PROGRESS ON CLIMATE ADAPTATION:

Identifying ways for enhancing the implementation and assessment of progress on climate adaptation

Dissertation

with the aim of achieving a doctoral degree
at the Faculty of Mathematics, Informatics and Natural Sciences Department of Earth Sciences at Universität Hamburg

Submitted by

Tania Yaoska GUILLÉN BOLAÑOS

from Masaya, Nicaragua

Hamburg, August 2024

Date of Oral Defense:
19.11.2024

Reviewers: Prof. Dr. Jürgen Scheffran

Prof. Dr. Daniela Jacob

Prof. Dr. Martina Neuburger

Members of the examination commission:

Commission Chair: Prof. Dr. Martina Neuburger

Co- Supervisor: Prof. Dr. Jürgen Scheffran

Co-Supervisor: Prof. Dr. Daniela Jacob

Panel chair: Dr. María Máñez

Prof. Dr. Felix Ament

Prof. Dr. Uwe Schneider

Prof. Dr. Eray Çaylı

Department of Earth Sciences

Chair of the Subject Doctoral Committee Earth System Sciences: Prof. Dr. Hermann Held

Dean of Faculty MIN: Prof. Dr.-Ing. Norbert Ritter

Ich versichere, dass dieses gebunderie Exemplar der Dissertation und das in elektronischer Form eingereichte Dissertationsexemplar (über den Docata-Upload) und das bei der Fakultät (zuständiges Studienbüro bzw. Promotionsbüro Physik) zur Archivierung eingereichte gedruckte gebundene Exemplar der Dissertationsschrift identisch sind.

I, the undersigned, declare that this bound copy of the dissertation and the dissertation submitted in electronic form (via the Docata upload) and the printed bound copy of the dissertation submitted to the faculty (responsible Academic Office or the Doctoral Office Physics)for archiving are identical.

19.08.2024	*Tania Yaoska GUILLÉN BOLAÑOS*	
Place, Date	**First name and surname**	**Signature**

"En cada uno de nuestros actos
-por triviales que sean
y por insignificantes-,
cada uno de nosotros es responsable
por la humanidad entera".

Gabriel García Márquez

"With each of our actions – no matter how small and insignificant they may be – each of us bears responsibility for humanity as a whole."

„Mit jeder unserer Handlungen – wie trivial und unbedeutend sie auch sein mögen – trägt jeder von uns Verantwortung für die gesamte Menschheit."

Table of Contents

Acknowledgements ..... **v**

Summary ..... **vii**

Zusammenfassung ..... **ix**

List of Publications ..... **xi**

Abbreviations ..... **xv**

Chapter I. Introduction **I-1**

1.1 Research Gaps *I-4*

1.2 Research Aim, Research Questions and Objectives *I-6*

1.3 Research Approach *I-7*

1.4 Chapters Overview *I-9*

1.4.1 Chapter II: "Climate Adaptation and Successful Adaptation Definitions: Latin American Perspectives Using the Delphi Method" I-9

1.4.2 Chapter III: "Assessing the Feasibility of Climate Adaptation Options using Local Expertise and Participatory Approaches: The Case of Puerto Morazán, Nicaragua" I-9

1.4.3 Chapter IV: "The Framework for Implementing Climate Adaptation (FICA): a Framework for Analyzing Adaptation Project Realities – An Exploration of GCF Adaptation Projects" I-9

1.5 Case Studies *I-10*

1.5.1 Latin American and the Caribbean Region I-11

1.5.2 African Least Developed Countries I-11

Chapter II. "Climate Adaptation and Successful Adaptation Definitions: Latin American Perspectives Using the Delphi Method" **II-13**

Abstract *II-15*

2.1 Introduction *II-15*

2.2 Why are Definitions for Climate Change Adaptation Important? *II-17*

2.3 Methodology *II-18*

2.3.1 The Delphi Method II-18

2.3.2 Implementation Framework II-19

2.4 Results *II-22*

2.4.1 Perspectives on the Definitions II-22

2.4.2 Operationalization of the Definition of Successful Adaptation II-24

2.5 Discussion *II-28*

2.5.1 Revision of the Definitions II-28

2.5.2 Aggregation II-29

2.5.3 Added Value of the Delphi Method for Co-Production of Climate Change Adaptation Knowledge II-29

2.6 Conclusions *II-30*

Appendix A *II-31*

Chapter II References *II-32*

Chapter III. "Assessing the Feasibility of Climate Adaptation Options Using Local Knowledge: The Case of Puerto Morazán, Nicaragua" **III-37**

Abstract *III-39*

3.1 Introduction *III-40*

3.2 Local Feasibility Assessment Of Climate Adaptation Options: A Methodological Advancement III-41

3.2.1 Phase I: Socio-Ecological System's Characterization III-42
3.2.2 Phase II: Identification Of Adaptation Options III-43
3.2.3 Phase III: Feasibility Assessment III-43

3.3 Applying the Framework: Assessing the Feasibility of Adaptation Options in Puerto Morazán, Nicaragua *III-45*

3.3.1 Identification of local Stakeholders and Experts III-45
3.3.2 The Socio-ecological System III-45
3.3.3 Planned And Implemented Adaptation Options III-47
3.3.4 Feasibility Assessment III-48

3.4 Discussion *III-55*

3.4.1 Climate Adaptation in Puerto Morazán III-55
3.4.2 Methodological Advances III-55
3.4.3 Policy Implications III-56

3.5 Conclusions *III-57*

3.6 Chapter III References *III-58*

3.7 Chapter III Supplementary Information *III-62*

SI Text - Feasibility Assessment Guidance and Legends III-62
S2 Text - Applying the framework: assessing climate adaptation in Puerto Morazán III-65

Chapter IV. "The Framework for Implementing Climate Adaptation (FICA): Analyzing Adaptation Project Realities – An Exploration of GCF Adaptation Projects" IV-91

4.1 Introduction *IV-93*

4.2 Implementation Science and its Implications for Climate Adaptation *IV-95*

4.2.1 Framework for Implementing Climate Adaptation (FICA) IV-97

4.3 Case Study and Methods *IV-100*

4.3.1 GCF's Adaptation Projects in Latin America and the Caribbean and African Least Developed Countries IV-100
4.3.2 Methods: Sample Selection Criteria, Interviews, Document Screening IV-101

4.4 Findings *IV-102*

4.4.1 Barriers and Challenges for Implementation: Stakeholders and Beneficiaries IV-103
4.4.2 Barriers and Challenges for Implementation: Adaptation Projects IV-104
4.4.3 Barriers and Challenges for Implementation: Implementation Process IV-106
4.4.4 Adaptation Outcomes and Outputs of Adaptation Projects IV-114
4.4.5 Working with the GCF IV-116

4.5 Discussions *IV-119*

4.5.1 Implementation Science Supporting Climate Adaptation IV-119
4.5.2 Main Factors Contributing to the Implementation Gap IV-120
4.5.3 What Constitutes a Successful Implementation Process IV-122

4.6 Conclusions *IV-122*

Chapter IV References *IV-124*

Chapter IV Annexes *IV-129*

Annex A Components and elements of the Framework for Implementing Climate Adaptation (FICA) (adapted from Damschroder et al. 2009; 2022) IV-130
Annex B Stakeholders Roles within the GCF IV-141
Annex C GCF Adaptation Projects IV-142

Annex D Findings (complete) IV-146

Chapter V. Synthesis V-159

5.1 Main Findings V-161
5.1.1 Defining Climate Adaptation and Successful Adaptation (RQ1, RQ2) V-161
5.1.2 Importance of Generating Evidence Integrating Local Knowledge and Expertise for Adaptation Action (RQ3) V-162
5.1.3 Bridging the Gap Between Planning and Implementation: Implementation Science for Climate Adaptation (RQ4) V-164

5.2 Conclusions V-165
5.2.1 Novelty of the Research Approach V-166
5.2.2 Policy Implications V-167
5.2.3 Limitations V-168

5.3 Outlook for Future Research V-168

5.4 References (Chapters I & V) V-170

List of Figures and Tables

List of Figures

Figure I-1 Dissertation chapters contributing to the IAP (based on UNFCCC-AC 2023) - Chapter IV contributes to all the steps, with a particular focus on implementation (identified by dotted lines). I-8

Figure I-2 *Case studies regions of this research* I-10

Figure II-1 Aggregation of information on Aggregation of information on adaptation progress (GST: global stocktake; GGA: global goal on adaptation; NAPs: national adaptation plans; AdComm: adaptation communications; NDCs: national determined contributions). II-18

Figure II-2 Summary of the steps, methods, and measures taken (adapted from [36]) II-19

Figure II-3 Adaptation experts' country of residence II-20

Figure II-4 Agreement with the IPCC's [16] definition of climate adaptation: (a) first round, (b) second round (source: SurveyHero). II-22

Figure II-5 Agreement with Doria et al.'s [17] definition of successful climate adaptation: (a) first round, (b) second round (source: SurveyHero). II-23

Figure II-6 Successful adaptation definition general usefulness: (a) first round, (b) second round. II-25

Figure II-7 Usefulness of the successful adaptation definition at different management levels (first round). II-25

Figure III-1 Steps for conducting the local feasibility assessment of adaptation options. III-42

Figure III-2 Phase III steps to perform the feasibility assessment using local expert expertise (modified from Singh et al. (2020b) III-44

Figure III-3 Case Study area: Puerto Morazán III-46

Figure III-4 Priorities among indicators (Panel A) and dimensions (Panel B) identified by local experts using the AHP. III-49

Figure IV-1 Components of the Framework for Implementing Climate Adaptation (FICA) IV-97

Figure IV-2 Barriers and challenges: Stakeholders and Beneficiaries (source: interviews, annual performance reports, Annex D.1). NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AR: Annual Performance Reports. IV-104

Figure IV-3 Barriers and challenges: Adaptation project (source: interviews, annual performance reports, Annex D.2). NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; NDA/EE: National Designated Authority and Executing Entity; AR: Annual Performance Reports. .. IV-105

Figure IV-4 Barriers and challenges: Implementation process design (Panel A) (source: interviews, annual performance reports, Annex D.3) NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; AR: Annual Performance Reports. IV-107

Figure IV-5 Barriers and challenges: Implementation process design (Panel B) (source: interviews, annual performance reports, Annex D.3) NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; AR: Annual Performance Reports IV-109

Figure IV-6 Barriers and challenges: Implementation readiness (source: interviews, annual performance reports, Annex D.3) NDA: National Designated Autho AR: Annual Performance Reports.rities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; NDA/EE; AR: Annual Performance Reports. IV-110

Figure IV-7 Barriers and challenges: Implementation climate (source: interviews, annual performance reports, Annex D.3) NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; NDA/EE: National Designated Authority and Executing Entity; AR: Annual Performance Reports. .. IV-113

Figure IV-8 Successful implementation process characteristics (source: interviews, Annex D.5) NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; NDA/EE: National Designated Authority and Executing Entity. IV-115

Figure IV-9 Challenges and barriers in working with the GCF (source: interviews, annual performance reports, Annex D.6) NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity. IV-117

List of Tables

Table I-1 Overview of research questions, objective, and chapters I-7

Table II-1 Adaptation expert's profiles II-20

Table II-2 Usefulness of the definition of successful adaptation at different management levels II-25

Table II-3 Useful elements of the successful adaptation definition..... II-26

Table II-4 Elements missing from the successful adaptation definition..... II-26

Table II-5 Identified methods and approaches II-27

Table II-6 Identified criteria and indicators for the different management levels..... II-27

Table III-1 Adaptation options identified in Puerto Morazán III-47

Table III-2 Overall feasibility of adaptation options. Green: High feasibility (insignificant barriers). Yellow: Medium Feasibility (mixed or moderate but still existent barriers). Red: Low feasibility (Multiple barriers, in this dimension, may block implementation). III-50

Table III-3 Feasibility of adaptation options per dimension. Green: High feasibility (insignificant barriers). Yellow: Medium Feasibility (mixed or moderate but still existent barriers). Red: Low feasibility (Multiple barriers, in this dimension, may block implementation). (NLP) No local priorities considered; (LP) Local priorities considered III-52

Table IV-1 Connections between the Iterative Climate Risk Management and Implementation Science (based on New et al., 2022; Damschroder et al., 2009, 2022;) .. IV-96

Table IV-2 Overview of the interviews conducted and codes used in this work IV-101

Table IV-3 Interviewees Statements about Working with the GCF IV-118

Acknowledgements

I couldn't have made it to the end of my PhD without the help, support, and teamwork of my family, friends, and colleagues. Therefore, I would like to express my gratitude to them all.

This doctoral work would not have been possible without the support of the Climate Service Center Germany (GERICS), especially from its director, Prof. Daniela Jacob, who has also co-supervised this work. I'm really grateful to you, Daniela, for allowing me to develop this project and for all your understanding and empathy when I needed it most. Also, thanks for giving me the push I needed to reach this final phase. I'm also grateful to you for allowing me to participate and represent GERICS in different spaces. This has given me the chance to continue gaining knowledge and skills, and play a (small) part in the vital dialogue between science and politics.

I would also like to express my sincere gratitude to my supervisor at the Universität Hamburg, Prof. Jürgen Scheffran, for all his support, feedback, guidance, and availability to meet with me and follow up on my work.

I'm also increadibly greatful to Dr. María Máñez for her unwavering support, guidance, and invaluable advice throughout this journey. Your mentorship has greatly enriched my professional journey. Thanks for generously sharing your experiences and knowledge, and for being more than just a colleague.

Likewise, thanks to my Nicaraguan colleagues who allowed me to develop the case study in Nicaragua, even though there were a lot of limitations. Thank you for making the workshop happen, sharing your knowledge about Puerto Morazán and climate policies in Nicaragua, and collaborating with the article preparation. I would also like to thank Centro Humboldt, Nicaragua, now Asociación Centroamericana Centro Humboldt, for making the field visits and accompaniment possible. Despite the challenges, your efforts will keep flourishing.

Thanks to Chandni Singh for her comments and recommendations regarding the feasibility framework. A big thank you to Prof. Kris Ebi for mentoring me in the final phase of my PhD. Your insights and collaboration were vital to developing the FICA framework.

Also, thanks to all my GERICS colleagues, particularly those who have closely accompanied my PhD process. Thanks, Eulalia, who, even from the distance, has been very supportive in this process. Thanks, Eu, for all the chats and encouragement. To Jeewa, thanks for being there for me over the past year and for all the advice.

I would also like to thank all the experts who gave me their time and knowledge on adaptation and implementing Green Climate Fund projects in Latin America and African LDC countries.

Over the past few years, while working on my PhD, I went through one of the hardest periods of my life. I lost many loved ones and faced other challenges that made it difficult for me to be at my best. So, completing this project would not have been possible without the constant and unwavering support of my entire tribe (mi tribu): my family (especially my Ma and Simon) friends, who, from wherever they are, are always cheering me on. Encouraging me in every step. Both in the ups and downs. Accompanying me in my sadness and joy. Your joy for my joys has been a fundamental energy generator for this stage. You know who you are, BIG THANKS! ¡GRACIAS TOTALES! An additional thank

goes to the “Mindful Co-Writing” girls, who have been great company and source of motivation over the past few months.

In particular, I would like to thank the one who has become a fundamental pillar in my life. Thank you, Simon, for everything. For your unconditional love, support, understanding, and care through thick and thin. Thanks for always having faith in me, even when I didn't. The last two years have been marked by much joy together. And now, I am ending this professional stage to start another, a much more exciting new personal experience with you, zu dritt.

I particularly dedicate this effort first all to my mother, Dr. Fátima Bolaños, because even though I refused for many years to follow her path - having experienced during my adolescence how hard this process can be - here I am culminating such a challenging phase. Thank you, Ma, for being an example in so many ways. Thank you for always being there for me.

I also dedicate this effort to those who have physically departed these past few years but who I know are with me always. Thank you because each of you is in me, now and always. Tío Rogelio, Tía Cheya, Abue Coco, Tío Jairo, José, Karl, Onkel Erik, this is for you!

Summary

The progressive consequences of climate change for human and ecological systems can be observed worldwide. To reduce the associated negative impacts and risks, numerous adaptation initiatives are being implemented. To monitor and evaluate the progress of climate action, including adaptation, the Global Stocktake (GST) was established under the Paris Agreement. The first GST in December 2023 and the latest assessments by the Intergovernmental Panel on Climate Change (IPCC) made in 2023 show a considerable discrepancy between the need for adaptation on the one hand and the current adaptation strategies, the financial resources currently available as well as the status of the implementation of adaptation measures on the other. The assessments also show that a global approach to measuring progress across different regional and local contexts does not produce consistent results. As far as the implementation of the measures is concerned, the lack of financial resources is seen as the biggest hurdle. Beyond, the effectiveness of the implementation and thus the success of the measures is influenced by numerous other factors. However, for an effective measurement of adaptation success it is crucial to recognize that assessments on a global scale can only inadequately reflect progress and obstacles in the implementation of adaptation measures at local level. This is particularly true for the Global South, where information is often inadequate or not examined at all compared to the research situation in the Global North. For current adaptation research, this results in conceptual and empirical difficulties for the definition of adaptation and what can be regarded as progress or success in adaptation efforts overall.

Considering the above, the main purpose of this dissertation is to identify ways to improve the implementation of adaptation measures in general and the assessment of their progress in particular. To this end, the theoretical and empirical foundations that influence monitoring and evaluation efforts as well as the effective implementation of adaptation initiatives are examined. This task translates into four research objectives: (1) to develop proposals for expanding the definition of adaptation and successful adaptation to promote their general applicability and thus their use in assessing adaptation success; (2) to identify criteria and indicators that could support efforts in compiling information on adaptation success; (3) to develop and implement an innovative approach assessing the feasibility of adaptation measures at the local level with possible further use of the results also at regional and global levels; (4) to develop an integrative framework to improve the execution of adaptation measures and to enhance the design of the assessment process: The Framework for Implementing Climate Adaptation (FICA).

To achieve the above mentioned objectives, the views of experts from Latin America in relation to definitions of adaptation and successful adaptation are examined at frist. The experts were asked to assess the suitability of the same definitions for monitoring and evaluation purposes. In a second step, the IPCC approach to the design and feasibility assessment of adaptation initiatives is methodologically extended to allow for the integration of local priorities, knowledge and expertise. Here, the case study of Puerto Morazán, Nicaragua, was used for development and testing. Third, an additional methodological approach is presented to support the implementation and evaluation of climate adaptation projects. Thereby, the approach draws on findings from implementation science and uses adaptation projects of the Green Climate Fund (GCF) as case studies. The projects are situated in Latin America and the Caribbean (LAC) as well as in some African Least Developed Countries (Af-LDCs) for validation and further elaboration.

The implementation of the above three steps provided the following results: The analysis of the definitions of adaptation and successful adaptation highlights the importance of

understanding the numerous regional and local differences for successful climate adaptation. Understanding this shows as a prerequisite for a robust assessment of adaptation efforts across different regional and local contexts. It is also revealed that parts of the Global Goal for Adaptation can be used to potentially improve the definitions examined here. Finally, a list of criteria and indicators is proposed for use at different levels of governance. The methodological advancement of the IPCC approach to assess feasibility represents the first scientific attempt to capture conditions at the local level. It shows that approaches developed at the global level can be altered with a view to successfully integrate local circumstances and expertise - a basic prerequisite for the success of adaptation efforts. At the same time, the use of locally adapted approaches allows knowledge gained at the global level to be applied effectively at the local level. The importance of including local priorities in the assessment of possible adaptation measures is also illustrated by the research results obtain with this thesis, which shows that the assessment results vary. In the case of Puerto Morazán considered here, the assessment approach further developed in this thesis supported the identification of three possible adaptation strategies as feasible options. The Framework for Implementing Climate Adaptation (FICA) is based on approaches from implementation science. The results of the GCF adaptation projects are consistent with previous research showing that the availability of financial resources is not the only factor hindering the implementation of adaptation measures. In fact, the implementation of measures is determined by several factors, including practical aspects and the behavior of organizations. Possible criteria for assessing adaptation performance are also suggested. Finally, specific concerns regarding the operational approach of the GCF are identified, including the complexity and duration of procedures, as well as the lack of flexibility and the structuring of power at the GCF.

Based on the theoretical and empirical challenges associated with the implementation of adaptation measures, this work develops methodological assessment approaches from adaptation research with the aim of further harnessing regional and local specificities from currently under-researched areas of the Global South more effectively for the design of the measures to be taken. This is achieved through the integration of local perspectives, knowledge and expertise as well as through the investigation of novel approaches to the evaluation of climate adaptation measures.

Keywords: climate adaptation, successful adaptation, monitoring and evaluation, feasibility assessment, implementation science, participatory methods, local knowledge integration

Zusammenfassung

Die fortschreitenden Folgen des Klimawandels für menschliche und ökologische Systeme lassen sich weltweit beobachten. Um die mit diesen Folgen verbundenen negativen Auswirkungen und Risiken zu verringern, werden zahlreiche Anpassungsinitiativen umgesetzt. Um den Fortschritt bei den Klimaschutzmaßnahmen, einschließlich jenen zur Anpassung, verfolgen und messen zu können wurde im Rahmen des Pariser Abkommens der Global Stocktake (GST) als Form einer globalen Bestandsaufnahme ins Leben gerufen. Der erste GST im Dezember 2023 und die neusten Bewertungen des Intergovernmental Panel on Climate Change (IPCC) aus 2023 weisen eine erhebliche Diskrepanz zwischen dem Anpassungsbedarf einerseits und den aktuellen Anpassungsstrategien, den aktuell zur Verfügung stehenden finanziellen Mitteln und dem Stand bei der Umsetzung der Anpassungsmaßnahmen andererseits auf. Die Bewertungen zeigen darüber hinaus, dass ein globaler Ansatz bei der Fortschrittsmessung über unterschiedliche regionale und lokale Kontexte hinweg keine konsistenten Ergebnisse ermöglicht. Was die Umsetzung der Maßnahmen betrifft, so wird der Mangel an finanziellen Mitteln als die größte Hürde angesehen. Jedoch wird die Wirksamkeit bei der Umsetzung und damit der Erfolg der Maßnahmen durch zahlreiche weitere Faktoren beeinflusst. Für eine effektive Messung des Anpassungserfolgs ist es jedoch vor allem von entscheidender Bedeutung anzuerkennen, dass Bewertungen auf globalem Maßstab Fortschritte und Hindernisse bei der Umsetzung von Anpassungsmaßnahmen auf lokaler Ebene in nur ungenügendem Maße abbilden können. Dies gilt vor allem für den Globalen Süden, dessen Informationslage im Vergleich zum Globalen Norden oft nur unzureichend oder gar nicht erforscht ist. Für die aktuelle Anpassungsforschung ergeben sich daraus konzeptionelle und empirische Schwierigkeiten für die Definition von Anpassung und was als Fortschritt oder Erfolg bei den Anpassungsbemühungen angesehen werden kann.

Vor dem Hintergrund der oben genannten Umstände besteht das Hauptanliegen dieser Dissertation darin, Wege zur Verbesserung bei der Umsetzung von Anpassungsmaßnahmen im Allgemeinen sowie bei der Bewertung ihrer Fortschritte im Besonderen aufzuzeigen. Um dieses Ziel zu erreichen, werden die theoretischen und empirischen Zusammenhänge untersucht, welche die Monitoring- und Bewertungsbemühungen sowie die effektive Umsetzung von Anpassungsinitiativen beeinflussen. Dazu verfolgt diese Arbeit vier Forschungsziele: (1) Entwicklung von Vorschlägen zur Erweiterung der Definition von Anpassung und erfolgreicher Anpassung, um ihre allgemeine Anwendbarkeit und damit ihre Verwendung bei der Bewertung des Anpassungserfolgs zu fördern; (2) Identifizierung von Kriterien und Indikatoren, die die Bemühungen bei der Zusammenstellung von Informationen zum Anpassungsfortschritt unterstützen könnten; (3) Entwicklung und Umsetzung eines innovativen Ansatzes zur Bewertung der Durchführbarkeit von Anpassungsmaßnahmen auf lokaler Ebene mit möglicher weiterführender Verwendung der Ergebnisse auch auf regionalen und globalen Ebenen; (4) Vorstellung eines integrativen Rahmens zur Verbesserung der Ausführung von Anpassungsmaßnahmen und zur Verbesserung bei der Gestaltung des Bewertungsprozesses: Framework for Implementing Climate Adaptation (FICA).

Um die oben genannten Ziele zu erreichen, werden in einem ersten Schritt die Sichtweisen von Experten aus Lateinamerika im Zusammenhang mit Definitionen von Anpassung und erfolgreicher Anpassung untersucht. Die Experten werden ebenfalls um eine Bewertung der Eignung der gleichen Definitionen für Monitoring- und Bewertungszwecke gebeten. untersucht. In einem zweiten Schritt wird der IPCC-Ansatz zur Konzeption und Machbarkeitsbewertung von Anpassungsinitiativen methodisch erweitert um die Integration lokaler Prioritäten, Kenntnisse und Expertise zu ermöglichen. Dazu wurde die Fallstudie von

Puerto Morazán, Nicaragua, zur Entwicklung und Erprobung herangezogen. In einem dritten Schritt wird ein zusätzlicher methodischer Ansatz vorgestellt, welcher bei der Umsetzung und Bewertung von Klimaanpassungsprojekten unterstützen soll. Dieser Ansatz greift dabei auf Erkenntnisse aus der Implementation Science zurück. Zur Entwicklung und Validierung dieses Ansatzes wurden Anpassungsprojekte des Green Climate Fund (GCF) in Lateinamerika und der Karibik sowie in Least Developed Countries in Afrika als Fallstudien herangezogen.

Die Durchführung der oben genannten drei Schritte zeigt folgende Ergebnisse: Die Analyse der Definitionen von Anpassung und erfolgreicher Anpassung verdeutlicht die Wichtigkeit des Verständnisses der zahlreichen regionalen und lokalen Unterschiede für eine erfolgreiche Klimaanpassung. Dies ist die Voraussetzung für eine belastbare Bewertung von Anpassungsbemühungen über verschiedene regionale und lokale Kontexte hinweg. Ebenso wird deutlich, dass Teile des Globalen Ziels für Anpassung zur potenziellen Verbesserung der hier untersuchten Definitionen herangezogen werden können. Schließlich wird eine Liste von Kriterien und Indikatoren zur Anwendung in den verschiedenen Governance Ebenen vorgeschlagen. Die methodische Weiterentwicklung des IPCC-Ansatzes zur Bewertung der Durchführbarkeit stellt den ersten wissenschaftlichen Versuch dar Gegebenheiten auf lokaler Ebene zu erfassen. Damit wird gezeigt, dass auf globaler Ebene entwickelte Ansätze mit Blick auf eine erfolgreiche Integration lokaler Umstände und Expertise weiterentwickelt werden können – eine Grundvoraussetzung für das Gelingen von Anpassungsbemühungen. Gleichzeitig erlaubt die Verwendung lokal angepasster Ansätze, Erkenntnisse, welcher auf globaler Ebene gewonnen wurden, effektiv auf lokaler Ebene anzuwenden. Die Bedeutung lokale Prioritäten bei der Bewertung möglicher Anpassungsmaßnahmen miteinzubeziehen, wird auch durch die Forschungsergebnisse dieser Arbeit verdeutlicht. Im hier betrachteten Fall von Puerto Morazán unterstützte der in dieser Arbeit weiterentwickelte Bewertungsansatz die Identifikation von drei möglichen Anpassungsstrategien als umsetzbare Optionen. Das Framework for Implementing Climate Adaptation (FICA) basiert auf Ansätzen aus der Implementation Science. Die Ergebnisse der GCF-Anpassungsprojekte stimmen mit früheren Forschungsergebnissen überein, die zeigen, dass die Verfügbarkeit von finanziellen Mitteln nicht der einzige Faktor ist, der die Umsetzung von Anpassungsmaßnahmen behindert. Tatsächlich wird die Umsetzung von Maßnahmen durch mehrere Faktoren bestimmt, einschließlich praktischer Aspekte und dem Verhalten von Organisationen. Ebenfalls werden mögliche Kriterien zur Bewertung von Anpassungsleistungen vorgeschlagen. Schließlich werden spezifische Bedenken hinsichtlich des operativen Ansatzes des GCF aufgezeigt, darunter die Komplexität und Dauer der Verfahren, sowie die mangelnde Flexibilität und die Machtverhältnisse innerhalb des GCF.

Ausgehend von den theoretischen und empirischen Herausforderungen wie sie im Zusammenhang mit der Umsetzung von Anpassungsmaßnahmen vorkommen entwickelt die hier vorliegende Arbeit methodische Bewertungsansätze aus der Anpassungsforschung mit dem Ziel weiter regionale und lokale Besonderheiten aus aktuell noch weniger erforschten Gebieten des Globalen Südens effektiver für die Gestaltung der zu ergreifenden Maßnahmen nutzbar zu machen. Dies wird durch die Integration lokaler Perspektiven, Kenntnisse und Expertise sowie durch die Untersuchung neuartiger Ansätze zur Bewertung von Klimaanpassungsmaßnahmen erreicht.

List of Publications

Table A *Publications included as part of this dissertation.*

Chap-ter	***Title of section or contribution***	***Doctoral candidate's contributions***	***Co-author's contributions***
2	Climate Adaptation and Successful Adaptation Definitions: Latin American Perspectives Using the Delphi Method. Sustainability 2022, 14, 5350. doi:10.3390/su14095350. ***(Article)*** **Published** (2022) in Sustainability	**Conceptualization** (completely) **Methodology** (completely) **Results Analysis:** (completely) **Manuscript writing** (predominantly)	**Manuscript review and editing:** Scheffran, J.; Máñez, M.
3	Assessing the feasibility of climate adaptation options using local knowledge: the case of Puerto Morazán, Nicaragua. ***(Article)*** **Submitted** (to PLOS Climate, in review)	**Conceptualization** (completely) **Methodology** (predominantly) **Data collection** (predominantly) **Results Analysis:** (predominantly) **Manuscript writing** (predominantly)	**Methodology:** Scheffran, J. **Data collection:** García, A.; López, H.; Castillo, M. **Results Analysis:** García, A.; López, H.; Castillo, M.; Mánez, M. **Manuscript review and editing:** Scheffran, J.; García, A.; López, H.; Castillo, M.; Máñez, M.; Jacob, D.
4	Implementation science for climate change adaptation. ***(Chapter)*** **Dissertation chapter**	**Conceptualization** (predominantly) **Methodology** (predominantly) **Data collection** (completely) **Results Analysis:** (predominantly) **Manuscript writing** (predominantly)	**Conceptualization:** Ebi, K. **Methodology:** Ebi, K. **Results Analysis:** Mánez, M. **Manuscript review and editing:** Ebi, K.; Scheffran, J.; Máñez, M.; Jacob, D.

Table B *List other publications not included in this dissertation but related to the topics covered.*

	Type and Title	***Authors***	***Doctoral candidate's specific contribution(s)***
1	Peer-reviewed article in scientific journal **"Central America urgently needs to reduce the growing adaptation gap to climate change."** Published in Frontiers in Climate (2023), Section Climate Risk Management as Police and Practice Review Article. Part of ther Research Topic "Adaptation Research Priorities for the Next Ten Years: Addressing Conceptual, Empirical and Policy Needs After The IPCC Sixth Assessment Report"	Ley, D.; **Guillén Bolaños, T.**; Castaneda, A.; Hidalgo, H.; Girot, P.; Hernández, R.; Alfaro, E.; Castellanos, E.	**Contributions:** Conceptualization, literature review, writing (original draft), review and editing. **Relation with dissertation:** The article provides an overview of climate change adaptation in Central America, one of the case study areas of this dissertation.
2	Book chapter **"Toward a Sustainable Adaptation Plausibility Framework."** In Hamburg Climate Futures Outlook, 234. Universität Hamburg. Hamburg, Germany. Annual Hamburg Climate Futures Outlook (2023)	Gonçalves Gresse, E., Schrum, C., Hanf, F.S., Hoffmann, P., **Guillén Bolaños, T.**, Langendijk, G., Schneider, U., Huang-Lachmann, Neuburger, M., Reveco Umaña, C., Seiffert, R., Wickel, M., Sillmann, J., Scheffran, J., Held, H.	**Contributions:** Literature review, writing (original draft), review, and editing. **Relation with dissertation:** The chapter proposes key concepts and guiding principles toward a sustainable plausibility framework, which can be related to the feasibility framework used in Chapter III of the dissertation.
3	Book chapter **Cross-Chapter Box FEASIB: Feasibility Assessment of Adaptation Options: An Update of the SR1.5.** In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation, and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK and New York, USA, pp 2769–2807	Ley, D., Adams, H., Araos, M., Basu, R., Bazaz, A., Conte, L., Davis, K., Dockendorff, C., Ford, J., Fuss, S., Gilmore, E., **Guillén Bolaños, T.**, Hoegh-Guldberg, O., Howde, M., Kalyan, B., Moro, L., Mosurska, A., Mechler, R., Portugal-Pereira, J., Revi, A., Sharma, S., Sietsma, A., Singh, C., et al.	**Contributions:** Listed as IPCC's Contributing Author & Expert Reviewer. Literature review, writing (original draft), and editing. Assessment of three adaptation options. Peer-review of other adaptation options. **Relation with dissertation:** The cross-chapter box provides an update of the feasibility assessment performed in the IPCC's

Type and Title	Authors	Doctoral candidate's specific contribution(s)
Working Group II contribution to IPCC's AR6 (2022)		special report on the 1.5ºC of global warming. The feasibility framework was used in Chapter III of this dissertation.

Abbreviations

AE	Accredited Entity
Af-LDCs	African Least Developed Countries
CADC	Central American Dry Corridor
CFIR	Consolidated Framework for Implementation Research
EE	Executing Entities
FICA	Framework for Implementing Climate Adaptation
GCF	Green Climate Fund
GGA	Global Goal on Adaptation
GST	Global Stocktake
IAP	Iterative Adaptation Process
ICRM	Iterative Climate Risk Management
IPCC	Intergovernmental Panel on Climate change
IS	Implementation Science
LAC	Latin America and the Caribbean
M&E	Monitoring and Evaluation
MEL	Monitoring, Evaluation and Learning
NAPs	National Adaptation Plans
NDA	National Designated Authority
UNFCCC	United Nations Framework Convention on Climate Change

Chapter I. Introduction

Introduction

"Most observed adaptation is fragmented, small in scale, incremental, sector-specific, designed to respond to current impacts or near-term risks, and focused more on planning rather than implementation *(high confidence) (IPCC 2022a, p. 20)*."

The world is currently experiencing a global temperature increase of about 1ºC relative to preindustrial levels (1850-1900) (IPCC 2021). The effects of this change are already being observed in natural and human systems. Therefore, adaptation measures to reduce the current impact and project risks are being implemented, and further efforts will be required at higher levels of warming (IPCC 2018, 2022b; Hoegh-Guldberg et al. 2019). Accordingly, the Paris Agreement of the United Nations Framework Convention on Climate Change (UNFCCC) aims to reinforce the global response to the threat of climate change. In this regard, three principal approaches have been identified: mitigation, which pertains to the reduction of greenhouse gases that contribute to global warming; adaptation, which encompasses the adjustment or response to new or evolving conditions (UNFCCC 2015); and loss and damage, which refers to the adverse impacts of climate change, including both economic and non-economic consequences.

However, in the past, adaptation was regarded as a less crucial aspect than mitigation. To address this situation and acknowledge the difficulties associated with the current levels of global warming, Article 7 of the Paris Agreement established the Global Goal on Adaptation (GGA). The GGA comprises three components: enhancing adaptive capacity, strengthening resilience, and reducing vulnerability to climate change (UNFCCC 2015). Nevertheless, negotiations regarding the goal's indicators persist nine years later within the UNFCCC. At the 28th Conference of the Parties to the UNFCCC (held in 2023), the United Arab Emirates – Belém work program on indicators was launched with the objective of measuring the progress made on adaptation action at scale and all levels. This includes measuring progress made on the specific targets related to the dimensions of the Iterative Adaptation Process (IAP) (UNFCCC 2023a).

Furthermore, the progress on adaptation should be evaluated in accordance with the GGA components as part of the Global Stocktake (GST) (UNFCCC 2015). The GST was established as a cyclical evaluation process of the progress made concerning the agreement's stated objectives. The first GST was conducted in 2023, during the COP28, and is scheduled to occur every five years thereafter. The initial GST calls for implementing immediate, incremental, transformational, and country-driven adaptation actions tailored to the specific national circumstances. Moreover, it acknowledges the existence of the adaptation implementation gap and the necessity for support and assessment of the adequacy and effectiveness of adaptation options. The first GST also recognized the importance of monitoring and evaluation efforts (UNFCCC 2023b).

Reviewing the progress, adequacy, and effectiveness of adaptation is critical to the GST (UNFCCC 2018a). This reflects and responds to the need for a better overview of whether and how well we are adapting to climate change. Therefore, adaptation metrics need to be developed. However, these metrics should take into account contextual aspects (e.g., "national circumstances") and allow aggregation to comprehensively assess adaptation efforts on a global scale (Magnan 2016). In recent years, research on adaptation evaluation has gained prominence due to the work on the GST and the GGA. Additionally, monitoring and evaluation of climate adaptation action should also consider or integrate aspects related to other important global agendas, such as the 2030 Agenda for Sustainable Development and its goals and the Sendai Framework for Disaster Risk Reduction, in order to avoid additional burdens related to reporting processes (Gonçalves Gresse et al. 2023; Jin et al. 2023).

1.1 Research Gaps

Given the context presented above, three research gaps emerge for improving the implementation and assessment of climate adaptation. First is the need for a better understanding of what successful adaptation entails. Second, there is still limited evidence on the effectiveness and implementation of climate adaptation options, particularly at the local level and using local knowledge and expertise. Third, there is a need to address the existing implementation gap even when financial resources are available.

RESEARCH GAP 1: NEED FOR A BETTER UNDERSTANDING OF ADAPTATION AND SUCCESSFUL ADAPTATION

The first research gap relates to the conceptual discussion on the definition and dimensions of climate adaptation, which remains a topic of debate. Adaptation can be considered either a process or an outcome (Moser and Boykoff 2013; Dilling et al. 2019). There is also a debate about what progress, effectiveness, or success[1] in adaptation means, which are the better ways to assess it (Berrang-Ford et al. 2015; UNEP 2017; Christiansen et al. 2018; Dilling et al. 2019), and whether standardized or quantifiable indicators alone will help in this assessment (UNEP 2017; Dilling et al. 2019; Morecroft et al. 2019). An example of the difficulty in finding a common definition is the conclusion of the UNFCCC Adaptation Committee report (Adaptation Committee 2014, p. 4), which states that "success is context-specific and dynamic, i.e., it means different things at different levels and to different stakeholders," which is consistent with available research (Adger et al. 2005; Leiter 2015; Dilling et al. 2019).

The limited resources available for adaptation action need to be well invested. Therefore, the need to monitor and evaluate the progress has increased (Ford et al. 2013; GCA 2019; Ryan and Bustos 2019; New et al. 2022). In this context, monitoring and evaluation (M&E) of adaptation investments, identified as one of the four pillars of the iterative adaptation process, becomes more critical. Monitoring refers to tracking progress in implementing adaptation, while evaluation refers to determining the effectiveness of adaptation actions (Adaptation Committee 2014; UNFCCC-AC 2023). Learning is another recently highlighted component complementary to monitoring and evaluation activities, referred to as MEL. Taken together, MEL activities can create spaces for dialogue in which different perspectives and values are taken into account and, together with improving the effectiveness and efficiency of adaptation actions, help to avoid unintended negative consequences (i.e., maladaptation[2]) (Dilling et al. 2019; New et al. 2022).

Adaptation actions are embedded within the context of multi-level governance processes. While global or national policy agendas may provide guidance for adaptation, the implementation of adaptation options is typically conducted at the local level (Nalau et al. 2015). Consequently, the implementation and success of adaptation actions depend highly on site-specific conditions, including environmental and socioeconomic factors. As a result of these complexities, the majority of M&E efforts have concentrated on the community, project, program, or sector level (Leiter et al. 2019), with some examples pertaining to outputs at the national level (e.g., Ford et al. 2015; Lesnikowski et al. 2015; UNFCCC 2015; Berrang-Ford et al. 2019; Leiter 2021). However, the discrepancy between local and national

[1] Success or successful adaptation, in this dissertation, are used as synonym of effective adaptation.

[2] Maladaptation: "action taken ostensibly to avoid or reduce vulnerability to climate change that impacts adversely on, or increases the vulnerability of, other systems, sectors or social groups" in Barnett and O'Neill 2013 in (Atteridge and Remling 2018).

M&E systems precludes the aggregation of information for incorporation into global assessment processes, such as the GST (Leiter et al. 2019).

RESEARCH GAP 2: LIMITED EVIDENCE ON THE EFFECTIVENESS AND IMPLEMENTATION OF CLIMATE ADAPTATION OPTIONS USING LOCAL KNOWLEDGE AND EXPERTISE

The second research gap pertains to the necessity for more evidence that includes local knowledge and expertise. Significant progress has been made in the generation of global assessments of the progress of adaptation policies and their implementation (e.g., IPCC 2022; UNEP 2023). However, a significant limitation of these global assessments is that they remain predominantly anchored in scientific, peer-reviewed literature, where there is still a notable imbalance in the representation of Global South regions and communities (Nalau and Verrall 2021; Sietsma et al. 2021). Moreover, the assessments and the information on which they are based frequently exclude traditional, local, and Indigenous Knowledge (IK), which are vital for a comprehensive understanding of climate change impacts, adaptation strategies, and MEL processes (IPCC et al. 2019; New et al. 2022). Such forms of knowledge can, for instance, serve to reinforce scientific data and information concerning the impacts, values, solutions, and feasible adaptation options (New et al. 2022). Nevertheless, despite the significance of these forms of knowledge, they have historically been excluded from the field (Cundill et al. 2024). Therefore, diverse voices and knowledge systems from Global South regions and indigenous communities must be incorporated into the scientific literature and assessment processes to ensure a more comprehensive and accurate evaluation of climate change impacts and adaptation strategies worldwide. Furthermore, robust participatory processes and the examination of the interactions between the stakeholders at various levels of governance may facilitate the enhancement of equity, adaptive capacities, design, implementation, and effectiveness in adaptation action (Nalau et al. 2015; Castellanos et al. 2022).

To improve the quality of assessments and the representation of underrepresented and vulnerable groups in the literature on climate adaptation, it is crucial to employ participatory and mixed frameworks[3] (i.e., a combination of qualitative and quantitative approaches) for evaluating local adaptation progress. These approaches allow for a more comprehensive understanding of adaptation progress, particularly in the context of local climate action. For example, quantitative metrics can facilitate comparisons or aggregation efforts. However, there are constraints for the aggregation of information. Not all metrics can provide the same information and can not be used at all levels (Christiansen et al. 2018). Therefore, the latest literature calls for using mixed approaches, using qualitative methods to provide context-related information crucial for decision-making processes (UNFCCC-AC 2021). The utility of these two types of information for decision-makers depends on the specific objectives of the assessments in question.

RESEARCH GAP 3: THE NEED TO ADDRESS THE ADAPTATION IMPLEMENTATION GAP

The third research gap is linked to addressing the adaptation implementation gap. The most recent IPCC assessment cycle has revealed advancements in the domain of climate adaptation (de Coninck et al. 2018; IPCC 2022b). However, it also reveals a discrepancy between the planned or intended actions and measures for addressing the impacts of climate change and their actual implementation (IPCC 2022b, 2023; UNEP 2022). The discrepancy

[3] In this dissertation we understand "frameworks" as structured approaches that outline key concepts, processes, and methodologies to support climate adaptation research and action.

persists regardless of whether developing or developed countries (Bednar-Friedl et al. 2022; Castellanos et al. 2022; Trisos et al. 2022; Cabana et al. 2023). This situation is also reflected in the implementation of National Adaptation Plans (NAPs). For instance, as of August 2023, 46 developing countries have submitted their NAPs (UNFCCC 2023d), yet their implementation remains inadequate. One issue that has been identified is the necessity for plans to be translated into fundable and implementable projects (Trisos et al. 2022). Furthermore, Cabana et al. (2023) have identified that only 1% of the adaptation research relates to implementing adaptation actions in coastal areas. Additionally, the most recent Adaptation Gap Report (UNEP 2023) has indicated that information on the implementation of adaptation actions was provided for just 6% of the 670 actions identified, thereby highlighting an ongoing need for data on results beyond mere outputs to assess the effectiveness of these actions accurately.

Several frameworks have been developed to assess adaptation effectiveness, adaptation readiness, and the analysis of barriers and enablers to adaptation. One such framework is the feasibility assessment. The IPCC introduced the multidimensional feasibility assessment framework in its special report on the 1.5ºC of global warming (IPCC 2018). The framework is based on the "barriers" frame, which is comprehensible to policymakers and adaptation practitioners (Singh et al. 2020b). The objective of the feasibility assessment framework is to ascertain the viability of implementing a specific adaptation option or strategy (IPCC 2018). Nevertheless, the majority of previous efforts to assess the feasibility of adaptation strategies have been based on scientific literature (de Coninck et al. 2018; Singh et al. 2020a; Williams et al. 2021). Moreover, merely assessing an option as feasible does not guarantee its implementation. Additional considerations must be considered, such as institutional support, technical capacity, and financial resources (New et al. 2022).

To address the gap in the implementation of adaptation strategies, it is essential to align policies, secure funding, build technical capacity, engage stakeholders, and ensure the successful execution of planned actions. Adaptive management, which encompasses monitoring, evaluation, and learning strategies, is crucial for making necessary adjustments during implementation to guarantee the effectiveness of climate adaptation measures and their contribution to the development of resilience against the impacts of climate change (New et al. 2022). The implementation of adaptation actions may also be hindered by the lengthy process of securing financial resources, even when such resources are available or committed. As an illustration, there are instances where projects approved by the Green Climate Fund (GCF) have required more than four years to start the implementation phase (GCF 2024a).

In light of the considerations presented above, this dissertation seeks to examine the theoretical and empirical complexities, feasibility, and implementation of adaptation. To this end, the dissertation examines the definitions of adaptation and successful adaptation. Furthermore, it develops an advancement of the adaptation feasibility assessment for application at the local level. Moreover, this research investigates the connections between implementation science and climate adaptation, a nascent field of study that has the potential to facilitate the implementation of (successful) adaptation action. As a result of this investigation, we propose the Framework for Implementing Climate Adaptation (FICA) as a tool to facilitate efforts related to the assessment of the implementation of adaptation.

1.2 Research Aim, Research Questions and Objectives

Considering the context mentioned above and the identified research gaps, the overarching objective of this research is to ***identify ways for enhancing the implementation and assessment of progress on climate adaptation.*** To address this objective, the research questions addressed in this dissertation are as follows:

RQ1. What constitutes climate change adaptation, and what defines its success?

RQ2. What criteria and indicators could support the evaluation of adaptation at the local level?

RQ3. What methodologies can be employed to generate evidence of climate adaptation at the local levels, and how can local and scientific knowledge be integrated to facilitate the implementation and evaluation of adaptation?

RQ4. What are the main factors that contribute to the gap between planned adaptation interventions and their effective implementation?

In order to respond to the aforementioned research questions, the following objectives were established:

RO1. Provide guidance on the aspects of the definition of adaptation and successful adaptation to foster their general operability and use in adaptation success assessment.

RO2. Identify criteria and indicators that could support efforts to aggregate information on adaptation progress, for example, in the context of the GST.

RO3. Develop and apply an advanced feasibility assessment framework at the local level while gathering evidence to inform assessment efforts at higher levels of governance.

RO4. Propose an integrative framework for enhancing the implementation and assessment of adaptation actions.

1.3 Research Approach

To fulfill this research's overarching objective and specific research objectives, the work is structured in three research chapters (Chapters II to IV) and one synthesis chapter (Chapter V). **Table I-1**presents the contribution of the research chapters to this study's research questions and objectives.

Table I-1 *Overview of research questions, objective, and chapters*

	Research Objective / Research Question	***CHII***	***CHIII***	***CHIV***
Research questions	**RQ1**. What constitutes climate change adaptation, and what defines its success?	x		x
	RQ2. What criteria and indicators could support the evaluation of adaptation at the local level?	x		x
	RQ3. What methodologies can be employed to generate evidence of climate adaptation at the local levels, and how can local and scientific knowledge be integrated to facilitate the implementation and evaluation of adaptation?		x	x
	RQ4. What are the main factors that contribute to the gap between planned adaptation interventions and their effective implementation?			x
Research	**RO1.** Provide guidance on the aspects of the definition of adaptation and successful adaptation to foster their general operability and use in adaptation success assessment.	x		

	Research Objective / Research Question	*CHII*	*CHIII*	*CHIV*
	RO2. Identify criteria and indicators that could support efforts to aggregate information on adaptation progress, for example, in the context of the GST.	x		x
	RO3. Develop and apply an advanced feasibility assessment framework at the local level while gathering evidence to inform assessment efforts at higher levels of governance.		x	
	RO4. Propose an integrative framework for enhancing the implementation and assessment of adaptation actions.			x

In summary, the components of this dissertation are designed to contribute to enhancing elements of the Iterative Adaptation Process (IAP) (UNFCCC-AC 2023), which is analogous to the Iterative Climate Risk Management (ICRM) decision-making process (New et al. 2022) (**Figure I-1**). Chapter II provides a direct contribution to assessing impacts, vulnerabilities, risk, and resilience, which collectively inform the question of what to adapt to. Chapter III presents an advancement of the feasibility framework for the adequate selection of adaptation options as the basis for adaptation planning. Finally, Chapter IV supports all the steps of the IAP, focusing on implementation.

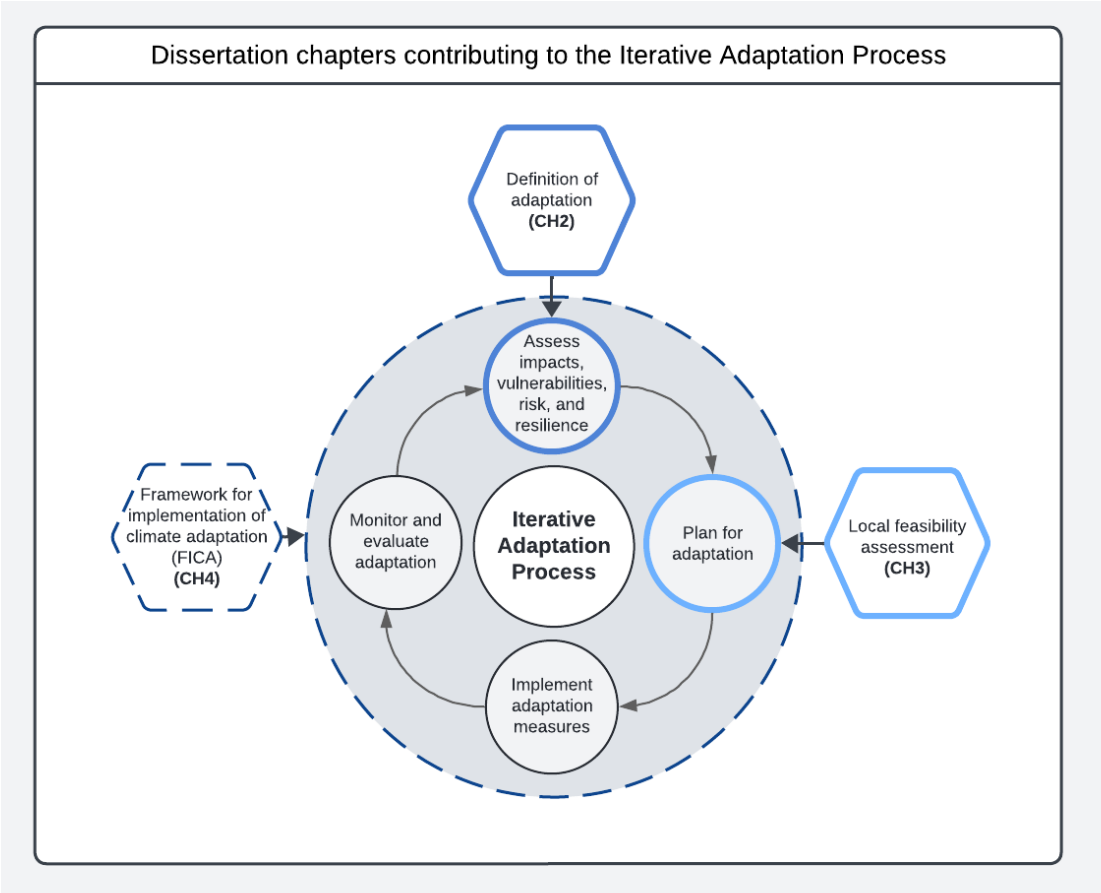


Figure I-1 *Dissertation chapters contributing to the IAP (based on UNFCCC-AC 2023) - Chapter IV contributes to all the steps, with a particular focus on implementation (identified by dotted lines).*

1.4 Chapters Overview

This dissertation is comprised of three main chapters. The following section provides a summary of each chapter, including a description of the research questions, objectives, and methods employed. Chapter V presents the overall findings and conclusions of this research project.

1.4.1 Chapter II: "Climate Adaptation and Successful Adaptation Definitions: Latin American Perspectives Using the Delphi Method"

Despite the urgent need to adapt to observed climatic changes and their implications for the natural and human environment, there is still a lack of consensus on what should be considered climate adaptation. Furthermore, there is no consensus on a definition that could be used to evaluate what constitutes successful adaptation. One of the most significant challenges in adaptation is the context-specific nature of adaptation, whereby progress or successful adaptation recognized by one community may not be acknowledged in the same way by another. Accordingly, Chapter II

offer the perspectives of experts concerning the definitions of adaptation given by the Intergovernmental Panel on Climate Change (IPCC) and the definition of successful adaptation proposed by Doria et al. (2009), with a particular emphasis in Latin America.

The Delphi method was employed to identify pertinent knowledge and perspectives on the adaptation discourse. Furthermore, the research offers a list of criteria and indicators that could enhance the assessment of climate adaptation options at various management levels and facilitate the aggregation of information on adaptation progress.

1.4.2 Chapter III: "Assessing the Feasibility of Climate Adaptation Options using Local Expertise and Participatory Approaches: The Case of Puerto Morazán, Nicaragua"

Adaptation options are being implemented globally to reduce current and projected climate change impacts. Nevertheless, further information is required on the assessments of the array of options available, including their feasibility. One of the primary constraints is that current feasibility assessments are grounded in scientific literature, where adaptation research and practice in the Global South are acknowledged to be underrepresented. Furthermore, while research conducted by those directly involved in implementation (i.e., practitioners) is of considerable value (Boyer et al. 2020; New et al. 2022), it remains marginalized in scientific publications. For this reason, using Puerto Morazán in Nicaragua as a case study area, Chapter III

proposes a methodological advancement of the IPCC's feasibility framework by integrating local knowledge and expertise.

The proposal examines the extent to which the results of the adaptation feasibility assessment may vary when considering the local priorities. The proposal aims to address the limitations of the existing literature on national and local levels by employing three main methods: literature review and desktop analysis, a participatory integrative modeling technique, and expert knowledge elicitation.

1.4.3 Chapter IV: "The Framework for Implementing Climate Adaptation (FICA): a Framework for Analyzing Adaptation Project Realities – An Exploration of GCF Adaptation Projects"

Recent reports have indicated advancements in climate adaptation, as evidenced by the findings of the UNEP (2023). Nevertheless, a gap between planned and implemented steps of adaptation persists. To address the implementation gap, it is necessary to implement

adaptive management strategies that are capable of continuously assessing progress, identifying gaps, and making the required adjustments to ensure that climate adaptation measures are effectively implemented and contribute to building resilience against the impacts of climate change (New et al. 2022).

Implementation science originated in the health sector, is defined as "the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, and, hence, to improve the quality and effectiveness of health services (Bauer et al. 2015, p. 3)." A core concept in the field of implementation science, particularly relevant to climate adaptation processes, is that the optimal benefits of innovation rely on successful implementation as a prerequisite (Damschroder et al. 2022). Nevertheless, despite the potential for synergies, there has been a paucity of research connecting implementation science and climate adaptation. Implementation science could play a valuable role in providing a systematic and evidence-based approach to monitor and evaluate the implementation of adaptation strategies and interventions. Therefore, Chapter IV

investigates the connections between implementation science and climate adaptation and proposes the Framework for Implementing Climate Adaptation (FICA) to foster the implementation of adaptation.

The FICA provides insights into how implementation science can be integrated into the IAP and applied to adaptation-related options or strategies in general. The framework was developed by synthesizing two primary methods: literature review and interviews. Chapter IV illustrates how implementation science can be applied to adaptation-related options or strategies, focusing on Green Climate Fund (GCF) adaptation projects.

1.5 Case Studies

To fulfill the objectives defined for this dissertation and to illustrate the proposed scientific advancements, the work concentrates on two main groups of countries or regions: Latin America and the Caribbean (LAC) and the African Least Developed Countries (Af-LDCs) (***Figure I-2***). The two country groups were utilized as the foundation for examining GCF adaptation initiatives to elucidate the interconnections between implementation science and climate adaptation.

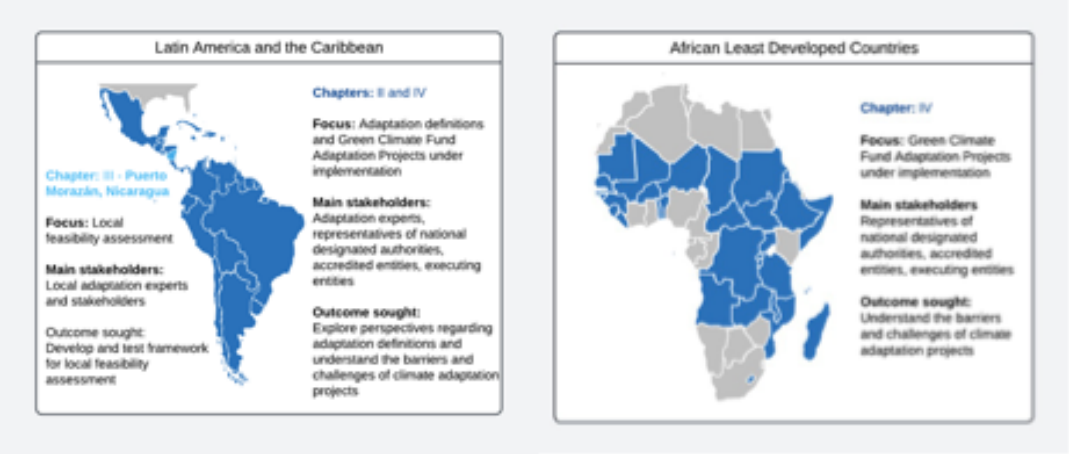


Figure I-2 *Case studies regions of this research*[4]

[4] The borders and geographical representations depicted on this map are not guaranteed to be accurate. They do not reflect official endorsements or recognition of territorial boundaries.

