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EVIDENCE REVIEW ON COASTAL AND TERRESTRIAL WATER-SECTOR INTERVENTIONS IN DEVELOPING COUNTRIES

Protocol for a systematic review

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Jennifer Pampolina, Martin Prowse, Andreas Reumann

August 2023

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08/2023

CONTENTS

Acknowledgements.....	iv
List of authors	v
Abbreviations	vi
Abstract	vii
A. Background	1
1. Description of the problem.....	1
2. Why is it important to do this review?.....	3
B. Objectives of the review.....	3
C. Methods	4
1. The overall systematic review design approach	4
2. Theory of change.....	4
3. Criteria for inclusion and exclusion of studies in the review.....	13
4. Searching for evidence.....	18
5. Data collection and analysis.....	22
D. Conclusion	28
E. Distribution of main roles	28
APPENDICES.....	29
Appendix 1. Summary inclusion and exclusion criteria	30
Appendix 2. Search terms	34
Appendix 3. PRISMA diagram (Preferred Reporting Items for Systematic Reviews and Meta-Analyses).....	37
Appendix 4. Data extraction tool	38
Appendix 5. Critical appraisal tool	50
Appendix 6. Example of grading of recommendations assessment, development and evaluation tool.....	54
Appendix 7. The governance and management of water resources as common pool resource systems	56
Appendix 8. The complementary relationship between natural and built infrastructure interventions	57
Appendix 9. Water resource management, climate variability and climate change	59
REFERENCES	60

TABLES

Table 1. Intervention types and related activities.....	9
Table 2. Outcome definitions	10
Table 3. List of targeted databases	18

FIGURES

Figure 1. Theory of change.....	8
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ACKNOWLEDGEMENTS

The authors would like to thank the members of the engagement committee for their comments and suggestions on this approach paper. The engagement committee includes Lifeng Li (Director, Land and Water Division, Food and Agriculture Organization), Beom-Sik Yoo (Senior Adviser Asia/Oceania, Secretariat of the Ramsar Convention on Wetlands), Amgad Elmahdi (Water Resources Management Senior Specialist, Green Climate Fund), Tomos Avent (Head of International Programmes, Wildfowl and Wetlands Trust), Bernhard Seliger (Hanns Seidel Foundation) and Hyun-Ah Choi (Hanns Seidel Foundation). We also extend our appreciation to Junior Abdul Wahab (Independent Evaluation Unit, Green Climate Fund) for his assistance in co-drafting the terms of reference for the evidence review and Zephaniah Danaa (Independent Evaluation Unit, Green Climate Fund) for drafting the summary at the start of this approach paper.

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ABBREVIATIONS

CPR	Common pool resources
GCF	Green Climate Fund
GHG	Greenhouse gas
GRADE	Grading of Recommendations, Assessment, Development and Evaluations
ICT	Information and communication technologies
PICOS	Population, Intervention, Comparator, Outcome, and Study framework
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PSM	Matching/Propensity Score Matching
RCTs	Randomized controlled trials
SD	Standard deviation
SE	Standard error
ToC	Theory of change
WASH	Water, sanitation and health

ABSTRACT

Objectives

The changing climate severely affects global water resources, threatening water security goals. However, our understanding of the impact of key interventions, particularly in coastal zones and certain types of terrestrial water projects, is limited. This review aims to systematically assess the effectiveness of coastal and terrestrial water-sector interventions at different scales in developing countries.

What are evidence reviews? Why are they useful?

Evidence reviews are rigorous and comprehensive surveys of the evidence base on a particular subject matter or question. They summarize existing knowledge, inform decision-making, identify research gaps, evaluate the impact of specific types of interventions and identify best practices.

Systematic review

The goal of this systematic review is to identify, assess and synthesize evidence on the effectiveness of eight intervention types: nature-based options, built infrastructure, technological options, informational/educational schemes, institutional interventions, financial/market mechanisms, social/behavioural and coastal interventions conducted in non-Annex I countries.¹ The main outcome areas are adaptive capacity alongside mitigation co-benefits. A series of meta-analyses will be conducted for similar interventions and outcomes where effect sizes will be calculated. The results for selected intervention types will be reported, whether significant or not.

The rationale for this evidence review

Interventions - projects, programmes, or policies - that aim to enhance adaptive capacity and mitigation co-benefits in the coastal and terrestrial water sectors are critical to achieving water security. Therefore, identifying relevant coastal and terrestrial interventions and analysing their impacts will help developing countries achieve climate targets. To the best of the authors' knowledge, no systematic reviews currently assess the effectiveness of coastal and terrestrial water-sector interventions on adaptive capacity in developing countries. This review will address this gap and consider the implications for climate programming.

Methods

This evidence review was guided by a theory of change (ToC) and adopted a Population, Intervention, Comparator, Outcome, and Study (PICOS) framework to develop inclusion and exclusion criteria:

- **Population:** Studies conducted in non-Annex I countries across all intervention and outcome categories. In addition, the review will include studies conducted in Annex I countries for selected interventions and outcomes (with a focus on natural systems). The review will also include studies conducted in non-Annex I and Annex I countries (jointly) if the study disaggregates the effects. The review will consider studies conducted in any unit of observation.

¹ Annex I and non-Annex I are delineated in the Kyoto Protocol.

- **Intervention:** Coastal and terrestrial water-sector interventions delivered at any administrative level, administered to any beneficiary and implemented by any actor. The review categorizes the interventions into eight groups, as outlined above.
- **Comparison:** Studies that control for confounding factors through experimental or quasi-experimental designs (i.e. treatment and control).
- **Outcomes:** Outcomes measured a reasonable time after the onset of intervention. The review will consider all outcome areas for non-Annex I countries and only selected outcomes for Annex I countries.

Unintended effects: The review will consider positive, negative, and spillover effects on non-participants of the intervention, including reduced resilience.

- **Study design:** The review will target experimental or quasi-experimental studies published from 2000 onward. The review will include both peer-reviewed and grey literature articles. The review will consist of only English-language articles.

Contribution

The evidence review contributes to the literature or evidence base by:

- offering evidence-based insights to facilitate the implementation of coastal and terrestrial water-sector interventions in a changing climate.
- deepening our understanding of the effectiveness of water-sector interventions.
- leveraging lessons learned and best practices to guide future GCF projects and evaluations.
- providing comprehensive evidence to guide project developers and policymakers in making informed decisions, particularly regarding climate adaptation and mitigation co-benefits.

A. BACKGROUND

1. DESCRIPTION OF THE PROBLEM

Water is crucial for attaining internationally agreed goals and targets, including the 2030 Agenda for Sustainable Development (United Nations, 2023). The Secretary-General’s Plan: Water Action Decade 2018-2028 recognizes water as the heart of these agreements (United Nations, 2018). It connects and supports terrestrial, freshwater, coastal and marine ecosystems through the hydrological cycle, making it valuable from an environmental, economic, cultural and political standpoint (United Nations, 2023). Water is also recognized in the recently adopted 2022 Kunming-Montreal Global Biodiversity Framework at the fifteenth Conference of the Parties, which replaced the Aichi Biodiversity Targets. Climate change affects – and is affected by – global water resources. Climate change has modified all components of the global water cycle in recent decades, and hundreds of millions of people are now regularly experiencing hydrological conditions that were previously unfamiliar. It is reported that in 2018, 2.3 billion people (close to 30 per cent of the world’s population) lived in regions under water stress, with 3.6 billion people not having access to adequate water for at least one month per year (Food and Agriculture Organization of the United Nations and United Nations Water, 2021). About half of the world's 8 billion people are estimated to experience severe water scarcity for at least some part of the year due to climatic and non-climatic factors (Caretta and others, 2022). At the same time, greenhouse gas emissions also emanate from water-based processes (Ye, Porro and Nopens, 2022). For example, conventional treatment processes rely on a constant energy supply derived partly from burning fossil fuels. Sludge disposal methods and sewage treatment plants tend to generate methane, a highly potent greenhouse gas. Climate-smart water management has the potential to avoid and reduce emissions of carbon, methane and nitrous oxide released from water and wastewater management, as well as mismanaged or drained freshwater systems such as wetlands (United Nations, 2023).

Climate change, unsustainable human activities and poor environmental management affect water availability, quality and quantity, hindering the human right to water, sanitation, and a clean and healthy environment, among other related human rights (United Nations Educational, Scientific and Cultural Organization, and United Nations Water, 2020). According to the United Nations, “increasing climate extremes and variability, coupled with unsustainable growth and consumption, are leading to more severe and frequent water-related disasters and risks, worsening environmental degradation, including pollution, increasing water temperatures and ecosystem loss and profoundly affecting economies, societies and the environment”. In turn, this undermines the natural ability of ecosystems to combat both the causes and impacts of climate change. Simultaneously, responses to climate change also impact water resources and hydrological processes (United Nations, 2018).

In its Sixth Assessment report published in 2023, the Intergovernmental Panel on Climate Change states that, in the past decade, “human-induced climate change is already affecting many weather and climate extremes in every region across the globe”. The evidence of observed shifts in extreme weather events, such as heatwaves, heavy precipitation, droughts and tropical cyclones, has strengthened, particularly their link to human influence. The report warns that “continued global warming is projected to further intensify the global water cycle, including its variability, global monsoon precipitation and the severity of wet and dry events”. Climate change impacts due to changes in water availability are projected to increase with every degree of global warming (Caretta and others, 2022). The IPCC projects more frequent water-related hazards and threats to water availability and quality, exacerbated by increased global warming. In the absence of adaptation, an increase in global warming by 2⁰C or 3⁰C may result in direct flood damages that are 1.4 to 3.9 times higher than would occur with a 1.5⁰C increase. River basins dependent on snowmelt, glaciers,

groundwater availability and surface water storage will be affected (Intergovernmental Panel on Climate Change, 2022). This confirms previous predictions that global warming will cause substantial changes in the water cycle at both global and regional scales unless a large scale reduction in greenhouse gas (GHG) emissions is attained (Douville and others, 2021).

Unless urgent action is taken, this will alter temporal and spatial rainfall patterns with implications for runoff, surface and groundwater storage, and river flow regimes (United Nations Framework Convention on Climate Change, 2014). These impacts will occur in different parts of the world and be most severely felt in developing countries (Japan International Cooperation Agency, 2010). As a result, all major human livelihood systems, particularly those dependent on direct access to natural resources, will be negatively affected. In Africa, for instance, most countries depend heavily on agriculture and natural resources that are inextricably linked to water availability and are highly sensitive to climate change's impacts (United Nations, 2023). Rain-fed agriculture, human settlement patterns and movement, water supplies, sanitation and irrigation, will all be affected, leading to changes in human health, wealth and security (Nicol and Kaur, 2009). Susceptibility to water-related impacts of climate change and extreme weather is already being felt in all major sectors, including agriculture; energy and industry; water for health and sanitation; water for urban, peri-urban and municipal sectors and freshwater ecosystems (Caretta and others, 2022).

These changes will aggravate the water challenges on the demand side. In addition to the estimated 4 billion people who currently experience severe water scarcity for at least some part of the year due to climatic and non-climatic factors (Caretta and others, 2022), economic development together with population growth and movement will lead to spatial and temporal changes in demand for water resources. Some estimates (Greve and others, 2018) suggest that global water demand for domestic, industrial and agricultural uses may increase by 20–30 per cent by 2050. The rudimentary infrastructure and increasing water demand in developing countries emanating from population growth and rapid urbanization exacerbate the threat posed by climate change.

Addressing these challenges requires robust strategies at all levels—global, regional, national and local. These strategies should support communities in adapting to emerging changes in their water resources and manage the many risks these changes pose. As such, adaptation strategies must address the different dimensions of change, including uncertainty, variability and increasingly extreme weather events. Furthermore, as identified by the Global Commission on Adaptation (2019), they will have to mobilize a range of responses to enhance the resilience of societies and communities and support their adaptation efforts. However, as well as ensuring that such innovation is relevant in the different social and political contexts, it will be important to work with natural systems to strengthen societal resilience to climate change. Responses will include new approaches to using and managing natural water resources and the development of cost-effective institutional and risk management innovations. They will also include designing, implementing and financing-built infrastructure for water resource management.

Without sufficient knowledge of the scales required, there is a risk that policymakers and practitioners will make mistakes and generate “maladaptation” responses. There is also a danger that inappropriate adaptation interventions may miss the opportunity to deliver significant co-benefits for mitigation (increased carbon sinks or reduced emissions) while delivering sustainable development, including strengthened livelihoods, reduced poverty, and improved gender equity (Boyd and others, 2022). It is thus imperative to identify which adaptation interventions can work in different contexts to promote sustainable development and to consider how they may be designed to generate significant co-benefits. In the process, it is recognized that human communities have developed approaches to water resource management for thousands of years that have enabled their societies to grow and thrive (Muller, 2021). The knowledge and insights derived from this history of practice and more recent, formal research offer a potentially invaluable resource to guide today's

communities in addressing the new challenges climate change poses. The present review represents an attempt to begin to unlock this knowledge resource.

2. WHY IS IT IMPORTANT TO DO THIS REVIEW?

The authors conducting this review aim to examine which interventions effectively promote desired outcomes at various scales. While we primarily focus on nature-based interventions, we recognise that most hydrological systems consist of complex relationships between built infrastructure that supports water abstraction and storage and other water uses, such as recreation, navigation and power generation, and the original pristine water infrastructure and its accompanying ecosystems. Water is a complex sector due to the intrinsic linkage between using freshwater resources and its impact on other sectors and ecosystems. For example, dams and water diversions in one location will impact users and ecosystems in another part of the water resource system. In addition, adaptive interventions may have significant consequences for mitigation with potential co-benefits and synergies but also negative trade-offs. Trade-offs are especially significant in the water sector, where conflicts may exist between water security and clean energy generation provided by large scale projects and their environmental impacts (United Nations Framework Convention on Climate Change, 2014). Conflicts may also exist between adaptation interventions to recuperate wetlands and the additional GHG emissions they generate. Responding to climate change thus poses considerable challenges to water managers, users and policymakers at different levels. In developing their planning and implementation processes, they must consider a range of potential intervention and impact scenarios within and between sectors and hydrological geographies.

Through this review, we will identify and synthesize the current evidence regarding selected coastal² and terrestrial water-sector interventions in developing countries. Further, we will consider what this evidence means for climate programming, specifically adaptive capacity and climate risk mitigation at various scales. At the time of writing, no systematic reviews have been identified that assess the effectiveness of coastal and terrestrial water-sector interventions on adaptive capacity in developing countries. Current reviews not only vary in geographical scope but also tend to focus on terrestrial interventions in fields such as infrastructure (Zheng and others, 2021), agriculture (Zheng and others, 2019; Jiang and others, 2019), and institutions (Bisaro, Roggero and Villamayor-Tomas, 2018). No systematic reviews have been identified that assess the impact of coastal interventions. On the outcomes side, systematic reviews do not evaluate adaptive capacity but address areas such as water use, poverty, soil fertility and resilience. This suggests a gap in the analysis necessary to understand the full effects of climate change on human and natural systems and how policymakers can improve adaptive capacity and mitigation co-benefits at all levels.

B. OBJECTIVES OF THE REVIEW

The primary objective of this systematic review is to identify, assess, and synthesize evidence on the effectiveness of coastal and terrestrial water-sector interventions in achieving desired outcomes at various scales in developing countries. The goal is to facilitate the use of evidence in informing policy and practice decisions within the water sector, particularly climate adaptation and mitigation co-benefits and feed into the future evaluation of the Independent Evaluation Unit of the Green Climate Fund (GCF). In doing so, we address the following review questions:

² The review originally considered marine interventions but based on advisory group feedback, the scope was refined to focus on coastal interventions.

- What is the effectiveness of selected coastal and terrestrial water-sector interventions at achieving desired outcomes (including mitigation co-benefits) at various scales in developing countries?
- What factors influence the effectiveness of coastal and terrestrial water sector interventions in developing countries?

C. METHODS

1. THE OVERALL SYSTEMATIC REVIEW DESIGN APPROACH

This assignment requires producing a full systematic review compliant with the guidelines for conducting systematic reviews set by the Campbell Collaboration.³ The systematic review approach will comply with Campbell Collaboration standards for systematic reviews and 3ie's⁴ guidelines for reviews in international development. We drafted this detailed review protocol according to Campbell Corporation's guidelines.⁵

2. THEORY OF CHANGE

The ToC helped to inform the PICOS design framework we will use to develop inclusion and exclusion criteria (see Figure 1 below). Given the broad area of focus ("*coastal and terrestrial water-sector*") and the extensive outcomes to be considered (broadly, "adaptive capacity" and "mitigation co-benefits" more generally), this is necessarily a broad remit. A further challenge is that the "water sector" is extremely diverse and involves most areas of human activity, closely determining human impact on the natural environment and, in turn, impacted directly by climate variability and change.

This is illustrated by the inherent outcome goal of the water sector summarized as the achievement of water security defined succinctly as "the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environments and economies" (Grey and Sadoff, 2007). In the present context, the goal is expanded to include the assurance that the water security goal can be achieved even when considering the likely impacts of climate change on existing climate variability and extremes.

A particular challenge is that, unlike other sectors such as energy and transport, activities involving the use and management of water as a "common pool resource" are governed by a proliferation of formal and informal institutions at various scales that are often guided by non-commensurate values. Different groups of users may take individual action to meet their water needs, often using built infrastructure that may negatively impact other groups (see Appendix 7). Integrated water resource management and development approaches are promoted to address such potential conflicts. These

³ For systematic reviews: <https://onlinelibrary.wiley.com/pb-assets/Campbell%20Policies%20and%20Guidelines%20Dec2020-1608292090217.pdf>.

⁴ 3ie stands for International Initiative for Impact Evaluation.

⁵ Note that we suggest submitting the protocol as well as the full systematic review for publication to the Campbell Collaboration. However, given the turnaround and peer-review timelines, project milestones cannot rely on Campbell's feedback. Further, engagement is required to identify the most relevant review coordinating group within Campbell for submission.

encourage identifying and adopting systemic interventions that will optimize using natural systems in ways that may complement or replace built infrastructure (see Appendix 8).

Unlike many other sectors, water use and water management are already undertaken in a manner that more or less explicitly tries to support societies to achieve resilience to climate variability, including climate extremes (see Appendix 9). Therefore, many significant adaptation and mitigation interventions will involve identifying, intensifying and expanding existing practices rather than adopting new approaches. This poses challenges for attempts to attribute effects to specific interventions. It also suggests that interventions to strengthen existing water management institutions to enable them to perform their functions more effectively may contribute significantly to adaptation. However, such broad interventions are beyond this review's scope.

