Economics of Climate Adaptation

September 2021

Executive Summary

Cần Thơ, Vietnam

Compound Flood Risk & Heat Waves

UNITED NATIONS UNIVERSITY
UNU-EHS

A project implemented on behalf of InsuResilience Solutions Fund

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List of Acronyms

BMZ	*German Ministry for Economic Cooperation and Development*
CCA	*Climate Change Adaptation*
CCCO	*Climate Change Coordination Office*
CRO	*Climate Resilience Office*
ECA	*Economics of Climate Adaptation*
ISF	*InsuResilience Solutions Fund*
IPCC	*Intergovernmental Panel on Climate Change*
KfW	*German Development Bank*
UNU-EHS	*United Nations University – Institute for Environment and Human Security*
WSDI	*Warm Spell Duration Index*

MAIN FINDINGS

In this report, flood and heat wave adaptation measures were analyzed for the city of Can Tho (in selected districts) with respect to their cost-efficiency and effectiveness on adaptation and risk reduction. 17 measures (10 measures for flood, 4 measures for heat waves and 3 measures for both, flood and heat waves) were successfully assessed using the modelling platform CLIMADA. The main findings are summarized below:

COMPOUND FLOOD RISK (TIDAL & PLUVIAL-FLUVIAL FLOOD)

1) Current annual expected damage is a cumulated USD 4.3m, increasing to over USD 18m by 2050 (moderate climate change);
2) A majority of selected measures are cost efficient for the respective assets to be protected;
3) Even if implemented combined these measures will not be sufficient to account for the total climate risk (94% of the total risk may be averted);
4) Remaining risks could be managed applying an insurance solution as the measure offering the highest risk mitigation potential for pluvial/fluvial flood;
5) The top three cost-efficient measures for TIDAL and PLUVIAL-FLUVIAL FLOOD are:
    a. "Mobile flood embankment"
    b. "Flood awareness"
    c. "Rehabilitation of drainage"

For compound flood risk, with the top three cost-efficient measures, Can Tho will be able to avoid an estimated USD 300 million in damages and protect around 15 000 people over the next three decades with an investment of under USD 5.8 million.

HEAT WAVE RISK

1) Current annual expected damage is a cumulated USD 87m, increasing to over USD 340m by 2050 (moderate climate change);
2) All selected measures are cost-efficient for the respective assets to be protected;
3) All measures combined are not sufficient to account for the total climate risk and a large protection gap remains (only 6% of the total risk may be averted);
4) Climate insurance for assets is can help cover residual risk after the three (3) most cost-efficient measures have been implemented;
5) The top three cost-efficient measures for HEAT WAVE are:
    a. "Cooling Centers"
    b. "Climate Smart Agriculture"
    c. "White Roofs"

With the top three cost-efficient measures, Can Tho will be able to avoid an estimated USD 250 million in damages from heat waves and protect around 800 000 people over the next three decades with an investment of under USD 16 million.

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 City of Can Tho, Vietnam, to identify the most cost-efficient measures to address the negative impacts of floods and heat waves. 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 and heat wave events in Can Tho. Stakeholders were asked to provide input and feedback on the assumptions, decisions, data, and adaptation options assessed. A total of 17 adaptation measures for flood and heat waves were identified and validated using 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

Global mean temperatures are constantly rising and already predicted risks associated with extreme events will continue to increase[1]. Among several countries worldwide, Vietnam is adversely affected by climate change and its effects through extreme weather events. According to the Global Climate Risk Index Report (2020), Vietnam has been identified as one of the ten most affected countries to extreme

[1] IPCC 2014. Retrieved from https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

events within the last two decades[2]. An often recurring event in Vietnam are floods. Flood risk is expected to increase, particularly in coastal areas in which population growth, urbanization and rapid socio-economic development are most abundant[3]. The Mekong River Delta is Vietnam's most important and largest region with respect to agricultural and aquacultural production systems, whereas a large extend of the delta is just under two meters above sea level[4]. A key concern in this region are the climate change impacts on existing flood regimes.

As a rapidly growing city, Can Tho faces multiple threats such as recurring (seasonal) flooding, sea-level rise, tidal surges land subsidence, salinization and extreme heat waves. Factors causing urban flooding in Can Tho City are Mekong River upstream floods combined with the high-tide regime of the Eastern Sea, which occurs at the start and middle of the lunar month[5]. These factors can often occur combined with a third flood regime caused by rain. Rainfall in Can Tho City usually lasts from 30 minutes to 2 hours with precipitation at 40–70 millimetres. In the middle of the rainy season, from August to October, urban flooding usually occurs right after the rain, especially in the lower areas inside the city[6]. Commonly, river discharges in Can Tho are high every season from September to November, whereas tidal flood often occur from October to January[7]. In 2008, 21 main streets were inundated to a depth up to 50 centimetres by high tides and a combination of heavy rains[8]. In October 2011, Can Tho faced a severe peak flood with a water level of 2.15 meters, inundating almost the whole city causing sensitive damages to the city's infrastructure, businesses and agricultural areas[9]. Some parts of the city, close to the river, were inundated for several months, with the consequence that about 27,000 houses were inundated and a total economic loss of 11.3 million USD occurred towards the city's infrastructure, businesses and agriculture[10].

