



ELSEVIER

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

# Climate Risk Management

journal homepage: [www.elsevier.com/locate/crm](http://www.elsevier.com/locate/crm)

## Adaptation rationales and benefits: A foundation for understanding adaptation impact

Edward R. Carr<sup>a,\*</sup>, Johanna Nalau<sup>b</sup><sup>a</sup> International Development, Community, and Environment Department, Clark University, 950 Main St. Worcester, MA 01609, USA<sup>b</sup> Cities Research Institute, School of Environment and Science, Griffith University, Parklands Dr. Southport QLD, 4222, Australia

### ARTICLE INFO

#### Keywords:

Adaptation  
Benefits  
Typology  
Rationales  
Theory of change

### ABSTRACT

Efforts to achieve coordinated, effective, and impactful adaptation outcomes are complicated by factors ranging from the local specificity of adaptation needs to the challenges of politics and prioritization that drive funding decisions. However, these and other challenges are perpetuated and exacerbated by poorly constructed, often implicit, and generally institution- or context-specific impact pathways connecting policy/institutional priorities through their materialization in specific actions to their intended outcomes. We call these impact pathways adaptation rationales, as they represent the logic of an adaptation action. The implicit nature of most current adaptation rationales makes it difficult to identify and test the accuracy and veracity of claims and assumptions underlying everything from policy priorities to intervention selection. In this article, we address this foundational challenge for the adaptation community of practice by proposing a typology of adaptation benefits (reduced exposure, reduced sensitivity, and increased adaptive capacity) that facilitates the construction of meaningful, transparent adaptation rationales. We lay out what these well-understood components of vulnerability mean in the context of adaptation benefits and provide guiding questions for their use in constructing adaptation rationales. Using hypothetical and real-world examples of projects and portfolios, we illustrate how this typology and the adaptation rationales it enables focus attention on the goals of a given action, its likely effectiveness, and for whom it is likely to be effective. Each of these issues offers an opportunity to strengthen project design, implementation, monitoring, and evaluation, while also facilitating portfolio-level understandings of adaptation approaches, assumptions, and efficacy. This typology does not, by itself, presume to resolve the many debates in adaptation practice, such as the tension between incremental and transformational goals, the tradeoffs between actions addressing exposure via infrastructure versus those aimed at the underlying structures of inequality that render some populations more vulnerable to these impacts than others. However, by bringing issues of governance and justice the forefront of adaptation conversations, the typology, and the adaptation rationales it enables, allows for the productive, situationally-appropriate negotiation of these debates to improve the outcomes of adaptation policy and action.

### 1. Introduction

While estimates of adaptation costs vary, there is agreement that the mobilization of adaptation finance is being outstripped by actual adaptation needs (Chapagain et al., 2020; IPCC, 2022; United Nations Environment Programme, 2022). Current estimates for

\* Corresponding author.

<https://doi.org/10.1016/j.crm.2023.100479>

Received 24 May 2022; Received in revised form 12 January 2023; Accepted 16 January 2023

Available online 18 January 2023

2212-0963/© 2023 The Authors. Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

these costs in developing countries alone are US\$70 billion dollars annually, expected to reach “between US\$160 billion – US\$340 billion in 2030,” and increase to between “US\$315 billion and US\$565 billion in 2050” (United Nations Environment Programme, 2022, p. 19). In this context, improving the prioritization and coordination of limited funds to address the greatest and most pressing adaptation needs while designing and implementing effective, impactful projects and programs is an increasingly urgent challenge.

Many factors complicate the design and implementation of coordinated, effective, and impactful adaptation actions (Nalau, 2021; New et al., 2022). For example, adaptation concerns vary by place and circumstance, which complicates the assessment of relative need within and across contexts (Singh et al., 2021). The efficacy of interventions is also greatly shaped by the socio-ecological context, challenging efforts to create broad assessments of impact that might inform political processes which otherwise reward quick and visible adaptation strategies (e.g. seawalls, grey infrastructure) at the expense of other, “softer” strategies (Pörtner et al., 2022). However, these and other challenges are perpetuated and exacerbated by poorly constructed, often implicit, and generally institution- or context-specific impact pathways connecting policy/institutional priorities through their materialization in specific actions to their intended outcomes (Magnan et al., 2020; New et al., 2022). The current state of such impact pathways, which we call adaptation rationales, makes it difficult to identify and test the accuracy and veracity of claims and assumptions underlying everything from policy priorities to intervention selection. Without testing, competing assumptions and claims about the efficacy and impacts of policy and action can vie with one another without reference to actual outcomes.

A critical barrier to the construction of effective, transparent adaptation rationales is the absence of goals for adaptation action that, while general enough to capture the range of actions needed to address impacts in the world’s diverse socio-ecological settings, are concrete enough to allow for the assessment of their achievement. To fill this gap, we propose a simple organizing typology of intended benefits associated with adaptation policies and actions. We construct this typology on current framings of the components of climate risk: the reduction of exposure to climate-related impacts and the reduction of climate vulnerability through lowered sensitivity to those impacts and increased adaptive capacity for addressing those impacts (IPCC, 2022, 2018, 2014). Exposure, sensitivity, and adaptive capacity are not novel concepts. Their utility lies in their familiarity within the adaptation community of practice. However, our framing of these concepts goes beyond equating adaptation with vulnerability reduction (Atteridge and Remling, 2018; Eriksen et al., 2021; Smit and Wandel, 2006). Instead, we draw on recent research on the transformative potential of vulnerability and risk reduction (Carr, 2020, 2019) and take a broad view of adaptive capacity that encompasses not only technical knowledge but also the empowerment of local, and particularly marginalized, groups to identify both climate-related challenges and solutions. Each category of benefit is an opportunity to move people and places toward climate resilient development pathways (Schipper et al., 2022).

