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Limits to Ecosystem-based Adaptation for Managing Coastal Flood Risk in the face of Climate Change: The case of Pacific small island states

A preliminary review of existing knowledge with recommendations for further research

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Acknowledgements

This summary document aims to provide a foundation for further research in addressing a knowledge gap[1], *lack of knowledge to integrate ecosystem-based adaptation into programme design and lack of knowledge of the limits to EBA in the face of future climate change*, as identified through the Lima Adaptation Knowledge Initiative in the Pacific small islands states sub-region[2].

This report was prepared by a group of graduate students as part of their studies towards an MSc in Global Environmental Economics at the University of Galway. The lead authors of the report, in alphabetical order, are Master's students Alfred Afeku, Brenda Daly and Jack Flannery. The students were supervised by Dr Thomas K.J. McDermott, Programme Director for the MSc in Global Environmental Economics. Report cover, design, and graphics are courtesy of Luigi Ryan at the University of Galway.

This project would not have been possible without the UN Climate Change and Universities Partnership Programme and the collaboration between the UNFCCC and the University of Galway. We give special thanks to the UNFCCC Secretariat and in particular Lilian Daphine Lunyolo and Fatema Rajabali, for their guidance and collaboration. We also gratefully acknowledge financial support for the project from the Discipline of Economics and from the College of Business, Public Policy and Law (CBPPL) at the University of Galway, and the support of Murray Scott, Vice-Dean for Internationalisation at the CBPPL, University of Galway.

[1] See https://www4.unfccc.int/sites/NWPStaging/Pages/Lima-Adaptation-Knowledge-Initiative-(LAKI)-for-the-Pacific-sub-region.aspx, Lima Adaptation Knowledge gap 49

[2] The Lima Adaptation Knowledge Initiative works with global, subregional, national and local partners to identify priority knowledge gaps in a specific subregion and then catalyze activities to close the knowledge gaps with target knowledge users in mind.

Introduction

Risk management strategies are urgently needed given the growing effects of climate threats and the destruction of coastal ecosystems (Narayan et al., 2016). The need to adapt and manage coastal risk is especially crucial for small island governments and coastal low-lying settlements (Reguero et al., 2020). Due to human-induced climate change, small island states, like those in the South Pacific, are especially susceptible to flooding (Daigneault et al., 2016). In the Pacific Islands, around 50% of populations live near the coast, while many economic hubs containing critical infrastructure are located in vulnerable coastal areas (IPCC, 2022). Risk management strategies are urgently needed as monetary losses due to coastal flooding place an increasing strain on people and businesses and may threaten economic growth in many nations (Reguero et al., 2020).

There are a range of different types of ecosystem-based disaster risk reduction strategies that are often implemented across a wide variety of situations. For instance, protecting coastal habitats through coral reef restoration or mangrove reforestation may help mitigate coastal flooding and damage to coastal areas.

The concept of ecosystem-based disaster risk reduction is becoming increasingly popular among policymakers for the purpose of adapting to climate change (Morris et al., 2018). It is becoming more widely recognized as an adaptation option for coastal communities – as a sustainable and cost-effective means to mitigate coastal flood risks (Reguero et al., 2014, 2018; Sierra-Correa and Cantera Kintz, 2015; Global Man-grove Alliance, 2018; Martyr-Koller et al., 2021; Beck et al., 2022). Ecosystem-based Adaptation (EbA) is defined as a strategy that harnesses nature-based solutions and ecosystem services for adapting to climate change (UNEP, 2021). EbA has been increasingly implemented as a potential resilience solution in coastal areas around the world. Questions still remain however, as to how effective EbA can be across a lengthy time frame, especially if it is implemented in an area that is highly vulnerable to extreme weather events and what its distributional effects are.

There are currently National Adaptation Plans (NAPs) available for three of the 14 SIDS; Tonga, Kiribati and Fiji. Due to little or no mention of EbA in either Tonga or Kiribati's NAP, it may be beneficial to focus our study on Fiji, as it has a full section dedicated to the concept.

