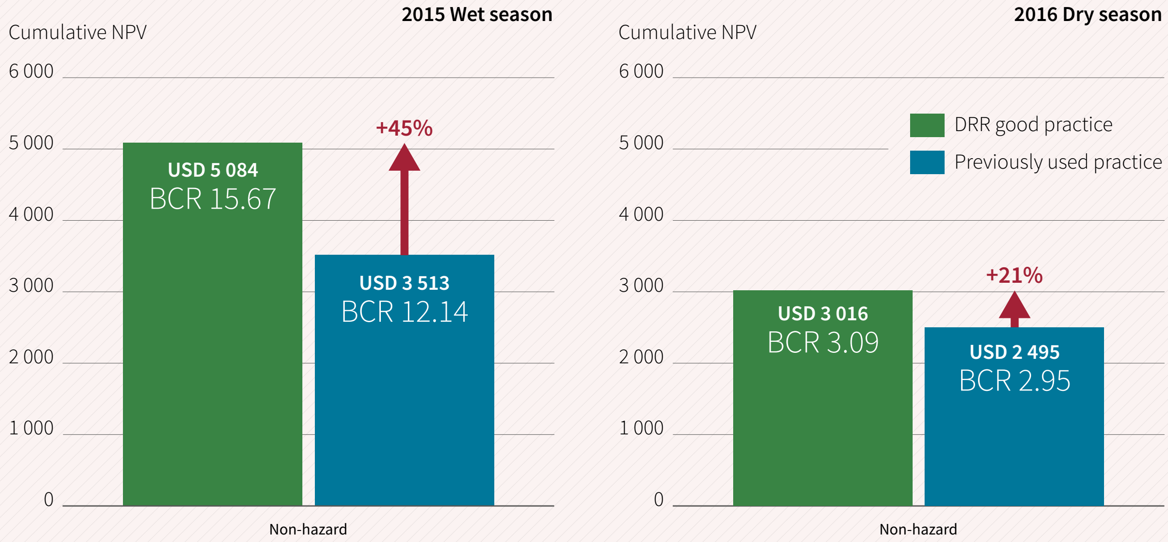
An alternative practice of rearing vaccinated goats in confinement was introduced on small farms in two provinces in the Lao People's Democratic Republic, with the objectives of avoiding and reducing disease-associated animal losses and to curtail disease spread between herds. The enclosed area also helps prevent the theft of goats and limits the negative impacts of free roaming on pasture and soil health and on crop production.

Goats were vaccinated against Foot and Mouth Disease (FMD) and other parasites. They were reared in an enclosed area that included a shelter. Fodder was brought to the goats by the farmers.

During the 2015 wet season, the performance of this DRR good practice was monitored on three farms in Savannakhet province; while during the 2016 dry season, 29 farms were monitored in Savannakhet (3) and Khammouane (26) provinces. The good practice was compared to the performance of goat raising under free roaming conditions. While there was less rain during the study period than normal, in particularly during the rainy season, none of the farms suffered from disease outbreaks; therefore, only the non-hazard scenario could be assessed.

Cost–benefit analyses were conducted using quantitative data collected during the monitoring period in both the 2015 wet season and the 2016 dry season. The analysis looks at the average costs and benefits of raising one goat, assuming each goat is slaughtered after 140 days and immediately replaced. Results from the wet season show an increase of 45 percent in net benefits for the DRR good practice compared to the free roaming practice (in non-hazard conditions). That is, after deducting all costs, goat farmers using the DRR method earned 45 percent more than farmers who did not vaccinate and let goats roam free.

Figure 8. BCR and cumulative NPV over 11 years under non-hazard conditions, DRR good practice vs. previously used practice(s) – USD/average herd size



During the dry season the benefit still occurred but decreased to 21 percent. This can be explained by the fact that during the dry season the availability of water and feed is reduced meaning that spending is increased by their purchase. Also, fodder scarcity causes goats to lose mass and become less productive, and an increased care burden entails additional labour costs.
These impressive results strongly suggest that this DRR good practice package be prioritized for upscaling as an effective resilience-building measure, but adequate technical assistance from extension workers and training for farmers are highly recommended. Additionally, in post-study interviews 100 percent of participating farmers indicated that they would like to continue to implement the DRR good practice package. None mentioned any negative side-effects. At the same time, 72 percent said that they would like to receive additional trainings on vaccination and breeding techniques as well as feed processing, to better implement the package.

Avoiding that goats roam free gives farmers more control over pasture health; so, this good practice brings knock-on environmental co-benefits by avoiding overgrazing and land degradation. It also facilitates the collection of manure for use in crop cultivation. Finally, both villages where the DRR good practice was implemented are prone to floods, and farmers noted that the use of enclosures would make it easier to rescue animals in such cases.

DRR good practice performance in different hazard contexts

Out of the 40 agricultural seasons during which this study assessed various DRR good practices, cold waves, frost and snow occurred in four seasons; flooding conditions took place in two; 21 were hit by drought or dry spells, while; two were affected by strong winds. Those seasons during which no hazard stress occurred have been excluded from this part of the analysis.

Table 3 shows the average benefits gained through the use of analysed DRR practices as a response to similar/same hazard types. The BCR and NPV differentials for each of the four hazard contexts are high. It stands out, however, that the highest NPV increase was achieved via good practices responding to strong winds (229%) and drought and dry spells (145%).

Table 3. Performance of good practices by hazard type

Hazard type addressed	Number of good practices monitored under hazard conditions	Average % increase in net benefits	Average BCR	Average resilience score (qualitative ranking by farmers)
Cold wave	4	31%	2.4	4.9
Dry spell/drought	21	145%	3.1	4.7
Flood	2	71%	2.3	4.9
Typhoon/strong wind	2	229%	4.2	3

Similarly, the highest average BCR was obtained by good practices implemented in dry spell (3.1) and strong wind (4.2) contexts. While the figures for cold waves and floods are less noteworthy, the assessed DRR good practices still outperform previous practices, confirming the value of these measures in addressing those specific hazards. Importantly, the high NPV of good practices addressing strong winds is largely driven by the excellent performance of fish pots as a substitute for bottom-set longlines in the Philippines case study. This good practice significantly reduced losses of fish catch under strong winds conditions while simultaneously reducing fishing costs.

Beneficiary farmers assigned very high scores to the effectiveness of good practices in responding to all hazard types, except those addressing strong winds. This is due to the case of Haiti, where despite the benefits brought by planted live barriers, extremely strong winds from hurricane Matthew caused extensive crop damage. Overall, the farmers who tested the good practices appreciated their impact on building livelihood resilience.

The majority of practices tested involved measures to mitigate the impacts of dry spells and/or drought. This focus stems from the fact that the agriculture sector is highly impacted by these event types; indeed, a large share of damage and losses in agriculture in the countries analysed occur as a result of dry spells/drought.

It merits pointing out that country-levels study partners helped select the practices to be studied, so this focus also reflects the great need they see for good practices that build resilience to drought and dry spells. It is therefore extremely important to assess, validate and implement solutions targeting these threats. An outstanding example of one such good practice is that implemented for banana cultivation in Uganda, which yielded a BCR of 2.2 under hazard conditions and a stunning 886 percent increase in NPV compared to the usually employed practice. (This good practice was chosen for an additional upscaling analysis in the next chapter.)

Equally outstanding is the outcome achieved by introducing rooftop rainwater harvesting structures combined with gravity drip irrigation as a dry spell mitigation measure for tomato growing in Jamaica: with a BCR of 4.3 and an NPV increase of 131 percent, this points to the high importance of sustainable water resources management in dry areas.

For good practices responding to cold waves, frost and snow-related damage, all four such good practices analysed showed similar BCRs, ranging between 2.2 and 2.7. Increases in NPV were fairly low, except for one practice in the Lao People’s Democratic Republic that involved the introduction of improved chicken breeds and vaccination measures. That generated an impressive increase of 100 percent in NPV, due to the higher disease resistance of the new breeds.

Both practices tested under flooding conditions were targeted to rice growing farmers in Southeast Asia. In particular new, more flood-tolerant rice varieties were tested in the Lao People's Democratic Republic and the Philippines and provided significant differences in yields compared to previously used rice varieties.

Overall, this analysis confirms the importance of aligning investment in farm-level measures with the main hazards that usually affect the targeted areas. Drought and dry spells pose the greatest threat to agriculture, which is why a focus on measures in this field emerges. In the case of good practices responding to dry spells/droughts, the very high increase in NPV as compared to a more modest (though still high) average BCR could be interpreted as justifying enhanced government, private sector or donor support, both in assisting with upfront capital investments as well as in creating an enabling environment to kick-start and facilitate the implementation of promising resilience strategies.

DRR good practice performance by similar types of practices

In addition to the analysis organized according to the main hazard addressed, here the study groups DRR good practices into five clusters according to their type or main characteristics, namely:

1. agronomic practices and livelihood diversification measures
2. measures involving the use of new or modified structures or equipment
3. the introduction of drought- and flood-tolerant varieties (crops) and species (livestock)
4. crop-specific good practice packages
5. livestock-specific good practice packages

Within each of the five categories, aggregated results are presented. For each category cluster, one relevant case study is discussed in more detail.

Agronomic practices and livelihood diversification measures

DRR good practices clustered here include practices such as mulching and trenching; use of sustainable inputs (e.g. organic fertilizers and pesticides); agroforestry activities, such as planting shade trees; intercropping; innovations in planting, such as line-sowing, and; livelihood diversification measures. Clustering these practices into a consolidated category of agronomic practices and livelihood diversification" reveals an average BCR of 2.8 under non-hazard conditions and a BCR of 2.5 in the contexts of drought or dry spells. The BCRs of good practices under this cluster are higher than the BCRs of the previous practices. Although some of these agronomic practices entail higher upfront and running costs, these are not disproportionately higher than those of previous practices, and thus may not represent a major barrier to immediate uptake by farmers.

Compared to the agronomic practices previously used on study sites, net benefits resulting from the use of the introduced DRR good practices and livelihood diversification strategies increased 162 percent under non-hazard conditions and 146 percent under hazard conditions. Due to low upfront costs, both agronomic practices and livelihood diversification strategies offer easily-accessible options for farmers working in the cropping sector to increase resilience to hazards.

Table 4. Performance of practices in the agronomic practices/livelihood diversification cluster

Country	Good practice	Hazard occurred	BCR non-hazard scenario (BCR of previously used practice in brackets)	BCR hazard scenario (BCR of previously used practice in brackets)	NPV increase (compared to previously used practice) non-hazard scenario	NPV increase (compared to previously used practice) hazard scenario
Bolivia (Plurinational State of)	Cattle raising in silvopastoral systems	Dry spell/ drought	n/a	3.8 (1.9)	n/a	+109%
Cambodia	Home vegetable gardening with rooftop water collection, drip irrigation and plastic mulching	None	1.9 (1.8)	n/a	+18%	n/a
the Lao People's Democratic Republic	Indoor mushroom production for livelihood diversification	None	1.7 (n/a)	n/a	+98%	n/a
	Rice cultivation with guano fertilizer to keep moisture and improve soil fertility in paddy fields (dry season)	Dry spell/ drought	n/a	2.4 (2.3)	n/a	+2%
	Rice cultivation with guano fertilizer to keep moisture and improve soil fertility in paddy fields (wet season)	Cold wave	n/a (1.5)	1.5 (1.3)	n/a	+78%
Pakistan	Rice cultivation with line sowing and Alternate Wet and Dry (AWD) method	Dry spell/ drought	n/a	1.8 (1.5)	n/a	+85%
Uganda	Indoor mushroom production for livelihood diversification	Dry spell/ drought	5.3 (n/a)	4.7 (n/a)	+827%	+633%

n/a: refers to situations in which data could not be collected for the corresponding hazard/non-hazard condition(s)

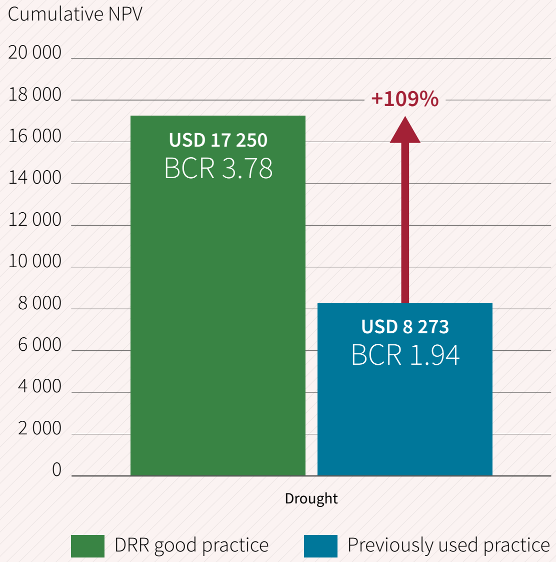
▹ CASE STUDY 3.
Cattle raising in silvopastoral systems in the Plurinational State of Bolivia

Located in the south-eastern part of Bolivia (Plurinational State of), the Chaco eco-region consists of a large expanse of arid flatland. The Chaco is characterized by an irregular climate, marked by high thermal and rainfall variations. Average annual rainfall varies between 450 millimetres and 700 millimetres (mm) and is concentrated (about 85 percent of the year's total) between December and March. The area usually sees a dry period between May and October. Given these specific climatic conditions, the availability of pastoral resources is generally scarce, especially during the dry season.

Prior to the introduction of the DRR good practices, cattle were raised without the benefit of silvopastoral approaches and were fed using only trees and creeping herbaceous species. During drought periods, animals tended to suffer for several months resulting in weakened body conditions and heightened mortality.
In this context, as a DRR innovation the grass species Tangola and Camerún panameño were intercropped to diversify forage sources and strengthen existing tree-based forage systems, thereby enhancing the resilience of cattle to recurrent drought.

In this agroecosystem, trees present the foundation of pasture productivity and provide natural shelter for animals, making them a key element in coping with recurrent dry spells or drought. Also, leaves and tree litter can be used as forage during the dry season. But diversification of forage resources via the introduction of Tangola and Camerún panameño served to further diversify and increase forage availability (and quality) during the dry season, leading to greater animal weights. It also contributed to the better preservation of soil quality. However, land allocation and management under silvopastoral systems can be a challenge, and the groundwork for any such systems must in place in advance, as management practices must start in a timely fashion at the beginning of the rainy season.

Figure 9. BCR and cumulative NPV over 11 years under hazard conditions, DRR good practice vs. previously used practice(s) – USD/average herd size



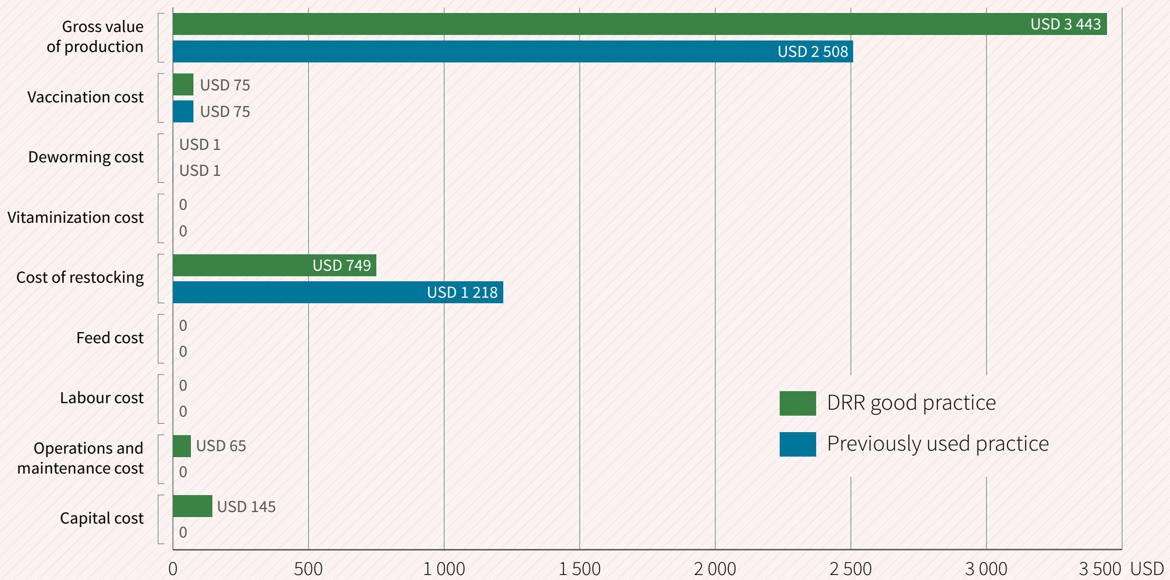
Cost–benefit analysis:

The performance of the improved practice was monitored in 2016 on seven farms in the Curuyuqui community in the municipality of Cuevo and on three farms of the Pueblo Nuevo community in the municipality of Boyuibe.

At both sites, very strong rains occurred at the beginning of the season, followed by a severe lack of rainfall during the remainder of the season. In Boyuibe, deficits of up to 45 percent less rain in September 2016 versus the 37-year monthly average were registered; in Cuevo, in September 2016 shortfalls of up to 39 percent compared to the 37-year monthly average were detected.

Since all farms were affected by the 2016 drought, the performance of good practice could only be assessed under hazard conditions. Data collected from good practice plots were compared with data collected from control plots on the same farms, or from neighbouring farms where the good practice had not yet been implemented.

Figure 10. Average costs and benefits – USD/average herd size/year



The costs and benefits were calculated using the average number of cattle on the monitored farms (i.e. 56 head). Results show that when prolonged drought occurs the cumulative net benefits of the good practice are about 109 percent higher than the benefits of practices previously used.

Shifting to cattle-raising in silvopastoral systems in the Bolivian Chaco means to reduce impacts of drought cleared yielded important benefits, with the BCR of the introduced good practice clocking in at 3.78, versus 1.74 for the previously applied practice.

Figure 10 illustrates the average annual costs and benefits/farm. No labour costs were calculated as no labourers were hired to work in monitored farms. The cost of restocking is calculated, assuming the goal would be to maintain a constant average herd size over time.

No labour costs were calculated as no labourers were hired to work in monitored farms. The cost of restocking is calculated, assuming the goal would be to maintain a constant average herd size over time. The replacement cost of cows assumes that adult cows are bought for restocking. Additionally, feed cost is treated as null, since free ranging is practiced in the case study area. The higher performance of the good practice is mainly attributable to a significant reduction of mortality rates, combined with an increase in average animal weight leading to an increase in production and a decrease in restocking costs.

Overall, pastoralists perceived the DRR good practice very positively: all those interviewed said they would be willing to replicate this DRR good practice over the subsequent years as they saw it as giving them the option of feeding more animals versus conventional open forest grazing approaches. They also gave the practice as a drought risk reduction measure a rating of five out of five underscoring its resilience-boosting potential in areas with similar conditions/ contexts.

Significant environmental co-benefits can also be attributed to the new good DRR practice, since silvopastoral systems can sequester significant amounts of carbon in soils as a result of improved pasture quality and enhanced standing tree biomass. Furthermore, leaves that fall on the ground add organic matter to soil, contributing to the improvement of soil quality that supports the growth of forage grass during summer season.

Rough seas and poor weather can cause small-scale fishers to lose both gear and harvests.

Structures and equipment

Small-scale DRR agricultural structures and equipment represents another strategic entry point for reducing risk exposure and enhancing the resilience of smallholders in hazard-prone areas. This study's infrastructure focused cluster specifically included practices requiring an upfront capital investment for the purchase and installation of DRR technologies. The good practices were monitored in small-scale farming and fishing communities in Uganda, Jamaica, and the Philippines.

The aggregate quantitative results for the DRR good practices combined in this cluster exhibit an average benefit–cost ratio of 4.6 under non-hazard conditions and a BCR of 3.9 under hazard conditions. The majority of practices analysed under this cluster show lower BCR than previous practices. This is largely due to the higher upfront capital costs required to purchase, install and maintain the new structures and equipment. However, compared to practices previously used by farmers on study plots, the absolute net benefits increased by 112 percent under non-hazard conditions and by 142 percent under hazard conditions. While upfront investments can be high, agriculture-related infrastructure measures lead to higher profits over time. This highlights the importance of providing support (e.g. subsidies, access to credit) to farmers who are willing to adopt these practices but are discouraged due to financial barriers. All the implemented practices are also no-regret options that bring benefits even in the absence of disasters.

Table 5. Performance of practices in the structures and equipment cluster

Country	Good practice	Hazard occurred	BCR non-hazard scenario (BCR of previously used practice in brackets)	BCR hazard scenario (BCR of previously used practice in brackets)	NPV increase (compared to previously used practice) non-hazard scenario	NPV increase (compared to previously used practice) hazard scenario
Jamaica	Tomato cultivation with rooftop rainwater harvesting and gravity drip irrigation	Dry spell/ drought	n/a	4.3 (3.8)	n/a	+131%
	Sweet pepper cultivation with rooftop rainwater harvesting and drip irrigation	Dry spell/ drought	n/a	2.5 (2.6)	n/a	+29%
the Philippines	Fish pots as passive fishing gear to prevent fish losses in case of extreme events	Typhoon, strong wind	2.5 (1.1)	2.5 (1.1)	+222%	+405%
Uganda	Tomato cultivation with rooftop water harvesting and water storage tanks	Dry spell/ drought	n/a	2.2 (5.8)	n/a	-5%
	Cabbage cultivation with rooftop water harvesting and water storage tanks	Dry spell/ drought	n/a	3.4 (11.6)	n/a	+86%
	Ntula cultivation with rooftop water harvesting and water storage tanks	Dry spell/ drought	n/a	6.6 (16.7)	n/a	+102%

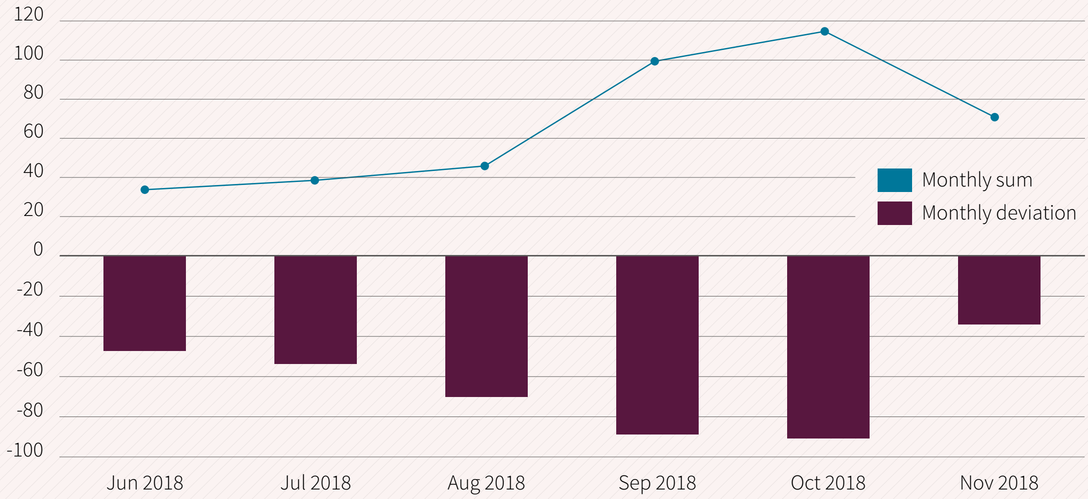
n/a: refers to situations in which data could not be collected for the corresponding hazard/non-hazard condition(s)

▷ CASE STUDY 4.
Tomato and sweet pepper cultivation with rooftop rainwater harvesting and gravity drip irrigation in Jamaica

Southern St. Elizabeth is a highly agriculturally productive parish in Jamaica. However, the parish is prone to dry spells, prolonged drought, high temperatures during summer months (during June to September) and high winds. The 30-year mean for rainfall is 1399 mm/year while the mean maximum temperature is 32°C. Conditions favour high evaporation and reduced water availability. Due to regular temperature increases, the area is also prone to frequent outbreaks of beet armyworm. Over the years, farmers have built resilience to drought by using soil mulch (Guinea grass) and labour-intensive hand watering. Most farmers purchase irrigation water, but its availability is scarce during drought.

For the studied DRR good practice, a rain water harvesting system was introduced, consisting of rooftop catchments, a 1 000-gallon plastic storage tank, and a gravity-drip irrigation system. The practice made farmers more resilient to dry spells/drought, allowing them to produce crops

Figure 11. Rainfall during the study period



Source: Earthmap, 2019

during the dry season and prolonging the crop harvesting cycle while generating additional income.

The good practice was introduced on 35 fields across the parish, located in Yardley Chase, Southfield and South St. Elizabeth Districts. Twenty farmers' plots were selected for data collection including ten tomato plots and ten sweet pepper plots under drip irrigation. Results were compared against yields obtained from 20 control plots where farmers watered manually.

As Figure 11 shows, there was a severe lack of rainfall during the monitored season in St. Elizabeth. The precipitation deficit ranged from as low as -48 percent compared to the 37-year monthly average precipitation.

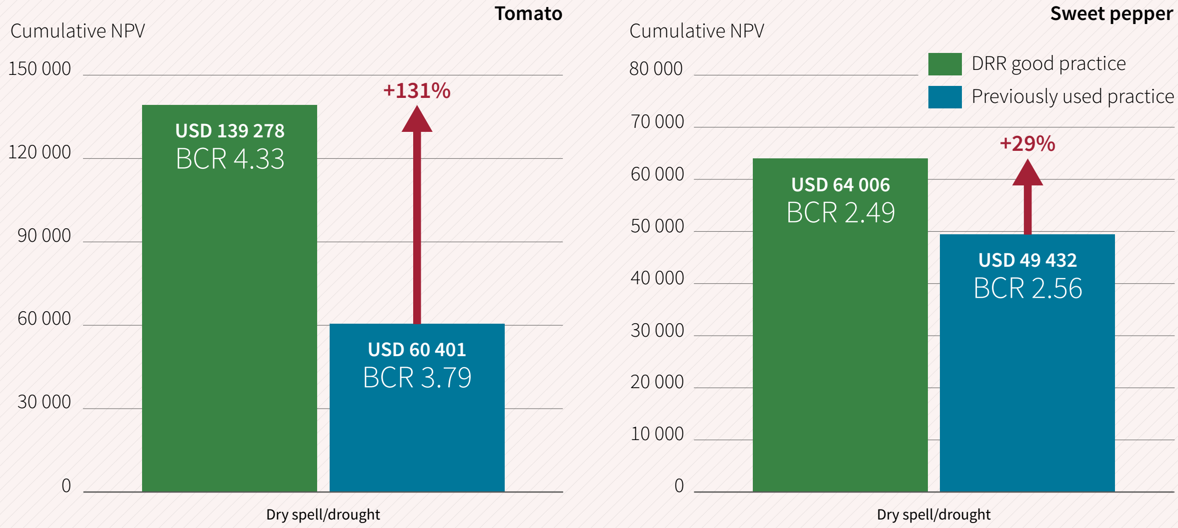
Using data collected between June and November 2018, cost benefit analyses were conducted for the introduction of the rain water harvesting system for tomato and sweet pepper production. The analysis projected the cumulative NPV of benefits obtained per each hectare of tomatoes or sweet peppers over a period of 11 years (applying a 10 percent discount rate).