Building adaptation rationales grounded in contributions to one or more of these broad benefits renders transparent the expected contribution of a policy or adaptation action to the delivery of specific adaptation benefits. As these benefits are applicable to nearly all contexts, they offer a structure for adaptation rationales whose assumptions and outcomes can be tested and compared within and across contexts. The result is a broad framing that informs the design, implementation, and evaluation of adaptation actions, the prioritization of adaptation actions, the coordination of actions across organizations, and learning from practice. In short, these rationales facilitate analysis that can inform efforts to move adaptation action from “fragmented, small in scale, incremental, sector-specific” actions (IPCC, 2022, p. 20) towards the more transformational practice that is now required.

## 2. Classifying adaptation benefits

In this section, we lay out the three categories of adaptation benefits in the proposed typology. For each, we offer a definition, some examples of adaptation actions that fall under that category, and provide a guiding question to illustrate the classification of an action.

### 2.1. Exposure benefits

An intervention provides an exposure benefit if it lowers the frequency and/or magnitude of impacts on a person, population, or system targeted by the project. For example:

- An infrastructure investment moves a transportation corridor further from the coast to avoid existing or projected flooding.
- A project supports the planting of urban tree cover to lower the urban heat island effect, reducing daytime temperatures, speeding night time cooling, and thus reducing the number of days and hours in which the population is exposed to dangerous overheating.

When considering if an adaptation action provides an exposure benefit, a guiding question is “does this action reduce the frequency and/or magnitude of one or more climate impacts on the person, population, activity, or resource targeted by the project?” Actions for which the answer is yes provide an exposure benefit.

### 2.2. Sensitivity benefits

An intervention provides a sensitivity benefit if it reduces the impact of a climate-related event on a person, population, or system – that is, the event still occurs with the same/greater frequency and magnitude, but the person, population, or system is not as affected by the event as before the intervention. For example:

- An infrastructure investment builds a roadway out of more durable, permeable materials to allow increasingly-frequent floodwaters to pass and recede quickly with minimal damage.

- A project identifies a sustainable source of irrigation, allowing farmers to plant crops that demand predictable, regular sources of water even as seasonal rainfall becomes increasingly unpredictable.
- A project develops a low-cost cooling system that allows urban dwellers to find relief from rising temperatures associated with the urban heat island and climate change.

When considering if an adaptation action provides a sensitivity benefit, a guiding question is “if the person, population, or system targeted by the project cannot reduce exposure to a climate impact, does this action make those climate impacts less problematic?” Actions for which the answer is yes provide a sensitivity benefit.

### 2.3. Adaptive capacity benefits

An intervention provides an adaptive capacity benefit if it increases the ability of a person, population, or system to manage climate impacts or realize an opportunity emerging from climate change, including by transforming how and where they live. This can happen even if that population, person, or resource remains exposed to and very sensitive to a climate impact, though typically increasing adaptive capacity facilitates productive efforts to lower exposure and sensitivity. For example:

- Investments in extension services often increase farmer knowledge and access to agricultural resources. In places where the climate is marked by increasing variability, extension services can help farmers understand how to interpret seasonal forecasts such that they select appropriate seed varieties for likely seasonal conditions. In this example, the extension services provide an adaptive capacity benefit, while the seeds the farmers learn how to access provide a sensitivity benefit.
- Investment in local planning capacity can yield improved zoning and land management in urban areas, allowing municipalities to avert impacts like flooding by reducing the land use driver of this challenge. Here, the investment in improved planning is an adaptive capacity benefit, which yields an exposure benefit by improving the quality of zoning and land management to reduce flooding.
- A project works to increase the capacity of women to write adaptation project grant proposals and to participate in adaptation decision- and policy making processes, generating adaptation plans and actions that address the needs of different women alongside those of men. The investment in training is an adaptive capacity benefit, producing improved adaptation plans and actions that, depending on their character, provide exposure or sensitivity benefits.

When considering if an action provides an adaptive capacity benefit, a guiding question is “does this action increase the ability of people to identify challenges and opportunities created by climate variability and change in a manner that allows them to address those challenges and mobilize those opportunities?” If the answer is yes, the action provides an adaptive capacity benefit.

Table 1 summarizes this discussion and provides further examples of adaptation actions that provide each adaptation benefit.

While some adaptation actions provide only one benefit, others will provide multiple benefits. As noted in the examples of adaptive capacity benefits, an action that clearly provides one adaptation benefit might implicitly deliver another benefit. For example, the introduction of new seeds or farming practices might be intended to deliver a sensitivity benefit, but implicitly there must be some increase in adaptive capacity created through the knowledge of how to use these seeds and practices effectively. Table 2 illustrates this by showing the adaptation benefits and co-benefits provided by a selected set of adaptation actions.

The typology of benefits presented here makes co-benefits explicit and frames them within the adaptation rationale. This makes the assumptions behind the achievement of these co-benefits transparent and serves to identify the activities and investments needed to

**Table 1**  
The adaptation benefits typology.

Adaptation Benefit	Description	Example Actions
<b>Exposure Benefits</b>	Reduces or modifies the exposure of people and activities to climate change impacts to limit negative impacts	Channelizing waterways Coastal protection Early warning systems Evacuation, retreat, or migration Flood and storm shelters
<b>Sensitivity Benefits</b>	Reduces or modifies the sensitivity of critical activities and assets to climate change impacts to limit negative impacts	Installation of irrigation Risk shifting tools like insurance Crop switching Erosion control Introducing GMOs
<b>Adaptive Capacity Benefits</b>	Increases the ability of people to adapt to climate change impacts that cannot be avoided	Knowledge sharing Extension services Climate services Microcredit and microfinance

ensure they are delivered.

