A natural capital approach to climate adaptation

Placencia, Belize

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The challenge of adapting to climate change

Governments, companies, and communities around the world are increasingly interested in mitigating and adapting to the impacts of climate change, such as increasing annual temperatures, erratic weather patterns, and new ecosystem conditions.[2] But the costs and benefits of adapting to these changes are not widely understood, limiting the ability of decision makers to prepare for future challenges.

Adaptation is crucial for coastal zones, where ecosystems face unique climate-related vulnerabilities (e.g. ocean acidification, coastal hazards and sea level rise). In Belize, climate adaptation is of particular urgency due to the prominent role of natural capital in the development and sustainment of the tourism industry and other coastal sectors.

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Selecting adaptation options in Placencia, Belize

The Natural Capital Project, World Wildlife Fund (WWF), the Belize Coastal Zone Management Authority and Institute (CZMAI) and the Inter-American Development Bank (IDB) analyzed tradeoffs among climate adaptation strategies in Placencia, Belize to answer the question: *What are the relative costs and benefits of climate adaptation options in Placencia?*

This pilot study uses an ecosystem services[3] framework and cost-benefit analysis (CBA) to advance an approach that considers natural capital supply in climate adaptation. The analysis accounts for coastal-marine ecosystem services like tourism opportunities, protection from storms and sea level rise, carbon storage and sequestration, and spiny lobster catch. Analyzing these specific services provides actionable knowledge about the economic and environmental tradeoffs among different management options.

Individually, ecosystem service and cost-benefit analysis have been used before. CBA is an approach for estimating economic outcomes when allocating scarce resources. The approach can be used to determine whether the total advantages of a policy intervention (benefits) exceed the disadvantages (costs).[4,5] CBA has previously been applied to assess coastal zone adaptation, specifically to inform adaptation to sea level rise and extreme events.[6] The approach enables managers to prioritize among options by considering cost-efficient adaptation investments.

The InVEST (Integrated Valuation of Environmental Services and Tradeoffs) suite of modeling tools can map, quantify, and estimate the value of ecosystem services, helping to comprehensively evaluate the economic and spatial impacts of development and climate change. In effect, it helps decision-makers answer questions of what to do, where and at what cost. InVEST combines spatial and biophysical models with economic techniques (e.g. avoided damage cost or market valuation) to value ecosystem services,[7] and was used to develop Belize's national Integrated Coastal Zone Management Plan.[8]

Our approach improves upon traditional CBA by including the valuation of ecosystem services, addressing variation in the distribution of costs and benefits across an area, and helping to identify *who* and *what* bear the risk of climate change effects or the benefits of corresponding adaptation measures. Our approach also draws upon extensive stakeholder engagement and collaboration with policy makers to ensure the relevance and feasibility of adaptation scenarios. This collaborative process proved useful in the coastal zone planning process with CZMAI and the Belize Climate and Development Knowledge Network (CDKN) initiative led by WWF.[9,10]

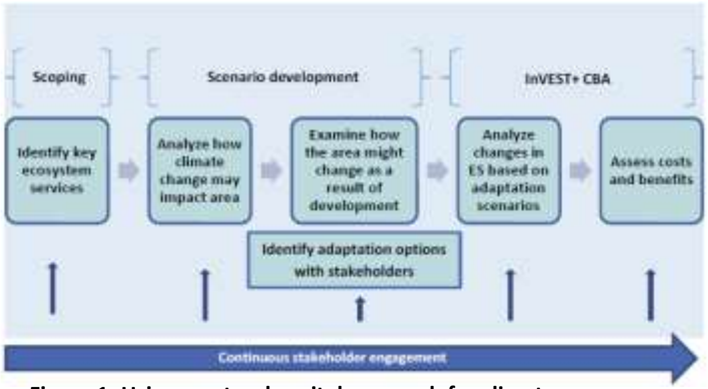

Figure 1: Using a natural capital approach for climate adaptation. *Adapted from Rosenthal et al. 2013.*

A natural capital approach to climate adaptation begins with an assessment of current provision of ecosystem services. Next, scenarios are developed that account for climate change impacts, human activities and development, and alternative adaptation options. Finally, ecosystem service models (InVEST) are used to assess the ecosystem service impacts and possible costs and benefits of alternative adaptation scenarios, which are then compared in a CBA framework (Figure 1). Ideally, these steps are iterated to refine options and outputs, and to improve final decisions governing adaptation measures.

Using spatial-temporal scenarios for cost-benefit analysis

In order to calculate the costs and benefits of adaptation, the team built three climate adaptation scenarios (Figure 2). These scenarios combine previous research incorporating stakeholder input with literature review, field data, and expert workshops. Specific adaptation measures were incorporated into the scenarios based on local priorities, feasibility, and potential for mapping, modeling, and valuation.