As Figure 12 shows, both tomato and sweet pepper production benefitted greatly from the introduction of the good practice, with an NPV increase of 131 percent for tomato production and a 29 percent in sweet pepper production compared to the previously applied practice. The difference in net benefits was larger for tomatoes than for sweet pepper. Indeed, the good practice applied to sweet pepper production shows a lower BCR than that of the previous practice, pointing to high upfront capital costs as a potential barrier to uptake.

While upfront capital costs of purchasing and installing rainwater harvesting, and drip irrigation system are high, they are more than compensated for by the value of production. A key driver of higher yields was an increase in the number of plants cultivated, as farmers were able to plant more seedlings on the irrigated good practice plot than on the control plot. The cost of water was higher under the good practice than previous practice, chiefly because it was initiated during a dry spell meaning that farmers were not able to collect rainwater but rather purchased trucked-in water. While its performance was not measured outside of the dry season, the good practice will likely generate higher benefits in subsequent seasons, as farmers will be able to harvest rainwater during the rainy season (Oct–Nov) which they will be able to use in the next dry season.

All farmers interviewed said that they would be willing to replicate this DRR good practice in subsequent seasons as it contributed to increase yields and reduced watering-related labour

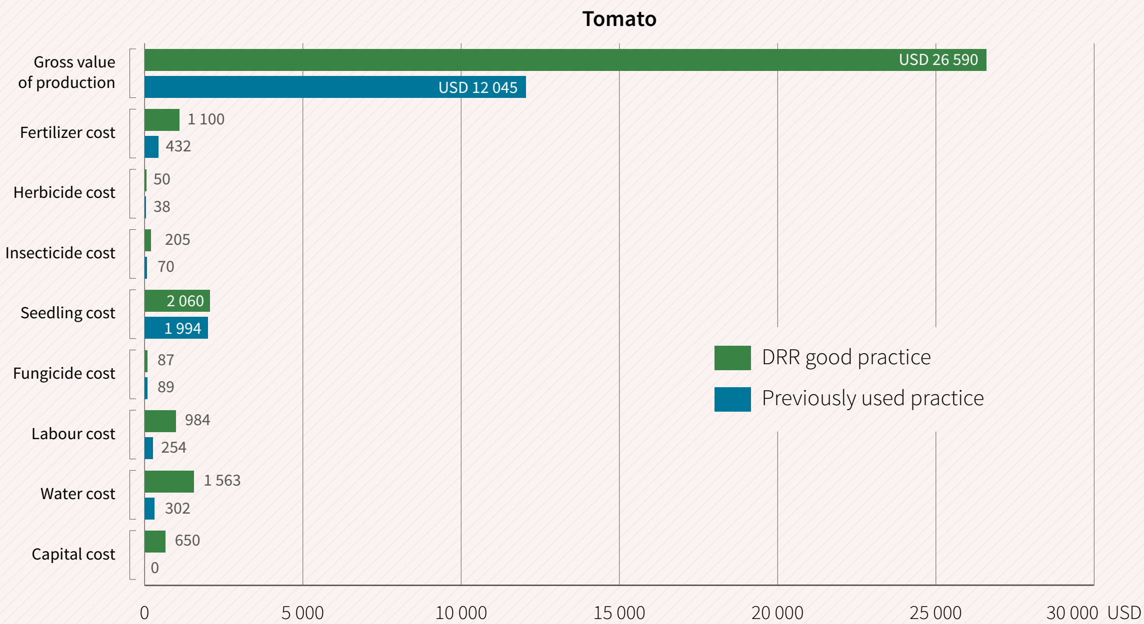
Figure 12. BCR and cumulative NPV over 11 years under hazard conditions, DRR good practice vs. previously used practice(s) – USD/hectare

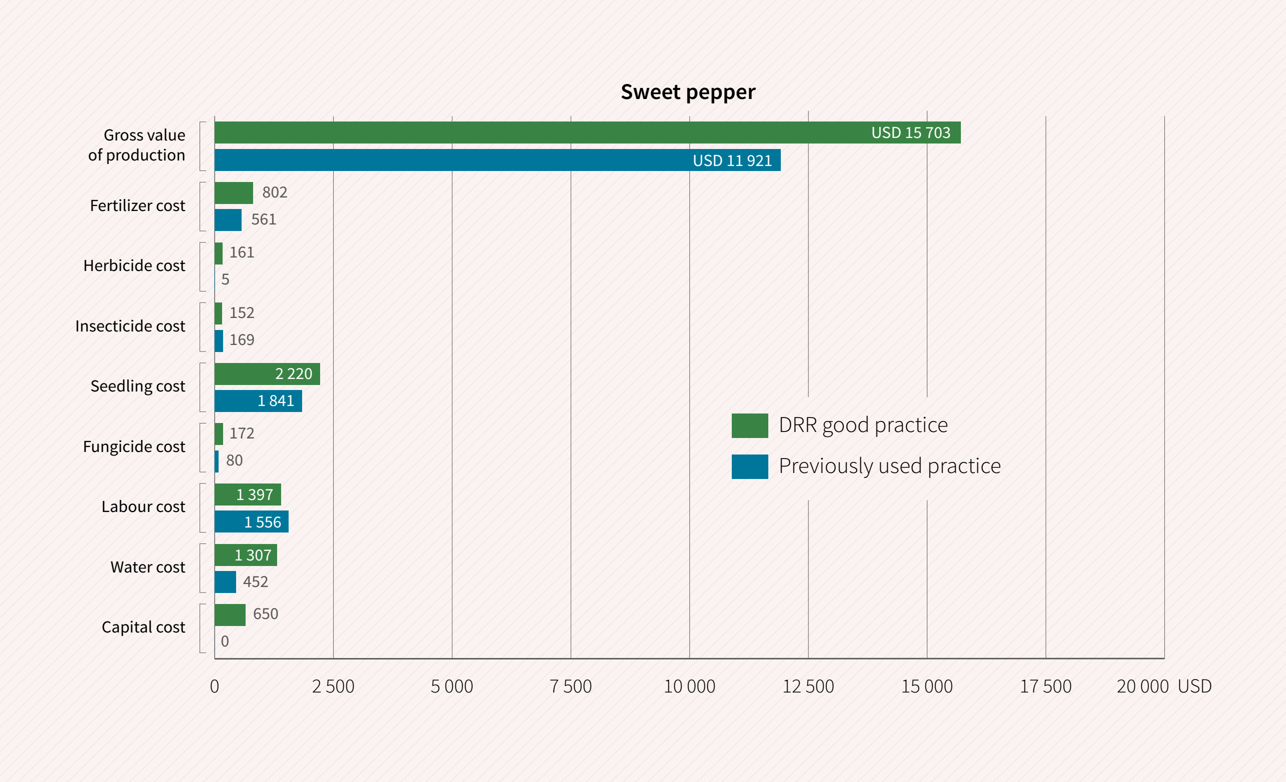


efforts. Farmers gave the practice's performance in the face of extreme events a rating of 4.9 out of 5. Most (93 percent) also indicated that they acquired new knowledge, especially regarding how to construct water harvesting sheds, use drip irrigation systems, and apply fertilizers. In addition, the good practice brings environmental benefits, as it allows a more efficient use of water.

The practice has great potential as a resilience building measure in contexts similar to those found in Southern St. Elizabeth. The upfront capital costs of the rainwater harvesting / drip irrigation system may represent an initial barrier to uptake. Support should therefore be provided to farmers in this regard, for example in the form of improved access to credit, or subsidies.

Figure 13. Average costs and benefits during the dry season – USD/hectare/season





Improved drought- and flood-tolerant varieties and species

This category includes good practices that introduced improved, stress-tolerant varieties and species.

Improved crop varieties for rice, beans, maize and cassava were tested in the Lao People's Democratic Republic, the Philippines, and Uganda. In addition, the performance of drought-resistant fish species in aquaculture was monitored in the Lao People's Democratic Republic. The seven good practices listed below were observed on 456 small-scale farms and fishing communities between 2015 and 2016.

This set of practices shows the highest average BCR, coming in at 6.6 in non-hazard conditions and 5.1 in hazard scenarios. The BCR of good practices are higher than those of previous practices, indicating that costs may not represent a major barrier to immediate uptake by farmers. On the other hand, farmers identified the limited availability of improved varieties and species in local markets as an important barrier to uptake.

Compared to usually employed practices, net benefits increased 73 percent in non-hazard conditions; that grew to 88 percent under hazard conditions. This was largely due to a considerable increase in production that resulted from the use of improved varieties, and which translated into improved household food security and resilience.

These benefits notwithstanding, an issue that must be considered during any replication or upscaling are unintended side-effects as reported by some participants, in which widespread uptake of the new varieties leads to scarcity of conventional/local varieties, with possible implications for agricultural biodiversity. Such environmental and social concerns must be considered when designing interventions based on new varieties.

Table 6. Performance of practices in the drought- and flood-tolerant varieties and species cluster

Country	Good practice	Hazard occurred	BCR non-hazard scenario (BCR of previously used practice in brackets)	BCR hazard scenario (BCR of previously used practice in brackets)	NPV increase (compared to previously used practice) non-hazard scenario	NPV increase (compared to previously used practice) hazard scenario
Bolivia (Plurinational State of)	Early-maturing cassava variety	None	32 (11.8)	n/a	+189%	n/a
the Lao People's Democratic Republic	Early-maturing rice varieties – dry season	Cold spell	2.3 (2.2)	2.3 (2.2)	n/a	+116%
	Early-maturing rice varieties – wet season	Dry spell/ drought	n/a	1.5 (1.3)	0%	+6%
	Flood-tolerant rice varieties	Flood	1.4 (1.2)	1.4 (1.2)	+149%	+109%
	Drought-tolerant aquaculture species	Dry spell/ drought	6.5 (5.4)	2.7 (2.2)	+25%	+46%
the Philippines	Multi-stress tolerant Green Super Rice (GSR) varieties – dry season	Dry spell/ drought	4.3 (4)	3.5 (2.8)	+19%	+53%
	Multi-stress tolerant Green Super Rice (GSR) varieties – wet season	Flood	6.1 (4.6)	3.1 (2.8)	+58%	+33%
Uganda	Multi-stress tolerant bean varieties	Dry spell/ drought	n/a	1.4 (1.4)	n/a	+123%
	Improved maize varieties	Dry spell/ drought	n/a	2.9 (1.8)	n/a	+140%

n/a: refers to situations in which data could not be collected for the corresponding hazard/non-hazard condition(s)

Combined packages involving crops

The study also covered a range of interventions that combined, in one testing plot, multiple and complementary DRR good practices to maximize benefits and risk reduction potential. To allow for a comparative analysis between interventions, these were considered in one top-level analytical cluster spanning both crop-related and livestock-related measures, collectively titled "good practice packages". Within this cluster, both crop- and livestock-related packages were also considered independently. The livestock-related packages are discussed in the next section.

A total of nine crop-related DRR good practice packages were tested in Cambodia, Haiti, Pakistan and Uganda. Most aimed at increasing soil moisture and water retention to sustain crop production during dry seasons or dry spells; some also involved the introduction of improved varieties.

This crop-related good practice package cluster returned high percentage increases in NPVs compared to previously applied practices, showing increases of 154 percent in hazard cases and 140 percent under non-hazard scenarios, on average. This indicates that very high benefits can be gained through the combination of context-specific DRR practices. In some cases, however, the BCR of previously used practices was higher than that of the new, introduced good practice packages. To a great extent, this can be explained by the higher upfront investment costs required for the analysed combined packages. In absolute terms, however, they still pay off over the longer lifecycle of the intervention.

Coffee being grown using agro-forestry techniques, Uganda.

Table 7. Performance of practices in the combined packages (crops) cluster

Country	Good practice	Hazard occurred	BCR non-hazard scenario (BCR of previously used practice in brackets)	BCR hazard scenario (BCR of previously used practice in brackets)	NPV increase (compared to previously used practice) non-hazard scenario	NPV increase (compared to previously used practice) hazard scenario
Cambodia	Home vegetable gardening with rooftop water collection, drip irrigation and plastic mulching	None	1.1 (0.3)	n/a	n/a	+115%
Haiti	Pea cultivation with live barriers, conservation agriculture and agroforestry	Typhoon, strong wind	6.8 (8.5)	6 (7.9)	+110%	+52%
	Bean cultivation with conservation agriculture and agroforestry	Plant pest	1 (0.3)	0.5 (0.2)	+102%	+47%
Pakistan	Vegetable cultivation with ridge sowing, farm yard manure (FYM), multi-cropping and Integrated Pest Management (IPM)	Dry spell/ drought	n/a	6.8 (4.3)	n/a	+34%
	Wheat cultivation and levelling and IPM	Dry spell/ drought	n/a	2.7 (2.3)	n/a	+53%
	Cotton cultivation with laser levelling ridge sowing, IPM and compost application	Dry spell/ drought	n/a	3.9 (2.7)	n/a	+35%
	Wheat cultivation with FYM and compost	Dry spell/ drought	n/a	1.9 (2)	n/a	+21%
Uganda	Coffee cultivation with mulching, digging of trenches for water retention, organic composting and planting of shade trees	Dry spell/ drought	n/a	3.9 (17.5)	n/a	+14%
	Banana cultivation with mulching, digging of trenches for water retention, organic composting and improved varieties	Dry spell/ drought	n/a	2.2 (1.2)	n/a	+886%

n/a: refers to situations in which data could not be collected for the corresponding hazard/non-hazard condition(s)

▹ CASE STUDY 5.
Pea cultivation with live barriers, conservation agriculture and agroforestry in Haiti

Owing to its geographic location in the hurricane belt, Haiti is exposed to recurrent storms which cause extensive damage and losses to the agriculture sector. In 2008, for instance, the island nation was hit by four major storms and hurricanes (Fay, Gustav, Hanna and Ike), whose economic impacts corresponded to roughly 15 percent of its gross domestic product (GDP).

The communes of Bainet and Grand Goave are primarily comprised of semi-humid lowlands. Average annual temperature is in the range of 26–27°C and annual rainfall averages 1 300–1 400 mm. Primary subsistence crops in these municipalities are maize, beans, Congo peas and wild peas. Over a one-year cycle, two growing seasons for peas are possible: The main one, in spring, extends from March to June; the secondary winterer season runs from July to October. The chief risks that farmers in Bainet and Grand Goave must cope with are hurricanes, floods and landslides.

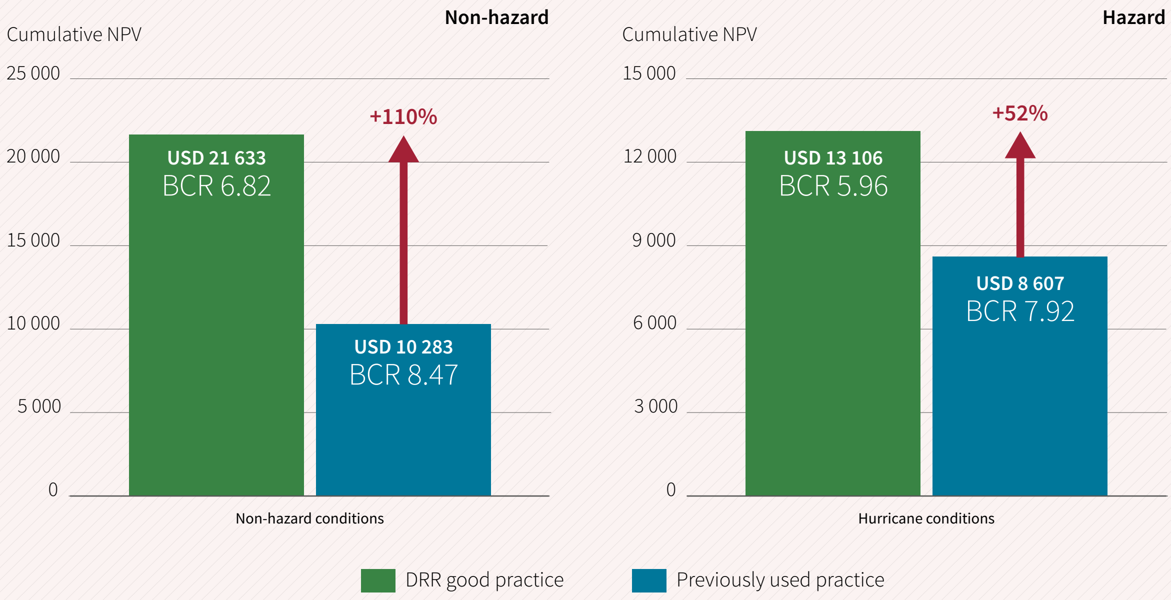
To stabilize soils and avoid or at least mitigate the impact of strong winds on crops, a good practice package has been introduced, combining the planting of trees and elephant grass for soil stabilization and wind sheltering purposes, and the planting of hedgerows.

On some farms, live barriers were also combined with conservation agriculture and additional agroforestry techniques to improve soil quality, reduce water loss from evapotranspiration and runoff, and improve water infiltration. This included mulching, intercropping, ridging, minimum tillage and the elimination of slash and burn techniques.

The good practice was introduced on six farms in Bainet and Grand Goave starting from July 2016. In October, Category 5 Hurricane Matthew hit the southwestern part of Haiti, with wind speeds reaching up to 240 km/h and causing several fatalities and widespread impact to agriculture and the economy. While not directly hit, Bainet was partially affected by strong winds and related heavy rains. These impacts did not reach the other study area in Grand Goave.

Cost–benefit analyses were conducted using data collected during the 2016 winter season

Figure 14. BCR and cumulative NPV over 11 years under both non-hazard and hazard conditions, DRR good practice vs. previously used practice(s) – USD/hectare



(July–October) from 12 hazard affected farms in Bainet and three non-affected farms in Grand Goave. The analysis projected the cumulative NPV of benefits obtained on one hectare of peas over a period of 11 years (applying a 10 percent discount rate).

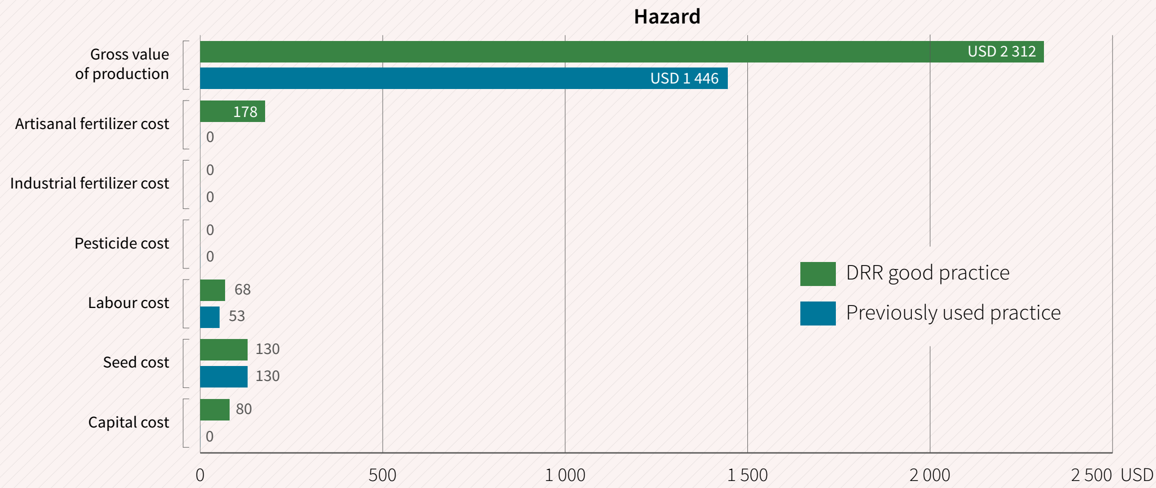
The BCR of the previously used practice under both hazard- and non-hazard conditions was higher than that of the DRR good practice, indicating that upfront capital costs may represent a barrier for farmers to adopt this practice, unless adequately supported. The NPV of the good practice outperformed that of past practice – notably so in non-hazard conditions, but also in the face of hurricanes. As shown in Figure 14, the cumulative net benefits from good practice plots under non-hazard conditions were 110 percent higher than those obtained from plots cultivated with traditional agriculture techniques and without trees or live barriers. Additional research would be needed to identify the key drivers of higher crop productivity, but the positive effects of conservation agriculture techniques have certainly played a role.

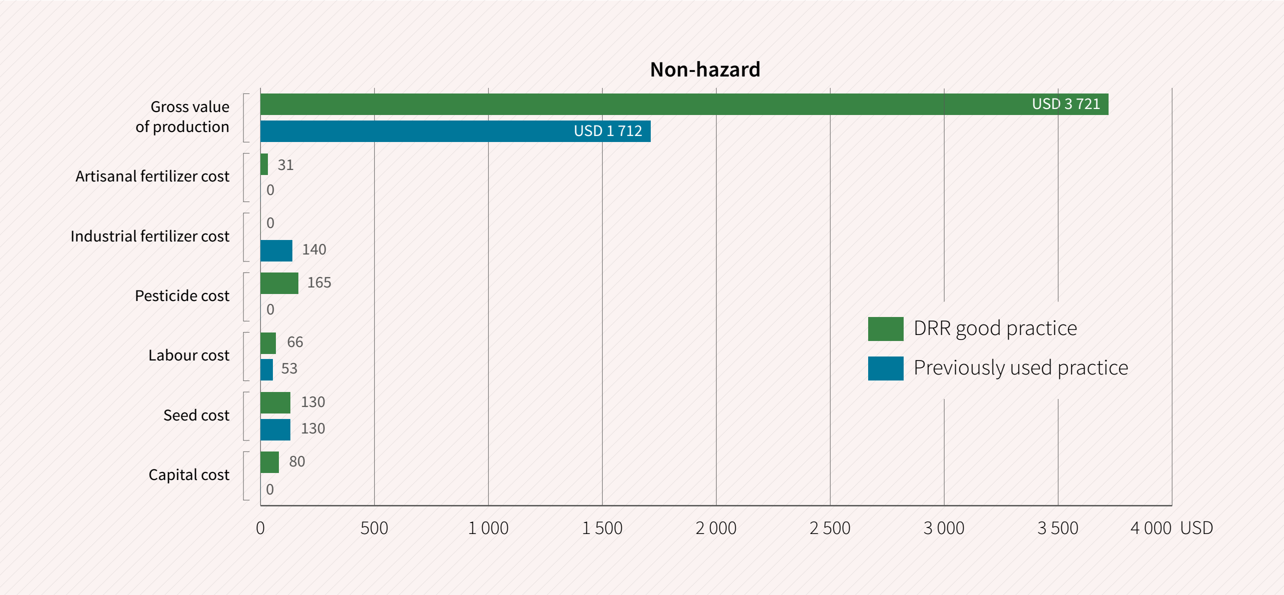
On farms affected by Hurricane Matthew's strong winds and heavy rains, the absolute benefits of pea cultivation were significantly lower; even so, returns from good practice plots were still 52 percent higher than those from plots that continued previous practices, underscoring the effectiveness of the DRR good practice as a resilience building measure. The lower BCR for the good practice option can be explained as a factor of the high absolute costs involved, including particularly capital investment requirements and artisanal fertilizer costs.

Promising quantitative results were mirrored in farmers' perceptions regarding the new practice: almost all of them indicated they hoped to replicate the introduced DRR good practice in the future, continuing with the new methods rather than that previous, lower-yielding practices. However, for this to occur additional trainings on techniques would need to be provided, as well as measures to improve farmers' access to inputs and additional tools for managing disaster risks. Indeed, the BCR results clearly show that upfront investment costs for the DRR good practice are higher than those of the previously applied practices, and out of reach for many farmers in rural Haiti. Financial support (for example, through micro credits) is therefore needed to enable uptake of the new DRR good practices.

All the farmers perceived the practice to be more resistant to climate constraints. Additionally, the DRR good practice introduced in Haiti afforded significant knock-on socio-economic and environmental advantages, with tree planting and conservation agriculture serving to sequester carbon thereby offering climate change mitigation co-benefits.

Figure 15. Average costs and benefits – USD/ha/season





Good practice packages involving livestock

In many developing countries, livestock makes important contributions to smallholders' household income. Climatic and heat stresses can both directly impact livestock, increasing morbidity and mortality, as well as indirectly by reducing the quality and availability of feed and forage. In the livestock sub-sector seven DRR good practice packages were implemented and evaluated, in four countries: Uganda, Bolivia (Plurinational State of), the Lao People's Democratic Republic and Colombia. The analysed packages involved at least two of the three main components: the addition or improvement of infrastructure; the improved management practices or use of improved breeds; and the introduction or enhancement of animal health measures.

As with the crop good practice packages studied, the performance of the combined livestock interventions highlights the value of integrating several measures into one holistic farm-level risk reduction strategy. As Table 8 shows, the studied livestock good practice packages generated high benefits for implementing farmers. At the same time, they required fewer inputs while reducing pressures on land resources. The average BCR of the livestock good practice packages was 4.2 in non-hazard conditions and 3.6 in hazard conditions. For all good practices analysed under this cluster, the BCR was higher than that of previous practices. This indicates that cost barriers to uptake are not as relevant as for other good practices that showed lower BCR. The average percentage increase in NPV under non-hazard conditions, compared with previously applied practices, was found to be 104 percent and under hazard conditions 101 percent.

Table 8. Performance of practices in the combined packages (livestock) cluster

Country	Good practice	Hazard occurred	BCR non-hazard scenario (BCR of previously used practice in brackets)	BCR hazard scenario (BCR of previously used practice in brackets)	NPV increase (compared to previously used practice) non-hazard scenario	NPV increase (compared to previously used practice) hazard scenario
Bolivia (Plurinational State of)	Camelid raising with livestock shelters (*corralones*) and veterinary pharmacies	Frost, snow, heavy rain	n/a	2.7 (2.2)	n/a	+18%
	Cattle raising with livestock refuge mounds, deworming and preventive vitaminization	None	5.5 (1.5)	n/a	+132%	n/a
Colombia	Sheep and goat raising with health care and improved corrals	Dry spell/ drought	n/a	1.2 (1.3)	n/a	+59%
the Lao People's Democratic Republic	Chicken raising with improved chicken breeds and vaccination - wet season	None	1.4 (1.3)	n/a	+115%	n/a
	Chicken raising with improved chicken breeds and vaccination – dry season	Cold wave	2.5 (1.6)	2.2 (1.8)	+45%	+100%
	Goat raising in controlled areas and with vaccination – wet season	None	15.7 (12.1)	n/a	+45%	n/a
	Goat raising in controlled areas and with vaccination – dry season	None	3.1 (3)	n/a	+21%	n/a
Uganda	Cattle raising with zero grazing, improved cattle breeds and drought-tolerant fodder	Dry spell/ drought	n/a	2.9 (2.2)	n/a	+197%
	Chicken raising in chicken houses and with improved chicken breeds	Dry spell/ drought	n/a	1.5 (1.2)	n/a	+245%

n/a: refers to situations in which data could not be collected for the corresponding hazard/non-hazard condition(s)

Socio-economic and environmental co-benefits

Quantifiable benefits discussed previously have been further informed and qualified by additional qualitative findings that were gathered during the course of this study. Factoring in such additional qualitative considerations allows for better-informed planning and decision-making regarding risk-sensitive development interventions, as well as their upscaling. Indeed, this study highlights that a number of socio-economic and environmental benefits may underscore (or in some cases contradict) quantitative results. To capture such "hidden" benefits and costs – and to better understand how farmers, pastoralists and fisher folk perceived the introduced DRR good practices – semi-structured interviews and focus group discussions were conducted.