This typology of adaptation benefits is not prescriptive regarding the content or appropriateness of a given action. By itself, it cannot resolve the complex, place-specific social, economic, and political agendas that shape adaptation action (Dilling et al., 2019). It is not intended to classify an action as inherently incremental or transformational, nor does it prescribe one or the other as appropriate (Magnan et al., 2020). It does not adjudicate between actions focused on physical defenses against climate impacts and those that address the underlying structures of inequality that render some populations more vulnerable to these impacts than others (Eriksen et al., 2021). However, it is important to note that all three benefits invoke issues of governance and justice, as benefits are rarely distributed evenly among those affected by a policy or project. The construction of adaptation rationales can and should bring these issues to the fore, facilitating discussions of the goals of a given action, its likely effectiveness, and for whom it is likely to be effective.

### 3. Constructing adaptation rationales with the adaptation benefits typology

The construction of an adaptation rationale requires connecting adaptation goals to specific actions, and then linking those actions to expected adaptation benefits. Generally speaking, adaptation goals are best identified through processes that allow the widest possible range of stakeholders to bring forward both climate-related challenges and opportunities to address them (e.g. Jagannathan et al., 2020; Vincent, 2022). In practice, such grassroots goals are filtered through country governments and bilateral or multilateral development organizations through processes of political negotiations that can produce shifts in priorities. We capture this complex interplay under the heading “Stakeholder Priority” in Fig. 1, recognizing that local populations, national governments, and bilateral/multilateral organizations all become stakeholders in any project.

To illustrate this process, consider a hypothetical adaptation project in a semiarid agrarian region. The project area is experiencing significant climate variability manifesting as extended dry periods during the farming season and infrequent but extreme rainfall events that can bring flooding during the dry season. The country’s government, responding to local demands to address these challenges, has prioritized early warning systems to protect its population from the immediate risks of these extremes, while also building in improved land management strategies to increase the resilience of agricultural production to variable precipitation. The project implements these priorities by developing a flood early warning system, improving climate services aimed at delivering seasonal forecasts to farmers, and delivering a package of climate-smart land management practices aligned with those forecasts to farmers via the country’s extension services.

Each of these project activities has the potential to deliver an adaptation benefit. The early warning system can reduce the *exposure* of people and at least some assets to flooding. The seasonal forecasts, if accurate and actionable, can reduce farmer *sensitivity* to variable precipitation by informing everything from variety selection to planting and harvest dates. Implicitly, the use of seasonal forecasts requires the *capacity* to interpret those forecasts into meaningful on-farm actions. The climate smart land management practices also have the potential to reduce the *sensitivity* of agricultural production to climate variability, though this intervention also assumes a degree of *capacity*-building such that farmers understand and can employ these practices.

Fig. 1 illustrates this intervention’s adaptation rationales, connecting stakeholder priorities to particular interventions which are intended to produce specific adaptation benefits. The priority for early warning systems to protect the population from climate shocks and stresses is materialized in flood early warning systems, which are intended to provide an exposure benefit. However, this priority, when combined with the prioritization of improved land management, is also materialized in improved seasonal forecasts that can,

**Table 2**  
Examples of benefits and co-benefits associated with adaptation actions.

Sample Adaptation Action	Exposure Benefits	Sensitivity Benefits	Adaptive Capacity Benefits
Channelizing waterways	Benefit: at least in the short term, reduces exposure to flooding		
Early warning system	Benefit: allows people to move out of the way of incoming hazards		
Diversification of livelihoods activities	Co-benefit: if new activities are in locations or use resources not affected by climate impacts	Benefit: if new activities are not climate-dependent or located in the path of climate impacts	Co-benefit: new activities can increase incomes or provide new skills
Risk-shifting tools (i.e. insurance)		Benefit: allows for reduced hedging by providing a floor for livelihoods outcomes	Co-benefit: savings from reduced hedging can be productively invested
Microcredit/ Microfinance			Benefit: provides access to needed resources for investment in key assets
Extension services		Co-benefit: can inform seasonal livelihoods decisions to minimize impacts	Benefit: provides technical training to facilitate livelihoods transformations