1.5.1 Latin American and the Caribbean Region

Latin America and the Caribbean (LAC) is related to Chapters II and IV. Despite its minimal contributions to climate change, the LAC region is among the most adversely affected. Substantial evidence indicates constraints and limits to adaptation in all regional sectors (Castellanos et al. 2022). Concurrently, the region receives a relatively modest allocation of the global climate finance. Furthermore, most financial resources are allocated to mitigation efforts (UNFCCC 2018b; Schalatek and Watson 2020; New et al. 2022; GFLAC 2023). In its most recent assessment cycle, the IPCC has also identified research gaps related to the impacts and the adaptation options implemented in the region. Additionally, M&E frameworks in the region are constrained to climate impact drivers, excluding social and economic aspects that may influence the effectiveness of adaptation measures (Castellanos et al. 2022; Pörtner et al. 2022b).

Puerto Morazán, Nicaragua

Puerto Morazán is used as the case study related to Chapter III. The municipality is situated northwest of Nicaragua, within the Central American Dry Corridor (CADC). The territories comprising the corridor are already exhibiting warming and drying trends. Consequently, aridity and agricultural and ecological drought are becoming more prevalent. Mean annual and summer precipitation are likely to decrease. However, there is uncertainty regarding the magnitude of the changes (Hidalgo et al. 2019; Arias et al. 2021; Depsky and Pons 2021; Stewart et al. 2022). The increasing frequency and magnitude of droughts may indicate that the limits of adaptation have been reached (Depsky and Pons 2021; Hagen et al. 2022). The economy of Puerto Morazán is heavily reliant on sectors that are sensitive to climate change, particularly agriculture (which is mainly rainfed subsistence farming), livestock, fisheries, and aquaculture. Adaptation options have been identified in local and sub-national adaptation plans (Cárdenas 2014; MARENA 2015). However, their implementation has been minimal. This case study was used to test the proposed advancement of the feasibility adaptation framework based on local knowledge and expertise (Chapter III).

1.5.2 African Least Developed Countries

The study presented in Chapter IV is developed using two groups of countries: African least developed countries and other countries. Least Developed Countries (LDCs) are defined by the United Nations as countries with "low levels of income and face severe structural impediments to sustainable development" (UN 2024). The effects of climate change are already being observed in the development trajectories and economic opportunities of LDCs. Adaptation represents a pivotal concern for LDCs, yet adaptation finance only accounts for 45% of the total climate finance disbursed (UNCTAD 2023). 30% of the total GCF portfolio is for LDC countries (GCF 2024b).

A total of 33 countries in Africa are currently classified as LDCs. African LDCs are particularly vulnerable to the adverse effects of climate change due to their limited adaptive capacities, constrained financial resources, and reliance on climate-sensitive sectors such as agriculture. These countries encounter considerable obstacles in the implementation of effective climate adaptation strategies. The confluence of poverty, political instability, and underdeveloped infrastructure exacerbate their susceptibility to climate-induced risks, including droughts, floods, and extreme weather events (Trisos et al. 2022).

Chapter II. "Climate Adaptation and Successful Adaptation Definitions: Latin American Perspectives Using the Delphi Method"

sustainability

IMPACT FACTOR 3.3

CITESCORE 6.8

Article

Climate Adaptation and Successful Adaptation Definitions: Latin American Perspectives Using the Delphi Method

Tania Guillén Bolaños, Jürgen Scheffran and María Máñez Costa

Special Issue

Methods and Approaches for Coproduction of Knowledge in Climate Change Adaptation Research

Edited by
Dr. Halvor Dannevig

MDPI

https://doi.org/10.3390/su14095350

sustainability

MDPI

Article

Climate Adaptation and Successful Adaptation Definitions: Latin American Perspectives Using the Delphi Method

Tania Guillén Bolaños [1,2,*], Jürgen Scheffran [2] and María Máñez Costa [1]

[1] Climate Service Center Germany (GERICS), Helmholtz-Zentrum Hereon, Fischertwiete 1, 20095 Hamburg, Germany; maria.manez@hereon.de
[2] Research Group Climate Change and Security, Institute of Geography, University of Hamburg, 20144 Hamburg, Germany; juergen.scheffran@uni-hamburg.de
* Correspondence: tania.guillen@hereon.de; Tel.: +49-40-226338-444

Abstract: Across the world, policies and measures are being developed and implemented to reduce the risks of climate change and adapt to its current and projected adverse effects. The Paris Agreement established the global stocktake to evaluate the collective progress made on adaptation. Nevertheless, various challenges still exist when evaluating adaptation progress, among which is the lack of standard definitions to support evaluation efforts. Therefore, we investigated the views of experts regarding the definitions of adaptation given by the Intergovernmental Panel on Climate Change (IPCC) and the definition of successful adaptation by Doria et al., with a focus on Latin America. Using the Delphi method, we obtained relevant knowledge and perspectives. As a result, we identified a high level of consensus (85%) among the experts regarding the IPCC's definition of climate adaptation. However, there was no consensus on the definition of successful adaptation. For both definitions, we present the elements on which the experts agreed and disagreed, as well as the proposed elements that could improve the definitions to support adaptation evaluation efforts. Additionally, we introduce a list of criteria and indicators that could improve the evaluation of adaptation at different management levels and facilitate the aggregation of information on adaptation progress.

Keywords: adaptation; successful adaptation; monitoring and evaluation; Latin America; Delphi method; knowledge co-production

check for updates

Citation: Guillén Bolaños, T.; Scheffran, J.; Máñez Costa, M. Climate Adaptation and Successful Adaptation Definitions: Latin American Perspectives Using the Delphi Method. *Sustainability* **2022**, *14*, 5350. https://doi.org/10.3390/su14095350

Academic Editor: Brent Jacobs

Received: 6 February 2022
Accepted: 20 April 2022
Published: 29 April 2022

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Currently, natural and human systems are experiencing the adverse effects of more than 1 °C of mean global warming compared to pre-industrial levels [1,2]. Therefore, there is a need for ecosystems and societies to adapt to the changing climate conditions. Policies and measures to adapt to and reduce climate-change-imposed risks are therefore being developed and implemented at different scales and in different settings across the globe [3–5]. However, due to the inherent complexities of adaptation, it is not easy to assess whether the climate adaptation measures implemented are actually helping ecosystems and societies to adapt successfully. Context-specificity, meaning that what is identified as progress or successful adaptation by one community may not be recognized as such by another, is one of the key adaptation complexities involved [4–15].

Acknowledging such complexities, an important prerequisite to conducting a meaningful assessment of adaptation success is to have a sound understanding of what adaptation means. The IPCC's Working Group II [16] (p. 118) is the most commonly cited definition of climate 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"*. In the realm of successful adaptation an example is given by Doria et al. [17] (p. 817): *"successful adaptation is any adjustment that reduces the risks associated with climate*

change, or vulnerability to climate change impacts, to a predetermined level, without compromising economic, social, and environmental sustainability".

Despite these and other academic efforts to define climate adaptation (e.g., [16,18]) and successful adaptation (e.g., [5,9,17]), the literature still shows a limited understanding of both. For instance, scholars identify the IPCC's definition of adaptation as being not "operational", since it does not include specific elements that would allow measuring the progress obtained through adaptation measures [17,19–21]. Similarly, to the discussion on a standard definition for adaptation, the issue of successful adaptation has also been identified as an adaptation research priority [13,22,23].

Current climate adaptation research is even more limited for the case of vulnerable regions in the Global South [24,25]. One of these regions is Latin America [2,24–26], which has been identified as "highly exposed, vulnerable and strongly impacted by climate change" [25], with the level of implementation of adaptation lagging behind the actual needs [25,27,28]. Equally, there are insufficient financial resources [27,28], as well as scarce information on the feasibility, and monitoring and evaluation (M&E) of adaptation options in the region [25,26,29]. Overcoming these informational and financial limits is essential for the adequate funding and implementation of adaptation priorities [30].

Moreover, it is crucial to note that the scope of the adaptation policies and monitoring and evaluation frameworks used in Latin America is limited to climate impact drivers, excluding social and economic aspects that influence the effectiveness of adaptation measures [25,31]. Among the barriers limiting adaptation policy monitoring and assessment in the region are the lack of a clear delimitation of adaptation policies, the lack of indicators to assess the effectiveness of adaptation measures, and the lack of mechanisms with which to track adaptation [29].

The limitations on monitoring and evaluation in Latin America fall short of the ambitions for adaptation set at the global policy level. The global stocktake (GST) and global goal on adaptation (GGA) were established by the Paris Agreement within the United Nations Framework Convention on Climate Change (UNFCCC). The GST serves as the overarching mechanism with which to assess collective progress on mitigation, adaptation, and climate finance based on national reporting instruments. As part of the GST and in the realm of adaptation, the GGA includes a reduction in vulnerability, increase in resilience, and increase in adaptive capacities [32].

However, most of the literature on the implementation and progress of adaptation is related to measures implemented at the local level. This and the circumstances of adaptation as they are at present, for example, in Latin America, present challenges at other levels of management in terms of data availability and comparable and meaningful indicators or proxies to measure adaptation, especially from the local to the global scale [20].

The first GST is planned for 2023, and it will also review the overall progress made concerning the GGA [32]. However, how can the impact of adaptation policies and interventions be measured or assessed if we do not have a common definition of adaptation or what successful adaptation entails? Moreover, how can we use information produced at local or subnational levels at the international (aggregated) level to inform the GST?

To contribute to the establishment of definitions of climate adaptation and successful adaptation, especially one that is applicable to different contexts and local specificities across the globe, it is pivotal that different perspectives be taken into account [6]. Therefore, we investigated the views of Latin American experts on the definition of adaptation according to the IPCC [16], as well as those on the definition of successful adaptation developed by Doria et al. [17].

We used the Delphi method, a "group facilitation technique", which utilizes an iterative, multistage process, to transform opinion into group consensus [33] (p. 1008). The method has been used in a wide range of sectors and for multiple objectives, including for aspects relating to climate change adaptation (e.g., [17,34–38]). The method has already been applied by Doria et al. [17] in their development of their own definition of successful adaptation. The Delphi method allowed us to identify the perspectives obtained from

a heterogeneous panel of Latin American adaptation experts. The method facilitated a co-production process between the researchers and experts by identifying elements of agreement and disagreement. In this way, this method also facilitated the identification of ways to improve the existing definitions. Additionally, the method let us identify a list of criteria and indicators that could be used for aggregating information on adaptation from the local level to the global level to inform the GST.

With our work, we aim to provide guidance on (1) the aspects of definitions of adaptation and successful adaptation to foster their general operability and their use in adaptation success assessment, and (2) criteria and indicators that could support efforts to aggregate information on adaptation progress, for example, in the frame of the GST. To strengthen the respective research focusing on the Global South we apply our efforts to the case of Latin America.

2. Why Are Definitions for Climate Adaptation Important?

Definitions aim to establish and clarify what a word entails. They help to avoid ambivalences or ambiguities. Bassett and Folgemann [39] (p. 51) highlight that "how we think and talk about adaptation matters in current and future debates on transformative climate action". Until recently, adaptation to climate change was considered a nascent policy and research field [40–42]. However, new literature shows that climate adaptation research is rapidly increasing in volume and diversifying [24,43,44]. Moreover, following the establishment of the GST, research related to adaptation assessment has gained prominence.

Nevertheless, the definition of climate adaptation and, more importantly, what is considered successful adaptation, remains a challenge. Moreover, the usefulness of a definition of successful adaptation is being debated (e.g., [14]). Questions remain about what it is necessary to evaluate (what is adaptation?) [39,45–47] and what we can classify as progress or success (what is successful adaptation?) [9,13,30,48–50].

Recent literature speaks of climate adaptation as a public good [9], as a public goal [51], and as an investment [13]. Moreover, is seen as a process, an adjustment, or an outcome [50,52]. All those perspectives highlight the need to evaluate adaptation measures, especially in light of the limited financial resources available, the global policies in place, and the risk of maladaptation [3,30,50,53,54]. The questions regarding the definition of adaptation and successful adaptation are relevant to all levels where the planning, design, and implementation of adaptation take place. However, there might be "no easy or political answers" [9] (p.1), underpinning the need for a profound scientific understanding of what adaptation and its success entail.

As part of a wider debate, there are discussions on the need to differentiate adaptation from development [19,55,56], as well as discussions about whether adaptation outcomes should be additional or complementary to those obtained from development interventions alone [19,54].

According to Moser and Boykoff [9], investigating successful adaptation achieves the following goals: communication and public engagement, deliberate planning and decision-making, improved fit with other policy goals, justification of adaptation expenditures, improved accountability, and support for learning and adaptive management.

Regarding the assessment of adaptation measures and the aggregation of relevant information, the UNFCCC guides policies and actions undertaken at different management levels. In this regard, Magnan and Ribera [45] (p. 1282) find it "crucial to overcome the intuitive and subjective understanding of adaptation". The establishment of the GST as part of the Paris Agreement reflects and responds to the need for a better overview of how well or how successfully we adapt to climate change. However, how do we arrive at a reliable overview? Magnan [57] indicates the need to develop metrics, which must comply with two characteristics: the consideration of context-dependent aspects ("national circumstances") and allowing for the aggregation of information from the local through to the global level.

The UNFCCC already recognizes the multiple dimensions where adaptation actions or interventions take place [32]. Despite this, much of the literature describes adaptation as a "local" issue [44]. As a result, monitoring and evaluation (M&E) frameworks are mainly developed for use at the local level (e.g., for a community or project/program) [58]. Likewise, the GST's evaluation of adaptation progress is based on national assessments, and accordingly most efforts to inform the GST focus on the national level (e.g., [59–63]). However, adaptation and reporting on adaptation progress also need to be considered as part of broader subnational, national, regional, and global mechanisms, such as the GST [64] (see Figure 1). Nevertheless, there are also limits to an aggregated view of adaptation, as not all metrics can be used at all levels [19].

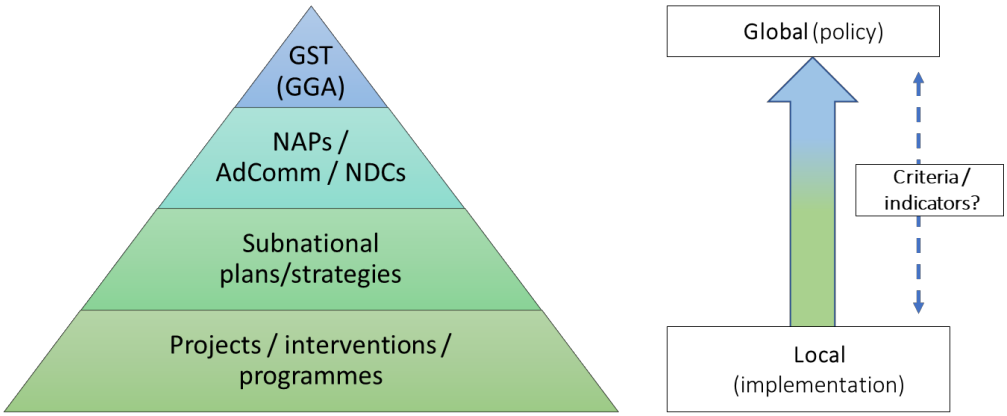


Figure 1. Aggregation of information on adaptation progress (GST: global stocktake; GGA: global goal on adaptation; NAPs: national adaptation plans; AdComm: adaptation communications; NDCs: national determined contributions).

In addition to the disconnection between the levels where adaptation policies are developed and actions implemented, most M&E frameworks developed for adaptation focus on providing accountability. This approach aligns with the need to guarantee that the limited resources available for adaptation are invested efficiently [65]. However, it does not provide guidance on, for example, the goals of vulnerability reduction or how to increase resilience [54,66]. Policymakers and practitioners face this type of challenge when evaluating and aggregating information on adaptation progress, together with those related to context, definitions chosen, and the availability of information [49,67,68].

3. Methodology

3.1. The Delphi Method

The Delphi method is a versatile and valuable social research technique [33,69,70]. The key characteristics of the Delphi method are that it is an iterative process between rounds of questionnaires that guarantees anonymity, has controlled feedback, and provides a statistical response [70,71].

The development of a Delphi exercise does not require face-to-face meetings. Instead, it allows reaching consensus through rounds of questionnaires, which are later analyzed and fed back to the panel members (experts) [33,70]. Each round of questionnaire answers serves as the basis for the next. As a result, direct interaction between experts is limited. This last aspect has been identified as a limitation of the method, as limited interactions could also imply that meaningful exchange within the expert group is absent from the process [72]. Nevertheless, this method allows the identification of the elements of agreement, level of consensus, and hierarchization among the different aspects that a group of experts evaluates.

The anonymity allowed by the Delphi method helps with the co-production of knowledge by avoiding issues of power and prestige between the experts, which could affect the co-production process [73]. The questionnaire and reports summarize the information and

arguments given by the experts. It is necessary for the coordinating team to have strong abilities to analyze and extract the views from the experts [33].

Another characteristic of the Delphi method is that it does not rely on a random or representative sample. Thus, the results obtained through the method represent only the professional opinion of those experts who participate in the exercise [74]. Additionally, reaching consensus might not necessarily mean that the correct answer has been found [74,75]. However, the results obtained can be used to further deepen the debate around the issue under study [33].

3.2. Implementation Framework

Based on the information presented previously, this section describes the process and steps we followed to implement the Delphi method in our research. Figure 2 summarizes the actions taken by the researchers (left) and the actions taken by the members of the panel of experts (right). The black and blue arrows represent their interactions.

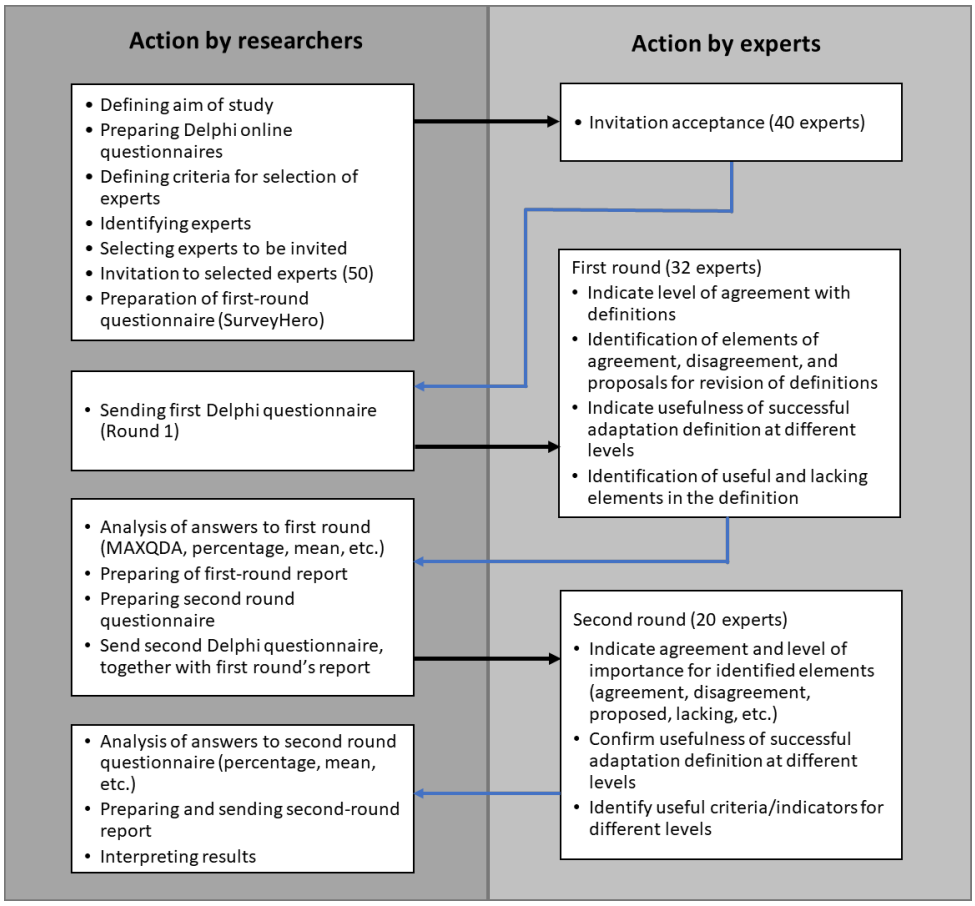


Figure 2. Summary of the steps, methods, and measures taken (adapted from [36]).

3.2.1. Selection of Experts and Communication

Experts are "informed individuals" and "specialists in their field" [74] (p. 196). Considering that adaptation policies and implementation are developed at different scales and by different actors [5,76], we aimed to gather different perspectives on definitions of adaptation and successful adaptation from a heterogeneous panel of Latin American climate adaptation experts.

We identified a pool of 77 professionals working in academia, non-governmental organizations, and governmental dependencies designing and implementing adaptation actions. A total of 50 out of the 77 identified professionals were invited by e-mail to participate in the panel as experts. Out of the 50 invitees, 40 experts (80%) accepted the invitation. The selection was based on the experts' publications, known experience, and

professional networks. Of the 40 invited, 32 participated in the first round and 20 in the second. This decrease in the experts' participation between both rounds is reported as a common situation in Delphi exercises (e.g., [17,71,74,77]).

After the selection, the facilitator contacted the experts via e-mail. That first contact included an introduction to the aims of this work and the Delphi method.

The invitation also included the estimated time taken to answer the online questionnaires and how often the researchers would contact them. Finally, we offered a meeting to clarify any questions or doubts concerning the goals and methods used. Once the experts confirmed their interest in participating, an e-mail containing the link to the questionnaire was sent. In addition, the facilitator sent reminders prior to the questionnaires' deadlines.

3.2.2. Profile of Members of the Panel of Experts

The researchers aimed to assemble a heterogeneous panel of Latin American experts to collect governmental, non-governmental, and academic perspectives. Table 1 and Figure 3 confirm that that objective was achieved. The majority of the experts resided in Colombia, Guatemala, Uruguay, and Mexico.

Table 1. Adaptation experts' profiles.

	Gender (%)		Years of Experience (%)				Type of Organization * (%)					Current Professional Role + (%)				Professional Background # (%)			
	F	M	0–4	5–9	10–14	>15	G	A/R	D	NGO	C	R	P	C	O	ES	AS	SS	E&S
Round 1 (n = 32)	53	47	9	22	31	38	28	25	22	22	3	38	25	22	19	41	16	37	6
Round 2 (n = 20)	50	50	5	20	35	40	30	30	15	20	5	45	15	20	20	50	20	30	0

* (G) Governmental; (A/R) Academia/Research; (D) Development aid; (NGO) Non-governmental; (C) Consultancy. + (R) Researcher; (P) Policy-maker; (C) Consultant/governmental advisor; (O) Other. # (ES) Environmental/natural sciences; (AS) Applied sciences; (SS) Social sciences; (E&S) Environmental and social sciences.

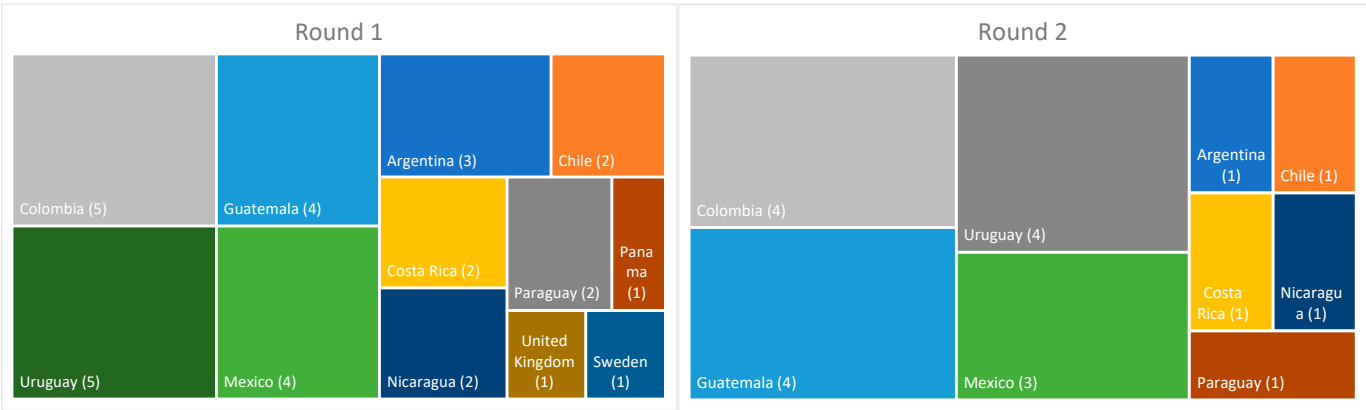


Figure 3. Adaptation experts' country of residence.

Table 1 provides an overview of the experts' gender, years of experience, type of organization where the experts acquired most of their experience in adaptation, current professional role, and professional background. In terms of gender, the participation of women and men was balanced in the two rounds. A significant number of the experts had long-standing (>10 years) adaptation-related professional experience (69% and 75% for the first and second rounds, respectively). In terms of the type of institution/organization in which they had spent most of their adaptation-related career, the results were also well distributed between government (G), academia/research (A/R), development aid (D) organizations, and non-governmental organizations (NGOs). In terms of their current role, most experts identified themselves as researchers (38% and 45% in each round), followed by policymakers (25%, 15%) and consultants (22%, 20%). In addition, the experts identified other professional roles (19%, 20%), such as director, manager, independent consultant, specialist, and professor. Most experts had backgrounds in environmental or

natural sciences (41%, 50%), followed by social sciences (37%, 30%) and applied sciences (16%, 20%). Only 6% of the experts included in the first round indicated that they had a background in environmental and social sciences.

3.2.3. Questionnaires

In this exercise, we performed two rounds of online questionnaires. We developed and shared the online questionnaires using Survey Hero (https://www.surveyhero.com/). Together with sharing and collecting the information, the tool calculated the arithmetic average, mean and standard deviation, and weighting (where appropriate).

Following the Delphi method (Section 3.1), the first questionnaire primarily consisted of open-ended questions to allow experts to have freedom in their responses and allow us to obtain individual perspectives, which should be the basis of the following questionnaire. The second questionnaire was mainly made up of closed questions.

To obtain information on both definitions being studied and provide guidance on the aspects that could be improved, the questionnaires included information about the study's aim, a summary of the Delphi method, and additional background information. The questions were organized into three main sections: (A) adaptation definition, (B) successful adaptation definition, and (C) elements for operationalizing the definition of successful adaptation. Sections A and B included questions on the overall level of agreement, the elements of the definitions under study that the experts agreed and disagreed with, and additional elements that could be considered to improve the definitions. We also included a question on the need for definitions specific to each management level. Section C included questions on the operationalization of the definition of successful adaptation. Here, the experts could identify useful and missing elements in the definition that could support the evaluation of adaptation at different management levels. Finally, the first questionnaire included an additional section (D) relating to the experts' background information.

The second questionnaire was prepared based on the answers to the first questionnaire [33,70]. First, we analyzed the answers (including the frequencies, means and standard deviations, where appropriate). Afterwards, we grouped similar items. In this case, we listed all the elements identified by the experts in each question. Based on that, the experts confirmed their agreement or disagreement with the listed elements. Additionally, they identified the degree of importance for improving the definitions or the usefulness of those elements. Experts could identify more than one aspect that they agreed or disagreed with. Furthermore, each section had an additional field where the experts could share further comments.

In both questionnaires, Likert-type scale questions were included to identify and verify their level of agreement with both definitions (total disagreement to total agreement). The average agreement included a scale of 3 (−/+). We calculated the level of consensus considering the answers given as "agree and totally agree" scales (scales 4 and 5). To avoid misunderstandings, in this work the percentage symbol (%) included in the results refers to the number of experts answering a question or indicating their agreement/disagreement. Weights on importance or usefulness are reported as a fraction of 1 (0 not important or not useful/1 very important or very useful). The weights included in this work represent the average weight for each element, as indicated by the experts.

In terms of time, the experts had at least one month to answer and complete the questionnaires. After the analysis, we prepared and shared a report presenting the answers and arguments for each questionnaire round. The questionnaires were developed in Spanish and implemented between September 2020 and March 2021.

3.2.4. Qualitative Analysis

We based our analysis on the information provided by the experts in the first questionnaire. In addition, we developed a category system using inductive category formation (categories based on the data) [78], which allowed us to identify the elements of the def-

initions under analysis with which the experts agreed or disagreed. We also used this approach to identify elements proposed to improve the definitions.

Once the category system was developed, we extracted and analyzed information about the frequency of the different elements. That information served as the basis with which to develop the list of elements provided in the second questionnaire, in which the experts could identify their agreement or disagreement.

The researchers used the MAXQDA software to qualitatively analyze the answers given in the open-ended questions in the first questionnaire.

3.2.5. Consensus with the Definitions

The Delphi exercises stop once a predetermined level of consensus is reached. To define the experts' level of consensus with the definitions under study, we followed the limit used by Doria et al. [17] (>80%).

Therefore, this exercise stopped after the second questionnaire, as the level of agreement with the definition of adaptation reached 85%. However, as we were not proposing a new definition of successful adaptation, we also decided to stop the exercise with an agreement level of only 50%. While the level of agreement with the definition of successful adaptation was lower than the >80% defined by Doria et al. [17], the authors considered it a stable response (compared to the 53% obtained in the first questionnaire). Stable responses could be a "more reliable indicator of consensus" [33] (p. 1011). This low level of agreement reflects the experts' different concerns about this definition.

4. Results

Below, we present the main results related to the revision of the definitions of adaptation together with those of successful adaptation. In a separate section, we present the results relating to the aggregation of information. Appendix A presents a summary of the results.

4.1. Perspectives on the Definitions

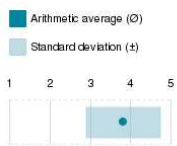
In this section, we present the results related to the level of agreement or consensus, the elements upon which the experts agreed, and those upon which they disagreed. Additionally, we list the elements identified by the experts which could be considered in future revisions of the definitions.

4.1.1. Consensus with the Definitions

We consulted with the experts regarding their level of agreement with the IPCC's [16] definition of adaptation. In both rounds, the level of agreement with the IPCC's definition was high (75% and 85% of the answers, respectively). Therefore, there was consensus among the experts (>80%) regarding this definition. The average agreement levels were 76% and 79% (Figure 4).

(**a**)

left	– – (1)		– (2)		–/+ (3)		+ (4)		++ (5)		right		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%		Ø	±
Total disagreement	1×	3.13	2×	6.25	5×	15.63	18×	56.25	6×	18.75	Total agreement	3.81	0.93



(**b**)

left	– – (1)		– (2)		–/+ (3)		+ (4)		++ (5)		right		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%		Ø	±
Total disagreement	1×	5.00	-	-	2×	10.00	13×	65.00	4×	20.00	Total agreement	3.95	0.89

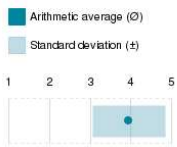


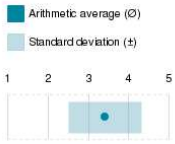
Figure 4. Agreement with the IPCC's [16] definition of climate adaptation: (**a**) first round, (**b**) second round (source: SurveyHero).

General comments on the definition of climate adaptation mentioned its complexity, which depends on different factors such as level of implementation, sector, and type of adaptation. Comments also highlighted that more than specific definitions, work on adaptation needs to be guided by general principles or criteria, allowing the alignment of actions with specific objectives.

Similarly, as for the definition of adaptation, experts identified their level of agreement with the definition of successful adaptation proposed by Doria et al. [17]. The experts agreed less with the definition of successful adaptation than with the presented definition of adaptation. After the two rounds, no consensus was reached. The levels of agreement were 53% and 50%. The average levels of agreement were 68% and 70% for each round, respectively (Figure 5).

(**a**)

left	– – (1)		– (2)		–/+ (3)		+ (4)		++ (5)		right		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%		Ø	±
Total disagreement	1×	3.13	4×	12.50	10×	31.25	15×	46.88	2×	6.25	Total agreement	3.41	0.91



(**b**)

left	– – (1)		– (2)		–/+ (3)		+ (4)		++ (5)		right		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%		Ø	±
Total disagreement	1×	5.00	-	-	9×	45.00	8×	40.00	2×	10.00	Total agreement	3.50	0.89

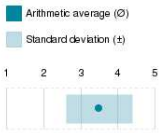


Figure 5. Agreement with Doria et al.'s [17] definition of successful climate adaptation: (**a**) first round, (**b**) second round (source: SurveyHero).

Regarding the need to have specific definitions for each management level, 69% of the experts did not identify such a need related to the definition of adaptation. In the case of the definition of successful adaptation, in the first questionnaire 56% of the experts identified that having a specific definition for each level of management could be useful. Therefore, the question was reframed in the second questionnaire. We asked the experts to identify their preference for these two options: (1) specific definitions for each management level, and (2) a general definition adaptable to each level of management. As a result, 90% of the experts chose option 2.

4.1.2. Elements of Agreement with the Definitions

In the first round, the experts were asked to identify the elements of the definitions with which they agreed. Regarding the adaptation definition, there were two aspects with which the experts agreed more: adaptation as a process of adjustment (56%) and the inclusion of human systems (56%). These were followed by the indirect reference to variability and climate change (34%) and human intervention in natural systems (34%). On the other hand, only 13% agreed with the reference to both systems (natural and human), and 6% agreed with the differentiation among both systems.

Some of the elements listed above were listed separately in the second round (e.g., variability and climate change). Experts were asked to confirm their agreement with and identify the importance of each element. More than 75% of the experts agreed with all the listed elements. Regarding importance, the reference to both systems in the definition scored the highest (0.91). The element about which all experts (100%) agreed was the reference to "exploit beneficial opportunities", while it achieved the lowest weight in terms of importance (0.68).

Regarding the definition of successful adaptation, the experts agreed on reducing risks and vulnerability (44%) as well as sustainability (31%) in the first round. In addition, other aspects were mentioned, such as adjustment (16%), predetermined level (13%), and a focus on climate change (6%).

In the second round, the experts confirmed their agreement with those elements and identified their importance. The experts agreed with most of the elements (>80%). Only the reference to a predetermined level obtained less than 80% agreement (55%). Most experts agreed (95%) with the reference to reducing risks. However, the experts identified reducing vulnerability as the most important element (0.96).

4.1.3. Elements of Disagreement with the Definitions

Despite the high level of agreement with the definition of adaptation, 41% of the experts identified elements of it with which they disagreed. The aspects identified in the first round were the differentiation of both systems (41%), adaptation as an adjustment process (22%), and the limitation to climate change (3%). Except for the limitation to climate change, the experts agreed with all the elements identified as elements of the agreement in the first round. Therefore, we asked the experts to confirm their agreement or disagreement with the elements in the second round. As a result, the only element most of the experts disagreed with was the limitations to climate change (50%).

For successful adaptation, many of the aspects where experts showed agreement in the first round were also identified as elements of disagreement: sustainability (31%), predetermined level (28%), adjustment (15%), measurement elements (9%), scope (9%), and the focus on climate change (6%). In the second round, the experts confirmed whether they agreed or disagreed with the listed elements. In this case, the experts disagreed with two elements: a lack of elements that allowed measuring progress (75%) and the reductionist approach (related to disaster risk reduction, not considering the transformative character of adaptation) (40%).

4.1.4. Proposed Elements

In the first round, the experts identified elements which in their view were missing in the IPCC's [16] definition of adaptation; among these were components of the global goal on adaptation (34%), scope (22%), systemic approach (19%), and type of adaptation (16%). In addition, the experts also mentioned the definition of adjustment (9%), global change (9%), sustainability (6%), temporality (6%), and maladaptation (6%).

In the second round, the experts indicated which elements they agreed with and identified their importance to improve the definitions. The four elements with which the experts agreed the most (>80%) were the increase in adaptive capacity (90%), reduction in vulnerability (90%), systemic approach (85%), and temporality (80%). The reference to reducing vulnerability ranked the highest in terms of importance (0.94).

The experts also identified elements that could be part of a future revision of the definition of successful adaptation. The elements identified in the first questionnaire were the components of the global goal on adaptation (38%), sustainability (25%), scales (19%), type of adaptation (19%), elements of measuring and monitoring (19%), scope (16%), climate variability (9%), stakeholders (9%), predetermined level (6%), and other elements (16%).

In the second round, the experts identified their agreement with and the importance of the listed elements. As a result, more of the elements received a high level of agreement among the experts (>70%). Increasing resilience garnered the most agreement (100%). In terms of importance, the increase in adaptive capacity scored the highest (0.93).

4.2. Operationalization of the Definition of Successful Adaptation

Despite the efforts made, the academic literature states that the existing definitions are not operational. That is, at present the definitions do not support efforts to evaluate progress made through climate change adaptation measures implemented at different management levels [7,14,19,55].

In this section, we present the results related to the usefulness of Doria et al.'s definition [17] for measuring progress in climate adaptation. Additionally, we present methods and approaches that could facilitate the aggregation of information on progress. To this

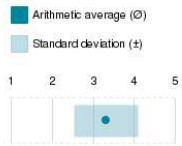
end, we introduce a list of the criteria and indicators identified by the experts which could improve capacities to measure progress at different levels of management.

4.2.1. Usefulness of the Definition of Successful Adaptation at Different Management Levels

We asked the experts to identify how useful the definition of successful adaptation is, in general, for supporting the evaluation of climate change adaptation (Figure 6). In total, 41% and 60% of the experts found the definition useful, in each of the rounds.

(**a**)

left	– – (1)		– (2)		–/+ (3)		+ (4)		++ (5)		right		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%		Ø	±
Not at all useful	1×	3.13	2×	6.25	16×	50.00	12×	37.50	1×	3.13	Very useful	3.31	0.78



(**b**)

left	– – (1)		– (2)		–/+ (3)		+ (4)		++ (5)		right		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%		Ø	±
Not at all useful	1×	5.00	-	-	7×	35.00	9×	45.00	3×	15	Very useful	3.65	0.93

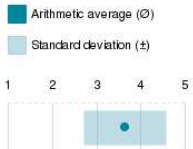


Figure 6. Successful adaptation definition general usefulness: (**a**) first round, (**b**) second round.

When asked about the usefulness at the different management levels (local, subnational, national, and global), the experts stated that the definition was progressively more useful when moving from the local to higher management levels (31%, 44%, 66%, and 75%, respectively) (Figure 7). However, at the local level only, some experts (13%) stated that the definition was not useful, and 9% identified it as not applicable.

left	– – (1)		– (2)		–/+ (3)		+ (4)		++ (5)		N/A (6)		right		
	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%	Σ	%		Ø	±
Local	4×	12.50	8×	25.00	7×	21.88	6×	18.75	4×	12.50	3×	9.38	Local	3.22	1.52
Subnational	-	-	7×	21.88	9×	28.13	8×	25.00	6×	18.75	2×	6.25	Subnational	3.59	1.21
National	-	-	1×	3.13	9×	28.13	10×	31.25	11×	34.38	1×	3.13	National	4.06	0.95
Global	-	-	3×	9.38	3×	9.38	10×	31.25	14×	43.75	2×	6.25	Global	4.28	1.05

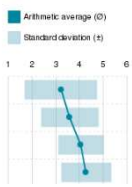


Figure 7. Usefulness of the successful adaptation definition at different management levels (first round).

In the second round, the definition was identified as useful for the local and subnational levels by 80% of the experts and for the national and global levels by 85%. This time, the experts also identified the degree of usefulness of the definition for each level. The experts identified the definition as less useful at the local level (0.65) compared to the national level (0.76). The experts gave the same weight (0.73) for the subnational and global levels (Table 2). In this case, the difference for the different levels was smaller than the one identified in the first round.

Table 2. Usefulness of the definition of successful adaptation at different management levels (second round).

	N	Useful (%)	N/A	Degree of Usefulness (Weight)
Local	16	80	4	0.65
Subnational	16	80	4	0.73
National	17	85	3	0.76
Global	17	85	3	0.73

After identifying the general usefulness of the definition of successful adaptation, the experts identified useful and missing elements for different levels of management. Table 3

shows that the experts identified the same elements for the different levels with slight differences in the agreement and usefulness (weight).

Table 3. Useful elements of the successful adaptation definition.

Useful Elements of the Definition					
Local			**Subnational to Global**		
Element	**%**	**Weight**	**Element**	**%**	**Weight**
Vulnerability reduction	90	0.94	Vulnerability reduction	90	0.91
Predetermined level	80	0.71	Predetermined level	85	0.69
Process of adjustment	75	0.78	Process of adjustment	80	0.71
Sustainability	80	0.79	Sustainability	80	0.85
Applicability to different levels of management	65	0.74	Applicability to different levels of management	75	0.67

On the contrary, there were differences when comparing the elements identified as missing from the definition (Table 4). The experts identified three elements to be missing for the different levels of management: adaptive capacity, resilience, and measuring elements. In comparison, the definition of the scope, climate variability, levels of management, and cultural aspects were identified as missing only for the local level. In addition, the elements of context and the definition of adjustment were identified as missing only for the subnational to global levels.

Table 4. Elements missing from the successful adaptation definition.

Missing Elements in the Definition					
Local			**Subnational to Local**		
Element	**%**	**Weight**	**Element**	**%**	**Weight**
Adaptive capacity	90	0.91	Adaptive capacity	90	0.91
Measuring elements	85	0.83	Measuring elements	90	0.76
Resilience	80	0.85	Resilience	80	0.85
Scope	80	0.73	Context	65	0.82
Climate variability	70	0.81	Definition of adjustment	60	0.75
Levels of management	65	0.64			
Cultural aspects	55	0.79			

4.2.2. Aggregation

Another component of the exercise was investigating aspects of the feasibility of aggregating information on adaptation. In this case, we refer to information from the local level that can inform progress made at the national level, which at the same time could serve to inform global progress made in adaptation, as suggested by Magnan [57].

In the first questionnaire, the experts identified elements used to measure progress at the local level that should be considered at the global level. As a result, 66% of the experts indicated criteria or indicators, 19% mentioned methods of measuring progress, and 9% referred to approaches. Table 5 shows the methods and approaches indicated by the experts. Section 4.2.3 includes more detail on the identified criteria and indicators.

Additionally, 28% of the experts questioned the overall feasibility of aggregating information on adaptation. Considering the results obtained from the first questionnaire, we asked the experts specifically about the feasibility of aggregating information on adaptation progress from the local to the global level in the second round. As a result, only 35% agreed on the feasibility, while 15% thought that it was not possible to aggregate information. A total of 50% of the experts were unsure.

Table 5. Identified methods and approaches.

Methods			Approaches		
Element	**%**	**Utility (Weight)**	**Element**	**%**	**Utility (Weight)**
Objective measures	90	0.73	Sustainability	85	0.82
Inductive methods	80	0.58	Environmental safeguards	85	0.75
Expert judgement	70	0.62	Equity	85	0.82
Perception	65	0.62	Human rights	80	0.81

4.2.3. Criteria and Indicators for Each Level of Management

As mentioned before, in the first questionnaire 66% of experts identified criteria or indicators that would support adaptation monitoring and evaluation efforts at different management levels, which would, at the same time, facilitate the aggregation of information progress on adaptation. We grouped the criteria and indicators identified in the previous round into the three components of the global goal on adaptation, i.e., increasing adaptive capacity, increasing resilience, and reducing vulnerability. The information was presented for each level: local, subnational, national, and global. The experts identified whether the criteria and indicators were useful for that specific management level and their degree of usefulness (Table 6).

Table 6. Identified criteria and indicators for the different for management levels.

		Local			Subnational			National			Global		
	Criteria/Indicator	***F***	**P**	**U**	***F***	**P**	**U**	***F***	**P**	**U**	***F***	**P**	**U**
	Adaptive Capacity												
1	Responsiveness and risk management	19	95	0.81	18	90	0.89	18	90	0.93	18	90	0.85
2	Use and access to climate information	20	100	0.84	19	95	0.84	19	95	0.88	14	70	0.86
3	Financial resources allocated/managed	18	90	0.80	18	90	0.80	19	95	0.86	18	90	0.91
4	Participatory processes	18	90	0.87	18	90	0.83	18	90	0.81	16	80	0.79
5	Integration of traditional knowledge and cultural richness	17	85	0.84	16	80	0.73	15	75	0.73	14	70	0.57
6	Resources invested in losses and damages due to weather events	17	85	0.76	17	85	0.86	18	90	0.91	19	95	0.86
7	Education and training strategies	16	80	0.83	19	95	0.84	19	95	0.79	17	85	0.82
8	Type of technology/measures	16	80	0.60	15	75	0.67	16	80	0.71	14	70	0.74
9	Design and implementation of plans/policies	16	80	0.79	15	75	0.80	16	80	0.90	17	85	0.86
10	Human development index	13	65	0.67	14	70	0.60	15	75	0.67	11	55	0.67
11	Access to public services	13	65	0.72	11	55	0.64	13	65	0.67	9	45	0.63
	Resilience												
1	Ecosystem services	18	90	0.78	18	90	0.83	18	90	0.81	17	85	0.88
2	Strengthening/diversification of livelihoods	17	85	0.84	17	85	0.84	16	80	0.75	12	60	0.81
	Vulnerability												
1	Risk reduction	16	80	0.88	17	85	0.90	17	85	0.82	17	85	0.84
2	Beneficiaries	13	65	0.82	13	65	0.82	15	75	0.78	13	65	0.67
3	Avoid maladaptation	13	65	0.79	12	60	0.83	13	65	0.79	13	65	0.74

F = Frequency (n = x). P = Percentage (%). U = Usefulness (weight).

Besides the elements listed in Table 6, in the second round, some experts identified additional elements for each component of the GGA. These results might indicate that additional elements could have been identified if additional rounds were performed.

5. Discussion

This section presents our reflections on the results obtained from a panel of Latin American experts regarding the revisions of the definitions of climate adaptation [16] and successful adaptation [17]. We present the level of agreement with the definitions and the elements that could help in evaluation and aggregation efforts. Additionally, we reflect on the Delphi method and its limitations for the co-production of knowledge in climate change adaptation research.

5.1. Revision of the Definitions

This exercise did not aim to produce new definitions but rather to revise and identify different elements and issues related to the definitions under study. Below, we present our reflections based on the issues identified by the panel of experts.

5.1.1. Adaptation Definition

We identified a consensus among the experts regarding the IPCC's [16] definition of adaptation. The element upon which most experts agreed was the reference to "exploit beneficial opportunities". Nevertheless, that reference scored the lowest in terms of importance. This result could reflect the concerns expressed by some experts regarding a "positive" view of the effects of climate change. According to some of the comments, the definition should focus on the adverse effects of climate change.

Opinions were divided (50%) about the focus on climate change as an element of disagreement after the two questionnaire rounds. For example, some experts proposed including general aspects of global change (i.e., environmental degradation). This result could reflect the debate of identifying (or not identifying) adaptation as a separate issue from the development agenda [19,54].

Among the elements proposed by the experts, the ones identified as more important were those related to the components of the global goal on adaptation (GGA). This is relevant as it confirms the importance of evaluating progress in the three components of the GGA, which is an issue covered in the current preparation work ahead of the first global stocktake.

5.1.2. Successful Adaptation Definition

In the case of Doria et al.'s [17] definition of successful adaptation, most experts agreed with the reference to a reduction in risks (95%). However, the experts identified the reduction in vulnerability as the most important element. This last aspect is aligned with research that highlights the fact that reducing vulnerability should be one of the objectives of adaptation (e.g., [30,50]). On the other hand, the experts disagreed with the lack of elements to allow for measurement (75%).

Regarding the elements used to improve the definition, most experts agreed on increasing resilience (100%) and increasing adaptive capacity (95%). The experts identified adaptive capacity as the most important element, in line with Ford and Berrang-Ford [44] and Dilling et al. [14].

Regarding the general usefulness of the definition for evaluation purposes, 60% of the experts identified the definition as useful. Additionally, most of the experts (90%) agreed that there was no need for a specific definition for each management level. Instead, the experts identified a general definition adaptable to each management level as the best alternative. This general definition could be supported by criteria and indicators applicable to each level. The results presented in Table 6 are an example of how the criteria and indicators might vary depending on the level of implementation of adaptation measures.

Additionally, according to the experts, the definition of successful adaptation has a lower degree of usefulness at the local level than when compared to higher management levels. While there are some critics of the view of adaptation as only a local concern (e.g., [44]), the results of this research confirm that it is necessary to consider the local context and its complexities when developing criteria and indicators for the evaluation of climate adaptation. Moreover, care is needed regarding the framing used to define how successful or effective an adaptation measure is [30]. Finally, any effort related to evaluating adaptation needs first to showcase the characteristics of the level where adaptation is implemented.

5.2. Aggregation

Contrary to mitigation, it is difficult to aggregate information on the progress on adaptation [19]. However, the global stocktake of the Paris Agreement's aim of assessing collective progress [32] demands that academia, practitioners, and policy-makers find ways to present information on adaptation progress.

This exercise reflects how challenging the effort to aggregate information on adaptation can be, with only 35% of the experts thinking it to be feasible. Nevertheless, the experts identified three approaches—objective measures, expert judgment, and inductive methods—that need to be considered when evaluating adaptation. In this regard, as shown in Table 5, most of the experts considered objective measures as the preferred and most useful ones. However, at the same time, the experts mentioned the challenges of measuring or establishing adaptation indicators in different sections of the questionnaires. This might imply that a combination of approaches should be used when evaluating progress made on adaptation. This is consistent with different research that suggests the use of different approaches (i.e., [10]).

At the same time, and as a more detailed contribution than the criteria identified by Doria et al. [17], it was possible to investigate different criteria and indicators at the different levels of management that could support efforts to aggregate information to inform global processes, such as the global stocktake. Experts identified the usefulness of the proposed criteria and indicators at each management level.

5.3. Added Value of the Delphi Method for Co-Production of Climate Change Adaptation Knowledge

This exercise has proven the Delphi method to be helpful for the co-production of knowledge related to adaptation to climate change. It allowed us to investigate, in an interactive way, the views on the definitions of adaptation and successful adaptation from the IPCC [16] and Doria et al. [17], respectively.

As a field related to different sectors and levels of governance, efforts related to climate adaptation require processes and methods that allow for exchange and inclusion among a diverse group of stakeholders. In this case, the use of the Delphi method fulfills many characteristics of co-production: as a means of addressing complex problems, producing knowledge, and recognizing different perspectives, while also allowing collaboration among various actors. The feedback process can be considered a social learning process [73]. Moreover, in this exercise, the Delphi method facilitated collecting information and identifying different perspectives from a heterogeneous group of experts with different backgrounds, with different levels of technical expertise, and from different countries, despite the ongoing pandemic.

The information obtained can facilitate a common understanding of the goals and results achieved from adaptation actions. Furthermore, the method proved to be flexible, a valuable characteristic for adaptation research, considering the different contexts in which adaptation measures are designed and implemented.

Although the results obtained are not a statistical representation, they present the view of experts in the field, reflecting on critical aspects that need to be considered when evaluating adaptation. Moreover, in this case, the information reflects a regional perspective.

As a limitation of this study, it should be mentioned that only the survey coordinator performed the coding and analysis of the responses. This could have led to biases in the list of elements or issues identified. Sufficient time needed to be allocated for the coding phase, especially after the first round of questionnaires, which mainly consisted of open-ended questions. Following an inductive analysis, the coding phase was the most time-consuming part of the exercise. Furthermore, there were challenges related to the possibility of different interpretations of the questions and the different nature of the issues identified by each expert during the development of the exercise [33,71].

6. Conclusions

Global policy agendas might guide adaptation actions, but actions are implemented at the local level. Adaptation implementation and success depend on site-specific conditions. Therefore, before adaptation progress or success can be evaluated more consistently on such different levels, we need to know how climate adaptation is defined and what is considered progress and success. Additionally, there is a need to identify ways to support efforts to aggregate information on adaptation progress. However, this discussion is absent from the climate-related literature on Latin America. Therefore, we investigated the perspectives of Latin American experts on the aforementioned issues using the Delphi method. Our results confirm the complexity of the discourse on adaptation.

Overall, the Delphi method proved to be useful for the co-production of knowledge, facilitating the identification of different aspects that can serve as a basis for improving climate change adaptation monitoring and evaluation activities.

We found a consensus (>80%) with the IPCC's definition of climate adaptation [16] among the Latin American experts. In contrast, there was no consensus regarding the definition of successful adaptation developed by Doria et al. [17]. The aspects with which most of the experts disagreed were the lack of elements to support evaluation efforts and the lack of recognition of the potential for transformation that adaptation can provide. Instead, the experts identified resilience and adaptive capacity as elements that could improve Doria et al.'s [17] definition of successful adaptation.

Additionally, we presented a list of criteria and indicators of successful adaptation that could support evaluation and aggregation efforts. Such indicators have been identified as a knowledge gap in the Latin American region. Here, we observed that most of the criteria and indicators proposed by the experts were related to adaptive capacity, identified in the climate-related literature as a crucial component when implementing adaptation measures. Our results confirm that there is no one method or one approach for evaluating adaptation.

The criteria and indicators identified in this exercise can help in the investigation of successful adaptation characteristics applicable at different management levels while providing guidance for policy makers and practitioners ahead of the first global stocktake. While our results are limited to the identification of criteria and indicators, they could specifically contribute to a structured approach that captures aspects of representativeness and comparability, as suggested by Magnan and Ribera [45]. For example, regarding the criteria and indicators identified for the adaptive capacity component of the GST, the elements of context and the factors that influence the performance of the adaptation measures could be investigated.

Additionally, future research efforts should focus on developing and characterizing the identified criteria and indicators for the different levels of management by identifying the kind of information needed at each level, how the information should be collected, and how it could be aggregated and integrated into the reporting tools. The Delphi method could also be applied to these objectives. Similar exercises could also be developed in other regions to identify, compare and analyze how the different perspectives, elements, criteria, and indicators identified depend on the geographical context.

In conclusion, we present the level of agreement of experts and ways to improve the definitions of climate adaptation and successful climate adaptation, as well as criteria and indicators that could help to aggregate adaptation information from the local to the global

level. The outcomes, which present a regional perspective, can guide the Paris Agreement's global stocktake and contribute to the debate on successful climate adaptation.

Author Contributions: Conceptualization, T.G.B.; methodology, T.G.B.; formal analysis, T.G.B.; writing—original draft preparation, T.G.B.; writing—review and editing, T.G.B., J.S. and M.M.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. This research was funded by the Climate Service Center Germany (GERICS), Helmholtz-Zentrum Hereon.

Institutional Review Board Statement: This paper does not present medical research. Participation in the research was voluntary. The framing and settings were non-coercive. The nature of the collected information posed no harm to participants. The collected information was treated confidentially, and data are available, if requested, only in anonymized form.

Informed Consent Statement: The questionnaires followed the principle of prior informed consent: all participants were informed about the research's background, method, and aim. Additionally, written informed consent was obtained from the experts included in the first questionnaire.

Data Availability Statement: The original material of this investigation is in Spanish. The data presented in this study are available on request from the corresponding author. The data are not publicly available to guarantee the participants' anonymity.

Acknowledgments: The authors are grateful to the Latin American experts who participated in the first and second round of the Delphi method exercise: A. Aguilar, X. Apestegui, F. Aragón-Durand, A.C. Borda, R. Bórquez, M. Caffera, N. Canales, E. Castellanos, A. Cid Salinas, J. Cordano, I. Delgado-Pitti, P. Devis, L. Di Pietro, M. Florian, G. Fuentes Braeuner, H. Garate, A. García González, P.M. García Meneses, M. Jadrijevic, C. Jones, O. Jordan, I. Lorenzo, A. Martín, F. Menna, G.J. Nagy, L.A. Ortega Fernández, N.C. Páez Ortiz, A. Rodríguez Osuna, D. Ryan, J.O. Samayoa Juárez, R. Scribano, and A. Sobenes. We also would like to thank E. Gómez, S. Muwafu, and G. Langendijk for their valuable comments, which helped to improve the manuscript. This research contributes to the climate cluster of excellence CLICCS funded by DFG.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1 presents the summary of the results obtained after the second round of the Delphi panel regarding the most important elements of the definitions of adaptation [16] (consensus > 80%) and successful adaptation [17].

Table A1. Summary of findings.

Adaptation Definition (IPCC [16])	
Agreement with definition	85%
Elements of agreement	- Reference to natural and human systems - Reference to human intervention in natural systems - Reference to climate change - Reference to climate variability - Reference to moderate or avoid damages
Elements of disagreement	- Limitation to climate change
Proposed elements	- Reduction in vulnerability - Adaptive capacity - Systemic approach - Increase in resilience - Sustainability - Right-based approach

Table A1. *Cont.*

Adaptation Definition (IPCC [16])	
Successful adaptation definition (Doria et al. [17])	
Agreement with definition	50%
Elements of agreement	- Reference to reduction in vulnerability - Reference to reduction in risks - Reference to sustainability
Elements of disagreement	- Lack of elements to allow for measurement - Reductionist approach
Proposed elements	- Adaptive capacity

References

1. Hoegh-Guldberg, O.; Jacob, D.; Taylor, M.; Guillén Bolaños, T.; Bindi, M.; Brown, S.; Camilloni, I.A.; Diedhiou, A.; Djalante, R.; Ebi, K.; et al. The Human Imperative of Stabilizing Global Climate Change at 1.5 °C. *Science* **2019**, *365*, 1263. [CrossRef] [PubMed]
2. IPCC. Summary for Policymakers. 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*; Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., et al., Eds.; Cambridge University Press: Cambridge, UK, 2022; *in press*.
3. UNEP. *Adaptation Gap Report 2020*; United Nations Environment Programme (UNEP): Nairobi, Kenya, 2021; ISBN 9789280738346.
4. de Coninck, H.; Revi, A.; Babiker, M.; Bertoldi, P.; Buckeridge, M.; Cartwright, A.; Dong, W.; Ford, J.; Fuss, S.; Hourcade, J.-C.; et al. Strengthening and Implementing the Global Response. In *Strengthening and Implementing the Global Response. In: Global Warming of 1.5 °C. An IPCC Special Report on the Impacts of Global Warming of 1.5 °C above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*; Masson-Delmotte, V., Zhai, P., Pörtner, H.O., Roberts, D., Skea, J., Shukla, P.R., Pirani, A., Moufouma-Okia, W., Péan, C., Pidcock, R., et al., Eds.; World Meteorological Organization: Geneva, Switzerland, 2018; pp. 313–443.
5. Adger, W.N.; Arnell, N.W.; Tompkins, E.L. Successful Adaptation to Climate Change across Scales. *Glob. Environ. Chang.* **2005**, *15*, 77–86. [CrossRef]
6. New, M.; Reckien, D.; Viner, D.; Adler, C.; Cheong, S.-M.; Conde, C.; Constable, A.; de Perez, E.C.; Lammel, A.; Mechler, R.; et al. 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*; Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2022; *in press*.
7. Berrang-Ford, L.; Pearce, T.; Ford, J.D. Systematic Review Approaches for Climate Change Adaptation Research. *Reg. Environ. Chang.* **2015**, *15*, 755–769. [CrossRef]
8. AC. *Report on the Workshop on the Monitoring and Evaluation of Adaptation*; UNFCCC: Bonn, Germany, 2014.
9. Moser, S.C.; Boykoff, M.T. (Eds.) *Successful Adaptation to Climate Change: Linking Science and Policy in a Rapidly Changing World*, 1st ed.; Routledge: New York, USA, 2013; ISBN 9780415525008.
10. Leiter, T. Linking Monitoring and Evaluation of Adaptation to Climate Change across Scales: Avenues and Practical Approaches. In *Monitoring and Evaluation of Climate Change Adaptation: A Review of the Landscape*; New Directions for Evaluation; Bours, D., McGinn, C., Pringle, P., Eds.; Wiley Online Library: Hoboken, NJ, USA, 2015; pp. 117–127.
11. Barnett, J.; O'Neill, S.; Waller, S.; Rogers, S. Reducing the Risk of Maladaptation in Response to Sea-Level Rise and Urban Water Scarcity. In *Successful Adaptation to Climate Change: Linking Science and Policy in a Rapidly Changing World*; Moser, S.C., Boycoff, M.T., Eds.; Routledge: London, UK, 2013; pp. 37–49.
12. Engle, N.L.; de Bremond, A.; Malone, E.L.; Moss, R.H. Towards a Resilience Indicator Framework for Making Climate-Change Adaptation Decisions. *Mitig. Adapt. Strateg. Glob. Chang.* **2014**, *19*, 1295–1312. [CrossRef]
13. Janetos, A.C. Why Is Climate Adaptation so Important? What Are the Needs for Additional Research? *Clim. Chang.* **2020**, *161*, 171–176. [CrossRef]
14. Dilling, L.; Prakash, A.; Zommers, Z.; Ahmad, F.; Singh, N.; de Wit, S.; Nalau, J.; Daly, M.; Bowman, K. Is Adaptation Success a Flawed Concept? *Nat. Clim. Chang.* **2019**, *9*, 572–574. [CrossRef]
15. Ishtiaque, A.; Eakin, H.; Vij, S.; Chhetri, N.; Ramhan, F.; Huq, S. Multilevel Governance in Climate Change Adaptation: Conceptual Clarification and Future Outlook. *Reg. Env. Chang.* **2021**, *21*, 1–15. [CrossRef]
16. IPCC. Annex II: Glossary. In *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*; Mach, K.J., Planton, S., von Stechow, C., Eds.; IPCC: Geneva, Switzerland, 2014; pp. 117–130.