The issues examined through these interviews and discussions, and which then informed the process of validating a studied practice as DRR good practice, included environmental and socioeconomic considerations alike.

For example, many of the analysed technologies contributed to reducing pressure on water resources in drought-prone areas (a benefit whose value will only increase as climate change continues to impact on water resources). Rainwater harvesting measures considered in Uganda, Cambodia and Jamaica improved access to water for domestic use and reduced pressure on groundwater resources. In Cambodia, on-farm water use declined by four times after the introduction of drip irrigation systems; levels of fertilizer run-off also decreased. Altogether, for all DRR good practices evaluated in this study, 63 percent of farmers felt they offered increased resilience in the face of climate hazards.

"I want to continue planting green super rice, because it has a good taste, good grain quality, high yields, and resistance to hazards. It is more marketable."

Daniel, a farmer from Surigao del Norte, Caraga, the Philippines, on his experience using on Multi-stress tolerant Green Rice

Similarly, the use of early maturing crop varieties and fast-growing, improved breeds lowered the amount of inputs used in agricultural production, thus reducing the environmental footprint of productive activities.

In many cases, improved soil quality resulted from the introduction of DRR good practices in the crop and livestock sectors. This, for example, took place in Cambodia, the Lao People's Democratic Republic and Uganda through the adoption of organic pesticides and fertilizers and a corresponding reduction in the application of chemical inputs. The implementation of zero grazing in Uganda, similarly, helped cut down on overgrazing and so preserved soil fertility for crop production. By avoiding letting their goats range free, farmers in the Lao People's Democratic Republic gained greater control over pasture cover.

Generally, farmers felt that completely avoiding or using fewer chemical products involved health benefits, for both farming households and consumers, by reducing exposure to toxins.

At the same time, farmer feedback indicates that many farm-level DRR good practices offered considerable social co-benefits, because they are less labour- and time-intensive. Fish pots studied at several sites could be left deployed over several days and with minimal monitoring, allowing fishers to pursue other livelihood activities without sacrificing the assurance of a catch.

> "With organic insecticides, I observed that it is not only repelling insects, but it also makes my vegetables grow well, keeps the leaves soft and green. I feel safe with it and do not worry about chemical residues remaining on my vegetables, which could have harmful effects on the health of myself and family members, particularly my children."
>
> *Pach, a 35-year-old mother of four small children in Cambodia's Oddar Meanchey Province, on the benefits of using a botanical herbicide*

In like manner, rainwater-harvesting tanks provided households easy access to water for domestic use, eliminating the time-consuming, daily task of walking long distances or waiting in line at communal boreholes. This freed up time for other important activities, such as working in the fields, or attending school. Rainwater-harvesting techniques were particularly beneficial to women, who in rural households often are typically responsible for harvesting water, and so contribute to gender-equality.

> Factoring in additional qualitative considerations, such as farmers' perceptions, allows for better-informed planning and decision-making regarding risk-sensitive development interventions, as well as their upscaling.

Not all good practices are less labour- and time intensive, however: construction of infrastructure measures often requires a substantial one-off work effort, while the collection of resources like manure can also increase time and labour needs. The shift to raising goats in confinement studied in the Lao People's Democratic Republic necessitated a time investment in terms of continuous monitoring as well as some additional work effort, compared to allowing free roaming. Indeed, only 30 percent of interviewed farmers found the introduced good practices to require less effort than free roaming. However, they also noted that this trade-off is compensated by higher returns due increased production. One farmer, for example, observed that "after considering all the factors, poultry rearing is a hidden treasure".

Many of the good practices studied also contributed to improved food security and nutrition. Rainwater harvesting in Uganda and Cambodia allowed farmers to produce food even when conditions were too dry to do so using previously used practices. Micro-irrigation kits for vegetable production as well as new productive activities for livelihood diversification (e.g. mushroom growing, poultry farming) contributed to dietary diversification. In Uganda, higher production from improved

> “If sea conditions are rough, we cannot go fishing, because it is very dangerous, and we can lose our equipment or boats, which cost a lot fix or replace. Using fishing pots is less risky, and we have more time to do other activities.
>
> *Eduardo, a fisherman from Surigao del Norte, the Philippines, on the use of passive fishing gear*

cattle breeds raised with zero grazing system led to an increase in milk consumption, especially among children. Fish pots studied in the Philippines provided communities with more nutritious food and improved income. Since they can be deployed for longer periods and at deeper depths, beneficiaries noted an increase in the diversity of fish caught, including high-value species like groupers, difficult to land using previous practices.

Finally, several of the studied good practices led to pollution reduction, increased carbon sequestration, and curtailed greenhouse gas emissions, thereby offering substantial climate change mitigation co-benefits. The planting of shade trees on Ugandan coffee plantations and in Bolivian silvopastoral systems increased carbon sequestration while simultaneously preventing degradation of pastures and forests. The use of fish pots in the Philippines reduced the number of boat trips required to harvest the fish, lowering diesel fuel by 33 percent.

Farmers were also asked to provide an overarching appraisal of the aggregate pros and cons of the good practices they implemented, referred to by this study as a practice’s resilience score (1 to 5 rating scale). The average resilience score made of the various DRR good practices evaluated by this study was 4.6, indicating a high degree of farmer approval and buy-in. Likewise, 95 percent of farmers indicated their intention to replicate the DRR good practice in the future – but many also expressed a desire for more training, in particular on agronomic practices, such as cultivation techniques and soil fertility management. ◂

Challenges and opportunities for upscaling DRR good practices

The use at farm level of good agricultural practices for disaster risk reduction has vast potential to significantly reduce the impact of hazards on both agricultural assets and agricultural production. First by reviewing existing research, and then by presenting the results of this FAO study, the preceding chapters make a strong case for the benefits that farm-level DRR good practices can bring to farmers, fishers and livestock raisers whose livelihoods are recurrently threatened by weather and climate extremes. However, the full scale of potential benefits can be achieved only when suitable practices are systematically upscaled.

A key prerequisite for success is that a DRR good practice must be attuned to the livelihood strategies and cultural contexts of the people who will be using them, and well adapted to the agro-ecological zone, socioeconomic characteristics and vulnerability conditions where they are to be used. These prerequisites are just as crucial for any replication into wider target areas.

Furthermore, when evaluating practices as candidates for wider replication and upscaling, a number of additional interlinked factors need to be considered, including: market dynamics and access, availability of inputs, tools and equipment, access to credit, environmental sustainability, preservation of biodiversity, as well as potential impacts on other sectors and related livelihoods.

The process for upscaling DRR good agricultural practices usually follows two different paths:

- small-scale horizontal self-replication undertaken by farmers and communities at the local level and without much external support
- medium- to large-scale vertical upscaling driven by government or private sector-interventions, frequently covering larger geographic areas

To elaborate, in the context of this study, horizontal self-replication is understood as a process in which farmers take the initiative themselves to spread new practices within their local communities and networks, an "organic" process triggered by their own observations and judgements regarding a practice's merits. This generally takes place when good practices do not require significant capital investments, and key conditions for replication (e.g. value chains, inputs) are already in place. In this case, awareness-raising regarding the benefits of switching from previous practice to the DRR good practice may be sufficient to prompt self-replication.

Vertical upscaling, for its part, is treated in this study as processes in which the spread and replication of a limited number of carefully selected priority practices comes as a result of higher-level strategic planning and investment led by external actors. Vertical upscaling generally refers to practices that require high upfront investment, or practices that need to be promoted and implemented over large or extended areas (i.e. that are regional or national in scale). In these cases, successful upscaling

Farmers participate in a field school, Mbaiki, Central African Republic.

depends on the provision of government or private sector services to create conditions conducive to large-scale dissemination and upscaling. Interventions and incentives to promote vertical upscaling may include direct public investments (for instance, building of infrastructure) as well as the introduction of new policies or regulatory instruments that encourage the wide adoption of the good practice.

This chapter describes and discusses preconditions for success, potential barriers, and opportunities for the upscaling of DRR good practices. Three specific practices are presented as examples possessing high potential for upscaling. They were selected using a set of criteria aimed at ensuring that the potential returns of their upscaling could be adequately simulated and effectively demonstrated. The analysis considers production parameters, hazard risk exposure, demographic and macroeconomic dynamics in the areas identified for dissemination of the good practices, and points to a range of expected monetary benefits that would be achieved by vulnerable farmers under different hazard frequency scenarios.

The results of these analyses, combined with a detailed look at local contexts, are intended to inform decision-making by two key groups of actors:

1. farmers, as they evaluate practices they could replicate on their own, in their local context, to sustainably enhance farm benefits while reducing risk exposure
2. government and private sector decision-makers, as they consider the most effective upscaling paths to purse and how to prioritize investments to support the spread of selected, high-potential DRR good practices

> The wider use of DRR good practices requires effective training and effective extension efforts.

The first good practice upscaling simulation was conducted for Green Super Rice (GSR), a multi-stress tolerant rice variety, tested in the Philippines. This practice was chosen because it showed high returns during field-testing under both dry spell and normal conditions. Additional key criteria behind the selection of this practice as a case study in upscaling potential were the importance of rice as a staple crop, rice's large contribution to agricultural livelihoods and food security, and the large extension of rice-cultivated land in the Philippines.

The second upscaling simulation focuses on a DRR good practice combination that combines two interventions, both of which help reduce the risk exposure of camelids in the Altiplano region of the Plurinational State of Bolivia. It includes the use of improved animal shelters protecting camelids from heavy rains, frost and snow, as well as the establishment of veterinary pharmacies close to camelid raising communities as a means of facilitating access to and use of animal treatments. This good practice combination was selected because of the importance of camelid raising to livelihoods in the Andes, and given the major threat that extreme weather events pose to animals in mountainous regions of South America, among other factors.

The third case study involves a combination of good practice interventions for soil and water conservation that enhance the resilience of banana plantations to increasingly frequent and intense dry spells in Uganda's Central Region.

The integrated good practices sample includes:

1. mulching, a low cost practice that consists of covering soil with locally available and degradable plant materials to reduce water runoff and evapotranspiration and improve soil quality
2. the use of contour trenches to harvest water during the rainy season while preserving soil quality
3. application of organic compost to improve soil fertility at low cost
4. the introduction of improved banana varieties to increase yields and reduce losses in the dry season

This good practice was selected due to its high returns in comparison to previously applied banana cultivation practices, as well as its low cost and high replicability in the analysed area.

Table 9. Criteria used to select good practices for upscaling simulation

	Multi-stress tolerant Green Super Rice (GSR) – Bicol Region, the Philippines	Camelid raising with livestock shelters (*corralones*) and veterinary pharmacies – Oruro Department, Bolivia (Plurinational State of)	Banana cultivation with mulching, digging of trenches, organic composting and improved varieties – Central Region, Uganda
Capital cost	No major capital costs involved	Upfront capital investment required for building camelid shelters	Limited upfront capital investment required for digging contour trenches
Availability of inputs	Green Super Rice seeds are easily accessible by farmers and can be saved across seasons.	Camelid shelters built with locally available, low-cost materials	Organic matter for mulching and compost available on farm at no cost; basic construction materials needed for trenches; improved varieties can be replicated by planting suckers
Market access	Relatively good access to local markets by smallholder farmers thanks to connectivity between villages and cities, and well established/widely linked extension services (De Silva, 2011)	Vulnerable camelid herders engaged mostly in subsistence production. Camelid meat is traded in informal markets, but export potential is limited due to difficulties in complying with sanitary regulations (Ansaloni *et al.*, 2013).	High local and international demand for bananas. Small banana producers sell their products to market vendors. However, value addition is limited due to large number of actors involved in the value chain, deficits in rural infrastructure and limited market information for small producers (Arihok *et al.*, 2015). A key challenge for exports is high post-harvest losses due to short green-life of bananas and poor post-harvest handling (Asha *et al.*, 2015).
Capacity development need for replication	High potential to enhance farmers' capacity on GSR cultivation, due to widespread presence of extension workers.	Limited capacity building required on the use and maintenance of camelid shelters.	Technical capacity building is required on mulching, creation and use of contour trenches and organic composting. Trainings conducted during field trials proved to be effective and low-cost.
Agro-ecological conditions/potential for replication	High potential. Several GSR varieties have been developed to maximize their adaptability to different soil and climatic conditions in the Bicol Region.	High potential. The camelid shelters are designed specifically for the highlands of Bolivia (Plurinational State of).	High potential. Improved banana varieties (M-9, Kabana 6H) were developed by national research institutes and adapted to the respective agro-ecological zones of the Central Region.
Relevance to hazard risk exposure	Different hazards and climatic stresses affect rice cultivation in the region, including drought, floods, salinity and pests, among others (Yorobe *et al.*, 2014). Multi-stress tolerant rice varieties such as GSR lines are particularly suitable to address multiple hazards.	The highlands of Oruro Department experience significant daily variations in temperature (extremes ranging between 27 C during the day and around -14 C at night). Extreme weather and climate events such as frost, snow, heavy rains and hailstorms have a strong impact on camelids.	This region of Uganda is affected by recurrent dry spells/drought, which cause extensive damage and losses to banana plantations. Reduced rainfall and increasing temperatures due to climate change are likely to exacerbate the impact of drought on crops (FAO, 2017).

Relevance to socioeconomic and food security context	Agriculture provides employment to about 40 percent of the population in Bicol Region. In 2015, Bicol was the sixth region by rice production in the country, accounting for 7 percent of national production. However, rice production's annual growth rate is low (0.5 percent in 2015). Agriculture contributes about 24 percent of the regional GDP. Rice is an essential crop for food security in the region (Government of the Philippines, 2017).	More than 80 percent of camelids in the Andes are owned by smallholder farmers with very limited resources, located in remote areas and with limited or no access to basic services. Camelid herders in the highlands of the Oruro Department rely almost entirely on the consumption and sale of camelid products for their livelihoods and food security (Ansaloni *et al.*, 2013).	Banana is grown on about 15 percent of the total cultivated land in the Central Region of Uganda. In Uganda, about 24 percent of agricultural households cultivate bananas. The majority of banana producers in Uganda are smallholder farmers owning less than 0.5 hectares of land. Uganda is the largest consumer of cooking banana in the world, which contribute 17 percent of total daily per capita caloric food intake in the country (Asha *et al.*, 2015).
Observed benefits through field trials	Large differences were found in yield and net benefits from GSR trials as compared to usual varieties. Additional benefits were relatively higher under stress conditions than normal conditions.	Significant differences in animal mortality were observed between adopters and non-adopters, even under moderate stress conditions. However, moderate differences in net benefits were found. Benefits are partially outweighed by the capital costs of building shelters.	Very large differences in net benefits were found between adopters and non-adopters. The overwhelming increase in yields due to the crops' enhanced resistance to dry spells more than compensated for the capital costs and additional labour costs required.

The results of the simulations conducted in this study are complemented with a description of both opportunities and potential obstacles to upscaling good agricultural practices, based on the experiences and perceptions expressed by interviewed beneficiary farmers, plus the analysis of primary data collected through farm-level monitoring.

Upscaling simulation methodology

The potential for – and benefits of – upscaling selected DRR good agricultural practices were assessed using customized simulation models. The System Dynamics (SD) methodology was employed. This flexible approach allows for the incorporation of biophysical variables in monetary models, and vice versa. SD models are descriptive models that seek to represent key causal relations (i.e. the main drivers of change) by explicitly accounting for feedback, delays and non-linearity through the representation of stocks and flows. Several models have been created to date using this methodology to assess the impact of policies and practices across different sectors, at the global, national and local levels (UNEP, 2011; UNEP, 2014; Bassi, 2015).

Farmers wrap up planting a rice variety in one of the provinces susceptible to flooding.

For each of the three case studies presented in this chapter, two main scenarios were simulated:

- Good practice upscaling scenario
  This scenario assumes that the analysed DRR good practice is widely adopted by farmers in the target area (at sub-national level). Upscaling assumptions are defined based on the context and type of good practice being examined.

- Business-as-usual (previous practice) scenario
  This is the counterfactual scenario against which the DRR good practice is assessed. It assumes the continuation of previously used productive practices by farmers. It holds as an implicit assumption that no other DRR good practices are introduced during the simulation period in the analysed area.

Furthermore, three hazard frequency scenarios were simulated:
- low hazard frequency, assuming hazards return every three years
- medium hazard frequency, assuming a recurrence frequency of two years
- high hazard frequency, assuming recurrence frequency of one year

These frequency scenarios were decided based on the intensity of hazards observed during field monitoring. Since the hazards reported by farmers were of moderate or low-intensity, a minimum return period of three years

was assumed for all three case studies for which upscaling simulations were run; historical data on disaster frequency in the targeted areas was also considered.

Given the above, the results of the upscaling simulations reflect low-intensity hazard scenarios only; additional research is needed to ascertain the potential benefits of the DRR good practices under high-intensity hazard scenarios.

The main outputs of the simulations include projections of investments required to upscale the DRR good practice and a projection of the potential added benefits and/or avoided costs associated with upscaling. Investments include upfront capital costs (if any) required to upscale good practices. Asset depreciation and replacement costs are also considered throughout the simulation period. Added benefits correspond to increases in agricultural yields and production that could be potentially achieved regardless of hazard occurrence. Avoided costs represent potential savings gained by, for example, avoiding damage and losses caused by natural hazards or reducing input consumption. These benefits are directly linked to improvements in hazard resilience that could be achieved by upscaling the good practice.

For both of the main scenarios (good practice upscaling, business as usual), investments, added benefits and avoided costs were calculated;

the same was done for each hazard frequency scenario as well. The final result shows the difference in average annual NPV gained by farmers under each of these scenarios, over an 11-year period. (A discount rate of 10 percent was used, and sensitivity analysis was performed assuming a 15 percent and a 5 percent discount rate).

Development of this model took place in the following sequence:

1. The key issues to be examined (e.g. benefits, costs and expected broader effects of upscaling the good practices) were defined to establish the precise key indicators to be included in the model. Mapping of causal relations and feedback loops across indicators was undertaken to clarify the boundaries of the model and to gain an understanding of the functioning of the analysed system.

2. Available literature regarding the assessed good practice was reviewed, as well as agricultural development plans, resilience strategies and any other relevant policy and planning documents focusing on the study area.

3. Key quantitative data for the area identified for the upscaling simulation was collected. This included historical macroeconomic and household level data, as well as historical data on population, land use, agricultural production, hazard frequency and intensity. Different data sources were used, including national and international datasets. When possible, data triangulation was employed to ensure consistency and reliability.

4. The mathematical model was created. This involved translating causal relations into mathematical modules, with numerical inputs and equations, depending on data availability. The data collected from field experiments was used to account for differences between agricultural outputs under the DRR good practice and the previous practice. A relatively small and simple model was developed and fully tailored to each specific context and good practice.

   Key interrelated modules include: a) population; b) GDP; c) government revenues and expenditures; d) households' income, consumption and investments; and e) agricultural production (adapted according to the good practice being appraised).

   Both endogenous and exogenous variables are included in the model. For example, GDP, population, and key agriculture related variables are endogenously determined. Other variables that have an important influence on the assessed good practice, but which are only weakly influenced by the issues analysed, are exogenously represented.

5. Model calibration: this final step involved the calibration of the business as usual scenario against existing historical data collected

Beneficiaries of an FAO rainwater harvesting project in Senegal irrigate their crops.

from national and international sources. Assumptions from the literature were used in certain cases to fill data gaps. The simulation starts in the year 2 000, allowing for historical behavioural validation over a period of approximately 17 years, depending on data availability. Once the business as usual scenario was validated, alternative scenarios could be simulated.

Importantly, the simulated good practice upscaling scenarios do not aim to predict the exact net benefits brought by DRR good practice upscaling. Rather, they seek to provide a range of potential returns, as a way of making it easier to identify potential challenges and entry points for government or private sector intervention.

Additionally, the analysis does not consider broad market dynamics and spill-over effects and is restricted to the sub-national areas identified for potential upscaling. Also, a limitation of system dynamics models relates to their realistic identification of the causal relations that describe the functioning of the analysed system. This stems from their use of causality rather than correlation as well as their reliance on a large set of assumptions regarding trends for the key variables considered.

Simulation: Potential benefits of upscaling multi-stress tolerant Green Super Rice varieties in Bicol Region, the Philippines

This upscaling simulation assumed the adoption of GSR lines on 50 percent of the total land area currently being cultivated with rice in Bicol Region (i.e. half of the roughly 342 000 hectares cultivated in 2016). This upscaling scenario was compared with a "previous practice scenario" that assumed that pre-existing rice production patterns and trends in the region were continued, unaltered.

The following key assumptions were used for these scenario simulations:

- Rice yields under normal and hazard conditions were based on the average yields reported by farmers during interviews conducted between 2015 and 2016.
- The simulated hazards were assumed as having the same intensity as that reported by farmers during the monitored period between 2015 and 2016.
- The time needed to switch from local rice varieties to GSR was assumed to be one year.
- GSR seeds were presumed as being readily available to farmers.
- It was presumed that there is market potential for the commercialization of GSR varieties.

Box 1. Multi-stress tolerant Green Super Rice in the Philippines: results of field experiments

Agriculture employs about 40 percent of the population in the Bicol Region of the Philippines, and accounts for about 24 percent of regional GDP. In 2015, Bicol was the sixth largest rice producer in the country, contributing 7 percent of national production. Despite a low annual growth rate for this key staple (0.5 percent in 2015), rice remains an important foundation of livelihoods and component of food security in Bicol, where almost half of all cultivated areas are dedicated to rice (892 000 hectares in 2015; Government of the Philippines, 2017).

The average annual rainfall in the region ranges from 1 900 to 3 500 millimetres. There are two major seasons in the Philippines: the dry season (December to May) and the wet/rainy season (June to November). Seasonal rainfall, as well as mean temperatures in all seasons, are expected to increase due to climate change. Climate change may also contribute to a rise in extreme events.

The Philippines is already one of the most disaster-prone countries in the world, and within the country, Bicol is one of island nation's most disaster-prone areas, due to its geographic location at the east coast (FAO, 2013). The livelihoods of vulnerable smallholder farmers are constantly threatened by recurrent hazards. Between 2007 and 2011, Bicol sustained about USD 122 million worth of damage and losses in its rice sector due to typhoons, flooding, and dry spells/drought (Israel and Briones, 2012).

This case study analyses the potential added benefits and avoided losses gained by upscaling use of the Green Super Rice (GSR) multi-stress tolerant varieties within Bicol Region. GSR lines are inbred, non-genetically modified rice lines developed by Chinese researchers in 2011 (IRRI, 2016). Stresses that GSR lines are tolerant to include abiotic stresses (e.g. drought, salinity, alkalinity, iron toxicity), diseases (e.g. blast, bacterial leaf blight, sheath blight, bacterial leaf streak, false smut) and insects (e.g. brown planthopper, green leafhopper, stem borer).

The performance of GSR lines 1, 5a, 8, 11, 12a (tolerant to drought, flood and saline conditions) was monitored on 256 farms over three consecutive seasons (2015 dry and wet

seasons, and 2016 dry season) in the provinces of Camarines Norte, Camarines Sur, Catanduanes, Masbate and Sorsogon. About half of the farms were affected by dry spells during that period. In the monitored dry seasons, rainfall was around 32 percent lower than the 20-year average in the targeted provinces, on average. Most farmers noted that the experienced dry spells were of moderate intensity, primarily consisting of delays in the rainy season and dry periods of short duration.

The field trials yielded positive results under both hazard stress and non-hazard conditions (defined as being within the range of long-term average weather), confirming the effectiveness of GSR lines in mitigating the impacts of hazards and climatic stresses, at the same time that they bring additional benefits in agricultural seasons that do not experience hazards. Indeed, the data reveal that under non-hazard conditions GSR brings additional net benefits in both the dry (19 percent higher) and wet (58 percent) season when compared to previously used rice varieties. This makes the introduction of GSR a “no-regret” practice. In farms affected by dry spells during the dry season, when GSR was used production losses were reduced 53 percent (corresponding to USD 74 / ha annually) versus control plots where previously used varieties continued to be cultivated. In the wet season, 33 percent of losses experienced on control plots affected by floods and pests were avoided (adding up to about USD 219 / hectare each season).

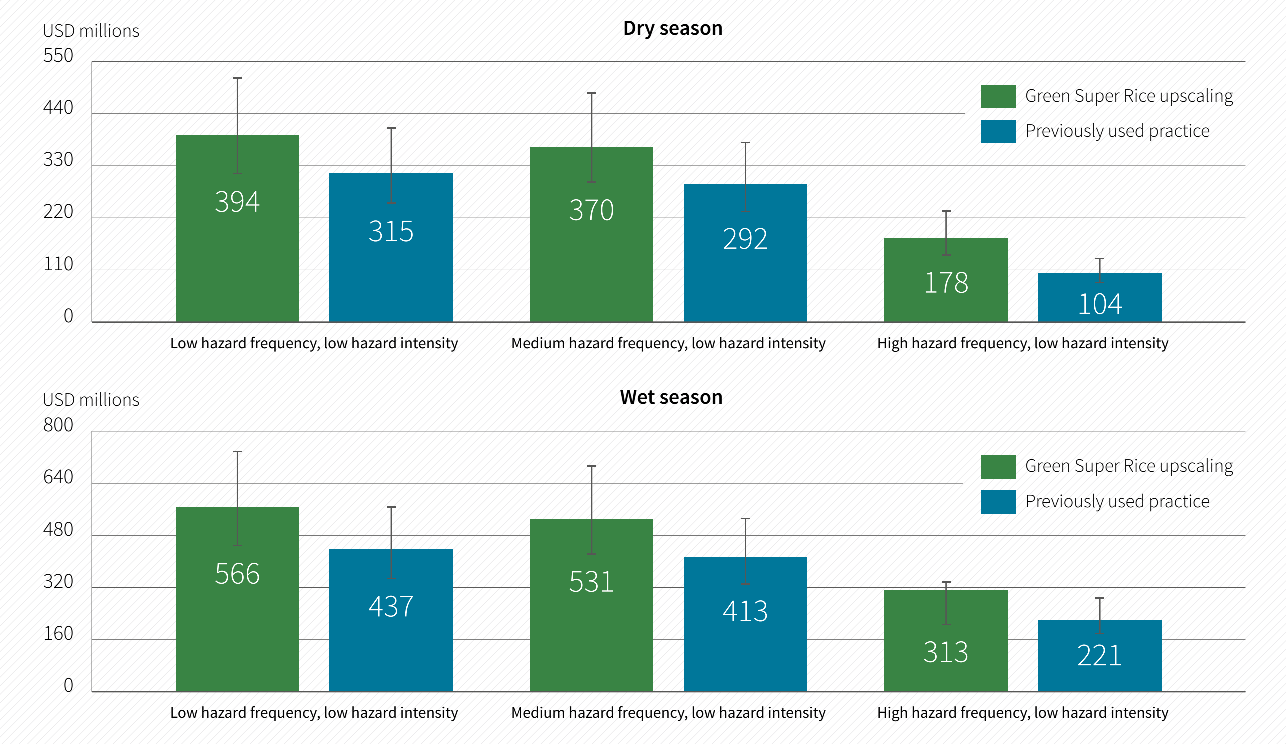
The costs of the DRR good practice considered in the simulation included labour costs, fertilizer costs, pesticide costs, and seed costs. Benefits were measured in terms of the value of rice production, expressed in farm-gate prices.