Interventions

This systematic review uses the summary definition of “water security” to guide identifying the areas water interventions address. These interventions will include measures that may enhance resilience and adaptive capacity and, in turn, directly impact achieving most of the United Nations Sustainable Development Goals. The review will also consider water sector interventions that may affect GHG emissions, recognizing that some may generate additional emissions while others will produce mitigation co-benefits through emission reductions.

In this context, a broad set of eight water-sector interventions⁶ has been identified that could have effects on climate change mitigation and adaptation which are adapted from Biagini and others (2014), in line with Doswald and others (2020). In turn, these effects would have outcomes related to “livelihoods, ecosystems and production,” including those that address risks posed by water systems to “people, environments and economies”. Table 1 provides definitions of the coastal and terrestrial water-sector interventions. *Nature-based solutions* are activities that use ecosystems and biodiversity and sustainable management, conservation and restoration of ecosystems to achieve water security goals. Examples include the use of wetland/pond-based systems for water quality management and wastewater treatment. *Built infrastructure* involves actions that involve structural components built to achieve water security goals such as dams. User-level technical interventions to improve water use efficiency and reduce water loss, including lining canals, and using efficient irrigation systems also fall into this category. *Technological options* interventions include, for instance, information and communication technologies (ICT)-driven system management and reduction of evaporation by using shade cloth and plastic sheeting. The review also considers *informational/educational schemes* which aim to inform and educate water managers and users to influence behaviour. Examples include water conservation education and early-warning systems related to floods and droughts. *Institutional interventions* address the societal mechanisms through which access to, use and protection of water resources is governed and managed. These also include informal mechanisms of partnership and collective governance as well as formal mechanisms of governance and regulatory action. These system-level technical interventions guide the operation of large water resource systems such as stochastic modelling and management of multipurpose systems that support food and energy production whilst meeting direct human water needs. *Financial/market mechanisms* refer to financial transactions or are market driven such as environmental levies, payment for ecosystem services and individual or collective insurance for flood damage or drought-

⁶ Nature-based solutions and coastal interventions are cross-sectorial/cross-cutting such that at the data extraction stage, a study will be coded in both intervention categories where relevant. The theory of change will be refined at intervention specific level at the synthesis stage.

related production losses. *Social/behavioural* interventions are “nudges” to encourage more efficient water use and examples include reminders, message framing and micro-incentives. *Coastal interventions* focus on the coastal-freshwater interface and aim to optimise the contribution of mangroves and other estuarine wetlands to disaster risk reduction, adaptation, and emission mitigation. They also mitigate the impacts of saltwater intrusions and support coastal ecosystem protection and restoration more generally.

Considering its limited financial and time resources, the review will not address interventions involving the development of new infrastructure for water resource management as a primary intervention for achieving water security goals. Similarly, the review will not address interventions that use existing water storage and hydropower infrastructure to support and optimise the use of other intermittent, renewable energies to aid the regulation of electricity generation and transmission systems. However, these may offer substantial adaptation and mitigation benefits and may complement and expand the contribution of nature-based interventions. Subsequent reviews may usefully consider these issues.

Outcomes

As with the range of interventions, the range of outcomes is equally broad. They are not necessarily mutually exclusive, as one intervention could target more than one outcome. These are described in Table 2. The outcomes are divided into three distinct parts namely process and implementation outcomes, secondary outcomes and final outcomes. The first part is the process and implementation outcomes related to uptake by including participants’ knowledge, perceived acceptability, and feasibility as well as the actual adoption of the intervention being conducted. Furthermore, any changes in participants’ knowledge (e.g. increased awareness about water conservation) and attitudes (e.g. perceptions about water conservation) form part of the process/implementation outcomes. Lastly, the category also includes the intention to change behaviour/practice, that is, planned future modifications of behaviours following the intervention.

The second part of the outcomes is subdivided into three sets. Firstly, shocks and stresses. These outcomes refer to the ability of targeted groups to address shocks and stressors, simultaneously minimizing permanent, adverse effects on their longer-term livelihood security. These outcomes can be disaster risk reduction and management approaches. Secondly, outcomes relating to the targeted groups’ ability to identify and respond to possible future impacts. These include changing activities or shifting their location to minimize potential shock or stress (decoupling), providing information on needs for future action (forecasting) and storage or rationing to allow for consistent and predictable provision of a good or services (smoothing). The third set of secondary outcomes relates to common pool resources (CPR) governance processes adapted from Ostrom⁷’s principles for how commons are governed to ensure sustainability and equity in a community. For example, the establishment of institutional arrangements to govern the use of common resources and conflict management mechanisms.

The last part is the final outcomes. Like secondary outcomes, these are also divided into three sets. The first set is the adaptive capacity of both human and natural systems. For human systems, these relate to the ability of targeted groups to make pro-active and informed decisions about alternative livelihood strategies based on an understanding of evolving climate conditions. These include targeted groups’ buffer capacity, self-organisation and the ability to learn. In terms of natural systems, this refers to their ability to adjust and respond to changing environmental conditions

⁷ Ostrom (1990)

specifically biodiversity and species interactions, migration and range shifts as well as ecological succession and resilience. The second set of the final outcomes is mitigation co-benefits and trade-offs including changes in emissions, the value of offsets verified and validated, amounts of GHG emissions captured or sequestered and trade-offs in the form of opportunity costs of the interventions. Changes in GHG emissions will be limited to those directly related to the interventions undertaken in the areas concerned. Since adaptation interventions in the water sector may result in increased GHG emissions, net changes in emissions will be considered rather than the more limited identification of mitigation impacts as “co-benefits”. In this regard, it is expected that the majority of the impacts will relate to changes in net emissions of carbon dioxide and methane generated by natural processes in permanent and temporary wetland areas and emissions resulting from reductions in water use as a result of reduced energy consumption or through the introduction of efficiency gains. The third set of final outcomes is an adaptation of Ostrom’s principles for how commons are governed including systems for oversight and compliance, dispute resolution and governance of common pool resources.

There has been a growing focus on investigating the unintentional effects of development initiatives. This heightened attention can be attributed to the recognised connection between the consequences of climate change and issues concerning sustainable development (Serra and others, 2022). For example, in communities with a background of conflict, evidence indicates that interventions can substantially contribute to worsening the potential for conflict escalation (Froese and Schilling, 2019; Kohli and others, 2018). In this light, we also capture unintended consequences of coastal and terrestrial interventions including positive or negative consequences, spillovers to non-programme participants and reduced resilience to climate change.

Due to time and resource constraints, the review will not consider the potential impact of adjustments to the operational management of existing water resource infrastructure on GHG emissions from water resource systems. Similarly, the review will not consider the mitigation impact of energy storage from existing hydropower infrastructure and its contribution to integrating intermittent renewable generators into electricity systems and reducing the use of fossil fuel-generated electricity. If the review identifies notable evidence of such opportunities, it may be appropriate to propose a separate review to assess the significance of their potential contribution to mitigation.

The health impact of water interventions is outside the review’s scope. Although the effective provision of water supply and sanitation services, which underpin public health, derives from and impacts water resources, it is generally considered separately from the management of those resources. Water services have been the subject of many systematic evaluations and reviews that have also included climate change impacts. Their inclusion in this review would generate extensive evidence, distracting it from its primary focus on the challenges of managing the water resource itself and the nature-based interventions that can contribute to greater resilience.

Figure 1. Theory of change

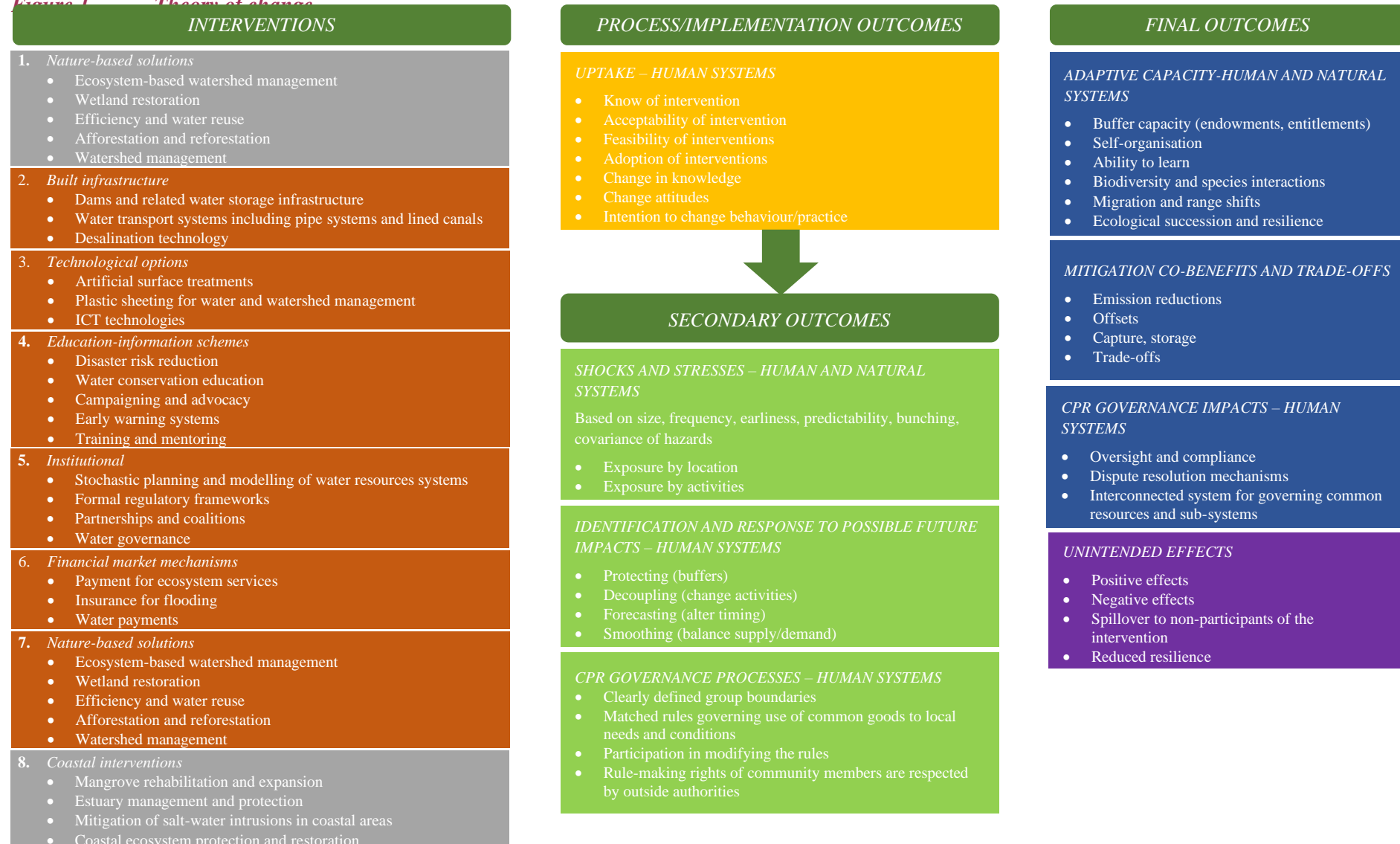


Table 1. Intervention types and related activities

INTERVENTION TYPE	DEFINITION	EXAMPLES ⁸
Nature-based options	Activities that use ecosystems and biodiversity and sustainable management, conservation and restoration of ecosystems to achieve water security goals.	Restoration of natural wetlands. Use of wetland/pond-based systems for water quality management and wastewater treatment. Ecosystem-based watershed management, including afforestation and reforestation and remediation and control of land erosion.
Built infrastructure	Activities that include structural components built to achieve water security goals.	Dams and related water storage infrastructure. Desalination plants. Water transport systems, including pipe systems and lined canals. Water-efficient irrigation systems (sprinkler and drip). Rainwater harvests tanks* ⁹ .
Technological options	Activities that apply specific technologies to support the achievement of water security goals.	ICT. Plastic sheeting for water and shade management. Artificial surface treatments. *Smart water meters ¹⁰ . *Monitoring networks.
Informational/educational schemes	Activities that aim to inform and educate water managers and users to influence behaviour.	Water conservation education. Flood and drought early-warning systems. Other disaster risk reduction interventions (business training and mentoring).
Institutional interventions	Activities that involve the development of institutional arrangements (including organizations, regulatory and	Development of a formal regulatory framework to govern water resource use, management and protection. Establishment of user-based organizations to manage common pool resources (e.g. farmers' water user associations, catchment management institutions etc.).

⁸ *Denotes examples of interventions per category provided by the advisory group.

⁹ Excludes water, sanitation and health (WASH) related intervention types.

¹⁰ Excludes WASH related intervention types.

INTERVENTION TYPE	DEFINITION	EXAMPLES ⁸
	operational frameworks) to support the achievement of water security goals.	Planning and modelling of water resource systems to guide their development and operation. *Smart decision support system systems. *Water user association.
Financial/market mechanisms	Activities that include financial transactions or are market driven.	Payment for ecosystem services, including user payment schemes. Insurance for losses due to flood and drought.
Social/behavioural	Activities that include social support and change or behavioural change.	Behavioural approaches-nudges. Migration due to floods/drought; social support due to floods/drought. *Catchment management plan.
Coastal interventions	Activities in the coastal environment and at the coastal/land interface.	Mangrove rehabilitation and expansion. Estuary management and protection. Mitigation of saltwater intrusions in coastal areas. Coastal ecosystem protection and restoration.

Table 2. Outcome definitions

OUTCOME	DEFINITION	
Process/implementation outcomes		
Uptake - human systems	Know of the intervention	Awareness of the intervention and its objectives.
	Acceptability of intervention	Perceptions about the intervention.
	Feasibility of interventions	Whether an intervention was implemented as planned.
	Adoption of interventions	Adoption of intervention activities.
	Change in knowledge	Acquisition of knowledge following the intervention.
	Change attitudes	Perceptions of the environment and developmental matters.
	Intention to change behaviour/practice	Future plans to modify behaviour towards the environment.
Secondary outcomes		

OUTCOME		DEFINITION
Shocks and stresses – human and natural systems Based on size, frequency, earliness, predictability, bunching, covariance of hazards	Exposure by location	These outcomes relate to the ability of targeted groups to address shocks and stressors while minimizing permanent, adverse effects on their longer-term livelihood security. These outcomes include those related to disaster risk reduction and disaster risk management approaches. Increased/decreased exposure/asset specificity.
	Exposure by activities (e.g. markets)	
Identification and response to possible future impacts – human systems	Protecting (defence mechanisms)	Measures to protect against (water-related) disaster risks.
	Decoupling (change activities)	Change in activities or shifting of their location to minimize potential shock or stress.
	Forecasting (alter timing)	Providing information that identifies and informs the need for future action.
	Smoothing (balance supply/demand)	Storage or rationing to enable consistent and predictable provision of a good or service.
CPR governance process – human systems	Clearly defined group	Identification of the societal grouping/s who use a shared resource.
	Rules governing the use of common goods	Institutional arrangements for using common pool resources developed and agreed upon among the communities of users.
	Participation in modifying the rules	Established mechanisms to resolve conflicts between existing and potential users over access to and use of common pool resources.
	Outside authorities respect the rule-making rights of community members	The institutional framework that confirms the scope and limits of action of common pool resources (CPR) governance institutions and provides for oversight and intervention to resolve conflicts between stakeholders.
Final outcomes		
Adaptive capacity – human and natural systems	These outcomes relate to the ability of targeted groups to make proactive and informed decisions about alternative livelihood strategies based on an understanding of changing conditions. The adaptive capacity of natural systems refers to their ability to adjust and respond to changing environmental conditions, including those associated with climate change.	
	Buffer capacity (endowments, entitlements)	Buffer capacity refers to the capacity to cushion change and to use emerging opportunities to achieve better livelihood outcomes.
	Self-organization	The ability of social actors to determine their own rules that affect them in a collective process of social cooperation within an overarching framework of public governance.
	Ability to learn	The acquisition of new knowledge and skills and the capacity to act on them.

OUTCOME	DEFINITION	
Biodiversity and species interactions	High biodiversity provides a greater pool of genetic variation and ecological interactions, which can enhance the resilience of ecosystems to climate change.	
Migration and range shifts	Natural systems can respond to climate change by shifting their geographic ranges or expanding into new areas that offer more suitable conditions. This movement allows species to track suitable climates and maintain viable populations.	
Ecological succession and resilience	Natural systems can undergo ecological succession, where species composition and community structures change over time. This process allows for adaptation and resilience as new species are introduced or existing species adapt to new conditions. The ability of a system to resist, absorb, accommodate, adapt to, transform and recover from external impacts in a timely and efficient manner.	
Mitigation co-benefits and trade-offs – human and natural systems	Changes in emissions	GHG emissions avoided, reduced or increased.
	Offsets	Value of offset credits verified and validated.
	Capture, storage	Amount of GHG sustainably captured or sequestered.
	Trade-offs/opportunity costs	Opportunity costs of interventions incurred, including spatial and socioeconomic impacts.
CPR governance processes – human systems	Oversight and compliance	Systems established to monitor the behaviour of the CPR group.
	Dispute resolution mechanisms	Effective mechanisms in place for dispute resolution are accessible and affordable.
	Interconnected system for governing common resources and sub-systems	Institutional arrangements that recognize and provide linkages for the governance and management of activities in interconnected resource sub-systems.

3. CRITERIA FOR INCLUSION AND EXCLUSION OF STUDIES IN THE REVIEW

To systematically characterize a large, disparate literature on the effectiveness of coastal and terrestrial water-sector interventions, the scope of the evidence review is guided by an underlying focus on adaptive capacity and mitigation co-benefits. Formally, we adopt the PICOS framework to develop our inclusion criteria. Appendix 1 summarizes the inclusion criteria for the systematic review in developing and developed countries. The inclusion criteria define the precise characteristics of the studies included in the review. All evidence not meeting these criteria is beyond the review's scope.

a. Population

We follow the country-level categorization in the United Nations Framework Convention on Climate Change (Kyoto Protocol) and include studies assessing the effectiveness of selected coastal and terrestrial water-sector interventions in:

- Non-Annex I countries across all intervention and outcome categories.
 - Non-Annex I and Annex I countries jointly if the associated analysis distinguishes effects and reports results separately across the two samples. We will include studies where the intervention is conducted in Annex I countries if the empirical outcomes are measured in non-Annex I countries.
 - We will exclude any study that combines analyses of both Annex I and non-Annex I countries without reporting separate results across the two samples.
- Annex I countries for selected interventions and outcomes are specified below.
 - Annex I and non-Annex I countries jointly if the corresponding analysis separates the effects of the selected interventions and reports results separately across the two samples. We will include studies where the selected intervention is conducted in Annex I countries, and the selected empirical outcomes are measured in Annex I countries.
 - We will exclude any study that combines analyses of both Annex I and non-Annex I countries without reporting separate results across the two samples.
- The review will include studies conducted at any observation unit (e.g. individuals, households, communities and companies).
- We will consider studies published from the year 2000 onwards.

b. Interventions

We will only include selected coastal and terrestrial water-sector interventions informed by empirical research, principally from the water sector. These are categorized into eight groups: nature-based options, built infrastructure, technological options, coastal interventions, informational/educational schemes, institutional, financial market mechanisms and social/behavioural interventions. The review will assess the effectiveness of all eight intervention categories in non-Annex I countries. However, only one¹¹ category of interventions will be considered for Annex I countries: institutional interventions. These interventions can be delivered at

¹¹ We considered the inclusion of nature-based and coastal interventions for developed countries but due to the limited time and resources, this intervention type will not be included in the present review.

any administrative level and administered to any type of beneficiary (e.g. individual, household) by any actor (e.g. government, non-governmental organization).