Key findings from the initial research

Lack of Evidence on the Effectiveness of EbA

There is a growing amount of literature that seeks to assess the flood protection benefits of coastal EbA and compare it to alternative adaptation options, such as gray infrastructure (see e.g. Chausson et al., 2020 for a review). However, much of this literature relies on modelling studies (often at a global scale) as opposed to direct empirical or observational evidence of real-world EbA effectiveness (e.g. Beck et al., 2018; Menéndez et al., 2020).

A lack of site-specific evidence on coastal ecosystems has also been noted, with most studies to date based in the Global North (Chausson et al., 2020). Identified studies that are based in the Pacific Islands include Rao et al. (2013) and Daigneault et al. (2016), which compare the economic costs and benefits of EbA to gray infrastructure. However, these studies assume a given level of protection is provided by the ecosystem rather than estimate the damage function. As such, there is a clear knowledge gap in terms of the effectiveness of ecosystems in providing coastal flood protection in the Pacific Islands. **The first proposed research agenda item** is an ex-post empirical cost benefit analysis that compares actual real-world protection afforded by EbA and gray infrastructure in the Pacific Islands.

Why Don't We See More Investment in EbA approaches to coastal flood risk management?

In much of the literature, it is assumed that the uptake of EbA is slow because the evidence base on its effectiveness is weak (e.g. Reid et al., 2019; Jongman, 2018). We have not seen any research that supports this conclusion. According to Hills et al. (2013), the main barrier to EbA in the Pacific Islands is likely not finance but a lack of technical capacity within government departments. Hills et al. (2013) also found that the decision-making process is guided primarily by local preferences in the Pacific Islands which makes increasing adoption of EbA difficult.

Elsewhere, it has been noted that hard structures tend to be considered more reliable as they are more visible (Nunn et al., 2021). **A second proposed research agenda item** is therefore to carry out a piece of qualitative research, involving interviews with decision makers in the Pacific Islands about their attitudes to and perceptions of EbA, about how adaptation projects are evaluated more generally, and what barriers are faced.

Limits to Protection Provided by EbA Under Climate Change and Under More Extreme Scenarios

A knowledge gap also exists in terms of the limits to the effectiveness of EbA taking account of the effects of climate change. Chausson et al. (2020) found that less than half of the scenario modelling studies reviewed incorporated climate change and noted that assessing how EbA performs under different climate scenarios would help with its design and implementation. Seddon et al. (2020) also noted this as an "urgent need". In the study by Daigneault et al. (2016) comparing the economic costs and benefits of EbA and gray infrastructure in providing protection from inland flooding caused by heavy rainfall in two river catchments in Fiji,

Key findings from the initial research

scenarios under "current", "moderate" and "severe" levels of climate change were estimated. However, as mentioned above, this was based on assumed levels of protection.

There is also still a high level of uncertainty about the effectiveness of EbA against extreme weather events (Morris et al., 2018). This is particularly relevant for the Pacific Islands, many of which experience tropical cyclones which are expected to become less frequent but more intense as a result of climate change (The World Bank Group, 2021). There are studies which examine the effectiveness of EbA in different weather scenarios. Lallemant et al. (2021) developed a probabilistic risk analysis framework using a case study of the Chindwin River basin in Myanmar to quantify the benefits of EbA to flood risk.

The framework considers a full range of probable events, including both frequent and rare flooding events. The studies by Beck et al. (2018) and Menéndez et al. (2020) also considered a range of different scenarios in modelling the flood protection benefits of coastal ecosystems on a global scale. Beck et al. (2018) found that globally, coral reefs prevent annual property damages of $36 billion in 25-year events and $130 billion in 100-year events. Menéndez et al. (2020) found that globally, mangroves prevent annual property damages of $104 billion in 25-year events and $270 billion in 100-year events. We did not find a study that addresses this gap from a Pacific Island context.

A third research agenda item is a simulation study that estimates the (expected) coastal flood damages from EbA interventions against a full range of extreme weather events, under a range of climate change scenarios, for the specific context of (one or more of) the Pacific Islands. As was done by Beck et al. (2018) and Menéndez et al. (2020), the study would simulate the damages with and without the presence of the habitat in order to estimate the avoided damages. However, the simulations would be based on data specific to the South Pacific. Therefore, data on recent and historical tropical cyclones, near shore bathymetry and topography, distribution, biomass and canopy height of mangroves, depth and width of coral reefs, as well as spatial data on population and assets in the South Pacific would be required.