Simulation results show that GSR upscaling could trigger an increase in the annual average net benefits gained from rice production in Bicol Region in both the dry and rainy seasons. The largest difference between GSR upscaling and business as usual is observed when hazards are more frequent, suggesting that GSR lines are particularly effective under hazard conditions. Worth stressing is that GSR helps prevent a significant share of losses during the dry season, when farms are most affected by dry spells. Overall, the amount of potentially avoided losses achieved through GSR upscaling ranges between an estimated USD 33 and USD 129 million per season, on average at Bicol regional scale.

Table 10. Percentage differences in NPV under different hazard frequency scenarios: GSR DRR good practice upscaling scenario vs. previous practice scenario

	Low hazard frequency	Medium hazard frequency	High hazard frequency
Dry season	+ 25.1%	+ 26.7%	+ 71.2%
Rainy season	+ 29.5%	+ 28.6%	+ 41.6%

Figure 16 (top) and Figure 17 (bottom). Simulation results – Average annual NPV from rice production under different hazard frequency scenarios: DRR good practice upscaling scenario vs. previous practice scenario in Bicol Region, the Philippines (USD millions)



Appraisal period: 11 years. Discount rate: 10 percent. Sensitivity analysis uses 15 percent and 5 percent discount rate.

Three-quarters of participating farmers interviewed for the qualitative assessment firmly stated that they would like to continue planting GSR, even without external support for buying improved seeds or other inputs. More than 60 percent suggested introducing GSR on other farms, if adequate training were carried out when inputs were distributed.

Environmental co-benefits offer another rationale for upscaling the use of GSR. Given appropriate training, to cultivate GSR farmers use more organic and fewer chemical inputs, which has a positive impact on soil quality and ecosystems – a noteworthy value-added for an area where soil erosion represents a major challenge to the sustainability of rice production.

The positive results of the analysis further confirm the relevance of promoting the spread and upscaling of GSR varieties in Bicol Region. A government-led upscaling programme (vertical upscaling) was recommended to facilitate farmers' access to GSR seeds, ensure adequate training in its use, and establish enabling conditions for good practice uptake and dissemination. This vertical upscaling has been undertaken since the field trials covered by this study, as the government of the Philippines has recently been promoting wider use of GSR lines in suitable areas of the country through its flagship rice programme. The wide coverage of government agricultural extension services in Bicol represented a key comparative advantage in accelerating uptake of GSR and guaranteeing adequate monitoring and support during the transition.

Simulation: Potential benefits of upscaling camelid shelters and veterinary pharmacies to cope with extreme weather and climate events in the Oruro Department of Bolivia (Plurinational State of)

This upscaling simulation assumed that all camelid herders in Bolivia's Oruro Department (an estimated 12 800 households in 2018) would adopt the use of camelid shelters and gain improved access to animal treatments thanks to the establishment of veterinary pharmacies in nearby municipalities. The scenario was compared with a business as usual scenario under which no additional investments were made to upscale camelid shelters and veterinary pharmacies.

The following key assumptions were used for the simulations:

- average herd size per household is 85 camelids, based on data collected from herder interviews
- herders restock or destock either when the number of camels move below or above average herd size
- herders are availed of the financial resources necessary to invest in constructing of shelters
- the time required to build a shelter is one year, and the lifespan of a shelter is 20 years
- hazard intensity is the same as reported by herders during the monitored period. That is, the reported intensity of heavy rains was moderate, implying a limited impact on camelid mortality.

Box 2. Camelid shelters and veterinary pharmacies in the Plurinational State of Bolivia: results of field experiments

The highlands of Bolivia's Oruro Department are exposed to extreme weather and climate events such as cold waves, frost and snow during winter; and to heavy snow, heavy rains, and hailstorms during summer. The climate is harsh and dry, with precipitation concentrated between December and March (averaging about 410 mm). Temperatures can be as high as 2°C, with intense solar radiation during the day, and can drop to as low as -14°C at night. The dominant ecosystem is dry puna grassland, interspersed with some wetlands.

Extreme events cause significant mortality among camelids, the main source of livelihoods for herders in Oruro. (Indeed, more than 80 percent of camelids in the Andes belong to smallholder farmers possessing limited resources and located in remote areas and having limited or no access to basic services.) Camelid herders in the highlands of Bolivia's

Figure 18. Semi-roofed camelid shelters deployed in Bolivia's Oruro Department as a DRR good practice

Shelter dimensions

Oruro Department rely almost entirely on the consumption and sale of camelid products for their livelihoods and food security (Ansaloni *et al.*, 2013).

To limit the impact of extreme events on camelid production, FAO and partners have piloted the introduction of a DRR good practice in Oruro involving the construction of semi-roofed shelters that vulnerable herders can use to protect livestock (Figure 18). In addition, veterinary pharmacies were established in nearby municipalities to improve farmers' access to livestock treatments (e.g. de-wormers, multivitamins) that help animals cope with the effects of frost and snow.

In 2016, the performance of this good practice was monitored on 14 farms in the municipalities of Curahuara (8 farms), Toledo (2), Bolivar (2), and Tapacari (2). According to beneficiary herders, all monitored farms were affected by heavy rains during the analysis (the dry season running from April to November.) However, climate data from the nearest weather station indicates that rainfall was limited during the monitored period.

Although the duration and intensity of the hazard was relatively moderate compared to extreme events that occurred in previous years (based on information from interviewed herders), the good practice proved effective in reducing camelid mortality. Indeed, the results showed that on farms affected by frost, the cumulative net benefits resulting from the good practice were about 18 percent higher than the benefits of previously applied management practice (appraisal period: 11 years). The benefit cost ratio of the DRR good practice package was 2.69, as compared to 2.21 for the continued implementation of previously applied herding practice.

On the other hand, it should be noted that the increase in benefits was partially outweighed by the capital costs of building shelters as well as the monthly costs of travelling to the veterinary pharmacies located in the municipalities.

The costs of the DRR good practice considered in the simulation included upfront investment in shelter building; maintenance cost of shelters; animal treatment cost (vaccination, deworming, vitaminization); costs of travelling to veterinary pharmacies; and camelid re-stocking costs. Benefits considered included: the value of sale of live camelids (destocking) at farm gate prices; meat production value at farm gate prices; and wool production value at farm gate prices.

Figure 19 shows the results of the simulations in terms of annual average net economic benefits accrued by camelid herders in Oruro Department under the good practice upscaling and business as usual scenarios. Good practice upscaling would bring relatively limited additional benefits versus as usual: On average, between USD 48 000 and USD 93 000 would be saved each year as result of reduced camelid mortality in the case of heavy rains.

Figure 19. Simulation results – Average annual NPV from camelid production under different hazard frequency scenarios: DRR good practice upscaling scenario vs. previous practice scenario, Oruro Department, Bolivia (USD thousands)

Appraisal period: 11 years. Discount rate: 10 percent. Sensitivity analysis uses 15 percent and 5 percent discount rate.

The low difference between the two scenarios can be partially explained by the average annual capital cost of building new shelters, which corresponds to about 14 percent of the annual net benefits in the upscaling scenario (illustrated by the red lines in Figure 19). Furthermore, heavy rains reported by herders were localized events of short duration, which helps explains the small difference between the DRR good practice and previous practice as well as the small difference between the low-, medium- and high hazard frequency scenarios. That said, in relative terms the difference in mortality rate between the two scenarios is significant. Camelid mortality in the upscaling scenario is about 12 times lower than under previous practice, meaning that avoided camelid deaths and related damages and losses would likely be much higher in the case of intense and prolonged weather extremes. Another important factor to consider is that the benefits of improved access to veterinary treatment would be likely to accrue and become more evident over time. For these reasons, collecting additional data in the future to further assess mortality differences between beneficiaries and non-beneficiaries over time would be important.

In addition to the results of the cost benefit analysis, the positive perceptions expressed by beneficiary herders interviewed strongly suggest that this DRR good practice should be upscaled in Oruro Department. Herders assigned an average score of 5 out of 5 to the good practice as a buffer against extreme events, and they overwhelmingly found that the good practice made camelid herding safer and more profitable. On the other hand, beneficiaries warned that without external support covering the upfront investments required to build new shelters would

be a major challenge. Indeed, the upfront capital cost required to build camelid shelters as well as the annual maintenance cost of shelters played an important role in limiting the additional benefits brought by the good practice. This finding highlights that farmer-to-farmer replication (horizontal upscaling) of this good practice is unlikely to occur in the absence of government support (vertical upscaling). Subsidies or other incentives should be provided to herders to encourage and enable the replication of this good practice and its wide adoption by herder communities in Oruro.

Simulation: Potential benefits of upscaling good practices for banana cultivation against dry spell/drought in the Central Region of Uganda

This upscaling simulation assumed that the good practice package would be adopted on 50 percent of currently cultivated banana land in the Central Region (half of 283 000 hectares) by 2019. In 2008, the number of banana farming households in the region was about 460 000 in 2008. Considering that most households own under 0.5 hectares, it is reasonable to assume that upscaling would benefit at least 230 000 households. The good practice upscaling scenario was compared with a business as usual scenario, which assumes the continuation of current trends in banana production.

The following key assumptions were used for the scenario simulations:

- Banana yields under dry spell/drought conditions were based on average yields reported by farmers during interviews in 2016.
- No primary data was available on banana yields under normal/long term average weather conditions, since all interviewed farmers reported the occurrence of dry spells or drought-like conditions over the monitored period. Therefore, it was assumed that yields in normal/long term average weather conditions would be 40 percent higher than under hazard conditions in fields where the good practice has not been implemented, and 50 percent higher than under hazard conditions in fields where the good practice has been adopted. These assumptions were based on secondary data regarding the impact of drought on crop yields in 2016 (IPC, 2016) and represent a conservative estimate based on the expected combined effect of mulching and the use of improved varieties and contour trenches in terms of mitigating drought impacts.
- The costs of introducing the set of good practice measures for banana cultivation would be sustained by farmers.
- The time needed to build contour trenches is one year.
- The simulated recurrent dry spells are assumed to have the same intensity as those reported by farmers during the monitored period in 2016.
- The costs of banana seedlings were not accounted for, as farmers rely on banana suckers.

Box 3. Banana cultivation with mulching, contour trenches, organic composting and improved varieties in Uganda: results of field experiments

The Central Region of Uganda is home to about one-fifth of the country's population and about 20 percent of the country's agricultural households (Uganda Bureau of Statistics, 2009). The climate is equatorial, with temperatures ranging between 16 and 30°C. There are two rainy seasons (March to May, primary; September to November, secondary). Most of the country receives between 750 mm and 2 100 mm of rainfall per year. According to available meteorological data, mean countrywide annual temperatures have risen by 1.3°C since 1960 (Twinomuhangi, 2012) while rainfall has become more unpredictable and poorly distributed (ACCRA, 2011).

Banana is grown on about 15 percent of the total cultivated land in the Central Region. Country-wide, about 24 percent of agricultural households cultivate bananas. Most are smallholder farmers owning under 0.5 hectares of land who rely heavily on banana production for their livelihoods and food security. Indeed, Uganda is the largest consumer of cooking banana in the world, and banana accounts for 17 percent of total daily per capita caloric food intake (Asha *et al.*, 2015).

Dry spells and drought pose a severe threat to agricultural livelihoods in Uganda: between 2005 and 2015, about four percent of the country's potential agricultural production was lost due to recurrent drought events (FAO, 2018c). These events have a strong impact on banana production and related livelihoods, potentially causing yield losses between 20 percent and 65 percent in dry areas of the region (Van Asten *et al.*, 2011). Rainfall deficits may be further compounded by climate change, as projections show that dry spell/drought events could increase in frequency and intensity over the next decades (Taylor *et al.*, 2014).

As part of a Global Climate Change Alliance project on Agriculture Adaptation to Climate Change in Uganda, FAO and partners promoted the use of a set of good practices to enhance the resilience of banana farmers to increasing dry spells in the central cattle corridor of Uganda. The combination of DRR good practices included: 1) mulching, a low cost practice that consists of covering soil with locally available degradable plant materials to reduce water runoff and evapotranspiration and improve soil quality; 2) digging contour trenches to harvest water during the rainy season while preserving soil quality; 3) preparing and applying

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organic compost to improve soil fertility at low costs; and 4) introducing improved banana varieties (M-9, Kabana 6H) resistant to drought, pests and diseases like black leaf streak.

During the 2016 dry season (June to August), the performance of this good practice package was monitored on 16 farms in Kiboga (5), Mubende (2) and Sembabule (9) districts. All farms were affected by dry spells during the monitoring period. In particular, rainfall was 17 to 44 percent below normal in August (ranging between 16 mm and 59 mm on average in the monitored districts), causing a reduction in water availability. Experimental trials were conducted to compare the performance of banana production on DRR good practice plots versus the performance on "control plots" on the same farm on which the previously applied management practice was continued. The net benefits were about ten times higher using the new DRR good practice, despite the increase in labour costs it involved.

Cost–benefit analyses were conducted using quantitative data collected during the monitoring period in the 2016 dry season (June to August). These showed that under dry spell/drought conditions, the net benefit of banana production over 11 years was almost ten times higher on farms adopting the DRR good practice package, as compared to non-adopters. The DRR good practice does require additional labour, and indeed some farmers hired agricultural workers

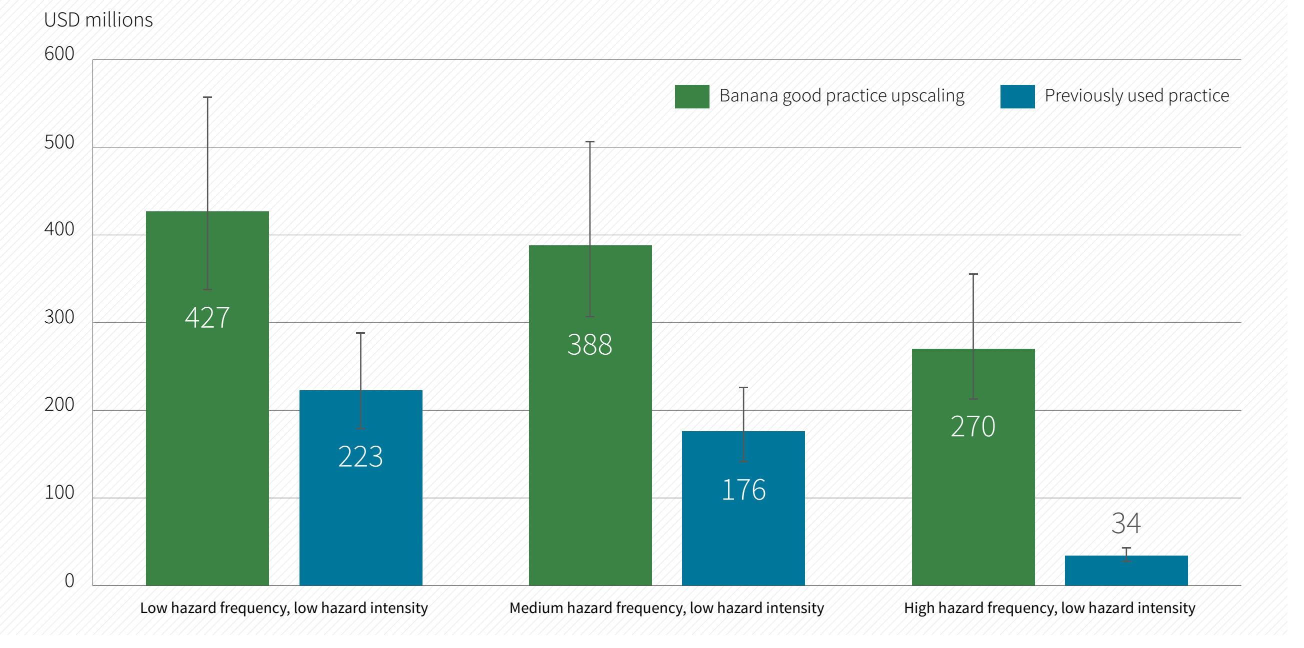
to help with plantation management activities. However, the overwhelming increase in yields due to the crops' enhanced resistance to dry spells more than compensated the additional input costs. The cost–benefit ratio of the good practice was calculated at 2.15, versus 1.16 for the previous practice. The low costs and high returns of this good practice package make it very suitable for this agro-ecological zone of Uganda.

The above notwithstanding, despite the large benefits brought by this combination of practices, banana farmers in Central Uganda are not yet widely adopting these measures. Interviews with farmers' associations suggest that awareness-raising and more widespread communication on the benefits gained from adopting this DRR good practice package are necessary to prompt farmer-to-farmer replication.

The costs of the DRR good practice considered in the simulation included upfront investments in building contour trenches, labour costs, fertilizer costs and pesticide costs. Benefit were measured in terms of the value of banana production, expressed in farm-gate prices.

Figure 20 shows the results of the simulations in terms of annual average net economic benefits accrued by banana farmers in the Central Region of Uganda under the good practice upscaling and the business as usual scenarios. The good practice package would bring both added benefits from increased banana yields in normal years and avoided losses from enhanced resistance of banana plantations in case of dry spells. The difference in average annual net benefits is overwhelming: the benefits of the good practice would be between 95 percent and 695 percent higher as compared to the previously applied practice, depending on the hazard frequency scenario. On average, avoided losses and added benefits between USD 212 million and USD 236 million could be gained every year by banana farmers in the Central Region through systematic upscaling.

Figure 20. Simulation results – Average annual NPV from banana production under different hazard frequency scenarios: DRR good practice upscaling scenario vs. previous practice scenario, Central Region, Uganda (USD millions)



Appraisal period: 11 years. Discount rate: 10 percent. Sensitivity analysis uses 15 percent and 5 percent discount rate.

These positive results underscore the merits of wider upscaling of the analysed DRR good practice package in the Central Region of Uganda. Although it was not possible to isolate the effects of each single intervention element of the DRR good practice on banana yields and returns, the synergies between the various interventions likely played a central role in enhancing the resilience of banana farming systems to rainfall deficits and dry spells.

The low-cost, high-return aspect of this good practice package suggest that farmer-to-farmer replication would be a viable upscaling process. Indeed, all farmers interviewed during the experimental trials expressed satisfaction with the performance of the good practice, giving its performance in the face of dry spells a score of 4.4 on a 1 to 5 scale.

At the same time, most farmers recommended conducting additional trainings on banana plantation management as a crucial support element. In that regard, a government programme for vertical upscaling would likely accelerate the upscaling process. This would need to give prominence to practical demonstrations, capacity building, and ensuring access to improved varieties. As part of this effort, extension services in the area could be further strengthened and expanded to ensure systematic support.

Opportunities for upscaling good practices

The case studies show that upscaling of effective DRR good practices can potentially bring significant returns in terms of added benefits and avoided losses (beyond individual farm level). Depending on the context, different approaches and instruments can be used to promote the dissemination of good practices. These may include incentives (for example, the provision of free inputs and trainings, or subsidies), regulatory instruments, or public investments to reduce the burden of upfront capital costs on farmers.

Hazard-prone countries could leverage a number of opportunities to create an enabling environment conducive to the upscaling of DRR good practices, and achieve broader policy and development gains as they do so. For example:

- Promoting the wide adoption of DRR good practices will help governments advance towards national and global goals on disaster risk reduction. The Sendai Framework highlights the need to promote inclusive, accessible, efficient and effective DRR practices. The DRR good practices examined in this chapter comply with all these criteria, as they are low-cost and easily accessible practices that have been successfully tested among vulnerable communities in disaster-prone areas.

- Tapping into the benefits of DRR good practices represents an additional means to achieve climate change adaptation goals. The lion's share of damages and losses in agriculture are caused by weather and climate related events (FAO, 2018). These events are likely to increase in frequency and intensity over the coming decades due to climate change, affecting agricultural livelihoods and threatening the food security of the planet's most vulnerable people. The contribution of DRR good agricultural practices to adaptation goals (e.g. the Nationally Determined Contributions submitted to the UNFCCC in the framework of the Paris Agreement) represent an important argument to promote their wider dissemination and upscaling.

- DRR good practice upscaling will also have positive cascading effects along the value chains of targeted agricultural products, thanks to the enhanced resilience of farmers, pastoralists and fishers in the face of increasing natural hazards. Therefore, governments have an opportunity to engage with all key value chain actors in the design and implementation of policies, plans and standards to promote DRR good agricultural practices.

- Most practices analysed in this study bring environmental co-benefits, ranging from emission reduction to preservation of ecosystems to saving natural resources. The contribution of DRR good practices to the sustainable management of natural resources and (when applicable) to climate change mitigation represents a further incentive for their promotion.

Challenges and potential barriers to upscaling and uptake

> Before selecting good practices for upscaling, governments, development and private sector actors and farmers must carefully consider a number of factors, to ensure the appropriateness and feasibility of innovation.

The preceding section described the value added that DRR good practices can produce at farm level; the simulations included in this section have demonstrated the scale of economic benefits that can be reached if systematic and widespread uptake of selected DRR practices is promoted.

Before selecting good practices for dissemination and upscaling, it is critical that governments, development and private sector actors, and farmers/farmer groups carefully consider a number of factors, in order to ensure the appropriateness and feasibility of innovations.

In the case of government-led vertical upscaling efforts, establishing an evidence base that reveals the scale of benefits that can be gained through DRR and the potential for upscaling is a *sine qua non* for inducing buy-in, investing, and policy-making.

At all levels, DRR good agricultural practices are highly context specific; their effectiveness depends not only on socioeconomic and hazard contexts but also on the agro-ecological characteristics of, and market dynamics in, the target area – to name just a few critical variables.

These are the contexts that will ultimately determine if the uptake and potential upscaling of a good practice is useful and feasible for farmers. Key challenges and potential barriers to upscaling that were highlighted by the farmers who tested the DRR good practices for this study include:

- **Availability of inputs.**
  While the inputs needed for many of the assessed practices can be sourced locally using available materials (e.g. mulch or organic compost), some practices do require the purchase of external materials and inputs. If these are not available on local markets, farmers will face difficulties in replicating the practice once demonstration projects end. For instance, this challenge was highlighted by farmers participating in this study who practiced indoor mushroom production as a livelihood diversification practice.

- **The time and labour needed to implement good practices can be another constraint.**
  If novel inputs like botanical pesticides are employed, their production can involve considerable time investments and may require advance planning. Although their use may pay off in terms of ultimate cost–benefit gains, doing so can be challenging for farmers already managing high workloads and who have only a limited labour force. This represents a particular problem, for example, when the preparation of inputs needs to happen in large quantities to be cost effective. Because botanical insecticides need to be used soon after production, within a month, farmers may find it difficult to balance production of inputs with storage and use of inputs. Similarly, excessive time investments can occur when farmers have to travel long distances in remote areas where transportation infrastructure is limited – as was the case in the study of camelid herders in the Plurinational State of Bolivia. In that case, even though the newly established veterinary pharmacies were located in relatively nearby municipalities, travel times remained significant.

- **Market access.**
  In many contexts, a lack of transportation infrastructure combined with farmers' weak purchasing power on local markets poses a barrier to market access. The promotion of new productive activities as well as of practices that might involve a significant increase in agricultural outputs should be preceded by a careful assessment of market dynamics and potential side effects within and across sectors. In some cases, producers will need to be supported in accessing value chains beyond local markets, since it is possible that local demand for a new product may not exist, or that local markets cannot absorb the increased production. However, many interviewed farmers indicated that even accessing local markets is difficult at times, as they are frequently in a weak negotiating position or do not have adequate information on prices and marketing opportunities, and so are forced to accept low sales prices; so, finding sustainable ways to interface with

distant markets should be a priority. Also, several farmers warned that market intermediaries are making the largest profits and raised the need for strengthening regulations to ensure favourable terms-of-trade for small-scale producers (for example, setting minimum farm-gate prices), even where market access does exist.

- **Capacities and awareness.**
  The most common suggestion heard from farmers is the need for more training and capacity building on the implementation of good practices. While most good practices are not difficult to implement, training can convince farmers of their value, ease the transition to their use, and ensure their ongoing sustainability.

- **High up-front costs.**
  Some farmers may not be able to bear the high upfront costs of structural measures, such as constructing rainwater harvesting systems, drip irrigation systems, or camelid shelters. In the case of the shelters studied in Bolivia (Plurinational State of), for instance, farmers requested financial support from their local municipality. External support for the implementation of these sorts of good practices will be a critical element in bringing them to scale. This could take the form of in-kind transfers; but improving farmer's access to credit sources (including microcredit) likely represents a more sustainable solution. For the use of improved varieties, the higher price of seeds compared to local varieties can undermine farmer buy-in and hinder upscaling, especially if farmers are not aware of the gains in yields and returns they will see. Also in the Plurinational State of Bolivia, for example, seeds of early maturing cassava evaluated in this study cost about three times more than those of traditional white cassava.

Of course, piloting DRR good practices at farm level alone will not automatically lead to significant benefits at the macro level. More thorough and broad-reaching research into the upscaling potentials of DRR good practice is urgently needed, and should be promoted by development programs. And an enabling policy environment and support mechanisms oriented toward evidence-driven upscaling are also required. Otherwise, the risk is that efforts will become stuck in a repetitive loop of piloting DRR practices at the individual and local level, as opposed to extensive and substantial implementation at larger scales. ◄

Conclusion: Implications of this study for policy and practice

This study systematically analysed various farm-level DRR interventions, comparing their performances under normal conditions and hazard stress conditions and measuring the benefits that accrued to farmers who used them. It also undertook an extensive literature review of previous cost benefit analyses of DRR interventions in agriculture from which a number of important lessons learned were drawn. (These are discussed in detail in the findings of the literature review on pp. 5–9 and in Annex I).

The unique methodology developed for this study and the findings it generated, greatly enhance the evidence base, making possible more in-depth and broad-reaching assessments of the dividends that farm-level DRR measures can generate for families, communities, regions and countries.

On average, the DRR good practices assessed here yielded benefits (including avoided damage and losses) under hazard conditions that were 2.2 times higher than benefits gained via the practices previously used by farmers under the same hazard conditions.

The average benefit–cost ratio of the new practices was 3.7 in hazard scenarios. Under non-hazard conditions the average BCR rose to 4.5.

When looking at the results of the net present values analyses, the pros of farm-level DRR measures emerge even more clearly. Not only do almost all good practices show positive NPVs, they also exhibit large NPV percentage increases versus previously used practices, in most cases. The NPV of the DRR good practices ranged from as little as two to as much as 886 percent in comparison to previously adopted practices. This shines a bright light on the scale of absolute benefits that farmers can achieve when investing in tested DRR good practices.