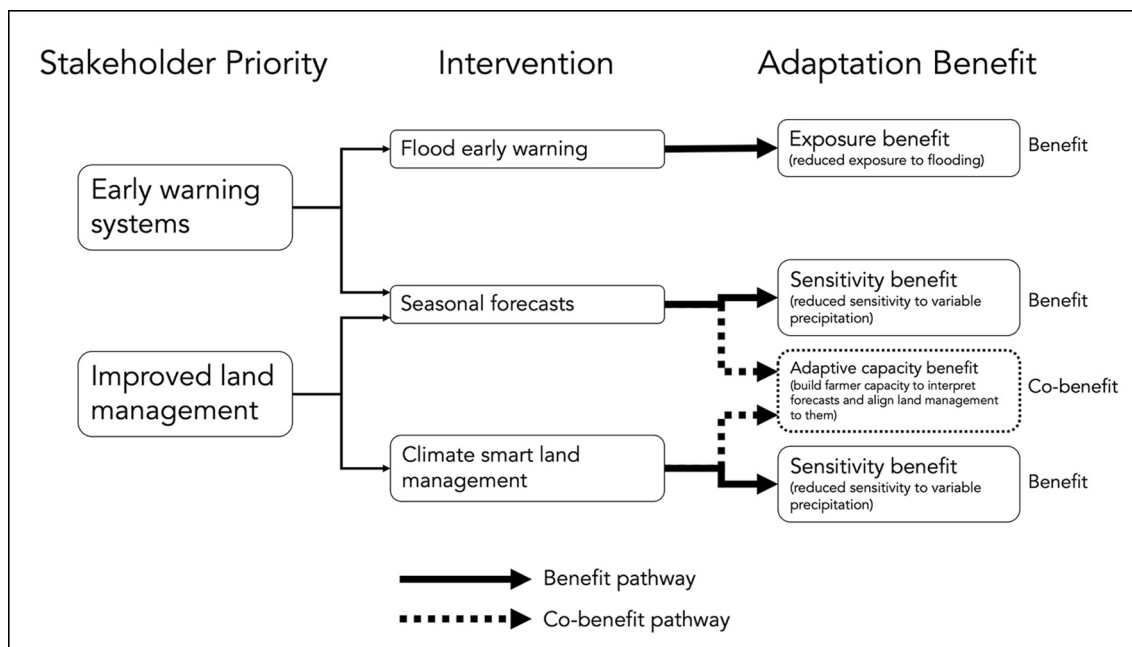


Fig. 1. Visual representation of the adaptation rationales in the hypothetical project.

among other things, inform land and soil management practices. These forecasts are intended to deliver a sensitivity benefit, but there is an implied adaptive capacity co-benefit. Finally, the improved land management priority is materialized in the introduction of climate smart land management practices which deliver a sensitivity benefit, but also have an implied adaptive capacity service.

Mapped out in this manner, the adaptation rationales undergirding this project allow project stakeholders and designers to make explicit decisions about project design. First, they can ask if the proposed interventions are the most appropriate and effective means of providing the desired benefits in this context. Second, they can ask if the adaptive capacity co-benefit, which connects two adaptation rationales, should become a formal part of project implementation with its own activities and impact pathways. Doing so might ensure the adaptive capacity benefit is delivered in a manner that makes it possible to realize the intended sensitivity benefits of the project.

#### 4. Adaptation rationales and adaptation impact beyond the project level

The example above demonstrates how adaptation rationales constructed on a typology of adaptation benefits can inform project design. However, the structure of adaptation rationales can also facilitate efforts to identify and assess portfolio priorities, the interventions used to enact those priorities, and the adaptation benefits associated with both institutional priorities and specific interventions. Further, this structure enables effective monitoring, evaluation, and learning. This is a critical need if the adaptation community of practice is to fill the substantial knowledge gaps regarding policy and intervention effectiveness and outcomes that stand between effective adaptation prioritization and the realization of benefits that improve human well-being in a changing climate.

In what follows, we illustrate the utility of this broad framework through an analysis of the initial proposal documents, called project information forms (PIFs) and project documents (Prodocs), associated with the projects proposed for funding under the Least Developed Countries Fund (LDCF) during the the Global Environment Facility’s (GEF) seventh funding cycle (GEF-7). The LDCF supports the 46 countries designated as least developed countries by the United Nations. To date, the LDCF has financed over 310

**Table 3**  
Priority themes for the GEF-7 cycle of the LDCF.

GEF-7 LDCF Themes
Agriculture
Climate Information Systems
Sustainable Land and Forest Management
Water
Coastal Zone Management
Health
Disaster Risk Management
Urban Development and Infrastructure, Energy
Sustainable Rural Livelihoods
Tourism

projects and 53 enabling activities with approximately \$1.7 billion in grants. The GEF-7 cycle included 51 projects proposed between 2018 and 2022.

For the purposes of this analysis, we broke down the projects in each PIF or Prodoc to its component interventions. We then aligned each intervention with one of the ten GEF-7 LDCF priority themes (Table 3) and the adaptation benefit or benefits they were intended to deliver. In so doing, we noted if these were benefits or co-benefits. This process effectively aggregated the many adaptation rationales in these projects to the portfolio level, allowing for the analysis of portfolio-level patterns of relationship between priorities, interventions, and benefits. We organize some observations below to illustrate the value of the adaptation rationale structure.

1 What institutional or country adaptation priorities are promoted by projects and wider portfolios?

The PIFs and Prodocs associated with this cycle of projects indicate a heavy emphasis on projects that embody the agriculture and water themes (Fig. 2). In contrast, relatively few projects focused on urban systems, coastal zone management, and health. As LDCF projects emerge from country governments, who develop projects in collaboration with GEF implementing agencies, there are many possible sources for this thematic emphasis at the portfolio level. For example, perhaps the GEF’s priorities were broader than those of the LDCs, suggesting the need for greater focus and enhanced consultation in the development of future thematic priorities. With this information in hand, portfolio managers will know what questions to ask to best inform decisions about future programming directions.

2 How are institutional or country adaptation goals translated into actions on the ground?

Transparent adaptation rationales at the project level can, when aggregated to the portfolio level, help illuminate how institutional-level or country-level adaptation priorities have been implemented in practice. Fig. 3 illustrates the interventions associated with the coastal zone management theme of the LDCF during the GEF-7 cycle. More than half of all coastal zone management projects were implemented through capacity-building interventions, such as support for planning, forecasting, and data analysis. With this information, portfolio managers can consider whether this emphasis is the most effective way to achieve desired adaptation benefits, or if a discussion is warranted regarding the rebalancing of interventions toward efforts to reduce exposure or sensitivity to climate impacts.

3 What adaptation benefits does the portfolio deliver?

Project-level adaptation rationales make clear what adaptation benefits are meant to be delivered at the project level. When aggregated to the portfolio level, policymakers and portfolio managers can use this data to better assess which types of adaptation benefits are being achieved based on their priorities or stated themes. For example, Fig. 4 illustrates the intended adaptation benefits associated with GEF-7 LDCF projects. These benefits are heavily slanted toward adaptive capacity, with relatively little effort dedicated to the reduction of exposure to climate-related shocks and stressors. With such information, it is possible to consider if this focus aligns with needs and concerns articulated in, for example, National Adaptation Plans (NAPs) and make needed adjustments to ensure the portfolio supports country goals. Further, this information can facilitate coordination across donors operating within a country or region, revealing who is focused on delivering which benefits. This information, combined with portfolio-level understandings of the adaptation actions being supported to deliver those benefits, allows donors to organize their efforts to maximize the benefits they deliver through their adaptation actions.

