Assessing Coastal Risk and the Economics of Climate Adaptation

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Abstract

As climate change progresses, so does the risk from hurricanes, flooding, and other natural disasters. As sea level rises, tropical cyclones will pose a greater risk of extreme flooding and are likely to inflict the greatest damages on highly populated shorelines. A catastrophic hurricane season in the Caribbean during 2017 is exemplifies how these events can strained government budgets and impact coastal communities. Globally, it is projected that coastal growth in population and development will outpace progress in risk reduction. The need to upgrade existing flood protection and to plan for future coastal risks is becoming increasingly apparent. However, effective adaptation requires understanding the different drivers of risk from an economic perspective, including coastal development and the impacts of climate change. There is a need for better strategic visions for risk reduction and climate adaptation that involves specific science and quantification to address stakeholder concerns and supports climate change policy. Analyses should be able to: (i) identify areas most at risk, (ii) quantify losses and damages under various present and future scenarios, and (iii) compare and prioritize potential solutions with cost-benefit analysis. This protocol describes a quantitative risk assessment framework to assess coastal flood risk (factoring both climate change and economic exposure growth) and to compare the cost effectiveness of different adaptation measures. These adaptation options may include nature-based (e.g. oyster reef restoration), structural or grey infrastructure (e.g., seawalls) and policy measures (e.g. home elevation or coastal development policies).

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Guidelines

The Protocol is described in the ‘Economics of Climate Adaptation’ framework, and is implemented in climada and, in particular, the ‘coastal module’.

The Economics of Climate Adaptation (ECA) framework is authored by the Economics of Climate Adaptation Working Group, *Shaping climate-resilient development: a framework for decision-making*, identifies significant potential for cost-effective adaptation measures. It presents a practical framework that national and local officials can use to quantify the risk that climate change poses to their economies, and to minimise the cost of adapting to that risk. For more information, consult: http://www.swissre.com/eca/

Before start

Risk occurs at the intersection of economic assets and the hazard of coastal flooding. Adaptation can have an effect of each component of risk. There are three distinctive parts to assess the cost effectinves of adaptation measures:

1) Assessing Current Risk

Risk is quantified as a loss associated with a certain probability. The event loss or damage is the sum of all individual losses resulting from a single occurrence of a natural hazard (e.g. floods). Each individual loss is quantified from three terms:

- **Hazard** (or 'peril'): defined by the location, frequency and intensity of events (storm flooding), i.e. where, how often and with what intensity do storms occur?
- **Assets exposed**: defined by the location and value of the distinct types of buildings and assets.
- **Damages to assets**: is the relationship between the extent of damage and the event intensity, defined by damage (or vulnerability) curves.

2) Assessing Future Risk

Future risk derives from both changes in climate and in economic exposure. The effects of climate change on the hazards should consider all the factors affecting flooding in coastal zones: land subsidence, sea level rise and changes in intensity and frequency of storms.

Additionally, future risk should also factor in changes in coastal exposure as this factor is particularly acute in the coastal areas due to the intense development that occur in coastal zones.

3) Assessing the Economics of Adaptation measures

Assessing the cost (i.e. construction and maintenance) and benefits (i.e. losses averted) of adaptation requires assessing the potential damage averted from each adaptation measure. This is done in a sequence of steps:

1. Define certain adaptation strategies that are composed by adaptation measures that have an effect on hazard attenuation or on coastal exposure.
2. Estimate the benefit of each measure: each measure at specific locations is assumed to protect a percentage of property for a certain period of time (for which the benefit is calculated).
3. Calculate the cost of each measure: includes the cost of construction (depends on dimensions

of the measure and unitary costs) and the cost of regular maintenance, as well as any other type of cost during its lifetime.

4. Calculate Net Present Value (NPV) of costs and benefits: the difference between the present value of cash inflows (benefits from adaptation) and the present value of cash outflows (cost and maintenance throughout the implementation period). NPV is calculated as follows:
    1. Calculate baseline risk (today) with and without the measure: calculate annual expected damage with no measures and with the effect of the measures applied; the difference is the benefit of implementing the measure today.
    2. Calculate future risk (e.g. in year 2050): using future assets and expose future hazards, calculate annual expected damage with no measures and with the measures applied; the difference represents the future benefit of the measure.
    3. Discount the benefit to present terms: discounting benefits for a total of T years, its NPV will be: , where *i* is the discounting rate, used in economic analysis to consider productivity of capital and the preferences of the population.
    4. Discount the cost to present terms: as for benefits.
5. Calculate the *benefit to cost ratio* for each measure. Costs estimates for each adaptation measures should consider construction, maintenance and other derived costs. Cost estimates can be obtained from review of past projects or local estimates.

Protocol

Assessment of coastal flooding

Step 1.

Historical and synthetic storms are simulated with climada.

Total water levels are calculated at the coast from the contribution of surges, tides, sea level rise and wave runup.

See Losada et al (2013) for a description of coastal flooding components and relevant datasets.

SOFTWARE PACKAGE (Matlab)

CLIMADA - COASTAL, 1.0

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https://github.com/borjagreguero/climada_coastal_hazards_module

DATASET

Sea Level Rise NOAA measurements

Assessment of coastal exposure

Step 2.

In GIS, data on building value is calculated for each ground height.

For this, floodmask are calculated using a bathtub approach for each ground height, accounting for connectivity with the sea (i.e. low lying areas inland that are not connected to the sea should be discarded for flooding purposes).

DATASET

Elevation model

Calculation of damages

Step 3.

Damages are calculated in climada, factoring in the distribution of assets at each ground height.

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Calculation of cost and benefits

Step 4.

a) Estimate adaptation strategies, assessing their potential for hazard attenuation, location, cost and percentage of assets they could protect.

b) Calculate costs and benefits in net present value over the period of time for which the adaptation measure is designed.

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