> The disaster risk reduction good practices yielded benefits under hazard conditions 2.2 times higher than those gained via practices previously used by farmers under the same conditions. The average benefit–cost ratio of the new practices was 3.7 in hazard scenarios. Under non-hazard conditions this rose to 4.5.

The fullest understanding of the value added of the DRR good practices appraised in this study is probably gained when "softer" metrics – such as environmental and social co-benefits – are factored in. While such benefits are more difficult to quantify they are immensely significant on a human scale. These include: environmental co-benefits like improved soil health; human health co-benefits associated with decreased use of chemical inputs; social benefits, including reducing the labour intensity of production and promoting improved gender equality.

Overall, the study's findings make a clear and compelling case for the value of both disaster risk reduction in agriculture in general – and in particular for implementing DRR good practices at farm level.

Accordingly, they also hold a number of implications for research, policy and practice. There are important lessons here for a range of actors, including: farmers and farmer associations; planners and development actors at all levels including donors; ministries of agriculture, disaster management, environment, finance, and planning; extension agents; the private sector; researchers; and others.

The case for farm-level DRR as a policy priority

- A range of farm-level DRR good practices exist which farmers can implement themselves, without dependency on upstream support services. However, there is a need to better communicate this knowledge to and across farming communities.
- Many farm-level DRR measures are easily within reach of even the most vulnerable farmers, and can yield benefits at household level that are extremely significant in the lives of resource-strapped rural families.
- By helping avoid disaster-associated damage and loss, investments in DRR at farm level save people's livelihoods, and deliver economic benefits at both the household and macro levels.
- Farm level DRR interventions are most useful as a means to build resilience in the face of low- and medium-intensity hazards. These occur with greater frequency than high-intensity hazards, and represent a more recurrent challenge for vulnerable farmers. Additionally, governments do not typically respond to such small-scale events.
- Systematic upscaling of selected DRR good practices can bring significant benefits at economic scale (even if only at the provincial or regional levels).

Previously, only very few studies had assessed DRR costs and benefits at farm level; most, rather, looked at entire projects and communities. However, by virtue of its practical methodology for measuring and acquiring data on the value added of farm-level DRR good practices, this study gives policy-makers, sectoral development planners, and other actors a tool that can help them differentiate between various practices of interest, select those most appropriate to a given context, and identify the optimal ways to promote their upscaling.

Importantly, with its sharply-focused analytical lens, this study reveals that relatively low-cost measures offer substantial improvements to strengthening the livelihoods and resilience of farmers, herders and fishers, with high returns – and that modest levels of investment at the most local level can be leveraged to produce significant results.

While the evidence base was already pointing in this direction (see the box on the following page), the results of this study render even more obvious that farm-level DRR must be a priority for policymakers and planners. ◂

The scale of benefits of farm-level DRR measures as shown by the evidence base

Both the literature review and this study's findings imply that, from a policy perspective, promoting and upscaling farm-level DRR measures makes a great deal of socioeconomic sense and should be a priority in decision making and budget making.

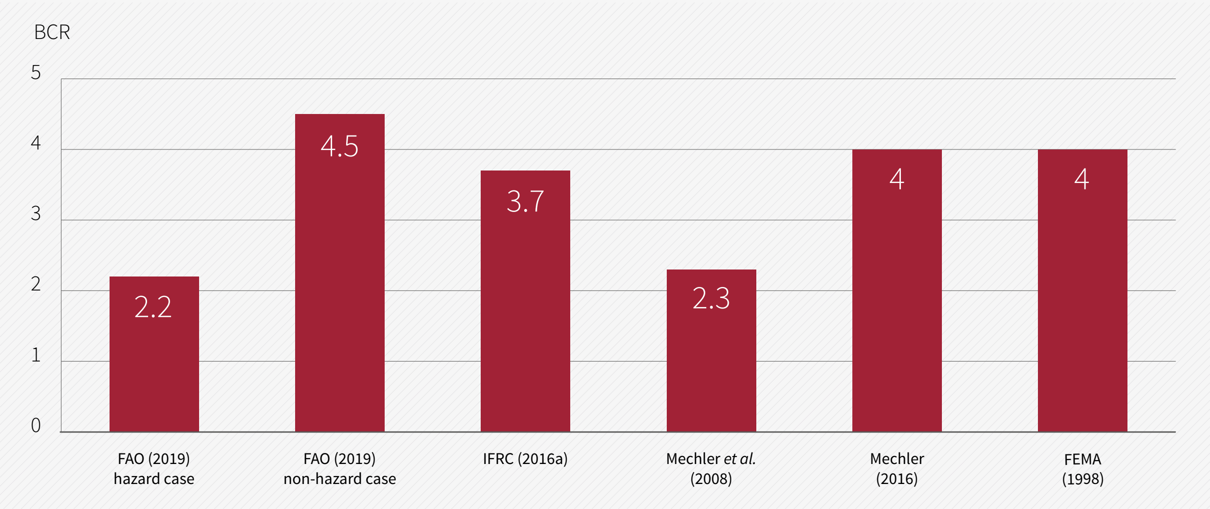
The most convenient metric to use when comparing this study's findings with other assessments of disaster risk reduction benefits is the BCR, which can easily enough be compared across studies.

The cost–benefit results of this study are in line with those of other assessments with a relatively similar scope and objective. However, this study advances the argument for more DRR investment at farm level, by highlighting the scale of economic benefits achieved.

Figure 21 shows the results of farm-level or household level cost–benefit analyses of DRR interventions, including this study (left) as well as two widely cited average BCR results for DRR in general (right). Despite some variations, the general trend observed is that small-scale farm-level measures bring positive economic returns.

This study has identified the BCR as a particularly suitable indicator for identifying potential constraints to the immediate uptake of practices by small holder farmers – namely the high upfront investment costs new DRR practices might involve. These may be a barrier for upscaling, despite higher absolute NPV values. In such cases, additional services geared towards improving access to finance and credit for the most vulnerable should be considered.

Figure 21. The scale of economic benefits gained from farm-level DRR good practices – overview of key studies



The way forward

> It is time to shift from the current focus on pilot-level disaster risk reduction interventions to more ambitious and systematic transformations – at significantly larger scales.

Farm-level DRR practices merit further promotion, targeted policymaking, and investment, as is shown in this study.

Not only can a wide range of gains can be achieved through the broader upscaling of farm level DRR, but preventative risk reduction investments at farm level also represent a smarter use of financial resources than costly spending on reconstruction and rehabilitation after hazards occur. This implies a policy shift from reactive, response-oriented modes of operating towards a greater emphasis on readiness and anticipatory investment.

At a human scale, farm-level DRR measures can prevent hazards from destroying the livelihoods of smallholder farmers. And since most DRR measures analysed in this study bring additional benefits (e.g. increased productivity and profits) regardless of hazard occurrence, they offer a way for farming families to improve their nutrition, food security and income streams, as stand-alone agronomic practices without DRR value-added.

At the macro scale, meanwhile, farm-level DRR actions make direct contributions to achieving the Sendai Framework's target[7] on reducing agricultural loss due to disasters, progress towards Sustainable Development Goal 1 (Ending Poverty), SDG Goal 2 (Zero Hunger) and SDG Goal 13 (Climate Action), as well as to the implementation of the Paris Climate Agreement.

Further research is of course needed. Additional data collection to build on the current study's sample and cover more extended time-frames. Doing so will provide an improved understanding of the medium- to long-term benefits of farm-level DRR as well as the investments required to make them a reality. And better data on damages and losses caused by extreme events to agriculture in general – and during monitoring of DRR good practices in particular – will better contextualize this study's results. Additionally, cost–benefit analyses should be systematically integrated into the design of DRR, climate change adaptation and other development projects, so that they are carried out as integral part of relevant field programmes. This would help avoid the type of challenges faced by this study in collecting relevant data at the local level over longer time periods.

The top level policy take away from this study is that it is time for a shift from the current focus on pilot-level DRR interventions to more ambitious and systematic transformations that aim at seeing ground level DRR measures not simply replicated locally, but rather deployed far more widely and at significantly larger scales.

However, policymakers and planners must not be blinded by the potential benefits of farm-level DRR in agriculture. The absolute costs of interventions merit careful consideration – particularly if they are to be paid upfront, with benefits materializing only later on. In cases where

[7] Target C: Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030. Target C's indicator C2 is "direct agricultural loss attributed to disasters."

The farmer interviews conducted for this study show again and again that the role of extension and capacity building is absolutely critical for upscaling.

relatively high upfront costs exist, and returns come much "later in the game," adequate government or donor support to allow farmers to take the first leap will be needed.

For this reason, it must be stressed yet again that any DRR good practices proposed for upscaling should be no regret options that deliver benefits even in the absence of hazards. Why? If they do not offer additional benefits beyond simple risk reduction, farmers will not have much incentive to change their standard way of doing business. Most certainly, for practices that require one-off upfront investments, establishing an enabling environment and putting in place systemic external (to the communities, at least) policy- and other support is of the utmost importance. Financial mechanisms should be reinforced to facilitate farmers' access to credit and financial support, and input services (like seed multiplication, storage, fertilizers) or measures aimed at enhancing market access should be expanded.

In terms of farmer-to-farmer upscaling, its comparatively low intervention costs – plus the potential for bottom up implementation – makes it a highly promising strategy for improved disaster risk reduction at very large scale. This pathway requires first and foremost raising the awareness of farmers regarding the existence and feasibility of DRR good practices and encouraging peer-to-peer learning.

Finally, as the post-study farmer interviews conducted for this study show again and again, the role of extension and capacity building is absolutely critical for upscaling, since the correct implementation of good practices at farm level is essential for their success. This additionally highlights that ministries of agriculture and other rural-development actors have a fundamental role to play in local DRR efforts, even more so than national disaster management agencies.

Working the land, Lanao del Sur, the Philippines.

Suggestions for policy and practice

- Agricultural development policy, planning and extension must treat disaster risk reduction as priority.
- Policymaking, planning, and agricultural extension systems should mainstream farm-level DRR in a deliberate manner.
- Much greater emphasis is needed on DRR at farm level as an effective and relatively low-cost way to prevent and mitigate the types of disasters that most frequently affect vulnerable farmers.
- DRR practices in agriculture are highly context- and location-specific. Great attention to local agro-ecological, market, and cultural dynamics is required prior to implementation and upscaling.
- Advance work must be undertaken to guarantee that proposed new measures aimed at reducing disaster risk are no regret options that provide increased benefits even in the absence of hazards.
- In order to replicate and scale up DRR good practices and realize benefits at a larger scale, challenges related to access by small-scale producers to inputs and markets need to be addressed through relevant policies and adequate investments.
- Communication, outreach, and extension should be key elements of upscaling efforts.

Zero Hunger depends on resilient agriculture

This study has sought to cast new light on the significant role that small scale, farm-level interventions can play in increasing peoples' resilience at the most local level, while also advancing sustainable development globally.

FAO has positioned building the resilience of rural communities in the face of shocks – such as through the DRR good practices assessed here – front and centre in its work to create a world with Zero Hunger.

Weakness in resilience can trigger a downward spiral after crises hit – on a very human scale, when communities' livelihoods are wiped away – but also at the national or larger levels, as development gains that took years to attain can be compromised and lost.

As this study has shown, disaster risk reduction at farm level offers a potent tool for preventing and reducing these impacts, at all scales – without regret, and with major benefits in both the human and economic dimensions.

But disaster risk reduction in agriculture is also something more. Because resilient agriculture is not just a mere means of subsistence or survival; rather, it lies at the heart of sustainable development, offering multiple opportunities for vulnerable families to enhance their standard of living, improve household food and nutrition security, achieve their children's educational goals, and build a brighter financial future for themselves. ◂

Annexes

Annex I: Literature Review

Methodological differences in cost–benefit analyses of DRR interventions

Methodological approach	Cost–benefit analyses either use purely quantitative, qualitative or combined methods. The large majority of CBAs for DRR is exclusively quantitative; some complement a quantitative approach with qualitative interviews, and sometimes with focus groups, while few studies only assess the cost–benefit of measures qualitatively. Amongst the case studies reviewed specifically for agriculture, 13 were exclusively quantitative, two were only qualitative and nine complemented a quantitative approach with qualitative interviews and focus groups. While quantitative approaches are the dominant approach for comparing costs and benefits, most studies caution that purely quantitative methods are inadequate to fully capture the costs and, above all, the benefits of DRR interventions, as not all of them can effectively be quantified. They recommend the use of complementary qualitative evaluation methods (see e.g. Wethli, 2014), which should be of participatory nature and adapted to the local context.
Timing of the analysis	Cost–benefit analyses are conducted *ex post* or *ex-ante*, thus relying on scenarios and trying to predict the future benefit–cost ratio (BCR). This approach appears to be the dominant one for DRR projects, presumably to justify their realisation in advance (Hugenbusch and Neumann, 2016). Only few studies evaluate the BCR of already- completed projects *ex post* and some employ combined approaches and *ex post* analyses. The case studies in the agriculture specific sub-sample of DRR CBAs included five ex *post* analyses, three combined studies and 15 *ex-ante* evaluations.
Consideration and calculation of risk	Risk incorporation is highlighted as an important cost–benefit analysis design criterion, as the degree to which risk is considered significantly impacts the CBA result (Mechler, 2016; Zurich Flood Resilience Alliance, 2014). This is a main complicating feature of DRR CBAs; while CBAs of common development projects only have to compare the intervention scenario with the non-intervention scenario, the evaluation of DRR projects requires taking disasters into account, which are by nature probabilistic events (Kull *et al.*, 2013). In many cost–benefit analyses of DRR interventions, risk is treated too simplistically, thus overestimating benefits and leading to very high benefit–cost ratios. In *ex post* analyses, the calculation of risk is ideally deterministic, after actual disasters occurred, whereas for *ex-ante* analyses the calculation of risk is necessarily probabilistic. However, due to data restrictions *ex post* analyses also at times resort to probabilistic risk identification, as well look at the longer-term impacts of interventions beyond the implementation period. Different degrees of complexity exist in probabilistic analyses: While some studies couple their assessment to Global Climate Models (GCM) to simulate the future impact of climate change on disasters, others use stochastic approaches such as Monte-Carlo Simulations to predict future disaster incidence based on historical disaster occurrence (e.g. Mechler *et al.* 2008). Or they simply assume future disaster probabilities (e.g. 40 percent annual drought probability in Khogali and Zewdu, 2009; 20 percent annual flood probability in IFRC, 2012). Different hazards naturally inhibit different risk factors, which have to be considered: floods occur more frequently than earthquakes, for instance, which is why risk has to be accounted for to arrive at a correct economic evaluation of the benefits of related DRR measures (Mechler, 2016). In addition, accommodating the reality that risk may change over time is very important; necessitating the integration of flexibility into risk assessment and subsequent BCR calculations.

Discount rate	Since typically a higher value is placed on the present than the future, a discount rate assigns a lower value to future benefits and costs than to those occurring in the present. Such a discount rate is a conspicuously sensitive assumption to make: high discount rates favour investments in short-term interventions, as they place limited value on future benefits. On the other hand, low discount rates favour investments in prevention but underestimate the high uncertainty regarding future disaster events. The most commonly- employed average discount rate in the quantitative studies reviewed ranged from 10 to 12 percent. About half of the studies conducted sensitivity analyses and calculated upper and lower bounds (e.g. including 3 percent and 15 percent discount rate) whereas the other half only worked with one discount rate. One study lowered the discount rate for the more distant future, from 3.5 to 3 percent (Wreford and Moran, 2015). Another study did not apply a discount rate, but factored in future inflation with 7.74 percent (IFRC, 2012). Generally, an average discount rate of 10 to 12 percent reflects a mainstream economics approach, whereas in the case of climate change there have been calls for low discount rates, so as to adequately value the future benefits of interventions (see notably Stern, 2006).
Type of benefits and costs	A common criticism is that quantitative cost–benefit analyses tend to focus only on economic and physical vulnerabilities and exclusively quantify immediate costs and benefits, neglecting more long-term effects as well as non-tangible benefits and costs, such as those of an environmental and social nature (Shreve and Kelman, 2014). Concrete examples are health impacts, crop salinization and other long-term environmental changes, migration and livelihood losses that result from disasters as well as business interruptions. Such costs or impacts would be difficult and time-consuming to assess. Naturally, studies using qualitative methods compile more comprehensive lists of costs and, notably, benefits – for instance asset creation and accumulation, improved food security and nutrition, entrepreneurship market development and linkages and skills training (IFRC, 2016a). Quantifiable measures of costs often include material, maintenance, training and labour costs for interventions, and opportunity costs. Quantifiable benefits most frequently include avoided disaster-associated losses, increased income, increased production, and others. As the wide range of costs and benefits shows, there is great diversity amongst studies with regard to their approach, which makes a comparative analysis difficult. A key recommendation in the literature is to integrate non-monetary costs and benefits into assessments, to arrive at a more holistic and comprehensive picture. To do this comprehensively but also efficiently, qualitative analysis is useful, as it allows for more in-depth analysis and avoids the problem of assigning weights to intangible benefits and costs. Perhaps most importantly, loss of human life is usually not accounted for (for obvious reasons given the immense difficulty to quantify the value of human life.) However, in some cases – such as CBAs on earthquake-related DRR interventions – accounting for avoided human deaths may be helpful in fully capturing the benefits of DRR measures. In general, it can be said that all studies not considering avoided human life losses underestimate the benefits of DRR measures.
Counterfactual	Some studies reviewed do not compare their results and simply compute the cost–benefit ratio of the project as it is (e.g. IFRC, 2016b). However, other studies compare the case of application of DRR measures with a non-application case, using different approaches to create the necessary counterfactual and with different degrees of accuracy and effort to ensure that the counterfactual is reliable. A few studies attempted to distinguish between the impacts of interventions in a changing or a constant climate, for instance Daigneault *et al.* (2016), who examined three different magnitude levels of climate change; only one study reviewed tried to compare hazard and non-hazard scenarios.

Existing literature on CBA of DRR interventions in agriculture

Table 11. Agriculture DRR studies reviewed, by intervention type and level of analysis[1]

	Infrastructure measures	People-centred measures	Combination of measures	Early warning systems	Nature-based interventions	Agricultural insurance
National (project) level		Rosenzweig and Tubiello (2007)	Van Niekerk *et al.* (2013), Cabot Venton *et al.* (2012), Arayaphong (2012)	Van Niekerk *et al.* (2013)		
District or regional level	Khan *et al.* (2008), Mechler *et al.* (2008)	ODI 2013, Kull *et al.* (2008)	ODI 2013	ODI 2013, Khan *et al.* (2008)	Baig *et al.* (2015)	Mechler *et al.* (2008)
Community/village level	Khogali and Zewdu (2009), Dewedeure (1998)	Tearfund (2013), Cabot Venton and Siedenburg (2010)	Yaron (2017), IFRC (2016c), IFRC (2012), Willenbockel (2011), White and Rorick (2010), Cabot Venton and Venton (2004)		Baig *et al.* (2015), Dewedeure 1998	
Farm level	FAO (2017), Kull *et al.* (2008)	IFRC (2016a), FAO (2017)	FAO (2017)	IFRC (2016a)	FAO (2017)	
Household level		Shongwe *et al.* (2014)	IFRC (2016b)			

When systematically comparing the content of more general, **non-sector specific** DRR cost–benefit analyses with **agriculture-specific** samples, a number of interesting differences stand out:

As regards the **type of interventions** studied, for DRR measures in general, infrastructure interventions have received most attention, particularly those responding to floods (Mechler, 2016). This includes construction of walls, elevation of houses in flood- prone areas as well as nature-based solutions like mangrove planting (Shreve and Kelman, 2014; Daigneault *et al.*, 2016). Only few studies specifically analyse nature-based solutions such as agroforestry and agro-ecological interventions, (Shreve and Kelman, 2014) or early warning systems and benefits stemming from agricultural risk insurance. The largest share of the studies looked at combinations of DRR measures, without distinguishing between different interventions types (e.g. Yargon, 2017)[2].

Although an important number of agricultural DRR studies do analyse the costs and benefits of infrastructural measures such as irrigation or rainwater harvesting, the majority focus on "people-centred" measures. These are interventions which aim to empower people to act themselves, such as capacity-building in better farming methods. This focus of agriculture-specific studies may be explained by the emphasis of agricultural DRR

[1] Note: Many of the multi-hazard studies looked at both floods and droughts; some also included earthquakes, storms and landslides

[2] In contrast, some studies analysed multiple interventions separately; in this study, each intervention was treated as a distinct case study.

practitioners working with marginalised communities at a local scale. In the case of more expensive projects, such as flood embankment or cyclone shelter building, *ex-ante* is often undertaken as a prerequisite for investors and decision-makers. And as such physical structures have highly visible effects, there may be higher demand from community members and civil society for evidence of their benefits. In contrast, DRR projects benefitting agriculture in developing countries, tend to concentrate on smallholder famers, which require different approaches beyond large-scale infrastructure measures.

With regard to **hazard focus**, most studies (agriculture and non-sector-specific) assess projects for flood protection, but there is considerably less attention to other hazards, including droughts and earthquakes. (Mechler, 2016; Price, 2018). Notably, volcanic eruptions have been neglected (Shreve and Kelman, 2014), as have landslides (e.g. Holcombe *et al.*, 2012). For earthquakes, the dearth of evidence may be explained by the fact that disaster risk mitigation in the face of seismic events often requires very costly and lengthy interventions, meaning these types of projects are less common (Kenny, 2012). Valcarcel *et al.* (2013) projected benefits of seismic risk reduction based on a hypothetical case, without concrete projects planned, aimed at improving school construction in Latin America and the Caribbean. Agriculture-specific DRR CBA studies mostly focus on floods and droughts, and most studies look at multiple hazards. Wildfires, landslides and storms are virtually absent in the agriculture DRR CBA studies reviewed.

As regards **the geographic area** of DRR interventions studied, only few meta-analyses and longitudinal studies span different countries and regions (Shreve and Kelman, 2014). Most focus only on a specific project in one geographic location. The majority were conducted in Asia and Sub-Sahara Africa; substantially fewer cover Northern Africa, the Middle East and Latin America and Caribbean. This is true for both general and agriculture-specific DRR CBAs.

An analysis of **the intervention levels** represented in the general and agriculture-specific literature shows that most case studies focus on local community programmes and projects, often implemented by NGOs. Although many others examine the regional level, the national and household scales have seen less attention. Only few studies drill down to look at farm-level. Farm-level interventions are closely linked to people-centred measures and can be defined as activities that small-scale and local level actors – - agricultural communities and households – - could implement before disasters occur to avoid, prevent or mitigate disaster risks and increase their resilience.

Comparing the results of other DRR cost–benefit analyses

Due to the range of methodologies employed and interventions studied, very different results are cited in the literature (Table 12). Nonetheless, the general statement that disaster risk reduction pays clearly emerges throughout the different assessments.

Table 12. Selection of results of DRR interventions presented in the literature

Study	DRR intervention type	BCR	Comments
Mechler, 2016	Different intervention types and areas	4	
US Federal Emergency Management Agency (FEMA), 1998	Review of 4 000 disaster risk mitigation programs in the US	4	
Zurich Flood Resilience Alliance (2014)	Flood protection measures	5	
Khogali and Zewdu, 2009	Drought risk reduction measures through an irrigation programme in Sudan	1800	Highest BCR found in this literature analysis; however, costs were not considered, only benefits
Chadburn *et al.* (2013)	Interventions implemented by Oxfam America in El Salvador	87	
Holocombe et al (2012)	Surface-water drainage measures to address landslide risk in the Easter Caribbean	2.7	

It merits pointing out that DRR measures are not always cost effective and in such cases do not have a BCR greater than 1. There are also situations in which anticipatory risk reduction measures are not efficient, as is very much the case when no hazards actually manifest (Shreve and Kelman, 2014). Additionally, Chadburn *et al.* (Tearfund, 2013) caution that there can be bias in project selection, particularly for cost–benefit analyses that are conducted *ex post*. As most of the CBA literature on DRR stems from organizations implementing and evaluating their own DRR projects, they may be tempted to only conduct analyses on more successful projects.

General trends in results by intervention type

Combined interventions

Combined interventions tend to bring higher BCRs than single interventions – for example, dual pond and river improvement in ODI, 2013; three combined interventions in Yargon, 2017; irrigation plus insurance in Mechler *et al.*, 2008. This is not surprising given that such interventions take a more holistic approach and seek to leverage the synergies of various sub-components.

Nature-based solutions

Interestingly, nature-based solutions appear to offer higher BCRs and overall benefits than hard infrastructure measures. In fact, for flood protection in Fiji, Daigneault *et al.* (2016) found that planting riparian buffer vegetation was the best option in terms of BCR, and that inland afforestation measures offered the highest net present value, since despite relatively high costs they also offer important ecosystem co-benefits. This was also found for mangrove protection and planting, which show higher NPVs and BCRs than engineering solutions like the construction of seawalls (IUCN, 2016). This could be due to lower input costs required for nature-based solutions as compared to grey infrastructure measures.

People-centred interventions

For people-centred approaches, generally high BCRs have been reported. The highest figures amongst the studies reviewed were found for a self-help group approach (involving community savings and credit scheme) in Ethiopia aimed at enhancing food security and people's ability to withstand droughts (Chadburn *et al.*, 2013). The BCRs reported ranged from 32 to 238, which points to the transformational change that can be brought about by local-level, people-centred approaches. Such interventions' high value can be explained by the low costs they involve, which making them likely no-regret options in most cases.

In a meta-study reviewing 23 CBAs of community-based DRR measures, Chadburn *et al.* (2013) found that soft resilience interventions fare better than infrastructure interventions. This is likely due to the wider development gains they bring, as well as the lowered costs as compared to hard infrastructural measures. Substantiating this claim, Shongwe, Masuku and Manyatsi (2013) found that measures with low costs are better suited for smallholder farmers, as they can be implemented without relying on government investment. Switching crops or changing cropping patterns, for instance, also over high net present values while requiring low upfront investments. Specifically, for flood protection, a case study involving local shrimp farmers in Thailand Seekao and Pharino (2018) found that while structural measures offered the most promising BCRs, non-structural measures and shifting the cropping calendar represented interesting alternatives for smallholder farmers who may not have the financial means to invest in costly infrastructure.

Climate smart agriculture/ farm-level DRR practices

Climate smart agriculture (CSA) practices do not directly fall under DRR, but the practices are very similar to — and in some cases are the same as — a number of DRR interventions. Sain *et al.* (2017) analysed eight different CSA practices in Guatemala and found that seven of them were profitable over their lifecycle, with payback periods ranging from one to 8.5 years. Generally, infrastructure measures appear to be less profitable than the use of improved varieties or agronomic measures. In western Kenya, Ng'ang'a *et al.* (2017) evaluated what they call climate-smart soil practices, such as the use of organic manure and improved seeds. For small-scale subsistence farming they recommend intercropping as a way to generate a high net present value, but all measures they assessed were generally found to be recommendable. In the Indian Himalaya region, indigenous measures of soil and water conservation were found by Mishra and Rai (2013) to be cost-effective, with the post promising approaches consisting of agroforestry (BCR of 1.99 and short payback periods), crop rotation (BCR 2.24) and vegetative barriers (BCR 13.8). However, especially in a small-scale

farming context the payback period of the measures and their initial effect on productivity also have to be considered, beyond NPV and BCR. This is why the construction of terraces is less enticing than other measures, since for the first two to three years after the introduction of the practice, farmers accrue net losses.