Additionally, we will not use any restrictions related to intervention-level characteristics, such as modality, intensity, duration or complexity of delivery. Expressly, we will not exclude studies based on restrictions related to sample size, ensuring the review captures pilot-scale interventions that often focus on newer, more innovative approaches. The review will not focus on studies examining water interventions for consumption and/or health, including water, sanitation and health.

c. Comparison

The review will only consider evaluation studies that identify at least two experimental groups: (i) a treatment group exposed to the intervention and (ii) a control group that does not receive the intervention. The nature of the control group will depend largely on the study's specific methods (e.g. the control group in a randomized controlled trial). It can refer to the population receiving no treatment, treatment as usual, placebo treatment, or pipeline treatment. We will consider synthetic control groups for inclusion. We will exclude any study that does not describe an articulated control group, for instance, descriptive/predictive analyses highlighting drivers and determinants of selecting coastal and terrestrial interventions. Quantitative methods for which comparison/control groups are irrelevant, such as life cycle assessments, will be excluded.

d. Outcomes

Overall, studies will have to assess the effect of the above interventions on the final and intermediate outcomes to be included. We will exclude studies that report on process/implementation outcomes only. Final outcome areas will include indices for adaptive capacity and proxy variables. In terms of mitigation co-benefits, outcome areas will be refined down to CO₂^e¹² or comparable metrics.

Additionally, long-term CPR governance processes form part of the review's final outcomes of interest. Intermediate outcomes related to programme uptake include the uptake of knowledge of the intervention, participation in the intervention, acquisition of knowledge and changing attitudes. The intermediate outcomes also include bunching, the covariance of hazards, the minimisation of negative impacts, the establishment of short-term CPR governance processes, and shocks and stresses based on size, frequency, earliness, and predictability. The review will only consider all outcomes areas for non-Annex I countries and only final natural systems outcomes for Annex I countries as stated below.

Non-Annex I countries

Final outcomes:

- 1) Adaptive capacity - Human and natural systems
 - a) Buffer capacity (endowments, entitlements)
 - b) Self-organization
 - c) Ability to learn
 - d) Biodiversity and species interactions
 - e) Migration and range shifts

¹² CO₂ equivalent

- f) Ecological succession and resilience
- 2) Mitigation co-benefits and trade-offs - Human and natural systems
 - a) Emission reductions
 - b) Offsets
 - c) Capture, storage
- 3) CPR governance processes – Human systems
 - a) Oversight and compliance
 - b) Dispute resolution mechanisms
 - c) Interconnected system for governing common resources and sub-systems

Secondary outcomes:

- 1) Shocks and stresses - Human and natural systems: based on size, frequency, earliness, predictability, bunching, covariance of hazards
 - a) Exposure by location
 - b) Exposure by activities (e.g. markets)
- 2) Identification and response to possible future impacts - Human systems
 - a) Protecting (buffers)
 - b) Decoupling (change activities)
 - c) Forecasting (alter timing)
 - d) Smoothing (balance supply/demand)
- 3) CPR governance processes – Human systems
 - a) Clearly defined group boundaries
 - b) Matched rules governing the use of common goods to meet local needs and conditions
 - c) Participation in modifying the rules
 - d) Outside authorities respect the rule-making rights of community members

Process/implementation outcomes:

- 1) Uptake - Human systems
 - a) Know of intervention
 - b) Acceptability of intervention
 - c) Feasibility of interventions
 - d) Adoption of interventions
 - e) Change in knowledge
 - f) Change attitudes
 - g) Intention to change behaviour/practice

Annex I countries

Final outcomes:

- 1) Adaptive capacity - Human and natural systems
 - a) Buffer capacity (endowments, entitlements)
 - b) Self-organization
 - c) Ability to learn
 - d) Biodiversity and species interactions
 - e) Migration and range shifts

- f) Ecological succession and resilience
- 2) Mitigation co-benefits and trade-offs - Human and natural systems
 - a) Emission reductions
 - b) Offsets
 - c) Capture, storage
- 3) CPR governance processes – Human systems
- 4) Oversight and compliance
- 5) Dispute resolution mechanisms
- 6) Interconnected system for governing common resources and sub-systems

Secondary outcomes:

- 1) Shocks and stresses - Human and natural systems: based on size, frequency, earliness, predictability, bunching, covariance of hazards
 - a) Exposure by location
 - b) Exposure by activities (e.g. markets)
- 2) Identification and response to possible future impacts - Human systems
 - a) Protecting (buffers)
 - b) Decoupling (change activities)
 - c) Forecasting (alter timing)
 - d) Smoothing (balance supply/demand)
- 3) CPR governance processes – Human systems
 - a) Clearly defined group boundaries
 - b) Matched rules governing the use of common goods to meet local needs and conditions
 - c) Participation in modifying the rules
 - d) Outside authorities respect the rule-making rights of community members

Process/implementation outcomes:

- 1) Uptake - Human systems
 - a) Know of intervention
 - b) Acceptability of intervention
 - c) Feasibility of interventions
 - d) Adoption of interventions
 - e) Change in knowledge
 - f) Change attitudes
 - g) Intention to change behaviour/practice

We will assess this range of outcomes measured at any unit of analysis (e.g. individual, household, community and company). Moreover, in line with our broad criteria related to study-level characteristics, we will consider studies that measure outcomes at any point following the administration of the relevant coastal and terrestrial water-sector interventions. We are not prespecifying relevant outcome indicators for including studies in this review and will assess the validity of indicators and outcome measures as part of the critical appraisal of evidence. We will also record information on unintended outcomes (e.g. an increase in environmental degradation or spill over to non-participants of intervention) and information on intervention costs or cost-effectiveness where reported.

e. Study design

We will include studies that assess the effects of interventions using experimental or quasi-experimental designs with a non-random assignment that allows for causal inference, in line with Lwamba and others (2022); Ategeka and others (2022). Specifically, we include the following:

- Randomized controlled trials (RCTs), with an assignment at an individual, household, community or other cluster level, and quasi-RCTs using prospective assignment methods such as alternation. These studies could also use natural experiments.
- Non-randomized studies with selection on unobservables:
 - Regression discontinuity designs, where the assignment is conducted on a threshold measured at pre-test and the study uses prospective or retrospective analysis approaches to control for unobservable confounding.
 - Studies using design or methods to control for unobservable confoundings, such as natural experiments with clearly defined intervention and comparison groups, which exploit natural randomness in implementation assignment by decision makers (e.g. public lottery) or random errors in implementation, and instrumental variables estimation.
- Non-randomized studies with¹³ pre-intervention and post-intervention outcomes data in intervention and comparisons groups, where data are individual-level panels or pseudo-panels (repeated cross-sections), which use the following methods to control for confounding:
 - Studies controlling for time-invariant unobservable confounding, including difference-in-differences or fixed- or random-effects models with an interaction term between time and intervention for pre-intervention and post-intervention observations; and
 - Studies assessing changes in trends in outcomes over a series of time points (interrupted time series), with or without contemporaneous comparison (controlled interrupted time series), with sufficient observations to establish a trend and control for effects on outcomes due to factors other than the intervention (e.g. seasonality).
- Non-randomized studies with control for observable confounding, including non-parametric approaches (e.g. statistical matching, covariate matching, coarsened-exact matching, propensity score matching) and parametric approaches (e.g. propensity-weighted multiple regression analysis).

In the absence of randomization, studies may be limited in their ability to make claims about causality as confounding factors may not be controlled. This shall be fully recognized within the systematic review. Sample sizes shall be re-assessed on a case-by-case basis. The systematic review may include underpowered experimental studies.

We will exclude all studies that do not fall under the above criteria. Examples of excluded study types are simulation studies that aim to predict the effect of a specific intervention, observational studies with no control for selection bias, life cycle analysis, process evaluations, acceptability studies and non-systematic literature reviews.

¹³ The review, based on inputs from the advisory group, considered inclusion of before and after studies (without treatment and control group). However, such study designs do not meet the Campbell Collaboration review standards and guidelines and are therefore excluded from the review.

f. Exclusion criteria

We will exclude studies not meeting the criteria outlined in (a) to (e) above. That is, we will exclude studies with interventions that do not meet our definition of coastal and terrestrial water-sector interventions and water services interventions for human consumption and/or health, including interventions in the water, sanitation and health (WASH) sector. Studies only reporting process/implementation outcomes will be excluded from this review. We will exclude all studies that do not clearly articulate a comparison/control group, e.g. process evaluations.

4. SEARCHING FOR EVIDENCE

a. Search steps

We will adopt a comprehensive strategy in searching research literature for qualifying studies to identify all available evidence relevant to the review question. The strategy's key objective is to be sensitive rather than specific by deliberately formulating over-inclusive search strings and search sources. This may increase the number of citations to be screened, but it reduces the risk of missing any relevant studies. The search strategy aims to find both academic and grey literature. To that end, we will employ a three-pronged search strategy: (i) a formal search of academic databases using predefined and explicit search strings and Boolean operators, (ii) a formal search of grey literature in key organizational websites using keywords but applying full search strings in cases where institutional databases allow the application of Boolean operators, and (iii) backwards and forward citation searches of included and seminal studies. Appendix 2 details the full search strategy.

b. Search databases and repositories

The database choice is guided by relevance and comprehensiveness in covering sectoral literature. We plan to conduct searches on the most appropriate databases for published literature and grey literature, specialist organizational websites and research institutes, as Table 3 highlights.

Table 3. *List of targeted databases*

DATABASE TYPE	NAME OF DATABASE
Academic	Centre for Agricultural Bioscience International Abstracts
	Scopus
	Web of Science (Social Science Citation Index, Science Citation Index Expanded, Emerging Sources Citation Index)
	EBSCO
	Biological and Agricultural Index
	Business Source Ultimate
	EconLit
	GreenFILE
	PsychInfo
	Urban studies abstracts
Waters and Oceans Worldwide	
Grey literature	African Development Bank: https://www.afdb.org/en
	Asian Development Bank: https://www.adb.org/
	Behaviour Evidence hub: https://www.bhub.org/

DATABASE TYPE	NAME OF DATABASE
	Bill & Melinda Gates Foundation: https://www.gatesfoundation.org/
	Building Resilience and Adaptation to climate extremes and disasters: http://www.braced.org
	Campbell Collaboration: https://campbellcollaboration.org/
	Collaboration for Environmental Evidence Database of Evidence Reviews: https://environmentalevidence.shinyapps.io/CEEDER/
	Center for Effective Global Action Research Publications: https://vcresearch.berkeley.edu/research-unit/center-effective-global-action
	Conservation Evidence: https://www.conservationevidence.com/
	Ecologic Institute EU (Ecologic): https://www.ecologic.eu/
	Earth–Eval: https://www.climate-eval.org/eLibrary
	Environmental Evidence Library: http://www.environmentalevidence.org/completed-reviews
	European Environment Agency: www.eea.europa.eu/
	Federal Environment Agency, Germany: www.umweltbundesamt.de/
	Global Environmental Facility: https://www.thegef.org/projects-operations/database
	Global Mangrove Alliance: https://www.mangrovealliance.org/
	Green Climate Fund: https://www.greenclimate.fund/publications
	Green Finance Platform: https://www.greenfinanceplatform.org/
	Innovations for Poverty Action Publications: https://www.poverty-action.org/publications
	Inter-American Development Bank: https://www.iadb.org/en/topics-effectiveness-improving-lives/impact-evaluations-repository
	International Drought Resilience Alliance: https://idralliance.global/
	International Fund for Agricultural Development: https://www.ifad.org/en/
	International Initiative for Impact Evaluation: 3ie Development Evidence Portal: https://developmentevidence.3ieimpact.org/
	International Institute for Environment and Development: www.iied.org/
	International Water Management Institute: https://www.iwmi.cgiar.org/
	J-PAL: https://www.povertyactionlab.org/evaluations
	Mangroves for the Future: http://www.mangrovesforthefuture.org/
	National Bureau of Economic Research: https://www.nber.org/
	Netherlands Water Partnership: https://www.dutchwatersector.com/about-us
	Netherlands Environmental Assessment Agency, NL: www.pbl.nl/en/
	Organisation for Economic Co-operation and Development: http://www.oecd.org/
	Ostrom Workshop: https://ostromworkshop.indiana.edu/index.html
	Ramsar: https://www.ramsar.org/resources
	Rare: http://www.rare.org
	Resilience, Evaluation, Analysis and Learning: https://www.fsnnetwork.org/REAL
	Restor: https://restor.eco/?lat=26&lng=14.23&zoom=3

DATABASE TYPE	NAME OF DATABASE
	The Blue Carbon Initiative: https://www.thebluecarboninitiative.org/
	The Nature Conservancy: https://www.conservationgateway.org/ConservationPlanning/ToolsData/Pages/tools-and-data.aspx
	The World Bank: www.worldbank.org/
	United Nations Development Programme: www.undp.org/
	United Nations Environment Programme (REDD+): https://www.unenvironment.org/explore-topics/climate-change/what-we-do/mitigation
	United Nations Framework Convention on Climate Change: https://unfccc.int/
	Food and Agriculture Organization of the United Nations: https://www.fao.org/home/en
	USAID Evaluations Clearinghouse: http://dec.usaid.gov/
	World Bank eLibrary: https://elibrary.worldbank.org/
	World Coastal Forum: https://www.worldcoastalforum.org/

c. Forward and backward citation searches

We will carry out backward citation searches by searching the reference lists of included studies, and forward citation searches using Google Scholar to find papers cited in included studies.

d. Search terms

Our search terms will provide broad but manageable coverage related to the systematic review objective. We will design sets of search parameters and individual terms, including wild card symbols (*) where appropriate, separated by the Boolean operator “OR”, separate for non-Annex I countries and non-Annex I countries where relevant. The sets are then combined using “AND”. The initial search terms (Appendix 2) are organized into the following categories.

- 1) Country terminology: This sub-category includes two population specifications as noted in the inclusion criteria, search terms for non-Annex I countries (P1) and search terms for Annex I countries (P2). These terms are often used interchangeably with or closely related to the phrase “developing countries” and “developed countries” and the specification of developing and developed country names, respectively.
- 2) Methods terminology: This category includes terminology related to the measurement and tracking of impacts, such as “impact evaluation*”, “impact assessment”, and “impact analysis”. It also articulates comparison groups, including “control” or “treatment” groups. Terms related to the specific empirical methods, such as “instrumental variable”, are also included as these do not always refer to explicit comparison groups but generate estimates of causal impacts that are comparative.
- 3) Intervention terminology: Terms related to the coastal and terrestrial water sector are highlighted in the ToC above. The development of the intervention terms aims to be broad and encapsulate numerous synonyms without limiting it to the technical definition of the coastal and terrestrial water interventions. This will ensure the search is wide enough not to miss relevant studies. The first set of search terms relates to interventions of interest in non-Annex I countries (IN1), and the second set of interventions considered in developed countries (IN2).

- 4) **General restrictions:** This category combines language and time-specific restrictions to enable us to restrict (academic database) search results to English-language articles and systematic reviews published in peer-reviewed academic journals in or after the year 2000.

The search terms are subject to refinement in subsequent search trials. The robustness of our search will be tested using a list of benchmark papers, that is, studies that ought to be in the search results. In cases where two-thirds of the benchmark papers are retrieved through database searches, the search strategy passes the robustness test.

e. Combination of search terms

Two separate searches will be conducted for non-Annex I and Annex I countries. The first category of search terms in this review is country terms. These contain two substrings, one for developing countries (P1) and one for developed countries (P2), thus constituting the “P” of the PICOS elements of the research question. Synonyms for identified developing and developed country terms are combined using the OR Boolean operator in each substring separately. The second category of search terms concerns the methodology of studies of interest to the review, the “S” part of the PICOS framework. It combines systematic and impact evaluation synonyms using the OR Boolean operator. The third group of substrings is the intervention terms divided into two search substrings shown in Appendix 2, the I component of the PICOS. The first set of substrings relates to all intervention groups relevant to non-Annex I countries. The second substring constitutes intervention terms considered for Annex I countries as outlined in section C3 above. These intervention synonyms are also combined using “OR” with truncations to improve the search. Two separate searches will be conducted for non-Annex I and Annex I countries. The overall combination of search concepts will follow this syntax:

- 1) Non-Annex I: “P1” terms **AND** (2) Methods “S” terms **AND** (3) Intervention “IN1” terms
- 2) Annex I: “P2” terms **AND** (2) Methods “S” terms **AND** (3) Intervention “IN2” terms

f. Screening of studies

We will manage the entire review process using EPPI-Reviewer 4, a software programme for conducting systematic and literature reviews from the Evidence for Policy and Practice Information and Co-ordinating (EPPI) Centre. All potentially relevant citations gathered from the academic sources above will be imported into the programme. They will undergo a manual screening process to be assessed for eligibility using the inclusion criteria highlighted above. The decisions for each citation will be recorded on the same platform. Search results from organizational websites and the citation searches will be captured in MS Word, and only studies deemed relevant for the map will be transferred to EPPI-Reviewer 4. Studies not already on EPPI-Reviewer will be inputted manually. Before proceeding with screening, all duplicates of titles will be excluded from the review using EPPI-Reviewer 4’s duplicate control function.

We will use EPPI Reviewer 4’s machine learning algorithm function, specifically the classifier, to enhance the speed and quality of the screening process. The classifier is an EPPI machine learning system that allows the organization of studies into groups based on their probability of inclusion in the review. The bespoke classifier will be built after double-screening a minimum of 20 per cent of all citations, which is enough for machine learning to analyse and “learn” from selected choices. To enhance the classifier’s efficiency, we will pay particular attention to the reasons for exclusion during the double-screening reconciliation process of the initial 10 per cent of citations. We will then screen a random sample of the automatically excluded studies to double-check the accuracy of the function. If all are excludable, we can auto-exclude the rest of the citations. A double-screening exercise of the title and abstract will focus on all records with a 20 per cent or higher likelihood of inclusion.