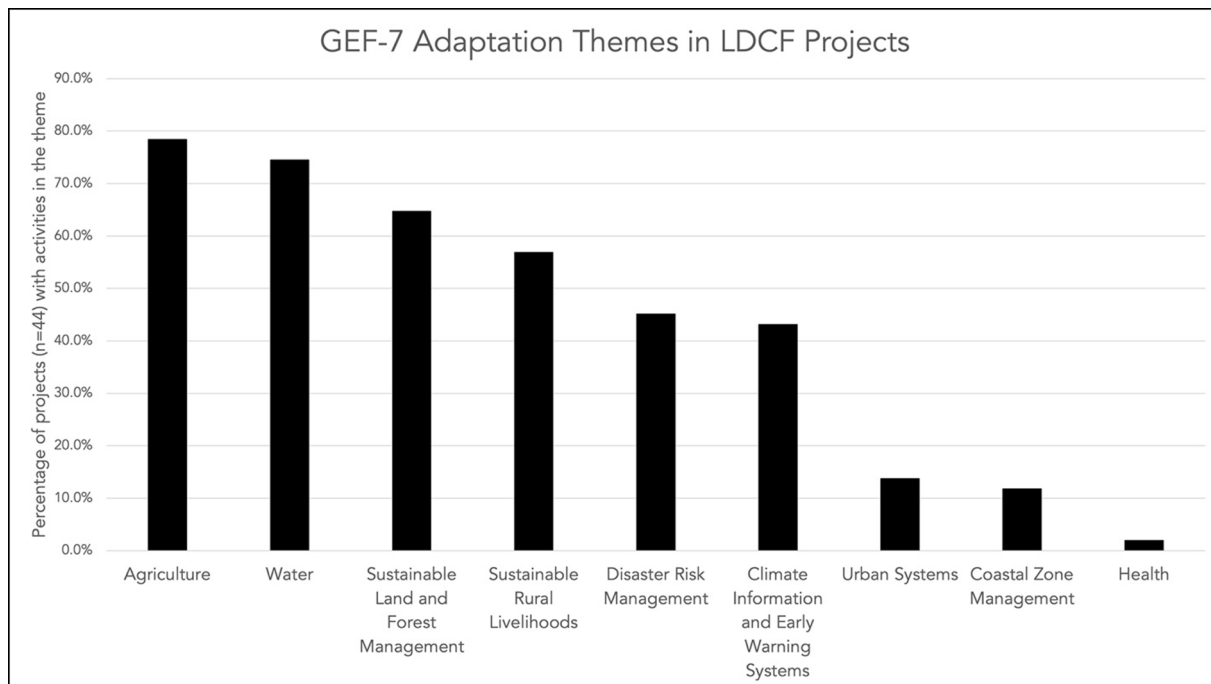


Fig. 2. Percentage of GEF-7 LDCF projects with activities related to GEF-7 LDCF themes.

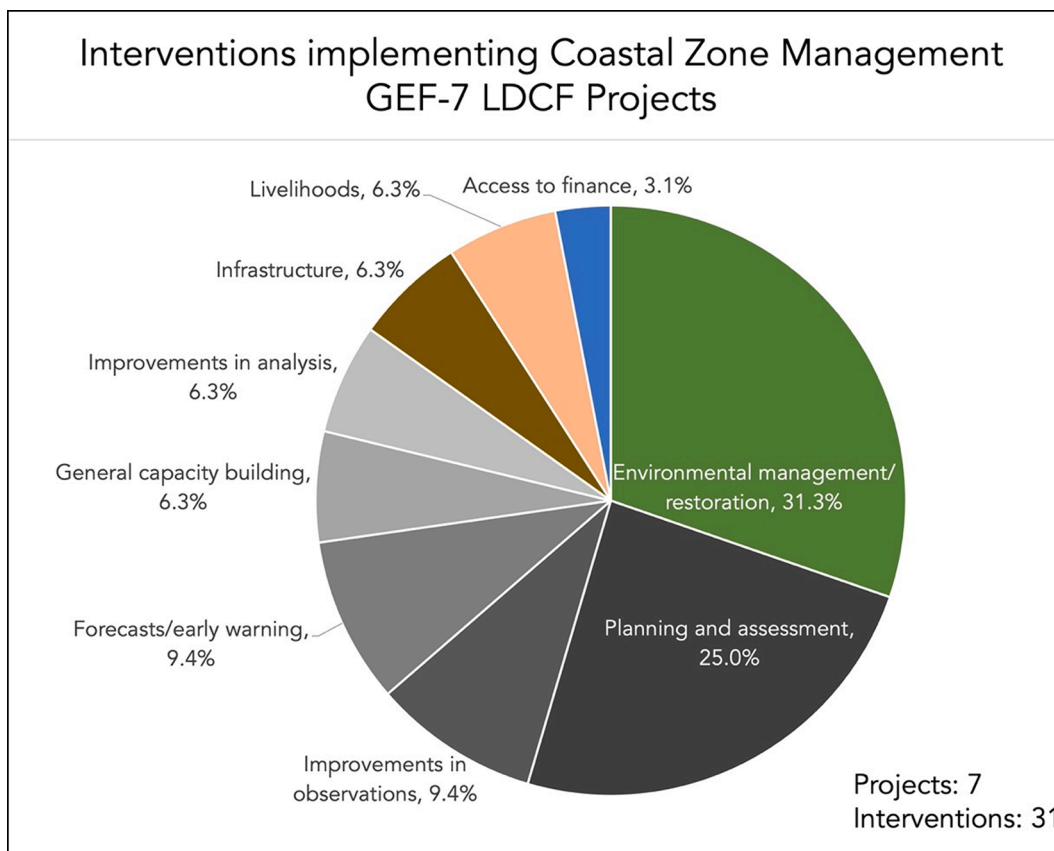


Fig. 3. Interventions implementing coastal zone management in GEF-7 LDCF projects.