Maintenance Costs and Lifetime Considerations, including synergies and trade-offs

The distinction between modelled costs and benefits and real-world performance is underlined by a number of studies that highlight shortcomings in implementation and maintenance of coastal defences in practice. For example, artificial structures are sometimes designed with lower levels of coastal defence effectiveness than is physically possible due to trade-offs with other environmental concerns such as poor water quality in stagnant areas behind breakwaters (Ferrario et al., 2014).

Similarly, seawalls are at times built too low due to limited funds, meaning that they will not provide adequate protection and are not rebuilt following collapse due to a lack of resources (Nunn et al., 2021). Engineered options also hinder the natural accumulation

Key findings from the initial research

process of sediments through the tides and require continual heightening and widening to keep up with increasing risk (Temmerman et al., 2013). Consequently, costs of maintaining hard infrastructure are expected to increase significantly under future climate change scenarios (Morris et al., 2018).

In contrast, coastal vegetation can adjust to sea level rise by raising the height of the land through sediment accumulation (Morris et al., 2018). Nunn et al. (2021) even argue that in some cases, especially in rural areas, constructing sea walls may be considered maladaptive. This occurs where poorly designed hard structures are put in place in areas without the resources required to maintain them, with reports claiming that there are numerous rural pacific coastlines littered with remains of failed coastal engineering projects (Nunn et al., 2021).

While the cost to implement an EbA project is generally expected to be lower than for gray infrastructure (Hynes et al., 2022), there is little evidence comparing maintenance costs of both solutions, especially when tested against more extreme and frequent weather events. This may be partially due to the fact that EbA as a concept is relatively new compared to that of gray infrastructure and the emerging principles on how EbA should be implemented. For example, the IUCN have introduced their first edition of the gold standard for nature-based solutions, which aims to create a user-friendly framework to upscale EbA.

It is widely noted that EbA options also offer a range of potential co-benefits, which are often not accounted for in existing cost-benefit studies (Seddon et al., 2020). These are generally framed in terms of spill-over benefits for local communities and their environment. However, an important trade-off for EbA is likely to be increased land-use demands. Several studies note that conventional hard infrastructure is likely to be more feasible in urban settings where the space required for EbA defences is not available (e.g. Temmerman et al., 2013; Nunn et al., 2021).

Ultimately some EbA solutions will reach hard adaptive limits and their effectiveness may diminish with more extreme climate change - e.g. due to coral reef bleaching or mangrove forests being damaged by more severe storms. It has even been argued that local adaptive solutions – whether gray or green – may provide only short-term relief, and in some cases a longer-term transformational solution is required to manage coastal flood risks (Nunn et al., 2021; Tellman and Eakin, 2022).

Perhaps future research could focus on addressing maintenance costs and the life span of EbA for coastal flooding in a pacific island. A potential question may be ''Compare and contrast maintenance costs and life span associated with implementing coastal ecosystem-based adaptation versus hard engineering projects in response to coastal flooding".

Key findings from the initial research

Distributional Effects of EbA for Flood Risk Reduction in PSIDS

Almost all public policies have distributional consequences, such as monetary policy (Arestis and Pérez-Moreno, 2022) and hence, EbA policy does not differ in this regard. In his study, Coase (1960) highlighted the fact that environmental policies might have substantial distributional effects. In order to achieve desirable outcomes, OECD (2021) report indicates that environmental policies should achieve a triple dividend that combines environmental effectiveness, economic efficiency, and equity. Distributional impact analysis according to HM Treasury UK (2020) is used to describe the assessment of the impact of interventions on different groups in society.

Bedoya Arguelles et al. (2021) indicated that policy changes do not affect everyone equally, while Serret and Johnstone (2006), asserted that policymakers are more concerned about the distributional impacts of environmental policies due to a widespread perception that poorer households bear a greater financial burden and receive fewer environmental benefits as a consequence. The importance of focusing on the equity is pertinent for environmental policy interventions (Bisaro, 2019). Some studies have shown that environmental policies can have a regressive outcome (Davies and Black, 2020) or progressive outcome (DCCAE, 2019). As a means of assessing the progressive effect of environmental policies, it is important to assess the distributional effect of the policy to determine who the winners are as well as the losers in its implementation (García-Muros, Morris and Paltsev, 2022).