We will then conduct a full-text screening of each study that meets the inclusion at the title and abstract screening stage. During this stage, two reviewers will screen a sample of 15 per cent of studies remaining from the title and abstract screening against the protocol and individually decide whether to include or exclude the study. Any disagreements between reviewers will be reconciled through the supervision of a senior review team member. Individual screening is only permissible if the similarity index of the screening exercise reaches 90 per cent. This stage will produce a set of studies suitable for inclusion in the review. The screening process will be reported using a PRISMA¹⁴ flow chart which includes the detailed steps for searching and reviewing grey material (see Appendix 3).

5. DATA COLLECTION AND ANALYSIS

a. Data extraction and management

We will use a predefined data extraction tool to extract data systematically and transparently from the included primary studies. The coding framework tool highlighted in Appendix 4 will be integrated into the EPPI-Reviewer 4 to extract the information required for the evidence mapping and the in-depth review and synthesis. The data will be entered directly into the EPPI-Reviewer database, and full-text reports examined, and studies coded on variables related to:

- Descriptive data, including authors, publication date, and status, as well as other information to characterize the study, including study design, country, type of intervention and outcome, population and context.
- Methodological information, analysis method, and type of comparison (if relevant).
- Quantitative data for outcome measures, including outcome descriptive information, sample size in each intervention group, outcome means and standard deviations and test statistics (e.g. t-test, F-test, p-values, 95 per cent confidence intervals).
- Information on intervention design, including how the intervention incorporates participation, participant adherence, contextual factors and programme mechanisms, including implementation fidelity.

To ensure consistency of coding quality, two reviewers will pilot the data extraction tool, working independently on a random sample (10 per cent) of eligible studies selected to test the tool on the complete range of the included impact evaluation designs and methods. The process will be repeated until a very high level of consistency, defined by a similarity index of 90 per cent in the reviewer's application of codes, is attained. The tool will then be deemed final. Following the piloting stage, the remaining studies will be coded by individual reviewers. A subset of these full texts will be coded by different combinations of the two reviewers independently extracting information from each study and comparing their decisions. Any uncertainties or disagreements will be resolved via discussion to review the study reports further. A third-party arbitrator will resolve any outstanding disagreements.

b. Critical appraisal

We will apply a critical appraisal tool to assess the trustworthiness of the impact evaluations included in the systematic review. Trustworthiness refers to the confidence that the findings

¹⁴ Preferred Reporting Items for Systematic Reviews and Meta-Analyses

reported in the included impact evaluations were rigorous and credible and are likely to reflect the evaluated interventions' results rather than the influence of the applied study design and research conduct. To assess the risk of bias in the primary studies, we will adapt the Cochrane risk of bias tool for randomized and non-randomized studies (Sterne and others, 2016). We have previously used and adopted this risk of bias tool in international development reviews (Stewart and others, 2015; Langer and others, 2018). Sterne and others (2016) used a domain-based risk of bias tool covering the following six indications of trustworthiness: (i) selection bias, (ii) confounding bias, (iii) bias due to departures from applied interventions, (iv) bias due to missing data (v) bias due to measurement of outcomes and (vi) bias due to selection of the reported result. Each bias domain will receive a low, moderate, high, or critical risk of bias rating, allowing for a transparent calculation of each study's overall bias risk score. Studies with a high likelihood of bias will be included in the review but excluded from the synthesis. If reviewers disagree about the risk of bias rating for a particular study, they will consult with a third reviewer.

Appendix 5 describes the critical appraisal tool used to assess studies for the systematic review. We will pilot the tool using a similar approach to that used for piloting the data extraction tool. Two reviewers will independently assess each study and then come together to compare their decisions. Where these reviewers disagree about the risk of bias rating for a particular study, they will seek a third reviewer's advice.

c. Methods for handling dependant effect sizes

i. Criteria for the determination of independent findings

Complex data structures are common in meta-analyses of impact evaluations. There are many scenarios where these complex structures can affect the meta-analysis. For example, several publications could originate from one study or several studies could originate from the same data set. Some studies might have multiple treatment arms compared to a single control group. Other studies may report outcome measurements from several time points or use multiple outcome measures to assess related outcome constructs. Such cases yield statistically dependent effect size estimates (Borenstein and others, 2009).

The research team will assess the extent to which relationships exist across the studies included in the review and avoid double-counting identical evidence by linking papers before data analysis. When several publications report the same effect, we will use effect sizes from the most recent publication. The team will use the information provided in studies to support these assessments. This information will include sample sizes, programme characteristics and key implementing and/or funding partners.

We will extract effects reported across different outcomes or subgroups within a study. Where information is collected on the same programme for different outcomes at the same or different periods, we will extract information on the full range of outcomes over time. Where studies report effects from multiple model specifications, we will adopt the author's preferred model specification. If this is not stated or is unclear, the specification with the most controls will be used. Where studies report multiple outcomes or evidence according to subgroups of participants, we will record and report data on relevant subgroups separately. Further information on the criteria for determining independent effect sizes is presented below.

We will deal with dependent effect sizes through data processing and selection techniques that utilize several criteria to select one effect estimate per study. When we have several publications reporting on the same study, we will use effect sizes from the most recent publication. For studies with outcome measures at different time points, we will follow De La Rue and others (2014) and synthesize outcomes measured immediately after the intervention (defined as one to six months) and

at follow-up (longer than six months) separately. We will adopt the most recent measure if multiple time points exist within these periods.

We anticipate that many of the interventions we address in our review will be ongoing programmes. We expect the follow-up will reflect a programme's duration rather than the time since the intervention. Where such studies report outcome measures at different time points, we will identify the most common follow-up period and include the follow-up measures that match this most closely in the meta-analysis. When studies have multiple outcome measures to assess related outcome constructs, we will follow Macdonald and others (2012) and select the outcome that reflects the construct of interest most accurately without referencing the results.

Studies may include multiple treatment arms with only one control group and the treatments representing separate treatment constructs. In such cases, we will calculate the effect size for treatment A versus control and treatment B versus control and include them in separate meta-analyses according to the treatment construct. Where treatments A and B represent variations of the same treatment construct, we will apply the following approach. We will calculate the weighted mean and standard deviation for treatments A and B before calculating the effect size for the merged group versus the control group, following the procedures outlined in Borenstein and others (2009, chapter 25). There may also be cases where different studies report on the same programme but use different samples (e.g. from different regions or separately for men and women). In such instances, we will include both estimates, treating them as independent samples, provided the effect sizes are measured relative to separate control or comparison groups.

ii. Effect size calculations

Using Excel, we will extract quantitative data for outcome measures, including outcome descriptive information, the sample size in each intervention group, the outcome means and standard deviations, and test statistics (e.g. t-test, F-test, p-values, 95 per cent confidence intervals). Effect size data will be stored, and any necessary cleaning will be conducted in Excel. Following the screening and descriptive data extraction process, two reviewers will pilot the extraction tool to determine the effect size. This will ensure consistent coding. The reviewers will work independently on a random sample (10 per cent) of included studies to test the tool across a range of the included impact evaluation designs and methods. We aim to achieve a minimum Kappa statistic score of 0.90 following a round of repeating the process for the tool to be finalized. After the piloting stage, individual reviewers will code the remaining studies, and a third reviewer will check the extracted data.

An effect size expresses the magnitude (or strength) and direction of the relationship of interest (Valentine, Aloe and Lau, 2015; Borenstein and others, 2009). We will extract data from each study to calculate standardized effect sizes for cross-study comparison wherever possible. For continuous outcomes comparing group means in a treatment and control group, we will calculate the standardized mean difference, or Cohen's *d*, its variance, and standard error (SE) using formulae provided in Borenstein and others (2009). A standardized mean difference is a difference in means between the treatment and control groups divided by the pooled standard deviation (SD) of the outcome measure. Cohen's *d* can be biased in cases where sample sizes are small. Therefore, in all cases, we will adjust *d* using Hedges¹⁵ method, adjusting Cohen's *d* to Hedges' *g* using the following formula (Ellis, 2010):

¹⁵ Hedges and Olkin (1985)

$$g \cong d(1 - \frac{3}{4(n_1 + n_2) - 9})$$

We choose an appropriate formula for effect size calculations in reference to, and dependent upon, the data provided in included studies. For example, for studies reporting means (X) and pooled standard deviation for treatment (T) and control or comparison (C) at follow-up only:

$$d = \frac{x_{Tp+1} - x_{Cp+1}}{SD}$$

If the study does not report the pooled standard deviation, it is possible to calculate it using the following formula:

$$SD_{p+1} = \sqrt{\frac{(n_{Tp+1} - 1)SD_{Tp+1}^2 + (n_{Cp+1} - 1)SD_{Cp+1}^2}{n_{Tp+1} + n_{Cp+1} - 2}}$$

Where the intervention is expected to change the standard deviation of the outcome variable, we use the standard deviation of the control group only.

For studies reporting means (X) and SD for treatment and control or comparison groups at baseline (p) and follow-up (p+1):

$$d = \frac{\Delta X_{p+1} - \Delta X_p}{SD_{p+1}}$$

For studies reporting mean differences (ΔX) between treatment and control and SD at follow-up (p+1):

$$d = \frac{\Delta X_{p+1}}{SD_{p+1}} = \frac{X_{Tp+1} - X_{Cp+1}}{SD_{p+1}}$$

For studies reporting mean differences between treatment and control, SE and sample size (n):

$$d = \frac{\Delta X_{p+1}}{SE\sqrt{n}}$$

As primary studies have become increasingly complex, it is common for authors to extract partial effect sizes in the context of meta-analysis (e.g. a regression coefficient adjusted for covariates). For studies reporting regression results, we will follow the approach suggested by (Keef and Roberts, 2004) using the regression coefficient and the outcome's pooled standard deviation. Where the outcome's pooled standard deviation is unavailable, we utilize regression coefficients and standard errors or t-statistics to do the following, where sample size information is available in each group:

$$d = t \sqrt{\frac{1}{n_T} + \frac{1}{n_C}}$$

where n denotes the sample size of the treatment group and control. We will use the following where only the total sample size information (N) is available, as suggested in (Polanin, Tanner-Smith and Hennessy, 2016):

$$d = \frac{2t}{\sqrt{N}} \quad Var_d = \frac{4}{N} + \frac{d^2}{4N}$$

We calculate the t -statistic (t) by dividing the coefficient by the standard error. If the authors only report confidence intervals and no standard error, we calculate the standard error from the confidence intervals. If the study does not report the standard error but reports t , we extract and use this as reported by the authors. In cases in which significance levels are reported rather than t or SE (b), then t was imputed as follows:

$$\text{Prob} > 0.1: t = 0.5$$

$$0.1 \geq \text{Prob} > 0.05: t = 1.8$$

$$0.05 \geq \text{Prob} > 0.01: t = 2.4$$

$$0.01 \geq \text{Prob}: t = 2.8$$

Where outcomes are reported in proportions of individuals, we calculate the Cox-transformed log odds ratio effect size (Sánchez-Meca, Marín-Martínez and Chacón-Moscoso, 2003):

$$d = \frac{\ln(OR)}{1.65}$$

where OR is the odds ratio calculated from the two-by-two frequency table.

Where outcomes were reported based on proportions of events or days, we use the standardized proportion difference effect size:

$$d = \frac{p_T - p_C}{SD(p)}$$

where p_T is the proportion in the treatment group and p_C is the proportion in the comparison group, and the denominator is given by:

$$SD(p) = \sqrt{p(1-p)}$$

where p is the weighted average of p_C and p_T :

$$p = \frac{n_T p_T + n_C p_C}{n_T + n_C}$$

An independent reviewer will evaluate a random selection of 10 per cent of effect sizes to ensure that the correct formulae are employed in effect size calculations. In all cases after synthesis, we will convert the pooled effect sizes to commonly used metrics such as percentage changes and mean differences in outcome metrics typically used whenever feasible (e.g. weight in kg).

d. Data synthesis

Based on studies assessed to be sufficiently similar, we will combine studies using meta-analysis only when identifying two or more effect sizes using a similar outcome construct and where the comparison group state is judged as similar across the two (cf. the approach taken by Wilson, Weisburd and McClure, 2011). We will combine studies in the same analysis when they evaluate the same intervention and outcome type. Where insufficient studies or included studies are considered too heterogeneous regarding interventions or outcomes, we will discuss the individual effect sizes along the causal chain. As the programme theory of interventions suggests, there will be heterogeneity across studies.¹⁶

We will use the “metan” package in Stata 16 software to conduct the meta-analyses.¹⁷ Where there are too few studies or included studies are considered too heterogeneous in terms of interventions or outcomes, we will present a discussion of individual effect sizes along the causal chain through a narrative synthesis.

¹⁶ We will account for this by adopting inverse-variance weighted random effect meta-analytic models (Higgins and others, 2019).

¹⁷ The amount of heterogeneity (i.e. $\hat{\tau}^2$), will be estimated using the DerSimonian-Laird estimator (DerSimonian and Laird, 1986). In addition to the estimate of $\hat{\tau}^2$, the Q -test for heterogeneity (Cochran, 1954) and the I^2 statistic (Higgins and Thompson, 2002) will be reported.

e. Subgroup analysis and investigation of heterogeneity

Whenever feasible, we will conduct moderator analyses to explain variations in effect sizes. Moderators are variables such as socioeconomic context and population characteristics, measured at baseline, that interact with treatment to change the outcome for each group (Pincus and others, 2011). Following the PROGRESS-Plus approach (Gough, Oliver and Thomas, 2017), we will use moderators falling into three broad categories of extrinsic, methodological, and substantive characteristics. Specifically, these categories include:

- Extrinsic characteristics: funder of the study (e.g. non-governmental organization/civil society organization versus private sector versus government investments), publication type, publication date.
- Methodological characteristics: study design, risk of bias, evaluation period, length of intervention.
- Substantive characteristics: participant characteristics (gender, age, socioeconomic status), context (geographical setting), intervention type, intervention features, and type of implementing agency.

We will use random effects meta-regression to investigate the association between moderator variables and heterogeneity of treatment effects (Borenstein and others, 2009) and subgroup analyses to investigate heterogeneity by treatment subgroups (e.g. men and women, poor and non-poor, and so on). If we do not have enough studies or data, we will discuss and explore the factors driving the heterogeneity of results narratively by conducting cross-case comparisons (Miles and Huberman, 1994).

f. Sensitivity analysis

We will conduct several sensitivity analyses to test the robustness of the meta-analysis results. Broadly, this will involve collecting data on and assessing the sensitivity of findings to (i) the methods of the primary studies and (ii) the review's methods. We anticipate that the included studies will vary methodologically. Therefore, we will conduct sensitivity analyses to examine the influence of these variations on the summary measures to offer possible explanations for the differences between studies when interpreting the results. We will examine whether the results were sensitive to the study design, the risk of bias associated with the study, the degree of missing/incomplete data, how outcomes are measured, and the timing of when they were measured. The main objective of the sensitivity analysis is to serve as a visual tool that allows informal comparisons to determine if the results of our meta-analyses are sensitive to the review team's methodological decisions. The sensitivity analyses will be carried out by adopting a one-way random effects analysis of variance model calculated in EPPI-Reviewer 4.

g. Strength of the evidence assessment

The last research step in the systematic review will be to conduct a Grading of Recommendations, Assessment, Development and Evaluations (GRADE) assessment to report on the overall strength of the evidence and recommendations based on the review's synthesis. This step is distinct from the critical appraisal step and considers additional factors for assessing the overall body of the evidence and how reliably it informs the recommendations. Appendix 6 presents the GRADE tool with hypothetical decisions for illustration purposes.

D. CONCLUSION

Projects, programmes or policies that aim to enhance adaptation in coastal and terrestrial water sectors are critical to achieving water security. This review will assess the effectiveness of key water-sector interventions on adaptive capacity in developing countries. It will address the current knowledge gap on effectiveness and consider the implications for climate programming by offering evidence-based insights to facilitate the implementation of interventions, deepening our understanding of the effectiveness of interventions and leverage lessons and best practices to guide future GCF programming and projects.