4 Were adaptation benefits delivered? If so, how? If not, why?

Finally, the adaptation rationales constructed on the adaptation benefits typology facilitate monitoring, evaluation, and learning (MEL) at levels from the community-based intervention to the global. Such rationales, which link policy to interventions to expected/desired benefits, facilitate the monitoring of project interventions to enable adaptive management, the testing of assumptions within adaptation rationales, and learning about the outcomes of different kinds of interventions targeting specific adaptation.

For example, consider an intervention from an LDCF project (United Nations Development Programme, 2022) implemented in Niger. Fig. 5 maps out the adaptation rationale for this intervention, from the priority policy themes it embodied to the adaptation benefits it was supposed to deliver, framing evaluation and learning questions at each stage of the adaptation rationale. When project-level answers to these questions are aggregated to the country or portfolio level, they can inform efforts to understand the often-complex reasoning behind intervention selection, levels of intervention efficacy, and even the effectiveness of policy priorities. They can open up spaces for conversations on the at times hidden processes of how decisions are and were made, and enable the evaluation processes to align more with reality on the ground. Learning from such efforts will facilitate the refinement of institutional portfolios, projects, and intervention selections to improve adaptation outcomes. Further, such practices can generate the evidence needed to fill the sizeable evidence gaps on adaptation efficacy identified by the IPCC (IPCC, 2022).

5. Towards the future/Moving forward

Adaptation rationales are critical tools for achieving adaptation benefits and shaping the design, planning and implementation of adaptation actions. Such rationales, however, require a foundational typology of adaptation benefits that also unpack the underlying assumptions and questions to be asked. This paper has proposed such a typology, drawing on well-understood concepts of exposure, sensitivity, and adaptive capacity. The typology does not prescribe what the correct composition of an effective project looks like in terms of adaptation benefits, as this will vary depending on the context. Further, it makes no claims about the appropriate composition of a national portfolio (again, due to local specificity) or institutional portfolio. Instead, it enables the construction of effective, transparent adaptation rationales that are relevant to the design, implementation, monitoring, and evaluation of adaptation actions. The information from these adaptation rationales is broadly comparable across contexts, enabling generalized learning, prioritization, and coordination of efforts. At the same time, the adaptation rationales this typology enables will necessarily engage politics, whether at the level of a community in which a project is being implemented, the government of a country, or the leadership of a funding

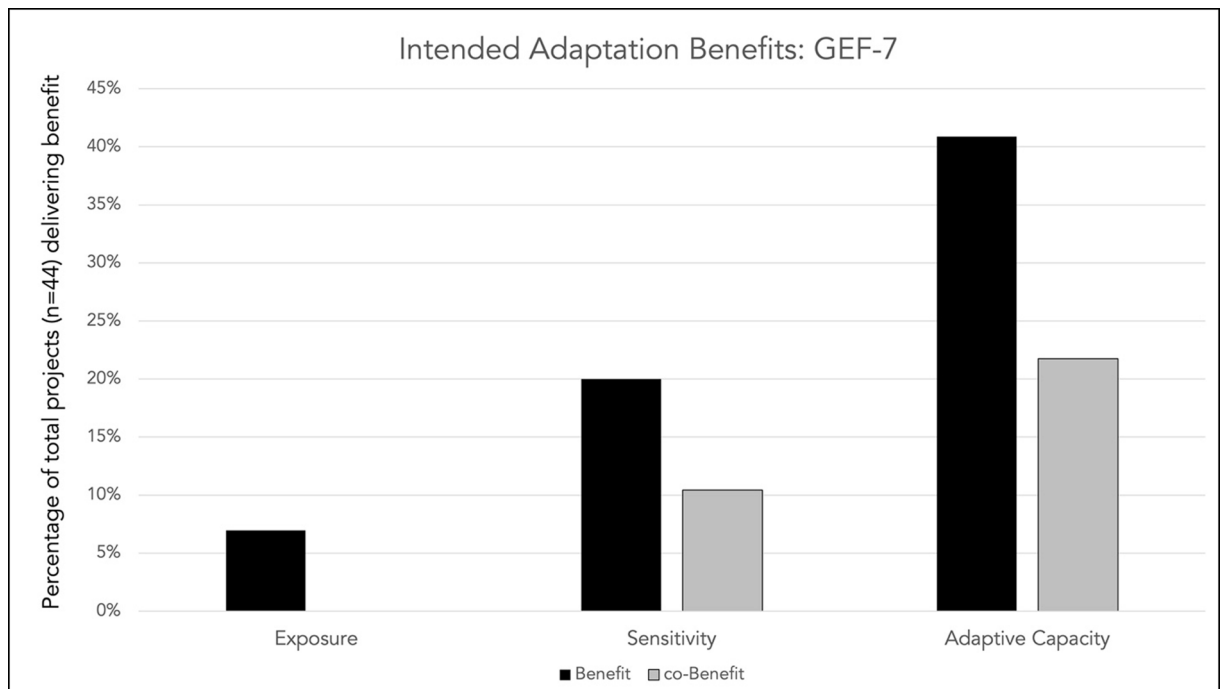


Fig. 4. Intended adaptation benefits of GEF-7 LDCF projects, as represented in their PIFs. An assessment of the benefits delivered by these projects is pending their completion.