Besides rapid urbanization, one important factor which influences floods in Can Tho is the water-system infrastructure. The different flood types increase the already high pressure on water supply-, sewage and drainage systems even further, while the sewer system is only partially capable of draining flood either from the river or from rain[11]. Sewer overflows induced by floods also present an increased health risk to the general population[12]. A need to re-route and re-design sewage and drainage networks and their interconnection has been recognized but represents a continuous challenge in the process of

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[2] D. Eckstein, V. Künzel, L. Schäfer, M. Winges. (2019). *Global Climate Risk Index 2020* (Briefing Paper), Germanwatch e.V. ISBN 978-3-943704-77-8. Retrieved from www.germanwatch.org/en/cri

[3] Do, T.C., Nguyen, D., Gain, A.K., Kreibich, H. (2017): Flood Loss Models and Risk Analysis for Private Households in Can Tho City, Vietnam. - Water, 9, 5.

[4] Tuan L.A., Chinvanno S. (2011) *Climate Change in the Mekong River Delta and Key Concerns on Future Climate Threats*. In: Stewart M., Coclanis P. (eds) Environmental Change and Agricultural Sustainability in the Mekong Delta. Advances in Global Change Research, Vol 45. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-0934-8_12

[5] Danh, V. T. (2019). Household economic losses of urban flooding. In *Groundwater and Environment Policies for Vietnam's Mekong Delta* (pp. 119-146). Springer, Singapore.

[6] Ibid.

[7] Chinh, D. T., Gain, A. K., Dung, N. V., Haase, D., & Kreibich, H. (2016). Multi-variate analyses of flood loss in Can Tho City, Mekong Delta. Water, 8(1), 6.

[8] Danh, V. T. (2019). Household economic losses of urban flooding. In *Groundwater and Environment Policies for Vietnam's Mekong Delta* (pp. 119-146). Springer, Singapore.

[9] Ibid.

[10] Chinh, D. T., Gain, A. K., Dung, N. V., Haase, D., & Kreibich, H. (2016). Multi-variate analyses of flood loss in Can Tho City, Mekong Delta. Water, 8(1), 6.

[11] Neumann, L., Nguyen, M., Moglia, M., Cook, S., & Lipkin, F. (2013). Urban Water Systems in Can Tho, Vietnam: Understanding the current context for climate change adaptation.

[12] Ibid.

urbanization and new residential clusters. Another challenge is the lack of a standardized approach for flood loss assessments in the Mekong Delta, including Can Tho City[13]. Flood hazard and risk assessments are typically only restricted to a single flood type.

A more increasing hazard occurring in Can Tho City and its surroundings are heat waves. Heat wave spells are considered as three consecutive days of extreme heat (maximum shade temperature reaches or exceeds 32.2°C) and the number is projected to increase in most areas of Central and South Vietnam[14]. Nonetheless, there is a challenge in recording and reporting statistics on damages due to heat waves, leading to the difficulty to appropriately evaluate the effects and introduce control measures. Forecasting and warning systems of heat waves become more sophisticated but often the effectiveness of preparedness and coping measures are still limited[15]. One study indicated that heat wave events caused a 12.9% increase in risk of hospitalization due to cardio-vascular diseases in Ho Chi Minh City[16]. Statistics on the affects from heat waves on urban infrastructure and people in Can Tho are not available. However, physical infrastructure such as energy systems, water storage, and transport could be affected by extreme heat both directly and indirectly, e.g. increased water and electricity demand during a heat wave, straining existing systems and potentially leading to shortages[17].

1.2.1 Policies and strategies to address Climate Change in Can Tho

National policies also require subnational governments to plan and manage for climate change, but no local government body has been established to mandate urban climate resilience planning. For this reason the Asian Cities Climate Change Resilience Network (ACCCRN), launched by the Rockefeller Foundation in 2008 provided funding and technical support to create provincial Climate Change Coordination Offices (CCCO's) in three Vietnamese cities – one of them being Can Tho City, who's CCCO was established in 2011. The role of Can Tho's CCCO is threefold: firstly, it provides and improves knowledge of local climate change impacts and interprets climate data for the use of other city departments; secondly, it coordinates climate action plans across sectors and identifies climate risks; and lastly, the CCCO intends to build capacity of other provincial government bodies to better understand and apply resilience plans[18]. In Can Tho the CCCO has coordinated the development of a climate change information database, including socio-economic data, which can be accessed by different city departments and agencies[19].

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[13] Chinh, D. T., Gain, A. K., Dung, N. V., Haase, D., & Kreibich, H. (2016). Multi-variate analyses of flood loss in Can Tho City, Mekong Delta. Water, 8(1), 6.

[14] IMHEN and UNDP. 2015. Viet Nam Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Retrieved from: https://www.vn.undp.org/content/vietnam/en/home/library/environment_climate/viet_nam_special_report_on_managing_the_risks_of_extreme_events_and_disasters.html

[15] Ibid.