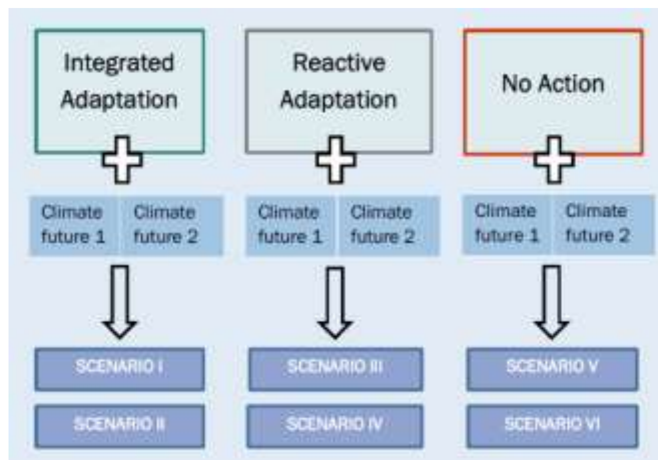

Figure 2: Creating adaptation scenarios. *Adapted from Rosenthal et al. 2013.*

The use of gray and green infrastructure was a key component of scenario development. Green infrastructure generally refers to the use of natural systems as physical structures to benefit society.[11] In this case, "green" approaches refer to conservation and restoration of coral reefs and mangroves to defend the coastline against sea level rise and coastal storms; alternative "gray" approaches include the construction of sea walls.

The first adaptation scenario, *Integrated Adaptation***,** prioritizes action to safeguard coastal resources and industries (specifically emphasizing tourism) while also adopting measures to preserve natural areas. The scenario is designed to limit the adverse impacts of sectors in the coastal zone (e.g., degraded coral reefs from marine transportation) and incorporate green adaptation strategies (e.g. restoration of sea grass). It establishes one marine protected area (MPA) and several private reserves. *Integrated Adaptation* includes strategic use of gray infrastructure in highly developed areas without high-value beachfront property. Adaptation strategies are implemented through government intervention and incentives for property owners.

In the second scenario, *Reactive Adaptation***,** gray infrastructure is the primary emphasis and sea walls are built to protect investments in tourism and private property. No areas are restored, resulting in loss of some green infrastructure and habitat (e.g. mangroves). The *Reactive Adaptation* scenario has the highest level of coastline devoted to both development and seawalls.

Finally, there is a *No Action* scenario in which the configuration of coastal and marine uses remains the same, because the government takes no action to adapt to climate change. This scenario was used as a baseline to compare relative outcomes of adaptation strategies.

These scenarios were combined with two possible climate futures – one in which the global community takes action to mitigate climate change through the UNFCCC starting in 2020, called "mitigation," and one in which it does not, called "global inaction" – to generate climate adaptation scenarios.

Calculating costs and benefits

After the adaptation scenarios were developed, InVEST and CBA were used to compare the different options, identifying costs and benefits for Placencia. The team calculated the cost of adaptation (e.g. how much does it cost to create an MPA, or build and maintain a seawall?) and quantified impacts on ecosystem services. Benefit calculations included the positive returns for ecosystem services, such as coastal protection from seawalls, as well as spillover effects such as the potential negative impacts on tourism from seawall construction. These integrated methods enabled analysis of complex relationships between adaptation activities, as well as tradeoffs among priorities for development, ecosystem services, and climate adaptation.

Data collection

The CBA calculations used values for key ecosystem services, the costs of implementation and maintenance of adaptation measures, and the cost of projected damages (e.g. due to coastal erosion) to calculate the Net Present Value (NPV) for each scenario. The ecosystem services data were collected as part of a three-year coastal zone planning process led by the Belize Coastal Zone Management Authority and Institute (CZMAI). Data were also provided by diverse sources such as government agencies in Belize, WWF offices, local NGOs and private entities, and peer-reviewed literature. Many of the adaptation measures considered came from the Climate and Development Knowledge Network (CDKN) initiative led by WWF and supported by the UK Department for International Development (DFID).

In addition, InVEST and CBA accounted for expected costs related to climate change from sea level rise and increasing temperatures, including changes in annual catch of spiny lobster and expected property damage from erosion and storms.

Findings

The InVEST Habitat Risk Assessment model determined risks to three habitats – sea grass, coral reefs, and mangroves – finding that the *Reactive Adaptation* scenario poses the highest risk to all habitats. This result is likely due to increased coastal development and associated uses (e.g., marine transportation). The area of habitat at-risk decreases if the *Integrated Adaptation* scenario is implemented. For example, areas of mangroves at-risk decrease by almost a factor of 10 relative to the *No Action* scenario.