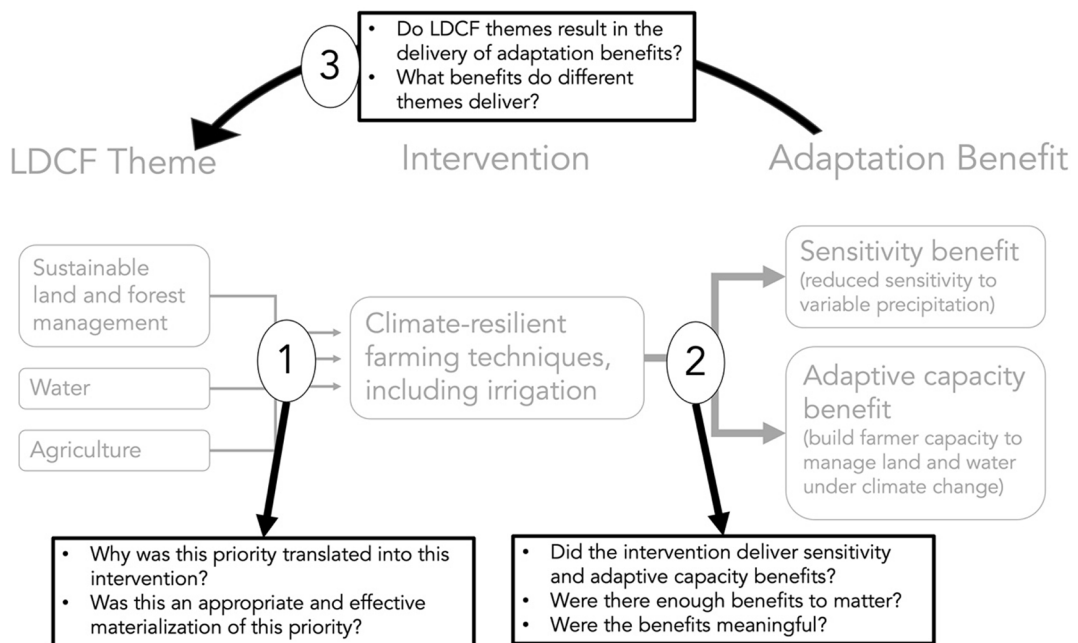


Fig. 5. The adaptation rationale for the climate smart agriculture intervention in the GEF-7 LDCF project in Niger, highlighting the opportunities to conduct M&E at various points in the rationale.

institution. Prescribing the “correct” outcome of any of these processes would erase the context specificity of these decisions and lower the efficacy of their outcomes. Instead, adaptation rationales render assumptions, emphases, and outcomes more transparent, which in turn can facilitate conversations about appropriate project design, national portfolios, and institutional portfolios. They challenge us to have more transparent conversations about what we think adaptation is, what we expect it to deliver, and how.



### Author contributions

Carr and Nalau contributed equally to the conceptualization and writing of the manuscript. Carr supervised the investigation of the GEF LDCF portfolio referenced as examples in the manuscript. Dr Nalau's contributions were made under the Australian Research Council's Discovery Early Career Research Award (DE190100940). The analysis of the GEF-7 cycle of the LDCF was conducted and supported by the Scientific and Technical Advisory Panel of the Global Environment Facility. The authors wish to thank Helen Rosko, Brennan VanDyke, Virginia Gorsevski, Mark Stafford-Smith, Rosina Bierbaum, and two anonymous reviewers for their constructive comments and suggestions.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

### Data availability

No data was used for the research described in the article.