17. Doria, M.d.F.; Boyd, E.; Tompkins, E.L.; Adger, W.N. Using Expert Elicitation to Define Successful Adaptation to Climate Change. *Environ. Sci. Policy* **2009**, *12*, 810–819. [CrossRef]
18. Adger, W.N.; Arnell, N.W.; Tompkins, E.L. Adapting to Climate Change: Perspectives across Scales. *Glob. Environ. Chang.* **2005**, *15*, 75–76. [CrossRef]
19. Christiansen, L.; Martínez, G.; Naswa, P. *Adaptation Metrics: Perspectives on Measuring, Aggregating and Comparing Adaptation Results*; Christiansen, L., Martinez, G., Naswa, P., Eds.; UNEP DTU Partnership: Copenhagen, Denmark, 2018; ISBN 9788793458277.
20. Berrang-Ford, L.; Biesbroek, R.; Ford, J.D.; Lesnikowski, A.; Tanabe, A.; Wang, F.M.; Chen, C.; Hsu, A.; Hellmann, J.J.; Pringle, P.; et al. Tracking Global Climate Change Adaptation among Governments. *Nat. Clim. Chang.* **2019**, *9*, 440–449. [CrossRef]
21. Olazabal, M.; De Gopegui, M.R.; Tompkins, E.L.; Venner, K.; Smith, R. A Cross-Scale Worldwide Analysis of Coastal Adaptation Planning. *Environ. Res. Lett.* **2019**, *14*, 1–10. [CrossRef]
22. Klein, R.J.T.; Adams, K.M.; Dzebo, A.; Davis, M.; Siebert, C.K. *Advancing Climate Adaptation Practices and Solutions: Emerging Research Priorities*; Stockholm Environment Instittue: Stockholm, Sweden, 2017.
23. Nelson, D.R.; Adger, W.N.; Brown, K. Adaptation to Environmental Change: Contributions of a Resilience Framework. *Annu. Rev. Environ. Resour.* **2007**, *32*, 395–419. [CrossRef]
24. Nalau, J.; Verrall, B. Mapping the Evolution and Current Trends in Climate Change Adaptation Science. *Clim. Risk Manag.* **2021**, *32*, 1–22. [CrossRef]
25. Castellanos, E.; Lemos, M.F.; Astigarraga, L.; Chacón, N.; Cuvi, N.; Huggel, C.; Miranda, L.; Moncassim Vale, M.; Ometto, J.P.; Peri, P.L.; et al. Central and South America. 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*; Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2022; *in press*.
26. Hagen, I.; Huggel, C.; Ramajo, L.; Chacón, N.; Ometto, J.P.; Postigo, J.C.; Castellanos, E.J. Climate Change-Related Risks and Adaptation Potential in Central and South America during the 21st Century. *Environ. Res. Lett.* **2022**, *17*, 033002. [CrossRef]
27. UNFCCC. *Biennial Assessment and Overview of Climate Finance Flows: Summary and Recommendations by the Standing Committee on Finance on the 2018 Biennial Assessment and Overview of Climate Finance Flows*; UNFCCC: Bonn, Germany, 2018; Volume 121.
28. Schalatek, L.; Watson, C. *The Green Climate Fund (GCF)*; Heinrich Böll Stiftung, ODI: Washington, DC, USA; London, UK, 2020.
29. Ryan, D.; Bustos, E. Knowledge Gaps and Climate Adaptation Policy: A Comparative Analysis of Six Latin American Countries. *Clim. Policy* **2019**, *19*, 1297–1309. [CrossRef]
30. Singh, C.; Iyer, S.; New, M.G.; Few, R.; Kuchimanchi, B.; Segnon, A.C. Daniel Morchain Interrogating 'Effectiveness' in Climate Change Adaptation: 11 Guiding Principles for Adaptation Research and Practice. *Clim. Dev.* **2021**, *13*, 761–765. [CrossRef]
31. Pörtner, H.-O.; Roberts, D.C.; Adams, H.; Adelekan, I.; Adler, C.; Adrian, R.; Aldunce, P.; Ali, E.; Begum, R.A.; Bednar-Friedl, B.; et al. Technical Summary. 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*; Pörtner, H.-O., Roberts, D.C., Tignor, M., Poloczanska, E.S., Mintenbeck, K., Alegría, A., Craig, M., Langsdorf, S., Löschke, S., Möller, V., et al., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2022; *in press*.
32. UNFCCC. *Decision 1/CP.21 Adoption of the Paris Agreement*; UNFCCC: Paris, France, 2015.
33. Hasson, F.; Keeney, S.; McKenna, H. Research Guidelines for the Delphi Survey Technique. *J. Adv. Nurs.* **2000**, *32*, 1008–1015. [CrossRef]
34. Hirschhorn, F.; Veeneman, W.; van de Velde, D. Inventory and Rating of Performance Indicators and Organisational Features in Metropolitan Public Transport: A Worldwide Delphi Survey. *Res. Transp. Econ.* **2018**, *69*, 144–156. [CrossRef]
35. Montijo-Galindo, A.; Ruiz-Luna, A.; Betancourt Lozano, M.; Hernández-Guzmán, R. A Multicriteria Assessment of Vulnerability to Extreme Rainfall Events on the Pacific Coast of Mexico. *Coast. Manag.* **2020**, *48*, 623–642. [CrossRef]
36. Mousavi, A.; Ardalan, A.; Takian, A.; Ostadtaghizadeh, A.; Naddafi, K.; Bavani, A.M. Health System Plan for Implementation of Paris Agreement on Climate Change (COP 21): A Qualitative Study in Iran. *BMC Public Health* **2020**, *20*, 13. [CrossRef]
37. Soleymani, A.; Farani, A.Y.; Karimi, S.; Azadi, H.; Nadiri, H.; Scheffran, J. Identifying Sustainable Rural Entrepreneurship Indicators in the Iranian Context. *J. Clean. Prod.* **2021**, *290*, 12. [CrossRef]
38. Kabir, M.H.; Mahbubul, M.A. Developing a Conceptual Model for Identifying Determinants of Climate Change Adaptation. *J. Clim. Chang.* **2021**, *7*, 25–35. [CrossRef]
39. Bassett, T.J.; Fogelman, C. Déjà vu or Something New? The Adaptation Concept in the Climate Change Literature. *Geoforum* **2013**, *48*, 42–53. [CrossRef]
40. Ford, J.D.; McDowell, G.; Jones, J. The State of Climate Change Adaptation in the Arctic. *Environ. Res. Lett.* **2014**, *9*, 9. [CrossRef]
41. Eriksen, S.H.; Nightingale, A.J.; Eakin, H. Reframing Adaptation: The Political Nature of Climate Change Adaptation. *Glob. Environ. Chang.* **2015**, *35*, 523–533. [CrossRef]
42. Vogel, B.; Henstra, D. Studying Local Climate Adaptation: A Heuristic Research Framework for Comparative Policy Analysis. *Glob. Environ. Chang.* **2015**, *31*, 100–120. [CrossRef]
43. Sietsma, A.J.; Ford, J.D.; Callaghan, M.W.; Minx, J.C. Progress in Climate Change Adaptation Research. *Environ. Res. Lett.* **2021**, *16*, 14. [CrossRef]
44. Ford, J.D.; Berrang-Ford, L. The 4Cs of Adaptation Tracking: Consistency, Comparability, Comprehensiveness, Coherency. *Mitig. Adapt. Strateg. Glob. Chang.* **2016**, *21*, 839–859. [CrossRef]

45. Magnan, A.K.; Ribera, T. Global Adaptation after Paris. *Science* **2016**, *352*, 1280–1282. [CrossRef]
46. Dilling, L.; Daly, M.E.; Travis, W.R.; Wilhelmi, O.V.; Klein, R.A. The Dynamics of Vulnerability: Why Adapting to Climate Variability Will Not Always Prepare Us for Climate Change. *Wiley Interdiscip. Rev. Clim. Chang.* **2015**, *6*, 413–425. [CrossRef]
47. Lorenz, S.; Berman, R.; Dixon, J.; Lebel, S. Time for a Systematic Review: A Response to Bassett and Fogelman's "Déjà vu or Something New? The Adaptation Concept in the Climate Change Literature". *Geoforum* **2014**, *51*, 252–255. [CrossRef]
48. Owen, G. What Makes Climate Change Adaptation Effective? A Systematic Review of the Literature. *Glob. Environ. Chang.* **2020**, *62*, 13. [CrossRef]
49. AC-UNFCCC. *Approaches to Reviewing the Overall Progress Made in Achieving the Global Goal on Adaptation*; Technical Paper; UNFCCC: Bonn, Germany, 2021.
50. Schipper, E.L.F. Maladaptation: When Adaptation to Climate Change Goes Very Wrong. *One Earth* **2020**, *3*, 409–414. [CrossRef]
51. Persson, Å. Global Adaptation Governance: An Emerging but Contested Domain. *Wiley Interdiscip. Rev. Clim. Chang.* **2019**, *10*, 18. [CrossRef]
52. UNFCCC. Monitoring and Assessing Progress, Effectiveness and Gaps under the Process to Formulate and Implement National Adaptation Plans: The PEG M&E Tool. 2015. Available online: https://www4.unfccc.int/sites/NAPC/Documents%20NAP/UNFCCC_PEGMonitoring_Tool.pdf (accessed on 5 February 2022).
53. GEF-STAP. *Strengthening Monitoring and Evaluation of Climate Change Adaptation*; Global Environmental Facility: Washington, DC, USA, 2017.
54. Fiala, N.; Puri, J.; Mwandri, P. *Becoming Bigger, Better, Smarter: A Summary of the Evaluability of Green Climate Fund Proposals*; Green Climate Fund Independent Evaluation Unit: Songdo, Korea, 2019.
55. UNEP. *The Adaptation Gap Report: Towards Global Assessment*; UNEP: Nairobi, Kenya, 2017.
56. Schipper, E.L.F.; Tanner, T.; Dube, O.P.; Adams, K.M.; Huq, S. The Debate: Is Global Development Adapting to Climate Change? *World Dev. Perspect.* **2020**, *18*, 1–5. [CrossRef]
57. Magnan, A.K. Metrics Needed to Track Adaptation. *Nature* **2016**, *530*, 160. [CrossRef]
58. Leiter, T.; Olhoff, A.; Al Azar, R.; Barmby, V.; Bours, D.; Wei, V.; Clement, C.; Bank, W.; Dale, T.W.; Davies, C.; et al. *Adaptation Metrics Current Landscape and Evolving Practices*; UNEP DTU Partnership: Rotterdam, The Netherlands; Washington, DC, USA, 2019.
59. Leiter, T. Do Governments Track the Implementation of National Climate Change Adaptation Plans? An Evidence-Based Global Stocktake of Monitoring and Evaluation Systems. *Environ. Sci. Policy* **2021**, *125*, 179–188. [CrossRef]
60. Kato, T.; Ellis, J. *Communicating Progress in National and Global Adaptation to Climate Change*; OECD: Paris, France, 2016.
61. Craft, B.; Fisher, S. Measuring the Adaptation Goal in the Global Stocktake of the Paris Agreement. *Clim. Policy* **2018**, *18*, 1203–1209. [CrossRef]
62. Tompkins, E.L.; Vincent, K.; Nicholls, R.J.; Suckall, N. Documenting the State of Adaptation for the Global Stocktake of the Paris Agreement. *Wiley Interdiscip. Rev. Clim. Chang.* **2018**, *9*, 1–9. [CrossRef]
63. Magnan, A.K.; Chalastani, V.I. *Towards a Global Adaptation Progress Tracker: First Thoughts*; IDDRI: Paris, France, 2019.
64. Atteridge, A.; Remling, E. Is Adaptation Reducing Vulnerability or Redistributing It? *Wiley Interdiscip. Rev. Clim. Chang.* **2018**, *9*, 1–16. [CrossRef]
65. Leiter, T. The Adaptation M&E Navigator: A Decision Support Tool for the Selection of Suitable Approaches to Monitor and Evaluate Adaptation to Climate Change. In *Evaluating Climate Change Action for Sustainable Development*; Uitto, J.I., Puri, J., van den Berg, R.D., Eds.; Springer: Cham, Switzerland, 2017; pp. 327–341.
66. UNFCCC. *Progress, Experience, Best Practices, Lessons Learned, Gaps, Needs and Support Provided in the Process to Formulate and Implement National Adaptation Plans*; UNFCCC: Bonn, Germany, 2018.
67. Ford, J.D.; Berrang-Ford, L.; Lesnikowski, A.; Barrera, M.; Jody Heymann, S. How to Track Adaptation to Climate Change: A Typology of Approaches for National-Level Application. *Ecol. Soc.* **2013**, *18*, 14. [CrossRef]
68. Brown, C.; Shaker, R.R.; Das, R. A Review of Approaches for Monitoring and Evaluation of Urban Climate Resilience Initiatives. *Environ. Dev. Sustain.* **2018**, *20*, 23–40. [CrossRef]
69. Landeta, J. Current Validity of the Delphi Method in Social Sciences. *Technol. Forecast. Soc. Chang.* **2006**, *73*, 467–482. [CrossRef]
70. Reguant-Álvarez, M.; Torrado-Fonseca, M. El Método Delphi. *REIRE. Rev. d'Innovació I Recer. Educ.* **2016**, *9*, 87–102. [CrossRef]
71. Hirschhorn, F. Reflections on the Application of the Delphi Method: Lessons from a Case in Public Transport Research. *Int. J. Soc. Res. Methodol.* **2019**, *22*, 309–322. [CrossRef]
72. Van Dijk, J.A.G.M. Delphi Questionnaires Group Interviews A Comparison Case. *Technol. Forecast. Soc. Chang.* **1990**, *37*, 293–304. [CrossRef]
73. Vincent, K.; Daly, M.; Scannell, C.; Leathes, B. What Can Climate Services Learn from Theory and Practice of Co-Production? *Clim. Serv.* **2018**, *12*, 48–58. [CrossRef]
74. Keeney, S.; Hasson, F.; McKenna, H.P. A Critical Review of the Delphi Technique as a Research Methodology for Nursing. *Int. J. Nurs. Stud.* **2001**, *38*, 195–200. [CrossRef]
75. Morgan, M.G. Use (and Abuse) of Expert Elicitation in Support of Decision Making for Public Policy. *Proc. Natl. Acad. Sci. USA* **2014**, *111*, 7176–7184. [CrossRef]

76. Adger, W.N. Vulnerability. *Glob. Environ. Chang.* **2006**, *16*, 268–281. [CrossRef]
77. Tetzlaff, J.M.; Moher, D.; Chan, A.W. Developing a Guideline for Clinical Trial Protocol Content: Delphi Consensus Survey. *Trials* **2012**, *13*, 10. [CrossRef] [PubMed]
78. Kuckartz, U.; Rädiker, S. *Analyzing Qualitative Data with MAXQDA. Text, Audio, and Video*; Springer: Cham, Switzerland, 2019; ISBN 9783030156701.

Chapter III. "Assessing the Feasibility of Climate Adaptation Options Using Local Knowledge: The Case of Puerto Morazán, Nicaragua"

(Submitted to PLOS Climate. Under review)

Chapter 3. Assessing the Feasibility of Climate Adaptation Options Using Local Expertise and Participatory Approaches: The Case of Puerto Morazán, Nicaragua.

Guillén Bolaños, Tania[1,2]*, Scheffran, Jürgen[2]; García, Abdel[3]; López, Haydée[4]; Castillo, Marcos[3]; Máñez Costa, María[1]; Jacob, Daniela[1]

[1] Climate Service Center Germany (GERICS), Helmholtz-Zentrum Hereon. Hamburg, Germany.

[2] Research Group Climate Change and Security, Institute of Geography, Universität Hamburg. Hamburg, Germany.

[3] Independent consultant, Nicaragua.

[4] Alcaldía de Puerto Morazán, Nicaragua.

Abstract

Adaptation options are being implemented globally to reduce the impacts of current and projected climate change. However, there is still limited information on assessments of the options available, especially related to adaptation research and practice in the Global South. Therefore, we present the local feasibility assessment of climate adaptation options as a methodological advancement, using Puerto Morazán's (Nicaragua) agriculture and livestock sectors as proof of concept. For this case study, we complement current frameworks with participatory approaches and local expert knowledge to contextualize global narratives on adaptation feasibility and overcome information availability challenges. As a result, we assess sixteen options across the agriculture and livestock sectors. We demonstrate that, depending on the context, not all dimensions and criteria are equally relevant. In Puerto Morazán, the environmental and economic dimensions were the most important. We also confirm that the assessment of the options varies when local priorities are considered. Our results highlight the importance of the local context when identifying adaptation options. Our expanded assessment framework helps assess and generate evidence from the local level, where information is usually limited. The advanced assessment can guide local and subnational adaptation processes and inform other policy or scientific assessments by identifying the dimensions where there might be barriers to implementing adaptation.

Keywords:

Climate change adaptation; feasibility assessment; Nicaragua; local knowledge; local expertise

3.1 Introduction

Global impacts of climate change on ecosystems and societies have led to an urgent need to implement and evaluate the success or failure of climate adaptation options (IPCC 2022). As a result, there is increasing evidence of adaptation. However, it mainly focuses on national policy progress (Berrang-Ford et al. 2019, 2021; Lesnikowski et al. 2019; Leiter 2021), in which general information about the Global South's vulnerable regions is underrepresented (Nalau and Verrall 2021; Sietsma et al. 2021; Ara Begum et al. 2022). Additionally, the literature does not reflect the feasibility assessments of actions at the subnational scales where adaptation is implemented (Abram, N. et al. 2019; Ara Begum et al. 2022; UNEP 2022). However, the assessment of adaptation depends not only on institutions that deal with the issue but also on the active and sustained participation of local stakeholders. Furthermore, the adaptation policy and action must be based on the best available science and, as appropriate, on traditional knowledge and local knowledge systems. Therefore, we propose a framework to foster the assessment of climate adaptation options at the local level, considering context-specificities, using participatory processes and local knowledge and expertise.

Climate adaptation assessments should inform global processes, such as the Global Stocktake (GST) and Global Goal on Adaptation (GGA), which are country-driven approaches established by the United Nations Framework Convention on Climate Change's (UNFCCC) Paris Agreement. For example, the GST aims to recognize adaptation efforts, enhance implementation, review their adequacy and effectiveness, and support provided. On the other hand, the GGA aims to improve adaptive capacity, strengthen resilience, and reduce vulnerability to climate change (UNFCCC 2015). However, assessing adaptation is a complex endeavor. The challenges faced when assessing adaptation include various adaptation options, context, time, perspective-specific aspects, comparability, and limited data availability across scales (Singh et al. 2020b; New et al. 2022; Guillén Bolaños et al. 2022). Therefore, decision-makers and technical adaptation staff must have analytical tools at their disposal to properly assist them in evaluating their options and the success of the implementation.

There are different approaches and methods to assess progress on adaptation policies and implementation; among them are adaptation effectiveness, adaptation readiness, and analysis based on barriers and enablers to adaptation, such as the feasibility assessment. The feasibility assessment framework is based on the "barriers" frame, which is easy to understand by policymakers and adaptation practitioners (Singh et al. 2020b). Feasibility is the "degree to which climate goals and response options are considered possible and/or desirable" (IPCC 2018, p. 549).

The feasibility assessment framework has been adopted in climate adaptation research, especially since the Special Report on 1.5 °C of the Intergovernmental Panel on Climate Change (IPCC) (de Coninck et al. 2018). Since then, scholarship related to assessments of the feasibility of adaptation options related to the global level, large regions, or sectoral scales has been published (e.g., Singh et al. 2020a; Williams et al. 2021; Ley et al. 2022; Tirado et al. 2022). However, despite the common understanding of the importance of the local or subnational levels or the different contexts and perspectives that can guide adaptation decision-making (Nalau et al. 2015), there is still limited information on these issues (New et al. 2022; Scott and Moloney 2022; Pollo et al. 2022). Subnational assessments should be integrated as part of national planning instruments (e.g., national adaptation plans or nationally determined contributions) or other country reporting instruments, such as the Adaptation Communications (also created as part of the Paris Agreement), informing global processes policies (i.e., GST, GGA) (Lesnikowski et al. 2015; UNEP 2017). The above highlights the importance of improving the coordination and assessment of adaptation

actions across scales (Guillén Bolaños et al. 2022), which could help improve resource efficiency and avoid maladaptive practices (Juhola et al. 2016; New et al. 2022).

Given that, effective implementation and accurate evaluation of climate adaptation options require recognition and understanding of potential disruption factors at various scales and dimensions. However, there is no balance in the availability of evidence about those factors. Therefore, we present a methodological improvement of the framework proposed by the IPCC (first in de Coninck et al. (2018) and further expanded by Singh et al. (2020b) to assess the feasibility of adaptation options. The IPCC framework has been used to evaluate adaptation options at the global level based on literature reviews. Thus, we expand the framework to conduct local feasibility assessments of adaptation options, including local priorities, expertise, and knowledge. For this, we use two approaches: generic integrative modeling (Máñez et al. 2017) and elicitation to integrate expert local knowledge and improve local scale adaptation assessments (Conway et al. 2019). To test our proposal, we use Puerto Morazán, located in Nicaragua, in territories of the Central American Dry Corridor (CADC), as a proof of concept.

In section 3.2, we describe the proposed framework as an advancement of current methodological frameworks to assess adaptation at the local level, using local knowledge and expertise. Section 3.3 presents the proposal's implementation results using Puerto Morazán as our case study. In sections 3.4 and 3.5, we offer the discussions and conclusions of our work.

3.2 Local Feasibility Assessment Of Climate Adaptation Options: A Methodological Advancement

For this work, we understand a local feasibility assessment as the analysis of factors that facilitate or hinder the implementation of adaptation options in a specific geographic area or community. The term "local" implies that the assessment is focused on the particular conditions, resources, and dynamics of a specific region or locality. Additionally, the assessment fosters the participation of local experts and practitioners and indigenous and local knowledge.

As already noted, the existing information on the evaluation of adaptation measures is mainly focused on global scales and based on academic literature reviews. However, different scales of governance need to be considered when reporting adaptation efforts. To enhance reporting and evaluation of adaptation efforts, subnational and local climate adaptation assessments must be considered:

a) The Indigenous and local knowledge systems are recognized as enablers for success and risk management, enriching adaptation policy and practice (Ara Begum et al. 2022; New et al. 2022).

b) Participatory support risk management can help decision-makers understand their decisions, the larger consequences of those decisions, and community expectations, perceptions, and how these can be integrated into responses (Ley 2017; Conway et al. 2019; Ara Begum et al. 2022). Participatory approaches enhance the involvement and cooperation of local stakeholders in decision-making processes and support the co-production of knowledge (Cvitanovic et al. 2019; Williams et al. 2020; New et al. 2022). Participatory approaches are also crucial to producing usable science to find solutions resulting from the interaction between science and society (Dilling and Lemos 2011; Cvitanovic et al. 2019).

Therefore, we propose a methodological advancement of the IPCC's feasibility assessment (de Coninck et al. 2018; Singh et al. 2020b) based on local knowledge and expertise,

including the prioritization among the dimensions and indicators proposed in the original methodology.

In our proposal, we intend to overcome limitations on literature available at subnational and local levels by using three main methods: literature review and desktop analysis, a participatory integrative modeling technique (Máñez et al. 2017), and expert knowledge elicitation.

Our framework for conducting local feasibility assessments consists of three phases (**Figure III-1**): characterization of the socio-ecological system (Phase I), identification of adaptation options (Phase II), and assessment of feasibility (Phase III). The involvement of local researchers and stakeholders supporting all phases is highlighted. The following sections describe the proposed phases, methods, and steps. More detailed information is provided in the electronic supplementary material (S1-S2 Text).

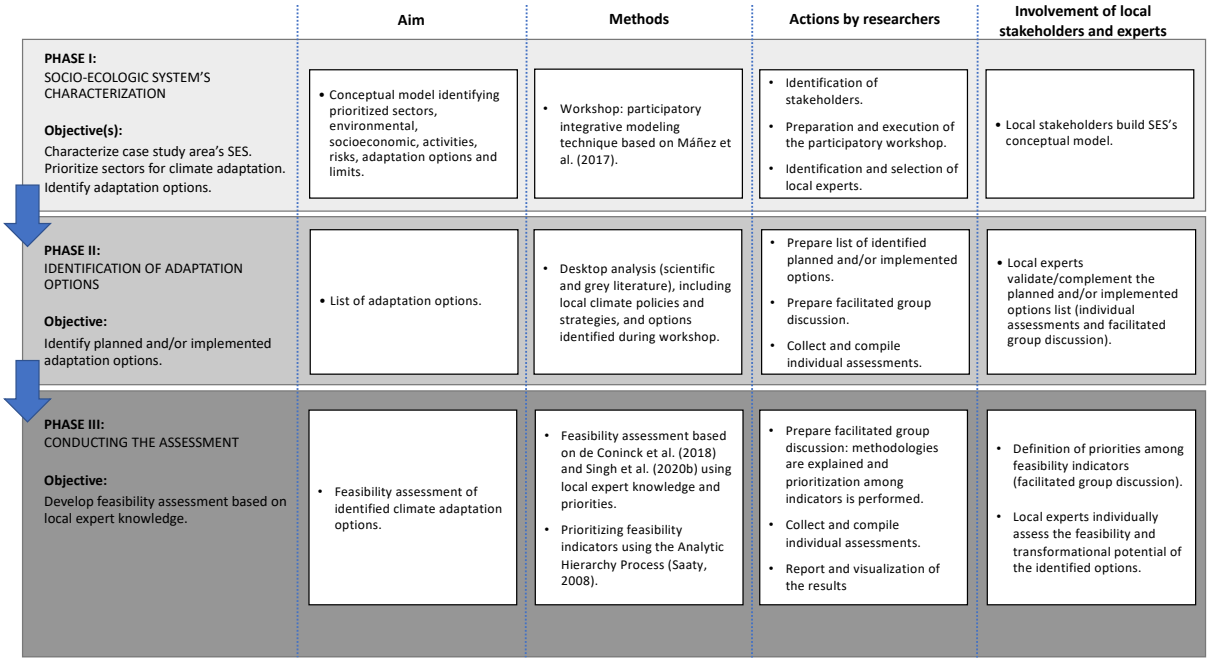


Figure III-1 *Steps for conducting the local feasibility assessment of adaptation options.*

3.2.1 Phase I: Socio-Ecological System's Characterization

To characterize a socio-ecological system, we propose to develop a conceptual model based on the participatory integrative modeling technique proposed by Máñez et al. (2017). This participatory technique allows interdisciplinary knowledge integration, including non-formal knowledge and different disciplines. The technique includes developing individual interviews (and constructing individual qualitative models) before creating a group model. However, a group model-building exercise could also be helpful to avoid overloading the stakeholders or when individual interviews are not possible. The integrative modeling technique has been used with different objectives related to climate adaptation. For example, von der Forst (2018) implemented it to identify the vulnerability of socio-ecological systems in Mexico and South Africa to climate change. Gómez and Máñez (2019) used the framework for participatory integrated planning. In Williams et al. (2020), the technique supported identifying leverage points for enhancing adaptive capacity.

Máñez et al. (2017) propose four factors, presented as the syntax of the model, for developing a conceptual model: environmental-related (natural capital), socioeconomic-related, activities or actions on the systems, and threats and/or risks. To include the climate component in the conceptual model, we propose grouping socioeconomic factors and

activities and adding adaptation options and limits as factors. As a result, we recommend six factors to help develop the conceptual model: environmental, socioeconomic, threats and vulnerabilities, adaptation limits, and adaptation options. Adapting the categories provides a more comprehensive and focused representative climate-related conceptual model. During the exercise, the stakeholders can be asked to prioritize the sectors and climate risks for which adaptation options should be assessed later.

A key step of this phase is the selection of the stakeholders. Due to their ability to provide knowledge regarding the natural and socio-economic systems they are involved in, stakeholders are considered systems experts (BenDor and Scheffran 2019). For this, researchers need to consider the local context, the power dynamics, and the sector under study, among other aspects (New et al. 2022). After identifying the stakeholders, the researchers can execute the participatory workshop where the conceptual model will be developed.

Researchers must identify and select local experts to perform the assessments in this phase. These experts, preferably, have excellent and comprehensive knowledge about climate change adaptation in the area under study and topics related to risks, vulnerabilities, and responses implemented. Novel approaches to identify stakeholders and experts, such as that suggested by Celliers et al. (2023) can be used in this phase.

3.2.2 Phase II: Identification Of Adaptation Options

We propose to identify the adaptation options considering three sources of information: (1) the options identified during the characterization of the SES (based on participatory processes), (2) desktop analysis (including scientific and grey literature related to the area), and (3) review of policy instruments such as local, subnational, and national climate change plans and strategies.

The experts can be requested to indicate whether the listed options have been implemented in the case area or not to compare planned versus implemented actions. Developing previous individual analyses helps to avoid biases during the expert consensus panel (Morgan 2014; O'Hagan 2019). The local experts can verify or revise the list of options individually and later jointly finalize it during the facilitated group discussion (Phase III).

3.2.3 Phase III: Feasibility Assessment

de Coninck et al. (2018) present a framework to assess the feasibility of adaptation and mitigation options, considering multiple dimensions: economic, technological, institutional, sociocultural, environmental, and geophysical. For each dimension, a set of indicators are identified. Each option is assessed at the indicator level, where it is analyzed if that indicator blocks the implementation of an adaptation option. Singh et al. (2020b) extended the framework for assessing climate adaptation options. The assessment of 23 options is similar to that of de de Coninck et al. (2018) follows a global perspective based on available scientific literature and applies it to the current feasibility of each option. When performing the analysis, each indicator can be classified as follows: (A) the indicator could block the feasibility of the option; (B) the indicator does not have a positive or a negative effect on the feasibility of the option (i.e., no measurable effect); or, (C) the indicator does not pose any barrier to the feasibility of this option. In addition, when appropriate, one could indicate whether the indicator is not relevant (NA), there is no evidence (NE), or there is limited evidence (LE).

de Coninck et al. (2018) and Singh et al. (2020b) base their assessments using nineteen indicators within six feasibility dimensions. In its last assessment, the IPCC added an indicator of the benefits of gender equity (Ley et al. 2022). In the IPCC work, all dimensions and indicators have the same importance regarding the feasibility of adaptation options. No

contextual differences are considered. We propose using those indicators because (1) they are part of the IPCC's framework for feasibility assessment (de Coninck et al. 2018; Singh et al. 2020b; Ley et al. 2022), which has been adopted in the IPCC's Six Assessment cycle, already guiding research efforts (i.e., Williams et al. 2021; Ley et al. 2022; Tirado et al. 2022); (2) adopting the indicators allows generating information at the local level, that can support bottom-up planning, evaluation and reporting efforts (national adaptation plans, adaptation communications, etc.); and (3), the results of feasibility assessments could be somehow comparable, allowing to identify general or specific enablers or barriers for the implementation of adaptation efforts at different scales.

Considering the above, Phase III comprises the key steps of the feasibility assessment once the scope and indicators have been defined, as suggested by Singh et al. (2020b). **Figure III-2** outlines the steps to perform the assessments using local expert knowledge. We propose five specific steps as part of Phase III: (1) prepare and share the assessment tools; (2) conduct a facilitated group discussion; (3) conduct individual assessments; (4) collect and combine individual assessments; and (5) reporting and visualization of the results.

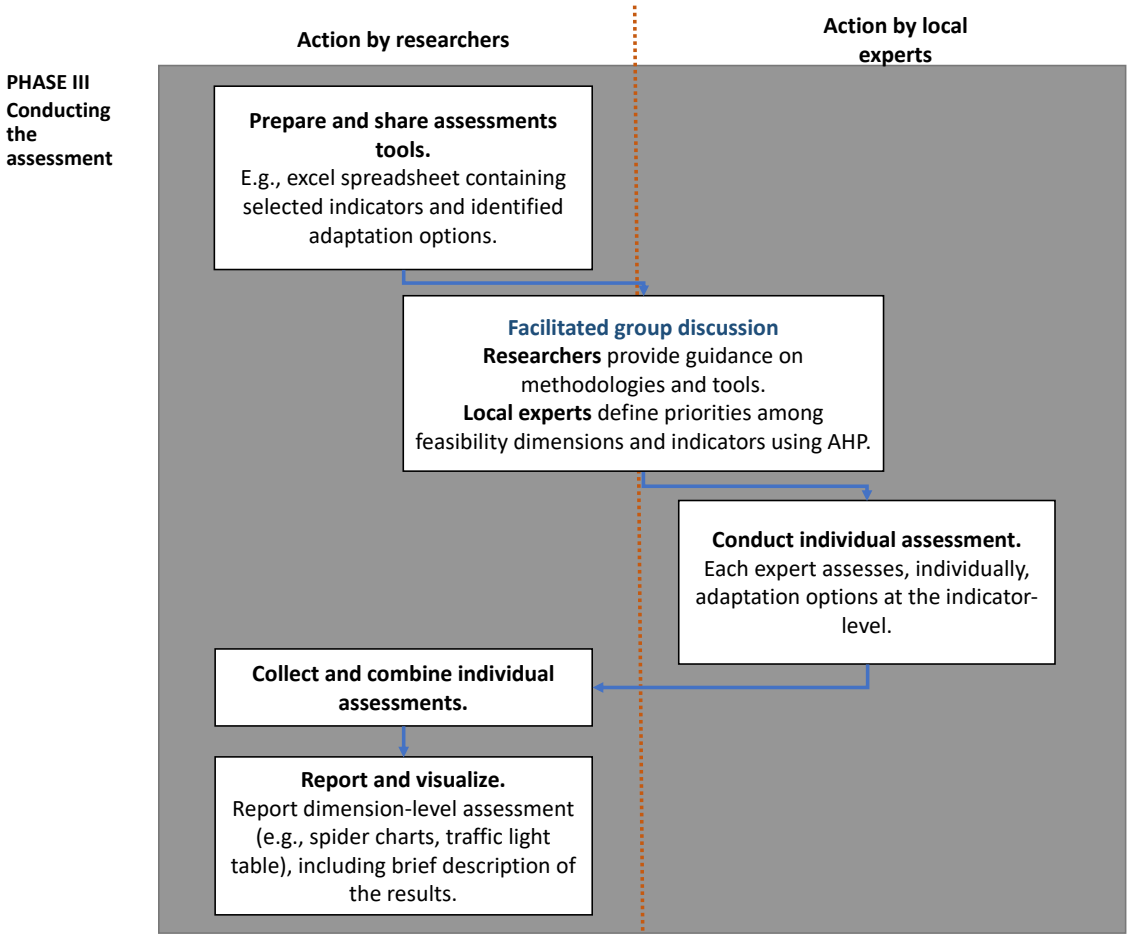


Figure III-2 *Phase III steps to perform the feasibility assessment using local expert expertise (modified from Singh et al. (2020b)*

As a methodological advancement, we propose to include the definition of the local priorities among the feasibility dimensions and criteria, as opposed to the IPCC framework, where all indicators are equally weighted. We perform the prioritization using the Analytical Hierarchy Process (AHP) (Saaty 2008), which is a multicriteria decision approach that allows the definition of priorities considering a specific objective. The AHP follows a hierarchy structure based on pairwise comparison and assigns numeric values to the judgments. Among its advantages is that the AHP allows local expertise integration and transparency and helps to

avoid biases. The method has been used for environmental-related analysis. Guillén Bolaños et al. (2016) outline the prioritization process using the AHP.

We propose to conduct the prioritization of dimensions and indicators using the AHP during a facilitated group discussion with the local experts. During the facilitated group discussion, guidance on the methodology and tool for the individual assessment must be provided. The tool (e.g., an Excel sheet) should include the adaptation options and the selected indicators to be assessed against. After collecting and combining the individual assessments, the results can then be classified, using a traffic light system, as "insignificant barriers – high feasibility" (2.5 – 3), "mixed or moderated but still existent barriers – medium feasibility" (1.5 – 2.5), or "significant barriers – low feasibility" (below 1.5) (de Coninck et al. 2018).

3.3 Applying the Framework: Assessing the Feasibility of Adaptation Options in Puerto Morazán, Nicaragua

We tested our framework for assessing the feasibility of climate adaptation options, using Puerto Morazán in Nicaragua as a case study. In this section, we briefly describe the results. Detailed information about the implementation of the framework can be found in S2 Text.

3.3.1 Identification of local Stakeholders and Experts

Stakeholders identification: We coordinated with representatives of the municipal authority (environmental and risks disaster management departments) and Centro Humboldt, a non-governmental organization that supported the coordination process. Together, the community representatives and stakeholders were identified. As a result, twelve local stakeholders (1 woman and 11 men) participated in the participatory integrative modeling technique workshop: four representing small-scale farmers, three fishermen, one shrimp farms representative, one local water committee representative, two municipality representatives, and one Ministry of Education representative.

Local experts identification: We identified three local experts: one representative of the municipal government and two independent consultants with broad expertise in climate, disaster risk reduction, conservation areas, and environmental management. Both independent experts have supported adaptation-related projects in the case study area.

Ethical statement and inclusivity in global research

Due to the research design, involving minimal risk to participants, and the setting of the institutions to which authors are affiliated, no prior ethical approval was obtained. Nevertheless, this research is framed under the DFG's policy for Ensuring Good Scientific Practice policy. In the case of the workshop developed in the case study area, co-organized by the local municipality, all participants were informed about the research's underlying context, methodology, and objectives. Formal consent procedures were not pursued, as the gathered data cannot be traced back to individual participants and poses no harm, being solely utilized for delineating the case study area. Confidentiality measures ensure anonymity, preventing the identification of workshop participants or their specific contributions. Additional information regarding the ethical, cultural, and scientific considerations specific to inclusivity in global research is included in the Supporting Information (S3 Checklist).

3.3.2 The Socio-ecological System

Puerto Morazán is a municipality located northwest of Nicaragua, part of the Central American Dry Corridor (CADC). Part of Puerto Morazán territories are located within the "Estero Real" natural protected area in the lower basin of the Estero Real River (**Figure III-3**). This section describes Puerto Morazán's socio-ecological system (SES) resulting from the participatory workshop (more information is available in S2 Text).

The workshop participants identified the protected area as the main asset in their territories. However, they prioritized and identified agricultural and livestock sectors as the most vulnerable to climate change. Therefore, the identification of adaptation options focused on these prioritized sectors. Droughts and –on a minor scale- floods were identified as the main climate-related hazards.

A*griculture* (mainly for subsistence) is, according to the local stakeholders, affected by climate change due to increased temperature, reduced precipitation, and higher frequency of droughts. Variations in minimum and maximum temperatures and relative humidity are also issues of concern. Droughts impact the yield productivity of different crops and agricultural systems, especially subsistence agriculture (i.e., corn, beans, and sorghum), sesame, and plantain plantations. Droughts can also affect water resources (including natural reservoirs) and monoculture activities (i.e., sugar cane and peanuts). However, it was indicated that, when needed, groundwater is extracted for monoculture activities (an option not available to smallholder farmers). Another negative impact of monoculture is the extensive use of agrochemicals (fertilizers and pesticides) for sugar cane plantations, which generates chemical pollution and affects water quality. At the same time, significant quantities of groundwater and surface water (i.e., from the Amayo River) are extracted for sugar cane plantations, which reduces water availability for smallholder farmers and rural communities in general. Reduced water availability indirectly affects the health and productivity of people involved in agriculture and livestock farming. Adaptation options identified for this sector are land-cover management, use of organic fertilizers and pesticides, diversification of crops and productive systems, and local climate monitoring.

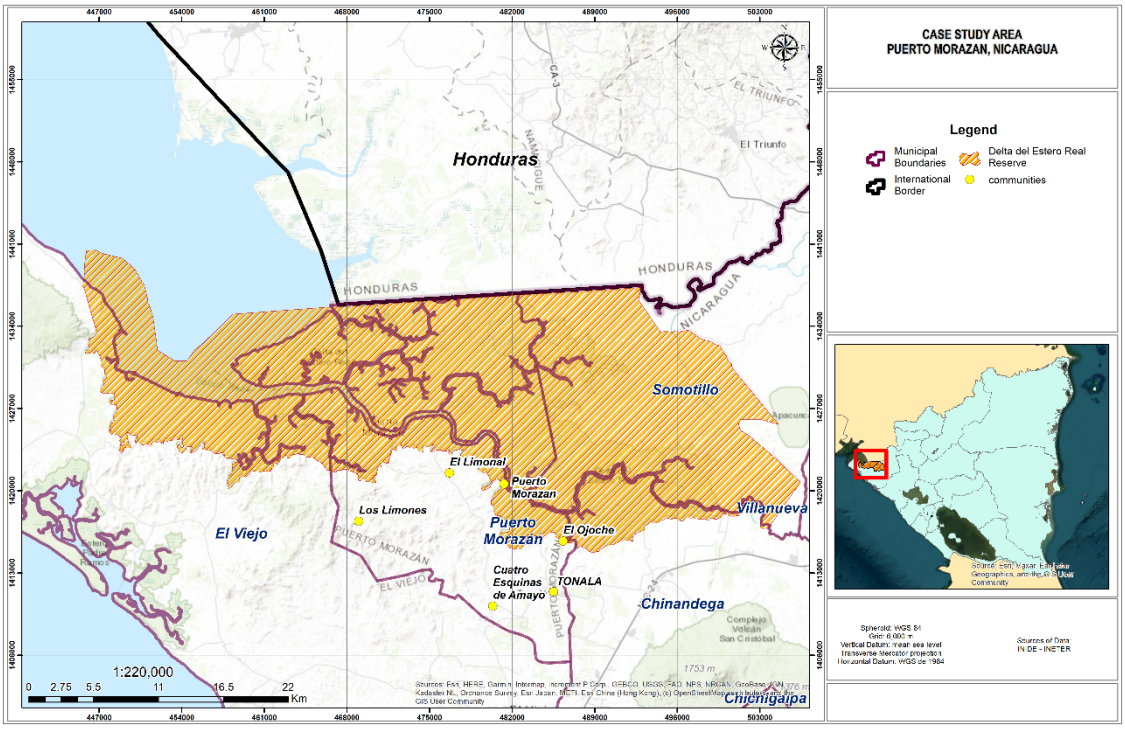


Figure III-3 *Case Study area: Puerto Morazán*

The stakeholders also identified the impacts of climate change on *livestock*. Similar to agriculture, drought is recognized as the main hazard. Drought generates water and heat stress on the cattle. At the same time, livestock activities are perceived as negatively impacting water availability, especially for agriculture (due to water extraction). The sector is also affected by the pollution generated by the agricultural industry (related to monoculture plantations) on the local water resources. Additionally, the stakeholders identified water availability as an adaptation limit. The adaptation measures identified for this sector are

controlled burning, technology, improved (climate-resilient) seeds, and cattle feed purchasing.

Adaptation options identified to reduce the risks posed by droughts to both prioritized sectors are watershed reforestation, change of crops, water harvesting, and irrigation systems.

3.3.3 Planned And Implemented Adaptation Options

There is limited information about planned or Implemented adaptation options in Puerto Morazán. Policy and planning instruments consider only a limited number of options. Initially, those practices were not implemented to respond to climate change but to other environmental challenges (i.e., soil, water, and ecosystem degradation). Additionally, most options have been implemented in isolated and short-term initiatives or as autonomous strategies from smallholder farmers or livelihoods, not part of long-term strategic programs.

As a result of the participatory workshop complemented by desktop analysis, we identified sixteen adaptation options for Puerto Morazán's agricultural and livestock sectors (**Table III-1**). Seven options relate to both sectors, five to agriculture and three to livestock. One is an overarching option, which does not only apply to both prioritized sectors. Section B of the supplementary material (S2 Text) includes the option's description based on reports of adaptation efforts in Nicaragua (MARENA 2018; FAO 2021).

Table III-1 *Adaptation options identified in Puerto Morazán*

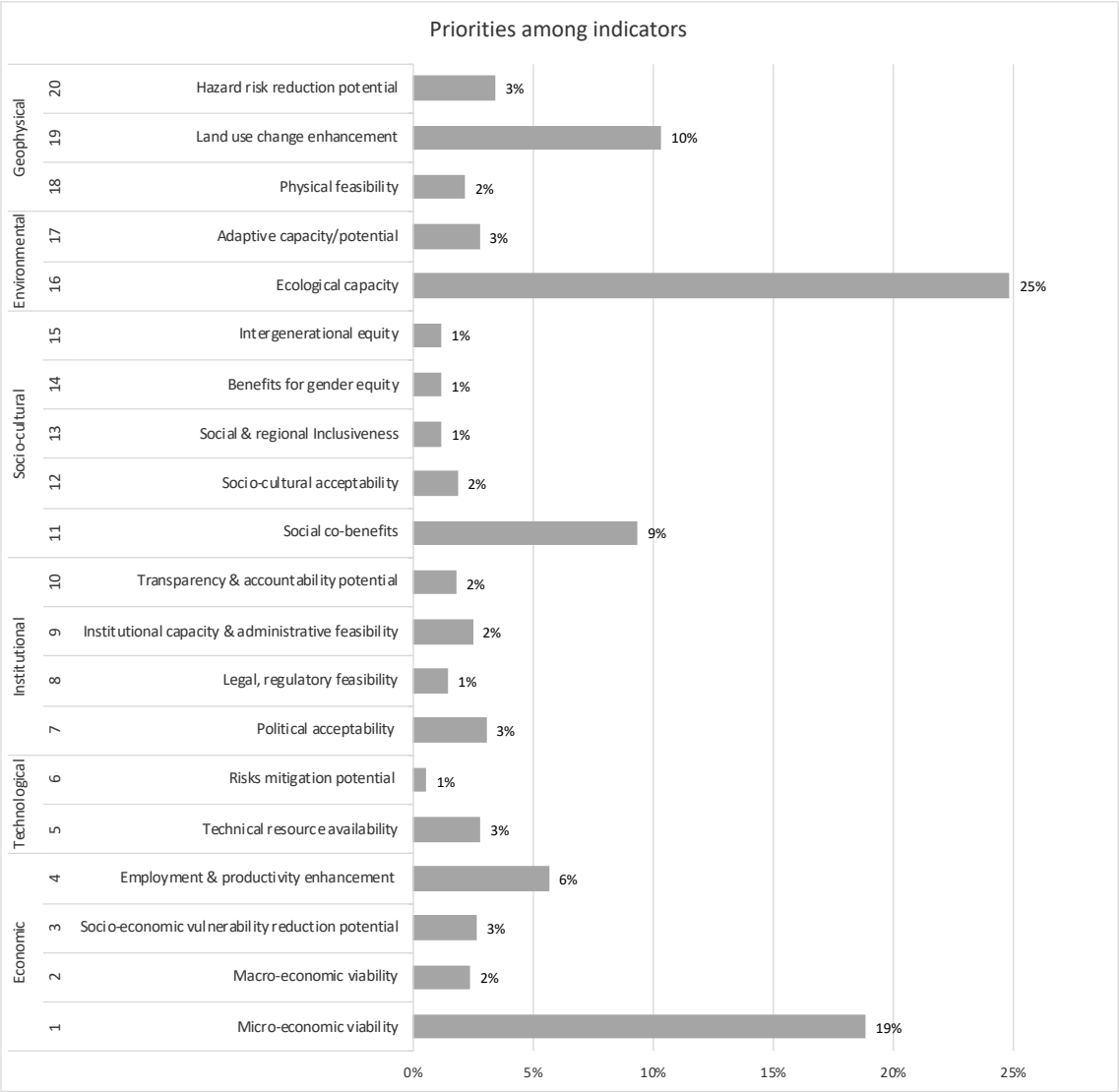
No	*Adaptation option*	*No*	*Adaptation option*
	AGRICULTURE & LIVESTOCK		**AGRICULTURE**
1	On-farm irrigation and water management	**8**	Agroforestry
2	Reforestation	**9**	Adjustment in plantation timing
3	Soil and water conservation practices	**10**	Use of organic fertilizers, pesticides
4	Agricultural diversification (e.g., mixed systems, new varieties)	**11**	Change or introduction of new varieties
5	Climate-resilient seeds (including native seeds)	**12**	Early warning systems (including local climate monitoring)
6	Water harvesting		
7	Elimination or controlled burning of pasture-agricultural land		
	LIVESTOCK		**OVERARCHING**
13	Implementation of silvopastoral systems	**16**	Land-use planning
14	Improvement of pasture and forage and establishment of grass forage banks		
15	Pasture rotation		

3.3.4 Feasibility Assessment

3.3.4.a Defined Priorities Among Dimensions And Indicators

As result of the AHP pairwise comparison, where the local experts identified their priorities, the economic and environmental dimensions resulted as the most important feasibility dimensions for climate adaptation-related options of Puerto Morazán. The feasibility dimensions with less priority are the institutional and technological ones. As a result of the prioritization, the indicators ranked as the most important for the assessment are ecological capacity, micro-economic viability, social co-benefits, and land-use change enhancement (**Figure III-4**).

(A)



(B)

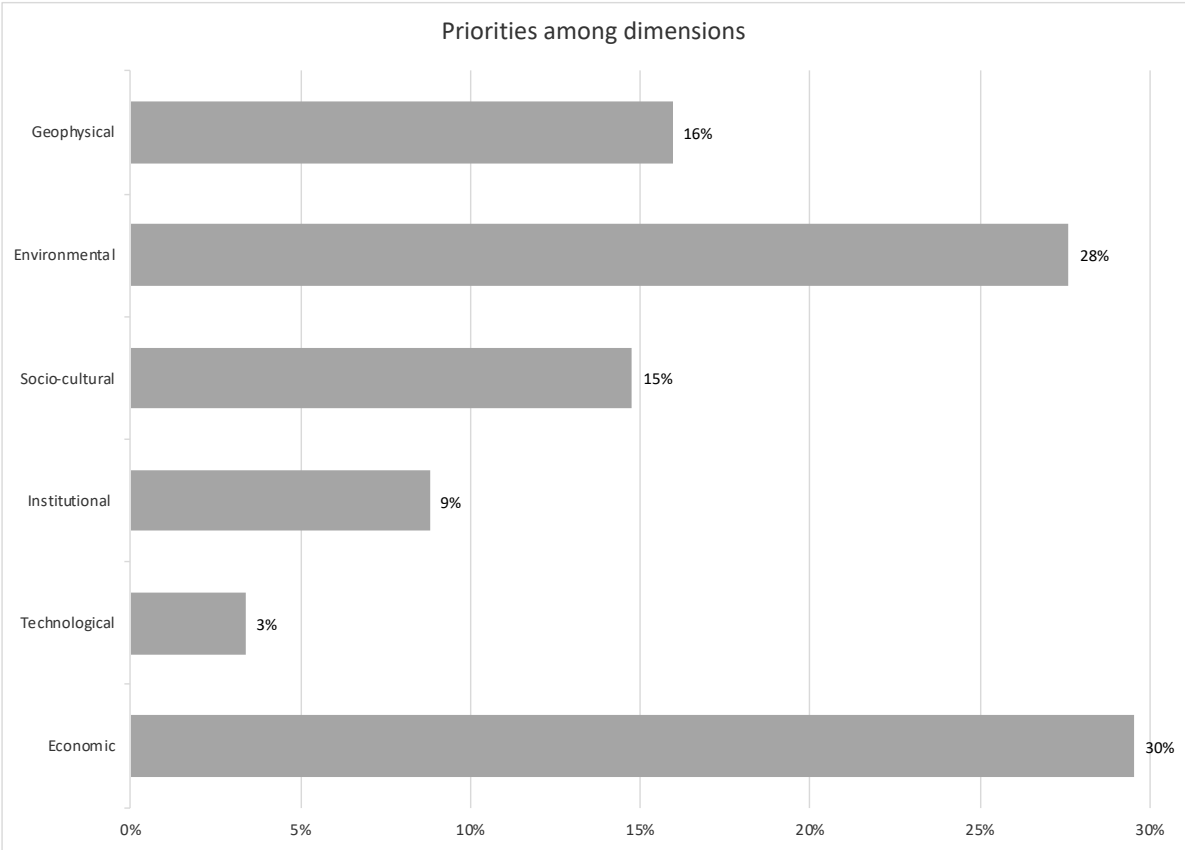


Figure III-4 *Priorities among indicators (Panel A) and dimensions (Panel B) identified by local experts using the AHP.*

3.3.4.b Overall Feasibility Of Adaptation Options

Table **III-2** shows the overall feasibility of the identified adaptation options in Puerto Morazán. We present two results: one following the process laid by de Coninck et al. (2018) and Singh et al. (2020b), where no local priorities are considered, and one in which the priorities, obtained using the AHP are considered. In the first assessment, all options were resulted in "medium feasibility." However, when considering the local priorities, the results of reforestation, soil and water conservation practices, and agroforestry change from “medium” to “high” feasibility.

No options were assessed with low feasibility in either assessment, which shows that the potential to implement the identified options can increase if policymakers and practitioners use the results to create more suitable enabling conditions. However, the results can also indicate that most options are well-known, and technical resources and capacities might be already available but need to be adequately allocated.

Table III-2 *Overall feasibility of adaptation options. Green: High feasibility (insignificant barriers). Yellow: Medium Feasibility (mixed or moderate but still existent barriers). Red: Low feasibility (Multiple barriers, in this dimension, may block implementation).*

	No.	Adaptation option	Overall feasibility	
			No local priorities considered	Local priorities considered
Agriculture and livestock	1	On-farm irrigation and water management		
	2	Reforestation		
	3	Soil and water conservation practices		
	4	Agricultural diversification (e.g., mixed systems, new varieties)		
	5	Climate-resilient seeds (including native seeds)		
	6	Water harvesting		
	7	Elimination or controlled burning of pasture-agricultural land		
Agriculture	8	Agroforestry		
	9	Adjustment in plantation timing		
	10	Use of organic fertilizers, pesticides		
	11	Change or introduction of new varieties		
	12	Early warning systems (including local climate monitoring)		
Livestock	13	Implementation of silvopastoral systems		
	14	Improvement of pasture and forage and establishment of grass forage banks		
	15	Pasture rotation		
	16	Land-use planning		

3.3.4.c Feasibility of The Options by Dimensions

There is a need to identify the feasibility within the feasibility dimensions, which can allow for the creation of more suitable enabling conditions for implementing adaptation options. Therefore, **Table III-3** shows the assessment results of the adaptation options for each of the six dimensions, considering the original framework and the methodological advance we propose. Additionally, we briefly describe the main findings of the assessment for each option (more detailed information S2 Text).

Table III-3 shows that no option resulted in low feasibility for any dimension. Among the seven options identified for both *sectors*, on-farm irrigation and water management, climate-resilient seeds, and elimination or controlled burning of pasture-agricultural land resulted in medium feasibility in all dimensions, even considering local priorities. On the other hand, reforestation and soil and water conservation practices resulted in high feasibility in the geophysical dimensions. Agricultural diversification of productive systems resulted in high feasibility in the technological dimension in both assessments. Finally, water harvesting obtained high feasibility in the economic dimension in both assessments. However, the

sociocultural dimension varied from “medium” to “high” feasibility when considering local priorities.

Among the options identified for the *agricultural* sector, the adjustment in plantation timing, change-introduction of new varieties, and early warning systems resulted in “medium” feasibility in all dimensions in both assessments. Agroforestry obtained high feasibility in the technological and environmental dimensions in both assessments. Drip irrigation resulted in high feasibility in the economic dimension in both assessments. However, using organic fertilizers or pesticides obtained “medium” feasibility in all dimensions when local priorities were not considered. When local priorities were considered, the feasibility of this option changed to “high” feasibility in the sociocultural dimension.

Regarding options identified for the *livestock* sector, pasture rotation obtained “medium” feasibility in all dimensions in both assessments. Implementation of silvopastoral systems resulted in high feasibility in the environmental dimension in both assessments. However, the assessment of the economic dimension changed from medium to high in the economic dimension when considering the local priorities. Improvement of pasture and forage obtained high feasibility in the environmental dimension in both assessments.

Land-use planning obtained medium feasibility in the economic and geophysical dimensions and low feasibility in the institutional dimension in both assessments. However, the feasibility increased from medium to high in the sociocultural dimension when the priorities were considered in the analysis.

Table III-3 *Feasibility of adaptation options per dimension. Green: High feasibility (insignificant barriers). Yellow: Medium Feasibility (mixed or moderate but still existent barriers). Red: Low feasibility (Multiple barriers, in this dimension, may block implementation). (NLP) No local priorities considered; (LP) Local priorities considered*

Sector		Dimension	Economic		Technological		Institutional		Sociocultural		Env. / ecological		Geophysical		
	No.	Adaptation option	NLP	LP	NLP	LP	NLP	LP	NLP	LP	NLP	LP	NLP	LP	Context
Agriculture and livestock	1	On-farm irrigation and water management													Barriers in all dimensions. The institutional and geophysical capacities (i.e., water availability) present the highest limitations. In the sociocultural dimension, intergenerational equity ranks the lowest.
	2	Reforestation													The institutional and sociocultural dimensions rank the lowest in the assessments.
	3	Soil and water conservation practices													The institutional and sociocultural dimensions rank the lowest in the assessments.
	4	Agricultural diversification (e.g., mixed systems, new varieties)													Barriers exist, especially in the economic and institutional dimensions. There might be challenges regarding the ecological capacity.
	5	Climate-resilient seeds (including native seeds)													Barriers in all dimensions exist, especially in environmental and geophysical dimensions.
	6	Water harvesting													Sociocultural feasibility increases when local priorities are considered. The technological dimension ranks the lowest.