While a growing amount of literature assesses the effectiveness of EbA by attempting to measure the aggregate net benefit in society (e.g. Munroe et al., 2012; Narayan et al., 2017; Global Mangrove Alliance, 2018; Reid et al., 2019; Menéndez et al., 2020; Beck et al., 2022), **distributional impacts of EbA for coastal flood risk reduction have been relatively neglected to date** (Bellon and Massetti, 2022). A possible hypothesis is that EbA for coastal flood risk reduction has distributional consequences and is not supported by society and politicians compared to gray adaptation. **Therefore, the fourth Research Agenda is to conduct empirical research to ascertain the distributional effects of EbA for coastal flood risk reduction in the Small Island Developing States of the Pacific.**

Alternative Considerations – bundling EbA with soft adaptation (or financial risk coping)

Another resilience strategy in relation to EbA could be to investigate the idea of incorporating risk transfer (insurance) with risk reduction in order to see increased investment into EbA. The concept is that the people at risk use savings from lower insurance rates that were earned owing to the decreased flood hazards due to EbA to partially finance their investment in a nature-based solution. Reguero et al. (2020) tests this strategy by using a fictional case study of a 5-km length coastal area with an economic asset value susceptible to flooding of $400 million. The results revealed that insurance premium reductions would cover 44 percent of the initial expenses of reef restoration in the first five years, and a Benefit Cost Ratio

Key findings from the initial research

(BCR) of 6.3 was predicted for the 25-year timeframe. This essentially means that over a 25-year period, the benefits would outweigh the initial costs over six times.

A potential way to develop this is to conduct the same study on an area which is highly susceptible to coastal flooding that is in an area of economic importance in a small island developing state.

Data Gaps

The project team has begun to build an inventory of available datasets that may be useful in carrying out elements of the research agenda that has been outlined here. However, various data gaps remain. Through reading literature, it has been difficult to obtain solid datasets in order to measure the effectiveness of EbA, however, a good place to start may be in some of the websites which are listed below. It seems that for many studies in the South Pacific, research was conducted using software technology such as HEC-RAS to assess historical coastal flood events and also to simulate future flood events. Another data gap which may be important to address is the lack of data on nature-based coverage and extent along coastal areas of SIDS. Having a map which shows where there is EbA in place and where there is not would be important information going forward, especially when comparing it to areas that have been hit by coastal flooding. There is also scanty information about flood damage data, local household income data, and household proximity to EbA coverage for distributional impact analysis.

Some available websites for potential data include:

Fiji Bureau of Statistics

https://www.statsfiji.gov.fj/

Used for descriptive data: e.g. population, GDP per-capita, etc.

The Pacific Data Hub

https://pacificdata.org/data/dataset?topic=Environment&member_countries=fj

Database which has information on various topics including climate change adaptation, disaster risk reduction and more in areas of the pacific.

Global Mangrove Watch

https://data.unep-wcmc.org/datasets/45

An interactive map which shows global mangrove coverage. It also has the option to show historical trends of mangrove cover dating back to 1996.

Fathom Global Flood Hazard Data & Maps

https://www.fathom.global/product/flood-hazard-data-maps/

Software program that models coastal flooding at a global level.

HEC-RAS Hydrological Modelling Software

https://www.hec.usace.army.mil/software/hec-ras/download.aspx

A modelling tool which can measure water flow through natural rivers and channels through simulations

World Bank Data Hub

https://data.worldbank.org/

Website containing a variety of socioeconomic data on a wide range of countries including those in pacific small islands.

OpenStreetMap

https://www.openstreetmap.org/#map=2/-17.2/0.0

An interactive map which provides geographical data on areas around the world including topography, aerial imagery and much more.

NASA Earth Data

https://www.earthdata.nasa.gov/learn/backgrounders/nighttime-lights

Satellite imagery of night lights in areas across the world. This could be used as a proxy for economic activity in measuring economic activity before and after a coastal flooding event.

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