### References

- Atteridge, A., Remling, E., 2018. Is adaptation reducing vulnerability or redistributing it? *Wiley Interdiscip. Rev. Clim. Change* 9. <https://doi.org/10.1002/wcc.500>.
- Carr, E.R., 2019. Properties and projects: Reconciling resilience and transformation for adaptation and development. *World Dev.* 122, 70–84. <https://doi.org/10.1016/j.worlddev.2019.05.011>.
- Carr, E.R., 2020. Resilient livelihoods in an era of global transformation. *Glob. Environ. Change* 64, 102155. <https://doi.org/10.1016/j.gloenvcha.2020.102155>.
- Chapagain, D., Baarsch, F., Schaeffer, M., D'haen, S., 2020. Climate change adaptation costs in developing countries: insights from existing estimates. *Clim. Dev.* 12, 934–942. <https://doi.org/10.1080/17565529.2020.1711698>.
- Dilling, L., Prakash, A., Zommers, Z., Ahmad, F., Singh, N., de Wit, S., Nalau, J., Daly, M., Bowman, K., 2019. Is adaptation success a flawed concept? *Nat. Clim. Change* 9, 572–574. <https://doi.org/10.1038/s41558-019-0539-0>.
- Eriksen, S., Schipper, E.L.F., Scoville-Simonds, M., Vincent, K., Adam, H.N., Brooks, N., Harding, B., Khatri, D., Lenaerts, L., Liverman, D., Mills-Novoa, M., Mosberg, M., Movik, S., Muok, B., Nightingale, A., Ojha, H., Sygna, L., Taylor, M., Vogel, C., West, J.J., 2021. Adaptation interventions and their effect on vulnerability in developing countries: Help, hindrance or irrelevance? *World Dev.* 141, 105383. <https://doi.org/10.1016/j.worlddev.2020.105383>.
- IPCC, 2014. Summary for policymakers, in: Field, C.B., Barros, V.R., Dokken, D.J., Mach, K.J., Mastrandrea, M.D., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., P.R. Mastrandrea, and L.L.W. (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, England, pp. 1–32.
- IPCC, 2018. Summary for Policymakers, in: Masson-Delmotte, V., Zhai, P., Pörtner, H.O., Roberts, D.C., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., Connors, S., Matthews, J.B.R., Chen, Y., Zhou, X., Gomis, M.I., Lonnoy, E., Maycock, T., Tignor, M., Waterfield, T. (Eds.), *Global Warming of 1.5°C: An IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-Industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*. Cambridge University Press, Cambridge, England. <https://doi.org/10.1017/9781009157940>.
- IPCC, 2022. Summary for policymakers. Pörtner, H.O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Lösschke, S., Möller, V., Okem, A. (Eds.), *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Pörtner, H.O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Lösschke, S., Möller, V., Okem, A., Rama, B. (Eds.), Cambridge University Press, Cambridge, England, 2022. 3–33. <https://doi.org/10.1017/CBO9781139177245.003>.
- Jagannathan, K., Arnott, J.C., Wyborn, C., Klenk, N., Mach, K.J., Moss, R.H., Sjöstrom, K.D., 2020. Great expectations? Reconciling the aspiration, outcome, and possibility of co-production. *Curr. Opin. Environ. Sustain.* 42, 22–29. <https://doi.org/10.1016/j.cosust.2019.11.010>.
- Magnan, A.K., Schipper, E.L.F., Duvat, V.K.E., 2020. Frontiers in Climate Change Adaptation Science: Advancing Guidelines to Design Adaptation Pathways. *Curr. Clim. Change Rep.* 6, 166–177. <https://doi.org/10.1007/s40641-020-00166-8>.
- Nalau, J., 2021. Assessing Adaptation Implementation. *Nat. Clim. Change* 11, 907–908. <https://doi.org/10.1038/s41558-021-01192-6>.
- New, M., Reckien, D., Viner, D., Adler, C., Cheong, S., Conde, C., Constable, A., de Perez, E.C., Lammel, A., Mechler, R., 2022. Decision making options for managing risk. In: *Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, p. 116.
- Pörtner, H.-O., Roberts, D.C., Adams, H., Adelekan, I., Adler, C., Adrian, R., Aldunce, P., Ali, E., Begum, R.A., Bednar-Friedl, B., Kerr, R.B., Biesbroek, R., Birkmann, J., Bowen, K., Caretta, M.A., Carnicer, J., Castellanos, E., Cheong, T.S., Chow, W., Cissé, G., Clayton, S., Constable, A., Cooley, S., Costello, M.J., Craig, M., Cramer, W., Dawson, R., Dodman, D., Efitre, J., Garschagen, M., Gilmore, E.A., Glavovic, B., Gutzler, D., Haasnoot, M., Harper, S., Hasegawa, T., Hayward, B., Hicke, J.A., Hirabayashi, Y., Huang, C., Kalaba, K., Kiessling, W., Kitoh, A., Lasco, R., Lawrence, J., Lemos, M.F., Lempert, R., Lennard, C., Ley, D., Lissner, T., Liu, Q., Liwenga, E., Lluch-Cota, S., Lösschke, S., Lucatello, S., Luo, Y., Mackey, B., Mintenbeck, K., Mirzabaev, A., Möller, V., Vale, M.M., Morecroft, M.D., Mortsch, L., Mukherji, A., Mustonen, T., Mycoo, M., Nalau, J., New, M., Okem, A., Ometto, J.P., O'Neill, B., Pandey, R., Parmesan, C., Pelling, M., Pinho, P.F., Pinnegar, J., Poloczanska, E.S., Prakash, A., Preston, B., Racault, M.-F., Reckien, D., Revi, A., Rose, S.K., Schipper, E.L.F., Schmidt, D.N., Schoeman, D., Shaw, R., Simpson, N.P., Singh, C., Solecki, W., Stringer, L., Totin, E., Trisos, C.H., Trisurat, Y., Aalst, M. van, Viner, D., Wairu, M., Warren, R., Wester, P., Wrathall, D., Ibrahim, Z.Z., 2022. Technical Summary. In: Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Lösschke, S., Möller, V., Okem, A., Rama, B. (Eds.), *Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, pp. 35–118.
- Schipper, E.L.F., Revi, A., Preston, B.L., Carr, E.R., Eriksen, S.H., Fernandez-Carril, L.R., Glavovic, B., Hilmi, N.J.M., Ley, D., Mukerji, R., Araujo, M.S.M. de, Perez, R., Rose, S.K., Singh, P.K., Resilient, C., Pathways, D., 2022. Climate Resilient Development Pathways, in: Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Lösschke, S., Möller, V., Okem, A., Rama, B. (Eds.), *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press, Cambridge, pp. 2655–2807. <https://doi.org/10.1017/9781009325844.027.2655>.
- Singh, C., Iyer, S., New, M.G., Few, R., Kuchimanchi, B., Segnon, A.C., Mochain, D., 2021. Interrogating 'effectiveness' in climate change adaptation: 11 guiding principles for adaptation research and practice. *Clim. Dev.* 14 (7), 650–664.
- Smit, B., Wandel, J., 2006. Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Change* 16 (3), 282–292.
- United Nations Development Programme, 2022. Strengthening the resilience of small farmers through Climate Smart Agriculture (PRP-AIC) techniques in Tahoua Region.
- United Nations Environment Programme, 2022. Adaptation Gap Report 2022: Too Little, Too Slow – Climate adaptation failure puts world at risk. Nairobi.
- Vincent, K., 2022. Development geography I: Co-production. *Prog. Hum. Geogr.* 46, 890–897. <https://doi.org/10.1177/03091325221079054>.