Economics of Climate Adaptation

July 2021

Executive Summary

San Pedro Sula - Honduras
Urban Flood Risk

UNITED NATIONS UNIVERSITY
UNU-EHS

A project implemented on behalf of InsuResilience Solutions Fund
managed by Frankfurt School of Finance & Management
funded by KFW
on behalf of Federal Ministry for Economic Cooperation and Development
In cooperation ETH zürich

Table of Contents

List of Acronyms

Annual Expected Damage (AED)

Comisión Permanente de Contingencias Honduras (COPECO)

Cross-Section (XS)

Departamento de Investigación y Estadística Municipal (DIEM)

Digital Elevation Model (DEM)

Disaster Risk Management (DRM)

Economics of Climate Adaptation (ECA)

Ecosystem Services Valuation Database (ESVD)

Fondo Hondureño de Inversión Social (FHIS)

German Development Bank (KfW)

German Ministry for Economic Cooperation and Development (BMZ)

Global climate model (GCM)

Hydrologic Engineering Center's - Hydrologic Modeling System (HEC-HMS)

Hydrologic Engineering Center's - River Analysis System (HEC-RAS)

Instituto Nacional de Estadística (INE)

Integrated Risk Management in Honduras (PEGIRH)

Intergovernmental Panel on Climate Change (IPCC)

InsuResilience Solutions Fund (ISF)

Law of the National Risk Management System (SINAGER)

Light Detecting And Ranging (LIDAR)

Mean damage degree (MDD)

Necesidades Básicas Insatisfechas (NBI)

Plan Maestro de Desarrollo Municipal (PMDM)

Representative Concentration Pathway (RCP)

Rossby Centre Regional Climate Model (RCA4)

San Pedro Sula (SPS)

The Economics of Ecosystems and Biodiversity (TEEB)

United Nations Economic Commission for Latin America and the Caribbean (UNECLAC)

United Nations University - Institute for Environment and Human Security (UNU-EHS)

MAIN FINDINGS

In this report, flood adaptation measures were analyzed for the municipality area of San Pedro Sula (in selected districts) based on cost-efficiency criteria for adaptation/risk reduction. A total of 22 measures (12 options of measures distributed in different locations) were successfully assessed using the modelling platform CLIMADA. The main findings are summarized below:

1) Today's annual expected damage is USD 7.3m, increasing to over USD 14m by 2042.
2) The majority of measures assessed are cost-efficient for the selected assets;
3) If implemented, all measures combined would be sufficient to avert the total flood risk in SPS, including the projected effects of climate change(although without considering storm risk);
4) For the timeframe of this study (2017-2042), measures for inundation have a positive impact on asset protection, especially under extreme climate conditions;
5) Small-scale grey measures (e.g. refurbishing collectors) as well as green measures (e.g. ecological restauration) were identified as the most efficient;
6) Climate index-insurance is an efficient option that can be quickly implemented, thus serving as a potential complementary measure such as an interim protection while grey measures are to be planned and build;
7) The top three cost-efficient measures are:
    a. "Vegetated Swales"
    b. "Refurbished Collectors"
    c. "Ecological Restauration"
8) With the top three cost-efficient measures, San Pedro Sula will be able to avoid an estimated USD 50 million in damages and protect around 30 000 people over the next three decades with an investment of under USD 36 million.

Economics of Climate Adaptation

Powered by CLIMADA

1 CONTEXT

1.1 Introduction

Storms, floods, droughts, and other extreme weather events can threaten urban and rural areas, from small regions to entire nations. Along with growing populations and economies, losses from natural hazards are rising in the World's most exposed areas as our climate continues to change. The Economics of Climate Adaptation (ECA) is a decision-making support framework that integrates climate vulnerability and risk assessments with economic and sustainability impact studies to determine the portfolio of optimal adaptation measures for various climate risks.

The United Nations University - Institute for Environment and Human Security (UNU-EHS) in cooperation with and funded by the InsuResilience Solutions Fund (ISF), is implementing the Economics of Climate Adaptation (ECA) framework in the Municipality of San Pedro Sula (SPS) in Honduras, to identify the most cost-efficient measures to address the negative impacts of floods. The ISF is funded by the German Development Bank (KfW) on behalf of the German Ministry for Economic Cooperation and Development (BMZ). Currently, the Economics of Climate Adaptation (ECA) framework is being implemented in three different countries (Vietnam, Honduras, and Ethiopia).

This report presents an executive summary of the different stages of the process of implementation of the ECA study and the final recommendations for adaptation measures to flood events in the Municipality of San Pedro Sula. A significant source of information for the study was the Plan Maestro de Desarrollo Municipal (PMDM), which the Municipality carried out through extensive research and data collection.