Sector		Dimension	Economic		Technological		Institutional		Sociocultural		Env. / ecological		Geophysical		
	No.	Adaptation option	NLP	LP	NLP	LP	NLP	LP	NLP	LP	NLP	LP	NLP	LP	Context
Agriculture	7	Elimination or controlled burning of pasture-agricultural land													Barriers in all dimensions exist. Economic and technological dimensions rank the lowest.
	8	Agroforestry													Technological and institutional dimensions rank the lowest.
	9	Adjustment in plantation timing													Barriers in all dimensions. Economic and technological dimensions rank the lowest.
	10	Use of organic fertilizers, pesticides													Sociocultural feasibility increases when local priorities are considered. Technological and institutional dimensions rank the lowest.
	11	Change or introduction of new varieties													Barriers in all dimensions exist. Technological, environmental, and geophysical dimensions rank the lowest.
	12	Early warning systems (incl. local climate monitoring)													Barriers in all dimensions. Geophysical, economic, and technological dimensions rank the lowest.
Livestoc	13	Implementation of silvopastoral systems													Economic feasibility increases when local priorities are considered. Institutional and sociocultural dimensions rank the lowest.

Sector		Dimension	Economic		Technological		Institutional		Sociocultural		Env. / ecological		Geophysical		
	No.	Adaptation option	NLP	LP	NLP	LP	NLP	LP	NLP	LP	NLP	LP	NLP	LP	Context
	14	Improvement of pasture and forage													Institutional and economic dimensions rank the lowest.
	15	Pasture rotation													Barriers in all dimensions. Institutional and sociocultural dimensions rank the lowest.
	16	Land-use planning													Technological and institutional dimensions rank the lowest. Sociocultural feasibility increases when local priorities are considered.

3.4 Discussion

We propose a framework to conduct local feasibility assessments of adaptation options, advancing the literature-based IPCC's framework. The proposal is based on participative approaches to integrate local knowledge and expertise, allowing the inclusion of local priorities in adaptation assessments. With this advancement, we aim to foster a process to generate evidence on climate adaptation efforts in regions where this information is scarce. In this way, we aim to help overcome barriers to implementing adaptation actions.

We used Puerto Morazán, in Nicaragua, as the case study area to test our proposal. Following the proposed framework, we identified adaptation options, included local priorities, and conducted the feasibility assessment. For this, we used participatory approaches and expert knowledge and expertise.

Below, we present general reflections on the findings related to the case study area, linking them to current literature. Additionally, we discuss the methodological advances presented in our work. Finally, we also discuss policy implications and future research.

3.4.1 Climate Adaptation in Puerto Morazán

During our research, we confirmed that despite the high vulnerability of Puerto Morazán to climate-related hazards, there is limited information available regarding observations, impacts, projections, and the implementation of adaptation options. That information is also missing in local climate policy and planning instruments. The lack or limited climate-related information is not unique to Puerto Morazán. It is common in adaptation planning instruments in Central American countries where monitoring and evaluation systems are not in place, the local observation networks are weak, there is no access to observational data, and there is little coordination among the related institutions (Moreno et al. 2020; Castellanos et al. 2022; Ley et al. 2023).

Moreover, despite the current and projected risks, only a limited number of adaptation options are considered in planning or policy instruments related to the case study area. A mismatch exists between the available climate adaptation-related literature (e.g., Olsson et al. 2019; Bezner Kerr et al. 2022) and local planning instruments and climate action. The identification of adaptation options, mainly developed with a participatory component, still relies on past experiences, as pointed out by Conway et al. (2019). Moreover, most of the options identified for Puerto Morazán can be categorized as "incremental" adaptation, which is defined as an "extension of actions and behaviors" (IPCC 2022, p. 2899), as they have been part of agricultural and conservation practices promoted for decades. In addition, adaptation planning or implementation happens on a small scale and as isolated actions. Additionally, the options represent the modification to usual practices and are implemented for single sectors or small geographic areas. These results align with the findings of recent global assessments (Adger et al. 2003; Ara Begum et al. 2022; O'Neill et al. 2022).

The ranking resulting from the feasibility assessment aligns with de Sousa et al. (2018) and Castellanos et al. (2022) found that reforestation and sustainable soil management are the preferred options among Central American farmers. Castellanos et al. (2022) also identify preventing measures against soil erosion among the options implemented in the region.

3.4.2 Methodological Advances

We propose to improve the feasibility assessment framework by incorporating local expert knowledge and priorities to evaluate the adaptation options identified for the prioritized sectors in Puerto Morazán, Nicaragua. The IPCC's framework, based on scientific literature, was designed for global scientific assessments. This literature is not always available for subnational scales or small communities in the Global South. Therefore, our proposal allows

for transferring concepts, methodologies, and approaches discussed in the latest literature to where that information is crucial. We advanced the methodology by identifying (1) adaptation options, (2) local priorities among the indicators and dimensions proposed in the original framework, and (3) by allowing local experts to perform the assessment.

The results confirmed the importance of including local knowledge and expertise and local priorities. When those aspects were considered, the assessment's results changed. Therefore, we align with the scholarship calling for stronger inclusion of local and expert knowledge and priorities during the different steps of the adaptation policy and implementation cycle (New et al. 2022). Facilitating such methodologies to local stakeholders improves translation of global narratives into practice in the territories. Additionally, deploying such methods also allows for the exchange and increase of the technical capacities of local experts.

While we acknowledge that the number of experts participating in our example is small (three), we believe it demonstrates the framework's potential. A small sample size might result from little work on climate adaptation in an area or other challenges (including socio-political contexts that create barriers to research efforts). Therefore, we recommend including as many local experts as possible in future similar endeavors. Additionally, our proposal and the results for the case study area can serve to generate evidence and identify leverage points for implementing climate adaptation options, for example, by looking at the results of the feasibility dimensions and indicators.

3.4.3 Policy Implications

Using Puerto Morazán as a showcase, we present an overview of the feasibility of the identified options, considering the current situation (i.e., local context, global warming of 1.1°C). However, decision-makers and practitioners could use the advanced framework to analyze how the feasibility of the options could change with, for example, further increases in global warming (hard limits), new policy implementation, or higher investment (soft limits). For this, more detailed information will be required, especially climate observations, projections, and evaluation of the options (e.g., information on the productivity of a particular crop under a certain level of global warming).

The challenges related to climate adaptation faced by Puerto Morazán are not unique. So, the proposed framework can be helpful for, but not exclusive to, other rural communities, especially those in the Central American Dry Corridor, a region identified as highly vulnerable to climate change. The framework could help to fill the gap in empirical evidence available regarding the region (Castellanos et al. 2022; Segura et al. 2022; Ley et al. 2023). Evidence can support the development of new and more transformative adaptation policies, improve implementation processes and outcomes, and allocate resources to face climate-related challenges, especially in reducing risk from the most vulnerable communities. Additionally, the evidence can showcase success and lessons learned, information limited in the region-related available literature.

Our analysis follows the approach presented in the analyzed policy and planning tools, where adaptation options are offered individually. However, we recognize that climate action and research cannot continue using siloed perspectives. This type of perspective challenges the analysis of, for example, potential synergies and trade-offs between the options, as was the case of Puerto Morazán, where no strong connection was identified between the prioritized sectors and the nearby protected area. Therefore, we recognize great potential in working with more systemic approaches, such as those proposed by the IPCC (2018, 2022). (i.e., system transitions, adaptation pathways, climate-resilient development pathways). Those approaches enable a more complete view, including aspects related to stakeholder enabling, participation, and involvement in transition processes needed to face current and expected challenges posed by climate change.

3.5 Conclusions

With our work, we confirm that local expert knowledge elicitation can help overcome the problem of the absence of data and information. Our results also corroborate that including local priorities changes the result of the assessments, hence their importance. Finally, we provide evidence of planned and implemented adaptation options for our case study area.

Additionally, our proposal could support generating information to help subnational and national processes (e.g., NAPs, NDCs) or scientific efforts (e.g., IPCCs assessment cycles) informing, for example, higher policy levels such as the UNFCCC's Global Stocktake.

We found that implementing adaptation options in Puerto Morazán, our case study area is still very limited and small in scale despite having identified a range of options that could be implemented. We presume that feasibility can be increased by allocating more financial and human resources to adaptation action in the region. The identified options are primarily presented in isolation, while their potential could thrive if given as complementary or part of adaptation pathways, considering synergies and trade-offs with development and biodiversity policies.

Additionally, future research efforts could focus on taking a deeper look at the feasibility indicators to identify leverage points and propose ways to improve the planning and implementation of adaptation; moreover, Singh et al. (2020b) suggested that future efforts can consider what different climate and socio-economic scenarios mean for the feasibility of adaptation options, as there is an imperative need for robust but adaptive plans to avoid lock-ins or maladaptation.

Acknowledgments

The authors thank and acknowledge the contributions of Puerto Morazán local stakeholders who participated in the workshop and Centro Humboldt's team for their support in developing this research. Additionally, we thank C. Singh, D. Ley, and E. Gilmore for their input to an early draft of this article. We thank J. Guevara for facilitating Puerto Morazán's map.

Competing interests

The authors declare no competing interest.

3.6 Chapter III References

Abram, N., Gattuso, J.-P., Prakash, A., et al (2019) Chapter 1: Framing and Context of the Report. In: Special Report on the Ocean and Cryosphere in a Changing Climate. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 73–129

Adger WN, Huq S, Brown K, et al (2003) Adaptation to climate change in the developing world. Prog Dev Stud 3:179–195

Ara Begum R, Lempert R, Ali E, et al (2022) Point of departure and key concepts. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, USA, pp 121–196

BenDor TK, Scheffran J (2019) Agent-Based Modeling of Environmental Conflict and Cooperation. CRC Press, Boca Raton, Fl.

Berrang-Ford L, Biesbroek R, Ford J, et al (2019) Tracking global climate change adaptation among governments. Nat Clim Change 9:440–449. https://doi.org/10.1038/s41558-019-0490-0

Berrang-Ford L, Siders AR, Lesnikowski A, et al (2021) A systematic global stocktake of evidence on human adaptation to climate change. Nat Clim Change 11:989–1000. https://doi.org/10.1038/s41558-021-01170-y

Bezner Kerr R, Hasegawa T, Lasco R, et al (2022) Food, fibre, and other ecosystem products. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, USA, pp 713–906

Castellanos E, Lemos MF, Astigarraga L, et al (2022) Central and South America. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, USA, pp 1689–1816

Celliers L, Rölfer L, Rivers N, et al (2023) Stratification of stakeholders for participation in the governance of coastal social-ecological systems. Ambio 52:1418–1430. https://doi.org/10.1007/s13280-023-01844-1

Conway D, Nicholls RJ, Brown S, et al (2019) The need for bottom-up assessments of climate risks and adaptation in climate-sensitive regions. Nat Clim Change 9:503–511. https://doi.org/10.1038/s41558-019-0502-0

Cvitanovic C, Howden M, Colvin RM, et al (2019) Maximising the benefits of participatory climate adaptation research by understanding and managing the associated challenges and risks. Environ Sci Policy 94:20–31. https://doi.org/10.1016/j.envsci.2018.12.028

de Coninck H, Revi A, Babiker M, et al (2018) Strengthening and implementing the global response. In: Masson-Delmotte V, Zhai P, Pörtner HO, et al. (eds). Global Warming of 15°C: IPCC Special Report on Impacts of Global Warming of 15°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 313–444

de Sousa K, Casanoves F, Sellare J, et al (2018) How climate awareness influences farmers' adaptation decisions in Central America? J Rural Stud 64:11–19. https://doi.org/10.1016/j.jrurstud.2018.09.018

Dilling L, Lemos MC (2011) Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. Glob Environ Change 21:680–689. https://doi.org/10.1016/j.gloenvcha.2010.11.006

FAO (2021) Catálogo de medidas de adaptación al cambio climático para el Corredor Seco de Nicaragua. Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO), Managua, Nicaragua

Gómez E, Máñez M (2019) Deliverable 5.5. DEMOs framework prototype for participatory integrated planning, Hamburg, Germany

Guillén Bolaños T, Mánez C. M, Nehren U (2016) Development of a prioritization tool for climate change adaptation measures in the forestry sector. Climate Service Center Germany (GERICS), Hamburg, Germany

Guillén Bolaños T, Scheffran J, Máñez Costa M (2022) Climate Adaptation and Successful Adaptation Definitions: Latin American Perspectives Using the Delphi Method. Sustainability 14:5350. https://doi.org/10.3390/su14095350

IPCC (2022) 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, UK and New York, USA

IPCC (2018) Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Cambridge University Press, Cambridge, UK and New York, NY, USA

Juhola S, Glaas E, Linnér BO, Neset TS (2016) Redefining maladaptation. Environ Sci Policy 55:135–140. https://doi.org/10.1016/j.envsci.2015.09.014

Leiter T (2021) Do governments track the implementation of national climate change adaptation plans? An evidence-based global stocktake of monitoring and evaluation systems. Environ Sci Policy 125:179–188. https://doi.org/10.1016/j.envsci.2021.08.017

Lesnikowski A, Ford JD, Berrang-Ford L, et al (2015) How are we adapting to climate change? A global assessment. Mitig Adapt Strateg Glob Change 20:277–293. https://doi.org/10.1007/s11027-013-9491-x

Lesnikowski A, Ford JD, Biesbroek R, Berrang-Ford L (2019) A policy mixes approach to conceptualizing and measuring climate change adaptation policy. Clim Change 1–23. https://doi.org/10.1007/s10584-019-02533-3

Ley D (2017) Sustainable Development, Climate Change, and Renewable Energy in Rural Central America. In: J. Uitto, J. Puri, R. van den Berg (eds) Evaluating Climate Change Action for Sustainable Development. Springer Nature, Cham, Switzerland

Ley D, Adams H, Araos M, et al (2022) Cross-Chapter Box FEASIB: Feasibility Assessment of Adaptation Options: An Update of the SR1.5. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK and New York, USA, pp 2769–2807

Ley D, Guillén Bolaños T, Castaneda A, et al (2023) Central America urgently needs to reduce the growing adaptation gap to climate change. Front Clim 5:. https://doi.org/10.3389/fclim.2023.1215062

Máñez M, Osorio J, Kovalevsky D (2017) Deliverable D13.1. Generic Integrative Modeling Approach

MARENA (2018) Estudio de tecnologías de adaptación al cambio climático en sectores priorizados. In: Tercera Comunicación Nacional de Cambio Climático - Nicaragua. Ministerio del Ambiente y de los Recursos Naturales (MARENA), Managua, Nicaragua

Moreno JM, Laguna-Defior C, Barros V, et al (2020) Adaptación frente a los riesgos del cambio climático en los países iberoamericanos. Informe RIOCCADAPT. McGraw-Hill, Madrid, España

Morgan MG (2014) Use (and abuse) of expert elicitation in support of decision making for public policy. Proc Natl Acad Sci 111:7176–7184. https://doi.org/10.1073/pnas.1319946111

Nalau J, Preston B, Maloney, M (2015) Is adaptation a local responsibility? Environ Sci Policy 48:89–98. https://doi.org/10.1016/j.envsci.2014.12.011

Nalau J, Verrall B (2021) Mapping the evolution and current trends in climate change adaptation science. Clim Risk Manag 32:1–22. https://doi.org/10.1016/j.crm.2021.100290

New M, Reckien D, Viner D, et al (2022) Decision Making Options for Managing Risk. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, USA, pp 2539–2654

O'Hagan A (2019) Expert Knowledge Elicitation: Subjective but Scientific. Am Stat 73:69–81. https://doi.org/10.1080/00031305.2018.1518265

Olsson L, H. Barbosa, S. Bhadwal, et al (2019) Land Degradation. In: H.-O. Pörtner, D. C. Roberts, P. Zhai, et al (eds) Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Cambridge University Press, Cambridge, UK, pp 345–436

O'Neill B, van Aalst M, Zaiton Ibrahim Z, et al (2022) Key risks across sectors and regions. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change. Cambridge University Press, Cambridge, UK and New York, USA, pp 2411–2538

Pollo A, Piccini I, Chiara J, et al (2022) An Innovative Approach for Subnational Climate Adaptation of Biodiversity and Ecosystems: The Case Study of a Regional Strategy in Italy. Sustainability 14:6115. https://doi.org/10.3390/su14106115

Saaty TL (2008) Decision making with the analytic hierarchy process. Int J Serv Sci 1:83–98. https://doi.org/10.1504/IJSSCI.2008.017590

Scott H, Moloney S (2022) Completing the climate change adaptation planning cycle: monitoring and evaluation by local government in Australia. J Environ Plan Manag 65:650–674. https://doi.org/10.1080/09640568.2021.1902789

Segura LD, van Zeijl-Rozema A, Martens P (2022) Climate change adaptation in Central America: A review of the national policy efforts. Lat Am Policy. https://doi.org/10.1111/lamp.12277

Sietsma AJ, Ford J, Callaghan M, Minx J (2021) Progress in climate change adaptation research. Environ Res Lett 16:14. https://doi.org/10.1088/1748-9326/abf7f3

Singh C, Bazaz A, Ley D, et al (2020a) Assessing the feasibility of climate change adaptation options in the water sector: Examples from rural and urban landscapes. Water Secur 11:100071. https://doi.org/10.1016/j.wasec.2020.100071

Singh C, Ford J, Ley D, et al (2020b) Assessing the feasibility of adaptation options: methodological advancements and directions for climate adaptation research and practice. Clim Change 162:255–277. https://doi.org/10.1007/s10584-020-02762-x

Tirado MC, Vivero-Pol JL, Bezner Kerr R, Krishnamurthy K (2022) Feasibility and Effectiveness Assessment of Multi-Sectoral Climate Change Adaptation for Food Security and Nutrition. Curr Clim Change Rep 8:35–52. https://doi.org/10.1007/s40641-022-00181-x

UNEP (2022) Adaptation Gap Report 2022: Too Little, Too Slow - Climate adaptation puts world at risk. Nairobi

UNEP (2017) The adaptation gap report: Towards global assessment. United Nations Environment Programme (UNEP), Nairobi, Kenya

UNFCCC (2015) Decision 1/CP.21 Adoption of the Paris Agreement. United Nations Framework Convention on Climate Change, Paris, France

von der Forst E (2018) Climate Change Vulnerability of Socio-Ecological Systems in Coastal Areas of River Basins in Mexico and South Africa – from Assessment to Management. University of Hamburg, Germany

Williams DS, Celliers L, Unverzagt K, et al (2020) A Method for Enhancing Capacity of Local Governance for Climate Change Adaptation. Earths Future 8:1–16. https://doi.org/10.1029/2020EF001506

Williams PA, Simpson NP, Totin E, et al (2021) Feasibility assessment of climate change adaptation options across Africa: An evidence-based review. Environ Res Lett 16:. https://doi.org/10.1088/1748-9326/ac092d

3.7 Chapter III Supplementary Information

SI Text - Feasibility Assessment Guidance and Legends

- The feasibility assessment we present is based on the IPCC framework (de Coninck et al. 2018; Singh et al. 2020; Ley et al. 2022).
- An Excel sheet listing the twenty indicators and the identified options to be analyzed was prepared and shared with local experts.
- Each local expert assessed the indicator-option combination. As a result, each combination had an assigned value (S1 Table 1).

S1 Table 1. Legend of the feasibility assessment (based on de Coninck et al. 2018)

Entry for indicator-option combination	***Value***	***Guidance for conducting the feasibility assessment of adaptation options***
A	1	The indicator could block the feasibility of this option.
B	2	The indicator does not have a positive nor a negative effect on the feasibility of the option.
C	3	The indicator does not pose any barrier to the feasibility of this option.
NA (not applicable)	0	Not applicable
NE (no evidence)	0	No evidence
LE (limited evidence)	0	Limited evidence

S1 Table 2. Legend of the overall feasibility assessment of each option of the dimension-options combination (based on de Coninck et al. 2018)

#indicators	*Number of indicators used to assess the overall feasibility of a dimension, typically two to five*	***#A***	*Number of indicators assessed as A*
#NA	Number of indicators that are not applicable (NA) to the option	**#B**	Number of indicators assessed as B
#NE&LE	Total number of indicators for which there is no evidence (NE) or limited evidence (LE)	**#C**	Number of indicators assessed as C
#effective indicators	#effective indicators = #indicators – #NA	**AVG**	AVG = (1*#A + 2*#B + 3*#C)/(#effective indicators – NE&LE)

S1 Table 3. Legend of the overall feasibility assessment of each option of the dimension-options combination (based on de Coninck et al. 2018)

	AVG ≤ 1.5	*Multiple barriers, in this dimension, may block implementation.*
	1.5 < AVG ≤ 2.5	Mix or moderate but still existent barriers
	AVG > 2.5	Few feasibility barriers

Steps for including local priorities

S1 Table 4 presents the fundamental scale of absolute numbers, which is used to perform the pairwise comparison according to the Analytical Hierarchy Process (AHP) (Saaty 2008).

The AHP steps based on Guillén Bolaños et al. (2016, p. 20):

1. Objective and alternatives definition
2. Criteria and indicator definition (hierarchy structuration)
3. Weighting of criteria and indicators
4. Definition of priorities (ranking)
5. Sensitivity analysis

S1 Table 4 Fundamental scale of absolute numbers based on Saaty (2008).

Intensity of importance	***Definition***	***Explanation***
1	Equal importance	Two indicators are equally important to the objective.
3	Moderate importance	Experience and judgment strongly favor one indicator over another.
5	Strong importance	Experience and judgment strongly favor one indicator over another.
7	Very strong or demonstrated importance	An indicator is favored very strongly over another; its dominance is demonstrated in practice.
9	Extreme importance	The evidence favoring one indicator over another is of the highest possible order of affirmation.
Reciprocals of above	If indicator *i* has one of the above non-zero numbers assigned to it when compared with indicator *j*,	A reasonable assumption.

Intensity of importance	*Definition*	*Explanation*
	then *j* has the reciprocal value when compared with *i*	
1.1-1.9	If the indicators are very close	It may be difficult to assign the best value, but when compared with other contrasting activities, the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

References S1 Text

de Coninck H, Revi A, Babiker M, et al (2018) Strengthening and implementing the global response. In: Masson-Delmotte V, Zhai P, Pörtner HO, et al. (eds). Global Warming of 15°C: IPCC Special Report on Impacts of Global Warming of 15°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 313–444

Guillén Bolaños T, Mánez C. M, Nehren U (2016) Development of a prioritization tool for climate change adaptation measures in the forestry sector. Climate Service Center Germany (GERICS), Hamburg, Germany

Ley D, Adams H, Araos M, et al (2022) Cross-Chapter Box FEASIB: Feasibility Assessment of Adaptation Options: An Update of the SR1.5. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK and New York, USA, pp 2769–2807

Saaty TL (2008) Decision making with the analytic hierarchy process. IJSSCI 1:83–98. https://doi.org/10.1504/IJSSCI.2008.017590

Singh C, Ford J, Ley D, et al (2020) Assessing the feasibility of adaptation options: methodo-logical advancements and directions for climate adaptation research and practice. Climatic Change 162:255–277. https://doi.org/10.1007/s10584-020-02762-x

S2 Text - Applying the framework: assessing climate adaptation in Puerto Morazán

A. Description of Puerto Morazán, Nicaragua

Puerto Morazán is a municipality located northwest of Nicaragua, part of the Central American Dry Corridor (CADC). The CADC territories are already experiencing warming and drying trends. As a result, aridity and agricultural and ecological drought are increasing. Mean annual and summer precipitation are likely to decrease. However, there is uncertainty regarding the magnitude of the changes (Hidalgo et al. 2019; Arias et al. 2021; Depsky and Pons 2021; Stewart et al. 2022). The Central and South American region is identified with more evidence on constraints and limits to adaptation, with all sectors ranging from medium to high evidence (O'Neill et al. 2022). Specifically, Central American smallholder farmers have already reached soft limits related to financial, governance, institutional, and policy constraints (IPCC 2022). Additionally, the increasing frequency and magnitude of droughts could represent hard limits also to be reached (Depsky and Pons 2021; Hagen et al. 2022).

Puerto Morazán's economy highly depends on climate-sensitive sectors, such as agriculture, livestock, fisheries, and aquaculture. Most of the local economy depends on rainfed subsistence farming. Extensive areas are dedicated to monocultures, such as peanuts, sugar cane, and bananas (Alcaldía Municipal de Puerto Morazán 2010, 2017). Part of the urban population lives in Puerto Morazán's district, a strip of land between the Estero Real River and the Estero Amayo River. The region is exposed to climate and non-climate-related hazards, such as droughts, hurricanes, landslides, flooding, forest fires, earthquakes, and volcanic eruptions (Alcaldía Municipal de Puerto Morazán 2010, 2017, 2020).

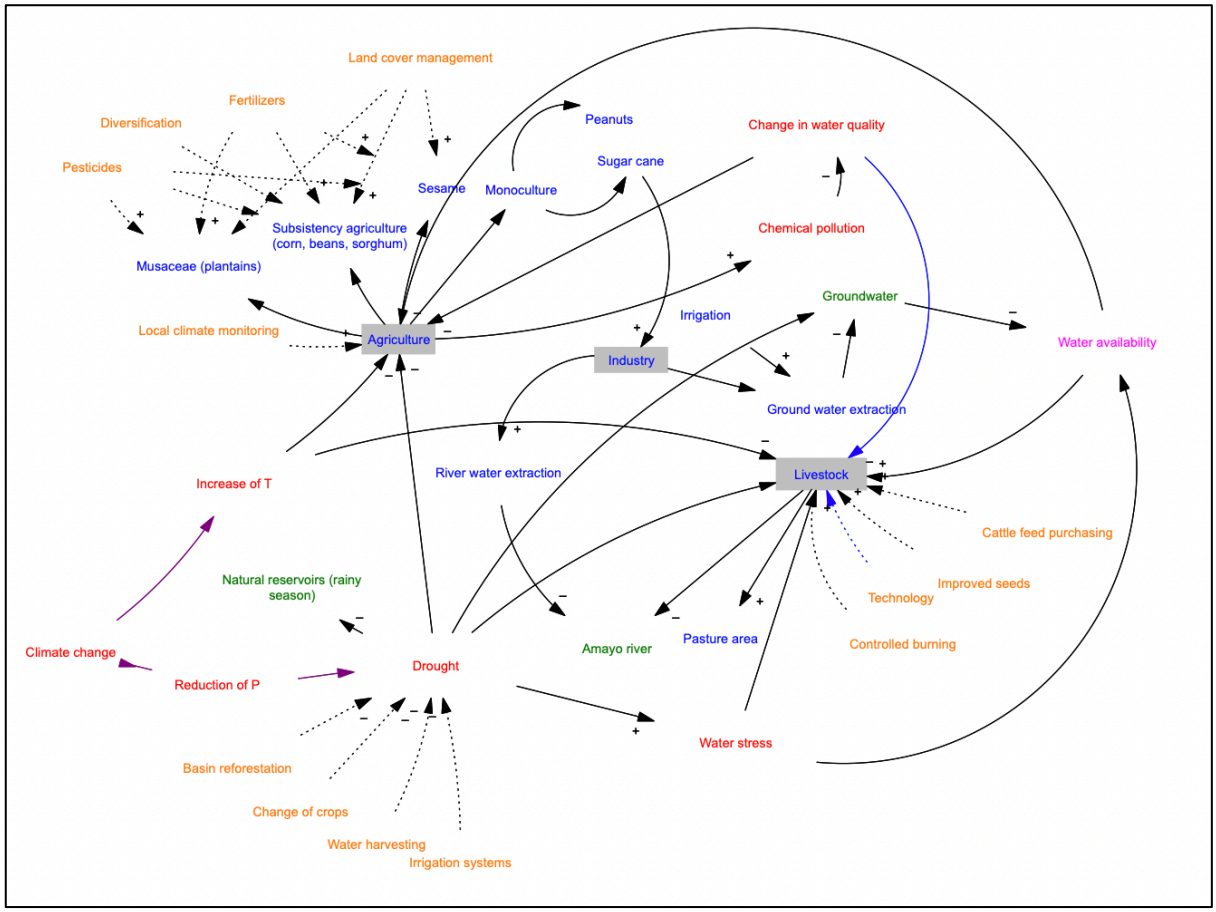
The climatic changes mentioned above have resulted in severe challenges related to water scarcity, impacting small and subsistence farmers, vulnerable to climate change as they practice rainfed agriculture (Castellanos et al. 2022). Projected reductions in precipitation during the summer wet season (June to August), which is crucial for agricultural production, might impact the food and energy sectors (Fuentes-Franco et al. 2015; Imbach et al. 2018; Stewart et al. 2022). Droughts have already led to emergency support delivered to approximately 346,500 farmers in the Nicaraguan part of the corridor (Ewbank et al. 2019) and are perceived as a significant risk in Puerto Morazán (Alcaldía Municipal de Puerto Morazán 2020). Additionally, climate change could affect the growth and flowering phases of mangrove forests, affecting the rest of the trophic chain, from which local communities depend (Ribalaygua et al. 2018).

In recent years, local and national policy instruments have been developed to address the current vulnerabilities, impacts, and projected risks (e.g., MARENA 2015; Gobierno de Nicaragua 2018, 2022). In Nicaragua's Nationally Determined Contribution (NDC), the need to develop a national water harvesting program and promote irrigation systems in the dry corridor is identified (Gobierno de Nicaragua 2020). The municipal climate action plan identifies eight sectors, but most proposed actions refer to agriculture, livestock, and fisheries (MARENA 2015). However, the instruments do not include information about climate-related projections, and no information is available about the results of implementing and evaluating the proposed actions. The actions are proposed only on perceived climate risks.

B. *Implementing the framework*

Phase I: Socio-ecologic system's characterization

Characterization of the socio-ecological system (SES)



S2 Fig 1. Conceptual model of Puerto Morazán's SES (focused on agriculture and livestock). *Color code: environmental factors in green; socioeconomic factors and activities in blue; threats and vulnerabilities in red; adaptation limits in pink. Dotted lines indicate identified adaptation options, in orange.*

We organized a **participatory workshop** to characterize Puerto Morazán's socio-ecological system (SES) and identify climate-related aspects. During the participatory session, we provided information on climate change and projected impacts based on the IPCC's AR5 and SR1.5 reports, allowing local stakeholders to access and consider the most recent information when analyzing/discussing the effects and solutions to climate change in their contexts.

We found limited information on Puerto Morazán during the desktop analysis, especially on climate-related adaptation and climate observations and scenarios. Current planning and policy instruments do not include robust climate projections and impact information. Climate adaptation literature about the area is mainly based on participatory workshops (e.g., Cárdenas 2014; De Loma-Ossorio et al. 2014; MARENA 2015). When climate scenarios and projections are mentioned, the information is based on only a limited number of climate models (e.g.,MARENA 2018). More robust climate model information is only found in larger resolution scales (e.g., GERICS 2016, p. 20), posing barriers to local or sectoral decision-making processes (Imbach et al. 2017). However, the currently available literature about

regional's projections concurs with the stakeholders' perceptions, i.e., droughts as one of the main climate-related hazards, especially in the CADC territories.

The sectors prioritized during the participatory workshop (agriculture and livestock) have shown, until now, opposing the conservation objectives of the protected area in which part of Puerto Morazán territories are located. The two sectors, especially extensive monoculture, are drivers of environmental degradation (Alcaldía Municipal de Puerto Morazán 2010; MARENA 2015). However, policy instruments and stakeholders identify these sectors as necessary for the development of their communities.

S2 Fig 2. *Building the conceptual group model*

Phase II: Identification of adaptation options

Desktop analysis and workshop results

We used Puerto Morazán's municipal climate plan (MARENA 2015) as the base instrument, complemented by the municipal environmental plan (Alcaldía Municipal de Puerto Morazán 2010) and the Nicaraguan adaptation policy (Gobierno de Nicaragua 2022) to identify the adaptation options. In addition, we analyzed options included in reports related to the case study area (e.g., Bouroncle et al 2013; MARENA 2018; Pörtner 22022) and those identified during the participatory workshop (S2 Table 1).

With the information listed above, we generated a list of adaptation options. The list was later sent to the experts for their validation. As a next step, the local experts were requested to indicate if the listed options have already been implemented in Puerto Morazán. This step serves as a way to compare planned versus implemented actions. Once the individual validations were compiled, the list was presented during the virtual facilitated group discussion. During the session, the experts agreed upon the final list of options (S2 Table 2).

S2 Table 1 Adaptation options identified by stakeholders

Agriculture	***Livestock***
Reforestation (using native trees)	Controlled or zero burning
Diversification (crops and productive systems)	Improved pasture seeds
Water harvesting	
Change of crops	
On-farm irrigation and water management	
Soil and water conservation practices (e.g., improvement of land cover management).	
Biological fertilizers	
Biological pest management and control	
Local climate monitoring	

S2 Table 2 presents the compiled list of options, including those identified by the stakeholders, those identified in planning/policy instruments, and supporting literature. In addition, three options that the stakeholders did not identify but included in reports related to climate adaptation in Puerto Morazán are included: Climate-resilient seeds (including native seeds), the adjustment in plantation timing, and change or introduction of new varieties.

S2 Table 2 Identified adaptation options for Puerto Morazán: agriculture and livestock sectors

	No.	***Adaptation option***	***Implemented? (Yes/No)***	***Planning/policy instrument***	***Supporting literature***
AGRICULTURE & LIVESTOCK	1	(*) On-farm irrigation and water management	Y	(MARENA 2015)	(Bouroncle et al. 2013; Cárdenas 2014; MARENA 2018; New et al. 2022; Pörtner et al. 2022)
	2	(*) Reforestation	Y	(MARENA 2015)	(Bouroncle et al. 2013; Cárdenas 2014; New et al. 2022)
	3	(*) Soil and water conservation practices	Y	(MARENA 2015; Gobierno de Nicaragua 2022)	(Bouroncle et al. 2013; Cárdenas 2014; De Loma-Ossorio et al. 2014; Banco Mundial and CIAT 2015; MARENA 2018; FAO 2021; Bezner Kerr et al. 2022; UNCCD 2022)
	4	(*) Agricultural diversification (e.g., mixed systems, new varieties)	Y	(MARENA 2015; Gobierno de Nicaragua 2022)	(Bouroncle et al. 2013; De Loma-Ossorio et al. 2014; Hernández and Bravo 2015; Smith et al. 2019; FAO 2021; Bezner Kerr et al. 2022)
	5	(*,+) Climate-resilient seeds	Y	X	(Bouroncle et al. 2013; Cárdenas 2014; De Loma-Ossorio et al. 2014;

	No.	Adaptation option	Implemented? (Yes/No)	Planning/policy instrument	Supporting literature
		(including native seeds)			Hernández and Bravo 2015; MARENA 2018; Smith et al. 2019)
	6	Water harvesting	Y	(MARENA 2015; Gobierno de Nicaragua 2022)	(Bouroncle et al. 2013; De Loma-Ossorio et al. 2014; MARENA 2018; FAO 2021; New et al. 2022; UNCCD 2022)
	7	(*,+) Elimination or controlled burning of pasture-agricultural land	Y	(Alcaldía Municipal de Puerto Morazán 2010)	(Bouroncle et al. 2013; Banco Mundial and CIAT 2015; Smith et al. 2019; FAO 2021; Bezner Kerr et al. 2022)
	8	Agroforestry	Y	(MARENA 2015; Gobierno de Nicaragua 2022)	(Banco Mundial and CIAT 2015; Olsson et al. 2019; Smith et al. 2019; FAO 2021; Bezner Kerr et al. 2022)
	9	(+) Adjustment in plantation timing	N	X	(Bouroncle et al. 2013; De Loma-Ossorio et al. 2014; Shukla et al. 2019; FAO 2021; Bezner Kerr et al. 2022; New et al. 2022)
AGRICULTURE	10	(*) Use of organic fertilizers, pesticides	Y	(MARENA 2015)	(Bouroncle et al. 2013; Banco Mundial and CIAT 2015; MARENA 2018; FAO 2021; Bezner Kerr et al. 2022)
	11	(*) Change or introduction of new varieties	Y	X	(Cárdenas 2014; Hernández and Bravo 2015; Shukla et al. 2019; FAO 2021; Bezner Kerr et al. 2022; Pörtner et al. 2022)
	12	(*) Early warning systems (including local climate monitoring)	Y	(Gobierno de Nicaragua 2022)	(Bouroncle et al. 2013; De Loma-Ossorio et al. 2014; Centro Humboldt 2020; FAO 2021; Bezner Kerr et al. 2022)
	13	Implementation of silvopastoral systems	Y	(MARENA 2015; Gobierno de Nicaragua 2022)	(Bouroncle et al. 2013; De Loma-Ossorio et al. 2014; Banco Mundial and CIAT 2015; MARENA 2018; Smith et al. 2019; FAO 2021; Bezner Kerr et al. 2022; New et al. 2022)
LIVESTOCK	14	(*) Improvement of pasture and forage and establishment of grass forage banks	Y	(MARENA 2015)	(De Loma-Ossorio et al. 2014; Banco Mundial and CIAT 2015; Hernández and Bravo 2015; MARENA 2018; Olsson et al. 2019; FAO 2021; Bezner Kerr et al. 2022; New et al. 2022)
	15	Pasture rotation	Y	(MARENA 2015)	(Bouroncle et al. 2013; FAO 2021)
OVERAR	16	Land-use planning	N	(MARENA 2015)	(Cárdenas 2014; New et al. 2022; UNCCD 2022)

(*) = Options identified during the participatory workshop
(⁺) = Options identified during desktop analysis (only if the information is referred to the case study area)
(x) = Identified during the participatory workshop but not found in planning/policy instruments
(Y) = Yes, the measure has been implemented; **(N):** No, the measure has not been implemented

Description of the identified adaptation options

Here we briefly describe the adaptation options identified by the stakeholders during the participative workshop and those found in policy and planning instruments. The description of the options is mainly based on two reports which describe climate adaptation options in Nicaragua (MARENA 2018; FAO 2021). Please refer to those two reports for more detailed information about the options.

1. **On-farm irrigation and water management**

Two irrigation options are included here: drip and sprinkler irrigation systems.

Drip irrigation technology consists of "efficient water distribution systems for crop irrigation that avoid wasting water resources. These systems are structures composed of a network of pipes that allows water to be conveyed to the plant and then through emitters or drippers to be distributed in small quantities periodically. This system, also known as drip irrigation, is mainly used to cultivate vegetables. Currently, there are several types of drip irrigation systems, from the most traditional ones with plastic bottles to those made up of polyethylene hoses with holes in the form of drippers" (MARENA 2018, p. 34).

Sprinkler irrigation technology is "a type of pressurized irrigation that simulates natural rainfall through mechanical and hydraulic devices, allowing water to be distributed over the crop from above. The water is sprayed using high-pressure sprayers on mobile platforms, improving water dispersion and efficient resource use. This type of technology has been mainly in the cultivation of vegetables. However, it can be used in a wide range of crops" (MARENA 2018, p. 35).

2. ***Reforestation***

Reforestation is "a silvicultural process through which areas are repopulated that in the historical past had forest cover and were eliminated due to factors related to overexploitation of the resource, increase in the agricultural and urban frontier, forest fires and natural phenomena, among others. Reforestation can fulfill several environmental and economic purposes, generating goods and services for the landowner. This technology is used to recover degraded ecosystems and restore forest strips to protect water resources" (MARENA 2018, p. 135,136).

In the case of Puerto Morazán, during the participative workshop, it was highlighted that reforestation efforts must be made with native species.

3. ***Soil and water conservation practices***

Soil and water conservation practices are "activities at the local level which maintain or enhance the land's productive capacity in areas affected by or prone to degradation. [These] practices include prevention or reduction of soil erosion, compaction, and salinity; conservation or drainage of soil water; maintenance or improvement of soil fertility" (FAO 2022a).

In Nicaragua, there are different options as part of the conservation practices, such as land cover management, terraces, enhanced water infiltration, ditches, reduced or zero tillage,

intercropping, and elimination of burning of pasture-agricultural land, among others (MARENA 2018; FAO 2021).

4. ***Agricultural diversification (e.g., mixed systems, new varieties)***

Bezner Kerr et al. (2022) identify agricultural diversification landscape, on-farm biodiversity (i.e., intercropping), mixed systems, and agroecological approaches at multiple scales as part of the agricultural diversification adaptation options. Here, we focus on mixed systems as identified by MARENA (2018) and FAO (2021).

"It is a practice that consists of planting different crops in the same area that have no affinity with each other. Crop diversification contributes to breaking the cycle of a pest and effectively using the soil by obtaining multiple crops in the same space, imitating the diversity of natural ecosystems, and avoiding the great efforts to support single crops. This concept includes crop rotation and multi-cropping. Rural families plant their crops in combination with fruit crops, vegetables, intercropping, and in some cases with minor species, as long as they have enclosures" (FAO 2021, pp. 93, 94).

5. ***Climate-resilient seeds (including native seeds)***

"Improved seeds not only have characteristics that allow them to cope with the new conditions imposed by climate change but also increase crop yields, improving the socioeconomic conditions of the national agricultural sector" (MARENA 2018, p. 81). MARENA (2018) identifies a trend in developing climate-resilient seeds in Nicaragua's agricultural sector. Protocols and research related to native and non-native species, which adapt to specific conditions, have been established by the Nicaraguan Institute of Agricultural Technology (INTA).

6. ***Water harvesting***

"Rainwater harvesting plays an important role in agricultural production and satisfying domestic needs, with intensive use in areas similar to Nicaragua's Dry Corridor. […] These technologies' main contribution is their support to the water recharge zone or water sources in the watershed and micro-watershed environment. Their application allows rural families to carry out their production processes sustainably and under an environmental protection approach. […] The practices for using water obtained from catchment are aimed at the rational, optimized, and responsible use of water" (FAO 2021, pp. 27, 28).

7. **Elimination of the burning of pasture-agricultural land**

This option could also be considered as a soil and water conservation practice. "Stubble burning has a negative influence on the physicochemical and biological properties of the soil, drastically reducing microbial biomass and soil organic matter content, which leads to a decrease in nutrient levels and soil quality... In addition, not burning stubble promotes the use of a) nitrogen contained in the crop residue, which would be lost between 98 to 100% if burned; b) phosphorus and potassium, which would be lost between 20 to 40% if burned; c) sulfur, which would also be lost between 70 to 90% when burning stubble or vegetation in the area to be planted" (FAO 2021, p. 73).

8. ***Agroforestry***

"Agroforestry systems are defined as a series of land use systems and technologies in which trees are combined with crops in a time and space-dependent manner to increase and optimize production sustainably. These systems can contribute to solving problems in using natural resources due to their biological and socioeconomic functions" (FAO 2021, p. 119).

9. **Adjustment of plantation timing**.

"For rural families and their productive units to be more resilient to climate variability, it is necessary to modify the planting date of crops or introduce new crops that can withstand these changes in climate behavior. In addition, understanding the response of different crops to variation in planting date is useful for estimating the effects of planned delays or unforeseen delays and making decisions to increase and stabilize production and improve efficiency." (FAO 2021, p. 74).

10. Use of organic fertilizers, pesticides

"Nutrient recycling processes, structure formation and preservation, better water utilization, and carbon sequestration occur in the soil. In the long term, combining minerals (fertilizers) and organic inputs such as leaf litter, manure, nitrogen-fixing plants, and decomposed roots offers better results, increasing nitrogen content and contributing to better nutrient recycling." (FAO 2021, p. 98).

MARENA (Gobierno de Nicaragua 2018) and FAO (2021) identify different types of techniques to produce organic fertilizers: the Bocashi technique, vermiculture, biofertilizers (produced with local materials), green manure in crop rotation, biofertilizers (animal manure), and compost. Only two were identified in the case study area's region: green manure in crop rotation and compost. Organic pesticides are prepared from basic materials such as leaves, roots, tubers, seeds, and fruits, such as tobacco, basil, neem, epazote, papaya, cypress, oregano, etc. (FAO 2021, p. 187).

11. Change or introduction of new varieties

"The use of improved varieties and species for crops and plantations is a determining aspect for crop management under the climatic variability that occurs in the Dry Corridor, particularly for the most important crops for the diet of rural families and their food security" (FAO 2021, p. 201).

MARENA (Gobierno de Nicaragua 2018) and FAO (2021) identify examples of varieties or enhanced species that could be used, for example, INTA NB-S and NB 9043 for maize, INTA Fuerte Sequía; or Chile Rosario, INTA seda Gasuyuca for beans. Other crops, resilient to droughts, such as sweet potato and cassava, are also mentioned (more detailed in the above reports).

12. Early warning systems (including local climate monitoring)

"Climate information and predictions serve as the basis for decision-making in public health, risk management, agriculture, fisheries, water management, tourism, transportation, and energy. These sectors urgently need science-based information to plan their activities. These real-time services meet the needs of rural households and contribute to weather-sensitive crop and livestock management strategies and activities aimed at improving agricultural production and food security. They can make a tremendous difference in agricultural production by helping rural families take advantage of good weather and minimize the adverse impact of bad weather" (FAO 2021, p. 176).

13. Implementation of silvopastoral systems

"Silvopastoral systems combine trees and/or shrubs, livestock, and pasture. Silvopastoral systems can be complex because of the range of combinations with different components, which can be: trees with pastures in secondary forests, agricultural plantations such as fruit trees in combination with pastures, annual or perennial crops, the implementation of the animal component in the same area. The best-known techniques in this system are live fences and windbreaks, which have already been analyzed in part on the use of land divisions. Therefore, we will address those that remain to be characterized" (FAO 2021, p. 137).

Among the practices included in silvopastoral systems in Nicaragua are: the use of trees in pasture areas, pasture areas among fruit and timber trees, and forage banks (MARENA 2018; FAO 2021).

14. Improvement of pasture and forage and establishment of grass forage banks

"This animal nutrition technology consists of the cultivation of forage plants of high nutritional value in livestock farms, being these forage plants chopped and supplied directly to the animal. Generally, plants such as shrubs or vines with high protein and vitamin content are used. This technology is normally used as a cattle feed supplement, an interesting alternative in pasture shortage due to critical drought periods" (MARENA 2018, p. 89).

"Fodder banks are compact areas densely sown with herbaceous forages for producing high-quality forage in large quantities for animal supplementation; these banks are managed for slashing or grazing. Fodder banks with short grasses make it possible to keep cattle stabled to avoid energy loss, improve their diet, have feed available at any time of the year, avoid the purchase of inputs for animal feed, and maintain the body condition of the cattle. This technique helps to maintain or increase milk and meat production in the dry season. In addition, feed availability avoids cattle's weakening and even death during critical periods" (FAO 2021, pp. 228, 229).

15. Pasture rotation

"Pasture rotation is a rational grazing system that consists of adequately alternating the period of use with the rest time of the paddock. Therefore, it is necessary to address different strategies to obtain maximum animal production per hectare through a sustainable production system. This practice is characterized by the farm being divided into several paddocks, maintaining the correct carrying capacity for each paddock, and allowing the grazing of one paddock at a time by the previously defined batch of cattle. The best way to manage the paddocks is by rotational grazing: having several paddocks and rotating the animals." (FAO 2021, p. 226).

16. Land-use planning

This is an overarching adaptation option. It "involves allocating land to different uses across a landscape to balance economic, social, and environmental values. Its purpose is to identify, in a given landscape, the combination of land uses that best meet the needs of stakeholders while safeguarding resources for the future" (FAO 2022b).

This option is included in the Nicaraguan Adaptation Policy (Gobierno de Nicaragua 2022). In addition, Cárdenas (2014) identifies it for Puerto Morazán, highlighting land use planning according to land vocation.

Phase III: Performing the assessment

Assessment tools

We developed a tool based on the methodologies mentioned above to allow local experts to perform their individual assessments. The tool is an Excel spreadsheets containing the indicators related to the feasibility assessment. The Excel tool is available upon request to: tania.guillen@hereon.de

Steps for the definition of local priorities for the assessment of adaptation options

The local experts conducted the definition of the local priorities (prioritization) among the adaptation feasibility indicators and dimensions during the facilitated group discussion. First, the experts identified the priorities among indicators within a feasibility dimension. Later, the experts identified the priorities among the feasibility dimensions. Once the priorities were

obtained, they were included in the feasibility assessment tool. We followed the process indicated in Section A.1 of this supplementary material. The calculations needed to obtain the priorities are included in the assessment tool provided in this supplementary material.

Facilitated group discussion and individual assessments

In this case, we performed a virtual facilitated group discussion due to barriers posed by the COVID-19 pandemic. The researchers presented the adaptation feasibility methodology during this session. Additionally, the researchers introduced the assessment tool so that the local experts could perform the assessment individually. After the session concluded, the researchers provided the tool to the experts. The experts then had two weeks to share their assessment with the researchers.

Overall assessment

Once the experts shared their assessments, the researchers aggregated them in an Excell spreadsheet.

Report and visualization

Once all individual assessments were collected, the researchers obtained traffic light tables (using the Excell assessment tool). To the results, a brief description of the most important aspects to consider within one dimension was included.

Results: Feasibility assessment

Below we present the results concerning the overall feasibility and the feasibility of the options by dimensions obtained for the sixteen options identified in Puerto Morazán. Here, we include the results showing the traffic light system and the values obtained from the assessments. The results confirm that the assessment can differ from the one obtained when no local priorities are considered among the feasibility indicators and dimensions.

Overall feasibility

S2 Table 3 *Overall feasibility assessment of adaptation options in Puerto Morazán*

	No.	Adaptation option	Overall feasibility	
			No local priorities considered	Local priorities considered
Agriculture and livestock	1	On-farm irrigation and water management	2.08	2.14
	2	Reforestation	2.41	2.58
	3	Soil and water conservation practices	2.42	2.59
	4	Agricultural diversification (e.g., mixed systems, new varieties)	2.24	2.11
	5	Climate-resilient seeds (including native seeds)	2.25	2.21
	6	Water harvesting	2.31	2.42
	7	Elimination or controlled burning of pasture-agricultural land	2.15	2.15
Agriculture	8	Agroforestry	2.36	2.53
	9	Adjustment in plantation timing	2.18	2.04
	10	Use of organic fertilizers, pesticides	2.13	2.14
	11	Change or introduction of new varieties	2.14	2.16
	12	Early warning systems (including local climate monitoring)	1.96	1.92
Livestock	13	Implementation of silvopastoral systems	2.24	2.48
	14	Improvement of pasture and forage and establishment of grass forage banks	2.19	2.33
	15	Pasture rotation	2.10	2.18
	16	Land-use planning	1.90	2.11

Feasibility of the options by dimensions

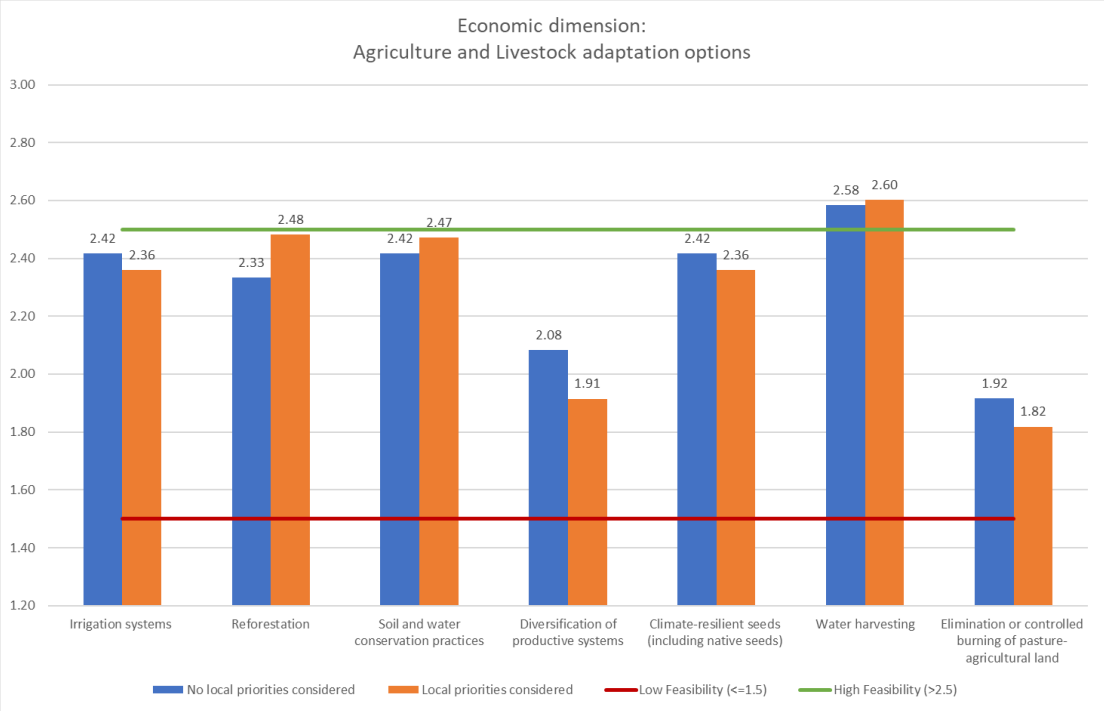
S2 Table 4 Feasibility assessment of adaptation options identified in/for Puerto Morazán. (NLP) No local priorities considered, based on the IPCC framework (de Coninck et al. 2018; Singh et al. 2020; Ley et al. 2022).; (LP) Local priorities considered

	Dimensions	Economic		Technological		Institutional		Socio-Cultural		Environmental/ecological		Geophysical	
	Adaptation option	NLP	LP	NLP	LP	NLP	LP	NLP	LP	NLP	LP	NLP	LP
Agriculture and livestock options	On-farm irrigation and water management	2.42	2.36	2.17	2.06	1.83	1.94	2.00	2.38	2.17	2.03	1.89	1.81
	Reforestation	2.33	2.48	2.33	2.33	2.00	2.01	2.13	2.07	3.00	3.00	2.67	2.86
	Soil and water conservation practices	2.42	2.47	2.50	2.39	1.92	1.90	2.13	2.24	3.00	3.00	2.56	2.82
	Agricultural diversification	2.08	1.91	2.67	2.67	2.00	2.05	2.13	2.25	2.33	2.07	2.22	2.31
	Climate-resilient seeds (including native seeds)	2.42	2.36	2.33	2.33	2.25	2.31	2.20	2.28	2.17	2.03	2.11	2.07
	Water harvesting	2.58	2.60	2.33	2.11	2.17	2.26	2.33	2.53	2.33	2.33	2.11	2.27
	Elimination or controlled burning of pasture-agricultural land	1.92	1.82	2.33	2.11	1.83	1.88	2.07	2.24	2.50	2.37	2.22	2.46
Agriculture options	Agroforestry	2.75	2.69	2.17	2.06	2.08	2.14	2.13	2.27	2.83	2.70	2.22	2.46
	Adjustment in plantation timing	2.08	1.70	2.50	1.94	2.00	2.03	2.00	2.18	2.50	2.37	2.00	2.03
	Use of organic fertilizers, pesticides	2.25	2.20	2.17	2.06	1.92	1.93	2.27	2.51	2.17	2.03	2.00	2.03

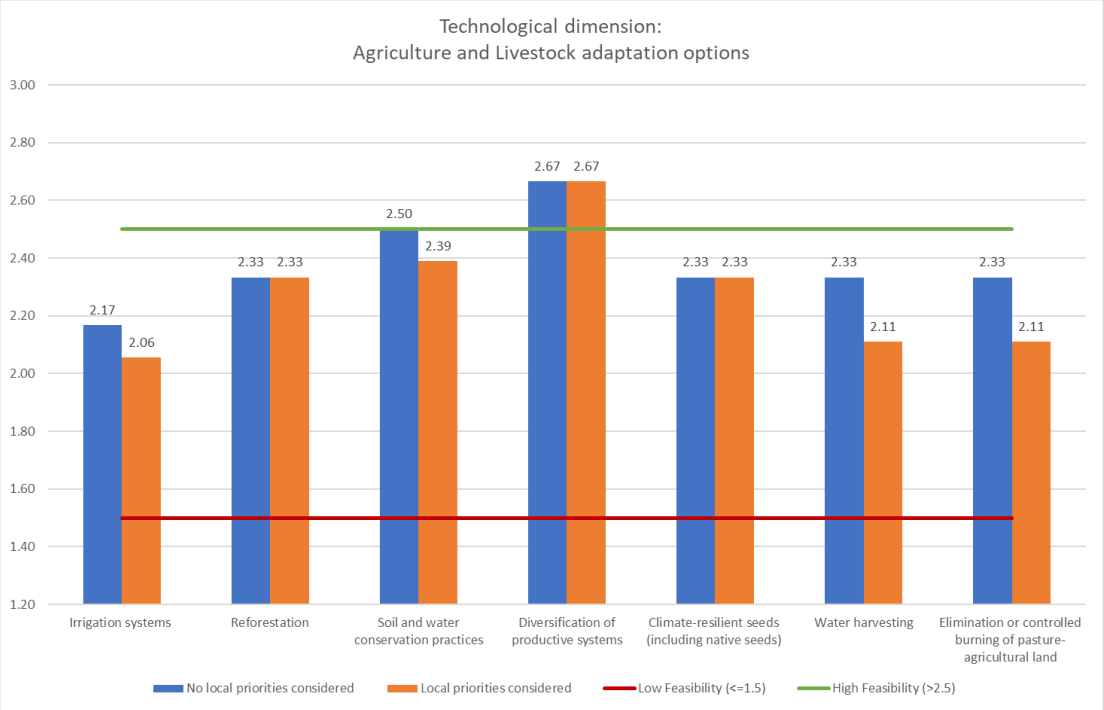
	Dimensions	Economic		Technological		Institutional		Socio-Cultural		Environmental/ecological		Geophysical	
	Adaptation option	**NLP**	**LP**	**NLP**	**LP**	**NLP**	**LP**	**NLP**	**LP**	**NLP**	**LP**	**NLP**	**LP**
	Change or introduction of new varieties	2.50	2.39	2.17	2.06	1.92	1.93	2.07	2.23	2.17	2.03	2.00	2.03
	Early warning systems (incl. local climate monitoring)	1.58	1.82	2.17	1.83	2.00	2.03	2.07	2.24	2.17	2.03	1.78	1.59
Livestock options	Implementation of silvopastoral systems	2.25	2.56	2.33	2.33	1.75	1.80	2.07	1.87	2.83	2.97	2.22	2.46
Livestock options	Improvement of pasture and forage	2.00	2.22	2.33	2.33	1.83	1.89	2.20	2.30	2.67	2.67	2.11	2.24
Livestock options	Pasture rotation	1.92	2.23	2.33	2.33	1.83	1.89	2.07	1.87	2.33	2.33	2.11	2.24
Overarching	Land-use planning	1.83	1.87	1.33	0.89	1.17	1.12	2.40	2.54	2.67	2.67	2.00	2.00

Agriculture and Livestock adaptation options:

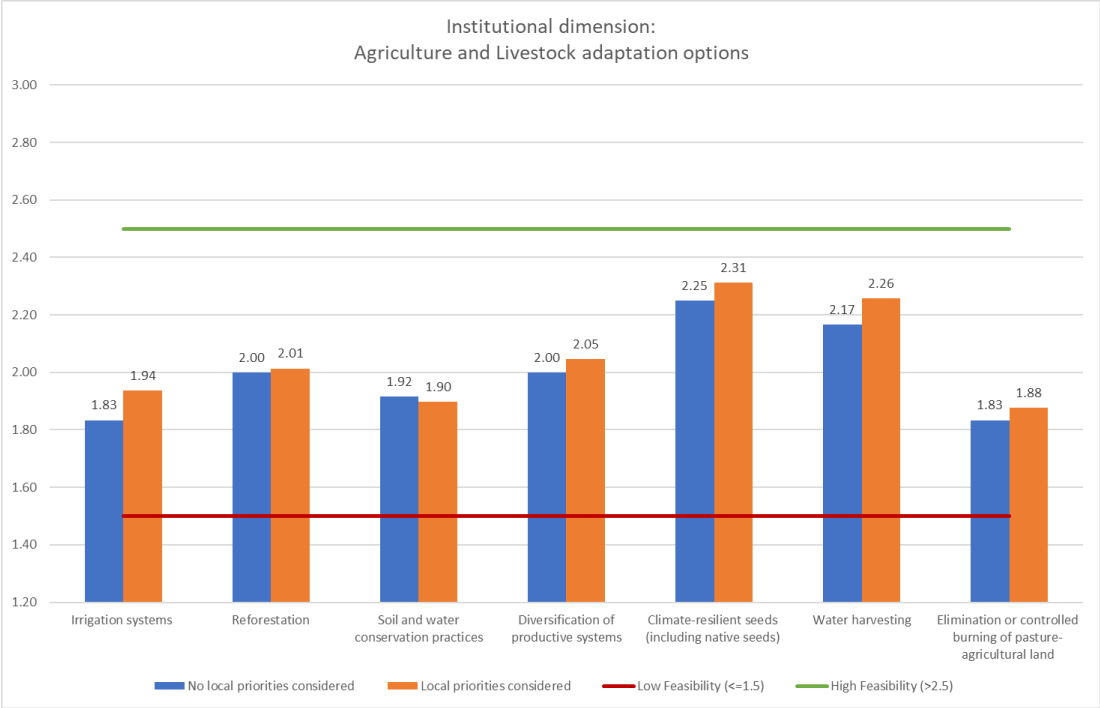
- Economic feasibility



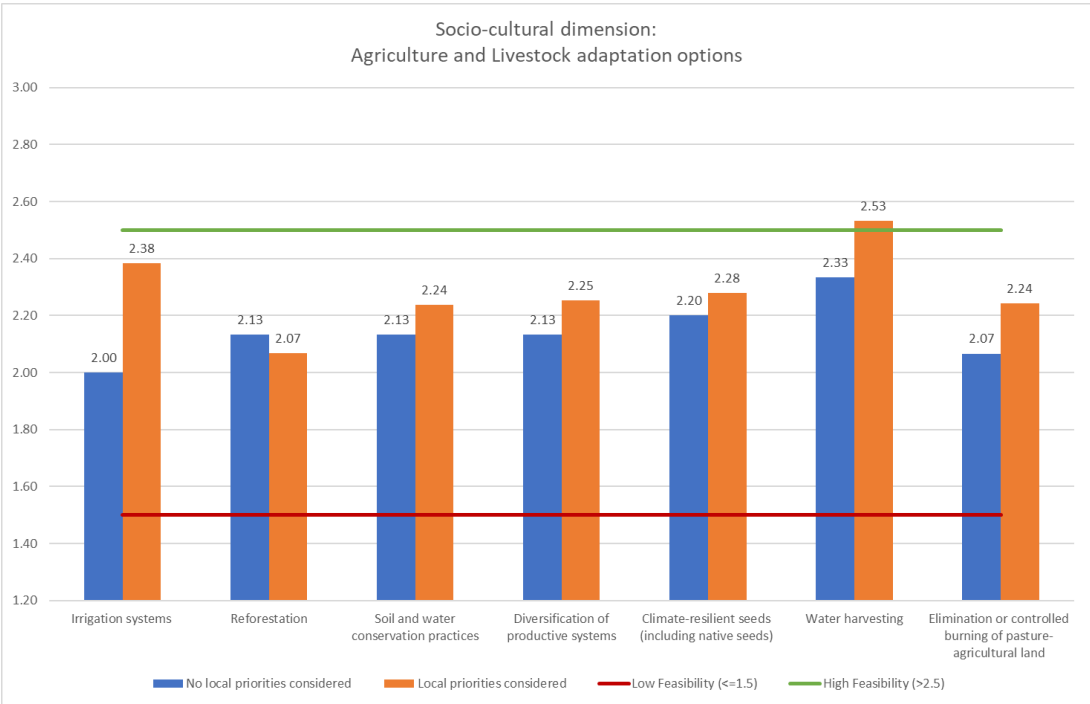
- Technological feasibility



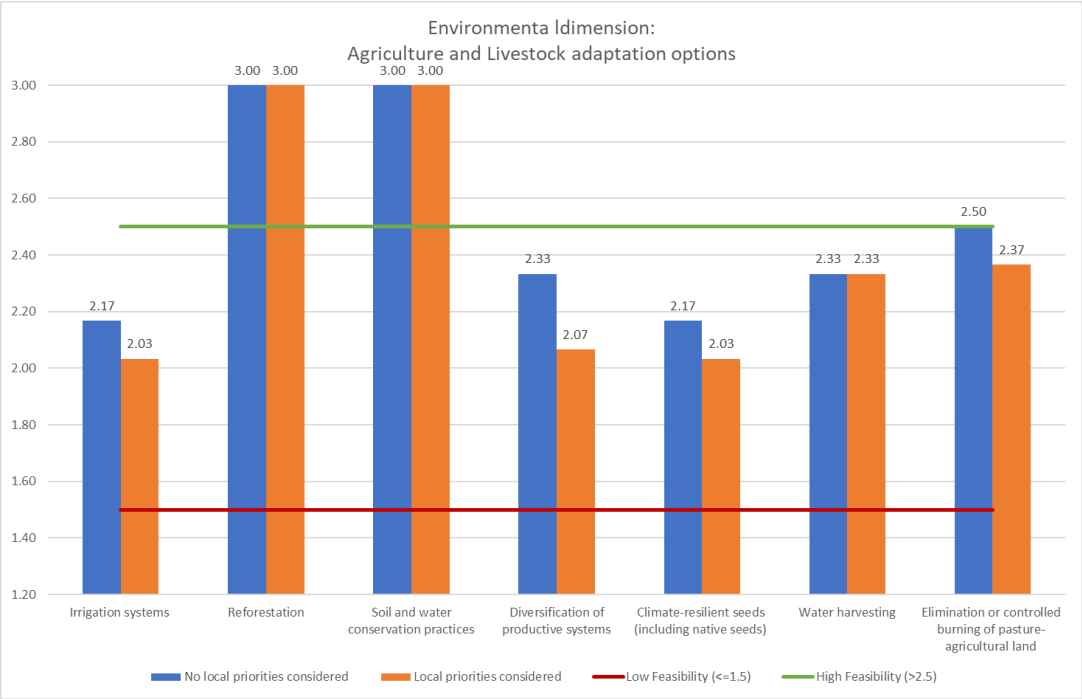
- Institutional feasibility



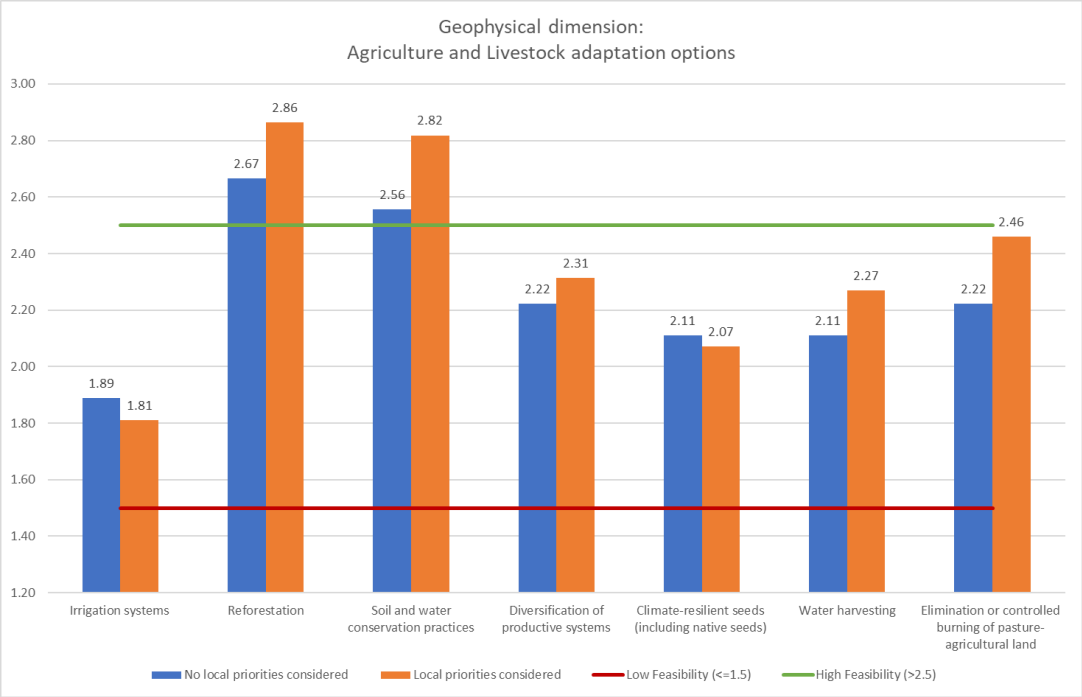
- Socio-cultural feasibility



- Environmental feasibility

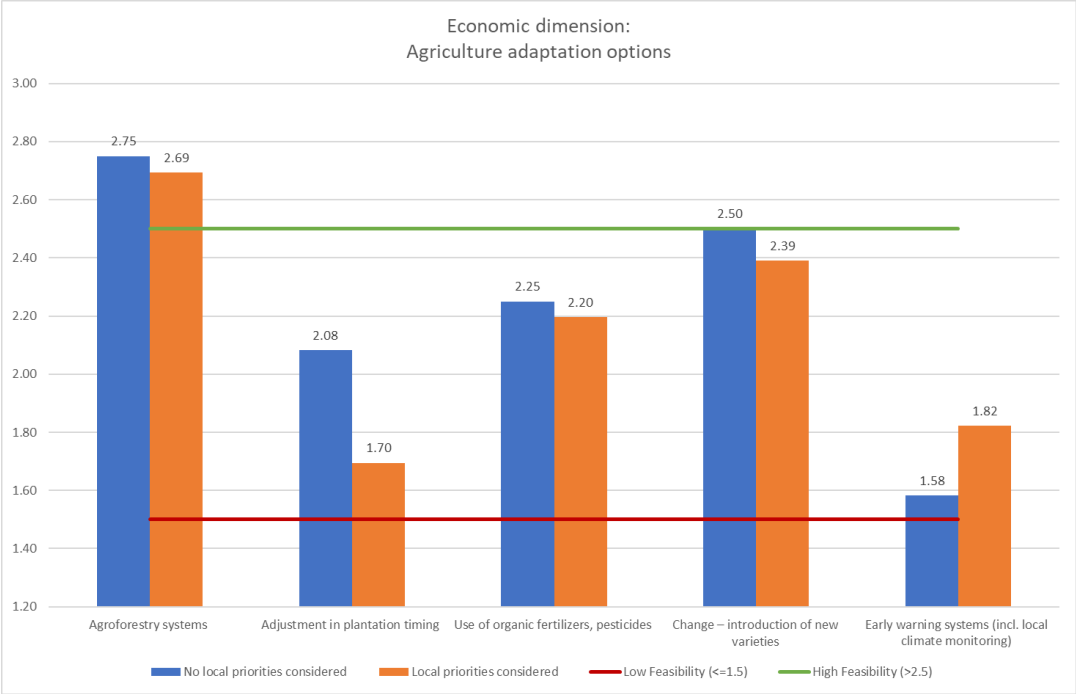


- Geophysical feasibility

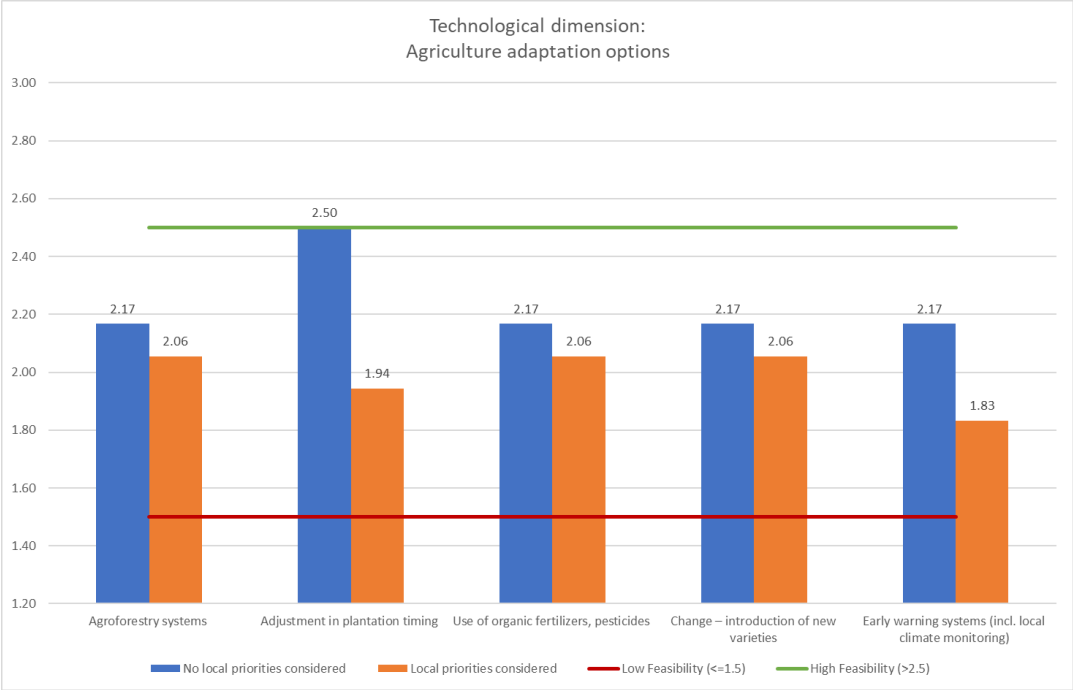


Agriculture adaptation options:

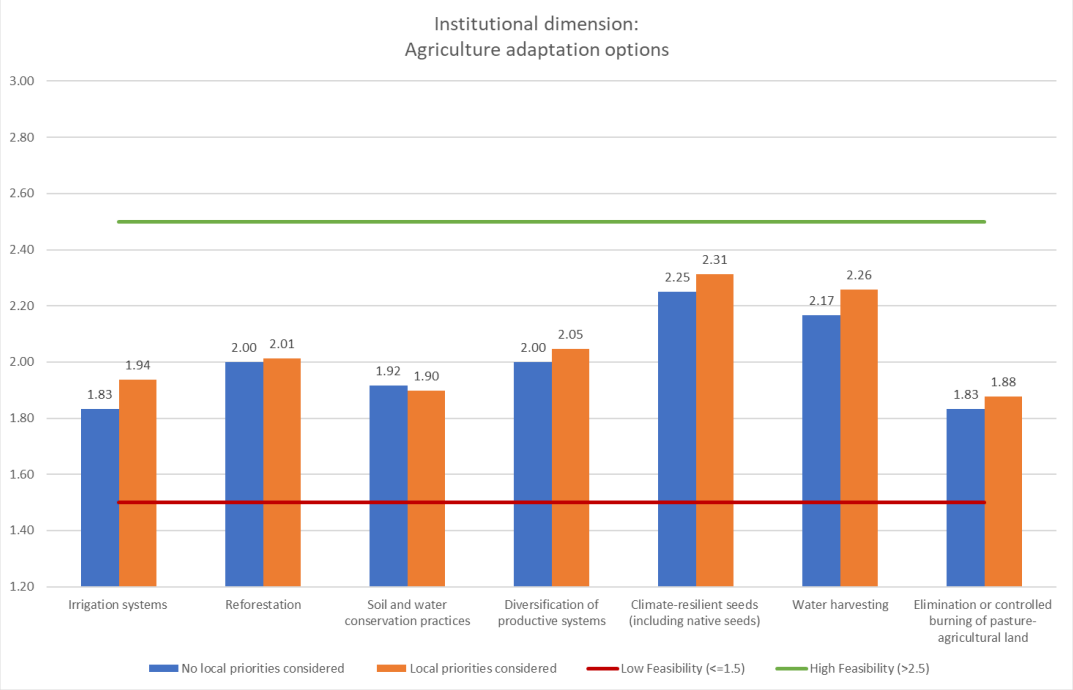
- Economic feasibility



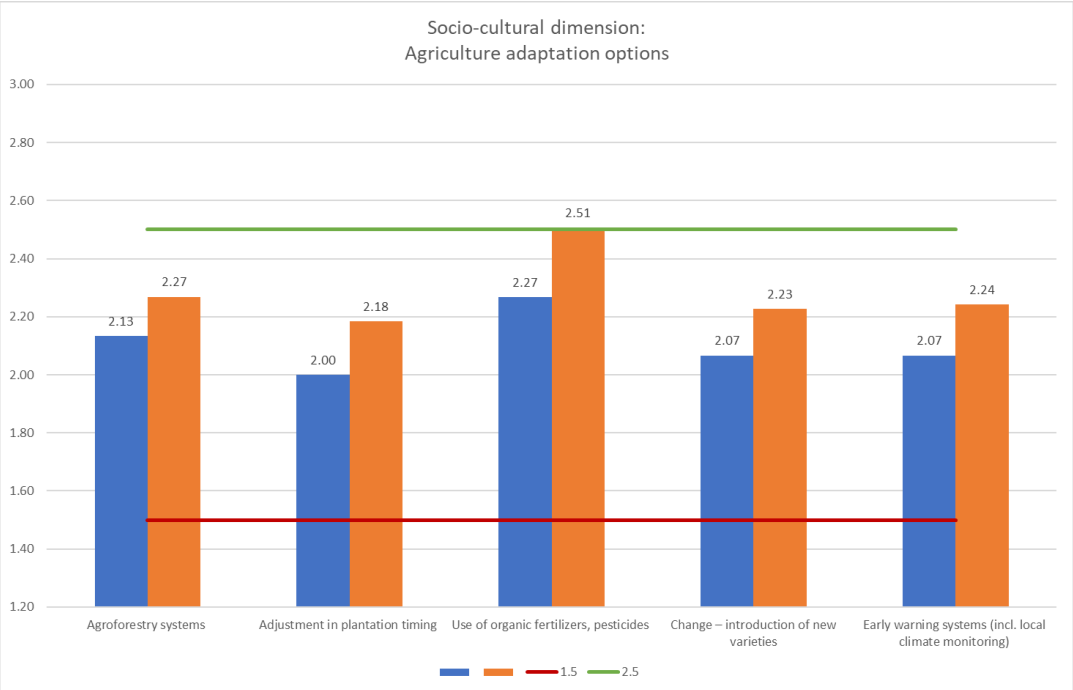
- Technological feasibility



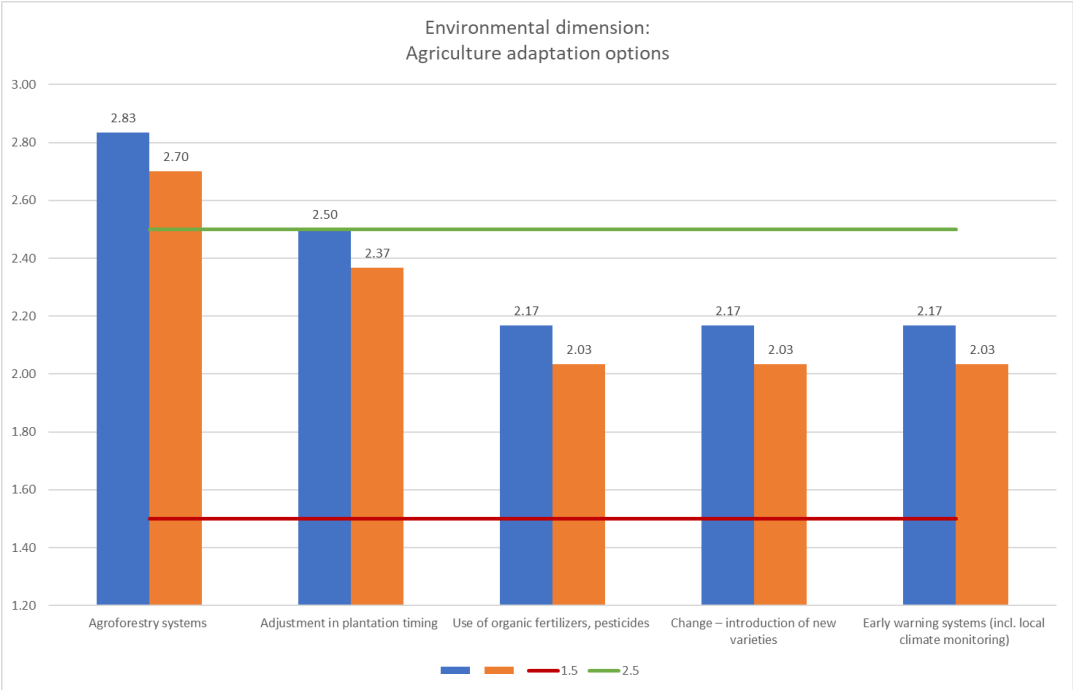
- Institutional feasibility



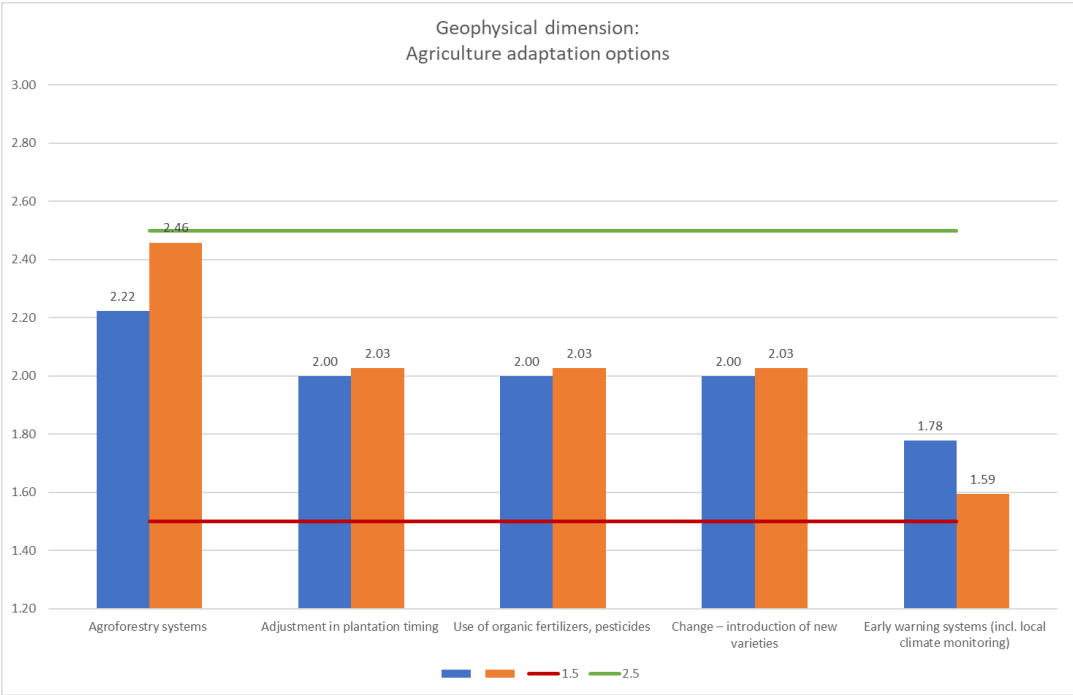
- Socio-cultural feasibility



- Environmental feasibility

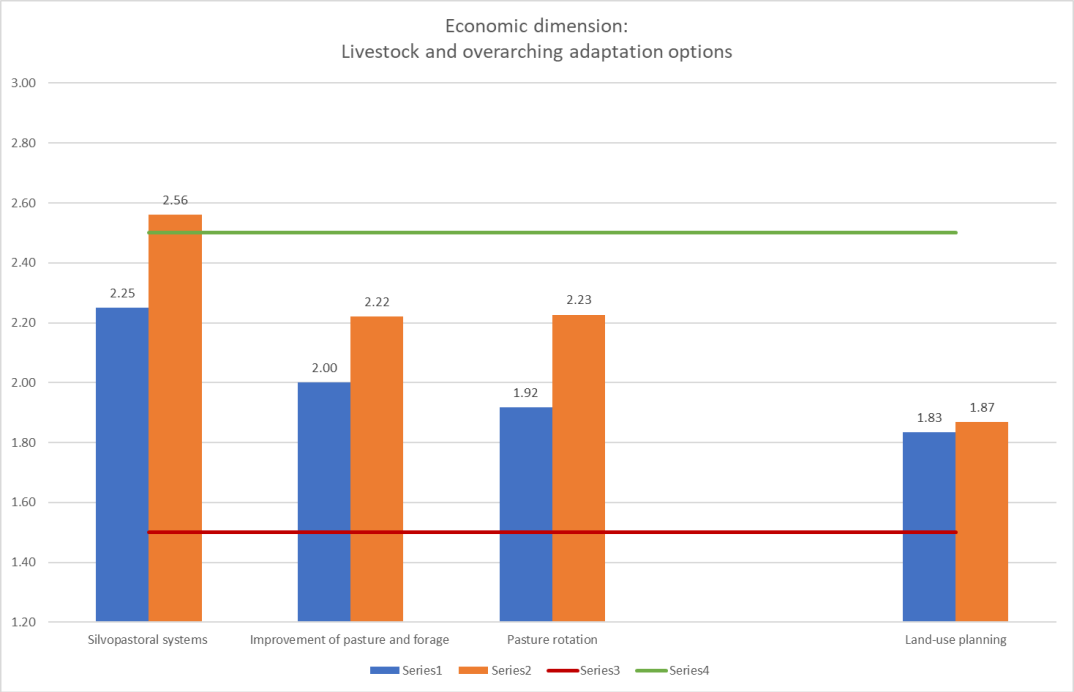


- Geophysical feasibility

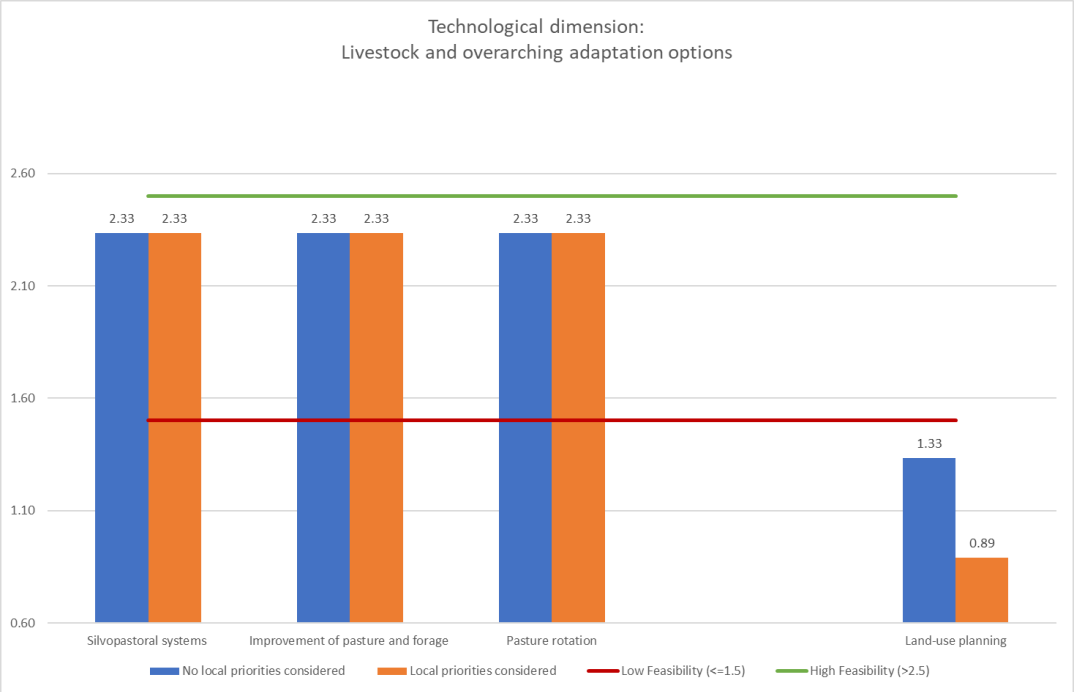


Livestock and overarching adaptation options:

- Economic feasibility

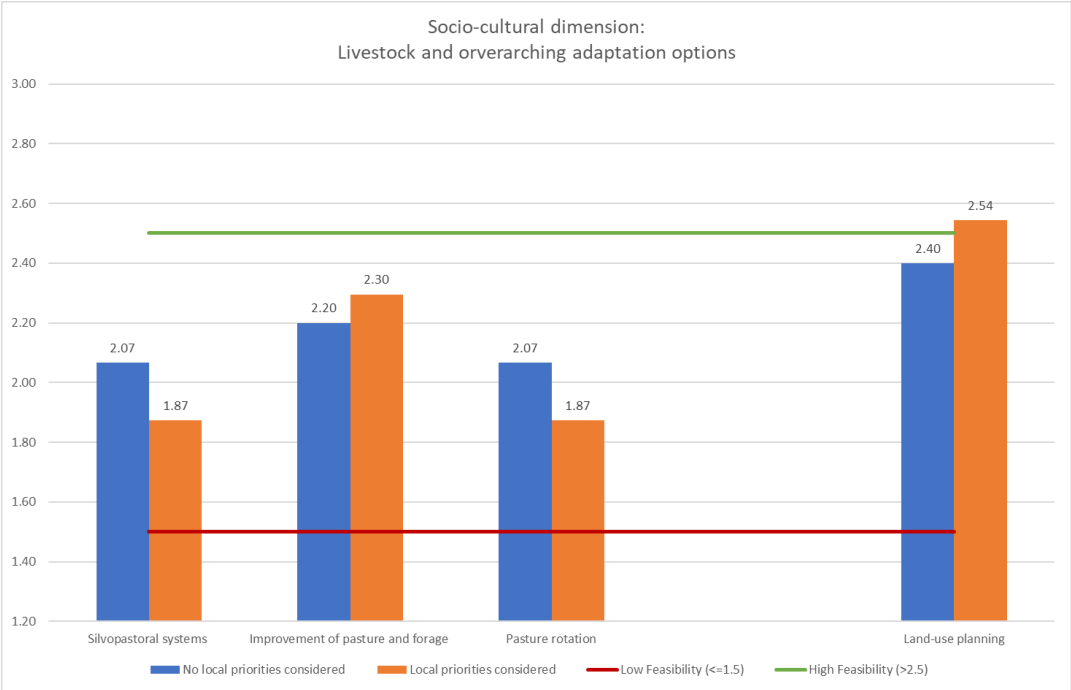


- Technological feasibility

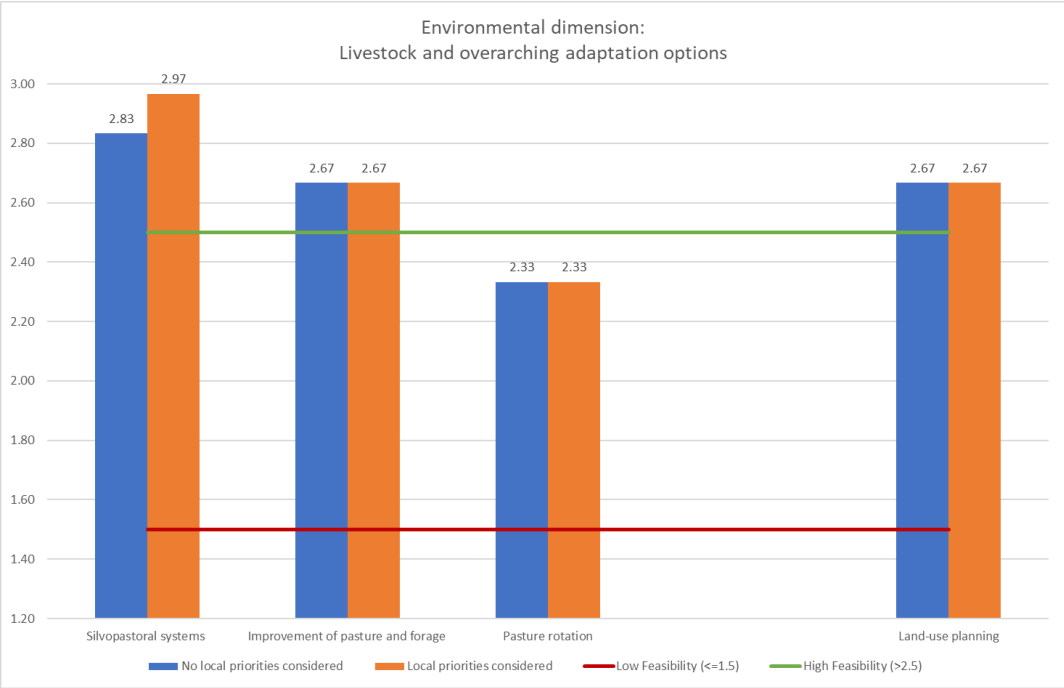


- Institutional feasibility

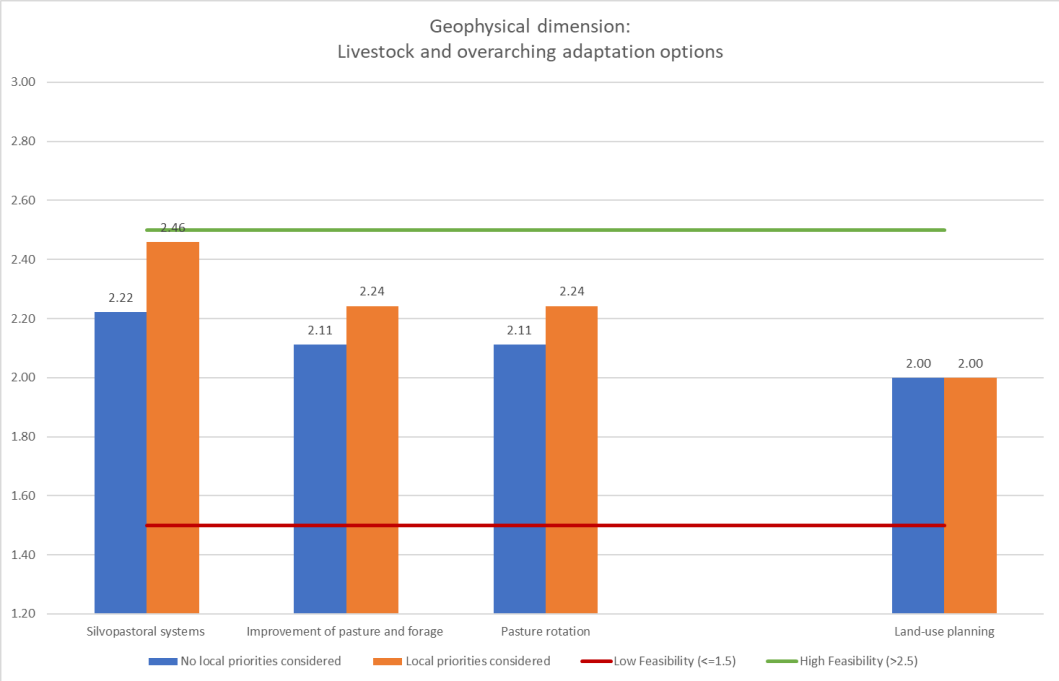
- Socio-cultural feasibility



- Environmental feasibility



- Geophysical feasibility



References S2 Text

Alcaldía Municipal de Puerto Morazán (2010) Plan Ambiental Municipal. Alcaldía Municipal de Puerto Morazán, Chinandega, Nicaragua.

Alcaldía Municipal de Puerto Morazán (2017) Caracterización Municipal - Puerto Morazán. Chinandega, Nicaragua

Alcaldía Municipal de Puerto Morazán (2020) Plan Municipal de Respuesta con enfoque Multiamenaza. Alcaldía Municipal de Puerto Morazán. Sistema Nacional para la Prevención, Mitigación y Atención de Desastres, Chinandega, Nicaragua.

Arias PA, Bellouin N, Coppola E, et al (2021) Technical Summary. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Re-port of the Intergovernmental Panel on Climate Change 33–144

Banco Mundial, CIAT (2015) Agricultura Climáticamente Inteligente en Nicaragua. Grupo del Banco Mundial, Washington D.C.

Bezner Kerr R, Hasegawa T, Lasco R, et al (2022) Food, fibre, and other ecosystem pro-ducts. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate Change 2022: Im-pacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA, pp 713–906

Bouroncle C, Imbach P, Imbach AC, et al (2013) Buenas prácticas para la adaptación al cambio climático en la América Latina rural: opciones y lecciones desde el enfoque de medios de vida. Programa EUROCLIMA, DG Desarrollo y Cooperación – Euro-peAid, Comisión Europea., Bruselas

Cárdenas J (2014) Estrategias de adaptación y/o mitigación al cambio climático, concertado con actores locales del Golfo de Fonseca en municipios de Puerto Morazán y El Viejo, en Nicaragua. Managua

Castellanos E, Lemos MF, Astigarraga L, et al (2022) Central and South America. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, USA, pp 1689–1816

Centro Humboldt (2020) Proyecto: Fortaleciendo la resiliencia territorial en comunidades de la Reserva Natural Delta del Estero Real, en el Golfo de Fonseca nicaragüense. Centro Humboldt, Managua, Nicaragua

de Coninck H, Revi A, Babiker M, et al (2018) Strengthening and implementing the global response. In: Masson-Delmotte V, Zhai P, Pörtner HO, et al. (eds). Global Warming of 15°C: IPCC Special Report on Impacts of Global Warming of 15°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 313–444

De Loma-Ossorio E;, García Ruiz A;, Córdoba Salinas M;, Ribalaygua Batalla J (2014) Estra-tegias de adaptación al cambio climático en municipios de Nicaragua del Golfo de Fonseca. EIH/ CIDEA-UCA, Managua

Depsky N, Pons D (2021) Meteorological droughts are projected to worsen in Central Ameri-ca's dry corridor throughout the 21st century. Environmental Research Letters 16:. https://doi.org/10.1088/1748-9326/abc5e2

Ewbank R, Perez C, Cornish H, et al (2019) Building resilience to El Niño-related drought: experiences in early warning and early action from Nicaragua and Ethiopia. Disas-ters 43:S345–S367. https://doi.org/10.1111/disa.12340

FAO (2021) Catálogo de medidas de adaptación al cambio climático para el Corredor Seco de Nicaragua. Organización de las Naciones Unidas para la Alimentación y la Agricultura (FAO), Managua, Nicaragua

FAO (2022a) FAO Soils Portal. In: Food and Agriculture Organization of the United Nations. https://www.fao.org/soils-portal/soil-management/soil-conservation/en/. Accessed 10 Sep 2022

FAO (2022b) Land-Use Planning. In: Sustainable Forest Management (SFM) Toolbox. https://www.fao.org/sustainable-forest-management/toolbox/modules/land-use-planning/basic-knowledge/en/?type=111. Accessed 9 Dec 2022

Fuentes-Franco R, Coppola E, Giorgi F, et al (2015) Inter-annual variability of precipitation over Southern Mexico and Central America and its relationship to sea surface tem-perature from a set of future projections from CMIP5 GCMs and RegCM4 CORDEX simulations. Clim Dyn 45:425–440. https://doi.org/10.1007/s00382-014-2258-6

GERICS (2016) Climate-Fact-Sheet: Guatemala - El Salvador - Honduras - Nicaragua. Climate Service Center Germany (GERICS), Hamburg, Germany

Gobierno de Nicaragua (2018) Contribución nacionalmente determinada a la mitigación del cambio climático (NDC) de la república de Nicaragua ante la Convención Marco de Naciones Unidas sobre el Cambio Climático (CMNUCC). Gobierno de Nicaragua, Managua

Gobierno de Nicaragua (2022) Política nacional de adaptación al cambio climático - Nicaragua

Gobierno de Nicaragua (2020) Contribución Nacionalmente Determinada de Nicaragua. Actualización 2020. Managua

Hagen I, Huggel C, Ramajo L, et al (2022) Climate change-related risks and adaptation po-

tential in Central and South America during the 21st century. Environmental Re-search Letters 17:033002. https://doi.org/10.1088/1748-9326/ac5271

Hernández N, Bravo JR (2015) Medidas de adaptación al cambio climático validadas por productores y técnicos en el Golfo de Fonseca de Honduras, Nicaragua y El Salvador

Hidalgo H, Alfaro E, Amador J, Bastidas Á (2019) Precursors of quasi-decadal dry-spells in the Central America Dry Corridor. Clim Dyn 53:1307–1322. https://doi.org/10.1007/s00382-019-04638-y

Imbach P, Beardsley M, Bouroncle C, et al (2017) Climate change, ecosystems and small-holder agriculture in Central America: an introduction to the special issue. Climatic Change 141:1–12. https://doi.org/10.1007/s10584-017-1920-5

Imbach P, Chou SC, Lyra A, et al (2018) Future climate change scenarios in Central America at high spatial resolution. PLoS ONE 13:e0193570. https://doi.org/10.1371/journal.pone.0193570

IPCC (2022) Summary for Policymakers. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Work-ing Group II to the Sixth Assessment Report of the Intergovernmental Panel on Cli-mate Change, Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 3–33

Ley D, Adams H, Araos M, et al (2022) Cross-Chapter Box FEASIB: Feasibility Assessment of Adaptation Options: An Update of the SR1.5. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge University Press, Cambridge, UK and New York, USA, pp 2769–2807

MARENA (2015) Plan municipal de protección Ambiental de las familias ante el cambio climático: Puerto Morazán. Ministerio de Ambiente y Recursos Naturales, Managua

MARENA (2018) Estudio de tecnologías de adaptación al cambio climático en sectores prio-rizados. In: Tercera Comunicación Nacional de Cambio Climático - Nicaragua. Minis-terio del Ambiente y de los Recursos Naturales (MARENA), Managua, Nicaragua

New M, Reckien D, Viner D, et al (2022) Decision Making Options for Managing Risk. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate Change 2022: Impacts, Adap-tation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, USA, pp 2539–2654

Olsson L, H. Barbosa, S. Bhadwal, et al (2019) Land Degradation. In: H.-O. Pörtner, D. C. Roberts, P. Zhai, et al (eds) Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Cambridge University Press, Cambridge, UK, pp 345–436

O'Neill B, van Aalst M, Zaiton Ibrahim Z, et al (2022) Key risks across sectors and regions. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assess-ment Report of the Intergovernmental Panel of Climate Change. Cambridge Univer-sity Press, Cambridge, UK and New York, USA, pp 2411–2538

Pörtner H-O, Roberts DC, Adams H, et al (2022) Technical Summary. In: Pörtner H-O, Rob-erts DC, Tignor M, et al. (eds) Climate Change 2022: Impacts, Adaptation, and Vul-nerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cam-bridge, UK and New York, NY, USA, pp 37–118

Ribalaygua J, Gaitán E, Pórtoles J, Monjo R (2018) Climatic change on the Gulf of Fonseca (Central America) using two-step statistical downscaling of CMIP5 model outputs. Theoretical and Applied Climatology 132:867–883. https://doi.org/10.1007/s00704-017-2130-9

Shukla PR, J. Skea, R. Slade, et al (2019) Technical Summary. In: P.R. Shukla, J. Skea, E. Cal-vo Buendia, et al. (eds) Climate Change and Land. Cambridge University Press, pp 35–74

Singh C, Ford J, Ley D, et al (2020) Assessing the feasibility of adaptation options: methodo-logical advancements and directions for climate adaptation research and practice. Climatic Change 162:255–277. https://doi.org/10.1007/s10584-020-02762-x

Smith P, J. Nkem, K. Calvin, et al (2019) Interlinkages between desertification, land degra-dation, food security and greenhouse gas fluxes: Synergies, trade-offs and integrat-ed response options Supplementary Material. In: P.R. Shukla, J. Skea, E. Calvo Buen-dia, et al. (eds) Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems. Cambridge University Press, Cam-bridge, pp 551–672

Stewart I, Maurer E, Stahl K, Joseph K (2022) Recent evidence for warmer and drier growing seasons in climate sensitive regions of Central America from multiple global da-tasets. International Journal of Climatology 42:1399–1417. https://doi.org/10.1002/joc.7310

UNCCD (2022) WOCAT SLM Database. https://qcat.wocat.net/en/wocat/list/?q=nicaragua&type=wocat. Accessed 28 Jul 2022

Chapter IV. "The Framework for Implementing Climate Adaptation (FICA): Analyzing Adaptation Project Realities – An Exploration of GCF Adaptation Projects"

Chapter IV. The Framework for Implementing Climate Adaptation (FICA): Analyzing adaptation project realities – an exploration of GCF adaptation projects

Guillén Bolaños, Tania[1,3]; Ebi, Kristie[2]; Máñez Costa, María [1]; Scheffran, Jürgen[3]; Jacob, Daniela[1]

[1] Climate Service Center Germany (GERICS), Helmholtz-Zentrum Hereon. Hamburg, Germany.
[2] Center for Health and the Global Environment, Schools of Medicine and Public Health, University of Washington, Seattle, WA, United States of America.
[3] Research Group Climate Change and Security, Institute of Geography, Universität Hamburg. Hamburg, Germany.

4.1 Introduction

> *"Most observed adaptation is fragmented, small in scale, incremental, sector-specific, designed to respond to current impacts or near-term risks, and focused more on planning rather than implementation (high confidence)* (IPCC 2022a, p. 20)*."*

Recent reports have indicated advancements on climate adaptation policies and actions. For example, the 2023 UNEP's Adaptation Gap Report (UNEP 2023) indicates that 85% of countries have at least one national-level adaptation planning instrument. Nevertheless, there's still a disparity or shortfall between the planned or intended actions and measures for addressing the impacts of climate change and their actual implementation (IPCC 2023; UNEP 2023). The gap between adaptation planning and implementation exists in both developing and developed countries (Bednar-Friedl et al. 2022; Castellanos et al. 2022; IPCC 2022a; Trisos et al. 2022). One significant factor contributing to this disparity is the insufficient allocation of adequate funding from public and private sources for climate adaptation projects, which impedes their comprehensive implementation and effectiveness. However, even when financial resources are available, the level of implementation remains low (UNEP 2023). This suggests that financial resources are not the sole issue. Therefore, in this study, we focus on investigating aspects related to the implementability of adaptation plans and projects. We define implementability as the likelihood or probability of an adaptation action being implemented or delivered (Damschroder et al. 2022).

It is of paramount importance to address the implementation gap to ensure effective climate adaptation. Effective adaptation is contingent upon the long-term objectives of the adaptation actions and the extent to which these objectives are reached (IIED 2016). The term "efficiency" is also used in the context of adaptation project implementation. However, it is more closely related to cost-efficiency and cost-benefit analysis, which do not always take into account non-monetary aspects. In the context of adaptation monitoring and evaluation, the concept of effectiveness is linked to the outcomes of the adaptation process, whereas efficiency is associated with the outputs. The literature identifies a number of barriers to the implementation of adaptation actions which can affect both outcomes and outputs of adaptation processes, including the alignment of policies, technical capacity, stakeholder

engagement, insufficient resources, prohibitive policies, competing or conflicting priorities for action, and uncertainty about future changes (Owen 2020; New et al. 2022). Runhaar et al. (2018) suggest that organizational structures, practices, and modes of collaboration, which are not contingent on financial resources, represent the primary impediments to implementation.

Monitoring, evaluation, and learning (MEL) strategies are essential for identifying the various barriers and challenges, by conducting continuous assessment of progress, and implementing necessary adjustments to ensure the effective implantation of climate adaptation measures and their contribution to resilience against the impacts of climate change (New et al. 2022). MEL strategies are an integral part of adaptive management, defined as "a process of iteratively planning, implementing, and modifying strategies for managing resources in the face of uncertainty and change" (IPCC 2022b, p. 2899). Adaptive management represents a vital approach to the implementation of climate adaptation-related initiatives. It entails continuous monitoring and adjustment of management strategies based on new information, increased learning at all levels, and changing circumstances. Pahl-Wostl (2006, p. 49) defines adaptation management as a process of "learning to manage by managing to learn." This approach ensures the effectiveness and success of management strategies in achieving their intended outcomes (Pahl-Wostl 2006; Hess et al. 2012; IPCC 2022b).

In the field of adaptation research, there is a growing body of literature examining the characteristics of successful adaptation (e.g., Adger et al. 2005; Moser and Boykoff 2013; Dilling et al. 2019; Owen 2020; Singh et al. 2022; Guillén Bolaños et al. 2022). New et al. 2022 synthesize successful adaptation into three main characteristics: adaptation that is (1) effective; (2) reduces climate impacts, vulnerabilities, and risks; and (3) balances synergies and trade-offs. However, there is a paucity of literature regarding guidance to enhance the implementation processes in order to increase the effectiveness and efficiency of adaptation initiatives (Cabana et al. 2023).

One of the most important instruments for assisting developing countries in transitioning towards low-emission and climate-resilient development is the Green Climate Fund (GCF). The GCF aims to achieve a 50:50 balance between mitigation and adaptation actions. As of June 2024, the GCF has committed approximately USD 14 billion for over 250 projects (44% of which are adaptation-related), of which 12 US billion are currently in the implementation phase. Nevertheless, only USD 4.4 billion (36% of the committed resources) have been reported as disbursed (GCF 2024a). Furthermore, due to the necessity of adhering to legal and technical requirements, the progression of a project proposal from design phase to approval and finally to implementation can span several years (GCF-IEU 2023a). This overview serves to illustrate once more than obstacles to implementing adaptation extend beyond financial concerns. In addition, studies related to GCF funding have elucidated the significance of resource efficiency (e.g., Ari and Isik 2022). In light of the pivotal role the GCF plays within the climate finance ecosystem and the pressing need to implement climate adaptation action, it is imperative to investigate novel approaches that can facilitate the rapid translation of research findings, practical knowledge of lessons learned, and successful interventions into actionable strategies to overcome non-climate obstacles and enhance the effectiveness of adaptation projects. This requires the development of more comprehensive and systematic methodologies to facilitate the generation of evidence (Nalau 2021).

In response to these identified gaps, our initial investigation focused on the potential for implementation science (IS), an approach originally developed in the health sector, to enhance the efficiency of adaptive management in climate adaptation projects. Based on our investigation of the potential for Implementation Science to enhance climate adaptation initiatives, we developed the Framework for Implementing Climate Adaptation (FICA), a structured methodology designed to support the evaluation of the challenges and barriers

faced during the implementation of climate adaptation initiatives. The framework encompasses multiple factors, including aspects related to stakeholders and beneficiaries, the project design, the implementation process, and the project's outcomes and outputs. In order to test and enhance the framework, an investigation was conducted into GCF projects that are currently in implementation in Latin America and the Caribbean, as well as in African Least Developed Countries, was conducted. The findings of this investigation are presented in the form of an analysis of the barriers and challenges encountered by GCF adaptation projects, complemented by findings related to the characteristics of a successful implementation process of climate adaptation initiatives.

4.2 Implementation Science and its Implications for Climate Adaptation

The Intergovernmental Panel on Climate Change (IPCC) developed and recently updated the Iterative Climate Risk Management (ICRM) framework (New et al. 2022), while the UNFCCC's Adaptation Committee refers to the Iterative Adaptation Process (IAP) at the policy level (e.g. (UNFCCC-AC 2023). The two frameworks are composed of the same four components and may be employed interchangeably: the assessment of climate risks and contextual factors, the appraisal of adaptation options and planning, the implementation of the options, and the monitoring, evaluation, and learning.[5] Nevertheless, while the implementation process itself is pivotal to the potential success of interventions (Schultes et al. 2022), there's limited literature available regarding the implementation of adaptation options (Cabana et al. 2023; UNEP 2023). This absence of documented lessons learned, best practices, and successful experiences may impede the uptake of knowledge regarding the effectiveness of adaptation in practice and the factors contributing to their success or failure.

The field of implementation science (IS) has its origins in the health sector. The term "implementation science" (IS) is defined as "the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, and, hence, to improve the quality and effectiveness of health services" (Bauer et al. 2015, p. 3). IS responds to the demand to evaluate not only final results or outcomes, but also the effectiveness of the implementation process itself by providing methodologies to systematically evaluate and ensure adjustments that are based on sound evidence. The objective of this evaluation is to identify strategies for maximizing the benefits, sustainability, and dissemination of lessons learned. In conclusion, implementation science, a relatively nascent field of studies, is concerned with identifying the most effective methods for implementing interventions and projects (Curran 2020). In the United States, it is identified as a key tool of the "learning healthcare system" (Bauer et al. 2015). In a recent investigation, Boyer et al. (2020, p. 2160), explored the applicability of this approach related to climate adaptation in the health sector. They defined IS as "a discipline focused on systematically studying the gap between knowledge and action."

A core concept in the field of implementation science is the proposition that achieving the maximum benefits of innovation relies on the successful implementation as a prerequisite (Schultes et al. 2022; Damschroder et al. 2022). A variety of methods and approaches have been developed for implementation science. The Consolidated Framework for Implementation Research (CFIR) (Damschroder et al. 2009, 2022) is one of the most utilized implementation frameworks (Curran 2020; Kononowech et al. 2021; Neta et al. 2022). It has been identified as a well-operationalized, multi-level implementation determinant framework derived from theory (Birken et al. 2017). Nevertheless, despite its broader utilization within the health sector, there has been a paucity of research connecting

[5] In this paper, we make reference to the ICRM without excluding elements or literature related to the IAP.

implementation science and climate adaptation for other sectors. The CFIR was initially constituted of five domains: the inner domain, the outer domain, the innovation domain, the implementation domain, and the individuals domain (Damschroder et al. 2009). In a recent update, Damschroder et al. (2022) put forth a conceptualization of different types of outcomes to complement the framework. The CFIR domains encompass a number of constructs, thereby facilitating the evaluation of the various components of the implementation process.

In the climate domain, implementation science, and the CFIR in particular, has the potential to contribute to a valuable systematic and evidence-based approach to the monitoring, evaluation and learning about the implementation of adaptation strategies and interventions (Boyer et al. 2020). However, there has been only limited exploration into the interconnections and potential synergies between implementation science and climate change in the context of adaptation in the health sector (Boyer et al. 2020; Neta et al. 2022). While the terminology utilized may differ between the steps of the ICRM process and the CFIR domains, the synergies and the complementary nature of these frameworks are evident (**Table IV-1**). The two frameworks identify five distinct components: stakeholder and beneficiaries; the contextual factors; the project or innovation itself; the implementation process; and the monitoring, evaluating and learning (MEL) component. The primary distinction between the two frameworks pertains to the MEL activities. While they are included as a ICRM step, the CFIR incorporates these activities within the implementation and the outcomes domain.

Table IV-1 *Connections between the Iterative Climate Risk Management and Implementation Science (based on New et al., 2022; Damschroder et al., 2009, 2022;)*

Type of elements	***ICRM process (New at al. 2022)***	***CFIR domains (Damschroder et al. 2009; 2022)***
Stakeholders & beneficiaries	Decision makers	Individuals domain
Contextual	Assess climate risk and contextual factors	Inner domain *(i.e., structural, political and cultural context)* Outer domain *(i.e., economic, political, and social context)*
Response / project	Choose and plan content-specific responses	Innovation domain *(the "thing" being implemented)*
Implementation process	Implement adaptation and risk management	Implementation domain *(the activities and strategies used to implement the innovation)*
Monitoring, evaluating, and learning (MEL)	Monitor progress and outcomes, evaluate and learn	Implementation domain *(including aspects of reflecting and evaluating)* Outcomes *(distinction between type of outcomes)*

4.2.1 Framework for Implementing Climate Adaptation (FICA)

In consideration of the substantial interconnections and synergies between the CFIR and ICRM frameworks that have been previously delineated, we propose the Framework for Implementing Climate Adaptation (FICA). The FICA is a comprehensive instrument that can facilitate the assessment of the effectiveness of adaptation initiatives, taking into account elements that extend beyond the mere availability of financial resources.

The FICA encompasses aspects of the four enabling conditions for adaptation and risk management, as outlined by New et al. (2022): governance, finance, knowledge and capacity, and catalyzing conditions. In this context, the terms "components" and "elements" are employed to refer to the elements that are referred to in the CFIR as "domains" and "constructs." **Figure IV-1** provides an overview of the FICA components (in gray), highlighting the elements of the implementation process component and the positioning of monitoring, evaluation, and learning (MEL) activities within the framework.

The following subsections describe and summarize the components proposed as part of the FICA framework, namely stakeholders and beneficiaries, the adaptation project, the implementation process, and outcomes and outputs. Annex A presents a comprehensive outline of the proposed structure, delineating the components, elements, and sub-elements. This outline can serve as preliminary guidance for evidence collection and assessing the implementation of adaptation projects.

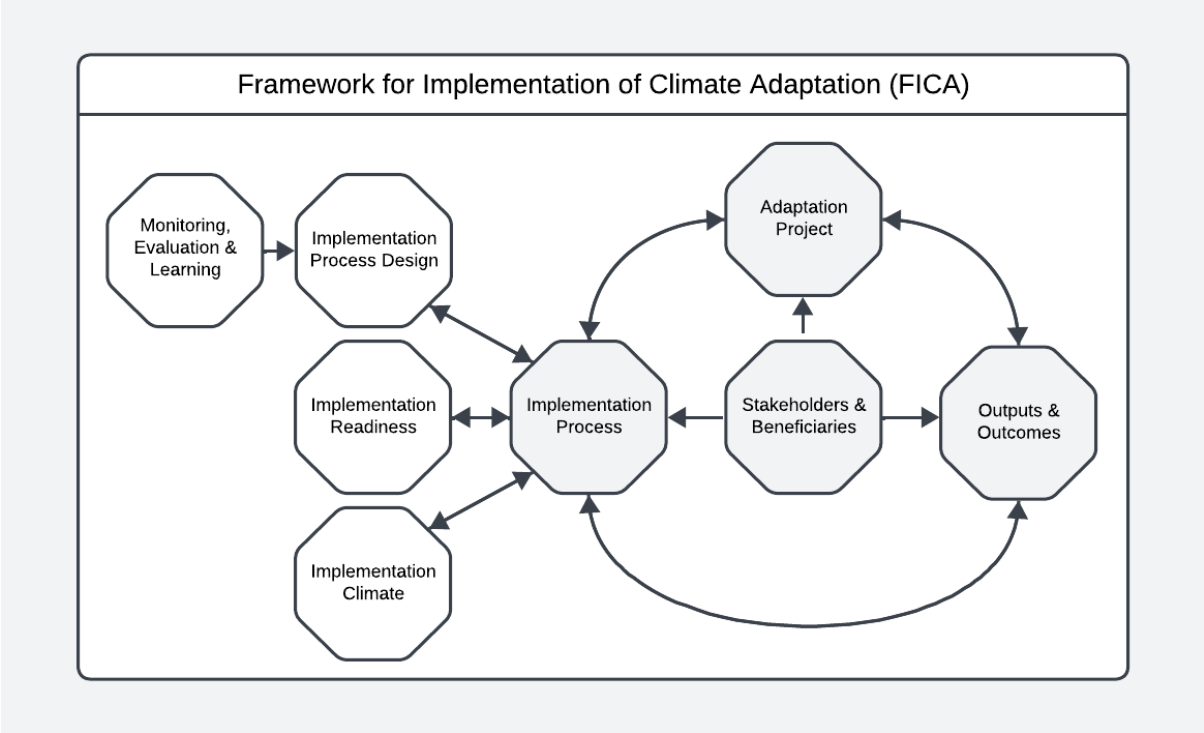


Figure IV-1 *Components of the Framework for Implementing Climate Adaptation (FICA)*

4.2.1.a Stakeholders & Beneficiaries

It has become increasingly evident that robust stakeholder engagement processes, inclusive of beneficiaries, are essential for the design and implementation of effective adaptation interventions. Individuals can act as catalysts for adaptation-related decision-making processes (Bo and Spanger-Siegfried 2004; New et al. 2022). Cinner et al. (2018) identify five domains of adaptive capacity: assets, flexibility, social organization, learning, and agency. In the ICRM, New et al. (2022) identify the "decision-makers" category, which primarily comprises representatives from civil society, the private sector, institutions, Indigenous

Peoples, etc. However, it is crucial to consider the agency and commitment not only from the institutional perspective but also from the individuals who are part of those institutions or groups (Wamsler et al. 2022). Individuals possess the capacity to make decisions and exert influence on others, which can impact implementation outcomes. They possess a multitude of cultural, organizational, professional, and personal perspectives (Damschroder et al. 2009).