Early Warning Systems

Early warning systems can be a useful addition alongside other DRR measures; however, the literature also suggests that it is difficult to assess them as a stand-alone measure, with results revealing comparatively lower benefits compared with hands-on interventions (see, for instance, Kull *et al.* 2013). However, in a study on a flood early warning system in Fiji, a BCR of 3.7–7.1 was estimated (Holland, 2008), highlighting the value that early warning can have. In a literature analysis, Urrea *et al.* (2016, cited in Costella *et al.*, 2017) estimated a BCR of 3:1 in beneficiaries' savings, outweighing the cost of cash transfers released upon flood early warning in Bangladesh.

Early Warning Early Action

Recent FAO studies have measured the return on investment of early actions triggered by early warnings that are intended to prevent or mitigate the impact of disasters on vulnerable farmers and herders. For every dollar invested by FAO in early action, farmers and herders obtained between 2.5 and 7.1 dollars in added benefits and avoided losses, depending on the country and hazard context. In Mongolia, for instance, feed and cash distribution ahead of forecasted harsh winter (*dzud*) contributed significantly to reducing negative impacts on livestock (mortality, animal body conditions, cashmere and milk production): the BCR of this intervention was 1:7.1 (FAO, 2018a). In Madagascar, the distribution of seeds, water pumps and micro-irrigation systems ahead of forecasted drought helped poor farmers cope with the strong impacts of prolonged rainfall deficits on food security, with a BCR of 1:2.5 (FAO, 2019). In Kenya and the Sudan, early distribution of animal feed and nutrient supplements ahead of forecasted drought helped pastoralist communities preserve their livestock assets: the BCRs were 1:3.5 and 1:6.7, respectively (FAO 2018b and FAO, 2018c).

Agricultural risk insurance

Another interesting thread that emerges from the literature relates to agricultural risk insurance. A study of drought risk management in India (Kull *et al.*, 2013) finds that, depending on the frequency of events, either traditional irrigation or insurance solutions can be more economically efficient. For high-frequency events, irrigation is better suited, whereas for low-frequency events with higher intensity, as a risk transfer mechanism, insurance can help buffer dramatic income shocks (Kull *et al.* 2013). Mechler (2016) adds that insurance solutions are better suited in costly, less frequent high-risk contexts where risk cannot fully be mitigated. In coping with typhoon impacts in China, Ye *et al.* (2016) find that insurance should be the preferred option to share risk, ahead of risk reduction measures like the costly windproof retrofitting of buildings. Agricultural insurance can motivate farmers to invest more, leading to increased income (Dinesh *et al.*, 2017). However, the insurance needs to be carefully designed, so as to avoid incentivizing risky behaviour and poor agricultural practices.

Annex II: Cost Benefit Analysis indicators

Net Present Value

In this study, the Net Present Value (NPV) of DRR good practices and previously used practices was calculated and compared to assess the added benefits and avoided costs brought by the good practice, under both normal and natural hazard conditions. The NPV corresponds to the difference between the value of future cash inflows and future cash outflows discounted to present value. The formula for the discounted sum of all cash flows is:

$$NPV = -C_o + \sum_{t=1}^{T} \frac{C_t}{(1+r)^t}$$

where:

- C_o is the upfront capital investment, if any (e.g. machinery, tools, installation costs)
- C_t is the net cash flow during the period t, calculated as the difference between total costs and benefits over the time period considered.
- r is the discount rate used to estimate the present value of costs and benefits. A 10% discount rate was applied in all CBAs conducted in this study.
- T is time. The period of appraisal for all the CBAs conducted in this study was 11 years.

Table 13. Different cases resulting from the comparison of the NPV of good DRR practices to that of usual practices

	NPV of good practice vs. usual practice		Result
	Hazard conditions	Non-hazard conditions	
Case 1	Higher	Higher or equal	The good practice proves effective in reducing damage and losses caused by the hazards addressed, and it is a ‘no-regret’ measure.
Case 2	Higher	Lower	The good practice proves effective in reducing damage and losses caused by the hazards addressed, but it brings lower returns than the usual practice in the absence of hazards or stress conditions.
Case 3	Equal or lower	Lower	The good practice proves not effective to reduce damage and losses caused by the hazards addressed, and it has lower performance than the usual practice in the absence of hazards or stress conditions.

Benefit Cost Ratio

The BCR indicates how many United States dollars (USD) are obtained for each dollar invested, and it is calculated as the ratio between the present value of benefits and the present value of costs:

$$BCR = \frac{PV_{benefits}}{PV_{costs}}$$

Annex III: Hazard context

Weather data was derived using Earthmap, a FAO-Google tool for historical analysis of environmental and climate parameters that integrates Google technologies with freely available datasets (see earthmapdemo.info).

Precipitation and temperature data were derived for each month of the monitored season in all districts where DRR good practices were monitored. The monthly average was then compared to the 37-year monthly average to identify anomalies in the weather patterns during the monitored period.

Data sources

Precipitation

Precipitation data was derived from processing Climate Hazards Group InfraRed Precipitation with Station data (CHIRPS v2) grids at 5-day temporal resolution to generate total annual precipitations analysis for the period 1981 to present. Precipitation data (mm) of each month during the monitored season was compared to the 37-year average, calculating a percentage deviation.

Full details on this methodology can be found here: Funk, C.C., Peterson, P.J., Landsfeld, M.F., Pedreros, D.H., Verdin, J.P., Rowland, J.D., Romero, B.E., Husak, G.J., Michaelsen, J.C., and Verdin, A.P., 2014, A quasi-global precipitation time series for drought monitoring: U.S. Geological Survey Data Series 832, 4 p., dx.doi.org/10.3133/ds832

Temperature

The minimum and maximum data is derived from processing European Centre for Medium-Range Weather Forecasts (ECMWF) climatic grids to generate a time series of mean annual minimum temperatures for the period 1989–2016.

The average of the minimum and maximum temperature data (Celsius degree) for each month during the monitored season was calculated and compared to the monthly 27-year average calculating a percentage deviation.

Full details on this methodology can be found here: The European Centre for Medium-Range Weather Forecasts (ECMWF), see www.ecmwf.int/.

Administrative layers[1]

Administrative layers (Level 0 – national, Level   – departments and Level 2 – district) were added to the Earthmap tool in order permit the retrieval of location-specific temperature and precipitation data. The administrative layers were derived from the GLOBAL ADMINISTRATIVE UNIT LAYERS (GAUL, see www.fao.org/geonetwork/srv/en/metadata.show?id=12691). In the cases of Bolivia (Plurinational State of) and the Philippines, administrative layers were derived from GADM (see gadm.org/index.html).

Data

The monthly precipitation and temperature data of each season and district where the good practices were monitored are presented in detail below. The months for which the data was not yet available are marked "not applicable" (N/A). Where the percentage difference is explained with the words "increase" or "decrease", it means that it was not possible calculate a numeric percentage change, because numbers were negative.

[1] The designations employed and the presentation of material in any map(s) used herein do not imply the expression of any opinion whatsoever on the part of FAO concerning the legal or constitutional status of any country, territory or sea area, or concerning the delimitation of frontiers.

BOLIVIA (PLURINATIONAL STATE OF)

Practice: Cattle raising in silvopastoral systems
Hazard addressed: drought

- Location (Municipality, Department) : **Boyuibe**, Santa Cruz

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27 years monthly average	Min temperature (°C) - Monthly Average	Min temperature 27 years monthly average	% difference of monthly min temperature compared to 27 years monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37 year monthly average
Dry Season 2016									
May-16	20.2	22.0	-8%	16.7	15.092	10%	16.0	18.1	-11%
Jun-16	18.6	21.1	-12%	11.1	13.581	-18%	19.1	13.2	45%
Jul-16	23.8	21.4	12%	13.2	12.391	6%	2.1	3.3	-35%
Aug-16	27.2	24.8	10%	15.1	14.238	6%	6.1	7.5	-19%
Sep-16	28.2	27.0	5%	15.6	16.132	-3%	5.4	10.0	-45%
Oct-16	30.6	28.4	8%	18.9	18.502	2%	25.3	31.5	-20%
Nov-16	29.6	28.9	3%	18.6	19.194	-3%	49.2	55.5	-11%
Seasonal Average			**2%**			**0%**			**14%**

- Location (Municipality, Department): **Cuevo**, Santa Cruz

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2016									
May-16	17.5	-3.0	Increase	12.4	13.103	-6%	12.579	15.2	-17%
Jun-16	16.3	19.7	-17%	9.5	11.482	-17%	19.2	12.5	53%
Jul-16	21.3	19.6	9%	11.3	10.139	11%	3.2	5.0	-36%
Aug-16	25.3	22.7	12%	12.7	11.703	9%	6.3	7.9	-21%
Sep-16	26.3	24.6	7%	13.3	13.489	-2%	8.9	14.5	-39%
Oct-16	28.3	26.0	9%	16.5	15.966	3%	29.6	36.6	-19%
Nov-16	27.3	26.4	3%	16.5	16.728	-1%	66.6	72.7	-8%
Seasonal Average			**Increase**			**0%**			**-12%**

Practice: Early maturing cassava variety
Hazard addressed: floods

- Location (Municipality, Department): **Rurrenabaque**, Beni

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2016									
Jun-16	25.3	25.4	-1%	19.3	19.1	1%	87.5	117.1	-25%
Jul-16	24.7	25.0	-1%	17.8	18.1	-2%	60.9	78.0	-22%
Aug-16	27.5	25.1	10%	18.8	17.0	10%	45.1	60.8	-26%
Sep-16	28.5	27.2	5%	19.6	17.8	10%	50.5	47.0	7%
Oct-16	28.5	28.1	1%	19.8	19.2	3%	87.3	78.4	11%
Nov-16	30.0	28.2	6%	21.8	20.6	6%	133.5	106.8	25%
Seasonal Average			**3%**			**5%**			**-5%**

Practice: Camelid raising with livestock shelters (*corralones*) and veterinary pharmacies
Hazard addressed: frost and snow

- Location (Municipality, Department): **Curahuara de Carangas**, Oruro

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2016									
Dec-15	17.5	13.7	28%	3.3	1.907	74%	51.6	55.5	-7%
Jan-16	17.2	12.0	43%	3.9	2.347	67%	128.5	98.9	30%
Feb-16	13.9	11.8	18%	3.6	1.684	114%	67.6	96.6	-30%
Mar-16	15.9	11.9	33%	3.0	1.687	76%	88.8	63.3	40%
Seasonal Average			**31%**			**83%**			**8%**
Dry Season 2016									
Apr-16	14.3	11.8	21%	1.1	-0.9	Increase	13.324	15.5	-14%
May-16	13.5	11.2	21%	-1.7	-2.9	Increase	8.681	6.3	37%
Jun-16	11.8	10.6	11%	-2.7	-3.5	Increase	1.458	1.6	-8%
Jul-16	12.0	10.5	14%	-2.6	-3.6	Increase	3.193	4.1	-22%
Aug-16	13.3	12.0	11%	-2.2	-2.9	Increase	6.468	8.6	-25%
Sep-16	15.0	13.6	10%	-1.7	-2.3	Increase	14.299	11.3	27%
Oct-16	15.8	15.1	4%	0.1	-0.5	Increase	13.688	12.0	14%
Nov-16	16.4	14.8	11%	0.4	0.7	-49%	9.913	15.1	-34%
Seasonal Average			**12%**			**Increase**			**-2%**

- Location (Municipality, Department): **Toledo,** Oruro

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2016									
Dec-15	21.5	18.1	19%	6.4	4.991	28%	33.2	57.9	-43%
Jan-16	20.1	16.3	23%	7.0	5.210	34%	47.2	86.3	-45%
Feb-16	17.9	16.1	11%	7.1	4.720	49%	97.6	76.4	28%
Mar-16	20.5	16.0	28%	5.4	3.797	43%	13.6	47.2	-71%
Seasonal Average			**21%**			**39%**			**-33%**
Dry Season 2016									
Apr-16	29.0	26.1	11%	3.7	1.8	110%	11.5	10.5	10%
May-16	25.7	23.7	8%	-1.2	-1.8	Increase	2.7	4.8	-44%
Jun-16	24.5	24.1	1%	-2.9	-3.1	Increase	4.0	4.5	-12%
Jul-16	28.4	27.7	3%	-2.5	-3.3	Increase	2.2	2.7	-17%
Aug-16	28.9	28.3	2%	-1.7	-2.1	Increase	5.1	7.5	-32%
Sep-16	28.9	27.9	4%	1.3	0.2	433%	5.2	12.3	-58%
Oct-16	30.4	30.4	0%	2.6	2.2	21%	17.0	14.2	20%
Nov-16	29.3	28.5	3%	3.6	3.6	-2%	12.0	19.8	-39%
Seasonal Average			**3%**			**Increase**			**-26%**

- Location (Municipality, Departament): **Bolivar**, Cochabamba

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2016									
Dec-15	16.9	14.7	15%	4.7	4.7	2%	38.8	62.6	-38%
Jan-16	14.9	13.4	11%	4.9	4.9	1%	84.5	94.5	-11%
Feb-16	14.7	13.3	11%	5.7	4.6	22%	105.1	97.0	8%
Mar-16	15.5	13.4	16%	4.7	3.9	22%	16.4	63.8	-74%
Seasonal Average			**13%**			**12%**			**-29%**
Dry Season 2016									
Apr-16	15.5	13.7	13%	3.7	2.2	68%	15.3	15.9	-4%
May-16	15.5	13.7	13%	0.4	-0.1	Increase	4.3	6.5	-34%
Jun-16	13.5	13.6	-1%	-0.8	-1.8	Increase	3.0	3.6	-17%
Jul-16	14.5	13.6	6%	-0.8	-2.1	Increase	2.6	3.4	-25%
Aug-16	15.4	14.8	4%	-0.8	-1.1	Increase	7.7	9.5	-19%
Sep-16	15.7	15.6	0%	1.8	1.7	1%	8.1	13.5	-40%
Oct-16	16.2	16.5	-2%	2.7	2.7	2%	23.7	19.0	25%
Nov-16	16.5	16.0	3%	2.9	3.8	-23%	13.7	29.8	-54%
Seasonal Average			**3%**			**Increase**			**-23%**

- Location (Municipality, Departament): **Tapacari**, Cochabamba

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2016									
Dec-15	17.8	15.0	19%	6.9	6.091	14%	53.9	76.8	-30%
Jan-16	16.4	13.9	18%	6.7	6.097	10%	114.9	119.9	-4%
Feb-16	15.7	13.7	14%	7.0	5.745	23%	126.3	117.8	7%
Mar-16	16.4	13.7	20%	6.6	5.158	28%	23.0	69.8	-67%
Seasonal Average			**18%**			**19%**			**-23%**
Dry Season 2016									
Apr-16	16.7	13.9	21%	5.2	3.8	39%	16.0	14.6	10%
May-16	16.3	13.7	20%	2.4	1.6	48%	5.7	9.2	-38%
Jun-16	14.7	13.5	9%	1.6	0.5	207%	4.2	5.1	-18%
Jul-16	15.3	13.4	15%	0.7	-0.3	Increase	3.8	4.7	-20%
Aug-16	16.2	14.5	11%	1.6	1.4	19%	9.4	10.8	-13%
Sep-16	16.7	15.3	9%	3.8	3.5	9%	9.7	14.9	-35%
Oct-16	16.7	16.1	3%	4.6	4.5	3%	38.2	27.6	38%
Nov-16	17.6	16.0	9%	5.0	5.4	-6%	23.5	39.6	-41%
Seasonal Average			**11%**			**Increase**			**-18%**

Practice: Cattle raising with livestock refuge mounds, deworming and preventive vitaminization
Hazard addressed: flood

- Location (Municipality, Department): **San Ignacio de Mojos**, Beni

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2016									
Dec-15	30.3	28.0	8%	23.0	21.593	7%	159.5	284.6	-44%
Jan-16	30.5	27.8	10%	23.7	21.605	10%	266.4	346.9	-23%
Feb-16	29.5	27.6	7%	23.5	21.540	9%	321.5	291.0	10%
Mar-16	29.4	27.6	7%	22.8	21.393	7%	205.3	265.1	-23%
Seasonal Average			**8%**			**8%**			**-20%**
Dry Season 2016									
Apr-16	29.0	27.2	7%	22.3	20.5	9%	168.4	146.3	15%
May-16	25.7	25.5	1%	19.2	18.8	2%	53.9	88.1	-39%
Jun-16	24.5	24.9	-2%	17.2	17.8	-3%	38.6	45.7	-15%
Jul-16	28.4	25.1	13%	18.9	16.6	14%	17.2	31.9	-46%
Aug-16	28.9	27.5	5%	19.4	17.8	9%	50.8	40.3	26%
Sep-16	28.9	28.6	1%	19.6	19.4	1%	95.3	78.4	22%
Oct-16	30.4	28.9	5%	22.1	20.8	6%	108.6	130.1	-16%
Nov-16	29.3	28.4	3%	21.7	21.1	3%	103.4	185.2	-44%
Seasonal Average			**4%**			**5%**			**-16%**

CAMBODIA

Practice: Home vegetable gardening with rooftop water collection, drip irrigation and plastic mulching
Hazards addressed: pests, dry spell/drought

- Location (District, Province): **Anlong Veng**, Oddar Meanchey

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
May-15	34.8	30.7	14%	25.9	24.2	7%	121.1	192.7	-37%
Jun-15	32.7	30.0	9%	25.2	24.2	4%	141.6	243.3	-42%
Jul-15	31.1	29.2	6%	25.0	23.8	5%	367.8	280.6	31%
Aug-15	31.0	28.9	7%	24.2	23.7	2%	262.2	301.7	-13%
Sep-15	30.0	28.2	6%	24.0	23.1	4%	274.3	327.4	-16%
Oct-15	30.3	28.6	6%	23.0	22.5	2%	152.5	180.9	-16%
Seasonal Average			**8%**			**4%**			**-15%**

- Location (District, Province): **Banteay Ampil**, Oddar Meanchey

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
May-15	36.3	31.0	17%	26.7	24.6	8%	96.7	166.4	-42%
Jun-15	33.8	30.5	11%	25.8	24.7	5%	126.6	183.0	-31%
Jul-15	32.7	29.7	10%	25.7	24.1	7%	267.6	228.3	17%
Aug-15	31.8	29.4	8%	24.8	23.9	4%	195.3	242.4	-19%
Sep-15	30.8	28.5	8%	24.7	23.3	6%	292.9	308.9	-5%
Oct-15	30.0	28.5	5%	23.8	22.6	5%	151.4	162.9	-7%
Seasonal Average			**10%**			**6%**			**-15%**

- Location (District, Province): **Trapeang Prasat**, Oddar Meanchey

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
May-15	34.5	30.6	13%	25.8	24.2	7%	136.2	211.0	-35%
Jun-15	32.5	29.9	9%	24.9	24.1	3%	155.0	249.0	-38%
Jul-15	30.9	29.2	6%	24.9	23.8	4%	374.9	309.8	21%
Aug-15	30.7	28.9	6%	24.0	23.6	2%	290.6	322.2	-10%
Sep-15	29.9	28.1	6%	23.9	23.0	4%	268.7	342.3	-21%
Oct-15	29.9	28.6	5%	23.1	22.4	3%	146.7	179.5	-18%
Seasonal Average			**7%**			**4%**			**-17%**

Practice: Home vegetable gardening with rooftop water collection, drip irrigation and plastic mulching
Hazard addressed: dry spell/drought

- Location (District, Province): **Kong Pisei**, Kampong Speu

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
May-15	35.0	31.3	12%	26.0	24.7	5%	118.6	140.3	-15%
Jun-15	33.0	30.7	8%	25.9	24.5	6%	102.5	132.4	-23%
Jul-15	34.0	30.3	13%	25.9	24.2	7%	184.8	181.9	2%
Aug-15	33.0	30.1	10%	25.0	24.2	4%	178.7	168.1	6%
Sep-15	32.0	29.3	9%	24.9	23.7	5%	213.6	224.2	-5%
Oct-15	30.9	29.0	6%	24.0	23.2	4%	188.4	263.8	-29%
Seasonal Average			**10%**			**5%**			**-11%**

- Location (District, Province): **Thpong**, Kampong Speu

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
May-15	33.9	30.6	11%	24.6	23.8	4%	135.5	185.0	-27%
Jun-15	32.3	30.2	7%	24.6	23.6	4%	147.8	200.4	-26%
Jul-15	32.6	29.7	10%	24.3	23.3	4%	193.3	205.7	-6%
Aug-15	31.5	29.4	7%	24.2	23.3	4%	291.1	272.7	7%
Sep-15	30.3	28.5	6%	23.6	22.9	3%	303.2	341.9	-11%
Oct-15	29.2	28.0	4%	23.5	22.5	4%	222.2	278.9	-20%
Seasonal Average			**8%**			**4%**			**-14%**

- Location (District, Province): **Somrong Tong,** Kampong Speu

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
May-15	35.4	31.3	13%	26.1	24.5	6%	112.6	145.0	-22%
Jun-15	33.4	30.8	9%	25.5	24.4	4%	110.9	150.8	-26%
Jul-15	34.4	30.3	14%	25.7	24.2	6%	168.9	171.0	-1%
Aug-15	33.4	30.1	11%	25.1	24.1	4%	200.6	189.8	6%
Sep-15	31.5	29.2	8%	24.7	23.6	5%	240.5	267.5	-10%
Oct-15	30.5	28.8	6%	24.0	23.0	4%	184.7	263.2	-30%
Seasonal Average			**10%**			**5%**			**-14%**

- Location (District, Province): **Odongk**, Kampong Speu

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
May-15	35.9	31.5	14%	26.3	24.7	7%	122.1	163.3	-25%
Jun-15	34.0	30.9	10%	26.0	24.6	6%	118.6	156.4	-24%
Jul-15	34.9	30.4	15%	26.0	24.3	7%	166.7	162.9	2%
Aug-15	33.6	30.3	11%	25.3	24.2	5%	238.6	214.3	11%
Sep-15	32.1	29.4	9%	25.0	23.8	5%	229.2	264.6	-13%
Oct-15	30.9	29.0	7%	24.2	23.2	4%	226.2	270.9	-17%
Seasonal Average			**11%**			**6%**			**-11%**

- Location (District, Province): **Phnom Sruoch**, Kampong Speu

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
May-15	34.0	30.6	11%	25.3	23.9	6%	132.1	165.3	-20%
Jun-15	31.9	30.0	6%	24.6	23.9	3%	156.7	207.8	-25%
Jul-15	32.4	29.5	10%	24.8	23.6	5%	256.2	288.0	-11%
Aug-15	31.6	29.3	8%	24.4	23.6	4%	291.9	293.7	-1%
Sep-15	30.2	28.5	6%	24.1	23.0	4%	324.1	334.1	-3%
Oct-15	30.1	28.1	7%	23.5	22.5	5%	187.7	278.5	-33%
Seasonal Average			**8%**			**4%**			**-15%**

COLOMBIA

Practice: Sheep and goat raising with health care and improved corrals
Hazard addressed: dry spell/drought and related increase in animal disease incidence

- Location (Municipality, Department): Uribia, La Guajira

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet and Dry Seasons									
Apr-16	31.5	31.1	1%	25.2	24.6	2%	1.6	1.7	-8%
May-16	31.7	31.4	1%	26.1	25.3	3%	24.1	13.6	78%
Jun-16	32.8	32.2	2%	26.1	25.8	1%	7.2	7.7	-7%
Jul-16	32.7	32.0	2%	25.8	25.6	1%	1.3	1.7	-21%
Aug-16	33.2	32.1	3%	26.2	25.7	2%	9.6	17.5	-45%
Sep-16	32.9	31.2	5%	26.2	25.6	3%	39.6	56.2	-30%
Oct-16	29.8	30.0	-1%	25.2	25.0	1%	117.9	105.7	12%
Nov-16	28.9	29.1	-1%	24.5	24.4	0%	93.5	61.0	53%
Dec-16	29.1	29.1	0%	24.4	24.0	2%	24.0	23.7	1%
Jan-17	NA			NA			4.5	3.0	52%
Fev-17	NA			NA			3.2	2.6	25%
Mar-17	NA			NA			1.0	0.6	70%
Apr-17	NA			NA			2.1	1.7	21%
May-17	NA			NA			7.7	13.6	-43%
Jun-17	NA			NA			4.2	7.7	-45%
Jul-17	NA			NA			1.2	1.7	-25%
Aug-17	NA			NA			14.7	17.5	-16%
Sep-17	NA			NA			45.9	56.2	-18%
Oct-17	NA			NA			43.1	105.7	-59%
Nov-17	NA			NA			58.7	61.0	-4%
Dec-17	NA			NA			14.2	23.7	-40%
Jan-18	NA			NA			3.6	3.0	22%
Fev-18	NA			NA			2.7	2.6	5%
Mar-18	NA			NA			0.5	0.6	-13%
Apr-18	NA			NA			1.0	1.7	-39%
May-18	NA			NA			4.7	13.6	-66%
Jun-18	NA			NA			7.9	7.7	2%
Jul-18	NA			NA			1.4	1.7	-16%
Seasonal Average			**2%**			**2%**			**-6%**

GUYANA

Practice: Poultry farming with black giant chicken breeds for livelihood diversification
Hazards addressed: dry spell/drought, flood

- Location (Municipality, Province): Ireng/upper Potaro, Region 8

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season									
Aug-18	NA	NA	NA	NA	NA	NA	133.7	178.5	-25%
Sep-18	NA	NA	NA	NA	NA	NA	133.9	78.0	72%
Seasonal Average									**23%**

HAITI

Practice: Pea cultivation with live barriers, conservation agriculture and agroforestry
Hazards addressed: strong winds, hurricanes

- Location (Arrondissement, Department): **Bainet**, Département Sud-Est

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Spring									
Jul-17	NA	NA	NA	NA	NA	NA	86.6	78.3	10%
Aug-17	NA	NA	NA	NA	NA	NA	125.6	112.6	12%
Sep-17	NA	NA	NA	NA	NA	NA	114.6	142.4	-20%
Oct-17	NA	NA	NA	NA	NA	NA	98.9	152.7	-35%
Seasonal Average			**NA**			**NA**			**-8%**

- Location (Arrondissement, Department): **Léogâne**, Département Ouest

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Spring									
Jul-17	NA	NA	NA	NA	NA	NA	110.0	96.8	14%
Aug-17	NA	NA	NA	NA	NA	NA	149.0	139.8	7%
Sep-17	NA	NA	NA	NA	NA	NA	131.2	164.2	-20%
Oct-17	NA	NA	NA	NA	NA	NA	103.7	167.5	-38%
Seasonal Average			**NA**			**NA**			**-9%**

Practice: Bean cultivation with conservation agriculture and agroforestry
Hazard addressed: pests