The representatives of the Municipality were asked to provide input and feedback on the assumptions, decisions, data, and adaptation options assessed. A total of 12 flood adaptation measures were identified and validated by the Municipality to be run in the modelling platform CLIMADA, including technological and engineering solutions, ecosystem-based (nature-based) approaches, maintenance/operational measures, instruments and tools that improve baseline hydro-meteorological data, and risk transfer/insurance solutions.

1.2 Background

Between 2014 and 2019, municipality records show that SPS alone was hit by more than 100 climate hazard events, including fires, droughts, hurricanes, storms, floods, landslides, and earthquakes. Amongst these recurring events, Hurricane Mitch (1998) caused the biggest damage in the recent history of Honduras, followed closely by the Eta and Iota tropical storms that hit San Pedro Sula within a week in early November 2020. In SPS, flooding events following Hurricane Mitch caused severe damages for the banana industry and the Municipality's infrastructure[1]. Bridges were particularly affected. Over 60% of the country and hundreds of towns and villages were engulfed by mud and water. More than 70% of the agricultural sector of Honduras was wiped out. It created immediate food shortages and reduced the export of bananas, coffee, and shrimp.

San Pedro Sula is the second-largest city in Honduras and the industrial and economic capital of the country. Located in the northwest of the country, around 50 km away from the Caribbean Sea, the city is part of the Sula Valley and the Merendón mountain chain. By 2016, SPS had a population of over 754,000 inhabitants, 94% of which can be found within the urban limits. According to the Permanent Committee for Contingency Management (COPECO), around 244,000 of these people live in high flood risk areas[2].

As described in Figure 1, hurricanes and floods are the most dangerous hazards in Honduras, as well as in SPS. Flooding will affect not only housing, especially in poor neighbourhoods but also public infrastructure, with transport systems and roads being most vulnerable.

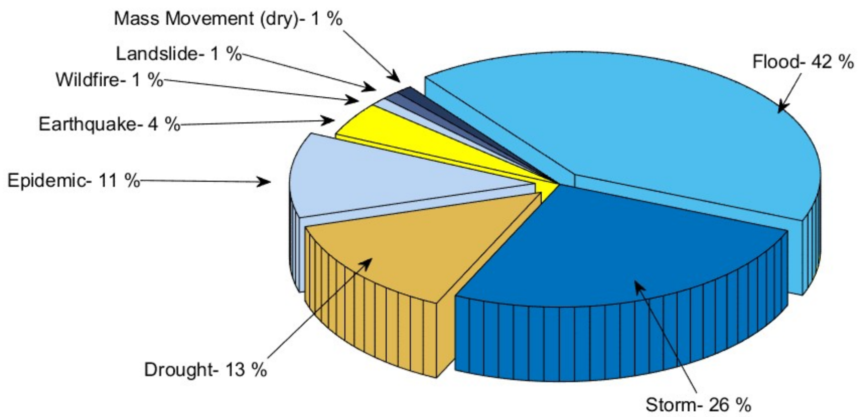

Figure 1 Average Annual Ocurrence of Natural Hazards (% per type of hazard) between 1900 and 2018, based on data from EMDat (2019)

Based on several studies[3,4], future projected changes in climate include[5] an increase in the average temperature of up to 2.5°C by 2050, as well as a significant decrease in average rainfall between 9-14% p.a. by 2050. Similarly, extreme rainfall volumes are expected to rise by 25%, leading to an expected increase in flood events p.a. by 60%.

1.2.1 Policies and strategies to address Climate Change in San Pedro Sula

The strategy that San Pedro Sula developed for achieving sustainable development is framed within the Master Plan for Municipal Development (PMDM)[6], which the administration is seeking to

---

[1] ibid

[2] https://reliefweb.int/report/honduras/un-mill-n-de-personas-en-el-rea-rural-viven-en-zonas-de-riesgo

[3] Smith, Joel B.; Strzepek, Kenneth M.; Cardini, Julio; Castaneda, Mario; Holland, Julie; Quiroz, Carlos et al. (2011): Coping with climate variability and climate change in La Ceiba, Honduras. In Climatic Change 108 (3), pp. 457–470. DOI: 10.1007/s10584-011-0161-2.

[4] Tucker, Catherine M.; Eakin, Hallie; Castellanos, Edwin J. (2010): Perceptions of risk and adaptation. Coffee producers, market shocks, and extreme weather in Central America and Mexico. In Global Environmental Change 20 (1), pp. 23–32. DOI: 10.1016/j.gloenvcha.2009.07.006.

[5] https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID%20ATLAS_Climate%20Change%20Risk%20Profile_Honduras.pdf.