Understanding the individual motivations and capacities within institutions can facilitate the identification of additional nuances related to the roles, needs, opportunities, capacities, and motivations that can enhance the implementation processes. This can be achieved by developing tailored strategies to enhance collaboration and effectiveness in climate adaptation efforts (Conde and Lonsdale 2004). Accordingly, the "individuals" component of the FICA

4.2.1.b Adaptation Projects/Options

In its most recent assessment, the IPCC defines adaptation options as "the array of strategies and measures that are available and appropriate for addressing adaptation" (IPCC 2022b, p. 2898). Adaptation options aim to reduce the risks associated with current and projected climate change. Such options can be structural, institutional, ecological, or behavioral in nature. In the context of the CFIR, the term "innovation" refers to the specific thing being or to be implemented (Damschroder et al. 2022).

Climate adaptation projects must be underpinned by robust evidence in order to guarantee their effectiveness and prevent unintended consequences (Garschagen et al. 2021; New et al. 2022). To determine which adaptation option should be implemented, it is necessary to assess the climate risks, and contextual factors need to be assessed (LEG-UNFCCC 2012; New et al. 2022). Climate funds, such as the GCF or the Adaptation Fund, require project proposals to be based on sound scientific information regarding the identification of climate vulnerabilities and risks, as well as the proposed solutions (GCF 2019a, 2022a, b)

The FICA's "adaptation project/options" component encompasses a range of considerations, including aspects of design and evidence-based, project adaptability (i.e., the avoidance of lock-ins), project complexity, project costs, and project appropriateness. The design sub-element encompasses a range of considerations, including environmental and social risk assessments, climate change (impact) scenarios, and options appraisal.

4.2.1.c Implementation Process

Once the potential adaptation options have been identified, the subsequent step is to design the implementation process. The implementation process consists of the activities and strategies employed to execute the project. The success of implementation strategies is contingent upon a multitude of contextual and intrinsic factors (Proctor et al. 2011; New et al. 2022; Neta et al. 2022; Damschroder et al. 2022).

The FICA proposes three elements of the implementation process: implementation design (referred to as the environmental/climate sector, or inner setting, involved in the project), implementation readiness (the extent to which the inner setting is ready for implementation), and implementation climate (the extent to which the inner setting has an implementation climate, including the setting in which the inner setting exists).

The implementation design element is comprised of the following sub-elements: planning, the tailoring of implementation strategies, country ownership, multi-stakeholder engagement, needs assessment, context assessment, and monitoring, evaluation, and learning (MEL) activities.

The implementation readiness element pertains to the extent to which the inner setting of a project is ready for implementation. The term "inner setting" is defined as the "structural, political, and cultural context through which the implementation process will proceed" (Damschroder et al. 2009, p. 5). Accordingly, the implementation readiness element encompasses the following aspects: teaming, requirements, relational connections/governance, structural characteristics, access to knowledge and information, communications, technical capacities, technology, available resources (co-finance, space for implementation, materials, and equipment), culture, and incentive systems.

The implementation climate element, which we define as the climate risks and contextual factors that could affect the implementation of the project, comprises local conditions, external pressure (societal and market pressure), acceptability, critical incidents / external risks, and local attitudes.

4.2.1.d Adaptation Outcomes & Outputs

A recent development regarding the CFIR is the "Outcomes Addendum," which focuses specifically on implementation outcomes (Damschroder et al. 2022). Although the original CFIR framework offers a comprehensive structure for assessing factors influencing the implementation process, the addendum provides a detailed perspective on the outcomes of the implementation itself, thereby shedding light on the effectiveness and success of these efforts. However, when analyzed with the climate adaptation lens, the outcomes defined by Damschroder et al. (2022) are classified as outputs. Therefore, in the context of developing the FICA, we explicitly distinguish between these two concepts. Two perspectives are employed to assess adaptation: the effectiveness of adaptation itself (outcomes) and the effectiveness of support and process (outputs). In addition, the outcomes and outputs of adaptation projects can be evaluated regarding their effectiveness and adequacy[6] (New et al. 2022; Singh et al. 2022; Gao and Christiansen 2023).

New et al. (2022) identify the characteristics that define a successful adaptation and its outcomes. The degree to which adaptation benefits human systems, ecosystems or ecosystem services, marginalized ethnic groups, women and girls, and low-income populations is a key factor in determining the success of adaptation. Two additional aspects are considered: the potential for transformational adaptation and mitigation (i.e., contribution to greenhouse gas emission reductions).

In our work, the term "outcomes" describes actual changes. These changes are related to a number of different factors, including climate risks, vulnerability, well-being, and development. In other words, they are concerned about the effects of adaptation on risk reduction. The GCF defines these as "changes in conditions such as the behavioral or systemic change that occur between the completion of project/program outputs and the achievement of impact" (GCF 2022a, p. 6). One of the principal elements of the outcomes of climate adaptation is effectiveness. In light of the available literature, we propose six aspects of effectiveness that warrant: (1) reducing risk and vulnerability; (2) balancing synergies and trade-offs with mitigation (i.e., reducing or avoiding GHG emissions); (3) enhancing social well-being (co-benefits); (4) avoiding adaptation limits; (5) enhancing adaptive capacity; and (6) increasing resilience (IPCC 2022b; Singh et al. 2022; Gao and Christiansen 2023). Another crucial sub-element included as an outcome of adaptation interventions are the benefits to human well-being regarding equity outcomes, economic co-benefits, and enhancing social well-being (social co-benefits) (New et al. 2022). Additionally,

[6] "Adequacy" has been referred as the capacity to satistfy the need to respond to climate change (Lawrence, 2015 cited in Gao and Christiansen 2023, p.6)

adaptation needs to reduce impacts on ecosystems, which can be evaluated by the quality and quantity of ecosystem services (New et al. 2022; Gao and Christiansen 2023). Furthermore, we include maladaptation as a sub-element of the framework. Maladaptation refers to the unintended negative consequences of adaptation interventions (IPCC 2022b; Reckien et al. 2023). The distinction between maladaptation and unsuccessful adaptation lies in the fact that the latter does not result in significant adverse effects (New et al. 2022).

Outputs, as noted above, refer to effectiveness in terms of support and processes, including the allocation of financial resources, capacity building, policies, and the implementation of policies. Notwithstanding its significance to the adaptation process, this type of information does not provide evidence of or demonstrate how much actual change occurs as a result of the implemented adaptation actions (New et al. 2022).

4.3 Case Study and Methods

4.3.1 GCF's Adaptation Projects in Latin America and the Caribbean and African Least Developed Countries

The Green Climate Fund (GCF) is the largest international climate fund. The GCF was established in 2010 by the United Nations Framework Convention on Climate Change (UNFCCC) to support developing countries. This is to be achieved by promoting the development of low-emission and climate-resilient development. Since 2015, it has become a pivotal institution in supporting the Paris Agreement and the realization of the National Determined Contributions (NDCs), which are the country's pledges in alignment with the agreement. The fund endeavors to balance financial support for mitigation (reducing greenhouse gas emissions) and adaptation (enhancing resilience to climate impacts).

The GCF seeks project proposals firmly grounded in robust evidence substantiating the identified needs and selected approaches (e.g., climate rationale) and adhering to rigorous consultation processes (GCF 2019a, 2022b). One of the principal instruments the GCF advocates during the proposal design phase is the formulation of a "theory of change." This entails delineating a rationale, strategies, and a results chain that collectively contribute to achieving the project's outcomes and goals (GCF 2022a).

As of June 2024, the GCF has committed nearly USD 14 billion for over 250 projects, focusing on a range of areas, including renewable energy, sustainable agriculture, water resources, forest management, and disaster risk reduction (GCF 2024a). The GCF operates through partnerships with accredited entities, which may be national, regional, or international organizations, with the primary objective of implementing projects on the ground. The fund aims to leverage additional financing from public and private sources, thereby facilitating transformative change in climate action across the globe (GCF 2023a). The GCF has identified three priority groups for support: African states, Least Developed Countries (LDCs), and Small Island Developing States.

In order to focus our efforts and limit the scope of our work, we concentrated our attention on adaptation projects in Latin America and the Caribbean (LAC) and African Least Developed Countries (Af-LDCs). Africa accounts for 38% of the GCF global portfolio, while LDCs represent 30% (GCF 2024b, c). Approximately 25% of the global GCF project portfolio is represented by Latin America and the Caribbean, with 66 approved projects, of which 59 are under implementation (GCF 2024d).

Despite their minimal contributions to climate change, countries in LAC and Af-LDCs are among the most adversely affected by climate-related events (IPCC 2022b). Research gaps, data constraints, and inequities regarding funding for adaptation are evident in both regions.

Additionally, the lack of adequate financing, technological limitations, and institutional constraints are significant barriers to adaptation in both regions. For instance, MEL frameworks in LAC are constrained to climate impact drivers, excluding social and economic aspects that may influence the effectiveness of adaptation measures (Castellanos et al. 2022; Pörtner et al. 2022).

4.3.2 Methods: Sample Selection Criteria, Interviews, Document Screening

The GCF project cycle involves the participation of various actors, including National Designated Authorities (NDAs), Accredited Entities (AEs), Executing Entities (EEs), the GCF Board, and the secretariat. Moreover, local stakeholders and the project's beneficiaries are engaged in the proposal design and implementation. A brief description of the various roles is provided in Annex B. This work focuses on the actors directly involved in project implementation to achieve our objectives. The actors mentioned above include National Designated Authorities (NDAs), Accredited Entities (AEs), and Executing Entities (EEs).

4.3.2.a Sample Selection Criteria

The GCF currently has a portfolio comprising more than 250 projects, 44% of which are related to adaptation (GCF 2024a). To narrow down the sample, specific criteria were established. First, we focus our analysis on projects aligned with the GCF result area of "health, food security, and water security." Secondly, our selection was limited to projects categorized as being under implementation. In addition, our analysis was limited to projects confined to country projects and the GCF's adaptation theme. Ultimately, the analysis was confined to country projects in Latin America and the Caribbean (LAC) and African Least Developed Countries (Af-LDCs). The aforementioned selection criteria pertain to the status of the projects in question as of September 2023, as presented on the GCF website (GCF 2024e). Following the application of the aforementioned criteria, twenty projects were identified (see Annex C.1). Sixteen projects are located in Af-LDCs (Senegal and Tanzania each have two projects), and four are situated in LAC. Of the sample, 16 projects are promoted and managed by international AEs, three by national AEs, and one by a regional AE.

4.3.2.b Interviews

Once the projects had been identified, the contact information of the NDA and AE representatives corresponding to the twenty projects was collected from the GCF website (as of September 2023). Subsequently, an invitation email was sent to request an online interview. In the email exchange with NDA and AE representatives, we requested the contact information of EE representatives. As a result, eighteen interviews were conducted. The individuals who participated in the interview are representatives of NDAs, AEs, and EEs associated with fifteen of the twenty projects. Two of the interviewees represented organizations that fulfilled more than one role. **Table IV-2** presents the number of interviews conducted, the role of the interviewee, and the corresponding codification.

Table IV-2 *Overview of the interviews conducted and codes used in this work*

Interviewees' Role	***#***	***Code***
National Designated Authority (NDA)	5	NDA1-NDA5
Accredited Entity (AE)	7	AE1-AE7

Interviewees' Role	*#*	*Code*
Executing Entity (EE)	4[7]	EE1, EE2-1, EE2-2, EE3
Combined role: *Accredited Entity and Executing Entity*	1	AE/EE1
Combined role: *National Designated Authority and Executing Entity*	1	NDA/EE1

The interviews were conducted via online platforms between November 2023 and April 2024. The duration of the interviews ranged from 30 to 70 minutes. Most interviews were audio-recorded with the interviewees' consent, subsequently transcribed, and coded in an iterative process. The semi-structured interview questions addressed the challenges and barriers faced during the implementation of adaptation projects per the components of the FICA framework. These components included (1) stakeholders & beneficiaries (individuals); (2) adaptation project design, (3) implementation process, and (4) adaptation outcomes and outputs. The coding process commenced with the application of predefined categories, which were structured in alignment with the interview structure and the proposed FICA framework. New codes were developed inductively during the coding process to ensure a comprehensive analysis. The results of this coding process are presented in the figures included in the Findings section. The resulting codes serve as the basis for the elements proposed as part of the FICA.

4.3.2.c Documents Screening

In addition to the interviews, fifty annual performance reports of fifteen projects[8] were subjected to analysis to provide supplementary information to that collected via the interviews. As with the interviews, the information was coded following the components of the FICA framework.

4.4 Findings

This section presents the findings of applying the FICA to GCF adaptation projects. While the present study is primarily concerned with the implementation phase, we have identified the main barriers and challenges associated with the stakeholders (section 4.4.1), the project itself (e.g., design) (section 4.4.2), and its implementation (section 4.4.3). Furthermore, section 4.4.4 presents the findings related to evidence of outputs and outcomes identified by the interviewees and project reports. In addition, section 4.4.1.a presents the characteristics of "successful adaptation" and "successful implementation process" as identified by the interviewees. Moreover, this research presents the main barriers and challenges specific to GCF's adaptation projects (section 4.4.5).

[7] There are two interviewees from the same executing entity.

[8] There were no reports available related to five projects.

The information mentioned above is presented following the components of the FICA. Sankey diagrams are employed to facilitate the presentation of results between each component and element. From left to right: The nodes of the diagrams represent the various components, elements, and sub-elements of the FICA. The endpoints (on the right) are organized according to the sources of information (roles and reports). The links that connect the nodes represent the flow between them, whether at the level of elements or sub-elements. The thickness of each arrow indicates the magnitude of the data, expressed as the number of respondents or reports that cite the specific barriers or challenges, classified under the components, elements, and sub-elements).

To underscore particular statements in interviews and reports that we deem illustrative of pivotal issues, we indicate the interview or country code (for a list of country codes, see Annex C.1). For a comprehensive overview of the findings, please refer to the tables in Annex D.

4.4.1 Barriers and Challenges for Implementation: Stakeholders and Beneficiaries

Figure IV-2 presents a synthesis of the findings related to the stakeholders and beneficiaries component. The findings indicate that despite the investment of time and resources during the design phase, it is necessary to clarify the distinct **roles**, arrangements, resource allocation, and contributions of the various stakeholders once a project commences its implementation. This aspect is of utmost importance to ensure the successful implementation of a project, as it helps to avoid any potential overlap or confusion among the involved stakeholders. This issue was predominantly identified in the project reports and mentioned during the interviews by representatives from NDAs, followed by representatives of AEs and EEs. Staff turnover, among other factors, results in a lack of or a weak historical record of the project activities, which may impede implementation processes. This issue was identified in the project reports and mentioned by representatives from NDAs and EEs.

Regarding **needs and capacities**, various projects have identified challenges on the technical capacities (at the national and sub-national levels) of the project's team. Such issues include issues pertaining to procurement processes, accounting, and monitoring activities. For example, monitoring activities rely significantly on the input of field staff. However, several projects reported difficulties in identifying professionals with expertise in monitoring and evaluation. In the event of a lack of available personnel, it becomes necessary to invest in training processes, resulting in longer timescales and a higher investment of resources. Furthermore, limitations regarding the field of procurement were identified. The procurement processes associated with this type of project may exceed the capabilities of local professionals, particularly given the complex procedures established by the accredited entities. This type of challenge is particularly pertinent in small countries.

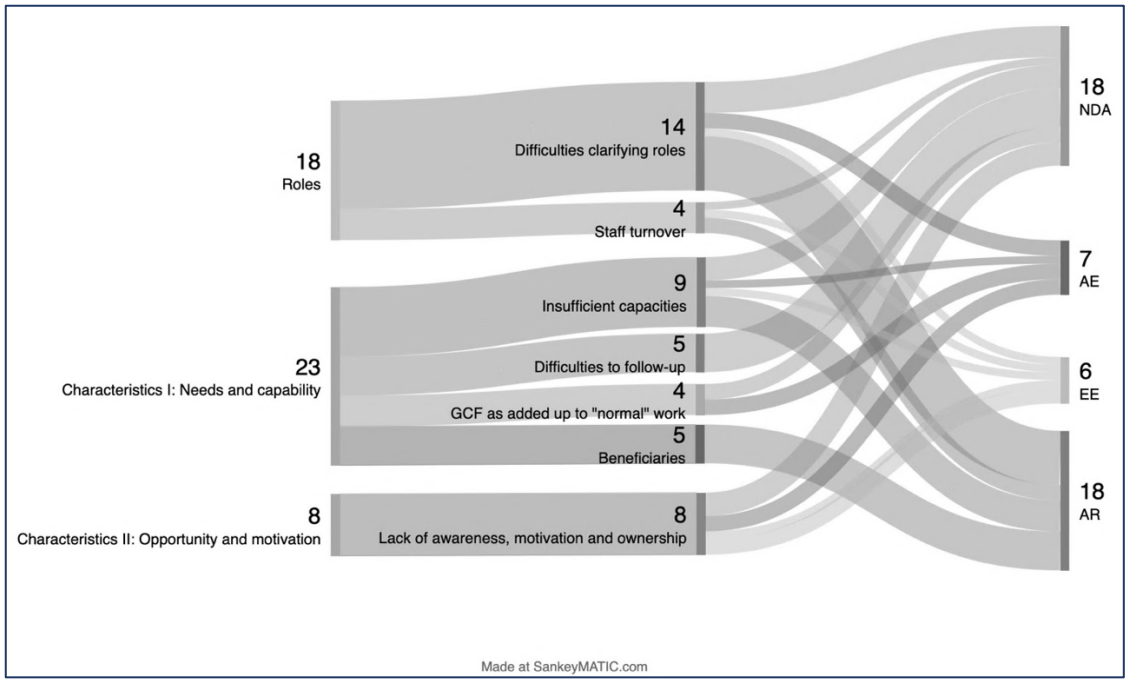


Figure IV-2 *Barriers and challenges: Stakeholders and Beneficiaries (source: interviews, annual performance reports, Annex D.1). NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AR: Annual Performance Reports.*

In their remarks, representatives of NDAs underscored the difficulties encountered in the follow-up to project implementation. This difficulty is most prevalent in projects with minimal governmental involvement, specifically when AEs and EEs are not governmental entities. This is particularly the case for multi-country projects promoted by international AEs. Minimal governmental involvement is observed once the governments have provided the requisite no-objection letter. This was identified as a critical aspect, particularly regarding compliance with environmental and social safeguards. It was observed that in some multi-country projects, the role of the governments is passive, with only NDAs receiving progress reports prepared by the international AEs. Moreover, NDA and AE representatives have identified an additional challenge: the workload of personnel with already numerous responsibilities is further burdened by the addition of tasks related to GCF projects.

As documented in annual reports, the beneficiaries' capacities may impact the adaptation project implementation. Such capacities may include access to financial services and inadequate infrastructure for installing proposed systems or technologies.

With regard to **opportunity and motivation**, the absence of awareness and ownership was also mentioned as a barrier to the implementation of the adaptation projects. The lack of awareness and ownership impacts the various stages of a project, from its inception to its implementation. One factor contributing to the limited in-country ownership is the tendency of international organizations to propose and design projects with limited involvement of governmental institutions. A lack of awareness and ownership results in a lack of commitment from the relevant institutions, organizations, or stakeholders, leading to delays or non-compliance with the project's objectives.

4.4.2 Barriers and Challenges for Implementation: Adaptation Projects

"The downside of the rigor is the extreme burden it's been placing in countries, especially low-income countries, that don't have the data and they don't have the science or the kind of budgets to do it." (AE5)

Figure IV-3 presents the overview of the findings pertaining to the challenges identified to the elements of the adaptation project component, namely project design and evidence, project costs, and project appropriateness.

During the implementation phase, challenges related to the project design were identified. The necessity of **designing** adaptation projects **based on evidence** is widely acknowledged among the interviewees. Nevertheless, as evidenced by the quotation above, the GCF's rigorous standards are perceived as an extreme burden, particularly for low-income countries that frequently lack the required resources (technical, financial, access to information, etc.) to invest in the design process and comply with all legal and technical requirements. This challenge was primarily identified by representatives of NDAs and AEs, who are the most directly involved in the project design process. Moreover, the issue of constrained national-level capacities and experience was also raised.

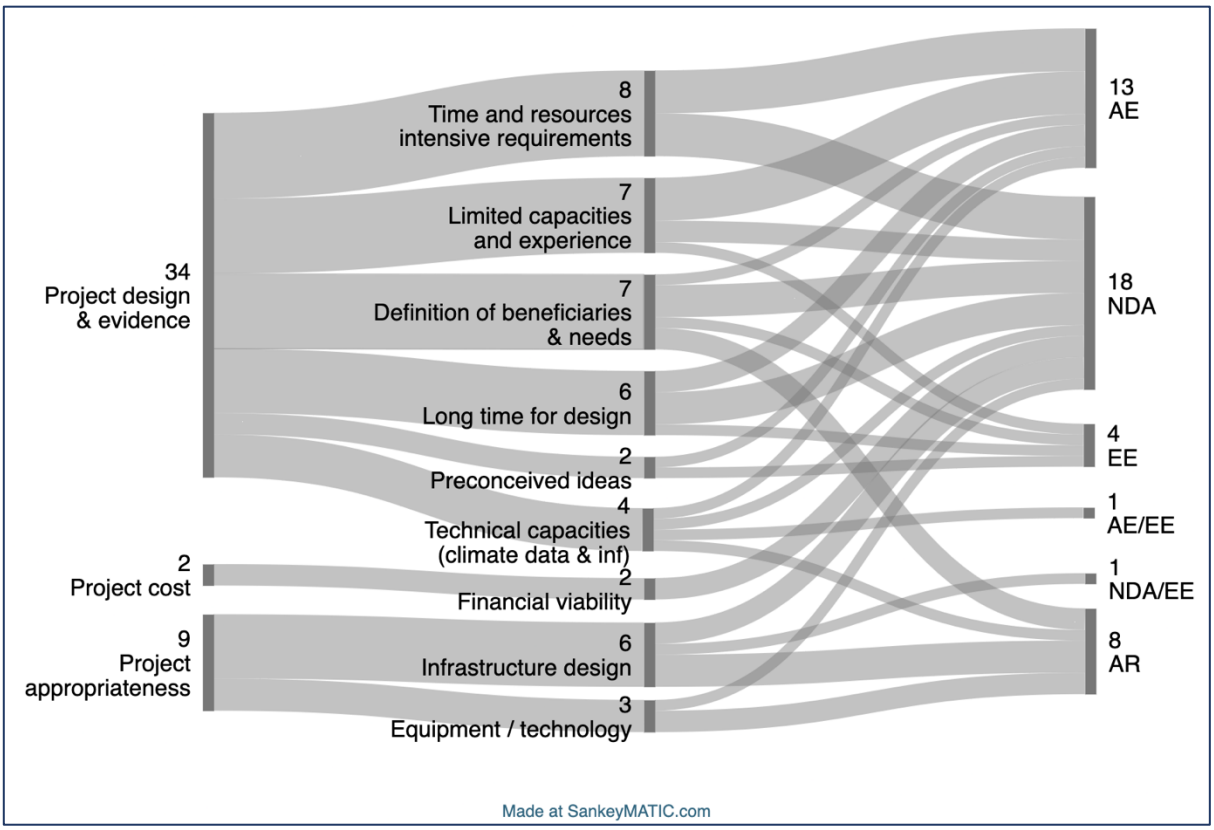


Figure IV-3 *Barriers and challenges: Adaptation project (source: interviews, annual performance reports, Annex D.2). NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; NDA/EE: National Designated Authority and Executing Entity; AR: Annual Performance Reports.*

Furthermore, interviewees underscored the challenges associated with identifying the needs of project beneficiaries, emphasizing the potential for those needs to evolve over time and in response to contextual factors. This issue significantly impacts the project implementation, particularly during the initial stages when the project baseline must be established to enable effective monitoring and evaluation activities. Moreover, accurately identifying needs can prevent misalignment between project activities and the actual requirements once the project has started, which could compromise the project's effectiveness in achieving its intended objectives. Furthermore, the design phase itself was also identified as a challenging aspect, particularly in terms of identifying the specific needs of beneficiaries. Additionally, the duration of the design phase was recognized as a challenge, as it can lead to difficulties when

implementing the project in a changing context (i.e., environmental, political, socioeconomic). This, in turn, can result in the emergence of different needs.

The lack of or low technical capacities and expertise in the field of climate data and information, which is indispensable for the advancement of proposals and the implementation process, has also been identified as a significant challenge. The source of the project idea is also identified as a challenge. Although only a limited number of interviewees address this issue, the authors consider it crucial. In a few cases, it was noted that AEs and their experts start the project design with preconceived ideas that do not always align with the context or the needs of the beneficiaries.

One primary challenge was identified with respect to the **project costs**, a crucial aspect of the design phase: financial availability. The financial viability of adaptation projects is perceived as a significant constraint. Consequently, the involvement of the private sector in adaptation initiatives is constrained

The **appropriateness** of adaptation-related infrastructure, equipment, and/or technology also poses difficulties during the implementation phase. Such issues encompass matters about weather stations, irrigation systems, and dams. These challenges were particularly evident when a considerable time had elapsed since the project's inception.

4.4.3 Barriers and Challenges for Implementation: Implementation Process

The implementation process subcomponent comprises three elements: implementation process design, implementation readiness, and implementation climate. The following sections present the findings structured around the elements mentioned above.

4.4.3.a Implementation Process Design

> *"Many of the problems that we see during implementation stemmed from problems that we had at design stage." (AE4)*

The findings regarding the implementation process are presented in **Figure IV-4** and **Figure IV-5**. The interviewees identified challenges within five sub-elements of the framework: planning, tailoring implementation strategies, country ownership, multi-stakeholder engagement, and monitoring, evaluation and learning (MEL).

In terms of **planning**, the most frequently referenced aspect is the considerable time lapse between the project's design and its subsequent approval. The delays mentioned above, when considered in conjunction with the temporal discrepancy between the design and the start of the implementation phase, give rise to significant complications. Most NDA and AE representatives cited this as a significant challenge. The complications arise because the context (e.g., political, social, economic, institutional) and needs may have undergone significant changes, making the original plans less appropriate by the time the project starts. Consequently, revisions and modifications to the initial design are required to align it with the new circumstances and the requirements of the relevant stakeholders. Furthermore, the time gaps result in periods of inactivity, which can erode trust and engagement from partners and/or stakeholders, including beneficiaries. For example, the average interval between approval and the start of the implementation phase among the twenty analyzed projects evaluated is 1.6 years (see Annex C.2), which supports the aforementioned findings.

Many activities, particularly those related to the agricultural sector, are contingent upon the prevailing seasonal conditions. Such activities are time-sensitive. The occurrence of administrative issues, such as delays in disbursements or the processing of change requests, has the potential to impact the implementation plans significantly. This is because activities can only be prepared and deployed during specific periods. Consequently, any delays in

these processes can result in the postponement of activities. Such circumstances inevitably generate delays that are not necessarily caused by or attributable to the EEs.

The primary challenge in **tailoring implementation strategies** is the GCF's lack of flexibility or adaptive management. This deficiency results in inefficiencies, delays, and, ultimately, significant delays or project failures. This was the primary concern articulated by AE representatives. In addition, issues were identified about the definition of implementation arrangements. The majority of NDA representatives interviewed highlighted this complexity. Issues related to the finalization of Memorandums of Understanding (MoUs) for project implementation, the absence or modification of bodies established as part of the project governance, and the lack of commitment of governmental agencies to project implementation were cited as barriers and challenges. Additionally, some NDA representatives emphasized further challenges related to the arrangements in the case of multi-country projects, particularly regarding monitoring activities (including environmental and social safeguards). The lack of clear guidelines or procedures regarding implementation arrangements can lead to conflicts between project stakeholders, hindering effective collaboration and coordination efforts.

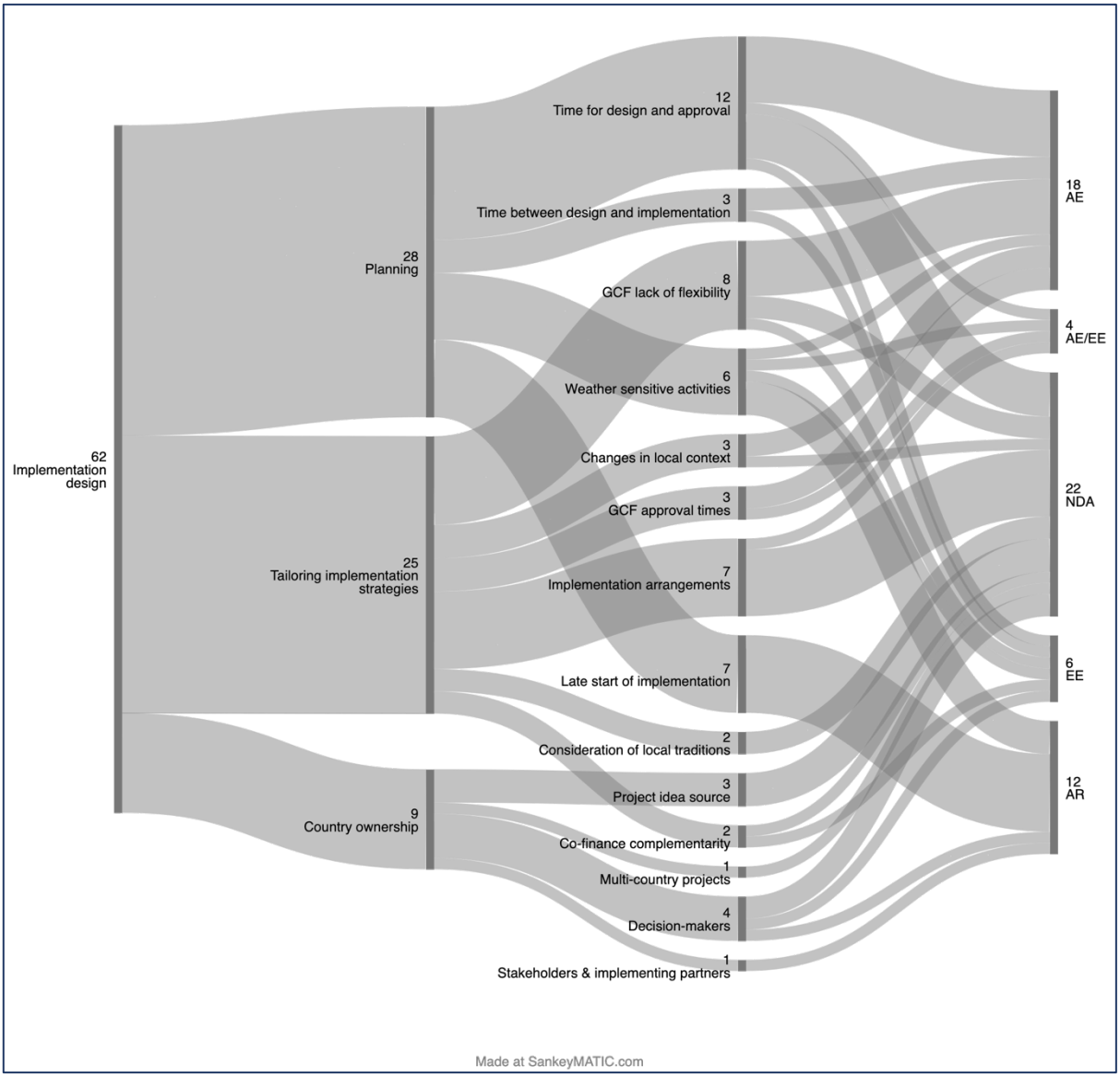


Figure IV-4 *Barriers and challenges: Implementation process design (Panel A) (source: interviews, annual performance reports, Annex D.3) NDA: National Designated Authorities; AE: Accredited*

Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; AR: Annual Performance Reports.

Additionally, AE representatives pointed out that the GCF's response to requests for changes, regardless of their nature (minor or major), is often considerable. In some cases, minor changes have resulted in delays of up to a year, affecting the disbursement of funds required for compliance with other activities.

Changes in the local context between the project design phase and the start of implementation create the need to tailor the implementation strategies. Another challenge identified was the lack of consideration of local traditions in the project design, which impacts the implementation process. An example of this is a project with a gender component that failed to consider traditional restrictions on women's access to specific territories. When the EE sought to implement certain activities in those territories, including women was impossible. Furthermore, Issues of complementarity of co-financed components of the projects were also highlighted.

Most of the challenges related to **country ownership** can be attributed to a lack of decision-makers's ownership of the decision-making process and the source of project ideas, which often originate from international AEs. These challenges can be linked to the issue of preconceived projects (by international AEs), which is also included in the adaptation project component.

The primary challenge identified with regard to **multi-stakeholder engagement** is related to the definition of community, beneficiary, and/or stakeholder involvement in project activities. Stakeholder engagement is seen as critical but also time and resource-intensive. During the design phase, when financial resources are limited, it is challenging to obtain comprehensive data. This complexity arises because the stakeholder mapping process, which identifies the relevant stakeholders, cannot be completed without initial funding to start the project. This creates a challenging situation in which progress is hindered by the need for comprehensive data and information unavailable until the project is underway. Additionally, several interviewees highlighted the necessity of preventing stakeholder fatigue and ensuring they feel respected and included, particularly given that community representatives frequently engage in these activities voluntarily. Moreover, some project reports have indicated low participation and slow uptake of activities by beneficiaries. This situation may be related to a discrepancy between the project objectives and beneficiaries's expectations.

Monitoring, evaluation, and learning (MEL) activities should be considered during the project design. Several challenges to MEL were identified, the most significant of which was the adequate allocation of resources for MEL activities during the project implementation. This includes the necessity for M&E systems to facilitate the availability and collection of data and information at various levels. Representatives of NDAs, AEs, and EEs raised the issue. In addition, there are challenges in defining the indicators to be monitored and evaluated, such as identifying beneficiaries. Furthermore, the lack of clarity regarding the implementation arrangements for MEL activities is also recognized as an issue. This includes monitoring activities related to environmental and social safeguards, particularly in the context of multi-country projects. NDA representatives mainly identified this challenge.

Other challenges include difficulties in collecting information from the field, such as the lack of standardized data collection tools and templates and difficulties in establishing baselines against which to monitor and evaluate. In some co-financed projects, double reporting (i.e., reporting for GCF and cofinancing institutions) was an issue, placing an additional burden on technical staff. To address this situation, one AE was in the process of hiring an external consulting firm to manage the project’s MEL activities.

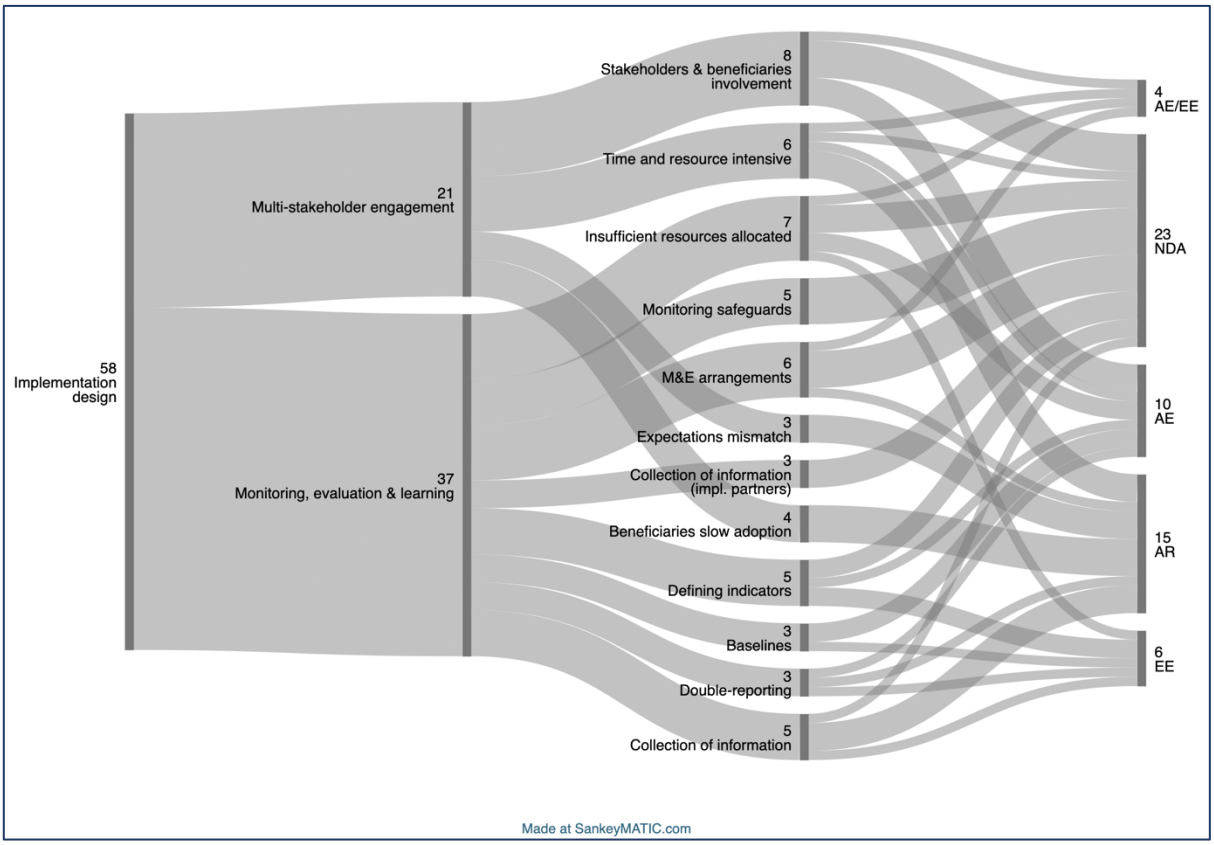


Figure IV-5 *Barriers and challenges: Implementation process design (Panel B) (source: interviews, annual performance reports, Annex D.3) NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; AR: Annual Performance Reports*

4.4.3.b Implementation Readiness

The interviews and annual performance reports have identified several sub-elements related to implementation readiness. The length of time between project design and project start significantly impacts implementation readiness. This leads to the necessity of updating the proposal, which implies that further time must be dedicated before the implementation phase begins. **Figure IV-6** illustrates the sub-elements of readiness identified among the challenges, including teaming or implementation arrangements, GCF and government requirements, and technical and operational capacities.

The following challenges were identified with regard to **teaming and implementation arrangements** were identified: implementation arrangements, changes in government, and slow government dynamics and procedures.

For projects such as the GCF projects to be successfully implemented, robust institutional arrangements must be in place among all stakeholders. However, this aspect proves to be challenging as it often involves coordinating different institutions that may have other interests and priorities. For instance, interviewees showed a discrepancy in opinion regarding the project management structure, even among experts working on the same project. The respondents preferred the entity in question to be situated within a government institution or as an independent unit. These different opinions underscore the importance of paying close attention to the local context during the design phase. Furthermore, this issue remains

challenging even when the project proposal incorporates guidance on the different roles and contributions. It is, therefore, necessary to review the arrangements before the project's implementation phase starts. NDA representatives primarily highlighted this issue.

Changes in governmental staff also have an impact on institutional arrangements. Such changes can lead to disruptions of project continuity, necessitating the allocation of additional time and resources to facilitate the onboarding of new staff. This, in turn, can impact the overall project timeline and effectiveness. Furthermore, the departure of key personnel can result in losing institutional knowledge and expertise, further complicating the smooth implementation of adaptation projects in an already challenging environment. This issue was also identified regarding the Stakeholders and Beneficiaries component.

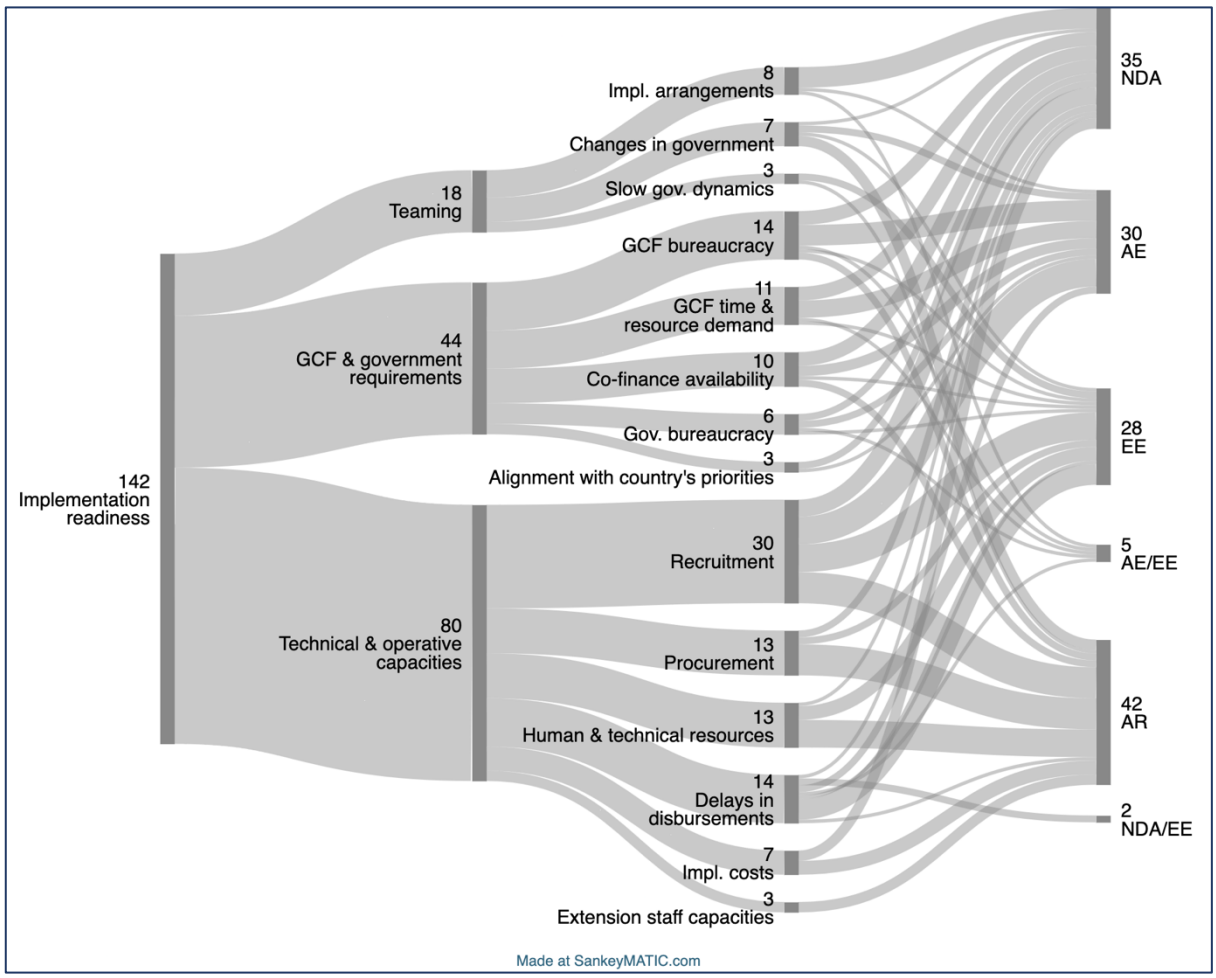


Figure IV-6 *Barriers and challenges: Implementation readiness (source: interviews, annual performance reports, Annex D.3) NDA: National Designated Autho AR: Annual Performance Reports.rities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; NDA/EE; AR: Annual Performance Reports.*

Slow government dynamics and procedures are linked to the time required for procedures. This is identified as a significant challenge, mainly by EE representatives. This problem can have a detrimental impact on the procurement and recruitment processes, which in turn impede the implementation of project activities.

Additionally, challenges pertaining to the **GCF and government requirements** have been identified, including the bureaucratic nature of the GCF procedures, the time and resource demands associated with GCF requirements, the availability of co-financing, the presence of governmental bureaucracy, and the alignment of project activities with country's priorities.

The bureaucracy of the GCF in terms of technical and legal requirements was identified as a significant challenge. One interviewee characterized this as "micro-management," which delays the implementation of project activities and decision-making processes. Furthermore, these challenges manifest when AEs seek "minor" changes. In particular, legal requirements such as those that are part of the Funded Activity Agreement (FAA) significantly impact the disbursement process, which should take up to six months[9] but often exceed this timeframe.

In addition, meeting the requirements is technically very time-consuming and resource-intensive, particularly when there is limited capacity and experience at the national level regarding the type of tools, information, analysis, and data required. The need for updated and approved baselines, environmental and social safeguards plans, and an implementation manual before the start of implementation represents a significant delay in the initiation of project activities on the ground. These issues are closely linked to the time- and resource-intensive requirements described in the Project Design and Evidence element.

"Because the criteria for prioritization of funds from GCF, I believe is not in the impact. But it's more related with the co-financing issue. Because we see that the projects that are entering would be with high percentage of co-finance. They have the great probability of being approved. They are being approved more quickly than those that have the small level of co-finance. […] Although this is not very clear, […] it becomes the main criteria of project approved." NDA4

At the outset of the implementation phase, a further crucial element is to guarantee the co-financing component of a project proposal, particularly government co-financing that a previous administration may have committed. This includes co-financing in kind, providing staff and vehicles, and organizing certain activities, among other forms of support. Among the projects analyzed, there are instances where the previously guaranteed co-financing was no longer available after the project approval. This was due to various factors, including changes in government, resource availability, and the impact of the COVID-19 global pandemic. In one project, resolving this issue, which involved negotiations between different institutions, took up to two years.

Furthermore, project start-up entails navigating government requirements and bureaucratic processes unique to each country. Such requirements may pertain to particular national regulations, procurement and hiring procedures, and technical requirements directly related to activities to be undertaken, such as the ones related to forestry or infrastructure sectors.

The main challenges identified in terms of **technical and operational capacities** required for the implementation of adaptation projects pertain to the recruitment of staff (including consultants and key personnel in territories), the procurement of materials and services, the availability of human and technical resources for co-financed activities, increased costs, and delays in the disbursement of funds.

The recruitment of project teams, including project managers and consultants, was identified as a significant challenge in implementing adaptation projects. Delays in recruitment result in delays in the implementation of the project activities, which represents a considerable challenge, particularly at the beginning of the project and when the funding proposal lacks clarity regarding the optimal composition of the team. In addition, recruiting specialists has proven challenging in small countries where the labor market is constrained. To illustrate, recruiting a hydrologist for one project took over two years. The unavailability of key personnel (e.g., accountants and extensionists staff) in the territories where the project activities are conducted has also been identified as a significant obstacle. Furthermore, the

[9] https://www.greenclimate.fund/project-cycle

limited capacity of extension staff to address climate adaptation issues represents a significant challenge.

Procurement issues were related to equipment (such as weather stations and technical specifications), agricultural inputs (such as seeds), contracts for the construction of project infrastructure, and land acquisition. Inadequate knowledge and expertise in bidding processes and limitations of local experts and proponents in meeting technical requirements have been identified as factors affecting procurement processes. Furthermore, the procurement and recruitment processes were also affected by the COVID-19 global pandemic.

A further significant issue is the lack of human and technical resources (e.g., vehicles for mobilization to project areas) available to government actors to fulfill their roles and responsibilities, including those related to co-financing and monitoring activities. This affects their ability to effectively oversee and ensure the successful completion of adaptation projects within the specified timelines and budget constraints.

Furthermore, delays in disbursement from the GCF to AEs at all stages of the project cycle and consequently to implementing partners are identified as a significant barrier to implementation. Such delays consequently result in delays to recruitment and procurement activities, which are critical to project implementation. However, project reports also cite delays in disbursement from AEs to EEs. Furthermore, there are concerns regarding the slow utilization of funds, which blocks further disbursements.

Several projects also face difficulties associated with increased implementation costs. Once implementation starts, projects encounter problems due to the elevated costs of equipment, technology, or adaptation measures, which have risen since the project was conceptualized. An illustrative example is the increase in interest rate calculations, which can make specific options unfeasible. This issue may be attributed to several factors, including the temporal discrepancy between project design (when financial estimates are made) and its subsequent implementation, fluctuations in the local economy, or unforeseen circumstances such as extreme weather events or the COVID-19 pandemic.

4.4.3.c Implementation Climate

The local implementation climate element encompasses several factors that can influence the implementation of adaptation projects. **Figure IV-7** illustrates the two aspects of the implementation climate elements identified during the interviews and in the project's annual reports: local conditions and critical incidents/external risks.

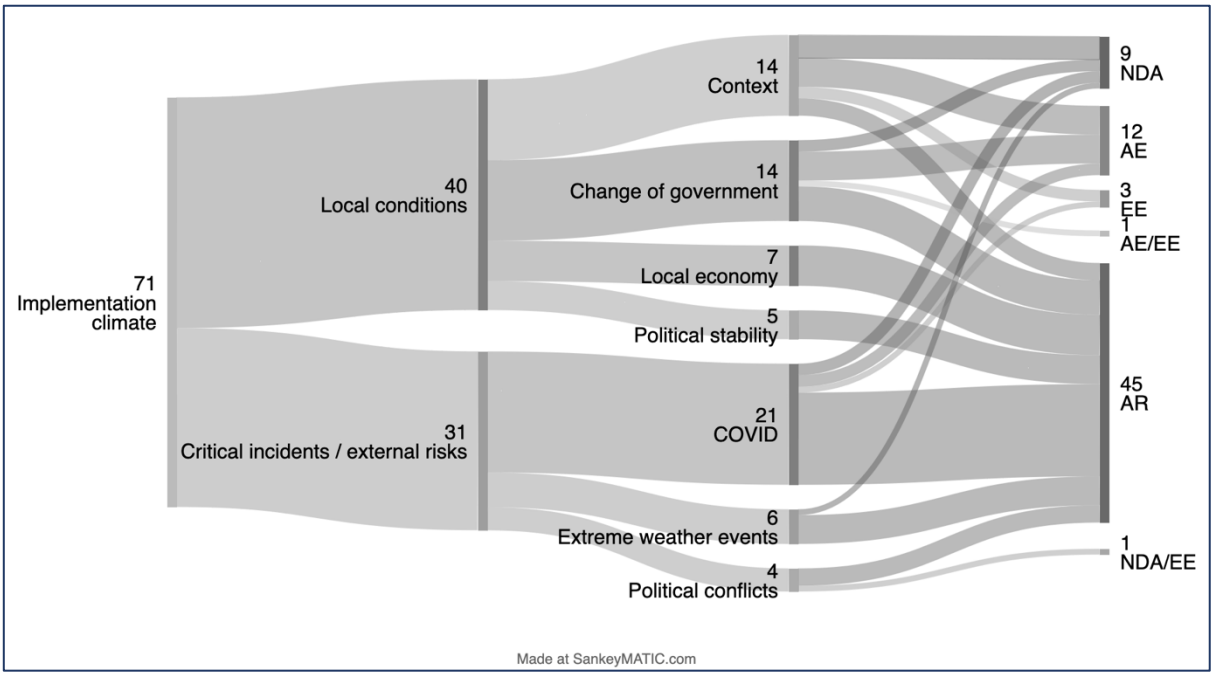


Figure IV-7 *Barriers and challenges: Implementation climate (source: interviews, annual performance reports, Annex D.3) NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; NDA/EE: National Designated Authority and Executing Entity; AR: Annual Performance Reports.*

The challenges associated with changes in **local conditions** are contingent upon the temporal distance between the project design and implementation phases. During this interval, some activities or components may no longer be feasible. In addition, this gap can create a loss of trust among the various stakeholders and beneficiaries. During this period, elections or government changes may occur, which can also affect the implementation of activities due to delays in disbursements, contracts, and procurement processes while new leadership teams, rules, or procedures are put in place.

Other factors affecting implementation, as identified in the projects analyzed, include political instability, which leads to uncertainty, risk, and safety and security concerns. Furthermore, political instability can lead to economic downturns, including inflation, price increases, and rising interest rates. These effects can be caused by internal conflicts and COVID-19, making some activities no longer viable. An example of this is the construction of infrastructure and the lack of financial participation of the beneficiaries.

Regarding **critical incidents and external risks**, it is notable that more than half of the projects initiated their implementation between 2019 and 2021. This period coincided with the start of the COVID-19 global pandemic, which significantly impacted activities in most countries worldwide. This is corroborated by the annual reports, which indicate that 16 projects encountered obstacles from the pandemic. These challenges led to delays in the implementation, including restrictions on-field activities, the cancellation or limitation of face-to-face meetings, and the cancellation of travel abroad, which affected the work of international experts and consultants, procurement, and recruitment activities. One interviewee expressed discontent with the expectation that the projects must meet the agreed-upon indicators and targets within the stipulated timeframe despite the considerable impact of the pandemic on various activities and components, including participatory activities and fieldwork, crucial for climate adaptation processes.

4.4.4 Adaptation Outcomes and Outputs of Adaptation Projects

Another area of investigation in the interviews and scanned in the project reports was the identification of outcomes and outputs of the analyzed projects. In this section, we provide a brief overview of selected elements of the FICA that were identified and that could be incorporated into MEL systems for evaluating adaptation projects. It is, however, important to emphasize that not all annual performance reports employ the same approach to identifying outcomes or outputs. Annex D.4 provides a detailed account of the elements according to the proposed components of the FICA framework.

Regarding adaptation outcomes, the subcomponent for which the most significant number of inputs were identified relates to effectiveness, encompassing enhanced adaptive capacity, reduced risk, and vulnerability. In addition, benefits to human well-being, including distributive equity and justice, improved social well-being, and economic co-benefits, were also identified.

With regards to the adaptation outputs pertaining to support and processes, the element for which the most significant number of inputs was identified is related to knowledge and technical capacities, followed by strengthened institutions, technology, and innovation. Notably, equity concerns, including those pertaining to recognitional, procedural, and gender, were identified as pivotal considerations in adaptation projects.

4.4.4.a Successful Implementation of Climate Adaptation

> *"A successful implementation process, for me, I look at the design itself. Well-designed. […] from the monitoring perspective, a successful project, will be when the people we work with, in this case, the communities we serve, are satisfied with the results. The activities are impacting their lives." (EE3)*

Additionally, our research examined the characteristics of successful climate adaptation and the processes through which they are implemented. **Figure IV-8** summarizes the numerous and varied characteristics of a successful implementation process identified during the interviews. As previously noted, numerous aspects related to the implementation are contingent on the project design, which in turn is dependent on a number of factors, including the effective and comprehensive engagement of stakeholders and beneficiaries.

Furthermore, strengthening institutional structures and achieving project objectives or indicators represent additional crucial characteristics that contribute to successful processes. In terms of institutional strengthening, EE representatives primarily identified the presence of robust institutions, whereas NDA representatives mainly emphasized clarity regarding implementation arrangements. The remaining aspects are followed by governmental ownership and the project's alignment with the country's priorities.

The extent to which a project achieves its stated objectives and indicators indicates a successful implementation. Aspects within this characteristic include respect for the project's underlying philosophy, design, and objectives; delivery of the project per the agreed specifications to the intended beneficiaries; and trust in the ability of the AE to reduce the need for micro-management.

A successful implementation process is contingent upon comprehensively understanding the beneficiaries' needs and incorporating their feedback. These characteristics underscore the significance of a robust stakeholder involvement process throughout the entire project lifecycle.

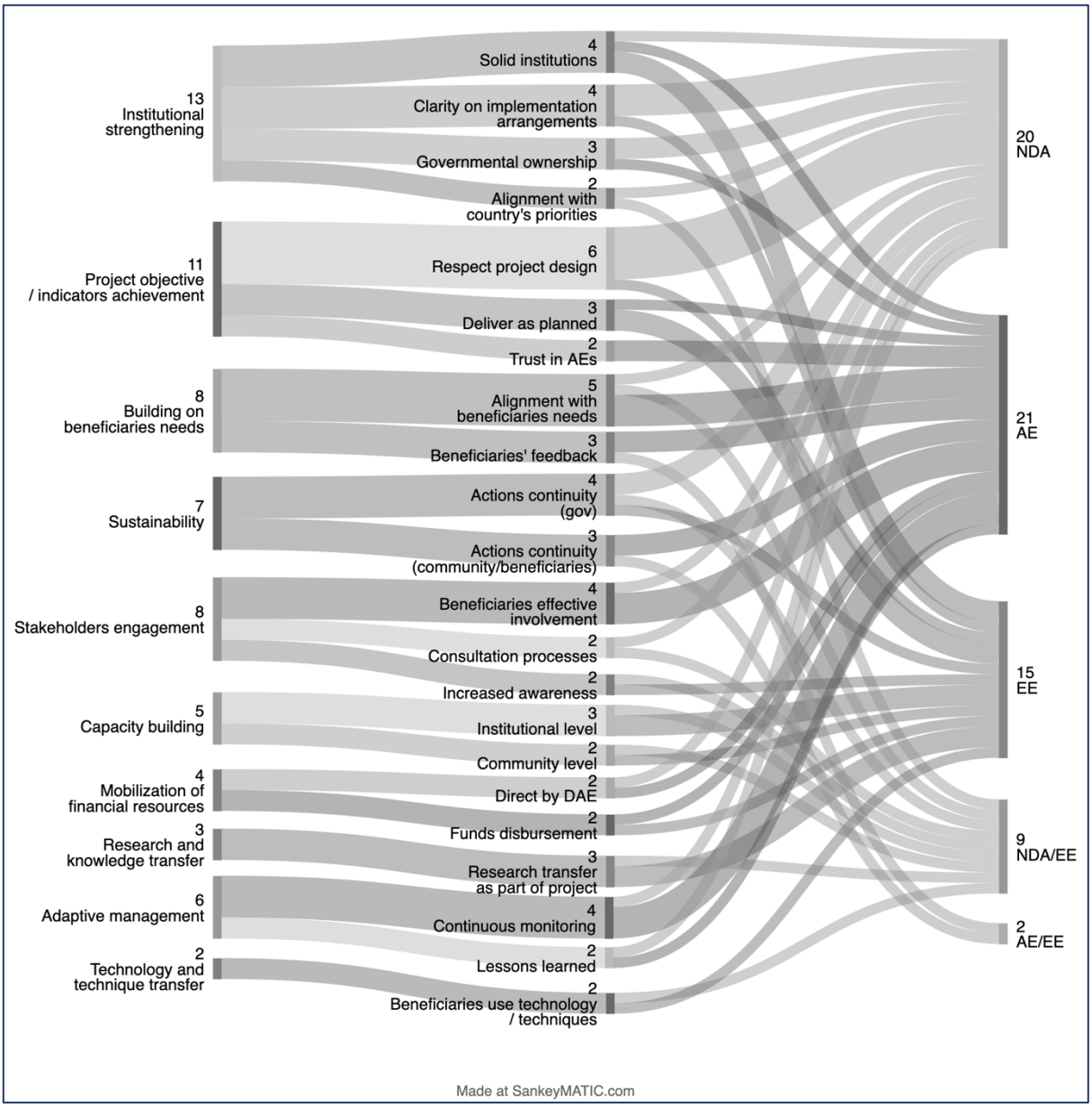


Figure IV-8 *Successful implementation process characteristics (source: interviews, Annex D.5) NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity; NDA/EE: National Designated Authority and Executing Entity.*

The sustainability of the project activities and results is also considered an indicator of success. However, the project may be vulnerable to potential risks if it does not align with the identified needs of the beneficiaries, as previously discussed. In this regard, the interviewees underscored the necessity of ensuring the sustainability of actions at the various institutional levels and by the communities or project beneficiaries.