E. DISTRIBUTION OF MAIN ROLES

PROJECT FUNDING AND EXECUTION

Genta Konci	Independent Evaluation Unit, Green Climate Fund
Jennifer Pampolina	Independent Evaluation Unit, Green Climate Fund
Dr. Martin Prowse	Independent Evaluation Unit, Green Climate Fund
Andreas Reumann	Independent Evaluation Unit, Green Climate Fund

PROJECT EXECUTION

South Africa Centre for Evidence

Dr. Laurenz Langer	<p>Project oversight and management</p> <p>PI: Project oversight and management, stakeholder and client engagement, finance and reporting, drafting and finalizing outputs and deliverables.</p> <p>Synthesis method lead: design of all research activities (including scientific searches of academic databases, grey literature, and snowballing), tools development, and research staff training and support where relevant. Lead on formulating inclusion criteria, statistical meta-analysis, GRADE assessment, and qualitative comparative analysis, if conducted.</p>
Promise Nduku	<p>Co-PI: Project management, stakeholder and client engagement, reporting, drafting and finalizing outputs and deliverables.</p> <p>Senior Synthesis Specialist: Co-design and implementation of all research activities, co-design and implementation of scientific searches of academic databases, grey literature, and snowballing; screening; data extraction; and critical appraisal for the systematic review. Lead on effect size calculation, co-lead on statistical meta-analysis, meta-regression, and GRADE assessment.</p>
Andile Madonsela	<p>Researcher: Implementation of all research steps from searching and screening, accessing full-text articles, to data extraction, cataloguing data, collating background information, and editorial support.</p>

Content expert

Prof. Mike Muller	<p>Subject input related to the water sector on the following areas: scope of the systematic review including the ToC; inclusion criteria; reviewing search strategy and output; data extraction variables for the review and synthesis; interpreting synthesis results; output review including review protocol and technical report; and stakeholder and client engagement.</p>
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APPENDICES

Appendix 1. SUMMARY INCLUSION AND EXCLUSION CRITERIA

A. INCLUSION AND EXCLUSION CRITERIA FOR THE SYSTEMATIC REVIEW IN NON-ANNEX I COUNTRIES

INCLUDED	INCLUSION DESCRIPTION	EXCLUDED
Population	<p>Studies that focus on selected coastal and terrestrial water-sector interventions in:</p> <ul style="list-style-type: none"> • Non-Annex I countries • Non-Annex I and Annex I countries (jointly) if analyses distinguish effects across the two samples • English-language literature <p>Publication date: 2000 onwards</p>	<ul style="list-style-type: none"> • Annex I countries only • Combination of both non-Annex I and Annex I countries if analyses do not distinguish the two samples • Studies published before the year 2000
Interventions	<ul style="list-style-type: none"> • Deliberate coastal and terrestrial water-sector interventions that seek to improve adaptive capacity to climate risks in the water sector • Delivered at any administrative level • Administered to any type of beneficiary (e.g. individual, household) by any type of actor (e.g. government, non-governmental organization) <p>These interventions include the following:</p> <ul style="list-style-type: none"> • Nature-based options (e.g. restoration of natural wetlands, use of wetland/pond-based systems for water quality management and wastewater treatment, ecosystem-based watershed management, including afforestation and reforestation and remediation and control of land erosion) • Built infrastructure (e.g. dams and related water storage infrastructure, desalination plants, water transport systems including pipe systems and lined canals, water-efficient irrigation systems [sprinkler and drip], rainwater harvests tanks) • Technological options (e.g. ICT, plastic sheeting for water and shade management, artificial surface treatments, smart water meters, monitoring networks) • Informational/educational schemes (e.g. water conservation education, flood and drought early-warning systems, other disaster risk reduction interventions (business training and mentoring) • Institutional (e.g. development of a formal regulatory framework to govern the use, 	<ul style="list-style-type: none"> • Intervention not in the coastal and terrestrial water sector • Water interventions for consumption and/or health, including interventions in the WASH sector

INCLUDED	INCLUSION DESCRIPTION	EXCLUDED
	<p>management and protection of water resources, establishment of user-based organizations to manage common pool resources (e.g. farmers' water user associations, catchment management institutions etc.), planning and modelling of water resource systems to guide their development and operation, smart decision support system, water user associations</p> <ul style="list-style-type: none"> • Financial market mechanisms (e.g. payment for ecosystem services including user payment schemes, insurance for losses due to flood and drought) • Social/behavioural (e.g. behavioural approaches-nudges, migration due to floods/drought; social support due to floods/drought, catchment management plan) • Coastal interventions (e.g. mangrove rehabilitation and expansion, estuary management and protection, mitigation of saltwater intrusions in coastal areas, coastal ecosystem protection and restoration) 	
Comparator	Studies that identify a comparison/control group	<ul style="list-style-type: none"> • Descriptive/predictive analyses without a clear comparison/control group • Methods that do not utilize comparison/control groups (e.g. life cycle assessment)
Outcomes	<p>Outcomes measured at any reasonable time after the onset of intervention following the coastal and terrestrial water-sector interventions leading to changes in final outcomes (adaptive capacity, mitigation co-benefits and trade-offs and CPR governance processes) and secondary outcomes (shocks and stresses, identification and response to possible future impacts and CPR governance processes) and process/implementation outcomes. See Table 2 for more details.</p>	<p>Studies reporting process/implementation outcomes only:</p> <ul style="list-style-type: none"> • Uptake - Human systems <ul style="list-style-type: none"> – Know of intervention – Acceptability of intervention – Feasibility of interventions – Adoption of interventions – Change in knowledge – Change attitudes – Intention to change behaviour/practice
Study design	<p>Impact evaluations (experimental, quasi-experimental). For example:</p> <ul style="list-style-type: none"> • Randomized controlled trials • Difference-in-differences design • Regression discontinuity design 	Non-counterfactual impact evaluation designs

INCLUDED	INCLUSION DESCRIPTION	EXCLUDED
	<ul style="list-style-type: none"> Instrumental variable design Propensity score matching designs 	

B. INCLUSION AND EXCLUSION CRITERIA FOR THE SYSTEMATIC REVIEW IN ANNEX I COUNTRIES

INCLUDED	INCLUSION DESCRIPTION	EXCLUDED
Population	<p>Studies that focus on the selected coastal and terrestrial water-sector interventions in:</p> <ul style="list-style-type: none"> Annex I countries Annex I and non-Annex I countries (jointly) if analyses distinguish effects across the two samples English-language literature <p>Publication date: 2000 onwards</p>	<ul style="list-style-type: none"> Non-Annex I countries Combination of both non-Annex I and Annex I countries if analyses do not distinguish the two samples Studies published before the year 2000
Interventions	<ul style="list-style-type: none"> Deliberate coastal and terrestrial water-sector interventions that seek to improve adaptive capacity to climate risks in the water sector Delivered at any administrative level Administered to any type of beneficiary (e.g. individual, household) by any type of actor (e.g. government, non-governmental organization) <p>These interventions include institutional, such as the development of formal regulatory frameworks to govern the use, management and protection of water resources, establishment of user-based organizations to manage common pool resources (e.g. farmers' water user associations, catchment management institutions etc.), planning and modelling of water resource systems to guide their development and operation, smart decision support systems, water user associations</p>	<ul style="list-style-type: none"> Intervention not in the coastal and terrestrial water sector Water interventions for consumption and/or health, including interventions in the WASH sector Nature-based options, built infrastructure, technological options, informational/educational schemes, financial market mechanisms, social/behavioural and coastal interventions
Comparator	<p>Studies that identify a comparison/control group</p>	<ul style="list-style-type: none"> Descriptive/predictive analyses without a clear comparison/control group Methods that do not utilize comparison/control groups (e.g. life cycle assessment)
Outcomes	<p>Outcomes measured at a reasonable time after the onset of intervention following the coastal and terrestrial water-sector interventions leading to changes in final outcomes (adaptive capacity,</p>	<p>Studies reporting process/implementation outcomes</p>

INCLUDED	INCLUSION DESCRIPTION	EXCLUDED
	<p>mitigation co-benefits and trade-offs and CPR governance processes), secondary outcomes (shocks and stresses, identification and response to possible future impacts and CPR governance processes), and process/implementation outcomes. See Table 2 for more details.</p>	<p>only:</p> <ul style="list-style-type: none"> • Uptake - Human systems <ul style="list-style-type: none"> – Know of intervention – Acceptability of intervention – Feasibility of interventions – Adoption of interventions – Change in knowledge – Change attitudes – Intention to change behaviour/practice
<p>Study design</p>	<p>Impact evaluations (experimental, quasi-experimental). For example:</p> <ul style="list-style-type: none"> • Randomized controlled trials • Difference-in-differences design • Regression discontinuity design • Instrumental variable design • Propensity score matching designs 	<p>Non-counterfactual impact evaluation designs</p>

Appendix 2. SEARCH TERMS

A. COUNTRY TERMS

1. NON-ANNEX I COUNTRIES (P1)

Africa OR Asia OR Caribbean OR “West Indies” OR “South America” OR “Latin America” OR “Central America” OR Afghanistan OR Albania OR Algeria OR Angola OR Antigua OR Barbuda OR Argentina OR Armenia OR Azerbaijan OR Bahamas OR Bahrain OR Bangladesh OR Barbados OR Benin OR Belize OR Bhutan OR Bolivia OR Bosnia OR Herzegovina OR Hercegovina OR Botswana OR Brasil OR Brazil OR Darussalam OR “Burkina Faso” OR “Burkina Fasso” OR “Upper Volta” OR Burundi OR Urundi OR Cambodia OR “Khmer Republic” OR Kampuchea OR Cameroon OR Camerouns OR Cameron OR Camerons OR “Cabo Verde” OR “Cape Verde” OR “Central African Republic” OR CAR OR Chad OR Chile OR China OR Colombia OR Comoros OR “Comoro Islands” OR Comores OR “Cook Islands” OR Congo OR Zaire OR “Costa Rica” OR “Cote d’Ivoire” OR “Ivory Coast” OR Croatia OR Cuba OR Cyprus OR Czechoslovakia OR “Czech Republic” OR Slovakia OR “Slovak Republic” OR Djibouti OR “French Somaliland” OR Dominica OR “Dominican Republic” OR “East Timor” OR “East Timur” OR “Timor Leste” OR Eswatini OR Ecuador OR Egypt OR “United Arab Republic” OR “El Salvador” OR Eritrea OR Estonia OR Ethiopia OR Fiji OR Gabon OR “Gabonese Republic” OR Gambia OR Georgia OR Ghana OR “Gold Coast” OR Greece OR Grenada OR Guatemala OR Guinea OR Haiti OR Honduras OR India OR Maldives OR Indonesia OR Iran OR Iraq OR Israel OR Jamaica OR Jordan OR Kazakhstan OR Kazakh OR Kenya OR Kiribati OR Korea OR Kosovo OR Kyrgyzstan OR Kirghizia OR “Kyrgyz Republic” OR Kirghiz OR Kirgizstan OR “Lao PDR” OR Laos OR Latvia OR Lebanon OR Lesotho OR Basutoland OR Liberia OR Libya OR Macedonia OR Madagascar OR “Malagasy Republic” OR Malaysia OR Malaya OR Malay OR Maldives OR Malawi OR Nyasaland OR Mali OR Mauritania OR Mauritius OR Mexico OR Micronesia OR “Middle East” OR Moldova OR Moldovia OR Mongolia OR Montenegro OR Morocco OR Mozambique OR Mocambique OR Myanmar OR Myanma OR Burma OR Namibia OR Nauru OR Nepal OR Nicaragua OR Niger OR Nigeria OR “Northern Mariana Islands” OR Niue OR Oman OR Pakistan OR Palau OR Palestine OR Panama OR Paraguay OR Peru OR Philippines OR Philipines OR Phillipines OR Phillippines OR “Puerto Rico” OR Romania OR Rumania OR Roumania OR Rwanda OR Ruanda OR “Saint Kitts” OR “St Kitts” OR Nevis OR “Saint Lucia” OR “St Lucia” OR “Saint Vincent” OR “St Vincent” OR Grenadines OR Samoa OR “Samoan Islands” OR “Sao Tome” OR Principe OR “Saudi Arabia” OR Senegal OR Serbia OR Montenegro OR Seychelles OR “Sierra Leone” OR Slovenia OR “Sri Lanka” OR Singapore OR “Solomon Islands” OR Somalia OR Sudan OR Suriname OR Surinam OR Swaziland OR Syria* OR Tajikistan OR Tadjhikistan OR Tadjikistan OR Tadjhik OR Tanzania OR Thailand OR Togo OR “Togolese Republic” OR Tonga OR Trinidad OR Tobago OR Tunisia OR Turkey OR Turkmenistan OR Turkmen OR Tuvalu OR Uganda OR Ukraine OR “United Arab Emirates” OR UAE OR Uruguay OR Uzbekistan OR Uzbek OR Vanuatu OR “New Hebrides” OR Venezuela OR Vietnam OR “Viet Nam” OR “West Bank” OR Yemen OR Zambia OR Zimbabwe OR “developing country” OR “developing countries” OR “developing nation” OR “developing nations” OR “developing world” OR “less-developed countr*” OR “less developed countr*” OR “less-developed world” OR “less-developed world” OR “lesser-developed countr*” OR “lesser developed countr*” OR “lesser-developed nation” OR “lesser developed nation*” OR “lesser developed world” OR “lesser-developed world” OR “under-developed countr*” OR “under developed countr*” OR “under-developed nation*” OR “under developed nation*” OR

“under-developed world” OR “underdeveloped world” OR “under developed world” OR
“underdeveloped countr*” OR “under-developed countr*” OR “Under developed countr*” OR
“under developed nation*” OR “under-developed nation*” OR “underdeveloped nation*” OR
“lower middle income countr*” OR “lower middle-income countr*” OR “lower middle income
nation*” OR “lower middle-income nation*” OR “upper middle-income countr*” OR “upper middle
income countr*” OR “upper middle-income nation*” OR “upper middle income nation*” OR “low-
income countr*” OR “low income countr*” OR “low-income nation*” OR “low income nation*”
OR “lower income countr*” OR “lower-income countr*” OR “lower income nation*” OR “lower-
income nation*” OR “Low- and Middle- Income countr*” OR “Low and Middle Income Countr*”
OR “underserved country” OR “underserved countries” OR “underserved nation” OR “underserved
nations” OR “underserved world” OR “under served country” OR “under served countries” OR
“under served nation” OR “under served nations” OR “under served world” OR “deprived country”
OR “deprived countries” OR “deprived nation” OR “deprived nations” OR “deprived world” OR
“poor country” OR “poor countries” OR “poor nation” OR “poor nations” OR “poor world” OR
“poorer country” OR “poorer countries” OR “poorer nation” OR “poorer nations” OR “poorer
world” OR “developing economy” OR “developing economies” OR “less developed economy” OR
“less developed economies” OR “lesser developed economy” OR “lesser developed economies” OR
“under developed economy” OR “under developed economies” OR “underdeveloped economy” OR
“underdeveloped economies” OR “middle income economy” OR “middle income economies” OR
“low income economy” OR “low income economies” OR “lower income economy” OR “lower
income economies” OR lmic OR lmic OR “third world” OR “lami country” OR “lami countries”
OR “transitional country” OR “transitional countries” LMIC OR LMICs OR LIC OR LICs OR
UMICs OR UMIC OR (“khmer” AND “republic”) OR (“cape” AND “verde”) OR (“central” AND
“african” AND “republic”)

2. ANNEX I COUNTRIES (P2)

Andorra OR “Antigua and Barbuda” OR Aruba OR Australia OR Austria OR Bahamas OR Bahrain
OR Barbados OR Belgium OR Bermuda OR “British Virgin Islands” OR “Brunei Darussalam” OR
Canada OR “Cayman Islands” OR “Channel Islands” OR Chile OR Croatia OR Curacao OR Cyprus
OR Czechia OR Denmark OR Estonia OR “Faroe islands” OR Finland OR France OR “French
Polynesia” OR Germany OR Gibraltar OR Greece OR Greenland OR Guam OR “Hong Kong” OR
Hungary OR Iceland OR Ireland OR “Isle of Man” OR Israel OR Italy OR Japan OR “South Korea”
OR Kuwait OR Latvia OR Liechtenstein OR Lithuania OR Luxembourg OR Macao OR Malta OR
Monaco OR Nauru OR Netherlands OR “New Caledonia” OR “New Zealand” OR “Northern
Mariana Islands” OR Norway OR Oman OR Panama OR Poland OR Portugal OR “Puerto Rico”
OR Qatar OR Romania OR “San Marino” OR “Saudi Arabia” OR “Seychelles” OR Singapore OR
“Sint Maarten” OR “Slovak Republic” OR “Slovenia” OR Spain OR “St. Kitts and Nevis” OR “St.
Martin” OR Sweden OR Switzerland OR Taiwan OR “Trinidad and Tobago” OR “Turks and Caicos
Islands” OR “United Arab Emirates” OR UAE OR “United Kingdom” OR UK OR Britain OR
“United States” OR USA OR Uruguay OR “developed countr*” OR “developed nation*” OR
“developed world” OR “high-developed countr*” OR “high-developed world” OR “high income
countr*” OR “high-income countr*” OR HIC OR “high income nation*” OR “high-income nation*”
OR “wealthy countr*” OR “wealthy nation*” OR “developed econom*” OR “high income
econom*” OR “high-income econom*” OR “high income econom*” OR “high-income econom*”
OR “first world countr*” OR “industrialized countr*” OR “industrialised countr*” OR “Global
North”

B. METHODOLOGY TERMS (S)

“impact stud*” OR “impact evaluation*” OR “comparison stud*” OR “longitudinal analysis*” OR “longitudinal stud*” OR “impact analysis” OR “random* control* trial*” OR “random* trial*” OR “comparison group*” OR “control group*” OR “control* treatment” OR RCT OR “program* evaluation*” OR “experimental control*” OR “comparative analysis” OR “controlled before and after” OR “controlled before after” OR “Quasi-experiment” OR “project apprais*” OR “cluster random* trial*” OR “propensity score matching” OR “PSM” OR “propensity weight*” OR “regression discontinuity design” OR “difference* in difference*” OR “diff in diff” OR “diff-in-diff” OR “control* random* trial*” OR “interrupted time series” OR “random* allocation*” OR “instrumental variable*” QED OR “quasi experiment” OR “experimental group*” OR “control community” OR “intervention commun*” OR “control communities” OR “intervention condition*” OR “control* condition*” OR “control participant*” OR “experimental condition*” OR counterfactual OR “discontinu* design” OR “fixed effect*” OR “double differenc*” OR “panel data” OR “double robust” OR “pipeline approach” OR “pipeline method” OR “pipeline comparison” OR “impact assessment” OR “econometric analys*” OR “cross-sectional data” OR “fixed effect*” OR “heckman*” OR “counterfactual” OR “counter factual” OR “counter-factual” OR “control* evaluation” OR “randomized field” OR “randomised field”

C. INTERVENTION TERMS

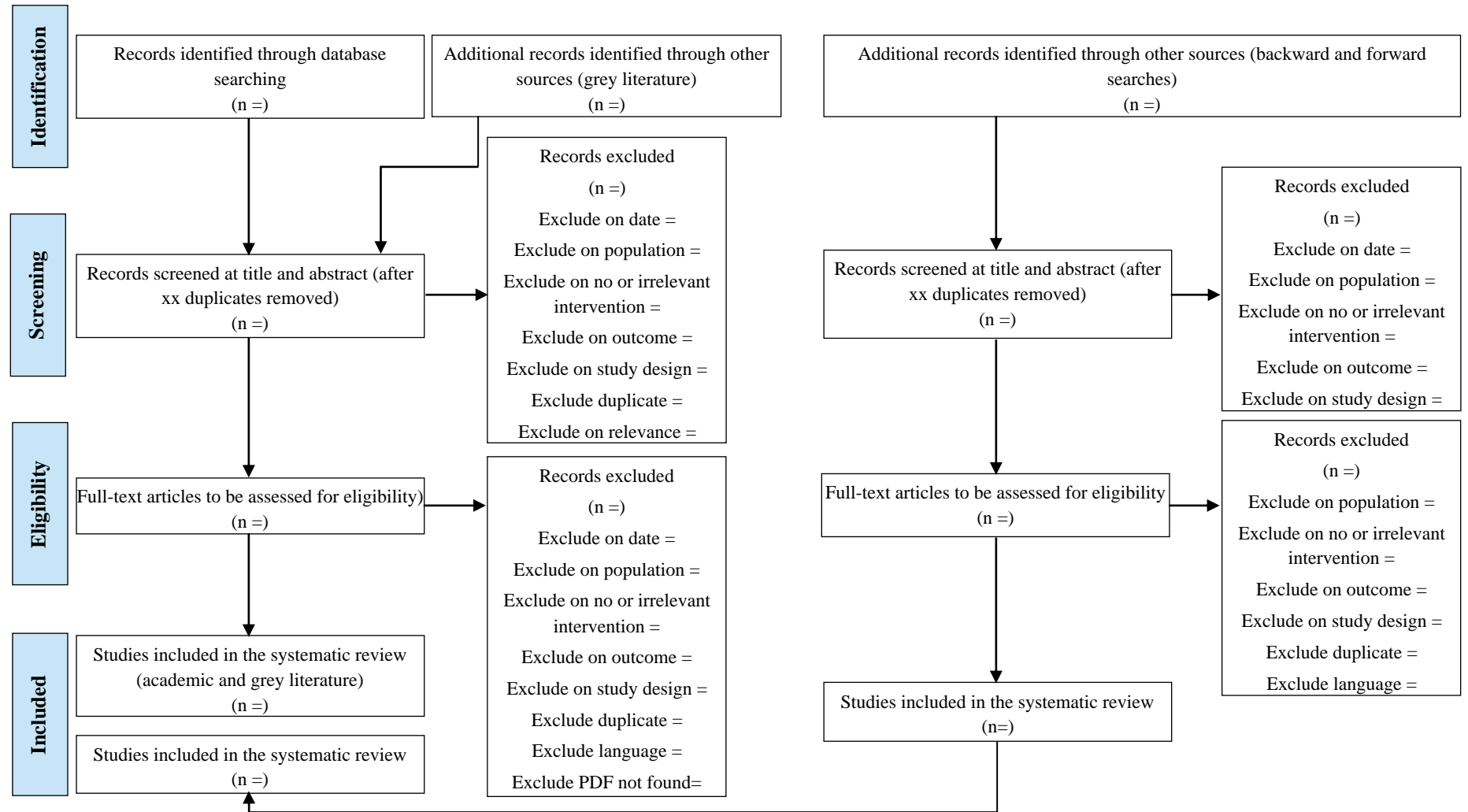
1. NON-ANNEX I COUNTRIES (IN1)