[6] Available in ANNEX 13 in digital form (please change to calibri)

implement with public and private partners. The PMDM is in line with the National Strategy for Climate Change (ENCC) and focuses on water resources, forests & biodiversity, and human security.

The results presented here will offer a basis for the underlying spatial planning of the Master Plan. This report also provides insights into the implementation of the Sustainable Development Plan of SPS, which aims at reducing the vulnerability of the district and its inhabitants against climate impacts. Potential adaptation measures include all types of grey and green infrastructure for rainwater management, ecosystem-based adaptation (EbA) measures, options to improve the resilience of buildings, spatial planning, early warning systems, etc.

Furthermore, the ECA study results can be used as input to prioritize the adaptation measures in future investment programs, be it with domestic or international funding. For instance, the German Development Bank (KfW) is considering extending the successful regional program "Urban Climate Adaptation in Central America" to SPS. This program focuses on grey and green infrastructure investments to increase the adaptive capacity of poor urban neighborhoods and the risk management capacities of the involved institutions.

1.3 The ECA Framework

The main objectives of the Economics of Climate Adaptation (ECA) framework are to support decision-makers in developing their adaptation strategy and prioritizing investments in climate change adaptation (CCA), including risk transfer. The ECA framework offers a systematic and transparent approach that fosters trust and initiates in-depth inter-sectoral stakeholder discussions. ECA can be flexibly applied from the national down to the local level to different stakeholder groups and different hazards. It further gives guidance on what aspects to focus on during a feasibility study. It provides key information for program-based approaches, insurance approaches and has the potential to support National Adaptation Plans (NAPs) development.

ECA offers a unique approach towards the flexible identification of cost-efficient CCA measures for a variety of projects and sectors. It addresses, in particular, the following questions:

1) What is the potential climate-related damage over the coming decades?
2) How much of that damage can be averted, using what type of CCA measures?
3) What investments will be required to fund those CCA measures and will the benefits of these investments outweigh their costs?
4) How do we quantify residual risk (the risk remaining once all considered physical CCA measures are implemented)?

A plethora of approaches has already been designed to respond to the complexity of climate change-related projects. With regard to the implementation of climate change adaptation strategies, they range from climate vulnerability assessments, risk assessments, economic and/or sustainability impact assessments to decision-making support tools. Among these approaches, none integrates the full range of processes from risk assessment to a feasibility study of CCA measures. Integration is the strength of ECA; it is linked to the open-source modelling platform CLIMADA. The latter, by using available data, calculates the potential impact of current and future hazards on several selected assets, including the cost/benefits of selected measures.

2 IMPACT ASSESSMENT

2.1 Methodology Overview

The Economics of Climate Adaptation (ECA) framework is set out to develop practical recommendations that enable national and local decision-makers to build a comprehensive assessment of the climate risk that their economies are facing while minimizing the cost of adaptation through cost-efficient strategies. A particular emphasis is made on a robust and integrated approach based on sound scientific facts.

The ECA as applied here contains three elements supported by the modelling platform CLIMADA:

1) Climate risk identification: Conduct an identification of climate risk in a defined region (e.g. urban area), identify areas and people at risk, spanning all significant climate hazards and the full range of possible impacts for different sectors
2) Climate risk quantification: Calculate the expected damage across multiple climates and economic scenarios
3) Identification and prioritization of CCA measures (using Cost-Benefit Analysis of CCA measures): Determine strategies including a portfolio of specific CCA measures with detailed cost/benefit assessment.

Additionally, ECA includes a strong component of stakeholder engagement to complement the hazard modelling and asset valuation.

Stakeholder Engagement: In the case of SPS, a series of workshops have been conducted to include the views of stakeholders from different sectors. These inputs range from providing data to validation of assumptions, surveys or facilitating exchanges between parties.

High-resolution Flood Modelling: This close collaboration, and the engagement of the Municipality and several other public institutions like COPECO (Permanent Contingency Committee), allowed for the set-up of a high-resolution (5m and 1m) flood model for the Municipality. This model, as well as all data, has been transferred to the beneficiaries of the study, i.e. the Municipality, in order to allow updates and additional analysis in the future by the community itself.

Asset Valuation: In collaboration with all stakeholders, 15 different types of assets were selected and valuated using household level field surveys, expert interviews, a real estate proxy estimation, and a structural valuation. Asset values used in this study were validated during an iterative process with the different stakeholders. Table 1 provides an overview of the aggregated value per asset category.