Effective stakeholder engagement is also a crucial element in a successful process. It is of the utmost importance that the involvement in question is not merely perceived as participation or consultations; rather, it should be a robust and integral aspect of the process. During the project design phase, it is of particular importance that the engagement is robust to ensure that the proposal responds to the beneficiaries' needs and considers the local context. Furthermore, consultation processes must be conducted throughout all project phases at all levels. Additionally, the objective of the engagement should be to enhance awareness about

the climate-related risks faced by the communities and the potential solutions that can increase project support.

An additional factor identified is related to adaptive management, whereby monitoring and evaluation activities are critical to implementing corrective measures in case of delays or issues affecting the project's implementation. Some interviewees referred to management approaches such as resource-based management or principles-based management, which prioritize outcomes over the means of achieving them. Such approaches allow for adaptive management by accredited and executing entities, which could streamline and abbreviate processes that impede GCF activities.

4.4.5 Working with the GCF

Notwithstanding the urgent need for climate action in the territories, the allocation of financial resources at the international level is a lengthy process, with a considerable lag between commitment and actual delivery. In this regard, the GCF also presents a significant challenge. To illustrate, the interval between submitting a project proposal (after the design phase) and its approval can exceed two years. Moreover, the start of the implementation of approved projects can also span several years. In our project sample, the average time between project approval and the beginning of the implementation phase is 1.6 years. The longest interval between approval and project start was 4.3 years, while the shortest was 0.1 years (see Annex C.2).

A review of the information available reveals that more than two-thirds of the sample's projects started official implementation before 2021. Consequently, the majority of the projects were significantly affected by the COVID-19 pandemic. As evidenced in the annual performance reports, 11 projects have experienced delays in at least one activity, as reported in the most recent year (see Annex C.2). However, the reports exhibit considerable variation in the level of detail they provide regarding the barriers and challenges encountered and the delays they generate.

Figure IV-9 summarizes the challenges and barriers related to working with the GCF identified by the interviewees. Four major issues are identified, which are strongly connected: process complexity and bureaucracy, lack of flexibility, lengthy process, and secretariat limitations. **Table III-3** presents a selection of statements from interviewees which exemplify the issues identified in this study.

The **GCF process** is perceived as a highly **bureaucratic and intricate** system that is challenging to navigate. The comments include elements related to project design, approval, start-up, and implementation phases. The design-to-approval phase is identified as the more complex, requiring the majority of the technical, human, and financial resources to formulate the proposal and all the annexes necessary (e.g., gender action plan, environmental and social safeguards, feasibility assessment). It is noted that, for instance, governments typically lack the requisite technical and financial capacities to develop and oversee project proposals for the GCF. NDA representatives underscored the intricacy and obstacles encountered by national institutions in their pursuit of accreditation with the GCF, a previous step to project design. Consequently, the majority of projects are led and managed by international AEs. Additionally, other observations indicated that projects should be implemented by national entities rather than international entities. These considerations were discussed in conjunction with the long-term sustainability of the projects, which is contingent upon country ownership and national capacities. According to the interviewees, these capacities are constrained when AEs are not national. Moreover, the high costs of hiring international or external consultants was also highlighted.

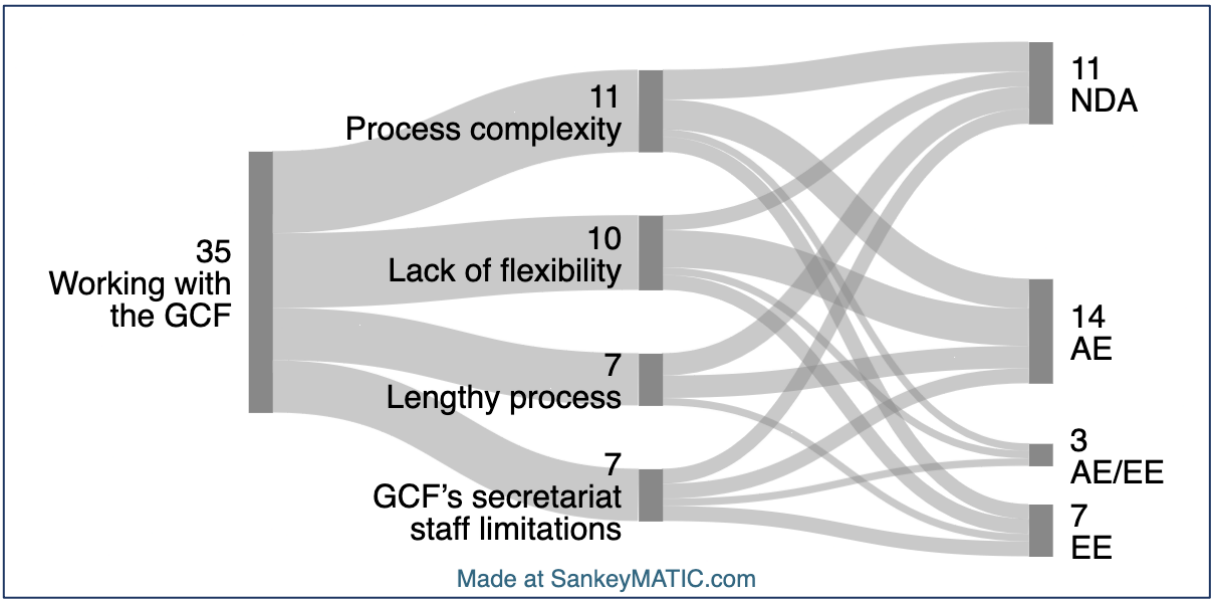


Figure IV-9 *Challenges and barriers in working with the GCF (source: interviews, annual performance reports, Annex D.6) NDA: National Designated Authorities; AE: Accredited Entity; EE Executing Entities; AE/EE: Accredited Entity and Executing Entity.*

Despite the GCF's implementation of a results-based management (RBM) approach, the interviewees identified a further significant challenge: the GCF's **lack of flexibility** or adaptive management. As previously discussed, this represents a significant challenge due to the time lapse between the initial design and subsequent implementation. Consequently, the majority of projects are required to adapt to contexts that differ from those prevailing at the time of design. Additionally, the context in which beneficiaries and stakeholders operate may have also changed. Notwithstanding the fund's objective of promoting adaptive management, different NDA and AE representatives characterize its way of work as "highly risk averse" and "transaction-heavy," with an approach based on micro-management. This constraint is also perceived as a lack of trust in the work of AEs, which is unwarranted given that they have undergone a rigorous accreditation process with the GCF.

Compounding the issues mentioned above, the GCF processes tend to take a **long time**, particularly the phase between design and implementation, giving rise to additional challenges. These include increased costs, misalignment with current conditions, stakeholders' frustration and disengagement, and institutional and staff turnover.

Another issue was identified with regard to **the GCF's secretariat**, which is responsible for the fund's day-to-day operations. Respondents cited issues resulting from the secretariat's high staff turnover in various interviews. This has been observed to affect the project's historical memory, leading to the generation of additional (and sometimes repetitive) requests that have the potential to delay reports and disbursement approvals, among other consequences. Concerns related to alteration in GCF templates and the complexity of coordinating with headquarters have also been raised. Furthermore, the lack of familiarity with national or local contexts among the GCF secretariat staff may result in the unnecessary repetition of documents and the imposition of excessive requirements.

Table IV-3 *Interviewees Statements about Working with the GCF*

Issue	***Problem Statement Examples***
Process complexity	"The process of the GCF is very tedious, is very improbable." "We wanted to change one activity, but it was really, it was not a major change. It was something small. […] And well, it took one year to negotiate this with the GCF. A lot of back and forth on the documents that we had to submit. They would come back with yet another request every time of every iteration. Also, things that were not really needed." "What we find is that they continually come back with to ask more questions, asked for more information, which then triggers, changes through the annexes, and so on. And we're all having to justify why we can't provide the level of information that they need."
Lack of flexibility	"One of the problems we have with the GCF is that they're very inflexible in, rescheduling things and what they consider to be major changes. And then, you know, if it's a major change, you have to go back to the board to get approval and so on. So these things can create quite significant delays." "In GCF the biggest barrier is the very micromanagement in their approach. And they're highly risk averse. So it's very transaction-heavy when you try to have some adaptive management in the project. So that I would say is actually, the biggest barrier with GCF on implementation compared to other funds." GCF is "very rules-based. They don't want to make errors."
Lengthy process	"So this is a big issue I see with GCF projects. It's the length. The time that it takes the design and that it takes to go from design to implementation. That really affects implementation because then things change, too much." "The situation is very different when you can go to the field and have to implement. So this is a big challenge that we see especially with this project that were designed long ago and then started implementation, after a while. But also with the most recent projects where we manage, to start implementation right after approval. Still, the design process takes three years."
GCF's secretariat staff limitations	"I know this is because the GCF and the others have the limited capacity or limited resource to come back to the same project and make all these revisions. I believe it's not easy for them." "And then quite often there are staff changes in GCF, and then you go back to the start again and people come in and start asking the same questions again, because they haven't been able to read back through all of the [] myriad of emails."

4.5 Discussions

Climate adaptation is a complex, dynamic, multidimensional, and multilayered process. The success of climate adaptation is contingent upon changes in the climate, as well as the impact of socio-economic, cultural, and environmental processes that shape the institutions, the society, and the ecosystems within which adaptation is implemented. It is, therefore, imperative to investigate and consider the potential impact of these factors on the adaptation process(es) to ensure effective or successful adaptation. This necessitates deploying adaptive management strategies based on a comprehensive understanding of the local context, active stakeholder engagement, and integrating traditional knowledge with scientific research. This approach facilitates the development of solutions aligned with the beneficiaries' needs. Accordingly, the present study utilized implementation science tools to examine climate adaptation project implementation.

Given that most adaptation-related frameworks are oriented towards the design of or planning phase, while implementation is a relatively neglected area, we developed the FICA framework. The novel integration of implementation science approaches with climate adaptation is designed to facilitate the assessment of factors influencing the gap between planned and effective adaptation interventions, identify gaps, barriers, and enablers for successful adaptation, and facilitate the evaluation of these factors.

To test the feasibility of our proposal, we selected to examine adaptation GCF projects currently in the implementation phase. As the largest financial institution supporting the achievement of the Paris Agreement goals, our findings provide essential insights that can inform improvements to the GCF's and other climate funds activities. The policy implications of our findings, as derived from the FICA framework, highlight the imperative for enhanced collaboration among stakeholders and the need to streamline access and deployment processes among financial institutions. Furthermore, the findings emphasize the necessity of continuous monitoring, evaluation, and learning processes to facilitate adaptive project management, enabling real-time adjustments that align with evolving circumstances and community requirements. Our findings confirm that adaptive management is a pivotal instrument for bridging the gap between planned adaptation and its success, thereby enabling a response to the adverse effects of climate change impacts. In addition, the FICA could also provide guidance for reducing the adaptation implementation gap related to processes such as the National Adaptation Plans (NAPs) and Nationally Determined Contributions (NDCs).

The present study is limited to examining adaptation GCF projects in African LDCs and the LAC region. Furthermore, the findings reflect only the perspectives of actors involved in the design and implementation of the projects. Nevertheless, we contend that the findings offer valuable insights that can inform the implementation phase of adaptation projects in countries of the Global South. It would be advantageous for future studies employing the FICA framework to consider the perspective of local actors and beneficiaries to obtain a more comprehensive understanding of the subject matter.

4.5.1 Implementation Science Supporting Climate Adaptation

Despite its relatively recent emergence as a field of research, the application of implementation science has increased within the health sector to accelerate the uptake of knowledge and lessons learned from the deployment of innovations. In this way, it has facilitated changes in the health sector. Nevertheless, thus far, the potential of deploying implementation science approaches in climate adaptation-related initiatives has only been investigated in the context of climate adaptation in the health sector (e.g., Boyer et al. 2020; Neta et al. 2022).

Therefore, this research identifies the interconnections between implementation science (i.e., CFIR) and climate adaptation approaches (i.e., ICRM) to support more effective design, implementation, and evaluation of adaptation projects. This comprehensive framework assists in identifying potential barriers and enablers, thereby facilitating a more strategic and informed approach to climate adaptation that builds resilience and sustainability in vulnerable communities. Furthermore, our findings confirm the complementarity and the potential for utilizing implementation science approaches to support evidence-based recommendations and decisions, which are pivotal to adaptive management, particularly in circumstances where adaptation decisions are contingent upon uncertain conditions.

As presented in this work, the FICA framework offers a structured approach to identifying the components and elements that should be given attention and included in the evidence base supporting adaptation decision-making processes. The framework is comprehensive in that it extends beyond the design of adaptation interventions, which has been the focus of previous efforts (e.g., LEG-UNFCCC 2012; Olazabal et al. 2017; UNEP 2023). Furthermore, we identify potential evidence on the outcomes and outputs of adaptation interventions, as recommended by recent climate adaptation literature (e.g., Owen 2020; Singh et al. 2021; Gao and Christiansen 2023).

Although the components and elements are presented as part of a structure, it should be noted that they may be interrelated in different project phases. These elements are interlinked and can enhance well-conceived projects, their effective implementation, and achieve their intended impacts. Examples of the connection between the FICA framework elements are the definitions of roles and capacities, which pertain to the stakeholders and beneficiaries component. However, these elements also play a pivotal role in the implementation process. This underscores the catalytic and leadership role that individuals can play in adaptive processes (Vignola et al. 2017; New et al. 2022).

One key area for future research is further empirical testing of the proposed framework. Furthermore, additional research is required to develop guiding questions or criteria as part of the FICA.

4.5.2 Main Factors Contributing to the Implementation Gap

The results of our study corroborate the assertion that many factors influence the effective implementation of climate adaptation options (Singh et al. 2020; Castellanos et al. 2022; New et al. 2022; Wells et al. 2023). Our findings are also consistent with the challenges identified by GCF-IEU (2023b), which reported that most challenges encountered during the years 2020 and 2021 were operational in nature. These were followed by challenges related to the impact of the COVID-19 pandemic (and other risks), procurement, financial, and political issues. As also identified by Runhaar et al. (2018), our results confirm that the availability of financial resources or lack of knowledge are not the only barriers and challenges. Organization structures (in this case, related to the GCF), practices, and ways of collaboration also present obstacles. Furthermore, project design, stakeholder roles and engagement and implementation arrangements, institutional and individual capacities, governance, knowledge, and information, and technical and financial considerations (including co-financing) are additional factors that must be considered.

The necessity of robust stakeholder engagement processes, including beneficiaries, has been increasingly recognized as a crucial element in adapting and implementing adaptation interventions (Bo and Spanger-Siegfried 2004; New et al. 2022). In accordance with André et al. (2023), the majority of interviewees indicated that engaging stakeholders not only enhances the effectiveness of these processes but also improves the integration of diverse perspectives, enhances legitimacy and self-awareness, and fosters a sense of ownership and community resilience in the face of climate change impacts. As suggested by Zamarioli et al.

(2020), our findings also confirm that the agency of specific GCF stakeholders, for example, from NDAs, is more dependent on national circumstances than on institutional structure at the international level. Additionally, our sample confirms that most projects are promoted and managed by international AEs, mainly due to the persisting inadequacy of national institutional capacity or the absence of Direct Accredited Entities (Zamarioli et al. 2020; Garschagen and Doshi 2022). This is an issue that numerous NDA representatives brought up during the interviews, emphasizing the necessity to enhance capacities at the national level to facilitate access to climate funds and to ensure the long-term sustainability of the projects. In particular, it has been observed that issues and delays associated with the beneficiaries' capacities, as documented in the annual performance reports, illustrate the need for a comprehensive assessment of their needs and capacities during the project design phase. This approach ensures that upon the commencement of project implementation, the beneficiaries are equipped with the necessary resources and support to engage in and actively benefit from the project activities. An illustrative example of this situation is the project in Grenada, where the beneficiaries lacked the required infrastructure to accommodate the proposed systems. The adequate identification of stakeholders, beneficiaries, and their needs reduces time-consuming and costly adjustments during the implementation phase, thus ensuring smoother, more efficient, and streamlined project execution. Furthermore, our findings underscore the significance of assessing individual stakeholders' capacities to implement adaptation projects successfully. This aligns with Cinner et al. (2018), which suggests that social and individual learning outcomes are more conducive to enhancing adaptive capacity than mere investment in assets.

The design of an adaptation project represents a critical phase that can facilitate a smooth or successful implementation process. However, despite the considerable time invested in the design of the projects, which require high financial and technical capacities, interviewees indicated that modifications or adaptations are commonly required before the implementation phase can be initiated. This additional step inevitably increases the time and resources needed to complete the project. The considerable time lapse between the design and implementation phases may negatively affect the projects' success due to the influence of contextual changes. The GCF is aware of this situation and strives to improve its performance metrics. As an example of these efforts, the operational time between approval and the initial disbursement has been reduced from 15 months in 2019 to 9 months in 2023 (GCF 2024f). Another recent example of these endeavors is the record time for the disbursement of a Cook Islands project, which took only 20 days between its approval (in March 2024) by the GCF Board and the first disbursement (GCF 2024g).

To illustrate an additional challenge related to the design phase that emerges during the implementation of the projects, we may consider issues regarding MEL activities. MEL activities must be aligned with the project's logical framework, and the necessary resources must be allocated to the project proposal. However, numerous interviewees highlighted the inadequate allocation of insufficient resources (technical and financial) to MEL activities during the implementation phase. Moreover, there is limited post-project follow-up, which precludes the ability to determine the extent to which sustainability was achieved and maintained.

The COVID-19 pandemic impacted most of the projects included in our analysis to varying degrees. Examples of challenges encountered include limitations for fieldwork and participatory activities, as well as procurement issues. Nevertheless, despite these challenges, most of the projects have demonstrated notable advancement. This is confirmed by the findings of the Second Performance Review of the GCF (GCF-IEU 2023a).

In the case of the projects under investigation, issues were found concerning the GCF and its associated processes. These include technical and legal requirements, project design, and

approval timelines. The GCF processes are perceived as time-consuming and resource-intensive, a conclusion supported by the data and results of the GCF's Second Performance Review (SPR). The perception among GCF stakeholders is that the secretariat's performance also presents challenges for implementation. These challenges include micro-management, delays in feedback, risk aversion, and disconnected disbursement processes, among other issues (GCF-IEU 2023a). The micro-management and delays in feedback were frequently cited as areas of concern by interviewees. This underscores the necessity for adaptive management as an integral component of the GCF's operational framework. In the context of a rapidly changing climate and uncertain socio-economic circumstances, it is imperative to guarantee projects' continued relevance and effectiveness in achieving their intended objectives. It is, therefore, key that mechanisms for ongoing MEL activities be incorporated throughout the design and implementation phases. This will ensure that any emerging challenge or opportunities can be responded to promptly and that the positive impact of GCF-funded projects can be maximized. The suggestions to improve the GCF's adaptation management focus primarily by implementing result-based or principles-based management.

In terms of barriers and challenges to the implementation of adaptation projects, future research efforts could focus on identifying the differences (if any) in the challenges faced by different countries. In addition, a more in-depth project-based analysis using the FICA could be developed. This would allow for a more nuanced understanding of the factors influencing the effectiveness of adaptation projects in different contexts.

4.5.3 What Constitutes a Successful Implementation Process

Our findings align with the adaptation literature in demonstrating the intricate interconnections between multiple factors that influence the successful implementation of climate adaptation projects. Adequate institutional arrangements, clear project objectives, robust stakeholder engagement, and adaptive management practices are all crucial for implementing climate adaptation projects (New et al. 2022). Moreover, our findings underscore the need for a comprehensive approach that systematically integrates these various elements to overcome the challenges and barriers encountered in implementing climate adaptation projects.

Even though adaptive management, as such, was not identified by the majority of the interviewees, it is nevertheless evident that adaptation management is also an important factor for the success of adaptation interventions. To be effective, adaptation responses must be flexible and respond to the diverse range of climate risks that can impact a territory. Moreover, they must be able to adapt as new strategies, evidence, technologies, and data tools become available. Furthermore, flexibility is a crucial element that enables to accommodate different decision-making contexts, regional conditions, time constraints, and specific needs (Gao and Christiansen 2023; UNFCCC-AC 2023). Adaptation to a changing climate is a dynamic process requiring a flexible and responsive approach. Given the inherent uncertainty associated with climate trends, adaptation plans, and projects must be prepared to adapt a range of potential scenarios. It is of the utmost importance to recognize that the objectives and effectiveness of adaptation strategies are not static; this enables an accurate evaluation of progress over time and the avoidance of lock-ins (Craft and Fisher 2016; Singh et al. 2020). In light of the evolving context in which GCF adaptation projects operate, a balance must be struck between the need for evidence-based decision-making (GCF 2022b) and the need to adapt to changing conditions.

4.6 Conclusions

Applying implementation science to sectors associated with climate action presents a promising avenue for enhancing the effectiveness and efficiency of adaptation strategies, thereby facilitating more robust and evidence-based decision-making processes in the

context of climate change challenges. The implementation framework proposed in this paper, which utilizes implementation science approaches, can facilitate the translation of evidence and practical knowledge into successful interventions and outcomes.

The Framework for Implementing Climate Adaptation (FICA) offers a systematic methodology for evaluating the implementation of climate adaptation projects, encompassing the multifaceted elements inherent to climate adaptation. It is applicable in a multitude of geographical and socio-economic contexts. By applying the FICA to GCF adaptation projects, we present an analysis of the barriers and challenges of projects concerning effective implementation.

Our findings indicate that financial constraints are not the sole impediment to implementing climate adaptation projects. The implementation of GCF projects is constrained by a number of factors, with behavioral, organizational practices, and operational aspects representing a significant challenge. Consequently, there is a necessity for the streamlining of administrative processes, the assurance of robust stakeholder engagement, and the investment in robust MEL systems (including post-project to assess the sustainability of the efforts). These steps are critical to achieving successful climate adaptation outcomes.

We emphasize the necessity of pursuing strategies that facilitate adaptive management, particularly in dynamic and evolving circumstances characteristic of adaptation initiatives, as postulated by the IPCC (2022b). It is not only the climate that can change but also the context or setting in which adaptation responses are implemented. This may occur due to changes in governments, extreme events, or other unexpected situations.

Chapter IV References

Adger WN, Arnell NW, Tompkins E (2005) Successful adaptation to climate change across scales. Global Environmental Change 15:77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005

Allen MR, Dube OP, Solecki W, et al (2018) Framing and Context. In: Masson-Delmotte V, Zhai P, Pörtner HO, et al. (eds) Framing and Context, In: Global warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 49-9

André K, Gerger Swartling Å, Englund M, et al (2023) Improving stakeholder engagement in climate change risk assessments: insights from six co-production initiatives in Europe. Front Clim 5:1120421. https://doi.org/10.3389/fclim.2023.1120421

Ara Begum R, Lempert R, Ali E, et al (2022) Point of departure and key concepts. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change. Cambridge University Press, Cambridge, UK and New York, USA, pp 121–196

Ari I, Isik M (2022) Assessing the Performance of the Developing Countries for the Utilization of the Green Climate Fund. Front Clim 4:813406. https://doi.org/10.3389/fclim.2022.813406

Bauer M, Damschroder L, Hagedorn H, et al (2015) An introduction to implementation science for the non-specialist. BMC Psychol 3:32. https://doi.org/10.1186/s40359-015-0089-9

Bednar-Friedl B, Biesbroek R, Schmidt DN, et al (2022) Europe. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK and New York, USA, pp 1817–1927

Birken SA, Powell BJ, Presseau J, et al (2017) Combined use of the Consolidated Framework for Implementation Research (CFIR) and the Theoretical Domains Framework (TDF): a systematic review. Implementation Sci 12:2. https://doi.org/10.1186/s13012-016-0534-z

Bo L, Spanger-Siegfried E (eds) (2004) Adaptation policy frameworks for climate change: developing strategies, policies, and measures. Cambridge University Press, Cambridge

Boyer C, Bowen K, Murray V, et al (2020) Using Implementation Science For Health Adaptation: Opportunities For Pacific Island Countries. Health Affairs 39:2160–2167. https://doi.org/10.1377/hlthaff.2020.01101

Cabana D, Rölfer L, Evadzi P, Celliers L (2023) Enabling Climate Change Adaptation in Coastal Systems: A Systematic Literature Review. Earth's Future 11:e2023EF003713. https://doi.org/10.1029/2023EF003713

Castellanos E, Lemos MF, Astigarraga L, et al (2022) Central and South America. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, USA, pp 1689–1816

Cinner JE, Adger WN, Allison EH, et al (2018) Building adaptive capacity to climate change in tropical coastal communities. Nature Climate Change 8:117–123. https://doi.org/10.1038/s41558-017-0065-x

Conde C, Lonsdale K (2004) Engaging Stakeholders in the Adaptation Process. In: Bo L, Spanger-Siegfried E (eds) Adaptation policy frameworks for climate change: developing strategies, policies, and measures. Cambridge University Press, Cambridge, pp 47–66

Craft B, Fisher S (2016) Measuring Effective and Adequate Adaptation

Curran GM (2020) Implementation science made too simple: a teaching tool. Implement Sci Commun 1:27. https://doi.org/10.1186/s43058-020-00001-z

Damschroder L, Aron D, Keith R, et al (2009) Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implementation Sci 4:50. https://doi.org/10.1186/1748-5908-4-50

Damschroder L, Reardon C, Opra Widerquist M, Lowery J (2022) Conceptualizing outcomes for use with the Consolidated Framework for Implementation Research (CFIR): the CFIR Outcomes Addendum. Implementation Sci 17:7. https://doi.org/10.1186/s13012-021-01181-5

Dilling L, Prakash A, Zommers Z, et al (2019) Is adaptation success a flawed concept? Nature Climate Change 9:572–574. https://doi.org/10.1038/s41558-019-0539-0

Ebi K, Lim B, Aguilar Y (2004) Scoping and Designing an Adaptation Project. In: Bo L, Spanger-Siegfried E (eds) Adaptation policy frameworks for climate change: developing strategies, policies, and measures. Cambridge University Press, Cambridge, pp 32–46

Fayolle, V., Dhanjal, M (2020) Green Climate Fund Proposal Toollkit 2020. Toolkit to develop a project proposal for the GCF. Acclimatise and Climate and Development Knowledge Network., London

Gao J, Christiansen L (eds) (2023) Perspectives: Adequacy and Effectiveness of Adaptation in the Global Stocktake. UNEP Copenhagen Climate Centre, Copenhagen

Garschagen M, Doshi D (2022) Does funds-based adaptation finance reach the most vulnerable countries? Global Environmental Change 73:102450. https://doi.org/10.1016/j.gloenvcha.2021.102450

Garschagen M, Doshi D, Moure M, et al (2021) The consideration of future risk trends in national adaptation planning: Conceptual gaps and empirical lessons. Climate Risk Management 34:100357. https://doi.org/10.1016/j.crm.2021.100357

GCF (2024a) Portfolio dashboard. In: Green Climate Fund. https://www.greenclimate.fund/projects/dashboard. Accessed 20 Apr 2024

GCF (2019a) Adaptation: Accelerating action towards a climate resilient future. Green Climate Fund (GCF), Incheon, South Korea

GCF (2022a) Integrated Results Management Framework: Results Handbook. Green Climate Fund (GCF), Incheon, South Korea

GCF (2022b) Steps to enhance the climate rationale of GCF-supported activities. Green Climate Fund (GCF), Incheon, South Korea

GCF (2023a) About GCF. In: Green Climate Fund. https://www.greenclimate.fund/about. Accessed 17 Jun 2024

GCF (2024b) GCF Spotlight: Africa. Green Climate Fund (GCF), Incheon, South Korea

GCF (2024c) GCF Spotlight: Least Developed Countries (LDCs). Green Climate Fund (GCF), Incheon, South Korea

GCF (2024d) GCF Spotlight: Latin America and the Caribbean. Green Climate Fund (GCF), Incheon, South Korea

GCF (2024e) Approved projects. In: Green Climate Fund. https://www.greenclimate.fund/projects. Accessed 20 Sep 2023

GCF (2024f) GCF at a Glancet: Performance Metrics (June 2024). Green Climate Fund (GCF), Incheon, South Korea

GCF (2024g) Cook Islands: First and fastest Green Climate Fund country project. In: Green Climate Fund. https://www.greenclimate.fund/news/cook-islands-first-and-fastest-green-climate-fund-country-project. Accessed 18 Jun 2024

GCF (2019b) Sustainability guidance note: screening and categorizing GCF-financed activities. Green Climate Fund (GCF), Incheon, South Korea

GCF (2022c) Guidance note to support the completion of the IRMF elements of the revised funding proposal template for PAP and SAP. Green Climate Fund (GCF), Incheon, South Korea

GCF (2023b) Concept Note. User's Guide. Green Climate Fund (GCF), Incheon, South Korea

GCF (2022d) Appraisal Guidance. A comprehensive guide to the tools and due diligence processes used to review and assess concept notes and funding proposals. Green Climate Fund (GCF), Incheon, South Korea

GCF (2022e) Sustainability Guidance Note: Designing and ensuring meaningful stakeholder engagement on GCF-financed activities. Green Climate Fund (GCF), Incheon, South Korea

GCF (2024h) GCF Board. In: Green Climate Fund. https://www.greenclimate.fund/boardroom. Accessed 18 Jun 2024

GCF (2023c) Secretariat. In: Green Climate Fund. https://www.greenclimate.fund/about/secretariat. Accessed 18 Jun 2024

GCF-IEU (2023a) Second Performance Review of the Green Climate Fund. Final Report. Volume I.

GCF-IEU (2023b) Second Performance Review of the Green Climate Fund. Annex to Final report. Volume II

Guillén Bolaños T, Scheffran J, Máñez Costa M (2022) Climate Adaptation and Successful Adaptation Definitions: Latin American Perspectives Using the Delphi Method. Sustainability 14:5350. https://doi.org/10.3390/su14095350

Hess JJ, Mcdowell JZ, Luber G (2012) Review Integrating Climate Change Adaptation into Public Health Practice: Using. Environmental Health Perspectives 120:171–179

IIED (2016) Reviewing the adequacy and effectiveness of adaptation and support. 13

IPCC (2022a) Summary for Policymakers. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC), Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, USA, pp 3–33

IPCC (2023) Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. (in press), Geneva, Switzerland

IPCC (2022b) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change. Cambridge University Press, Cambridge, UK and New York, USA

Kononowech J, Hagedorn H, Hall C, et al (2021) Mapping the organizational readiness to change assessment to the Consolidated Framework for Implementation Research. Implement Sci Commun 2:19. https://doi.org/10.1186/s43058-021-00121-0

LEG-UNFCCC (2012) National Adaptation Plans. Technical guidelines for the national adaptation plan process. United Nations Framework Convention on Climate Change (UNFCCC), Bonn, Germany

Moser S, Boykoff M. (eds) (2013) Successful Adaptation to Climate Change: Linking Science and Policy in a Rapidly Changing World. Routledge

Nalau J (2021) Assessing adaptation implementation. Nature Climate Change 11:907–908 https://doi.org/10.1038/s41558-021-01200-9

Neta G, Pan W, Ebi K, et al (2022) Advancing climate change health adaptation through implementation science. Lancet Planet Health 6:e909–e918. https://doi.org/10.1016/S2542-5196(22)00199-1

New M, Reckien D, Viner D, et al (2022) Decision Making Options for Managing Risk. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, USA, pp 2539–2654

Olazabal M, Galarraga I, Ford J, et al (2017) Towards successful adaptation: a checklist for the development of climate change adaptation plans. https://doi.org/10.13140/RG.2.2.35020.62080

Owen G (2020) What makes climate change adaptation effective? A systematic review of the literature. Global Environmental Change 62:13. https://doi.org/10.1016/j.gloenvcha.2020.102071

Pahl-Wostl C (2006) Transitions towards adaptive management of water facing climate and global change. Water Resour Manage 21:49–62. https://doi.org/10.1007/s11269-006-9040-4

Pörtner H-O, Roberts DC, Adams H, et al (2022) Technical Summary. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, NY, USA, pp 37–118

Prakash A, Conde C, Ayanlade A, et al (2022) Cross-Chapter BOX Gender: Gender, Climate Justice and Transformative Pathways. Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 2195–2231

Pringle P, Thomas A (2019) Climate Adaptation and Theory of Change : Making it work for you. Climate Analytics, Berlin, Germany

Proctor E, Silmere H, Raghavan R, et al (2011) Outcomes for Implementation Research: Conceptual Distinctions, Measurement Challenges, and Research Agenda. Adm Policy Ment Health 38:65–76. https://doi.org/10.1007/s10488-010-0319-7

Reckien D, Magnan AK, Singh C, et al (2023) Navigating the continuum between adaptation and maladaptation. Nat Clim Chang. https://doi.org/10.1038/s41558-023-01774-6

Runhaar H, Wilk B, Persson Å, et al (2018) Mainstreaming climate adaptation: taking stock about "what works" from empirical research worldwide. Reg Environ Change 18:1201–1210. https://doi.org/10.1007/s10113-017-1259-5

Schultes M-T, Albers B, Caci L, et al (2022) A Modified Implementation Mapping Methodology for Evaluating and Learning From Existing Implementation. Front Public Health 10:836552. https://doi.org/10.3389/fpubh.2022.836552

Singh C, Ford J, Ley D, et al (2020) Assessing the feasibility of adaptation options: methodological advancements and directions for climate adaptation research and practice. Climatic Change 162:255–277. https://doi.org/10.1007/s10584-020-02762-x

Singh C, Iyer S, New MG, et al (2021) Interrogating 'effectiveness' in climate change adaptation: 11 guiding principles for adaptation research and practice. Climate and Development 13:761–765. https://doi.org/10.1080/17565529.2021.1964937

Singh Ch, N. B, H. N (2022) Effectiveness of adaptation. In: Adaptation Gap Report 2022: Too Little, Too Slow - Climate adaptation failure puts world at risk. Nairobi, Kenya

Trisos CH, Adelekan IO, Totin E, et al (2022) Africa. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK and New York, USA, pp 1285–1455

UNEP (2023) Adaptation Gap Report 2023: Underfinanced. Underprepared. Inadequate investment and planning on climate adaptation leaves world exposed. United Nations Environment Programme, Nairobi, Kenya

UNFCCC-AC (2023) Monitoring and evaluation of adaptation at the national and subnational levels: Technical paper by the Adaptation Committee. United Nations Convention on Climate Change, Bonn, Germany

Venghaus S, Henseleit M, Belka M (2022) The impact of climate change awareness on behavioral changes in Germany: changing minds or changing behavior? Energy, Sustainability and Society 12:8. https://doi.org/10.1186/s13705-022-00334-8

Vignola R, Leclerc G, Morales M, Gonzalez J (2017) Leadership for moving the climate change adaptation agenda from planning to action. Current Opinion in Environmental Sustainability 26–27:84–89. https://doi.org/10.1016/j.cosust.2017.03.005

Wamsler C, Mundaca L, Osberg G (2022) Rethinking political agency: The role of individuals' engagement, perceptions and trust in transitioning to a low-carbon transport system. Journal of Cleaner Production 360:132197. https://doi.org/10.1016/j.jclepro.2022.132197

Wells CA, Saggioro E, Petty C, Cornforth R (2023) Using the Implementation Centric Evolving Climate Change Adaptation Process to bridge the gap between policy and action. Front Clim 5:1197027. https://doi.org/10.3389/fclim.2023.1197027

Williams DS, Celliers L, Unverzagt K, et al (2020) A Method for Enhancing Capacity of Local Governance for Climate Change Adaptation. Earth's Future 8:1–16. https://doi.org/10.1029/2020EF001506

Zamarioli LH, Pauw P, Grüning C (2020) Country Ownership as the Means for Paradigm Shift: The Case of the Green Climate Fund. Sustainability 12:5714. https://doi.org/10.3390/su12145714

Chapter IV Annexes

Annex A Components and elements of the Framework for Implementing Climate Adaptation (FICA) (adapted from Damschroder et al. 2009; 2022)

Components	***Elements & Sub-Elements***	***Description***	***Climate Adaptation Supporting References***
Stakeholders & Beneficiaries (individuals)	The roles, characteristics (e.g., needs and opportunities) of, and impacts on individuals involved, directly or indirectly, in the project.		
	• Roles	The roles applicable to the individuals in the frame of the project and location. Example: beneficiaries, decision-maker, civil society organization representative, private sector representative, project proponent, project implementer.	Conde and Lonsdale 2004; Ebi et al. 2004; New et al. 2022
	• Characteristics	Characteristics applicable to the roles (i.e., need, capability, opportunity, motivation).	Conde and Lonsdale 2004; New et al. 2022
	- Need	The individual(s) has deficits related to survival, well-being, or personal fulfillment, which will be addressed by implementation and/or delivery of the project.	
	- Capability	The individual(s) has interpersonal competence, knowledge, and skills to fulfill Role.	
	- Opportunity	The individual(s) has availability, scope, and power to fulfill Role.	
	- Motivation	The individual(s) is committed to fulfilling Role.	
Adaptation Project / Options	The "project" being implemented. Adaptation options are defined as "an array of strategies and measures available and appropriate for addressing adaptation. They include a wide range of actions that can be categorized as structural, institutional, ecological or behavioral" (IPCC 2022b, p. 2898).		
	• Project design and evidence-base	The innovation is well designed and packaged, including how it is assembled, bundled, and presented. It includes vulnerability assessments, climate change (impact) scenarios, etc.)	GCF 2019b, 2022c; Pringle and Thomas 2019; New et al. 2022

Components	*Elements & Sub-Elements*	*Description*	*Climate Adaptation Supporting References*
	- Vulnerability assessments	"Vulnerability assessment should be a compilation of vulnerabilities and a description of their context, root causes, trends and potential assumptions made."	LEG-UNFCCC 2012, p.66
	- Climate change (impact) scenarios	"An evidence-based analysis to show that a proposed activity is likely to be an effective adaptive response to the risk or impact of a specific climate change hazard."	GCF 2022d, p.5
	- Appraisal of adaptation options	Description of the project, and actions included in it, relative advantage in comparison with a scenario where no project or other activities/technologies are implemented (i.e., feasibility assessment of options).	Singh et al. 2020
	- Environmental and social risk assessments	Assessment of potential environmental and social risks that could affect the project.	GCF 2019b
	• Project adaptability	The project can be modified, tailored, or refined to fit local context or needs.	New et al. 2022
	• Project comprehensiveness	The comprehensiveness of the project is given by the range of types of measures considered. There is emerging consensus that a combination of strategies, especially bringing together infrastructural, nature-based and institutional solutions, tend to be more effective than single interventions.	Singh et al. 2022
	• Project costs	The total project costs are estimated.	GCF 2023b
	• Project appropriateness	The "perceived fit, relevance, or compatibility of the innovation […] for a given practice setting, provider, or consumer; and/or perceived fit of the innovation to address a particular issue or problem" (Proctor et al. 2011, p. 69).	

Components	*Elements & Sub-Elements*	*Description*	*Climate Adaptation Supporting References*
Implementation Design & Process	The activities and strategies used to implement the project.		
	i. Implementation Design	Aspects related to the project implementation that need to be considered to allow successful adaptation (*inner setting*). The *inner setting* refers to the environmental/climate sectors as they're usually the ones implementing adaptation projects.	New et al. 2022; Singh et al. 2022; André et al. 2023,
	• Planning	Identification of roles and responsibilities, outline specific steps and milestones, and definition of goals and measures for implementation success in advance.	Bo and Spanger-Siegfried 2004; LEG-UNFCCC 2012
	• Tailoring implementing strategies	Selection and operationalization of implementation strategies to address barriers, leverage facilitators, and fit context. Implementation strategies need to allow for adaptability / flexibility. They need to avoid lock-in of investments and actions.	GCF 2022c
	• Country ownership	Beneficiary country ownership of and capacity to implement a funded project/programme (policies, strategies and institutions).	GCF 2022c
	• Multi-stakeholder engagement	"Meaningful" stakeholder engagement encompasses a series of strategies and activities throughout the life of a project." Stakeholder engagement needs to include elements of procedural equity and justice. The process needs to attract and encourage the participation of potential deliverers and beneficiaries of the implementation and/or the project.	GCF 2022e, p. 8.
	• Needs assessments	Collection of information about priorities, preferences, and needs of people based on their roles and implementing strategies and project design.	

Components	*Elements & Sub-Elements*	*Description*	*Climate Adaptation Supporting References*
	• Context assessment	Collection of information to identify and appraise barriers and facilitators to implementation and delivery of the innovation.	Singh et al. 2020
	• Monitoring, evaluation and learning (MEL)	Design related to monitoring, evaluation and learning activities to assess project implementation. Outcomes and outputs to be evaluated are presented as an additional component.	New et al. 2022
	ii. Implementation Readiness	The extent to which the *inner setting* is ready for implementation (inner setting: The setting in which the innovation is implemented). The inner setting refers to the environmental/climate sectors as they're usually the ones implementing adaptation projects.	
	• Teaming / implementation arrangements	Coordination and collaboration on interdependent tasks, to implement the project. The organization of tasks and responsibilities within and between individuals and teams, and general staffing levels, support functional performance of the Inner Setting.	Williams et al. 2020; Wells et al. 2023
	• Relational connections / governance	Related to governance, international agreements, legislation and regulatory frameworks, political alignment, and policies coherence. The project aligns with current policies/priorities, including development policies/priorities.	
	• Structural Characteristics	Infrastructure components support functional performance of the inner setting (i.e., physical infrastructure and space, and information technology infrastructure)	
	• Access to knowledge and information	Guidance and/or training is accessible to implement and deliver the project.	Wells et al. 2023
	• Technical capacities	Technical capacities to implement project activities are in place (at least partly).	Wells et al. 2023

Components	*Elements & Sub-Elements*	*Description*	*Climate Adaptation Supporting References*
	• Technology	There is access to technologies proposed as part of the project.	
	• Available resources (incl. co-finance)	Resources are available to implement the project (e.g., finance, space for implementation, materials and equipment)	Wells et al. 2023
	• Culture	There are shared values, beliefs, and norms across the Inner Setting. Note: Use this construct to capture themes related to Culture that are not included in the subconstructs below.	
	• Incentives	Tangible and/or intangible incentives and rewards and/or disincentives and punishments support implementation and delivery of the innovation.	
	iii. Implementation Climate (outer setting)	The extent to which the inner setting has an implementation climate (enabling environment / outer setting). Adaptation projects are embedded in complex political and social realities (outer setting), where power and politics can shape adaptation outcomes. It is advised to keep this in mind to avoid inaccurate simplistic views. (New et al. 2022)	
	• Local conditions	Economic, environmental, political, and/or technological conditions enable the outer setting to support implementation and/or delivery of the project.	New et al. 2022
	• External pressure	External pressures drive implementation and/or delivery of the innovation (i.e., societal and market pressure).	
	• Acceptability	The extent to which the project is perceived as “agreeable, palatable, or satisfactory." The assessment of acceptability needs to be based on stakeholders knowledge (Proctor et al. 2011, p. 69).	
	• Critical Incidents / External Risks	Large-scale and/or unanticipated events disrupt implementation and/or delivery of the project.	

Components	*Elements & Sub-Elements*	*Description*	*Climate Adaptation Supporting References*
	• Local Attitudes	Sociocultural values (e.g., shared responsibility in helping recipients) and beliefs (e.g., convictions about the worthiness of recipients) encourage the Outer Setting to support implementation and/or delivery of the innovation.	
Outcomes	Actual changes induced, i.e., related to climate risks, vulnerability, well-being or development (i.e. the effects of adaptation on risk reduction) (		
	• Effectiveness	"The effectiveness of these implemented actions is assessed in terms of (1) their implications on reducing risks for human and ecological systems; (2) whether risk reduction is equitably distributed; (3) how effectiveness changes over time; (4) whether there are any reported trade-offs with climate mitigation goals; (5) contextual factors shaping effectiveness; and (6) potential limits to adaptation."	Singh et al. 2022, p.40
	- Reducing risks and vulnerabilities	"Reducing risk to climate change hazards through a qualitative or quantitative reduction in vulnerability, exposure, or risk to impacts; avoiding danger and promoting security; reducing sensitivity to climate-related threats; and increasing adaptive capacity or preparedness."	Gao and Christiansen 2023, p. 36
	- Balancing synergies and trade-offs with mitigation	Synergy (co-benefit): "A positive effect that a policy or measure aimed at one objective has on another objective, thereby increasing the total benefit to society or the environment." Trade-off: "A competition between different objectives within a decision situation, where pursuing one objective will diminish achievement of other objective(s)."	IPCC 2022
	- Enhancing social well-being (social co-benefits)	"Enhancements in social and community well-being, relationships and networks, such as increased cooperation, sharing resources and improved access to health services, food, water, education and housing."	Gao and Christiansen 2023, p. 36

Components	*Elements & Sub-Elements*	*Description*	*Climate Adaptation Supporting References*
	- Avoiding Adaptation Limits	"The point at which an actor's objectives (or system needs) cannot be secured from intolerable risks through adaptive actions. **Hard** adaptation limit: No adaptive actions are possible to avoid intolerable risks. **Soft** adaptation limit: Options may exist but are currently not available to avoid intolerable risks through adaptive action."	IPCC 2022, p. 2898
	- Enhancing Adaptive Capacity	Adaptive capacity is "the ability of systems, institutions, humans and other organisms to adjust to potential damage, to take advantage of opportunities or to respond to consequences."	IPCC 2022, p. 2899
	- Increasing Resilience	Resilience is "the capacity of interconnected social, economic and ecological systems to cope with a hazardous event, trend or disturbance, responding or reorganising in ways that maintain their essential function, identity."	IPCC 2022, p. 2920
	• Benefits to human well-being	"Changes in well-being and the achievement of successful development outcomes in the face of climate change can be viewed as the results of a host of actions to reduce the risks that climate change poses to individuals, human and natural systems."	Singh et al. 2022, p. 38
	- Equity outcomes	Distributive equity and justice. "Attention to distributional equity and justice aims to ensure that adaptation interventions do not exacerbate inequities and that the benefits and burdens of interventions are distributed fairly."	New et al. 2022, p. 2605
	- Economic co-benefits	"Greater access to economic resources through measurable increases to income and employment, access to economic services and loans, and reductions in poverty."	Gao and Christiansen 2023, p. 37
	- Enhancing social well-being (social co-benefits)	"Enhancements in social and community well-being, relationships and networks, such as increased cooperation, sharing resources and improved access to health services, food, water, education and housing."	Gao and Christiansen 2023, p. 36

Components	*Elements & Sub-Elements*	*Description*	*Climate Adaptation Supporting References*
	• Benefits to ecosystem services	"Improved ecosystems and environmental health, demonstrated through environmental services, and the quality and quantity of natural resources."	Gao and Christiansen 2023, p. 37
	• Avoiding maladaptation	"Maladaptation refers to current or potential negative consequences of adaptation-related responses that lead to an increase in the climate vulnerability of a system, sector or group by exacerbating or shifting vulnerability or exposure now or in the future and eroding sustainable development." (New et al. 2022, p. 2600). Criteria to be considered when evaluating maladaptation: benefits to people, benefits to ecosystem services, benefits to equity, transformational potential and contribution to mitigation (New et al. 2022).	New et al. 2022
Outputs	The way adaptation is organized and the actions taken – support and process (e.g., adaptation plans adopted – ie., processes, products and services).		
	• Adequacy	"Adequacy refers to a set of solutions that together are sufficient to avoid dangerous, intolerable, or severe climate risks."	Ara Begum et al. 2022, p. 124
		"Single adaptation interventions are less adequate than bundles of interventions. Further, adequacy is context-dependent (e.g. adequacy of the same heat action plans can be different in different populations acclimatized to different levels of heat). However, as expected, at higher warming levels, adaptation adequacy declines and the rate and quantum of reduction is unknown based on current evidence. To be adequate, adaptation needs to incorporate future climate risks that are relevant to the sectors or systems (e.g. the typical duration of infrastructure or of sector planning cycles)."	Singh et al. 2022, p.42
	- Finance	"Access to finance is an essential component of implementing adaptation measures". Some guiding questions: The resources allocated are enough to enable effective adaptation?	IIED 2016, p.7

Components	*Elements & Sub-Elements*	*Description*	*Climate Adaptation Supporting References*
		Are the financial resources reaching those who need to adapt?	
	- Sufficient Action to Be Effective	"To assess this dimension, activities or plans would need to be assessed against the anticipated current and future risks to ensure that the plans are of sufficient scale and magnitude to meet the identified climate risks and hazards."	IIED 2016, p.7
	- Geographical Coverage	"How much of the country and its vulnerable areas have been covered by adaptation measures? What is the spread of adaptation across space? Delving into where adaptation efforts occur should lead to considering issues of social inclusion and environmental justice, and urban and rural coverage."	IIED 2016, p.8
	• Efficiency	It "balances the costs of implementation against the benefits of an activity. While efficiency often considers economic costs or value, Adger et al. (2005) argue that it also includes property, human resources, ecological impacts, aesthetic impacts and services"	Gao and Christiansen 2023, p. 36
	• Equity	Equity "considers the distribution of benefits of an adaptation action and distribution of decision-making power during the adaptation process" (Gao and Christiansen 2023, p. 36). There are three types of equity that need to be considered in climate adaptation related processes and stakeholder involvement: recognitional equity and justice, distributive equity and justice and procedural equity and justice (New et al. 2022).	New et al. 2022; Gao and Christiansen 2023, p. 36
	- Recognitional Equity and Justice	"Recognitional justice focuses on inclusion and agency, that is, examining who is recognised as a legitimate actor and how their rights, needs, and interest are acknowledged and incorporated into action."	New et al. 2022, p. 2604
	- Procedural Equity and Justice	"Participation is employed to enable procedures that aim to redress power imbalances, which are assumed to be the root causes of	New et al. 2022, p. 2605

Components	*Elements & Sub-Elements*	*Description*	*Climate Adaptation Supporting References*
		vulnerability (i.e., the reasons that lead certain people and places to be differentially vulnerable to climate risks)"	
	- Gender Equity	"Adaptation actions do not automatically have positive outcomes for gender equality. Understanding the positive and negative links of adaptation actions with gender equality goals, (i.e., SDG 5), is important to ensure that adaptive actions do not exacerbate existing gender-based and other social inequalities […]. Efforts are needed to change unequal power dynamics and to foster inclusive decision making for climate adaptation to have a positive impact for gender equality."	Prakash et al. 2022, p. 2700
	• Legitimacy	"Legitimacy is the extent to which adaptation processes and actions are acceptable, appropriate and workable in local social, political and environmental contexts. It was often indicated by generating trust — both in the adaptation actions themselves and among the people involved — and that local users would support the action."	Gao and Christiansen 2023, p.36
	• Strengthen Institutions	"New or improved institutional relationships, conflict management or resolution, enhanced community participation or autonomy in decision-making and leadership, and changes to governmental or other institutional systems."	Gao and Christiansen 2023, p. 37
	• Technology	Degree to which the adaptation project contributes to technology deployment, dissemination, development or transfer and innovation.	GCF 2022a
	• Markets	Degree to which the adaptation project contributes to market development / transformation at the sectoral, local or national level.	GCF 2022a
	• Knowledge and Technical Capacities	Degree to which the adaptation project contributes to effective knowledge generation and learning processes, and use of good practices, methodologies and standards.	GCF 2022a

Components	*Elements & Sub-Elements*	*Description*	*Climate Adaptation Supporting References*
	• Increased Awareness	Degree to which the adaptation project increases the awareness, at various levels. Awareness has been identified as a driver for decision-making and implementation of climate action.	Allen et al. 2018; Venghaus et al. 2022
	• Adoptability / Adoption	The likelihood key decision-makers will decide to put the innovation in place/innovation deliverers will decide to deliver to innovation (previous start of the project). The extent key decision-makers decide to put the innovation in place/innovation deliverers decide to deliver the innovation (while the project is implemented).	
	• Implementability / implementation	The likelihood the innovation will be put in place or delivered. (previous start of the project). The extent the innovation is in place or being delivered. (while the project is implemented).	
	• Sustainability / Sustainment	The likelihood the innovation will be put in place or delivered over the long-term. (previous start of the project). The extent the innovation is in place or being delivered over the long-term. (while the project is implemented).	Gao and Christiansen 2023

Annex B Stakeholders Roles within the GCF

Role	***Description***
National Designated Authorities (NDAs)	"The NDA or Focal Point is the national focal agency and point of contact between countries and the GCF. The NDA/Focal Point develops work programmes and oversees funding proposals." (Fayolle, V. and Dhanjal, M. 2020, p. 4)
Accredited Entities (AEs)	"An AE is an institution that is accredited by and accountable directly to the GCF's Board for the overall management of projects such as developing and submitting funding proposals, as well as for the financial, monitoring and reporting aspects of project activities. The AE may be public or private and may include Direct Access Entities and International Access Entities." (Fayolle, V. and Dhanjal, M. 2020, p. 5)
Executing Entities (EEs)	"A project proponent that is not an AE can act as an Executing Entity (EE). While an AE acts as a country's fund programme managers, the EE oversees executing eligible activities supported by the GCF under the oversight of the AE. An AE can also execute projects itself." (GCF 2024h)
GCF Board	"The GCF Board is charged with the governance and oversight of the Fund's management. The Board is independent and guided by the Conference of the Parties (COP) to the Convention." (GCF 2023c)
GCF Secretariat	The Secretariat "is responsible for executing the day-to-day operations of the Fund. It services and is accountable to the Board." (GCF 2023c)
Beneficiaries	Individuals reached by actions of the project.
Project stakeholders	Individuals / organization representatives involved in the different project phases.

Annex C GCF Adaptation Projects

Annex C.1 Applied Criteria and Project Sample

Selection criteria

- **GCF result area:** Health, food security, and water security
- **Status:** Under implementation
- **Theme:** Adaptation
- **Regions/countries:** African LDCs & LAC

No	*Country*	*Country categories*	*GCF project Title*	*Project code*[10]	*GCF project code*
1	Belize	LAC	Resilient Rural Belize (Be-Resilient)	BLZ	FP101
2	Burkina Faso	LDC	Africa Hydromet Program – Strengthening Climate Resilience in Sub-Saharan Africa: Burkina Faso Country Project	BFA	FP074
3	Burundi	LDC	Climate proofing food production investments in Imbo and Moso basins in the Republic of Burundi	BDI	SAP017
4	Colombia	LAC	Scaling up climate resilient water management practices for vulnerable communities in La Mojana	COL	FP056
5	Comoros (The)	LDC	Ensuring climate resilient water supplies in the Comoros Islands	COM	FP094
6	Ethiopia	LDC	Responding to the increasing risk of drought: building gender-responsive resilience of the most vulnerable communities	ETH	FP058
7	Grenada	LAC	Climate Resilient Water Sector in Grenada (G-CREWS)	GRD	FP059
8	Guatemala	LAC	RELIVE – REsilient LIVElihoods of vulnerable smallholder farmers in the Mayan landscapes and the Dry Corridor of Guatemala	GTM	FP145
9	Guinea-Bissau	LDC	Adaptation of agricultural production systems in Coastal Areas of Northwest Guinea-Bissau	GNB	SAP025

[10] Codes based on the list provided by the UN Statistical Commision (https://unstats.un.org/unsd/methodology/m49/)

No	Country	Country categories	GCF project Title	Project code[10]	GCF project code
10	Liberia	LDC	Enhancing Climate Information Systems for Resilient Development in Liberia (Liberia CIS)	LBR	SAP018
11	Malawi	LDC	Scaling up the use of Modernized Climate information and Early Warning Systems in Malawi	MWI	FP002
12	Mali	LDC	Africa Hydromet Program – Strengthening Climate Resilience in Sub-Saharan Africa: Mali Country Project	MLI	FP012
13	Mozambique	LDC	Climate-resilient food security for women and men smallholders in Mozambique through integrated risk management	MOZ	SAP011
14	Senegal	LDC	Building the climate resilience of food insecure smallholder farmers through integrated management of climate risk (R4)	SEN1	FP049
15	Senegal	LDC	Increasing the resilience of ecosystems and communities through the restoration of the productive bases of salinized lands	SEN2	FP003
16	Sudan	LDC	Building resilience in the face of climate change within traditional rain fed agricultural and pastoral systems in Sudan	SDN	FP139
17	Tanzania	LDC	Tanzania Agriculture Climate Adaptation Technology Deployment Programme (TACATDP)	TZA1	FP179
18	Tanzania	LDC	Simiyu Climate Resilient Project	TZA2	FP041
19	Uganda	LDC	Building Resilient Communities, Wetland Ecosystems and Associated Catchments in Uganda	UGA	FP034
20	Zambia	LDC	Strengthening climate resilience of agricultural livelihoods in Agro-Ecological Regions I and II in Zambia	ZMB	FP072

Annex C.2 Project status as described in Annual Reports

The table below presents the overview of the 20 projects analyzed in our work (based on information available at GCF's website as of May 2024), indicating official start of the implementation phase, the years that have been reported, last reported year and the overview of activities reported as delayed in the last year reported.

**Green indicates projects with time between approval and the start of the implementation phase below the sample's average. Red indicates projects with time between approval and the start of the implementation phase above the sample's average.*

No	*Country*	*Time (y) from Approval to Implementation Start**	*Implementation status since*	*Years of project implementation reported*	*Last year reported*	*Activities reported as delayed*[11]
1	Belize	1,0	04.03.2020	3	2022	18/24
2	Burkina Faso	1,9	20.02.2020	2	2022	9/10
3	Burundi	1,2	04.02.2022	0	NA	NA
4	Colombia	0,7	29.05.2018	5	2022	1/8
5	Comoros (The)	0,7	25.06.2019	3	2022	0/15
6	Ethiopia	1,4	12.02.2019	4	2022	0/5
7	Grenada	1,7	25.11.2019	3	2022	7/13
8	Guatemala	2,3	30.03.2023	0		
9	Guinea-Bissau	0,9	15.09.2023	0	NA	NA
10	Liberia	1,9	03.10.2022	0	NA	NA
11	Malawi	1,6	28.06.2017	6	2022	1/9
12	Mali	4,0	17.01.2020	1	2020	9/10
13	Mozambique	1,3	24.02.2021	2	2022	4/17
14	Senegal 1	2,3	14.01.2020	3	2022	1/13
15	Senegal 2	4,3	13.02.2020	2	2022	15/22

[11] Reported as delayed versus total activities. According to last Annual Report available in GCF website as of April 2024.