“nature-based” OR “nature based” OR “ecosystem-based manag*” OR afforestation OR reforestation OR “land erosion” OR “water quality manag*” OR “wastewater treat*” OR “wetland restorat*” OR “watershed manag*” OR “pond-based system*” OR “water quality manag*” OR dam* OR “desalination technolog*” OR “water transport system*” OR “pipe system*” OR “lined canal*” OR “sprinkler system*” OR “drip system*” OR “rainwater harves*” OR “underground water storage*” OR “artificial surface treatment*” OR “plastic sheeting” OR “ICT technolog*” OR “smart water meter*” OR “smart decision support system*” OR DSS OR “water conservation educati*” OR “early-warning system*” OR “disaster risk reduction” OR “water manag*” OR “water resource* plan*” OR “water resource* model*” OR “water partnership*” OR “water coalition*” OR “water train*” OR “water govern*” OR “water regul*” OR “water institution*” OR “common pool resource*” OR CPR OR “water association*” OR “catchment manag*” OR “stochastic plan*” OR “water model*” OR “Payment for ecosystem service*” OR PES OR “flood* insurance” OR “water payment scheme*” OR “behavioural approach*” OR nudge OR flood* OR drought* OR “water allocation plan*” OR “water user association*” OR “mangrove rehabilitation” OR “mangrove expansion” OR “estuar* manag*” OR “estuary* protection” OR “salt-water intrusion*” OR “coastal protect*” OR “coastal restor*”

2. ANNEX I COUNTRIES (IN2)

“water govern*” OR “water regul*” OR “water partnership*” OR “water coalition*” OR “Smart decision support system*” OR DSS OR “water train*” OR “water govern*” OR “water institution*” OR “common pool resource*” OR “water association*” OR “catchment manag*” OR “stochastic plan*” OR “water mode

Appendix 3. PRISMA DIAGRAM (PREFERRED REPORTING ITEMS FOR SYSTEMATIC REVIEWS AND META-ANALYSES)



Appendix 4. DATA EXTRACTION TOOL

DESCRIPTION	QUESTION
Date when the form was completed	Date when the form was completed
ID of the person extracting data	ID of the person extracting data
Report identification	
Publication title	Title of publication
Publication ID	EPPI ID
Author details	Surname of first author
Publication date	Year (letter - if more than one study from that author and that year)
Publication type	What is the impact evaluation publication type? <input type="checkbox"/> Academic journal article <input type="checkbox"/> Research report <input type="checkbox"/> Government report <input type="checkbox"/> Dissertation/thesis <input type="checkbox"/> Online book chapter
Funding agency name	Who is funding the evaluation/study? Please add the name of the agency funding the evaluation.
Funding agency type	Type of agency funding the evaluation/study: <input type="checkbox"/> Academic institution <input type="checkbox"/> Charitable or private foundation <input type="checkbox"/> For-profit firm <input type="checkbox"/> Government agency <input type="checkbox"/> International aid agency <input type="checkbox"/> International financial institution <input type="checkbox"/> Non-profit organization <input type="checkbox"/> Not specified
Independence of evaluation	What level of independence is there between the implementing agency and study team? <input type="checkbox"/> Funding and author team independent of implementers/funders of programme <input type="checkbox"/> Funding independent of implementers/funders of programme, but includes authors from funder/implementer <input type="checkbox"/> Evaluation funded and undertaken by funders/implementers <input type="checkbox"/> Unclear
Independent data collection	Has an independent party collected the data? <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not clear
Conflict of interest	Is there a potential conflict of interest associated with the study which could influence the collected/reported results? (e.g. Is there a declaration of conflict

DESCRIPTION	QUESTION
	<p>of interest? Are any of the authors connected in any way to the funding or implementing institution?)</p> <p><input type="checkbox"/> Yes</p> <p><input type="checkbox"/> No</p> <p><input type="checkbox"/> Not clear</p>
Comments on conflict of interest	If yes, please add a reason for your answer to whether there is a conflict of interest.
Language of publication	Language of publication of the impact evaluation (e.g. Spanish, English etc.)
Other methods	If the impact evaluation addresses questions other than effectiveness, note the questions and methods used here.
Linked studies	If there is any study linked to this one, add the reference.
Context	
Country	List countries the study was conducted in.
Detailed location	If provided, give detailed information on where the study occurred within a country (e.g. regions/districts covered).
World Bank region	Select region(s) the study was conducted according to the World Bank. For more information regarding the region classification, see http://data.worldbank.org/country .
World Bank Income category	Select the World Bank income classification of the country at the time of the study.
Sector	<p>Choose sector options below:</p> <p><input type="checkbox"/> Agriculture</p> <p><input type="checkbox"/> Education</p> <p><input type="checkbox"/> Energy and extractives</p> <p><input type="checkbox"/> Forestry</p> <p><input type="checkbox"/> Financial</p> <p><input type="checkbox"/> Industry and trade/services</p> <p><input type="checkbox"/> Information and communication</p> <p><input type="checkbox"/> Public administration</p> <p><input type="checkbox"/> Transportation</p> <p><input type="checkbox"/> Environmental and disaster management</p>
Intervention information	
Programme or project name	State the programme or project name. If there is no name, list the location.
Study design	<p>Select the type of study:</p> <p><input type="checkbox"/> Randomized controlled trial</p> <p><input type="checkbox"/> Regression discontinuity</p> <p><input type="checkbox"/> Matching/Propensity Score Matching (PSM)</p> <p><input type="checkbox"/> Instrumental variable/2SLS</p> <p><input type="checkbox"/> Difference in Difference</p> <p><input type="checkbox"/> Interrupted time series analysis</p> <p><input type="checkbox"/> Controlled before and after</p> <p><input type="checkbox"/> Heckman</p>

DESCRIPTION	QUESTION
	<input type="checkbox"/> Fixed effects or random effects estimation <input type="checkbox"/> Natural experiment
Estimation methods	Brief description of the estimation methods.
Commentary on methods (if multiple methods are selected)	State here if multiple methods are selected.
Multicomponent intervention	<p>Is more than one intervention subcode applied to this intervention?</p> <ul style="list-style-type: none"> • If yes, go to question 2. • If no, code as “No”. <p>Is each intervention subcode evaluated independently (i.e. separate effect sizes estimated for each intervention subcomponent, e.g. 2x2 design, separate evaluations reported in one study)?</p> <ul style="list-style-type: none"> • If yes, code as “Multiple components, but evaluated separately”. • If no, code as “Multiple components, not evaluated separately”. <input type="checkbox"/> Multiple components, but evaluated separately <input type="checkbox"/> Multiple components, not evaluated separately <input type="checkbox"/> No
Number of treatment arms	State the number of treatment arms.
Treatment ID	<p>Please create an ID for each treatment of the intervention. ‘Treatment’ is defined here by ‘treatment arms’ (i.e. the combination of intervention components received by an arm of the evaluation).</p> <p>For example, in a case where there are three (3) intervention components A, B, and C, with two (2) treatment arms A+B and A+C, this would be coded on separate rows as:</p> <p>Treatment 1 Component A Treatment 1 Component B Treatment 2 Component A Treatment 2 Component C</p> <p>In cases where the intervention is the same (e.g. A+B and A+B), but the delivery mechanism is different (e.g. by community elders vs. by teachers), code as separate treatments.</p> <p>When a study does not have a ‘pure control’, in which the comparison arm receives some intervention component, that comparison is coded as another treatment arm, even if that arm measures no outcomes as a treatment.</p>
Component ID	<p>Please create a component ID for each component of the intervention.</p> <p>Component IDs need to be consistent across treatments. For example, if a component is repeated across treatments, it should have the same component ID.</p> <p>For example, in a case where there are three (3) intervention components A, B, and C, with two (2) treatment arms A+B and A+C, this would be coded on separate rows as:</p> <p>Treatment 1 Component A Treatment 1 Component B Treatment 2 Component A Treatment 2 Component C</p> <p>Component IDs should be captured alphabetically.</p>

DESCRIPTION	QUESTION
Intervention type	Select the intervention type: <input type="checkbox"/> Nature-based solutions <input type="checkbox"/> Built infrastructure <input type="checkbox"/> Technological options <input type="checkbox"/> Informational/educational schemes <input type="checkbox"/> Institutional <input type="checkbox"/> Financial market mechanisms <input type="checkbox"/> Social/behavioural <input type="checkbox"/> Coastal interventions
Other (add new if it does not fit existing categories)	If you are certain the intervention does not fit within any of the previously defined classifications of coastal and terrestrial water-sector interventions, code the intervention here, otherwise leave it blank. When developing a name, either use a description from the study or, if unclear, code it as a non-coastal/terrestrial intervention.
Description of intervention(s)	Write a short paragraph to describe the intervention type and characteristics. The description should be as detailed as possible. Add page numbers.
Objectives of intervention	State any objectives stated in the study or other document.
Scale of implementation	At which level was the intervention implemented? <input type="checkbox"/> Individual <input type="checkbox"/> Household <input type="checkbox"/> Firm <input type="checkbox"/> Community <input type="checkbox"/> District/region <input type="checkbox"/> National
What intervention (if any) did the comparison group receive?	<input type="checkbox"/> No treatment <input type="checkbox"/> As usual <input type="checkbox"/> Alternative intervention <input type="checkbox"/> Other <input type="checkbox"/> Unclear
Intervention implementing agency name	Who is implementing the intervention? State the name (and department) of the implementing agency?
Intervention implementing agency type	Type of agency for the implementation of the intervention: <input type="checkbox"/> Academic institution <input type="checkbox"/> Charitable or private foundation <input type="checkbox"/> For-profit firm <input type="checkbox"/> Government agency <input type="checkbox"/> International aid agency <input type="checkbox"/> International financial institution <input type="checkbox"/> Non-profit organization <input type="checkbox"/> Not specified
Intervention funding agency name	Who is funding the intervention? State the name (and department) of the funding agency.

DESCRIPTION	QUESTION
Intervention funding agency type	Type of funding/financial institution for the implementation of the intervention: <input type="checkbox"/> Academic institution <input type="checkbox"/> Charitable or private foundation <input type="checkbox"/> For-profit firm <input type="checkbox"/> Government agency <input type="checkbox"/> International aid agency <input type="checkbox"/> International financial institution <input type="checkbox"/> Non-profit organization <input type="checkbox"/> Not specified
Intervention target group	What were the characteristics of the beneficiaries targeted by the intervention? Were the characteristics of beneficiaries used to target the intervention? Open answer.
Target population gender	Indicate the gender of the targeted population: <input type="checkbox"/> Female <input type="checkbox"/> Male <input type="checkbox"/> Female and male <input type="checkbox"/> Unclear
Target population age	Indicate the population either <input type="checkbox"/> Children <18 <input type="checkbox"/> Young adults (18-35) <input type="checkbox"/> Adults (36-65) <input type="checkbox"/> Elderly (65+) <input type="checkbox"/> Mixed <input type="checkbox"/> Not specified
Target population income	Indicate the target population income <input type="checkbox"/> Low <input type="checkbox"/> Middle <input type="checkbox"/> Diverse <input type="checkbox"/> Not specified
Target population living environment	State the target population's living environment between <input type="checkbox"/> Protected area <input type="checkbox"/> Non-protected area <input type="checkbox"/> Both
Targeting methods	How were beneficiaries targeted for the programme (e.g. how was the targeting implemented)?
Target population-specific restrictions	Please provide details. Please provide details. In some instances, the target population is restricted to exclude population members that are difficult or impossible to interview.
Intervention start	Start date (if not stated, state study date) of intervention.
Intervention end	State end date (if ongoing state ongoing).
Intervention length/exposure to intervention (in months)	Start intervention length (months).

DESCRIPTION	QUESTION
Evaluation period (in months)	The total number of months elapsed between the end of the intervention and the point at which an outcome measure is measured post-intervention or as a follow-up measurement. If less than one month, use decimals (e.g. one week would be 0.25)
Consideration of equity	Does the study consider equity? <input type="checkbox"/> Yes <input type="checkbox"/> No
Equity focus ⁷	How does the study consider equity? <input type="checkbox"/> Intervention targets vulnerable population <input type="checkbox"/> Subgroup analysis by sex <input type="checkbox"/> Subgroup analysis (other than sex) <input type="checkbox"/> Heterogeneity analysis (other than subgroup) <input type="checkbox"/> Equity-sensitive analytical framework <input type="checkbox"/> Equity-sensitive methodology <input type="checkbox"/> Equity-sensitive research process <input type="checkbox"/> Measures effects on an inequality outcome <input type="checkbox"/> Research ethics informed by equity
Equity dimension	What dimension(s) of equity does the study consider? <input type="checkbox"/> Age (e.g. old or young age, but only if it provides arguments) <input type="checkbox"/> Conflict-affected <input type="checkbox"/> Culture (includes language) <input type="checkbox"/> Disability (medical, physical, neurological, mental disorders) <input type="checkbox"/> Education <input type="checkbox"/> Ethnicity <input type="checkbox"/> Head of household (female or male) <input type="checkbox"/> HIV/AIDS (people with or at risk of HIV) <input type="checkbox"/> Land size <input type="checkbox"/> Land ownership <input type="checkbox"/> Place of residence (rural, urban, peri-urban, informal dwellings) <input type="checkbox"/> Refugees <input type="checkbox"/> Religion <input type="checkbox"/> Socioeconomic status (income or poverty status) <input type="checkbox"/> Social capital <input type="checkbox"/> Sex (includes the use of the term gender meaning the biological sex of a person) <input type="checkbox"/> Sexual orientation <input type="checkbox"/> Sexual identity <input type="checkbox"/> Other (vulnerable groups not typified by any of the above). Answers might include orphans, sex workers, survivors of sexual violence etc. <input type="checkbox"/> Not applicable
Process and implementation	

DESCRIPTION	QUESTION
Information about programme take-up	<p>Is there any information about programme take-up? Take-up refers to participation in a programme among those who are eligible.</p> <p>Commentary by authors should be used when information on programme take up etc., is not supported by some form of research/when the authors do not report that/how they collected data to assess these areas.</p> <p><input type="checkbox"/> Yes, commentary from author</p> <p><input type="checkbox"/> Yes, formally assessed</p> <p><input type="checkbox"/> No</p>
Methods of assessing take-up	<p>Which methods are used to assess programme take-up?</p> <p><input type="checkbox"/> Observation by intervention staff</p> <p><input type="checkbox"/> Reporting by participants</p> <p><input type="checkbox"/> Other</p> <p><input type="checkbox"/> Commentary from author</p> <p><input type="checkbox"/> Not measured</p>
Results of the take-up assessment	<p>What is the result/information provided for the programme take-up assessment?</p> <p>Open answer.</p>
Information about programme adherence (among beneficiaries)	<p>Is there any information about programme adherence (how well the participants stuck to the programme requirements) among beneficiaries?</p> <p>Commentary by authors should be used when some form of research does not back up information on programme adherence etc., or when the authors do not report that/how they collected data to assess these areas.</p> <p><input type="checkbox"/> Yes, commentary from author</p> <p><input type="checkbox"/> Yes, formally assessed</p> <p><input type="checkbox"/> No</p>
Methods of assessing adherence	<p>Which methods are used to assess programme adherence for beneficiaries? This includes dropout rates and adherence to appointments, etc.</p> <p><input type="checkbox"/> Observation by intervention staff</p> <p><input type="checkbox"/> Reporting by participants</p> <p><input type="checkbox"/> Other</p> <p><input type="checkbox"/> Commentary from author</p> <p><input type="checkbox"/> Not measured</p>
Results of the adherence assessment	<p>What is the result/information provided of the assessment of programme adherence?</p> <p>Open answer.</p>
Information about implementation fidelity/intervention delivery quality (among implementers)	<p>Is there any information on implementation fidelity and intervention delivery quality?</p> <p>Commentary by authors should be used when information on programme adherence etc., is not backed up by some form of research/when the authors do not report that/how they collected data to assess these areas.</p> <p><input type="checkbox"/> Yes, commentary from author</p> <p><input type="checkbox"/> Yes, formally assessed</p> <p><input type="checkbox"/> No</p>