Table 1 Compilation of estimated values of assets within the selected districts

Asset Category	Total	Unit	Sample Size
Total Vulnerable Population	30 622	People	30 622
Exposed Population	34 168	People	34 168
Informal Housing (Los Bordos)	40 977 324	USD	6 778 Households
Formal Housing	3 516 200 869	USD	71 615 Households
Roads	951 726 239	USD	8 281 641 m2
Health Facilities	282 771 928	USD	23
Educational Centres	356 456 521	USD	100
Airport – buildings	225 008 495	USD	61 177 m2
Airport - paved areas	49 070 038	USD	426 993 m2
Fire Brigades	1 711 306	USD	4
Electrical Grid	37 449 408	USD	1 187 km
Electrical Substations	1 250 000	USD	2
Drainage	66 676 712	USD	330 738 m2
Lakes and Waterbodies	74 775 592	USD	690 ha
Green spaces/ Forest	2 156 648	USD	401 ha
Heritage Sites	19 387 328	USD	41
Total Population	**64 790**	**People**	
Total Asset Value	5 625 618 408	USD	

2.2 Expected Damage Today and in the Future

The annual expected damage (AED) is an estimation of the average foreseeable effects on assets and people per year, in this case, related to floods. AED can be measured in percentage or absolute values and incorporates climate change and socio-economic scenarios. One economic scenario and two climate scenarios were selected for this study. Figure 2 shows annual expected damage in the Municipality of San Pedro Sula for assets in USD (*a and b*) and persons (*c and d*) today as well as for the future. The first bar in yellow represents the current AED (damage expected today). The dark red bar on the very left represents the total aggregated expected damage in 2042. This takes into account that the expected damage will increase over the next decades due to economic (or population) growth plus climate change. The orange and light red bars in the middle reflect the respective impact of these two factors: The second bar represents the AED due to economic development (for assets) and population growth (for persons). The light red bar represents the additional AED due to climate change in San Pedro Sula.

"Today" has been defined as 2017 in alignment with the Master Plan for Municipal Development (PMDM) from San Pedro Sula. The total expected damage for assets is projected to rise by 2042 48% compared to the USD 7.4m in 2017 due to economic growth[7] and 46% due to climate change (136% on the extreme climate scenario). A total of USD 14m AED (USD 21m for extreme climate change scenario) is simulated for the time horizon 2042. The increase in AED in 2042 represents a rise of more

[7] For economic growth and the discount rate an average annual rate of 2.24% and 3.3% are applied respectively as described in the data report. For the reader's convenience the details of the economic scenario can again be found in the ANNEX 7.

than 94% in San Pedro Sula, due both to economic growth (assets will be more valuable) and climate change (hazard will be more frequent and more intense).