- Location (Arrondissement, Department): **Belle-Anse**, Département Sud-Est

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Winter									
Jul-16	26.851	26.2	2%	20.962	19.7	6%	45.3	59.8	-24%
Aug-16	26.519	26.2	1%	21.13	19.8	7%	59.1	99.5	-41%
Sep-16	26.05	25.7	2%	21.13	19.6	8%	96.9	127.1	-24%
Oct-16	24.989	25.0	0%	20.931	19.0	10%	218.1	149.1	46%
Seasonal Average			**1%**			**8%**			**-11%**

JAMAICA

Practice: Tomato and sweet pepper cultivation with roof top water harvesting and gravity drip irrigation
Hazard addressed: dry spell/drought

- Location (Parish, County): Saint Elizabeth, Cornwall

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2018									
Jun-18	NA	NA	NA	NA	NA	NA	33.7	81.0	-58%
Jul-18	NA	NA	NA	NA	NA	NA	38.5	92.2	-58%
Aug-18	NA	NA	NA	NA	NA	NA	45.9	115.9	-60%
Sep-18	NA	NA	NA	NA	NA	NA	99.4	188.1	-47%
Oct-18	NA	NA	NA	NA	NA	NA	114.7	205.5	-44%
Nov-18	NA	NA	NA	NA	NA	NA	70.8	104.7	-32%
Seasonal Average			NA			NA			**-50%**

THE LAO PEOPLE'S DEMOCRATIC REPUBLIC

Practice: Early maturing rice varieties
Hazards addressed: dry spell/drought, cold wave

- Location (Province): **Savannakhet**

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	31.8	29.1	9%	24.6	23.6	4%	154.7	222.8	-31%
Jul-15	28.7	28.3	1%	23.6	23.2	2%	316.5	341.0	-7%
Aug-15	29.6	28.0	6%	23.4	23.0	2%	272.1	398.7	-32%
Sep-15	29.6	28.0	6%	23.3	22.4	4%	278.5	319.5	-13%
Oct-15	29.2	28.1	4%	21.4	21.4	0%	111.3	138.3	-20%
Nov-15	30.0	27.5	9%	22.2	20.0	11%	38.1	39.8	-4%
Dec-15	28.1	25.8	9%	19.1	17.7	8%	19.5	21.4	-9%
Seasonal Average:			**6%**			**4%**			**-16%**
Dry Season 2016									
Jan-16	27.5	26.4	4%	18.6	16.9	10%	33.7	16.4	106%
Feb-16	26.3	28.4	-7%	16.0	18.2	-12%	11.8	22.9	-49%
Mar-16	32.0	30.3	6%	20.7	20.4	1%	11.0	37.8	-71%
Apr-16	35.5	31.1	14%	25.4	22.6	13%	27.2	61.5	-56%
Seasonal Average			**4%**			**3%**			**-17%**

- Location (Province): **Khammouane**

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.5	28.1	9%	23.485	22.6	4%	155.9	302.7	-49%
Jul-15	27.3	27.6	-1%	22.531	22.3	1%	502.6	483.3	4%
Aug-15	28.7	27.3	5%	22.438	22.0	2%	282.1	539.1	-48%
Sep-15	28.4	27.3	4%	22.222	21.3	4%	310.5	343.1	-9%
Oct-15	28.2	26.9	5%	19.98	20.0	0%	92.2	136.1	-32%
Nov-15	28.5	25.8	10%	20.177	17.9	13%	36.0	34.1	6%
Dec-15	25.6	23.5	9%	17.02	15.3	12%	14.9	16.9	-12%
Seasonal Average:			**6%**			**5%**			**-20%**
Dry Season 2016									
Jan-16	24.8	23.7	5%	16.107	14.5	11%	40.4	16.7	141%
Feb-16	23.8	25.6	-7%	13.166	16.0	-18%	15.0	35.5	-58%
Mar-16	30.2	28.0	8%	18.889	18.5	2%	18.2	53.0	-66%
Apr-16	33.8	29.5	15%	23.911	21.1	13%	51.5	75.6	-32%
Seasonal Average:			**5%**			**2%**			**-3%**

- Location (Province): **Champasak**

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year Monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.2	28.4	6%	23.5	23.0	2%	302.0	336.3	-10%
Jul-15	28.2	27.7	2%	22.8	22.6	1%	495.4	525.6	-6%
Aug-15	28.6	27.5	4%	22.7	22.3	1%	479.0	517.0	-7%
Sep-15	28.7	27.3	5%	22.6	21.9	3%	324.9	394.3	-18%
Oct-15	28.8	28.1	2%	21.8	21.1	3%	74.4	124.5	-40%
Nov-15	30.6	28.8	7%	22.2	20.1	11%	31.9	24.5	30%
Dec-15	30.8	28.6	8%	20.5	18.6	10%	3.1	4.7	-35%
Seasonal Average:			**5%**			**5%**			**-12%**
Dry Season 2016									
Jan-16	29.7	29.4	1%	20.4	18.1	12%	6.8	5.0	36%
Feb-16	30.4	30.9	-2%	18.0	19.7	-9%	10.1	16.2	-38%
Mar-16	33.0	31.7	4%	22.4	21.7	3%	8.7	34.7	-75%
Oct-15	28.8	28.1	2%	21.8	21.1	3%	74.4	124.5	-40%
Seasonal Average:			**1%**			**2%**			**-29%**

Other practices monitored in these locations and during these seasons:

Practice: Rice cultivation with guano fertilizer to keep moisture and improve soil fertility in paddy fields
Hazards addressed: dry spell/drought, cold wave

- Location (Province): **Savannakhet** – Jun 15 to Apr-16
- Location (Province): **Khammouane** – Jun 15 to Apr-16

Practice: Indoor mushroom production for livelihood diversification
Hazard addressed: dry spell/drought

- Location (Province): **Khammouane** – Jan-16 to Oct-16
- Location (Province): **Champasak** – Jan-16 to Oct-16
- Location (Province): **Savannakhet** – Jan-16 to Oct-16

Practice: Flood-tolerant rice varieties
Hazard addressed: flood

- Location (Province): **Savannakhet** – Jun-15 to Dec-15
- Location (Province): **Khammouane** – Jun-15 to Dec-15

Practice: Drought-tolerant aquaculture species
Hazard addressed: dry spell/drought

- Location (Province): **Savannakhet** – Jun 15 to Apr-16

Practice: Chicken raising with improved chicken breeds and vaccination
Hazards addressed: disease, cold wave

- Location (Province): **Savannakhet** – Jun 15 to Apr-16
- Location (Province): **Khammouane** – Jun 15 to Apr-16

Practice: Goat raising in controlled areas and with vaccination
Hazard addressed: disease

- Location (Province): **Savannakhet** – Jun 15 to Apr-16
- Location (Province): **Khammouane** – Jun 15 to Apr-16

PAKISTAN

Practice: Wheat cultivation with FYM and compost
Hazard addressed: dry spell/drought

- Location (District, Province): **Ghotki**, Sindh

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Rabi season 2017–18									
Nov-17	NA	NA	NA	NA	NA	NA	2.8	1.6	82%
Dec-17	NA	NA	NA	NA	NA	NA	5.2	3.1	69%
Jan-18	NA	NA	NA	NA	NA	NA	2.7	4.3	-37%
Feb-18	NA	NA	NA	NA	NA	NA	5.8	5.7	1%
Mar-18	NA	NA	NA	NA	NA	NA	4.7	8.7	-46%
Apr-18	NA	NA	NA	NA	NA	NA	3.0	3.4	-12%
Seasonal Average			NA			NA			**-24%**

Practice: Wheat cultivation with levelling and IPM
Hazard addressed: dry spell/drought

- Location (District, Province): **Kashmore**, Sindh

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Rabi season 2017–18									
Nov-17	NA	NA	NA	NA	NA	NA	2.9	1.7	70%
Dec-17	NA	NA	NA	NA	NA	NA	7.4	4.5	64%
Jan-18	NA	NA	NA	NA	NA	NA	7.4	11.6	-37%
Feb-18	NA	NA	NA	NA	NA	NA	8.7	10.5	-17%
Mar-18	NA	NA	NA	NA	NA	NA	7.7	15.6	-51%
Apr-18	NA	NA	NA	NA	NA	NA	5.2	6.2	-16%
Seasonal Average			NA			NA			**2%**

Practice: Rice Cultivation with line sowing and Alternate Wet and Dry (AWD) Method
Hazard addressed: dry spell/drought

- Location (District, Province): **Muzaffargarh**, Punjab

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Kharif season 2018									
Jun-18	NA	NA	NA	NA	NA	NA	20.5	16.0	29%
Jul-18	NA	NA	NA	NA	NA	NA	31.4	37.9	-17%
Aug-18	NA	NA	NA	NA	NA	NA	18.3	31.7	-42%
Sep-18	NA	NA	NA	NA	NA	NA	8.0	16.4	-51%
Oct-18	NA	NA	NA	NA	NA	NA	1.2	1.6	-23%
Seasonal Average			NA			NA			**-21%**

Practice: Vegetable cultivation with ridge sowing, FYM, multicropping and IPM
Hazard addressed: dry spell/drought

- Location (District, Province): **Ghotki**, Sindh, Pakistan

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Zaid Rabi season 2018									
Feb-18	NA	NA	NA	NA	NA	NA	5.8	5.7	1%
Mar-18	NA	NA	NA	NA	NA	NA	4.7	8.7	-46%
Apr-18	NA	NA	NA	NA	NA	NA	3.0	3.4	-12%
May-18	NA	NA	NA	NA	NA	NA	2.7	2.7	0%
Jun-18	NA	NA	NA	NA	NA	NA	10.7	7.6	40%
Seasonal Average			NA			NA			**-14%**

Practice: Cotton cultivation with laser levelling, ridge sowing, IPM and compost application
Hazard addressed: dry spell/drought

- Location (District, Province): **Ghotki**, Sindh, Pakistan

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Kharif season 2017									
Jun-17	NA	NA	NA	NA	NA	NA	15.9	7.6	108%
Jul-17	NA	NA	NA	NA	NA	NA	92.9	26.8	246%
Aug-17	NA	NA	NA	NA	NA	NA	27.7	32.0	-13%
Sep-17	NA	NA	NA	NA	NA	NA	5.8	8.3	-30%
Oct-17	NA	NA	NA	NA	NA	NA	1.6	1.8	-8%
Nov-17	NA	NA	NA	NA	NA	NA	2.8	1.6	82%
Seasonal Average			NA			NA			**61%**

PHILIPPINES

Practice: Multi-stress tolerant Green Super Rice (GSR)
Hazards addressed: dry spell/drought, disease, flood

- Location (Municipality, Province, Region): **Bula**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year Monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	29.0	28.9	0%	23.1	23.2	-1%	189.5	340.0	-44%
Dec-14	28.0	28.1	0%	23.1	22.6	2%	588.1	361.8	63%
Jan-15	27.0	27.6	-2%	22.1	22.1	0%	220.4	159.3	38%
Feb-15	28.0	28.2	-1%	21.1	22.1	-5%	46.2	111.8	-59%
Mar-15	29.0	29.0	0%	21.1	22.3	-5%	59.7	95.5	-37%
Apr-15	30.9	30.5	1%	23.1	23.2	0%	83.4	96.0	-13%
May-15	31.9	30.5	5%	25.1	24.2	4%	69.3	183.2	-62%
Seasonal Average			**0%**			**-1%**			**-16%**
Wet Season 2015									
Jun-15	30.9	29.7	4%	25.1	24.2	3%	149.6	219.7	-32%
Jul-15	29.9	28.9	4%	25.1	24.1	4%	257.8	331.1	-22%
Aug-15	29.9	29.1	3%	25.1	24.2	4%	177.2	206.5	-14%
Sep-15	29.9	28.6	5%	24.1	24.1	0%	240.9	351.9	-32%
Oct-15	29.0	28.8	1%	25.1	23.7	6%	227.8	343.1	-34%
Seasonal Average			**3%**			**3%**			**-27%**

- Location (Municipality, Province, Region): **Bato**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year Monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	28.7	28.7	0%	23.6	23.7	0%	201.8	367.8	-45%
Dec-14	27.7	28.0	-1%	23.6	23.2	2%	685.5	403.6	70%
Jan-15	26.8	27.6	-3%	22.4	22.7	-1%	270.7	197.4	37%
Feb-15	27.5	28.2	-2%	21.6	22.5	-4%	54.3	126.7	-57%
Mar-15	28.8	28.9	0%	22.2	22.9	-3%	73.1	113.4	-35%
Apr-15	30.1	30.2	0%	24.2	23.8	2%	90.1	98.6	-9%
May-15	30.5	30.1	1%	25.4	24.6	3%	77.0	189.6	-59%
Seasonal Average			**-1%**			**0%**			-14%
Wet Season 2015									
Jun-15	30.1	29.5	2%	25.4	24.7	3%	137.9	205.4	-33%
Jul-15	29.1	28.7	1%	25.4	24.6	3%	242.1	320.5	-24%
Aug-15	29.1	28.8	1%	25.4	24.7	3%	202.7	228.9	-11%
Sep-15	29.1	28.5	2%	25.2	24.5	3%	254.4	336.4	-24%
Oct-15	29.0	28.7	1%	25.4	24.0	6%	243.2	367.1	-34%
Seasonal Average			**2%**			**4%**			**-25%**

- Location (Municipality, Province, Region): **Canaman**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.3	29.6	2%	25.1	24.9	1%	138.9	206.4	-33%
Jul-15	29.5	28.8	2%	25.3	24.7	2%	262.7	327.6	-20%
Aug-15	29.5	29.0	2%	25.3	24.9	2%	178.6	212.9	-16%
Sep-15	29.5	28.5	3%	24.6	24.6	0%	231.5	354.7	-35%
Oct-15	29.0	28.4	2%	25.1	24.4	3%	253.8	379.2	-33%
Seasonal Average			**2%**			**2%**			**-27%**

- Location (Municipality, Province, Region): **Goa**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.0	29.6	1%	24.0	24.0	0%	122.1	201.8	-40%
Jul-15	29.0	29.0	0%	24.0	24.0	0%	253.1	336.5	-25%
Aug-15	29.0	29.0	0%	24.0	24.0	0%	182.1	229.3	-21%
Sep-15	29.0	28.5	2%	24.0	23.9	1%	185.2	301.6	-39%
Oct-15	28.0	28.1	0%	24.0	23.2	4%	317.9	476.4	-33%
Seasonal Average			**1%**			**1%**			**-31%**

- Location (Municipality, Province, Region): **Iriga City**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.3	29.4	3%	24.3	23.9	2%	221.3	226.3	-2%
Jul-15	29.3	28.6	2%	24.3	23.9	2%	269.7	322.3	-16%
Aug-15	29.3	28.7	2%	24.3	24.0	1%	207.5	268.8	-23%
Sep-15	29.3	28.4	3%	24.0	23.6	2%	231.7	340.6	-32%
Oct-15	29.0	28.3	3%	24.3	23.3	5%	690.9	439.9	57%
Seasonal Average			**3%**			**2%**			**-3%**

- Location (Municipality, Province, Region): **Magarao**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.3	29.8	2%	25.0	24.7	1%	144.7	206.3	-30%
Jul-15	29.3	29.0	1%	25.0	24.5	2%	261.7	323.3	-19%
Aug-15	29.3	29.0	1%	25.0	24.7	1%	174.1	209.9	-17%
Sep-15	29.3	28.6	2%	24.3	24.4	-1%	215.9	346.5	-38%
Oct-15	29.0	28.3	3%	25.0	24.2	3%	264.8	391.2	-32%
Seasonal Average			**2%**			**1%**			**-27%**

- Location (Municipality, Province, Region): **Nabua**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.7	29.6	4%	24.8	24.1	3%	127.7	205.2	-38%
Jul-15	29.7	28.8	3%	24.8	24.0	3%	245.1	317.5	-23%
Aug-15	29.7	28.9	3%	24.8	24.1	3%	194.4	225.5	-14%
Sep-15	29.7	28.5	4%	24.1	23.9	1%	227.4	333.6	-32%
Oct-15	29.0	28.6	2%	24.8	23.5	5%	244.6	369.2	-34%
Seasonal Average			**3%**			**3%**			**-28%**

- Location (Municipality, Province, Region): **Pili**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.7	29.8	3%	25.0	24.3	3%	139.7	225.8	-38%
Jul-15	29.7	29.0	2%	25.0	24.1	3%	269.1	349.6	-23%
Aug-15	29.7	29.1	2%	25.0	24.3	3%	175.4	208.2	-16%
Sep-15	29.7	28.6	4%	24.0	24.1	0%	193.8	328.8	-41%
Oct-15	29.0	28.6	1%	25.0	23.8	5%	236.7	364.6	-35%
Seasonal Average			**3%**			**3%**			**-31%**

- Location (Municipality, Province, Region): **Sagnay**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.0	29.3	3%	24.0	23.8	1%	116.5	222.1	-48%
Jul-15	29.0	28.5	2%	24.0	23.8	1%	253.8	316.2	-20%
Aug-15	29.0	28.6	2%	24.0	24.0	0%	193.7	231.9	-16%
Sep-15	29.0	28.2	3%	24.0	23.4	2%	178.1	330.4	-46%
Oct-15	29.0	28.1	3%	24.0	23.1	4%	272.5	432.8	-37%
Seasonal Average			**2%**			**2%**			**-33%**

- Location (Municipality, Province, Region): **San Fernando**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	29.6	29.2	1%	25.7	25.6	0%	151.7	219.7	-31%
Jul-15	29.3	28.5	3%	26.4	25.5	4%	245.6	324.5	-24%
Aug-15	29.3	28.6	2%	26.4	25.6	3%	193.3	219.1	-12%
Sep-15	29.3	28.4	3%	25.4	25.4	0%	270.4	380.7	-29%
Oct-15	29.0	28.4	2%	25.7	25.2	2%	234.9	358.2	-34%
Seasonal Average			**2%**			**2%**			**-26%**

- Location (Municipality, Province, Region): **Tiagon**, Camarines Sur, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.0	29.5	2%	24.0	23.9	0%	116.2	214.6	-46%
Jul-15	29.0	28.8	1%	24.0	23.9	1%	252.9	325.7	-22%
Aug-15	29.0	28.8	1%	24.0	24.0	0%	185.7	224.4	-17%
Sep-15	29.0	28.4	2%	24.0	23.7	1%	175.0	315.7	-45%
Oct-15	28.5	28.1	1%	24.0	23.1	4%	291.7	460.4	-37%
Seasonal Average			**1%**			**1%**			**-33%**

- Location (Municipality, Province, Region): **Basud**, Camarines Norte, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	27.0	27.4	-1%	24.0	24.8	-3%	419.8	541.4	-22%
Dec-14	26.0	26.4	-2%	24.0	24.3	-1%	750.7	608.6	23%
Jan-15	26.0	25.7	1%	22.0	23.9	-8%	437.5	317.1	38%
Feb-15	26.0	26.1	-1%	21.0	23.8	-12%	112.8	196.2	-43%
Mar-15	27.0	27.0	0%	22.0	24.1	-9%	143.8	219.7	-35%
Apr-15	29.0	28.7	1%	23.0	25.0	-8%	127.6	137.0	-7%
May-15	30.0	29.4	2%	25.0	25.8	-3%	84.8	168.6	-50%
Seasonal Average			**0%**			**-6%**			**-14%**
Wet Season 2015									
Jun-15	30.0	29.4	2%	25.0	25.9	-3%	164.4	194.2	-15%
Jul-15	29.0	28.8	1%	26.0	25.8	1%	245.2	317.6	-23%
Aug-15	29.0	29.0	0%	25.0	25.8	-3%	209.7	238.6	-12%
Sep-15	29.0	28.3	2%	25.0	25.4	-2%	204.3	314.1	-35%
Oct-15	28.0	27.9	1%	25.0	25.0	0%	401.2	539.7	-26%
Seasonal Average			**1%**			**-1%**			**-22%**

- Location (Municipality, Province, Region): **Labo**, Camarines Norte, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	27.4	27.7	-1%	23.5	23.7	-1%	522.1	553.8	-6%
Dec-14	26.4	26.7	-1%	22.9	23.2	-2%	822.8	633.6	30%
Jan-15	25.3	26.2	-4%	21.3	22.6	-6%	297.2	267.5	11%
Feb-15	25.8	26.8	-4%	20.5	22.5	-9%	87.1	180.7	-52%
Mar-15	27.4	27.8	-1%	21.2	22.9	-8%	117.4	209.9	-44%
Apr-15	28.9	29.7	-2%	22.5	23.8	-5%	73.2	126.2	-42%
May-15	30.8	30.1	2%	24.0	24.5	-2%	77.6	158.2	-51%
Seasonal Average			**-2%**			**-5%**			**-22%**
Wet Season 2015									
Jun-15	30.3	29.7	2%	24.5	24.6	0%	189.6	226.1	-16%
Jul-15	30.0	29.0	3%	24.5	24.4	0%	244.5	303.2	-19%
Aug-15	29.3	29.1	1%	24.5	24.6	0%	182.5	215.3	-15%
Sep-15	29.3	28.6	3%	23.8	24.3	-2%	189.4	291.3	-35%
Oct-15	28.7	28.2	2%	24.3	24.0	1%	395.1	545.6	-28%
Seasonal Average			**2%**			**0%**			**-23%**

- Location (Municipality, Province, Region): **Mercedes**, Camarines Norte, Bico

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	27.0	27.4	-1%	24.0	24.8	-3%	397.8	518.8	-23%
Dec-14	26.0	26.4	-2%	24.0	24.3	-1%	742.5	586.9	27%
Jan-15	26.0	25.7	1%	22.1	23.9	-8%	423.4	298.7	42%
Feb-15	26.0	26.2	-1%	21.1	23.8	-11%	105.5	174.3	-40%
Mar-15	27.0	27.0	0%	22.1	24.1	-9%	138.9	203.0	-32%
Apr-15	29.0	28.7	1%	23.1	25.0	-8%	120.8	127.9	-6%
May-15	30.0	29.4	2%	25.1	25.8	-3%	88.7	169.9	-48%
Seasonal Average			**0%**			**-6%**			**-11%**
Wet Season 2015									
Jun-15	30.0	29.4	2%	25.1	25.9	-3%	155.8	190.3	-18%
Jul-15	29.0	28.8	1%	26.0	25.8	1%	234.0	301.3	-22%
Aug-15	29.0	29.0	0%	25.1	25.8	-3%	210.4	241.4	-13%
Sep-15	29.0	28.3	2%	25.0	25.4	-2%	212.2	310.4	-32%
Oct-15	28.0	27.9	1%	25.0	25.0	0%	410.1	532.5	-23%
Seasonal Average			**1%**			**-1%**			**-22%**

- Location (Municipality, Province, Region): **Bato**, Catanduanes, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	29	28.9	0%	25.1	24.2	3%	149.6	219.7	-32%
Jul-15	29	28.5	2%	25.1	24.1	4%	257.8	331.1	-22%
Aug-15	29	28.8	1%	25.1	24.2	4%	177.2	206.5	-14%
Sep-15	29	28.4	2%	24.1	24.1	0%	240.9	351.9	-32%
Oct-15	29	28.1	3%	25.1	23.7	6%	227.8	343.1	-34%
Seasonal Average			**2%**			**3%**			**-27%**

- Location (Municipality, Province, Region): **San Miguel**, Catanduanes, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	28.0	27.5	2%	23.3	23.8	-2%	341.2	454.0	-25%
Dec-14	27.0	26.7	1%	23.3	23.3	0%	682.8	506.0	35%
Jan-15	25.2	25.9	-3%	21.5	22.9	-6%	455.6	406.5	12%
Feb-15	25.2	26.3	-4%	20.7	22.9	-10%	135.0	166.7	-19%
Mar-15	27.0	27.1	0%	21.7	23.0	-6%	112.8	177.7	-37%
Apr-15	28.0	28.5	-2%	22.7	24.0	-5%	134.4	137.1	-2%
May-15	29.0	29.2	-1%	23.7	24.3	-3%	133.9	199.7	-33%
Seasonal Average			**-1%**			**-5%**			**-10%**
Wet Season 2015									
Jun-15	29.0	29.3	-1%	24.3	24.4	0%	144.5	253.1	-43%
Jul-15	29.0	28.7	1%	24.5	24.3	1%	265.4	428.5	-38%
Aug-15	29.0	28.8	1%	24.5	24.4	0%	179.3	235.9	-24%
Sep-15	29.0	28.3	2%	23.5	24.2	-3%	216.1	361.4	-40%
Oct-15	28.2	27.9	1%	24.3	24.1	1%	472.0	629.2	-25%
Seasonal Average			**1%**			**0%**			**-34%**

- Location (Municipality, Province, Region): **Milagros**, Masbate, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	28.7	28.9	0%	24.5	24.4	1%	129.4	235.6	-45%
Dec-14	27.7	28.2	-2%	24.5	24.1	2%	496.3	275.5	80%
Jan-15	26.7	27.7	-4%	23.5	23.7	-1%	191.5	186.0	3%
Feb-15	27.4	28.2	-3%	22.8	23.6	-3%	38.1	97.5	-61%
Mar-15	28.4	28.9	-2%	23.5	24.0	-2%	60.0	95.4	-37%
Apr-15	30.4	30.2	1%	24.5	24.7	0%	21.0	47.1	-56%
May-15	30.7	30.3	1%	25.5	25.1	2%	31.2	148.9	-79%
Seasonal Average			**-1%**			**0%**			**-28%**
Wet Season 2015									
Jun-15	29.7	29.5	1%	25.5	25.0	2%	195.6	202.6	-3%
Jul-15	29.0	28.9	0%	25.5	24.9	3%	204.8	306.7	-33%
Aug-15	29.0	29.0	0%	25.5	25.0	2%	188.7	240.2	-21%
Sep-15	29.0	28.8	1%	24.8	24.8	0%	184.5	278.7	-34%
Oct-15	29.0	28.8	1%	25.5	24.5	4%	170.0	264.8	-36%
Seasonal Average			**0%**			**2%**			**-26%**

- Location (Municipality, Province, Region): **Masbate City**, Masbate, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	28.4	28.6	-1%	24.6	24.5	0%	79.7	205.7	-61%
Dec-14	27.5	27.9	-2%	24.4	24.3	0%	248.3	239.6	4%
Jan-15	26.5	27.4	-3%	23.4	23.8	-2%	82.1	195.9	-58%
Feb-15	27.1	27.8	-3%	22.9	23.8	-4%	46.7	87.6	-47%
Mar-15	28.1	28.5	-1%	23.6	24.2	-2%	36.5	84.2	-57%
Apr-15	30.1	29.8	1%	24.6	24.8	-1%	26.1	47.6	-45%
May-15	30.4	30.0	1%	25.6	25.2	1%	83.1	130.1	-36%
Seasonal Average			**-1%**			**-1%**			**-43%**
Wet Season 2015									
Jun-15	29.4	29.4	0%	25.6	25.2	2%	119.1	173.1	-31%
Jul-15	29.0	28.9	0%	25.6	25.0	2%	214.5	258.5	-17%
Aug-15	29.0	28.9	0%	25.6	25.2	1%	180.5	226.8	-20%
Sep-15	29.0	28.7	1%	24.6	24.9	-1%	198.4	254.8	-22%
Oct-15	29.0	28.7	1%	25.6	24.7	4%	409.9	251.7	63%
Seasonal Average			**1%**			**2%**			**-6%**