DESCRIPTION	QUESTION
Methods of assessing intervention fidelity	Which methods are used to assess implementation fidelity/intervention delivery quality by the implementing partner: <input type="checkbox"/> Observation by intervention staff <input type="checkbox"/> Reporting by participants <input type="checkbox"/> Other <input type="checkbox"/> Commentary from author <input type="checkbox"/> Not measured
Results of the intervention fidelity assessment	What is the result/information derived from assessing implementation fidelity/intervention delivery quality? Open answer.
Incentives	Were incentives provided to intervention participants? <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Not clear
Other descriptions of process/implementation factors	Any other description of process/implementation factors not covered above Open answer.
Results: barriers and facilitators	Report here any material relevant to causal mechanisms and barriers and enablers. Open answer.
Cost	Are any unit cost data/cost-effectiveness estimates provided? <input type="checkbox"/> Return on investment analysis <input type="checkbox"/> Cost-effectiveness <input type="checkbox"/> Cost-benefit <input type="checkbox"/> Cost only <input type="checkbox"/> No cost data
Cost details	If yes, report any unit cost details and/or total cost. Please also report the year and currency.
External validity	
Length of study	Length of study in months (Where study length is not reported, code as length of intervention and include a note in brackets) Number of months, if not reported N/A.
Efficacy or effectiveness trial	Was the intervention implemented under “real world” conditions? By real world we mean a programme implemented independently of the evaluation, either by a government, non-governmental organization, or international agency <input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> N/A

DESCRIPTION	QUESTION
Personnel implementing the programme	Who was in charge of implementing the programme? <input type="checkbox"/> PI/researchers (study authors) <input type="checkbox"/> Implementing agency staff <input type="checkbox"/> External agency (e.g. survey firm) <input type="checkbox"/> Others <input type="checkbox"/> Not clear
Author discussion of external validity	Do the authors discuss or explicitly address generalizability/applicability? <input type="checkbox"/> Yes <input type="checkbox"/> No
Outcome information	
Outcome type	Select the outcome type: Process/implementation outcomes <input type="checkbox"/> Uptake – Human systems Secondary outcomes <input type="checkbox"/> Shocks and stresses – Human and natural systems <input type="checkbox"/> Identification and response to possible future impacts – Human systems <input type="checkbox"/> CPR governance processes – Human systems Final outcomes <input type="checkbox"/> Adaptive capacity – Human and natural systems <input type="checkbox"/> Mitigation co-benefits and trade-offs <input type="checkbox"/> CPR governance impacts – Human systems
Outcome indicator description	Extract the exact name of the indicator used as the dependent variable in the analysis. Use this open answer field to enter, in the author’s own words, a description of the outcome in a sentence or so. Be selective and concise with the excerpts transcribed to ensure accurate and precise descriptions of the outcome. Include page numbers with every excerpt extracted.
Outcome timing	<input type="checkbox"/> Less than 1 year <input type="checkbox"/> 1 to 3 years <input type="checkbox"/> More than 3 years <input type="checkbox"/> Not clear
Timing of outcome measurement	<input type="checkbox"/> Only after <input type="checkbox"/> Before and after <input type="checkbox"/> Not clear
Unintended outcomes	State any unintended outcomes highlighted in the study.
Effective size calculations	
Treatment ID	Indicate the relevant treatment ID linked to the relevant effect size.
Outcome type	Select the outcome used to extract effect size data.
Post-intervention or change from baseline?	<input type="checkbox"/> Post-intervention <input type="checkbox"/> Change from baseline

DESCRIPTION	QUESTION
Nature of the measures/estimate type	Type of data for this effect size: <input type="checkbox"/> Continuous <input type="checkbox"/> Dichotomous outcome - proportions <input type="checkbox"/> Hand calculated data <input type="checkbox"/> Regression data
Direction of the effect	<input type="checkbox"/> Effect favours treatment <input type="checkbox"/> Effect favours comparison <input type="checkbox"/> Zero effect <input type="checkbox"/> Unclear
Reverse sign (i.e., decrease is good)	Record no if an increase is good, record yes if a decrease is good and the sign needs to be reversed. <input type="checkbox"/> Yes <input type="checkbox"/> No
Unit of analysis	<input type="checkbox"/> Individual <input type="checkbox"/> Household <input type="checkbox"/> Firm <input type="checkbox"/> Community <input type="checkbox"/> District/region <input type="checkbox"/> Unclear
When measuring this outcome, were there any differences between the treatment group participants and the comparison?	<input type="checkbox"/> Yes <input type="checkbox"/> No
Effect is statistically significant?	<input type="checkbox"/> Yes <input type="checkbox"/> No <input type="checkbox"/> Unclear
Treatment sample size	Insert treatment sample size here.
Control sample size	Insert control sample size here.
Subgroup	Is this analysis of a subgroup? <input type="checkbox"/> Yes <input type="checkbox"/> No
If yes to subgroup, describe the subgroup if applicable	Free text, describe the subgroup if applicable (e.g. boys, girls).
Source	Which page(s) contain the effect size data? Note the page number, table number, column, and row used to extract the data.
The following group of questions only applies if the Nature of the Measures is “Continuous”	
Treatment group mean	Insert numerical value.
Comparison group mean	Insert numerical value.
Are the means reported above adjusted?	<input type="checkbox"/> Yes <input type="checkbox"/> No

DESCRIPTION	QUESTION
Treatment group standard deviation	Insert numerical value.
Comparison group standard deviation	Insert numerical value.
Treatment group standard error	Insert numerical value.
Comparison group standard error	Insert numerical value.
t-value from an independent t-test	Insert numerical value.
The following group of questions only applies if the Nature of the Measures is “Dichotomous”	
Treatment group number of participants who experienced a change	Insert numerical value.
Comparison group number of participants who experienced a change	Insert numerical value.
Treatment group proportion of participants who experienced a change	Insert numerical value.
Comparison group proportion of participants who experienced a change	Insert numerical value.
Are the proportions above adjusted for pre-test variables?	<input type="checkbox"/> Yes <input type="checkbox"/> No
Logged odds ratio	Insert numerical value.
Standard error of logged odds ratio	Insert numerical value.
Logged odds ratio adjusted?	<input type="checkbox"/> Yes <input type="checkbox"/> No
Chi-square with df=1 (2 by 2 contingency table)	Insert numerical value.
Correlation coefficient	Insert numerical value.
The following group of questions only applies if nature of the measures is “Hand Calculated Data”	
Hand calculated d-type effect size	Insert numerical value.
Hand calculated error of the d-type effect size	Insert numerical value.
Hand calculated oddsratio effect size	Insert numerical value.
Hand calculated oddsratio standard error	Insert numerical value.

DESCRIPTION	QUESTION
Intermediate outcomes or themes (knowledge, skills)	State intermediate outcomes or themes here.
Questions applying to all studies	
Are there results coming from regressions?	<input type="checkbox"/> Yes <input type="checkbox"/> No
Sample size	Insert sample size here.
The following group of questions only applies if results are coming from regressions	
Method: Econometric model?	State the econometric model
Standard deviation effect	Insert numerical value.
Effect (mean)	Insert numerical value.
Controls	Insert numerical value.
Standard deviation: Y	Insert numerical value.
Standard deviation: X	Insert numerical value.
β (beta)	Insert numerical value.
Standard error β (beta)	Insert numerical value.
Degrees of freedom	Insert numerical value.
Data type	<input type="checkbox"/> Panel <input type="checkbox"/> Cross-section <input type="checkbox"/> Time series

Appendix 5. CRITICAL APPRAISAL TOOL

METHODOLOGICAL APPRAISAL CRITERIA				RESPONSE		
				Yes	No	Comment
(If randomized control trial, start after confounding bias. For all other study designs, start here.)						
I. Bias in the selection of participants for the study						
<i>Are participants selected in a way that minimizes selection bias?¹⁸</i>						
Appraisal indicators						
Consider whether:						
1) <i>There is an adequate description of how and why the sample was chosen (i.e., identified/selected/recruited).</i>						
2) <i>There is an adequate sample size to allow for representative and/or statically significant conclusions.</i>						
3) <i>Participants in the control¹⁹ group were sampled from the same population as that of the treatment.</i>						
4) <i>The group allocation process minimized the potential risk of bias (e.g., using computer algorithms).</i>						
5) <i>The selection of participants for the study (or the analysis) is based on participant characteristics observed after the start of the intervention.</i>						
Low risk of bias	Moderate risk of bias	High risk of bias	Critical risk of bias	Worth continuing? Y/N		
II. Bias due to confounding						
<i>Is confounding potentially controllable in the context of this study?</i>						
Appraisal indicators						
Consider whether:						
1) <i>There is potential for confounding the effect of the intervention in this study. If yes, provide examples of confounding domains in the comment box.²⁰</i>						
2) <i>Where matching was applied and, if so, whether it featured sufficient criteria.²¹</i>						
3) <i>Where relevant, the authors conducted an appropriate analysis that is controlled for all potential/remaining critical confounding domains after matching had been applied.</i>						

¹⁸ Selection bias can occur both in the way that individuals are accepted for participation in a study and in the way that 'treatment' is assigned to individuals once they have been accepted into a study. This section deals with both these understandings of selection bias.

¹⁹ The terms 'control' and 'comparison' group refer to any group with the treatment of interest is compared and is presumed to represent conditions in the absence of that treatment, whether it is true random or not.

²⁰ Confounding domains are those for which, in the context of this study, adjustment is expected to lead to an important change in the estimated effect of the intervention.

²¹ Matching can be done on the calculated propensity score or covariates. If the latter, it should ideally be done on the pre-test measures and other characteristics, such as demographic. Answer 'no' if the study only matched on pre-test measures of some or all variables used later as outcome measures or matched only on end line characteristics.

METHODOLOGICAL APPRAISAL CRITERIA				RESPONSE
4) <i>The authors avoided adjusting for variables identified after the intervention has been administered.</i>				
5) <i>The treatment and control group are comparable after matching/controls have been completed. Select one of the following:</i>				
<input type="checkbox"/> <i>No statically significant differences</i>				
<input type="checkbox"/> <i>Statistically significance difference</i>				
<input type="checkbox"/> <i>Negligible descriptive differences</i>				
<input type="checkbox"/> <i>Significant descriptive differences</i>				
Low risk of bias	Moderate risk of bias	High risk of bias	Critical risk of bias	Worth continuing? Y/N?

(If randomized control trial, skip I + II (above) and start here.)

III. Bias due to confounding (because of ineffective randomization)

Is the allocation of treatment status truly random?

Appraisal indicators

Consider whether:

1) *Eligibility criteria for study entry are specified.*

2) *There is a clear description of the randomization process and whether the methods are robust.*

3) *The unit of randomization and number of participants is clearly stated (pay special attention to treatment and control locations/balance).*

4) *Characteristics of both baseline and end line samples are provided, and the treatment and control groups are comparable at the end line. Select one of the following:*

No statically significant differences

Statistically significance difference

Negligible descriptive differences

Significant descriptive differences

Low risk of bias	Moderate risk of bias	High risk of bias	Critical risk of bias	If critical risk of bias, treat as non-random study
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IV. Bias due to departures from intended interventions

Was the intervention implemented as laid out in the study protocol?

Appraisal indicators

Consider whether:

1) *The critical co-interventions were balanced across intervention and control groups.*

2) *Treatment switches were low enough not to threaten the validity of the estimated effect of the intervention.*

3) *Implementation failure was minor and unlikely to threaten the validity of the estimated effect of the intervention.*

METHODOLOGICAL APPRAISAL CRITERIA				RESPONSE
4)	<i>It is possible that the intervention was taken by the controls (contamination and possible crossing-over).²²</i>			
5)	<i>It is possible that knowledge of group allocation affects how the two study groups are treated during the delivery and evaluation of the intervention.²³</i>			
Low risk of bias	Moderate risk of bias	High risk of bias	Critical risk of bias	Worth continuing? Y/N

V. Bias due to missing/incomplete data (attrition)

Are the intervention and control groups free of critical differences in participants with missing/incomplete data?

Appraisal indicators

Consider whether:

1)	<i>Outcome data are reasonably complete (80% or above).²⁴</i>			
2)	<i>If the level of attrition (or other forms of missing/incomplete data) is more than 20%, are the reasons for the missing data reported?</i>			
3)	<i>If the level of attrition (or other forms of missing/incomplete data) is more than 20%, do the authors demonstrate the similarity between remaining participants and those lost to attrition and are the proportion of participants with missing/incomplete data and reasons for missing/incomplete data similar across groups?</i>			
4)	<i>If the level of attrition (or other forms of missing/incomplete data) is more than 20%, were appropriate statistical methods used to account for missing data? (e.g. sensitivity analysis)²⁵</i>			
5)	<i>If it is impossible to control for missing/incomplete data, are outcomes with missing/incomplete data excluded from the analysis?</i>			
Low risk of bias	Moderate risk of bias	High risk of bias	Critical risk of bias	Worth continuing? Y/N

VI. Bias in measuring of outcomes

Are measurements appropriate, e.g., clear origin or validity known?

Appraisal indicators

Consider whether:

1)	<i>There was an adequate period for follow-up.²⁶</i>			
2)	<i>The outcome measure (e.g., employment status, income) was clearly defined and objective.²⁷</i>			

²² Whilst challenging in terms of estimating impact, spill overs might be an important finding.

²³ Consider only in extreme cases in which preferential treatment is evident; blinding is generally not expected in social interventions.

²⁴ The assumption here that the level of attrition (or other forms of missing/incomplete data) is sufficiently low to not require adjustment.

²⁵ Select 'no' if the study addresses missing/incomplete data through simple estimates of missing data and observations.

²⁶ In many social science interventions, follow-up is not required to coincide with the start of the treatment; further, longer periods of follow-up are often required to measure changes.

²⁷ Subjective measures (e.g. those based on self-report) are likely to have lower reliability and validity than objective measures.

METHODOLOGICAL APPRAISAL CRITERIA				RESPONSE
3) <i>Outcomes were assessed using standardized instruments and indicators.</i>				
4) <i>Outcome measurements reflect what the experiment set out to measure.</i>				
5) <i>The methods of outcome assessment were comparable across groups.</i>				
6) <i>Were outcome assessors aware of the intervention received by study participants?</i> ²⁸				
Low risk of bias	Moderate risk of bias	High risk of bias	Critical risk of bias	Worth continuing? Y/N

VII. Bias in the selection of results reported

Are the reported outcomes consistent with the proposed outcomes at the protocol stage?

Appraisal indicators

Consider whether:

1) <i>It is unlikely that the reported effect estimate has been selected for publication because it is a particularly notable finding among numerous exploratory analyses.</i>				
2) <i>It is unlikely that the reported effect estimate is prone to selective reporting from among multiple outcome measurements within the outcome domain.</i>				
3) <i>It is unlikely that the reported effect estimate is prone to selective reporting from among multiple analyses of the outcome measurements, including subgroup analysis.</i>				
4) <i>If subgroup/ancillary/adjusted analyses are presented, are these pre-specified or exploratory?</i>				
5) <i>The analysis includes an intention to treat analysis. (If so, was this appropriate and were appropriate methods used to account for missing data?)</i> ²⁹				
6) <i>Do the authors report on all variables they aimed to study (as specified in their protocol or study aims/research questions)?</i>				
Low risk of bias	Moderate risk of bias	High risk of bias	Critical risk of bias	

²⁸Consider only in extreme cases in which preferential treatment is clearly evident; blinding is generally not expected in social interventions.

²⁹Consider only in extreme cases in which preferential treatment is clearly evident; blinding is generally not expected in social interventions.

Appendix 6. EXAMPLE OF GRADING OF RECOMMENDATIONS ASSESSMENT, DEVELOPMENT AND EVALUATION TOOL

CERTAINTY ASSESSMENT						SAMPLE SIZE	EFFECT	CERTAINTY	IMPORTANCE
Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations				
Outcome 1									
RCT	serious	serious	not serious	serious	none	737	SMD 0.02 SD higher (0.12 lower to 0.16 higher)	⊕○○○ VERY LOW	Limited Importance
Outcome 2									
RCT – 3	serious	serious	not serious	not serious	none	4991	SMD 0.14 SD higher (0.01 higher to 0.28 higher)	⊕⊕○○ LOW	Important, but not critical
Outcome 3									
RCT – 6 QED – 2	very serious	not serious	not serious	not serious	none	9970	SMD 0.09 SD higher (0.02 higher to 0.16 higher)	⊕⊕○○ LOW	Important, but not critical
Outcome 4									
RCT	very serious	serious	not serious	not serious	none	3219	Two negative and three positive effect estimates with a 95% CI range of -0.08 to 0.16	⊕○○○ VERY LOW	Important, but not critical
Outcome 5									
RCT	very serious	serious	not serious	not serious	none	3219	SMD 0.02 SD higher (0.09 lower to 0.05 higher)	⊕○○○ VERY LOW	Important, but not critical

CERTAINTY ASSESSMENT						SAMPLE SIZE	EFFECT	CERTAINTY	IMPORTANCE
Outcome 6									
RCT	not serious	serious	not serious	serious	none	3543	Five positive effect estimates with a 95% CI range of -0.00 to 0.41	⊕⊕○○ LOW	Important, but not critical
Outcome 7									
RCT - 7	serious	serious	not serious	not serious	none	8359	SMD 0.06 SD higher (0.02 lower to 0.14 higher)	⊕⊕○○ LOW	Critical
Outcome 8									
RCT – 2 QED – 1	very serious	serious	not serious	not serious	none	5233	SMD 0.14 SD higher (0.02 higher to 0.26 higher)	⊕○○○ VERY LOW	Limited Importance

Appendix 7. THE GOVERNANCE AND MANAGEMENT OF WATER RESOURCES AS COMMON POOL RESOURCE SYSTEMS

Although detailed provisions for the governance and regulation of the use of water resources vary widely across jurisdictions within and between countries, there are common challenges to address. Nobel Laureate Professor Elinor Ostrom described and analysed these by characterizing natural water as a common pool resource (Ostrom, 1990).

The inherent challenge is that, under undisturbed natural conditions, water is a highly variable, fugitive natural resource often available to many potential users but cannot easily be captured, owned and managed as “fixed property”. This leads to a wide range of institutional and regulatory arrangements to allocate or share ‘usage rights’ between different users in specific hydrological contexts. To effectively protect the natural environment while supporting beneficial use and reducing conflict between different users, regulation must provide for use under different conditions of climate-determined availability.

The outcome is often a complex system of semi-private “use rights” that overlies a supporting system of common rights managed by regulation. This enables, for instance, a farmer to have user rights to take water from a river for irrigation which can be overridden by a common property right that restricts water usage to ensure a sufficient supply for human use during periods of scarcity and protects the aquatic environment.

While resource governance and management systems have evolved to manage extremes of climate variability, they are challenged by climate change altering the basic parameters of cooperation that underpin existing regulatory systems. In extreme cases, the outcome may be that certain large scale water uses (such as irrigation) are either no longer feasible or are likely to be constrained often enough to make long-term uses riskier and require a change of use (e.g. from multi-year orchard crops to annual field crops). They may also require additional expenditure on infrastructure to increase the amount of water that can be stored to ensure it is available for societally critical uses or reallocated temporarily to respond to climate-driven shortages to meet social, economic and environmental priorities (e.g. from irrigation to energy production or urban supply).