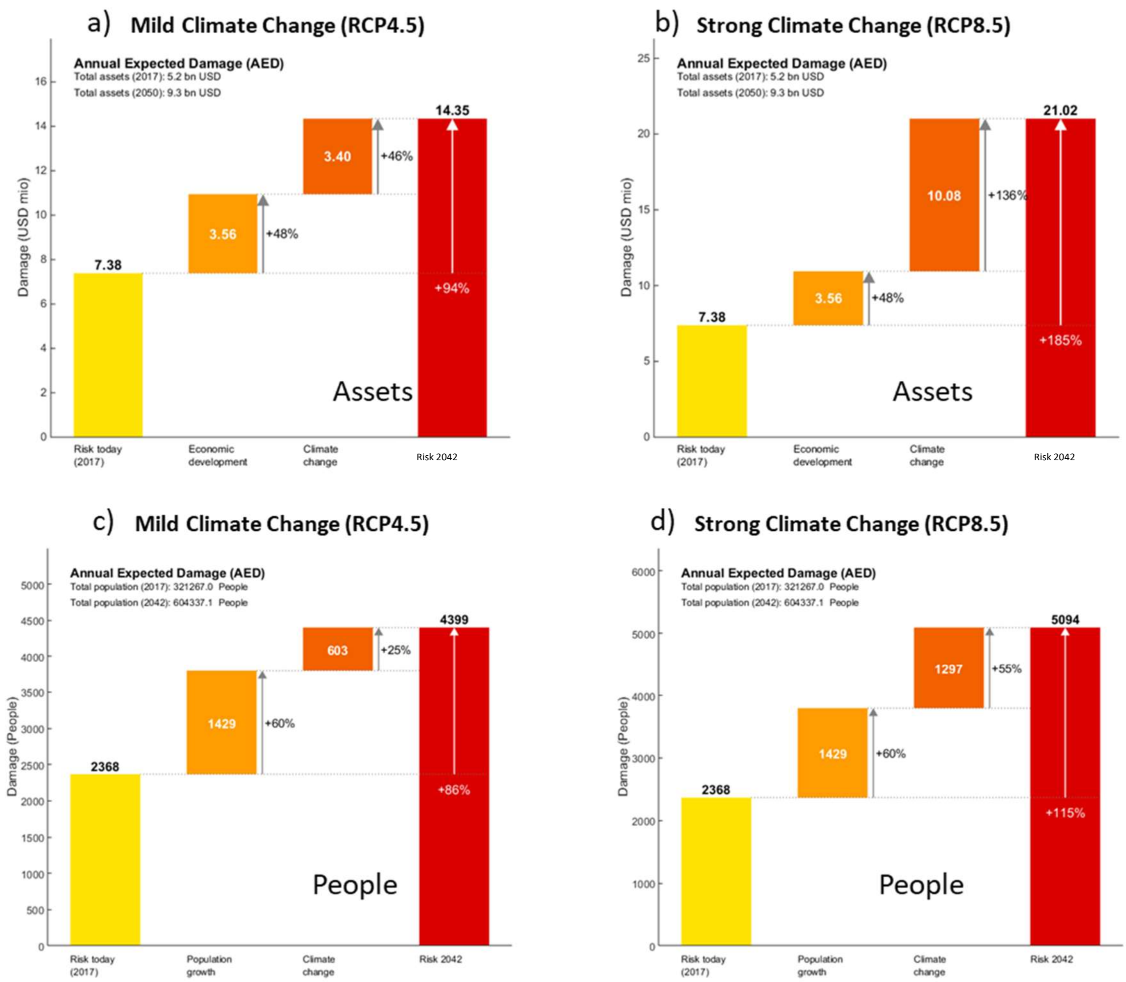

Figure 2 Annual expected damage (AED) in San Pedro Sula for Assets (a, b in USD) and people (c, d in people)

Regarding people, more than 2 300 people are expected to be affected by inundation annually in 2017. Although a relatively low rate of annual population growth is projected for the region, a cumulative increase of 60% is expected by 2042. The more intense climate will increase the number of affected persons by around 25% on a moderate climate change scenario and 55% with extreme climate. Taking both economic growth and climate change in consideration, a total of 4 400 (5 000 for extreme climate) people are expected to be affected in the year 2042. These figures have been compared to available historical damage data and show high confidence in the model outcomes and forecasting abilities. Notwithstanding, Eta and Iota hurricanes have demonstrated that large and rare events, statistically happening every 100 or 150 years, might happen more often and in a short amount of time after another.

3 ADAPTATION OPTIONS

3.1 Measures Costing

The adaptation measures were selected based on a comprehensive literature review and a consultation process with government officials from San Pedro Sula. In total, 47 adaptation measures were initially identified (referred to as "long list") and reduced to 12 (referred to as "shortlist") a transparent and participative selection process, including several stakeholder assignments and conducting a Multi-Criteria Analysis. 12 measures were introduced to CLIMADA, and later three (3) were highlighted as optimal by the modelling platform. These three (3) measures were further assessed during the pre-feasibility phase of the ECA study.

Table 2: Overview List of Flood Adaptation Measures for San Pedro Sula.

#	Name of Measure	Type of Measure	Zone	Total Cost (USD)
1	Establishment of flood collectors (Drainage system)	Grey	A, B, C	34 757 657
2	Water collection in existing buildings	Grey	A	563 257
3	Dry Flood-Proofing (housing)	Grey	A, C	6 243 582
4	“El Tablon” Hydropower Dam	Grey	C	279 489 491
5	Ecological restoration of river bank slopes	Green	A, B	834 721
6	Dry Detention Basins	Green	A	17 588 986
7	Reforestation of green spaces in urban areas	Green	A, B, C	8 226 158
8	Green Roofs	Green	A	22 893 988
9	Vegetated swales	Green	A, C	857 802
10	Flood Awareness & Preparedness Campaign	Operational	A, B, C	1 457 199
11	Community based solid waste management	Operational	A, B	1 794 590
12	Flood Index Insurance	Risk Transfer	A,B,C	-

In this study, costs, maintenance costs, and parameterization were calculated in close cooperation with local and international experts to achieve a reduced uncertainty related to measures. Nevertheless, unless using time-consuming modeling and engineering tools, the exact estimation of measures introduced in CLIMADA is difficult. The analysis offers only moderate confidence concerning the costs of measures presented in this report. Nevertheless, an update and detailed re-costing can be performed on measures selected for implementation within the Master Plan for Municipal Development.

3.2 Cost-Benefit Analysis

Next, the existing relationship between costs (investment and maintenance) and net averted damage of a given measure is analyzed. As stated before, the ECA framework estimates the benefit of adaptation measures based on their net averted damage.