Global Mitigation	No Action	Integrated	Reactive
NPV of total benefits	$0.790	$1.300 ✓	$0.650
NPV Lobster fishing	$0.008	$0.009 ✓	$0.006
NPV Tourism & recreation	$0.782	$1.273 ✓	$0.702
NPV Carbon storage & sequestration	-	$0.013 ✓	-$0.061
NPV of total implementation costs	-$0.005	-$0.015	-$0.191
NPV of erosion damages from sea level rise and storms	-$2.517	-$2.556	-$2.005 ✓
Total NPV of all benefits, costs and damages	-$1.731	-$1.275 ✓	-$1.550
NPV compared to No Action scenario	-	$0.456 billion ✓	$0.181 billion

Figure 3: Comparison of adaptation scenarios under global mitigation. Checkmarks indicate highest relative benefits. *Adapted from Rosenthal et al. 2013*

Returns were then calculated for a current scenario (2010-2024) and future scenarios (2025-2100). For both climate future, the greatest benefits overall and highest levels of efficiency are achieved with the *Integrated Adaptation* scenario. This result includes the highest returns for services like carbon storage, lobster fisheries, and tourism (figure 3).

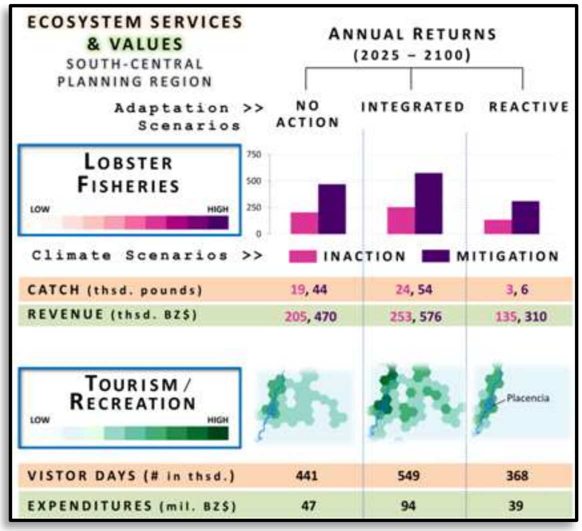

Figure 4: Annual returns of two ecosystem services, lobster fisheries and tourism, under the three adaptation scenarios. *Source: Gregory Verutes, Rosenthal et al. 2013.*

The InVEST lobster fisheries model was used to calculate impacts on catch amounts and revenue. Although the model indicates that warming temperatures are likely to reduce revenue from lobster fisheries regardless of the adaptation strategy, *Integrated Adaptation* provides the highest relative returns with only a 205,000 BZ$ reduction. In the *Reactive scenario*, 323,266 BZ$ is lost.

For tourism, *Integrated Adaptation* results in more than twice the number of visitor days spent in Placencia compared to *Reactive Adaptation* (549,000 days versus 368,000) and 1.5 times the revenue (figure 4). This is likely because the *Integrated* scenario blends conservation of key habitats with some increases in development in the northern part of the planning region, and tourism in Belize is typically nature-based.

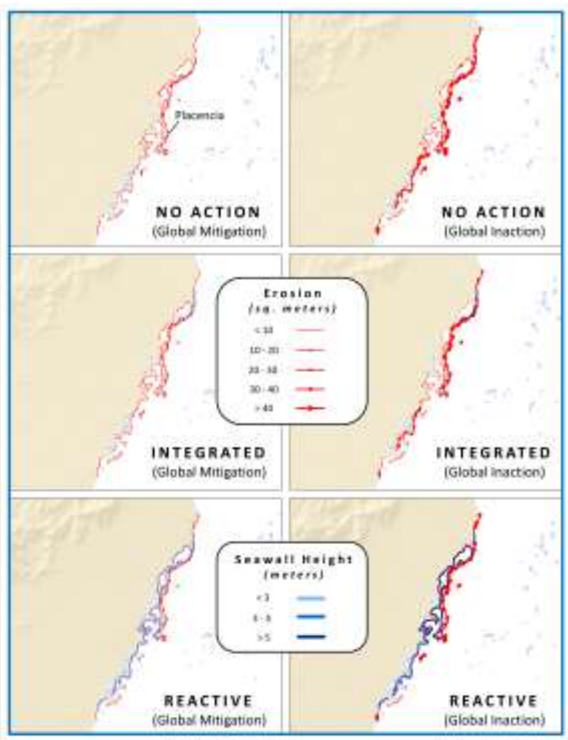

Figure 5: Erosion and engineered protection from a single catergory 1 hurricane event under three alternative management and two climate scenarios. *Source: Gregory Verutes, Rosenthal et al. 2013.*