- Location (Municipality, Province, Region): **Pilar**, Sorsogon. Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.9	29.6	5%	25.1	24.9	0%	163.5	180.4	-9%
Jul-15	29.0	29.0	0%	25.1	24.7	2%	225.3	282.7	-20%
Aug-15	30.0	29.1	3%	24.1	24.8	-3%	154.8	206.5	-25%
Sep-15	29.0	28.8	1%	24.1	24.5	-2%	191.8	298.4	-36%
Oct-15	29.0	28.7	1%	25.1	24.2	3%	240.3	323.5	-26%
Seasonal Average			**2%**			**0%**			**-23%**

- Location (Municipality, Province, Region): **Bacuag**, Surigao del Norte, Caraga

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	27.5	27.5	0%	22.5	22.5	0%	340.8	359.8	-5%
Dec-14	26.5	27.0	-2%	22.5	22.3	1%	865.2	538.8	61%
Jan-15	26.5	26.5	0%	21.9	21.8	0%	717.6	565.0	27%
Feb-15	26.5	26.9	-2%	21.5	21.8	-1%	190.5	380.9	-50%
Mar-15	26.9	27.7	-3%	20.9	22.0	-5%	81.3	340.5	-76%
Apr-15	28.9	28.7	1%	22.5	22.6	-1%	128.0	269.1	-52%
May-15	29.5	28.9	2%	23.9	23.2	3%	67.5	130.5	-48%
Seasonal Average			**-1%**			**0%**			**-21%**
Wet Season 2015									
Jun-15	28.0	28.4	-1%	23.9	23.2	3%	312.4	207.6	50%
Jul-15	29.0	28.5	2%	24.9	23.1	8%	86.4	204.2	-58%
Aug-15	28.5	28.7	-1%	24.5	23.3	5%	113.3	179.9	-37%
Sep-15	28.0	28.3	-1%	23.9	23.0	4%	156.8	168.3	-7%
Oct-15	28.5	27.9	2%	23.9	22.8	5%	137.2	247.3	-45%
Seasonal Average			**0%**			**5%**			**-19%**
Dry Season 2016									
Nov-15	27.5	27.5	0%	23.9	22.5	6%	297.1	359.8	-17%
Dec-15	27.5	27.0	2%	22.9	22.3	3%	392.4	538.8	-27%
Jan-16	27.5	26.5	4%	22.9	21.8	5%	202.6	565.0	-64%
Feb-16	26.5	26.9	-2%	22.9	21.8	5%	152.4	380.9	-60%
Mar-16	27.9	27.7	1%	22.9	22.0	4%	40.1	340.5	-88%
Apr-16	28.9	28.7	1%	23.5	22.6	4%	92.1	269.1	-66%
May-16	28.9	28.9	0%	24.5	23.2	6%	85.6	130.5	-34%
Seasonal Average			**1%**			**5%**			**-51%**

- Location (Municipality, Province, Region): **Castilla**, Sorsogon, Bicol

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Wet Season 2015									
Jun-15	30.8	29.5	4%	25.2	25.1	1%	154.8	163.9	-6%
Jul-15	29.0	28.9	0%	25.2	24.8	2%	187.3	260.5	-28%
Aug-15	29.9	29.0	3%	24.3	25.0	-3%	135.2	196.3	-31%
Sep-15	28.9	28.7	1%	24.3	24.6	-1%	163.4	261.8	-38%
Oct-15	29.0	28.6	1%	25.2	24.4	3%	243.7	316.6	-23%
Seasonal Average			**2%**			**0%**			**-25%**

- Location (Municipality, Province, Region): **Claver**, Suriago del Norte, Caraga

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	26.9	26.9	0%	21.9	21.9	0%	337.0	362.3	-7%
Dec-14	25.9	26.2	-1%	21.8	21.5	1%	904.2	566.7	60%
Jan-15	25.8	25.7	0%	20.8	21.1	-1%	710.5	566.8	25%
Feb-15	25.6	26.0	-1%	20.7	21.0	-2%	199.3	402.5	-50%
Mar-15	25.8	26.7	-4%	19.8	21.2	-6%	93.8	352.9	-73%
Apr-15	27.7	27.8	0%	21.7	21.9	-1%	124.5	257.5	-52%
May-15	28.7	28.2	2%	22.7	22.3	2%	72.4	156.7	-54%
Seasonal Average			**-1%**			**-1%**			**-22%**
Wet Season 2015									
Jun-15	27.8	27.8	0%	22.7	22.4	1%	344.4	228.9	50%
Jul-15	28.8	28.0	3%	23.5	22.3	6%	97.5	237.5	-59%
Aug-15	28.8	28.3	2%	23.5	22.6	4%	147.3	217.2	-32%
Sep-15	27.8	27.9	-1%	22.7	22.2	2%	178.6	178.1	0%
Oct-15	28.8	27.5	5%	22.7	22.1	3%	147.4	255.3	-42%
Seasonal Average			**2%**			**3%**			**-17%**
Dry Season 2016									
Nov-15	26.8	26.9	0%	22.7	21.9	4%	323.0	362.3	-11%
Dec-15	26.8	26.2	2%	21.8	21.5	1%	405.3	566.7	-28%
Jan-16	26.8	25.7	4%	21.7	21.1	3%	196.8	566.8	-65%
Feb-16	25.8	26.0	-1%	21.7	21.0	3%	159.0	402.5	-60%
Mar-16	26.8	26.7	0%	21.6	21.2	2%	41.8	352.9	-88%
Apr-16	27.8	27.8	0%	22.7	21.9	4%	78.4	257.5	-70%
May-16	27.8	28.2	-2%	23.7	22.3	6%	112.6	156.7	-28%
Seasonal Average			**0%**			**3%**			**-50%**

- Location (Municipality, Province, Region): **Del Carmen**, Surigao del Norte, Caraga

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	27.0	27.5	-2%	26.0	25.9	0%	303.2	351.3	-14%
Dec-14	27.0	27.1	-1%	26.0	25.7	1%	776.3	490.9	58%
Jan-15	26.0	26.9	-3%	25.0	25.1	-1%	563.2	543.6	4%
Feb-15	26.0	27.0	-4%	25.0	25.3	-1%	114.0	307.8	-63%
Mar-15	27.0	27.2	-1%	25.0	25.8	-3%	44.9	273.9	-84%
Apr-15	27.0	28.0	-4%	26.0	26.0	0%	96.8	212.3	-54%
May-15	30.0	28.3	6%	26.0	26.2	-1%	54.8	165.1	-67%
Seasonal Average			**-1%**			**-1%**			**-31%**
Wet Season 2015									
Jun-15	29.0	28.2	3%	25.0	26.4	-5%	358.6	208.5	72%
Jul-15	31.0	28.3	9%	26.0	26.4	-1%	66.9	192.1	-65%
Aug-15	31.0	28.5	9%	26.0	26.5	-2%	119.9	176.9	-32%
Sep-15	31.0	28.3	9%	26.0	26.1	-1%	203.3	196.0	4%
Oct-15	31.0	28.1	10%	26.0	26.0	0%	143.0	229.7	-38%
Seasonal Average			**8%**			**-2%**			**-12%**
Dry Season 2016									
Nov-15	29.0	27.5	5%	25.0	25.9	-4%	260.6	351.3	-26%
Dec-15	29.0	27.1	7%	25.0	25.7	-3%	317.4	490.9	-35%
Jan-16	29.0	26.9	8%	24.0	25.1	-4%	189.9	543.6	-65%
Feb-16	28.0	27.0	4%	25.0	25.3	-1%	97.6	307.8	-68%
Mar-16	28.0	27.2	3%	26.0	25.8	1%	30.8	273.9	-89%
Apr-16	29.0	28.0	4%	26.0	26.0	0%	64.0	212.3	-70%
May-16	29.0	28.3	3%	26.0	26.2	-1%	98.9	165.1	-40%
Seasonal Average			**5%**			**-2%**			**-56%**

- Location (Municipality, Province, Region): **Gigaquit**, Suriago del Norte, Caraga

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	27.0	27.0	0%	22.0	22.0	0%	340.2	362.2	-6%
Dec-14	26.0	26.4	-1%	22.0	21.7	1%	907.5	563.8	61%
Jan-15	26.0	25.8	1%	21.0	21.2	-1%	718.2	562.5	28%
Feb-15	26.0	26.1	0%	21.0	21.1	-1%	205.6	396.5	-48%
Mar-15	26.0	26.9	-3%	20.0	21.3	-6%	86.4	346.7	-75%
Apr-15	28.0	27.9	0%	22.0	22.0	0%	122.3	260.6	-53%
May-15	29.0	28.3	2%	23.0	22.4	3%	73.3	148.5	-51%
Seasonal Average			**0%**			**-1%**			**-21%**
Wet Season 2015									
Jun-15	28.0	28.0	0%	23	22.6	2%	334.7	226.6	48%
Jul-15	29.0	28.2	3%	24.0	22.4	7%	100.0	238.3	-58%
Aug-15	29.0	28.4	2%	24.0	22.7	6%	133.9	208.1	-36%
Sep-15	28.0	28.1	0%	23.0	22.4	3%	167.9	176.2	-5%
Oct-15	29.0	27.6	5%	23.0	22.2	4%	145.1	255.3	-43%
Seasonal Average			**2%**			**4%**			**-19%**
Dry Season 2016									
Nov-15	27.0	27.0	0%	23.0	22.0	5%	318.2	362.2	-12%
Dec-15	27.0	26.4	2%	22.0	21.7	1%	404.4	563.8	-28%
Jan-16	27.0	25.8	5%	22.0	21.2	4%	198.5	562.5	-65%
Feb-16	26.0	26.1	0%	22.0	21.1	4%	155.5	396.5	-61%
Mar-16	27.0	26.9	1%	22.0	21.3	3%	40.3	346.7	-88%
Apr-16	28.0	27.9	0%	23.0	22.0	4%	86.9	260.6	-67%
May-16	28.0	28.3	-1%	24.0	22.4	7%	111.2	148.5	-25%
Seasonal Average			**1%**			**4%**			**-49%**

- Location (Municipality, Province, Region): **Mainit**, Suriago del Norte, Caraga

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	27.8	28.0	-1%	23.3	23.6	-1%	333.3	354.0	-6%
Dec-14	27.0	27.7	-2%	23.3	23.4	0%	869.0	545.9	59%
Jan-15	26.8	27.3	-2%	23.2	22.9	1%	735.1	549.0	34%
Feb-15	26.8	27.7	-3%	22.3	22.9	-2%	186.5	374.8	-50%
Mar-15	27.8	28.5	-2%	22.3	23.2	-4%	70.1	336.9	-79%
Apr-15	29.7	29.4	1%	23.3	23.8	-2%	120.9	254.0	-52%
May-15	29.8	29.5	1%	25.2	24.4	3%	63.6	123.9	-49%
Seasonal Average			**-1%**			**-1%**			**-20%**
Wet Season 2015									
Jun-15	28.0	28.8	-3%	25.2	24.3	3%	303.9	197.2	54%
Jul-15	29.0	28.8	1%	26.2	24.3	8%	82.7	215.0	-62%
Aug-15	28.2	28.9	-3%	25.2	24.4	3%	106.5	180.3	-41%
Sep-15	28.0	28.5	-2%	25.2	24.2	4%	149.4	171.8	-13%
Oct-15	28.0	28.2	-1%	25.2	23.8	6%	137.9	240.5	-43%
Seasonal Average			**-1%**			**5%**			**-21%**
Dry Season 2016									
Nov-15	27.8	28.0	-1%	25.2	23.6	7%	288.0	354.0	-19%
Dec-15	27.8	27.7	1%	24.3	23.4	4%	407.5	545.9	-25%
Jan-16	27.8	27.3	2%	24.2	22.9	5%	183.3	549.0	-67%
Feb-16	27.0	27.7	-3%	24.2	22.9	6%	141.9	374.8	-62%
Mar-16	28.7	28.5	1%	24.2	23.2	4%	36.1	336.9	-89%
Apr-16	29.7	29.4	1%	24.3	23.8	2%	80.7	254.0	-68%
May-16	29.8	29.5	1%	25.2	24.4	3%	95.8	123.9	-23%
Seasonal Average			**0%**			**5%**			**-50%**

- Location (Municipality, Province, Region): **San Francisco**, Surigao del Norte, Caraga

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year Monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min Temperature 27-year Monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	27.0	27.4	-2%	25.0	25.7	-3%	302.0	348.5	-13%
Dec-14	27.0	27.1	0%	25.0	25.1	0%	683.2	477.8	43%
Jan-15	26.0	26.8	-3%	24.0	24.9	-4%	674.0	518.2	30%
Feb-15	26.0	27.0	-4%	24.0	24.9	-4%	141.5	324.6	-56%
Mar-15	27.0	27.3	-1%	24.0	25.1	-4%	64.0	368.5	-83%
Apr-15	28.0	28.0	0%	25.0	25.9	-3%	114.0	231.7	-51%
May-15	29.0	28.3	2%	26.0	26.1	0%	58.4	118.9	-51%
Seasonal Average			-1%			-3%			-26%
Wet Season 2015									
Jun-15	28.0	28.1	-1%	26.0	26.1	0%	279.4	170.6	64%
Jul-15	29.0	28.3	3%	27.0	26.0	4%	72.4	209.2	-65%
Aug-15	29.0	28.5	2%	26.0	26.2	-1%	115.7	184.1	-37%
Sep-15	28.0	28.2	-1%	26.0	26.0	0%	177.8	192.5	-8%
Oct-15	28.0	28.0	0%	26.0	25.9	0%	174.4	267.7	-35%
Seasonal Average			1%			1%			-16%
Dry Season 2016									
Nov-15	27.0	27.4	-2%	26.0	25.7	1%	279.9	348.5	-20%
Dec-15	27.0	27.1	0%	26.0	25.1	4%	360.1	477.8	-25%
Jan-16	27.0	26.8	1%	25.0	24.9	0%	173.3	518.2	-67%
Feb-16	27.0	27.0	0%	25.0	24.9	0%	129.7	324.6	-60%
Mar-16	27.0	27.3	-1%	25.0	25.1	0%	45.4	368.5	-88%
Apr-16	28.0	28.0	0%	26.0	25.9	0%	77.9	231.7	-66%
May-16	29.0	28.3	2%	26.0	26.1	0%	99.4	118.9	-16%
Seasonal Average			0%			1%			-49%

- Location (Municipality, Province, Region): **San Isidro**, Suriago del Norte, Caraga

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	28.0	27.8	1%	25.0	25.9	-3%	300.7	359.2	-16%
Dec-14	27.0	27.3	-1%	25.0	25.7	-3%	787.6	497.9	58%
Jan-15	27.0	26.9	0%	25.0	25.3	-1%	545.2	557.4	-2%
Feb-15	27.0	27.1	-1%	25.0	25.4	-2%	105.5	304.8	-65%
Mar-15	27.0	27.4	-2%	25.0	25.7	-3%	50.0	270.3	-82%
Apr-15	28.0	28.1	0%	25.0	26.1	-4%	92.6	214.7	-57%
May-15	29.0	28.4	2%	27.0	26.5	2%	51.4	165.4	-69%
Seasonal Average			**0%**			**-2%**			**-33%**
Wet Season 2015									
Jun-15	28.0	28.2	-1%	26.0	26.4	-2%	401.5	229.9	75%
Jul-15	29.1	28.4	2%	27.0	26.2	3%	72.3	184.4	-61%
Aug-15	29.1	28.7	1%	27.0	26.3	2%	131.2	192.2	-32%
Sep-15	29.1	28.4	3%	26.0	26.1	0%	239.3	216.2	11%
Oct-15	29.1	28.1	4%	27.0	26.1	3%	148.4	238.0	-38%
Seasonal Average			**2%**			**1%**			**-9%**
Dry Season 2016									
Nov-15	28.0	27.8	1%	26.0	25.9	0%	233.4	359.2	-35%
Dec-15	28.0	27.3	3%	26.0	25.7	1%	334.3	497.9	-33%
Jan-16	27.1	26.9	1%	25.9	25.3	2%	188.5	557.4	-66%
Feb-16	27.0	27.1	0%	26.0	25.4	2%	78.8	304.8	-74%
Mar-16	28.0	27.4	2%	26.0	25.7	1%	32.0	270.3	-88%
Apr-16	29.0	28.1	3%	27.0	26.1	3%	63.6	214.7	-70%
May-16	29.0	28.4	2%	27.0	26.5	2%	92.4	165.4	-44%
Seasonal Average			**2%**			**2%**			**-59%**

Practice: Fish pots as passive fishing gear to prevent fish losses in case of extreme events
Hazard addressed: strong wind

- Location (Municipality, Province, Region): **Del Carmen**, Surigao del Norte, Caraga

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2015									
Nov-14	27.0	27.5	-2%	26.0	25.9	0%	303.2	351.3	-14%
Dec-14	27.0	27.1	-1%	26.0	25.7	1%	776.3	490.9	58%
Jan-15	26.0	26.9	-3%	25.0	25.1	-1%	563.2	543.6	4%
Feb-15	26.0	27.0	-4%	25.0	25.3	-1%	114.0	307.8	-63%
Mar-15	27.0	27.2	-1%	25.0	25.8	-3%	44.9	273.9	-84%
Apr-15	27.0	28.0	-4%	26.0	26.0	0%	96.8	212.3	-54%
May-15	30.0	28.3	6%	26.0	26.2	-1%	54.8	165.1	-67%
Seasonal Average			**-1%**			**-1%**			**-31%**
Wet Season 2015									
Jun-15	29.0	28.2	3%	25.0	26.4	-5%	358.6	208.5	72%
Jul-15	31.0	28.3	9%	26.0	26.4	-1%	66.9	192.1	-65%
Aug-15	31.0	28.5	9%	26.0	26.5	-2%	119.9	176.9	-32%
Sep-15	31.0	28.3	9%	26.0	26.1	-1%	203.3	196.0	4%
Oct-15	31.0	28.1	10%	26.0	26.0	0%	143.0	229.7	-38%
Seasonal Average			**8%**			**-2%**			**-12%**

UGANDA

Practice: Indoor mushroom production for livelihood diversification
Hazard addressed: dry spell/drought

- Location (District, Region): **Kiboga**, Central Region

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2016									
Jun-16	29.0	27.8	4%	18.2	17.4	4%	66.8	58.8	14%
Jul-16	28.9	28.1	3%	18.2	17.4	5%	59.7	72.0	-17%
Aug-16	28.8	27.5	5%	17.9	17.3	4%	99.4	113.2	-12%
Seasonal Average			**4%**			**4%**			**-5%**

- Location (District, Region): **Mubende**, Central Region

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2016									
Jun-16	27.1	26.5	2%	17.1	16.2	6%	49.1	46.3	6%
Jul-16	27.8	27.0	3%	17.1	16.2	6%	39.5	52.3	-24%
Aug-16	27.9	26.7	5%	17.1	16.2	5%	70.6	104.7	-33%
Seasonal Average			**4%**			**5%**			**-14%**

- Location (District, Region): **Nakasongola**, Central Region

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperatu re compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2016									
Jun-16	28.3	27.2	4%	19.2	17.8	8%	74.9	66.0	14%
Jul-16	28.2	27.4	3%	19.0	17.6	8%	58.6	69.8	-16%
Aug-16	28.2	26.7	6%	19.0	17.6	8%	96.7	109.5	-12%
Seasonal Average			**4%**			**8%**			**7%**

- Location (District, Region): **Sembabule**, Central Region

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2016									
Jun-16	28.3	27.2	4%	19.2	17.8	8%	74.9	66.0	14%
Jul-16	28.2	27.4	3%	19.0	17.6	8%	58.6	69.8	-16%
Aug-16	28.2	26.7	6%	19.0	17.6	8%	96.7	109.5	-12%
Seasonal Average			**4%**			**8%**			**-7%**

- Location (District, Region): Nakaseke, Central Region, Uganda

Months monitored	Max temperature (°C) - Monthly Average	Max temperature 27-year monthly average	% difference of monthly max temperature compared to 27-year monthly average	Min temperature (°C) - Monthly Average	Min temperature 27-year monthly average	% difference of monthly min temperature compared to 27-year monthly average	Precipitation (mm) - Monthly Sum	Precipitation 37-year monthly average	% difference of monthly rainfall compared to 37-year monthly average
Dry Season 2016									
Jun-16	28.8	27.5	4%	18.2	17.2	6%	74.3	63.6	17%
Jul-16	29.1	27.8	5%	18.1	17.1	6%	63.7	73.6	-14%
Aug-16	28.7	27.2	6%	17.9	17.1	5%	98.1	112.0	-12%
Seasonal Average			**5%**			**6%**			**-9%**

Other practices monitored in these locations and during these seasons:

Practice: Cabbage cultivation with rooftop water harvesting and water storage tanks
Hazard addressed: dry spell/drought

- Location (District, Region): **Kiboga**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Mubende**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Nakasongola**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Sembabule**, Central Region, Uganda – Jun-16 to Aug-16

Practice: *Ntula* cultivation with rooftop water harvesting and water storage tanks
Hazard addressed: dry spell/drought

- Location (District, Region): **Kiboga**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Mubende**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Nakasongola**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Sembabule**, Central Region, Uganda – Jun-16 to Aug-16

Practice: Tomato cultivation with rooftop water harvesting and water storage tanks
Hazard addressed: dry spell/drought

- Location (District, Region): **Kiboga**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Mubende**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Nakasongola**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Sembabule**, Central Region, Uganda – Jun-16 to Aug-16

Practice: Multi-stress tolerant bean varieties
Hazard addressed: dry spell/drought

- Location (District, Region): **Kiboga**, Central Region, Uganda –Jun-16 to Aug-16
- Location (District, Region): **Mubende**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Nakasongola**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Nakaseke**, Central Region, Uganda – Jun-16 to Aug-16

Practice: Improved maize varieties
Hazard addressed: dry spell/drought

- Location (District, Region): **Kiboga**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Mubende**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Nakasongola**, Central Region, Uganda – Jun-16 to Aug-16

Practice: Coffee cultivation with mulching, digging of trenches for water retention, organic composting and planting of shade trees
Hazard addressed: dry spell/drought

- Location (District, Region): **Kiboga**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Mubende**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Sembabule**, Central Region, Uganda – Jun-16 to Aug-16

Practice: Banana cultivation with mulching, digging of trenches for water retention, organic composting and improved varieties
Hazard addressed: dry spell/drought

- Location (District, Region): **Kiboga**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Mubende**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Sembabule**, Central Region, Uganda – Jun-16 to Aug-16

Practice: Cattle raising with zero grazing, improved cattle breeds and drought tolerant fodder
Hazard addressed: dry spell/drought

- Location (District, Region): **Kiboga**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Mubende**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Nakasongola**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Sembabule**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Nakaseke**, Central Region, Uganda – Jun-16 to Aug-16

Practice: Chicken raising in chicken houses and with improved chicken breeds
Hazard addressed: dry spell/drought and disease

- Location (District, Region): **Kiboga**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Mubende**, Central Region, Uganda – Jun-16 to Aug-16
- Location (District, Region): **Sembabule**, Central Region, Uganda – Jun-16 to Aug-16

Annex IV: Glossary

Benefit Cost Ratio (BCR): Total discounted benefits are divided by total discounted costs. Practices with a BCR greater than 1 have greater benefits than costs, hence they have a positive Net Present Value. The higher the ratio, the greater the benefits relative to the costs.

Capacity: The combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience (UNISDR 2017).

Climate change: A change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (IPCC, 2014).

Climate change adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects (IPCC, 2014).

Climate Smart Agriculture (CSA): An approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. CSA aims to tackle three main objectives: sustainably increasing agricultural productivity and incomes; adapting and building resilience to climate change; and reducing and/or removing greenhouse gas emissions, where possible.

Cost Benefit Analysis (CBA): A systematic process for calculating and comparing the benefits and costs of a given action/project/investment. It is based on assigning a monetary value to all the activities performed as either input or output.

Damage: The monetary value of total or partial destruction of physical assets and infrastructure in disaster-affected areas, expressed as replacement and/or repair costs. In the agriculture sector, damage is considered in relation to standing crops, farm machinery, irrigation systems, livestock shelters, fishing vessels, pens and ponds, etc. (EU, UNDG and World Bank 2013, UNISDR 2017, FAO 2017a).

Disaster: A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental loss and impacts (UNISDR, 2017).

Disaster risk reduction (DRR): A policy objective aimed at preventing new risk and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and achievement of sustainable development (UNISDR, 2017).

Early-warning system: An integrated system of hazard monitoring, forecasting and prediction, disaster risk assessment, communication and preparedness activities systems and processes that enables individuals, communities, governments, businesses and others to take timely action to reduce disaster risks in advance of hazardous events (UNISDR, 2017).

Exposure: The situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas (UNISDR, 2017).

Food Security: A situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

Hazard: A process or phenomenon that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation (UNISDR 2017). Hazards may be natural, anthropogenic or socio-natural in origin; this report refers to hazards of natural origin only. Natural hazards are predominantly associated with natural processes and phenomena.

Internal Rate of Return (IRR): The discount rate that renders the net present value (NPV) of a project zero. In other words, it is the expected compound annual rate of return that will be earned on a project or investment.

Loss: The change in economic flows occurring as a result of a disaster. In agriculture, loss may include declines in crop production, decline in income from livestock products, increased input prices, reduced overall agricultural revenues and higher operational costs and increased unexpected expenditure to meet immediate needs in the aftermath of a disaster (EU, UNDG and World Bank 2013, UNISDR 2017, FAO 2017a).

Mitigation: The lessening or minimizing of the adverse impacts of a hazardous event (UNISDR, 2017).

Net Present Value (NPV): Calculated by subtracting the present (discounted) value of costs from the present value of benefits over the appraisal period; the greater the net present value, the more justifiable the investment.

Preparedness: Knowledge and capacities developed by governments, response and recovery organizations, communities, and individuals that allows them to effectively anticipate, respond to and recover from the impacts of a likely, imminent or current disaster (UNISDR, 2017).

Reconstruction: The medium- and long-term rebuilding and sustainable restoration of resilient critical infrastructures, services, housing, facilities and livelihoods required for the full functioning of a community or a society affected by a disaster, aligning with the principles of sustainable development and "building back better," to avoid or reduce future disaster risk (UNISDR, 2017).

Recovery: The restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society, aligning with the principles of sustainable development and "build back better," to avoid or reduce future disaster risk (UNISDR, 2017).

Rehabilitation: The restoration of basic services and facilities for the functioning of a community or a society affected by a disaster (UNISDR, 2017).

Resilience: The ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management (UNISDR, 2017).

Response: Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected (UNISDR, 2017).

Risk: The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity. The definition of disaster risk reflects the concept of hazardous events and disasters as the outcome of continuously present conditions of risk (UNISDR, 2017)

Vulnerability: The conditions determined by physical, social, economic and environmental factors or processes, which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards (UNISDR, 2017)

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Saving livelihoods saves lives

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ISBN 978-92-5-131429-6

CA4429EN/2/06.19