An adaptation cost curve plots benefit/cost ratio (axis Y) against aggregated averted damages (axis X) for each measure. The value one (1) represents the threshold for the benefit/cost ratio, or in other words, values above it are cost-efficient while values below it are not. On the Y-axis, the larger a measure is, the larger the damage averted by it, therefore the larger the benefit or the mitigation or adaptation impact of a measure. Hence, with this figure, each measure can be analyzed in terms of damage mitigation/adaptation efficiency and cost efficiency and compared with one another.

In Figure 3 a) and b) all measures are beneficial, except for "green roofs" for assets and "retention basins" for people, which are less beneficial. Altogether, and for the time horizon 2042, these measures account for more than USD 700m of averted damage when combined without overlapping effect. The selected measures, therefore, offer a beneficial adaptation strategy against climate and economic change.

Typical green measures, such as "Ecological restoration", offer both a substantial benefit (> USD 30m) and a high cost/benefit ratio, where each invested dollar accounts for more than USD 70 of averted damage. Similarly, grey measures such as "refurbished collectors" in different zones offer a good alternative to new and expensive infrastructure work such as "new collectors". Other grey measures, such as "dry flood-proofing" are typically more efficient in terms of averted damage, but show a limited cost/benefit analysis for each invested dollar. Interestingly, "waste management" shows high efficiency and impact for SPS, making this measure worth considering.

In general, measures that are beneficial for people, benefit assets as well. Grey measures, such as "dry flood-proofing" and "waste management" when applied to protect people, show similar results as for assets. The exception is "vegetated swales", which benefit the road network but not people (matching the housing assets).

Figure 3 a) and b) display the expected impacts of measures applied to assets (Net Present Value) and people accumulated by 2042 under a moderate climate scenario. In the case of flood risk, a large number of measures (12 types of measures distributed in different locations adding up to a total of 22 projects) were selected for the cost-benefit analysis.