No	Country	Time (y) from Approval to Implementation Start*	Implementation status since	Years of project implementation reported	Last year reported	Activities reported as delayed[11]
16	Sudan	0,1	21.09.2020	3	2022	3/9
17	Tanzania 1	1,0	20.09.2022	0	NA	NA
18	Tanzania 2	2,3	09.08.2019	2	2020	NA[12]
19	Uganda	0,6	30.06.2017	6	2022	0/10
20	Zambia	0,6	12.10.2018	5	2022	5/11

c)

[12] Last report (2020) indicates that implemementation had not started. The FAA is effective since August 2019 (agreements with the governement were signed in May 2019). First disbursement was done only in November 2020.

Annex D Findings (complete)

The following tables present the barriers and challenges as identified by the interviewees (identified by interview code and country code) in their responses.

Annex D.1 Stakeholders and Beneficiaries

Sub-component	***Barriers and Challenges***
Roles	- Difficulties on clarifying roles (design and implementation), institutional arrangement, and contributions to avoid overlaps or confusion (NDA1,3,4,5; AE1,7; EE3; BLZ, COL, GRD, MOZ, MWI, UGA, ZMB). Especially for multi-country projects, where roles might be diffuse (NDA1,4,5). - Staff turnover (from GCF, NDAs, AEs) which slows down the process (NDA3; EE2-2; ETH, GRD).
Characteristics: Needs And Capability	- Insufficient capacities at the national and/or sub-national level for project implementation (NDA1,2,3,4,5; AE1,4,7; EE1; BFA, MWI, SEN1, ZMB). - Difficulties of NDAs to follow up project's activities, environmental and social safeguards specially in the case of multi-country projects (NDA1,2,3,4,5). - GCF projects are added up to "normal" work of already limited personal with many responsibilities (NDA3,4; AE1,4). - Limited or lack of access to financial services (e.g., mobile money accounts) (MOZ, SEN1) or financial means (due to COVID) (GRD). - Infrastructure not adequate for the installation of proposed systems / measures (GRD, ZMB).
Characteristics: Opportunity & Motivation	- Lack of awareness, motivation and ownership of decision-makers and stakeholders (NDA1,3,4; AE1,6; EE2; GRD, ZMB).

Annex D.2 Adaptation Project Component

Sub-component	***Barriers and challenges***
Project Design and Evidence-Base	- GCF requirements are very time and resources demanding in technical terms (NDA1,2,4,5; AE2,3,5,7), with limited capacities and experience at national level (NDA1,4; AE1,2,3,4; EE1). - Lack of and low technical capacities regarding (climate) data and information (NDA1; AE7; AE/EE1; GRD). - Difficulties to define beneficiaries (AE3; NDA5; EE2-2; SEN2, ZMB) and their needs (NDA3,4). - Project design takes long time (NDA1,2,4; AE2,4; EE3). - AEs experts sometimes start design with already preconceived ideas, which not necessarily align with context or beneficiaries needs (AE4,7; EE1).
Project Cost	- Financial viability as a constraint (NDA1,4).

Sub-component	Barriers and challenges
Appropriateness	- Inappropriate infrastructure design (NDA1,4; NDA/EE; COM, GRD, SDN). - Issues with equipment / technology included in project design (NDA2; MWI, UGA).

Annex D.3 Implementation Process Component

Sub-component	Barriers and Challenges
Implementation Design	**Planning** - Long time for project design and approval (NDA1,3,4,5; AE2,3,4,5,6,7; AE/EE1; EE1). - Late start of the implementation phase generates changes in activities (ETH, MOZ, MWI, SEN1, SEN2, SDN). - Time sensitive activities (i.e., in the agriculture sector, depending on the seasons) (AE2, AE/EE1; EE2-1; MWI, SEN1, ZMB). - Long time between project design and implementation phase (AE4,7; EE1). **Tailoring implementation strategies** - GCF's lack of flexibility / adaptive management (NDA1,4; AE1,3,4,5,6; EE3). - Complexity to define implementation arrangements (NDA1,2,3,4,5,7; AE/EE1). - Long time needed by the GCF to approve changes, which delays further disbursement and implementation (AE3,4; AE/EE1). - Need to tailor implementation strategies due to changes in local context between project design and implementation (NDA4; AE4,5). - Little consideration of local traditions in project design (NDA3,5). - Issues about the complementarity of co-financed components / activities (AE2; EE1). **Country ownership** - Lack of ownership of decision-makers (AE1,6; EE2-2; GRD). - Project idea is generated by international AEs (NDA3,4,5). - Lack of ownership from different stakeholders / implementing partners (ZBM). - Low country ownership related to multi-country projects (NDA4). **Multi-stakeholder engagement** - Definition of communities / beneficiaries / stakeholders involvement (NDA1,3,4,5; AE1,3,7; AE/EE1). - Intense time and resources investment related to the involvement of local stakeholders / beneficiaries (NDA1; AE3; AE/EE1; COL, ETH, UGA), which can create fatigue (NDA5). - Lack of clarity in stakeholders / institutions participation in different project phases (NDA4,), especially in multicountry projects (NDA4).

Sub-component	*Barriers and Challenges*
	- Private sector lack of commitment with adaptation projects (AE1). - Lack of motivation to engage from governmental representatives (AE1). - Mismatch in the expectations of the local government and communities (NDA4, COM, UGA). - Slow adoption of measures from beneficiaries (including low participation in different activities) (COL, GRD, MOZ, UGA). **Assessing context** - GCF/AEs lack of local knowledge when assessing project progress (EE1). **Monitoring, Evaluation and Learning (MEL)** - Insufficient resources allocated for M&E activities (NDA4; AE1,3, AE/EE1), including M&E systems to facilitate data and information availability and collection (NDA1,5; EE1). - Unclear arrangements for M&E activities, including monitoring of safeguards (especially for multi-country projects) (NDA1,2,4,5; AE/EE1; GRD). - Difficulties of NDAs to follow up project's activities, environmental and social safeguards specially in the case of multi-country projects (NDA1,2,3,4,5). - Delays or difficulties in collecting information from implementing areas (due to, for example, data collection tools and templates) (NDA1, EE1; UGA, ZMB, SEN2). - Difficulties to establish baselines (AE1,2; EE1). - Difficulties with double reporting (in case of co-financed projects) (AE2; EE1; UGA). - Delays or difficulties in collecting information from implementing partners (MWI, SEN2, UGA). - Long time for approval and publication of annual reports by the GCF (EE3) - Inadequate monitoring due to excessive centralization and top-down approaches (UGA). - Challenges in recruiting M&E officers (EE1).
Implementation Readiness (Inner Setting)	**Teaming (Institutional arrangements)** - Difficulties to get in place implementation arrangements (including after project approval) (NDA1,2,3,4,5,7; AE2, AE/EE1). - Delays and issues in recruitment and setting project team (NDA2,5; AE2,5,7; EE1,2-1,2-2; SDN). - Changes in governmental staff which might break thread between needs, options proposed (project's history) (NDA3; EA4,6; EE2-2; BLZ, COL, ETH). - Slow governmental dynamics and procedures (EE2-1,2-2; SDN). - GCF not familiar with AEs modes of work (AE6; AE/EE1). **GCF and governmental requirements**

Sub-component	*Barriers and Challenges*
	- GCF bureaucracy (technical and legal requirements) (NDA1,3,4,5; AE2,3,4,5,6,7; AE/EE1; EE1; SEN1, MWI), including update of baseline, safeguards and gender plan (AE2). - GCF requirements are very time and resources demanding in technical terms, with limited capacities and experience at national level (NDA1,3,2,4; AE1,2,3,5,7; AE/EE1, EE1). - Guaranteeing availability of co-finance to guarantee approval and start of the project (NDA1,3,4,5; AE2,5,6; EE-2; BLZ, ZMB). - Governmental bureaucracy and requirements for starting the project (NDA1,3; AE2,5; AE/EE1), including requirements related to infrastructure, forestry, etc. (EE2-2). - Strong need to align project proposals with country's priorities and policy instruments (NDA3,5; AE1). - Slow governmental dynamics (EE2-1,2-2). - Changes in template, multiple iterations and request to add information from the GCF secretariat (NDA3; AE4). **Relational connections / governance** - Difficulties to prioritize projects to be submitted to GCF, therefore, to facilitate / get NDA endorsement (NDA4; AE/EE1). **Communication** - Lack of / delays in communication between EE and AE and GCF (EE1). - Lack of communication between AEs and NDAs and beneficiaries / stakeholders in the time between project approval and start of implementing phase (AE4). **Technical and operative capacities** - Delays in recruitment and setting project team / consultants (NDA2,5; AE2,3,5,7; EE1,2-1,2-2,3; BLZ, COM, GRD, MWI, SEN2, SND, ZMB). - Key personal unavailable in territories (e.g. accountants, extensionists) (NDA5; AE7; EE1; UGA). - Low existing capacities of extension staff on climate adaptation related topics (BLZ, ZMB, MWI). - Delays due to procurement (i.e., compliance with procurement requisites from AEs, governmental agencies, etc.) (NDA1,5; EE1,2-2; BLZ, BFA, COL, COM, GRD, MWI, SEN2, UGA, ZMB). - Lack of human and technical resources (e.g., available personal, vehicles) from governmental actors to implement co-financed and monitoring activities (NDA5, EE1,2-1,2-2, EE3; BLZ, BFA, COM, GRD, MWI, SDN, UGA, ZMB). - Delays in GCF disbursements (NDA4; NDA/EE1; AE4,6; AE/EE1; EE2-2; COL, ETH, MWI, TZA2, UGA, ZMB). - Delays in disbursements from AEs to EE (NDA/EE1; MWI). - Increased costs for implementation (NDA1,2,4; BLZ, COM, ETH, ZMB).

Sub-component	*Barriers and Challenges*
	- Increased cost of equipment / technology / measure included in proposal (including interest rate calculation) design (AE2,4,7; NDA1,2; EE1; GRD, ZMB). - Weak in-country capacity (project partners) for implementing GCF project (MWI). **Beneficiaries' technical capacities** - Limited or lack of access to financial services (e.g., mobile money accounts) (MOZ, SEN1) or financial means (due to COVID) (GRD). - Infrastructure nor adequate for the installation of proposed systems / measures (GRD, ZMB). - Language barriers when receiving climate information (SEN1). - Limited access to agricultural inputs, low/limited availability of inputs providers (MOZ). - Project resources (credits) used for immediate consumption (SEN1). **Culture** - Little consideration of local traditions in project design (NDA3,5).
Implementation Climate (Outer Setting)	**Local conditions** - Project's context changed between project design and implementation phase (NDA1,4,5,6; AE1,2,4,5,6; EE1,3; COL, SDN, MOZ). - Including government changes and election processes (NDA1,2; AE1,4,5,6,7; AE/EE1; COL) and community's needs (NDA1,2,4,5,6; AE1,2,4,5,6,7; AE/EE1; EE1,3; COL, SDN, MOZ). - Governmental changes and election processes during project implementation (AE6,7; BLZ, ETH, GRD, UGA, ZMB). - Political instability (BFA, ETH, MLI, MWI, SDN). - Changes in local economy (e.g. inflation) (COL, COM, ETH, GRD, MWI, SDN, ZMB). **Critical incidents / external risks** - Disruption due to lockdowns and limitations established due to COVID pandemic (NDA2,3; AE4,7; EE1; BLZ, BFA, COL, COM, ETH, GRD, MOZ, MWI, MLI, SEN1, MOZ, SEN1, SEN2, SDN, UGA, ZMB). - Affectation to project activities due to extreme weather events (droughts and heavy rain) (NDA1; BLZ, COL, MWI, UGA, ZMB). - Political conflicts (incl. armed) and worsening of security situation (NDA/EE1; COL, BFA, SDN).

Outcomes

Sub-component	***Evidence on outcomes***
Effectiveness	**Reducing risk and vulnerability** - Indicators related to water resources, ecosystems are complex (NDA1). - Better coping with extreme events (NDA5). - Risk reduction due to the provision of timely and accurate weather and climate information (ZMB). - Reduced exposure to climate risks (BLZ, COL, MWI, MOZ, SDN, UGA, ZMB). **Avoiding adaptation limits** - Guaranteeing social and environmental safeguards (NDA1). - Guaranteeing technical rigor (AE5; AE/EE1). **Balancing synergies and trade-offs** - Avoid trade-offs (NDA5). **Adaptive capacity** - Strengthened adaptive capacity (BLZ, COL, COM, MWI, MOZ, SEN2, SDN, UGA, ZMB). - Smallholder farmers are able to plan for and manage climate risk to support resilient agricultural production (ZMB). - Resilient agricultural livelihoods are promoted in the face of changing rainfall, increasing drought and occasional floods (ZMB). - Strengthened adaptive capacity and reduced exposure to climate risks (ZMB). - Increasing farmers' access to markets and commercialization of resilient agricultural products (ZMB). **Increased resilience** - Increased resilience and enhanced livelihoods of the most vulnerable people, communities and regions (MWI, UGA).
Avoiding maladaptation	- Guaranteeing compliance with social and environmental safeguards, including in relation with multi-country projects (NDA1). - Guaranteeing technical rigor while designing and implementing the project (AE5).
Benefits to human well-being	**Distributive equity and justice** - Adequate identification of beneficiaries and impacts (NDA5; AE1,3). **Enhancing social well-being** - Improvement of life conditions due to project interventions (NDA5; AE/EE1; EE3).

Sub-component	Evidence on outcomes
	- Delivering project objectives impacting positively the beneficiaries (EE1). - Improving of nutrition due to project interventions (EE3). - Improved agricultural practices and alternative livelihood options (UGA). - Resilient water users (GRD). **Economic co-benefits** - Increased prospects of household incomes (EE1; ZMB). - Beneficiaries have improved their access to financial services (AE/EE1; EE1). - Agricultural products are not only for subsistence, but they can also be absorbed by local and international markets (NDA5; EE1). - Changes to more innovative financial structures at the national level (NDA1). - Diversification of livelihoods (NDA5).
Benefits to ecosystem services	- Improvement of ecosystems and ecosystem services (NDA1; COL, ETH, UGA). - Climate resilient agro-ecosystems enhancing rural livelihoods (COL).

Outputs

Element	Evidence on outputs
Equity	**Recognitional equity and justice (focus on inclusion and agency)** - Adequate involvement of community's representatives (NDA2,3,5). - Adequate involvement of women (NDA3; AE7; AE/EE1; EE1). - Adequate involvement of youth (NDA3; AE7; EE1). - Adequate involvement of indigenous people (NDA3). **Procedural equity and justice (participation redress power imbalances)** - Adequate mapping of stakeholders (NDA3). - Adequate mapping of community representatives (NDA3). - Adequate participation of different stakeholders (NDA5). - Strength / create community's committees that benefit from capacity building and trainings and better knowledge capitalization (AE1). **Gender equity** - Empowerment of women to access to agricultural inputs, financial resources (NDA1; ZMB; EE1). - Analysis and action plans to facilitate focus on women and girls (AE5; EE-2-2).

Element	Evidence on outputs
Adoptability	- Establishment of Memorandum of Understanding (MoUs) with relevant institutions (EE1).
Implementability	- Implementing de-risking policies (AE5).
Sustainability	- Exit strategy to guarantee continuation of the activities promoted by the project (AE1,5,7). - Appropriate involvement of stakeholders during the design and implementation phases (NDA2,4; AE1; EE3). - Strengthening capacities of local and territorial institutions (NDA1,3; AE1) - Enhance country/institutions ownership of the project (NDA3).
Strengthened institutions	- Strengthening capacities of local and territorial institutions (NDA1,3; AE1; BLZ). - Enhance country/institutions ownership of the project (NDA3; AE1) for example by establishment of project management units within governmental / national institutions (AE1,4). - Strengthened institutional and regulatory systems for climate-responsive planning and development (BLZ, COM, ETH, SDN, SEN2). - Institutional and knowledge frameworks for managing climate change are strengthened (ETH, SEN2). - Resilience governance and institutions (GRD). - Institutional and regulatory systems that improve incentives for climate resilience and their effective implementation (BFA).
Technology and Innovation	- Establish data and information centers within ministries or governmental institutions (AE1). - Women and youth as early adopters of new technologies and innovation (EE1). - Adoption of technologies promoted by the project (AE/EE1; EE1). - Early Warning Systems (EWS) established and implemented (BFA, COL). - Improvement of meteorological network (BFA).
Markets	- Consider the value chain of what the intervention is about (NDA5; AE7; EE1). - Increasing farmer's access to markets and commercialization of resilient agricultural products (ZMB).
Knowledge and Technical Capacities	- Capacity building and trainings with participation of community representatives (AE1; EE1; ETH). - Build technical capacities within governmental institutions to design and implement GCF projects (NDA1,2,3; EE1). - Close cooperation with universities and research centers (EE1). - Strengthening access to climate and early warning information to farmers and other target communities (UGA). - Increased generation and use of climate information in decision-making (BLZ, COL, COM, MOZ, SDN).

Element	Evidence on outputs
	- Use of climate information products/services in decision-making (BLZ; BFA, SEN2). - Knowledge based is improved (COL, SEN2). - Targeted vulnerable communities including women in selected areas access and use climate related risk information to enhance livelihoods and increase resilience (MWI). - Regional learning and replication (GRD).
Increased Awareness	- Increased awareness among different stakeholders and beneficiaries (AE1, AE/EE1; EE1; COM).
Private Sector Involvement	- Increased involvement of the private sector in adaptation-related projects / activities (NDA1,5; EE3). - Alternative approaches to deal with climate adaptation in the agricultural sector (AE/EE1).
Infrastructure	- Resilient water supply systems (GRD). - Improved access to water to build resilient livelihoods (COL, ETH). - Investment in roads and small-scale irrigation and drainage (BLZ).
Production	- Increased in average annual crop yields (SDN).

Annex D.5 Successful adaptation

Successful characteristic (project implementation)	***Aspects to consider***
Institutional strengthening	- Solid institutional structure to support project implementation (NDA1; AE4; EE2-1,2-2). - Clarity implementation arrangements (NDA2,3,4; EE3). - Strengthen governmental ownership of the project (NDA1,3; AE2). - Project alignment with national policies or instruments (NDA3; NDA/EE1). - Increased institutional climate- resilience profile / work (AE/EE1).
Project objective / indicators achievement	- Respect to project philosophy, design, aims (AE1,2,3,6,7; EE2-2). - Deliver what was promised to the beneficiaries (AE1; EE1;3). - Trust in AEs capacities in case of minor changes to reduce bureaucracy (AE4,6).
Building on beneficiaries needs and feedback	- Actions need to align to beneficiaries needs (NDA2; NDA/EE1; AE7; EE2-2, EE3). - Beneficiaries feedback (e.g., grievance mechanism) (AE1;5; AE/EE1).
Sustainability of project actions	- Actions continue to be implemented (at least at some level) at the local, regional or national level (NDA1,3; NDA/EE1; EE2-1). - Communities / beneficiaries continue to implement actions (at least at some level) (NDA1,5; EE2-1). - Capacity built at governmental level (NDA3).
Stakeholders' engagement	- Effective involvement of beneficiaries and relevant stakeholders, especially during design phase (NDA4; AE4,5,7). - Consultation process during all project phases, at all levels (NDA3; NDA/EE1). - Increased awareness (NDA/EE1; EE2-2).
Capacity building	- Capacity building at the institutional level (NDA/EE1; EE1,3). - Capacity building at the community level (NDA/EE1; EE2-2).
Mobilization of additional financial resources	- Mobilization of financial resources by Direct Access Entities (NDA1; AE5). - Funds disbursements (AE5; EE3). - Development or implementation of new financial structures (NDA1).
Research and knowledge transfer	- Include research and knowledge transfer as part of project activities (NDA/EE1; EE1, EE2-1). - Establish cooperation with national universities / research centers (EE1).

Successful characteristic (project implementation)	***Aspects to consider***
Gender	- Women inclusion during design and implementation (AE7).
Learning process / adaptive management	- Continuous monitoring and mid-term evaluation and implementation of remedial measures (if needed) (NDA5; AE4,5,6). - Extraction and sharing of lessons learned and (NDA5; AE4).
Technology and technique transfer	- Beneficiaries made use of technologies / techniques promoted by the project (NDA/EE1; EE2-1).

Annex D.6 Working with the GCF

Domains	***NDA***	***AE***	***EE***
Bureaucracy	NDA1,2,3,4	AE2,3,4,5 AE/EE1	EE1,3
Lack of flexibility	NDA1,4	AE1,3,4,5,6 AE/EE1	EE1,3
Lengthy process	NDA2,3,4,	AE3,4,5	EE3
GCF's secretariat staff limitations	NDA3,4	AE3,4 AE/EE1	EE1,3
Lack of knowledge of local context	NDA2		EE1
Modification of requirements	NDA3		

Chapter V. Synthesis

Main findings, conclusions and outlook

Synthesis

This final chapter presents the primary findings of this research (Section 5.1), which are organized into three main sub-sections. The first addresses the definition of climate adaptation and successful adaptation. The second focuses on generating evidence that integrates local knowledge and expertise. The third discusses the strategies for bridging the implementation adaptation gap. The general conclusions of this dissertation are presented in Section 5.2, including the novel aspects of the research approach, the policy implications, and the limitations. Furthermore, Section 5.3 outlines prospective avenues for future research.

5.1 Main Findings

5.1.1 Defining Climate Adaptation and Successful Adaptation (RQ1, RQ2)

Climate adaptation involves actions at different governance levels (i.e., global to local), contexts, sectors, perspectives, types of knowledge, and time frames. Bassett and Fogelman (2013) highlight the importance of how we think and talk about climate adaptation. There are well-established definitions of adaptation, such as the one proposed by the IPCC (IPCC 2014), which was slightly revised in its latest assessment cycle (IPCC 2022c). In addition, there have been efforts to define what can be considered successful or effective adaptation (Doria et al. 2009; Moser and Boykoff 2013; Dilling et al. 2019). However, challenges arise when attempting to operationalize the definitions when conducting monitoring and evaluation efforts (Christiansen et al. 2018; Dilling et al. 2019). Therefore, this research contributes to the scholarship that explores the complexities of the adaptation discourse, particularly about the definitions mentioned above.

In light of the aforementioned considerations, Chapter II of this dissertation addresses the pivotal questions of what is to be evaluated (that is to say, what is adaptation?) and what can be classified as progress or effective adaptation (that is to say, what is successful adaptation?). To this end, Latin American experts were consulted to gain a deeper understanding of the definitions, and criteria and indicators that can inform the region's policy, planning, and decision-making.

In general terms, the findings of exploring the definitions serve to confirm the complexity of the adaptation discourse. A general consensus emerged regarding the IIPCC's definition of adaptation, as outlined in the IPCC (2014) report. It is argued that adaptation definitions should not be overly detailed and that it is unnecessary to develop bespoke definitions for the various management levels at which adaptation occurs. It is nonetheless recommended that definitions be complemented with general principles or criteria that can be adapted to different contexts and allow for operationalization at various management levels and alignment of actions with specific objectives. Nevertheless, the experts suggested enhancing the practical utility of the IPCC's definition concerning monitoring and evaluating efforts. These include incorporating the GGA components (namely, reducing vulnerability, strengthening adaptive capacity, and increasing resilience) and references to sustainability, temporality, and right-based approaches. The elements of sustainability and right-based approaches have been identified as pivotal elements of adaptation action in recent literature (New et al. 2022; Prakash et al. 2022; Gao and Christiansen 2023). It is crucial to consider the temporal aspect, as the effectiveness of adaptation options may diminish over time due to rising temperatures (New et al. 2022). Furthermore, experts recommended that the definition be augmented with an emphasis on systemic approaches. This aspect is related to the work presented in Chapter IV.

In regard to the definition of successful adaptation, Chapter II examined the definition presented by Doria et al. (2009). The research yielded no consensus regarding this definition. Notwithstanding the identification of useful elements in the definition by experts, the aspect on which there was the most significant divergence of opinion was the absence of elements to facilitate monitoring and evaluation efforts. Similarly, as with the definition of adaptation, experts proposed the integration of the components of the GGA, with increasing resilience emerging as the element on which there was consensus. However, adaptive capacity was identified as the more important element aligned with available literature (e.g., Ford and Berrang-Ford 2016; Dilling et al. 2019). It is also noteworthy that experts found the investigated definition of successful adaptation to be less useful for framing evaluation efforts at the local level than when compared to higher management levels.

As a general conclusion, Chapter II underscores the necessity of understanding the nuances of climate adaptation, including the definitions of progress or success, before consistently evaluating adaptation efforts. The components of the GGA were proposed as potential enhancements to the definitions under examination. Furthermore, suggestions were made to broaden the definition of adaptation to encompass other related subjects, such as development and disaster risk reduction. In addition, Chapter II emphasizes that there may not be a one-size-fits-all method or approach for assessing adaptation efforts.

In terms of methodology, the Delphi method proved to be an effective approach for the co-production of knowledge related to adaptation definitions. The process facilitated the identification of key aspects for improving monitoring and evaluation activities.

On criteria and indicators

As Magnan (2016) has observed, to inform global assessment processes such as the GST, it is necessary to develop or use metrics that align with two main characteristics: the incorporation of context-specific elements and the capacity to aggregate data from the local to the global level. To address this gap, Chapter II presents a list of criteria and indicators classified according to the GGA components. The chapter also indicates the usefulness and importance of these criteria and indicators at the different management levels, as identified by the consulted experts. Most of the proposed criteria and indicators pertain to the GGA's adaptive capacity component. In addition, one of the primary findings regarding the aggregation of information is that the majority of experts questioned the feasibility of such a process. However, they proposed alternative methodologies for this endeavor, including objective measures, expert judgment, and inductive techniques.

Chapter IV presents a list of elements that can be used to assess and enhance the implementation of adaptation projects. The elements mentioned above are structured within the five proposed components of the FICA framework. Furthermore, Chapter IV elucidates the characteristics of a successful adaptation process, including implementing adaptive management approaches that facilitate modifications during the implementation process. The characteristics include the strengthening of institutional structures, the achievement of project objectives and the attainment of set indicators, the engagement of stakeholders, the alignment of project activities with the needs of beneficiaries, and the incorporation of sustainability principles into project operations (including financial resources for post-project monitoring, evaluation, and learning activities).

5.1.2 Importance of Generating Evidence Integrating Local Knowledge and Expertise for Adaptation Action (RQ3)

Due to its inherent characteristics, the design and implementation of adaptation options need not only to be considered but also to build up on the unique socio-cultural contexts in which it is embedded, as well as the local, indigenous, and traditional knowledge and expertise in

those regions. This inclusion will ensure more effective and successful outcomes and enhance the adequacy and sustainability of the efforts in the long term (New et al. 2022). Therefore, methodologies are needed to help generate local evidence, which can translate into actionable knowledge for local and other management levels of decision-making. Chapters III and IV contribute to this effort by outlining and proposing specific strategies for integrating local knowledge and expertise into adaptation planning and implementation processes.

Chapter III presents the proposal to advance the feasibility framework outlined by the IPCC (de Coninck et al. 2018), designed as a global assessment based on scientific literature. As previously stated, the scientific literature needs to be more balanced in presenting information from vulnerable regions and communities in the Global South. Consequently, global assessments sometimes present a partial overview of adaptation assessments. To help bridge this gap, this research presents the advancement of the IPCC's framework based on the inclusion of local knowledge and expertise. The proposal allows following the logic proposed by the IPCC, using the same dimensions and indicators while integrating local priorities. The proposal was developed and tested with local experts and practitioners in Puerto Morazán, Nicaragua. The experience proved that (1) frameworks designed for global assessments, based on scientific literature, can be tailored to take advantage of local knowledge and expertise while improving or building technical capacities; (2) even in small, vulnerable communities, there is significant amount of knowledge available that can support generating evidence on adaptation efforts to feed national or global assessments; (3) the application of the method confirmed that including local priorities into the assessment can modify the assessment results, hence, confirming the importance of considering the local context when evaluating adaptation.

In the particular case of Puerto Morazán, the implementation of the framework resulted in categorizing all measures as having a medium level of feasibility without considering local priorities regarding the relative importance of the various dimensions. However, once the local priorities were considered, three adaptation options were identified as having high feasibility. In addition, the research found that (1) there's limited information related to the area; (2) adaptation options planned or implemented in the area are limited and can be classified as incremental adaptation; (3) adaptation happens on a small scale and in isolation. Furthermore, the research generates information on Central America, an underrepresented region in the adaptation scholarship (Ley et al. 2023).

Chapter IV of this dissertation explores the connection between implementation science and climate adaptation to enhance the process of translating research findings and practical knowledge on lessons learned and successful experiences into actionable strategies for climate resilience. Drawing on the Consolidated Framework for Implementation Research (CFIR) proposed by Damschroder (2009, 2022), the chapter introduces the Framework for Implementing Climate Adaptation (FICA). The FICA encompasses four main components analogous to the Iterative Adaptation Process: stakeholders and beneficiaries, adaptation project, implementation process, outputs, and outcomes. MEL elements are incorporated into the implementation process component. However, these elements are interconnected with all other components. Each component comprises distinct elements that must be considered in an iterative and continuous process at the level where implementation happens, using both local and expert knowledge, including the perspectives of practitioners, decision-makers, and beneficiaries, among other stakeholders.

Applying the proposed framework has yielded key findings from actors directly engaged in the design and implementation of GCF adaptation processes. The findings can be summarized as follows: (1) enhanced collaboration among stakeholders is required; (2) financial institutions must streamline their processes related to access and deployment of

adaptation projects; (3) the results underscore the need for MEL processes that facilitate adaptive management. Adaptive management is a key instrument in the context of uncertain circumstances, such as in which adaptation actions are implemented; (5) it is crucial to assess the capacity of individual stakeholders to guarantee successful implementation processes.

It is recommended that the FICA be applied by experts and practitioners who are directly involved in the implementation of adaptation projects. These individuals should engage in close dialogue with the relevant institutions and stakeholders to ensure a comprehensive understanding of the project context. Furthermore, stakeholders and beneficiaries must be included in any assessment process pertaining to the implementation of adaptation projects. This is to ensure that their needs are duly considered. It is essential to underscore that many FICA components and elements must be addressed from the initial design phase rather than solely after a project has commenced.

5.1.3 Bridging the Gap Between Planning and Implementation: Implementation Science for Climate Adaptation (RQ4)

Chapter IV examines the interconnections between implementation science and climate adaptation. Given the substantial interconnections between the principal frameworks in each field (i.e., CFIR and ICRM, respectively) and the potential of implementation science to facilitate evidence-based recommendations, Chapter IV proposes the "Framework for Implementing Climate Adaptation (FICA)" as a means of enhancing the implementation of adaptation action.

The GCF adaptation projects were selected to develop and test the FICA framework as a case study. The sample consisted of 20 GCF projects in African LDCs and LAC countries. Information from the sample was extracted through the performance of interviews and a review of the annual performance reports. Below are summarized the key findings related to the barriers and challenges encountered in implementing GCF adaptation projects.

The sample obtained an average of 1.6 years between approval and the start of the implementation phase. This is a cause of concern, particularly given that the design phase of a project typically requires a minimum of two years. Furthermore, the context of the project and the needs of the beneficiaries may have evolved during the interval between the design and approval phases, which subsequently complicates the implementation process.

Finance availability is one of many decisive factors affecting the implementation of adaptation projects. However, as outlined in the Second Performance Review of the GCF (GCF-IEU 2023), most of the challenges encountered in implementing adaptation projects are operational in nature. For instance, long bureaucratic processes or insufficient technical capacities among project teams have been identified as significant challenges. These deficiencies primarily pertain to procurement processes, accounting, and MEL activities. The limited capacities and experience are identified as factors affecting the adaptation project and implementation process components. This highlights the need for careful consideration of these aspects at the outset of the project planning phase. A further significant issue concerning stakeholders pertains to their awareness, motivation, and ownership. These considerations underscore the importance of evaluating and strengthening the individual capacities of stakeholders to enhance the implementation process. In addition, these findings can be linked to the fact that most of the projects are managed by international Accredited Entities, which may indicate a lack of capacity for national institutions to access GCF funding.

It's crucial to carefully consider the projects' design phase, as significant issues such as time—and resource-intensive requirements, limited capacities and experience, and the complexity of defining beneficiaries and their needs are identified as challenges. This careful consideration can help avoid potential issues during the approval and implementation. In

addition, the aspect that generates the most challenges regarding stakeholders and beneficiaries is the one related to difficulties in clarifying the roles for the implementation of adaptation projects.

With regard to the implementation process component, the implementation design's monitoring, evaluating, and learning (MEL) subcomponent is identified as presenting the most significant challenges. The primary challenges pertain to the necessity of increased resources for their development. These challenges include constraints imposed by financial and technical resources, which must be considered to ensure the long-term sustainability of MEL efforts following the conclusion of the projects. This limitation precludes an assessment of the extent to which the project activities were sustained.

Concerning the implementation readiness subcomponent, which pertains to the extent of preparation of the institutions for implementation, the most frequent challenges include technical and operational capacities, the GCF, and governmental requirements. With regards to the implementation climate, which encompasses external factors that may influence implementation, the majority of barriers and challenges were identified within the local conditions element, with changes in context and in governments being the primary considerations. Those changes are linked to the temporal spam between the design, approval, and implementation phases. Regarding critical incidents or external risks, the most frequent challenge cited was the impact of the COVID-19 pandemic. The majority of projects in the sample encountered considerable difficulties as a result of the unforeseen circumstances of the COVID-19 pandemic. This had a substantial impact on project timelines mainly due to limitations on the ability to perform fieldwork, participatory activities, and issues with procurement and recruitment. Notwithstanding these challenges, most projects have demonstrated notable advancement, as confirmed by GCF-IEU (2023).

In addition, Chapter IV outlines potential evidence about the outputs and outcomes of adaptation processes that bolster MEL processes, noting that this evidence should be collected throughout the process, not merely during the implementation or conclusion phase of the project. This approach should facilitate adaptive management.

Chapter IV identifies four particular challenges associated with the GCF. These include the complexity of the process, the GCF's secretariat's lack of flexibility, the lengthy process, and the limitations of staff within the secretariat. It is of the utmost importance to understand these challenges to successfully navigate the potential obstacles that may arise while implementing adaptation projects.

5.2 Conclusions

The speed and magnitude of current and projected climate change present significant challenges to all communities worldwide. There have been notable advancements in adaptation action on a global scale, particularly concerning the formulation of adaptation plans. However, there is an anticipated increase in the implementation gap. Therefore, monitoring and evaluating the implemented options is crucial to facilitate prompt adjustments in response to rapidly changing circumstances. To achieve this, adaptative management represents a vital instrument for guaranteeing efficient and effective utilization of resources and preventing lock-ins and maladaptation practices, as recommended by the most recent global assessment presented by the IPCC (2023). The deployment of adaptive management avoids lengthy bureaucratic procedures that could potentially impede effective stakeholder involvement.

This dissertation addresses both conceptual and empirical contributions to adaptation-related scholarship. In particular, it offers specific contributions to the Iterative Adaptation Process (IAP) steps to enhance the implementation of adaptation. This is achieved by taking

into account local perspectives, knowledge, and expertise and exploring new approaches for evaluating climate action. The frameworks developed in this research are designed to be adapted to different contexts, thereby facilitating the generation of additional evidence, which is typically insufficient in the case of Global South regions.

The Green Climate Fund is the principal financial mechanism established under the United Nations Framework on Convention on Climate Change. The fund's principal objective is to provide financial assistance to developing countries for mitigation and adaptation. This dissertation identifies challenges regarding the fund's operational aspects, including bureaucratic procedures and the necessity for enhanced flexibility. Furthermore, the formulation of GCF projects requires a considerable investment of time and resources, which are frequent for developing countries. Consequently, GCF projects are predominantly led by international organizations, which may have their procedures and may be detached from local realities, potentially impacting the project's implementation and effectiveness.

The results demonstrate that the success of climate adaptation projects is contingent upon factors beyond mere financial resources. While adequate funding is undoubtedly a prerequisite, the capacities for implementing actions at the national and local levels play a pivotal role in determining the overall effectiveness of these initiatives. Such capacities significantly facilitate the implementation process and the achievement of successful adaptation outcomes. It is, therefore, imperative that local capacities are built and that regions are equipped with the required skills, knowledge, and infrastructure if climate adaptation projects are to succeed. It is recommended that future efforts be directed toward strengthening these capacities and acquiring financial resources to ensure comprehensive and sustainable adaptation strategies.

5.2.1 Novelty of the Research Approach

This dissertation presents conceptual aspects of climate adaptation, the development of frameworks for gathering information on the feasibility of adaptation at the local level based on local knowledge and expertise, and the assessment of barriers and challenges to implementing adaptation projects. These building blocks contribute to the four pillars of the Interactive Adaptation Process.

First, this study takes a novel approach by exploring what adaptation and successful adaptation entails (Chapter II), taking into account regional, multi-, and transdisciplinary perspectives, and allowing the identification of criteria and indicators to support monitoring and evaluation efforts at the different levels where adaptation actions are planned and implemented. This exercise contributes to the body of literature aimed at better understanding adaptation and its complexity.

Most global adaptation assessments are based on scientific peer-reviewed literature in which vulnerable regions and communities of the Global South are underrepresented. Hence, the methodological innovation proposed in this research, which enables the generation of evidence from the local level based on local knowledge and experience (typically overlooked), has the potential to support national and global adaptation assessments, such as the UNFCCC's GST and IPCC's. Moreover, the proposed methodological innovation represents the first effort to use the feasibility assessment as a means of generating evidence at the local level. Furthermore, there is the issue of adapting existing methods, such as the IPCC's feasibility assessment, to new contexts, such as small, vulnerable communities, as illustrated by the case study in Nicaragua (Chapter III). Adopting such participatory and context-adapted methods at the aforementioned levels of governance has the potential to enhance stakeholder acceptance and involvement in the implementation of options, thereby increasing the likelihood of successful outcomes.

A significant contribution of this research is the examination of the interconnections between implementation science, a systematic research methodology, and climate adaptation. This investigation has led to the development of a comprehensive evaluation framework that assesses the various barriers and challenges associated with adaptation implementation. The framework generates actionable knowledge that can be utilized to enhance the effectiveness of adaptation implementation. More specifically, this research enhances adaptive and iterative adaptation approaches by developing implementation-focused methodologies. In contrast, the majority of existing literature has concentrated on the planning phase, covering issues such as vulnerability, addressing topics such as vulnerability, risk assessment and management, options appraisal, policy, and governance.

Additionally, this research presents the first exploration of employing implementation science to assess the performance of climate adaptation projects, with the GCF adaptation projects serving as a case study. The FICA framework proposed in this work is focused on investigating the implementation phase of adaptation projects, considering aspects related to the other steps of the interactive adaptation process to overcome the barriers and challenges faced when implementing adaptation projects. This framework may be applied to analyzing similar issues in projects funded by other institutions.

5.2.2 Policy Implications

This dissertation contributes to the existing scholarship related to progress on climate adaptation, which is currently a prominent theme within the UNFCCC. This is particularly evident in the frame of the GST and GGA frameworks and the indicators associated with these frameworks. The issues highlighted in this research pertaining to the definitions, criteria, and indicators can be integrated into subnational, national, and international climate policies and frameworks or in technical guidance prepared by the UNFCCC secretariat, such as those related to NAPs and NDCs.

Furthermore, this research offers frameworks and findings that facilitate the integration of evidence in areas where it is currently lacking. It is recommended that similar efforts be replicated in other underrepresented regions in the available literature. This is particularly important for global processes such as the GST and IPCC assessments. This information can inform decision-making processes at various governance levels, considering key aspects such as local knowledge and expertise (including practitioners), co-production processes, and the most recent scientific evidence. The involvement of local experts in adaptation assessments facilitates the translation of global and local narratives into practice while simultaneously fostering the development of local capacities. The integration of these elements enables policymakers and practitioners to develop and implement adaptation strategies that are more context-specific and effective. Ultimately, the proposals and results included in this dissertation can assist in creating more resilient and adaptive communities by providing insights that inform policies and practices that are both scientifically sound and locally applicable.

In addition, the findings of this research indicate a need for increased efforts by governmental and international organizations to enhance the capacity of national institutions, thereby improving the ability of local and national entities to access climate funding and to monitor and implement projects in an effective manner. Moreover, it underscores the vital role of stakeholder engagement and capacity building in designing and implementing climate adaptation strategies. Therefore, ensuring the robustness and inclusivity of stakeholders' processes is imperative. Furthermore, the findings highlight the necessity for a more comprehensive integration of local knowledge and expertise to bolster adaptation action.

Adaptation funding mechanisms, such as the GCF, are recommended to streamline their processes and include greater flexibility to allow for adaptive management in response to new information or changes in the local context.

Finally, the research calls for implementing more robust MEL processes that are adequately resourced (financial and technical) throughout the project lifecycle, from inception to completion, to assess the long-term impact of activities.

5.2.3 Limitations

The climate adaptation processes encompass many aspects and are embedded within complex multi-level governance systems. Furthermore, adaptation encompasses many perspectives, including regional, role-based, and type of knowledge and objectives that may vary from outcomes to outputs. The existing literature addresses many key areas, including adaptation planning, stakeholder engagement, and MEL. Nevertheless, there is limited information regarding the actual implementation of adaptation. To address this information gap, this thesis focused on contributing to the implementation phase of the Iterative Adaptation Process. However, due to time and resource constraints, the work primarily concerns these two regions: Latin America and the Caribbean (LAC) and African Least Developed Countries (Af-LDCs). It is acknowledged that the focus on these two regions may only partially capture the diversity of opinions, experiences, and practices observed in other regions.

Concerning the proposed advancement of the feasibility framework (Chapter III), the number and diversity of experts participating may be limited, which could result in the findings being less generalizable. Nevertheless, the potential for usability and transferability, which could assist local capacity-building, was validated.

Additionally, the dynamic nature of climate change, its impacts, and the need for adaptation underscore the necessity for continual revision. Therefore, the findings of this research, particularly those referring to barriers and challenges, might change. Furthermore, it is imperative to emphasize the significance of a continuous monitoring and evaluation process that enables adaptive management should be highlighted.

5.3 Outlook for Future Research

This dissertation provides different avenues for future research, specifically in further empirical testing of the frameworks proposed in Chapters III and IV. Additionally, the Delphi exercise (Chapter II) could be repeated with adaptation experts from other regions, which could provide a broader perspective on the definitions under study.

The criteria and indicators identified in this research could be further developed to allow their operationalization and explore their aggregation and comparability potential at different management levels during MEL efforts. The feasibility framework proposed in Chapter III can be enhanced to consider issues of adequacy and effectiveness of adaptation options over time (i.e., with different levels of global warming) to avoid lock-ins or maladaptation practices. There's the need to take a deeper look at the enablers, barriers, and challenges (identified in Chapters III and IV), for example, per dimensions/components and indicators, to allow identifying leverage points.

Furthermore, there's the potential to explore how the proposed approaches can include more systemic perspectives to create synergies with other development agendas such as the sustainable development goals (SDGs), the Sendai Framework for Disaster Risk Reduction, and the Convention on Biological Diversity. Among these approaches are those already introduced by the IPCC, such as system transitions, adaptation pathways, and climate-

resilient development pathways. In addition, due to the magnitude and speed of the impacts of climate change, incremental adaptation approaches will not be sufficient to face the increasing adverse effects on vulnerable communities. Therefore, there is a need to advance and examine how transformative the different adaptation options are and complement the proposed approaches.

5.4 References (Chapters I & V)

Adger WN, Arnell NW, Tompkins E (2005) Successful adaptation to climate change across scales. Global Environmental Change 15:77–86. https://doi.org/10.1016/j.gloenvcha.2004.12.005

Arias PA, Bellouin N, Coppola E, et al (2021) Technical Summary. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 33–144

Atteridge A, Remling E (2018) Is adaptation reducing vulnerability or redistributing it? Wiley Interdisciplinary Reviews: Climate Change 9:1–16. https://doi.org/10.1002/wcc.500

Bassett T, Fogelman C (2013) Déjà vu or something new? The adaptation concept in the climate change literature. Geoforum 48:42–53. https://doi.org/10.1016/j.geoforum.2013.04.010

Bauer M, Damschroder L, Hagedorn H, et al (2015) An introduction to implementation science for the non-specialist. BMC Psychol 3:32. https://doi.org/10.1186/s40359-015-0089-9

Bednar-Friedl B, Biesbroek R, Schmidt DN, et al (2022) Europe. In: Pörtner H-O, Roberts DC, Tignor M, et al (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK and New York, USA, pp 1817–1927

Berrang-Ford L, Biesbroek R, Ford JD, et al (2019) Tracking global climate change adaptation among governments. Nature Climate Change 9:440–449. https://doi.org/10.1038/s41558-019-0490-0

Berrang-Ford L, Pearce T, Ford JD (2015) Systematic review approaches for climate change adaptation research. Regional Environmental Change 15:755–769. https://doi.org/10.1007/s10113-014-0708-7

Boyer C, Bowen K, Murray V, et al (2020) Using Implementation Science For Health Adaptation: Opportunities For Pacific Island Countries. Health Affairs 39:2160–2167. https://doi.org/10.1377/hlthaff.2020.01101

Cabana D, Rölfer L, Evadzi P, Celliers L (2023) Enabling Climate Change Adaptation in Coastal Systems: A Systematic Literature Review. Earth's Future 11:e2023EF003713. https://doi.org/10.1029/2023EF003713

Cárdenas J (2014) Estrategias de adaptación y/o mitigación al cambio climático, concertado con actores locales del Golfo de Fonseca en municipios de Puerto Morazán y El Viejo, en Nicaragua. Managua

Castellanos E, Lemos MF, Astigarraga L, et al (2022) Central and South America. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, USA, pp 1689–1816

Christiansen L, Martínez G, Naswa P (2018) Adaptation metrics: Perspectives on measuring, aggregating and comparing adaptation results. UNEP-DTU Partnership, Copenhagen

Cundill G, Harvey B, Ley D, et al (2024) Engaging diverse knowledge holders in adaptation research. Nat Clim Chang 14:662–664. https://doi.org/10.1038/s41558-024-02056-5

Damschroder L, Aron D, Keith R, et al (2009) Fostering implementation of health services research findings into practice: a consolidated framework for advancing implementation science. Implementation Sci 4:50. https://doi.org/10.1186/1748-5908-4-50

Damschroder L, Reardon C, Opra Widerquist M, Lowery J (2022) Conceptualizing outcomes for use with the Consolidated Framework for Implementation Research (CFIR): the CFIR Outcomes Addendum. Implementation Sci 17:7. https://doi.org/10.1186/s13012-021-01181-5

de Coninck H, Revi A, Babiker M, et al (2018) Strengthening and implementing the global response. In: Masson-Delmotte V, Zhai P, Pörtner HO, et al. (eds). Global Warming of 15°C: IPCC Special Report on Impacts of Global Warming of 15°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 313–444

Depsky N, Pons D (2021) Meteorological droughts are projected to worsen in Central America's dry corridor throughout the 21st century. Environmental Research Letters 16:. https://doi.org/10.1088/1748-9326/abc5e2

Dilling L, Prakash A, Zommers Z, et al (2019) Is adaptation success a flawed concept? Nature Climate Change 9:572–574. https://doi.org/10.1038/s41558-019-0539-0

Doria M, Boyd E, Tompkins E, Adger WN (2009) Using expert elicitation to define successful adaptation to climate change. Environmental Science and Policy 12:810–819. https://doi.org/10.1016/j.envsci.2009.04.001

Ford JD, Berrang-Ford L (2016) The 4Cs of adaptation tracking: consistency, comparability, comprehensiveness, coherency. Mitigation and Adaptation Strategies for Global Change 21:839–859. https://doi.org/10.1007/s11027-014-9627-7

Ford JD, Berrang-Ford L, Biesbroek R, et al (2015) Adaptation tracking for a post-2015 climate agreement. Nature Climate Change 5:967–969. https://doi.org/10.1038/nclimate2744

Ford JD, Berrang-Ford L, Lesnikowski A, et al (2013) How to track adaptation to climate change: A typology of approaches for national-level application. Ecology and Society 18:. https://doi.org/10.5751/ES-05732-180340

Gao J, Christiansen L (eds) (2023) Perspectives: Adequacy and Effectiveness of Adaptation in the Global Stocktake. UNEP Copenhagen Climate Centre, Copenhagen

GCA (2019) Adapt Now: a Global Call for Leadership on Climate Resilience. Global Commission on Adaptation

GCF (2024a) Portfolio dashboard. In: Green Climate Fund. https://www.greenclimate.fund/projects/dashboard. Accessed 20 Apr 2024

GCF (2024b) GCF Spotlight: Least Developed Countries (LDCs). Green Climate Fund (GCF), Songdo

GCF-IEU (2023) Second Performance Review of the Green Climate Fund. Final Report. Volume I.

GFLAC (2023) Índice de Finanzas Sostenibles. Grupo de Financiamiento Climático para América Latina y el Caribe (GFLAC)

Gonçalves Gresse E, Schrum C, Hanf F, et al (2023) Toward a Sustainable Adaptation Plausibility Framework. In: Hamburg Climate Futures Outlook. Universität Hamburg, Hamburg, Germany, p 234

Hagen I, Huggel C, Ramajo L, et al (2022) Climate change-related risks and adaptation potential in Central and South America during the 21st century. Environmental Research Letters 17:033002. https://doi.org/10.1088/1748-9326/ac5271

Hidalgo H, Alfaro E, Amador J, Bastidas Á (2019) Precursors of quasi-decadal dry-spells in the Central America Dry Corridor. Clim Dyn 53:1307–1322. https://doi.org/10.1007/s00382-019-04638-y

Hoegh-Guldberg O, Jacob D, Taylor M, Guillén Bolaños, T et al (2019) The human imperative of stabilizing global climate change at 1.5ºC. Science 365:1263. https://doi.org/10.1126/science.aaw6974

IPCC (2022a) Summary for Policymakers. In: Pörtner H-O, Roberts DC, Tignor M, et al (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC), Cambridge University Press. Cambridge University Press, Cambridge, UK and New York, USA, pp 3–33

IPCC (2021) Summary for Policymakers. In: Masson-Delmotte V, Zhai P, Pirani A, et al (eds) Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, p 3–32

IPCC (2018) Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty. Cambridge University Press, Cambridge, UK and NY, USA

IPCC (2022b) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel onClimate Change. Cambridge University Press, Cambridge, UK and New York, USA

IPCC (2019) Summary for Policymakers. In: Pörtner H-O, Roberts DC, Masson-Delmotte V, et al (eds) The Ocean and Cryosphere in a Changing Climate: Special Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp 3–35

IPCC (2023) Climate Change 2023: Synthesis Report. A Report of the Intergovernmental Panel on Climate Change. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. (in press), Geneva, Switzerland

IPCC (2014) Annex II: Glossary. In: Mach KJ, Planton S, Stechow C von (eds) Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, pp 117–130

IPCC (2022c) Annex II: Glossary. In: Pörtner H-O, Roberts DC, Tignor M, et al (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change. Cambridge University Press, Cambridge, UK and New York, USA, pp 2897–2930

Jin S, Stokes G, Hamilton C (2023) Empirical evidence of urban climate adaptation alignment with sustainable development: Application of LDA. Cities 136:104254. https://doi.org/10.1016/j.cities.2023.104254

Leiter T (2015) Linking monitoring and evaluation of adaptation to climate change across scales: Avenues and practical approaches. In: Bours D, McGinn C, Pringle P (eds) Monitoring and evaluation of climate change adaptation: A review of the landscape. New Directions for Evaluation, pp 117–127

Leiter T (2021) Do governments track the implementation of national climate change adaptation plans? An evidence-based global stocktake of monitoring and evaluation systems. Environmental Science and Policy 125:179–188. https://doi.org/10.1016/j.envsci.2021.08.017

Leiter T, Olhoff A, Azar RA, et al (2019) Adaptation metrics current landscape and evolving practices. UNEP DTU, Rotterdam, The Netherlands and Washington, USA

Lesnikowski A, Ford JD, Berrang-Ford L, et al (2015) How are we adapting to climate change? A global assessment. Mitigation and Adaptation Strategies for Global Change 277–293. https://doi.org/10.1007/s11027-013-9491-x

Ley D, Guillén Bolaños T, Castaneda A, et al (2023) Central America urgently needs to reduce the growing adaptation gap to climate change. Frontiers in Climate 5:. https://doi.org/10.3389/fclim.2023.1215062

Magnan A (2016) Metrics needed to track adaptation. Nature 530:160. https://doi.org/10.1038/530160d

MARENA (2015) Plan municipal de protección Ambiental de las familias ante el cambio climático: Puerto Morazán. Ministerio de Ambiente y Recursos Naturales, Managua, Nicaragua

Morecroft M, Duffield S, Harley M, et al (2019) Measuring the success of climate change adaptation and mitigation in terrestrial ecosystems. Science 366:. https://doi.org/10.1126/science.aaw9256

Moser S, Boykoff M. (eds) (2013) Successful Adaptation to Climate Change: Linking Science and Policy in a Rapidly Changing World. Routledge

Nalau J, Preston B, Maloney, M (2015) Is adaptation a local responsibility? Environmental Science and Policy 48:89–98. https://doi.org/10.1016/j.envsci.2014.12.011

Nalau J, Verrall B (2021) Mapping the evolution and current trends in climate change adaptation science. Climate Risk Management 32:1–22. https://doi.org/10.1016/j.crm.2021.100290

New M, Reckien D, Viner D, et al (2022) Decision Making Options for Managing Risk. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, USA, pp 2539–2654

Pörtner H-O, Roberts DC, Adams H, et al (2022) Technical Summary. In: Pörtner H-O, Roberts DC, Tignor M, et al. (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, UK and New York, NY, USA, pp 37–118

Prakash A, Conde C, Ayanlade A, et al (2022) Cross-Chapter BOX Gender: Gender, Climate Justice and Transformative Pathways. Climate Change 2022: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change 2195–2231

Ryan D, Bustos E (2019) Knowledge gaps and climate adaptation policy: a comparative analysis of six Latin American countries. Climate Policy 19:1297–1309. https://doi.org/10.1080/14693062.2019.1661819

Schalatek L, Watson C (2020) The Green Climate Fund (GCF). Heinrich Böll Stiftung; Overseas Development Institute

Sietsma AJ, Ford J, Callaghan M, Minx J (2021) Progress in climate change adaptation research. Environmental Research Letters 16:14. https://doi.org/10.1088/1748-9326/abf7f3

Singh C, Bazaz A, Ley D, et al (2020a) Assessing the feasibility of climate change adaptation options in the water sector: Examples from rural and urban landscapes. Water Security 11:100071. https://doi.org/10.1016/j.wasec.2020.100071

Singh C, Ford J, Ley D, et al (2020b) Assessing the feasibility of adaptation options: methodological advancements and directions for climate adaptation research and practice. Climatic Change 162:255–277. https://doi.org/10.1007/s10584-020-02762-x

Stewart I, Maurer E, Stahl K, Joseph K (2022) Recent evidence for warmer and drier growing seasons in climate sensitive regions of Central America from multiple global datasets. International Journal of Climatology 42:1399–1417. https://doi.org/10.1002/joc.7310

Trisos CH, Adelekan IO, Totin E, et al (2022) Africa. In: Pörtner H-O, Roberts DC, Tignor M, et al. (eds) Climate change 2022: Impacts, adaptation and vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel of Climate Change (IPCC). Cambridge University Press, Cambridge, UK and New York, USA, pp 1285–1455

UN (2024) LDC Category | Office of the High Representative for the Least Developed Countries, Landlocked Developing Countries and Small Island Developing States. https://www.un.org/ohrlls/content/ldc-category. Accessed 16 Jul 2024

UNCTAD (2023) The Least Developed Countries Report 2023. https://unctad.org/system/files/official-document/ldc2023_en.pdf. Accessed 16 Jul 2024

UNEP (2017) The adaptation gap report: Towards global assessment. United Nations Environment Programme (UNEP), Nairobi, Kenya

UNEP (2023) Adaptation Gap Report 2023: Underfinanced. Underprepared. Inadequate investment and planning on climate adaptation leaves world exposed. United Nations Environment Programme

UNEP (2022) Adaptation Gap Report 2022: Too Little, Too Slow - Climate adaptation puts world at risk. Nairobi

UNFCCC (2015) Monitoring and assessing progress, effectiveness and gaps under the process to formulate and implement National Adaptation Plans: The PEG M&E tool. UNFCCC, Bonn, Germany

UNFCCC (2023a) Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on its fifth session, held in the United Arab Emirates from 30 November to 13 December 2023. UNFCCC

UNFCCC (2023b) First Global Stocktake. Outcome of the First Global Stocktake. UNFCCC

UNFCCC (2018a) Report of the Conference of the Parties serving as the meeting of the Parties to the Paris Agreement on the third part of its first session, held in Katowice from 2 to 15 December 2018. UNFCCC, Bonn

UNFCCC (2023c) Glasgow–Sharm el-Sheikh work programme on the global goal on adaptation referred to in decision 7/CMA.3. UNFCCC

UNFCCC (2023d) Submitted NAPs | NAP Central. https://napcentral.org/submitted-naps. Accessed 18 Aug 2023

UNFCCC (2018b) 2018 Biennial Assessment and Overview of Climate Finance Flows: Summary and recommendations by the Standing Committee on Finance on the 2018 Biennial Assessment and Overview of Climate Finance Flows

UNFCCC-AC (2014) Report on the workshop on the monitoring and evaluation of adaptation. United Nations Convention on Climate Change, Bonn, Germany

UNFCCC-AC (2023) Monitoring and evaluation of adaptation at the national and subnational levels: Technical paper by the Adaptation Committee. United Nations Convention on Climate Change, Bonn, Germany

UNFCCC-AC (2021) Approaches to reviewing the overall progress made in achieving the global goal on adaptation. Technical paper. Adaptation Committee. United Nations Framework Convention on Climate Change., Bonn, Germany

Williams PA, Simpson NP, Totin E, et al (2021) Feasibility assessment of climate change adaptation options across Africa: An evidence-based review. Environmental Research Letters 16:. https://doi.org/10.1088/1748-9326/ac092d

Eidesstattliche Versicherung | Declaration Upon Oath

"I hereby declare and affirm that this doctoral dissertation is my own work and that I have not used any aids and sources other than those indicated.

If electronic resources based on generative artificial intelligence (gAI) were used in the course of writing this dissertation, I confirm that my own work was the main and value-adding contribution and that complete documentation of all resources used is available in accordance with good scientific practice. I am responsible for any erroneous or distorted content, incorrect references, violations of data protection and copyright law or plagiarism that may have been generated by the gAI."

Hamburg, 19.08.2024

City. Date **Signature**