The only service for which *Integrated Adaptation* does not provide the highest relative economic benefits is coastal protection (measured by damages to infrastructure). Although the *Integrated* scenario provides the greatest amount of coastal protection spatially, the value of the service is lower; the lowest damage costs are projected in the *Reactive* scenario due to the use of seawalls. As with the other services, there is spatial variation in where erosion is expected within Belize; the analysis identified which locations are at the highest risk (figure 5). The windward side of Placencia is projected to experience higher rates of erosion due to sea level rise, exposure to storm waves and fewer seawalls. Seawalls are not used in this area in order to preserve its pristine beaches for tourism.

Integrated Adaptation provides better erosion control than *No Action*, with specific benefits for the west coast and southern part of the lagoon, where the amount of erosion is two to three times lower (most likely due to mangrove preservation and restoration). It is also important to note that the global inaction climate scenario intensifies the overall risk of erosion, due to increased water levels and weakened ability of corals to provide protection from storms.

Opportunities for further engagement

Despite the benefits of considering natural capital in climate adaptation, some key areas of uncertainty remain. Since there is a lack of data on how potential climate change impacts (e.g. sea level rise) will impact tourism, full consideration of these impacts was not possible. Topics for future research include consideration of additional coastal zone sectors like aquaculture, oil exploration and marine transport, as well as additional adaptation options, like catch shares and quotas for spiny lobster. Scenarios could also include more climate-related variables like changes in flood risk, ocean acidification, and storm intensity and frequency.

This pilot study demonstrates how ecosystem services information and valuation can inform decision-making, and integrate consideration of economic and environmental tradeoffs into climate adaptation efforts. This work will be expanded into a national assessment (Phase II), which will include additional ecosystem services and a broader scope of climate impacts. Phase II will support more comprehensive planning for national climate adaptation in Belize. In addition, early lessons from this study will be used to inform site-level decision making for permitting of coastal infrastructure. As Belize is subjected to more extreme changes in climate, frequent hurricanes, and coastal flooding, it will continue to be crucial to balance uses of the coastal zone while adapting to climate change.

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[1] This case study draws on the research and analysis detailed in the 2013 report "Identification and valuation of Adaptation Options in Coastal-Marine Ecosystems: Test case from Placencia, Belize." Rosenthal, A., Arkema, K., Verutes, G., Bood, N., Cantor, D., Fish, M., Griffin, R., and Panuncio, M., (2013). Identification and Valuation of Adaptation Options in Coastal-Marine Ecosystems: Test case from Placencia, Belize. The Natural Capital Project, Stanford University, World Wildlife Fund.

[2] IPCC. (2007). Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. M.L. Parry, O.F. Canziani, J.P.Palutikof, P.J. van der Linden and C.E. Hanson (Eds.). Cambridge University Press, Cambridge, UK.

[3] Ecosystem services are the benefits people obtain from ecosystems, including provisioning services such as food and water; regulating services such flood or disease control; cultural services such as spiritual or recreational benefits; and supporting services, such as nutrient cycling. For more information see The Millennium Ecosystem Assessment website.

[4] United Nations Climate Change Secretariat. (2011). Assessing the Costs and Benefits of Adaptation Options: an overview of approaches. Publication of the Nairobi Work Programme.

[5] United Nations Framework Convention on Climate Change. (2010). Potential costs and benefits of adaptation options - A review of existing literature.

[6] Ibid.

[7] Kareiva, P., Tallis, H., Ricketts, T. H., Daily, G. C., and S. Polasky (Eds.). (2011). Natural capital: Theory & practice of mapping ecosystem services. Oxford, UK: Oxford University Press.

[8] Clarke, C., M. Canto, S. Rosado. (2013). Belize Integrated Coastal Zone Management Plan. Coastal Zone Management Authority and Institute, Belize City. Draft for public review. Accessed via http://www.coastalzonebelize.org/?page_id=681, August 2013.

[9] Bood, N. and M. Fish (2012). Opportunities for triple-wins development in coastal Belize. Brief Paper submitted to CDKN as part of the CDKN funded project "Achieving triple wins in the coastal zone". Belize City, Belize. World Wildlife Fund.

[10] Smith, T. and N. Bood (2011). Mangrove conservation and preserves as climate change adaptation in Belize: A case study. World Wildlife Fund and Brooksmith Consulting.

[11] See the website of the National Oceanic and Atmospheric Administration for more information about green infrastructure and its application in policy.

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