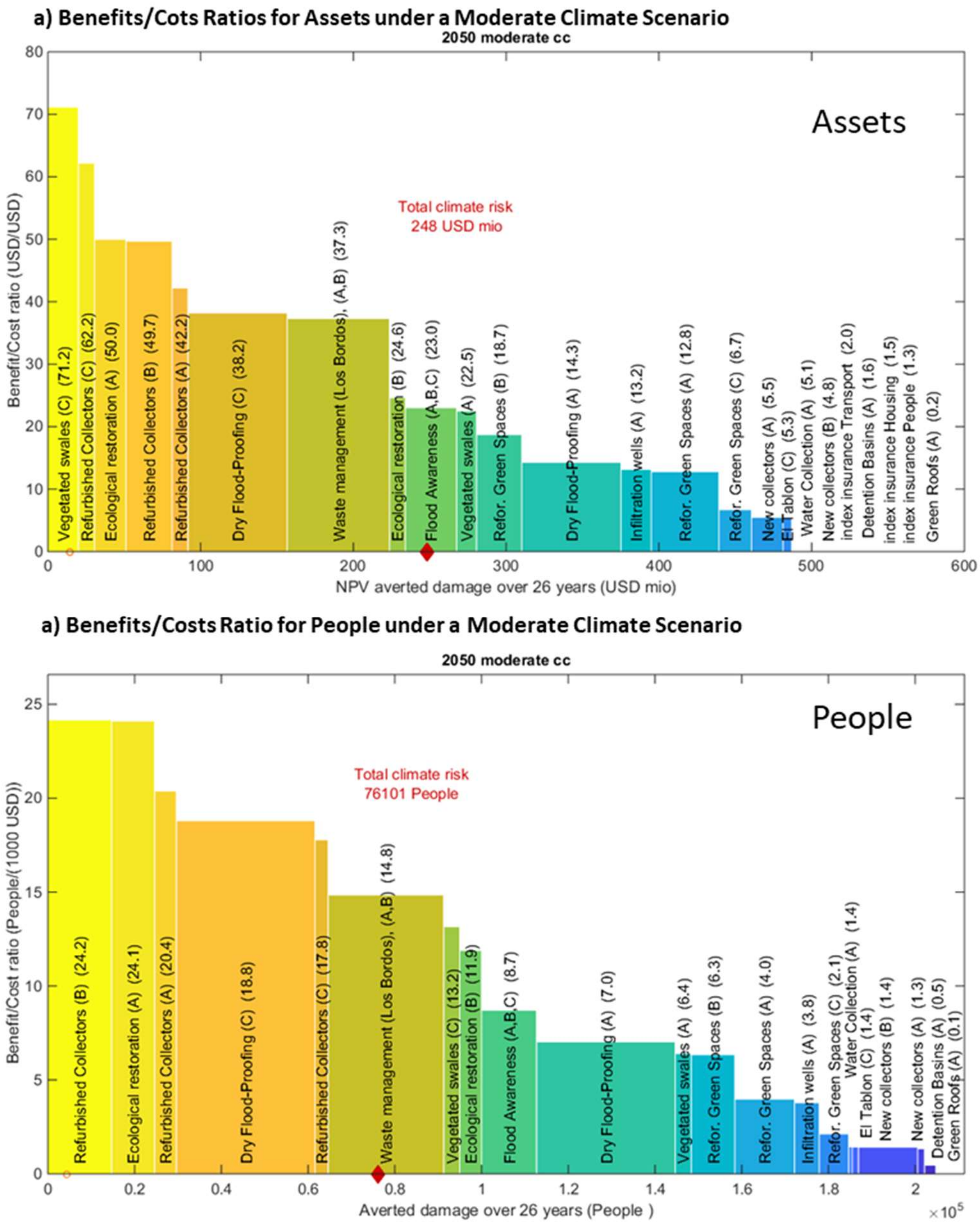

Figure 3 Adaptation cost curves for assets and people in SPS

3.3 Spatial Distribution of Benefits

Figure 4 and Figure 5 show the benefits of a measure, distributed according to the location of the assets that are affected. The benefits are represented by the annual averted damages averaged over a 26 years period on a certain asset. In Figure 4, we display the benefit of refurbished collectors in different zones for housing. Depending on the initial asset value, the benefit can be different from one asset to the other. Generally speaking, assets with a larger value for a similar hazard intensity are expected to show greater damages. Therefore, greater benefits are to be expected on these assets. Figure 5 shows similar results for the asset "road network" (each point represents a 100m section of the road network) and for the measures "reforestation" and "vegetated swales". The road network benefits the most from these measures, and its total accumulated value leads to significant benefits and cost/benefit ratios for these measures.

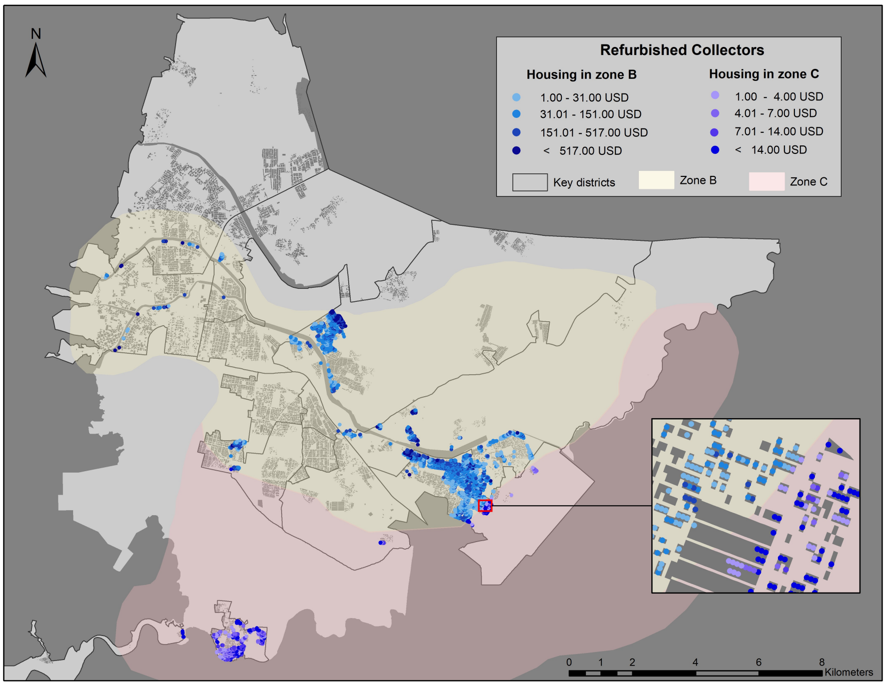

Figure 4 Spatial location of benefits for the measure "refurbished collectors" for housing