The complexity of such unpredictable contexts reduces the opportunities for adopting common, systemic interventions that can support the achievement of adaptation and environmental protection goals at a large scale. Even under normal climate variability conditions, a robust resource management capacity is required in larger and more complex systems; such management capabilities will have to be intensified to respond to the additional uncertainties and pressures climate change creates.

In many jurisdictions, the legal frameworks governing water resource allocation and use were developed under conditions of relatively plentiful resource availability and may no longer be adequate to address existing climate variability. The case of the Colorado River in the United States is a well-known example where legally determined “fixed” water allocations can no longer be assured under existing climates. In such cases, legal reform may be required to provide an adequate framework to ensure that adequate regulatory instruments with the necessary flexibility are available to successfully adapt to climate change in a socially equitable, environmentally sustainable and economically efficient manner.

Appendix 8. THE COMPLEMENTARY RELATIONSHIP BETWEEN NATURAL AND BUILT INFRASTRUCTURE INTERVENTIONS

Natural water resource systems support many human uses of water. Human water needs have historically been met by using water provided by “natural infrastructure”, which satisfied human needs by taking water from springs, rivers and lakes. Both crop and livestock agriculture has historically been practised under rainfed conditions with little or no constructed infrastructure to provide additional water. Human settlements arose alongside natural water courses and coastlines which provided the transport routes to enable communication and trade.

However, increasing demands for water for economic and social uses linked to the growth of populations and their expansion into less physically amenable environments has required the development of infrastructures to support the associated intensification of water use. Such infrastructure was necessary for (i) collecting water from river intakes, such as weirs and other diversions, (ii) storing it in sufficient quantities to remain available during dry periods, including dams and reservoirs, (iii) transporting it to where it was required through canals and pipelines, and (iv) distributing it to its users via canals and pipelines to public outlets or private properties. Similarly, water flows from natural springs initially fed from underground sources may be supplemented by further pumped extraction.

The growth of populations has also been associated with the generation of wastewater that may be both harmful and a nuisance. For relatively small quantities, such wastewater could be returned to the natural environment where natural processes assimilated it. This could be done without causing harm if waste was discharged sufficiently distant from extraction points. However, larger volumes of wastewater have required infrastructure to be built to reduce the immediate nuisance and to protect public health and the environment by treating and safely disposing of it.

In many respects, the built infrastructure has complemented natural infrastructure. Where possible, systems are designed to transport water by gravity rather than by pump. Wastewater treatment can be undertaken in large ponds by replicating a river’s natural assimilation processes. However, for various reasons, including cost, space, technical certainty, convenience and control, societies have increasingly relied on built infrastructure rather than complementing natural infrastructure. This imposes different environmental and energy costs, which is of increasing concern as societies seek to adapt to and mitigate the impacts of climate change.

The systematic review focuses on identifying adaptation and mitigation opportunities implemented with demonstrable success by applying nature-based approaches independently or combined with built infrastructure. Such nature-based solutions include catchment protection and management through erosion control and reforestation, flood mitigation through removing artificial channels and restoring flood plains to provide more “room for rivers” and using wetland systems to treat wastewater and mitigate floods and sea level rise impacts. These nature-based solutions also include managing the impact of saltwater intrusion from rising sea levels by supporting targeted recharging of aquifers and developing urban drainage systems that allow more significant infiltration and evaporation of rainwater.

Many of these interventions involve adapting engineered solutions, such as flood protection and wastewater treatment, to enhance the role of natural processes. Others include promoting land use practices that reduce flood impacts by slowing rainwater runoff and allowing greater infiltration to recharge groundwater resources. In urban areas, these adaptive approaches are reflected in the development of urban drainage systems, characterized as “sponge cities”, to better adapt cities to the impact of increased rainfall intensities.

In many of these cases, a formal review of impacts and outcomes requires that studies be undertaken to identify, acknowledge and monitor the constraints and potential dis-benefits that may arise from different interventions.

For example, in rapidly growing urban areas, adaptation interventions that require allocating greater areas of land may be contested where space is at a premium and urban expansion negatively impacts other environmental and socioeconomic indicators. Similarly, while wetlands can play an important role in flood mitigation, water quality management and carbon capture, there are many circumstances where they emit significant quantities of GHGs, aggravating rather than mitigating a community's overall emissions profile. For such cases, the objective would be to identify an appropriate mix of nature-based and built interventions that may provide optimal adaptation and mitigation benefits.

Appendix 9. WATER RESOURCE MANAGEMENT, CLIMATE VARIABILITY AND CLIMATE CHANGE

Water resource managers must understand the fundamental relationships between climatic and hydrological variables and the management interventions required to establish and sustain water security. Hydrological variables include rainfall, evaporation, runoff, infiltration and their variation in time and space. Regarding surface water systems, critical considerations include the following:

- The probable maximum flood that may occur in a river system, which a built the structure must be designed to accommodate without failing.
- The size of storage required to meet a given set of water use requirements reliably in the face of unpredictable inter- and intra-seasonal variations in rainfall and runoff.
- The likely changes in river flows and floods as a consequence of changing land use.
- The flows required in rivers and streams to sustain the aquatic environment in a desirable state, taking into account human use and other impacts.
- The impact of human activity on water quality in the aquatic system and the interventions required to sustain the aquatic environment in a desirable state.

Similar issues should be considered where human use and impacts involve systems dependent on groundwater resources.

Depending on the scale of the system concerned and the extent and intensity of human use, planning and implementing measures to sustain water security may require years or decades of planning. In systems under significant stress, where extensive existing water uses (particularly for agriculture) are potentially competing for access to water from large and growing urban and industrial centres, effective planning requires an options analysis process. Options considered will include interventions on both the supply side and demand sides. These interventions may include hard measures, such as infrastructure development, and soft measures, such as institutional and regulatory actions to influence demand and user behaviours and guide system operations.

Water resource managers require good, long-term climate and hydrological data for large hydrological systems to inform such long-range planning in the face of significant climate variability and uncertainty about human use and behaviour. In the short to medium term (annual to decadal), the impact of climate variability masks any long-term climate change trends. Inter-seasonal systems such as the El-Nino southern oscillation (ENSO) and the Indian Ocean dipole vary irregularly and interact to produce significant and unpredictable seasonal climate impacts - floods and droughts - over large regions.

Effective water resource planning systems must be sufficiently robust to foresee and provide for the extremes in water availability and climate impacts over such cycles. The impact of climate change in such systems is difficult to predict. Impacts are likely to include the intensification of rainfall extremes associated with flood and drought events and changes in rainfall-runoff-infiltration characteristics which determine surface water flows and groundwater availability. Higher temperatures will be associated with higher rates of evaporation. But they are also associated with more intense rainfall events, which may increase runoff and flows in surface water systems and infiltration into underground water systems. Climate change thus increases the uncertainties and unpredictability that water resource planning and management must contend with to ensure water security.

REFERENCES

- Ategeka, John, and others (2022). *Behavioural science interventions within the development and environmental fields in developing countries: A systematic review*. Available at <https://ieu.greenclimate.fund/document/systematic-review-behavioural-science-interventions-within-development-and-environmental>.
- Biagini, Bonizella, and others (2014). A typology of adaptation actions: A global look at climate adaptation actions financed through the Global Environment Facility. *Global environmental change*, vol. 25, pp. 97-108. Available at <https://doi.org/10.1016/j.gloenvcha.2014.01.003>.
- Bisaro, Alexander, Matteo Roggero and Sergio Villamayor-Tomas (2018). Institutional analysis in climate change adaptation research: A systematic literature review. *Ecological Economics*, vol. 151, pp.34-43. Available at <https://doi.org/10.1016/j.ecolecon.2018.04.016>.
- Borenstein, Michael, and others (2009). *Introduction to meta-analysis*. Chichester, West Sussex: John Wiley and Sons. Available at <https://doi.org/10.1002/9780470743386>.
- Caretta, M.A., and others (2022). Water. 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, H.-O. Portner, and others (eds.). Cambridge, UK and New York, NY, USA: Cambridge University Press, pp. 551–712. Available at https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_Chapter04.pdf.
- Cochran, William G. (1954). The combination of estimates from different experiments. *Biometrics*, vol. 10, No. 1, pp. 101-129.
- De La Rue, Lisa, and others (2014). School-based interventions to reduce dating and sexual violence: A systematic review. *Campbell Systematic Reviews*, vol. 10, issue 1, pp. 1-110. Available at <https://doi.org/10.4073/csr.2014.7>.
- DerSimonian, Rebecca, and Nan Laird (1986). Meta-analysis in clinical trials. *Controlled clinical trials*, vol.7, No. 3, pp. 177-188. Available at [https://doi.org/10.1016/0197-2456\(86\)90046-2](https://doi.org/10.1016/0197-2456(86)90046-2).
- Doswald, Nathalie, and others (2020). Evidence gap and intervention heat maps of climate change adaptation in low-and middle-income countries. DEval discussion paper (February). German Institute for Development Evaluation (DEval) and Green Climate Fund Independent Evaluation Unit (IEU). Available at <https://ieu.greenclimate.fund/sites/default/files/page/deval-discussion-paper-2-2020-egm-and-ihm-climate-change-adaptation-final.pdf>.
- Douville, H., and others (2021). Water cycle changes. In *Climate Change 2021: The Physical Science Basis*, Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, Masson-Delmotte, V., and others (eds.). Cambridge, UK and New York, NY, USA: Cambridge University Press. Available at https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter08.pdf.
- Ellis, Paul D. (2010). *The essential guide to effect sizes: Statistical power, meta-analysis, and the interpretation of research results*. Cambridge, New York: Cambridge University Press. Available at <https://doi.org/10.1017/CBO9780511761676>.
- Food and Agriculture Organization of the United Nations and United Nations Water (2021). *Progress on level of water stress: Global status and acceleration needs for SDG Indicator 6.4.2, 2021*. Rome. Available at <https://doi.org/10.4060/cb6241en>.
- Froese, Rebecca, and Janpeter Schilling (2019). The nexus of climate change, land use, and conflicts. *Current climate change reports*, vol. 5, pp. 24-35. Available at <https://doi.org/10.1007/s40641-019-00122-1>.
- Global Commission on Adaptation (2019). *Adapt now: a global call for leadership on climate resilience*. Report (September). World Resources Institute. Available at https://files.wri.org/s3fs-public/uploads/GlobalCommission_Report_FINAL.pdf.
- Gough, David, Sandy Oliver and James Thomas (2017). *An introduction to systematic reviews*, 2nd ed. Sage.

- Greve, Peter, and others (2018). Global assessment of water challenges under uncertainty in water scarcity projections. *Nature Sustainability*, vol. 1, issue 9, pp.486-494. Available at <https://doi.org/10.1038/s41893-018-0134-9>.
- Grey, David, and Claudia W. Sadoff (2007). Sink or swim? Water security for growth and development. *Water policy*, vol. 9, issue 6, pp. 545-571. Available at <http://cip.management.dal.ca/publications/Water%20security%20for%20growth%20and%20development.pdf>.
- Hedges, Larry V., and Ingram Olkin (1985). *Statistical methods for meta-analysis*. San Diego, CA: Academic Press.
- Higgins, Julian P.T., and others, eds. (2019). *Cochrane handbook for systematic reviews of interventions*, 2nd ed. Chichester, UK: John Wiley & Sons.
- Higgins, Julian P.T., and Simon G. Thompson (2002). Quantifying heterogeneity in a meta-analysis. *Statistics in Medicine*, vol. 21, issue 11, pp.1539-1558. Available at <https://doi.org/10.1002/sim.1186>.
- Intergovernmental Panel on Climate Change (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, H.-O. Pörtner, and others (eds.). Cambridge, UK and New York, NY, USA: Cambridge University Press., 3056 pp. Available at https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_FrontMatter.pdf.
- Japan International Cooperation Agency (2010). *Handbook on Climate Change Adaptation in the Water Sector: A Resilient Approach that Integrates Water Management and Community Development*. Version 0 (March). Available at https://www.jica.go.jp/english/our_work/thematic_issues/water/pdf/guideline_02.pdf.
- Jiang, Yu., and others (2019). Water management to mitigate the global warming potential of rice systems: A global meta-analysis. *Field Crops Research*, vol. 234, pp. 47-54. Available at <https://doi.org/10.1016/j.fcr.2019.02.010>.
- Keef, Stephen P., and Leigh A. Roberts (2004). The meta-analysis of partial effect sizes. *British Journal Mathematical and Statistical Psychology*, vol. 57, issue 1, pp. 97-129. Available at <https://doi.org/10.1348/000711004849303>.
- Kohli, Anik, and others (2018). *Fragility and Conflict*. Climate Change & Environment Nexus Brief. Bern, Switzerland: Swiss Agency for Development and Cooperation. Available at <https://www.weadapt.org/knowledge-base/sdc-climate-change-environment-network/climate-change-environment-nexus-brief-fragility-and-conflict>.
- Langer, Laurenz, and others (2018). Women in wage labour: A systematic review of the Effectiveness and Design Features of Interventions Supporting Women’s Participation in Wage Labour in Higher-growth and/or Male-dominated Sectors in Low-and Middle-income Countries. Technical report. London: EPPI- Centre; Social Science Research Unit; UCL Institute of Education; University College London.
- Lwamba, Etienne, and others (2022). Strengthening women's empowerment and gender equality in fragile contexts towards peaceful and inclusive societies: A systematic review and meta-analysis. *Campbell Systematic Reviews*, vol. 18, issue 1, e1214. Available at <https://doi.org/10.1002/cl2.1214>.
- Macdonald, Geraldine, and others (2012). Cognitive-behavioural interventions for children who have been sexually abused: A systematic review. *Campbell Systematic Reviews*, vol. 8, issue 1, pp.1-111. Available at <https://doi.org/10.4073/csr.2012.14>.
- Muller, Mike (2021). Learning from the River Nile about engineering sustainable futures. *Proceedings of the Institution of Civil Engineers - Civil Engineering*, vol. 174, No. 5, pp. 24-31. Available at <https://doi.org/10.1680/jcien.20.00042>.
- Nicol, Alan, and Nanki Kaur (2009). Adapting to climate change in the water sector. Background note. London: Overseas Development Institute. Available at <https://www.ircwash.org/sites/default/files/Nicol-2009-Adapting.pdf>.

- Ostrom, Elinor (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge, UK: Cambridge University Press. Available at <https://doi.org/10.1017/CBO9781316423936>.
- Pincus, Tamar, and others (2011). Methodological criteria for the assessment of moderators in systematic reviews of randomised controlled trials: a consensus study. *BMC Medical Research Methodology*, vol. 11, issue 1, pp. 1-14. Available at <https://doi.org/10.1186/1471-2288-11-14>.
- Polanin, J.R., Emily E. Tanner-Smith and Emily A. Hennessy (2016). Estimating the difference between published and unpublished effect sizes: A meta-review. *Review of Educational Research*, vol. 86, issue 1, pp. 207-236. Available at <https://doi.org/10.3102/0034654315582067>.
- Sánchez-Meca, Julio, Fulgencio Marín-Martínez and Salvador Chacón-Moscoso (2003). Effect-size indices for dichotomized outcomes in meta-analysis. *Psychological methods*, vol. 8, No. 4, pp. 448-467. Available at <https://doi.org/10.1037/1082-989X.8.4.448>.
- Serra, Vittorio, and others (2022). Integrating adaptation to climate change into sustainable development policy and planning. *Sustainability*, vol. 14, issue 13, 7634. Available at <https://doi.org/10.3390/su14137634>.
- Stern, Paul C., and others (2016). Opportunities and insights for reducing fossil fuel consumption by households and organizations. *Nature Energy*, vol. 1, No. 5, article No. 16043. Available at <https://doi.org/10.1038/nenergy.2016.43>.
- Sterne, Jonathan A.C., and others (2016). ROBINS-I: a tool for assessing risk of bias in non-randomized studies of interventions. *BMJ*, vol. 355, i4919. Available at <https://doi.org/10.1136/bmj.i4919>.
- Stewart, Lesley A., and others (2015). Preferred reporting items for a systematic review and meta-analysis of individual participant data: the PRISMA-IPD statement. *Jama*, vol. 313, No. 16, pp. 1657-1665. Available at <https://doi.org/10.1001/jama.2015.3656>.
- United Nations (2018). United Nations Secretary-General's Plan: Water Action Decade 2018-2028. Available at https://sdgs.un.org/sites/default/files/2021-05/UN-SG-Action-Plan_Water-Action-Decade-web_0.pdf.
- United Nations (2023). Interactive dialogue 3: Water for climate, resilience and environment – source to sea, biodiversity, climate, resilience and disaster risk reduction. Concept paper prepared by the Secretariat**. Midterm Comprehensive Review of the Implementation of the Objectives of the International Decade for Action, “Water for Sustainable Development”, 2018– 2028, 22-24 March. New York. Available at https://sdgs.un.org/sites/default/files/2023-04/Concept%20Paper%20UNWC_ID3_Website.pdf.
- United Nations Educational, Scientific and Cultural Organization, and United Nations Water (2020). *United Nations World Water Development Report 2020: water and climate change*. Paris. Available at <https://digitallibrary.un.org/record/3892703#:~:text=The%202020%20edition%20of%20the,m anagement%20offers%20in%20terms%20of>.
- Valentine, Jeffrey C., Ariel M. Aloe and Timothy S. Lau (2015). Life after NHST: How to describe your data without “p-ing” everywhere. *Basic and Applied Social Psychology*, vol. 37, issue 5, pp. 260-273. Available at <https://doi.org/10.1080/01973533.2015.1060240>.
- Wilson, David B., David Weisburd and David McClure (2011). Use of DNA testing in police investigative work for increasing offender identification, arrest, conviction and case clearance. *Campbell Systematic Reviews*, vol. 7, issue 1, pp. 1-53. Available at <https://doi.org/10.4073/csr.2011.7>.
- Ye, Liu, Jose Porro and Ingmar Nopens, eds. (2022). Quantification and modelling of fugitive greenhouse gas emissions from urban water systems. Scientific and technical report series No. 26. London: IWA Publishing.
- Zheng, Huifang, and others (2019). Irrigation leads to greater maize yield at higher water productivity and lower environmental costs: a global meta-analysis. *Agriculture, Ecosystems & Environment*, vol. 273, pp. 62-69. Available at <https://doi.org/10.1016/j.agee.2018.12.009>.

Zheng, Xinzhu., and others (2021). Green roofs for stormwater runoff retention: A global quantitative synthesis of the performance. *Resources, Conservation and Recycling*, vol. 170, 105577. Available at <https://doi.org/10.1016/j.resconrec.2021.105577>.

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