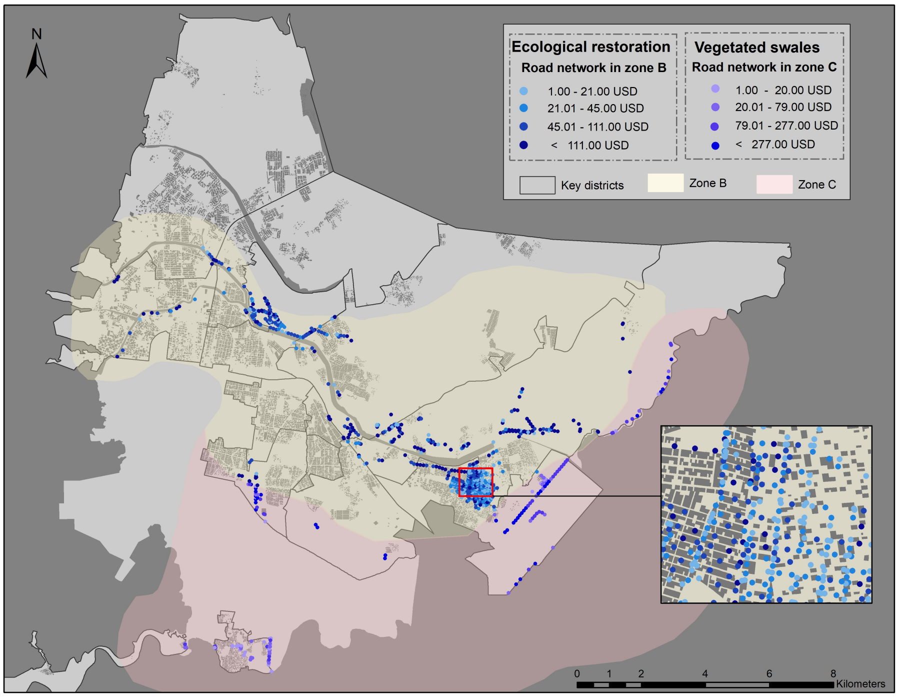

Figure 5 Spatial location map of benefits from the measures "ecological reforestation" and "vegetated swales" for the road network.

4 NEXT STEPS

Along with growing populations and economies, losses from natural hazards are rising. San Pedro Sula, like other urban areas in the world, is threatened by floods, droughts, and other extreme weather events. In this report, we applied the Economics of Climate Adaptation (ECA), a decision-making support framework, to integrate climate risk assessments and to identify the optimal portfolio of adaptation solutions.

In its first part, this report recalls the scope of the study that was agreed on in coordination with all stakeholders regarding the areas of the Municipality to be included, the scenarios (climatic and economic) to be applied, and what assets should be impacted. During several workshops and webinars, a portfolio of measures (from a longlist to a shortlist) was discussed and later modelled. Values have been validated by stakeholder's concertation and expert interviews.

Further, this report presents a brief overview of ECA and the main results of flood impact today and in the future using CLIMADA, a probabilistic modelling platform. By 2042, even in a moderate climate scenario flood damages in the Municipality are expected to rise by over 100% in San Pedro Sula, due both to economic growth (assets will be more valuable) and climate change (hazard will be more frequent and more intense).

Introducing a selection of adaptation measures provides insights for the development of a sound climate impact portfolio under the selected scenarios. Green measures and grey measures such as channel refurbishment give the best return on investment while offering good protection against future climatic risks. These measures represent an investment of USD 36m and would take approximately three years to implement. These measures are listed below:

1) Improvement and renovation of the rainwater collection and conduction systems, which includes the construction of 17,084 meters of new collectors and the renovation of 35,456 meters of existing collectors.
2) Ecological restoration of riverbank slopes through the introduction of reforestation and/or afforestation practices of 191 hectares.
3) Construction of vegetated water retention and absorption areas using 140 km of grassed ditches to reduce runoff from streets and sidewalks.

These measures were evaluated at the pre-feasibility level and were considered technically feasible considering regulations, technological feasibility, location, resources, and sustainability. In addition to being cost-efficient, the measures also have co-benefits such as reducing adverse health effects.

Economics of Climate Adaptation

Authors: Alvaro Rojas, David Daou, Florian Waldschmidt, Eike Behre, Teresa Arce Mojica, Preeti Koirala, Irafan Ullah, Zita Sebesvari, Sönke Kreft and Maxime Souvignet

Contributors: Annette Detken and Lena Laux

Design: Aileen Orate (UNU-EHS)

Suggested citation: *UNU-EHS & Frankfurt School of Finance & Management (2021). Urban Flood Risk in San Pedro Sula – Honduras: Executive Summary. Bonn/Frankfurt: United Nations University / Frankfurt School of Finance & Management GmbH. 15pp.*

Prepared by

UNITED NATIONS UNIVERSITY

UNU-EHS

Imprint: The research presented herein has been funded by the InsuResilience Solutions Fund programme, financed by KfW Development Bank on behalf of the Federal Ministry for Economic Cooperation and Development (BMZ) and is published as joint cooperation by Frankfurt School of Finance & ManagementgGmbH and United Nations University (UNU-EHS).

A project implemented on behalf of InsuResilience Solutions Fund

managed by Frankfurt School of Finance & Management

funded by KFW

on behalf of Federal Ministry for Economic Cooperation and Development

In cooperation ETH zürich