[16] Phung, D., Chu, C., Rutherford, S., Nguyen, H. L. T., Do, C. M., & Huang, C. (2017). Heatwave and risk of hospitalization: A multi-province study in Vietnam. *Environmental Pollution*, *220*, 597-607.

[17] Singh, R., Arrighi, J., Jjemba, E., Strachan, K., Spires, M., Kadihasanoglu, A., Heatwave Guide for Cities. 2019. Red Cross Red Crescent Climate Centre.

[18] Institute for Social and Environmental Transition (ISET)-International. 2017. *The Role of Climate Change Coordination Offices in Building Resilience*. *Lessons from the Asian Cities Climate Change Resilience Network* (ACCCRN). Retrieved from: https://www.preventionweb.net/files/56917_cccolessonlearnedsten170526v2.pdf

[19] Ibid.

Can Tho also has been engaged in the 100 Resilient Cities (100RC) programme supported by the Rockefeller Foundation[20]. The 100RC programme supported 100 cities worldwide to develop resilience strategies against the impacts of climate change. For this purpose, a local Climate Resilience Office (CRO) has been established in Can Tho to mandate and execute the 100RC programme. However, after three years, in July 2019 the programme was concluded with the creation and delivery of a *Can Tho Resilience Strategy (2030)*, focusing on four resilience dimensions: leadership and strategy, infrastructure and environment, economy and society, and health and well-being[21]. Despite the end of the 100RC programme, the Rockefeller Foundation continues its support to the CRO's through the Global Resilient Cities Network[22].

The Government of Vietnam has recognized the country's high vulnerability to the impact of climate change and reacted with the following initiatives and policies[23]:

National focus:

- National Target Program to Respond to Climate Change (Decision No. 158/2008/QD-TTg dated December 2, 2008), and the subsequent National Strategy to implement some of its provisions (2139/2011/QĐ-TTg), all updated for the period 2012-2015 in Decision 1183/2012/QĐ-TTg)
- Ministry of Construction, has requested all provinces to consider the impacts of climate change when planning and approving urban development (Decision 2623/2013/QĐ-TTg dated 31/12/2013)
- Ministry of Planning and Investment has prepared guidelines to support prioritization of climate adaptation actions in preparation of SEDP (Decision 1485/2013/QĐ-BKHĐT dated 17/10/2013)
- Ministry of Agriculture and Rural Development: Disaster Risk Reduction (DRR) policy (GoV Decision 1002/2009/QĐ-TTg on CBDRM dated 13/07/2009) and urban DRR guidelines
- Vietnam's National Adaptation Plan (NAP) for the period 2021-2030, Vision 2050 (ongoing process)
- Intended Nationally Determined Contribution (INDC) of Vietnam (2016-2050) to meet the needs of the Paris Agreement[24]

Sub-national focus:

- Can Tho's (100RC's) Resilience Strategy Framework (2030), 2019[25]
- Master Plan for Socio-Economic Development of Can Tho City through 2020 with vision towards 2030 (Decision No. 1533/QD-TTg)[26]
- Master plan of the Can Tho City till 2030 and with a vision to 2050 (Decision No: 1515/QD-TTg)[27]
- Government Resolution 120 /NQ-CP on Sustainable and Climate-Resilient Development of the Mekong Delta of Viet Nam[28]

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[20] https://www.100resilientcities.org/

[21] https://www.100resilientcities.org/wp-content/uploads/2019/06/Resilience-Strategy-Can-Tho-English.pdf

[22] https://www.preventionweb.net/news/view/70490

[23] IMHEN and UNDP. 2015. Viet Nam Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. Retrieved from: https://www.vn.undp.org/content/vietnam/en/home/library/environment_climate/viet_nam_special_report_on_managing_the_risks_of_extreme_events_and_disasters.html

[24] https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Viet%20Nam%20First/VIETNAM'S%20INDC.pdf

[25] https://www.100resilientcities.org/wp-content/uploads/2019/06/Resilience-Strategy-Can-Tho-English.pdf

[26] http://www.fao.org/faolex/results/details/en/c/LEX-FAOC164832

[27] https://vanbanphapluat.co/decision-no-1515-qd-ttg-the-project-on-adjustment-of-the-master-plan-of-can-tho-city-till-2030

[28] https://www.mekongdeltaplan.com/regional-coordination/government-resolution-120

- Can Tho Climate Change Activities Strategy in the Period 2015-2030, Can Tho's People's Committee, 2015[29]

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.

[29] https://www.acccrn.net/sites/default/files/publication/attach/150526-canthoresilienceactivitiesstratergy-15-30f.pdf

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 Can Tho, 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: The 2D flood model was developed in collaboration with DLR with a high resolution LIDAR digital elevation model (DEM) with 5m resolution, providing the highest accuracy possible in the region. To date, no other studies attempted simulation at this resolution for such a large area. The DEM was enhanced by buildings locations (relevant for water flows) using the latest generation of high resolution satellite imagery (Quickbird, 2012) provided by German Aerospace Center (DLR). It is intended to seek further cooperation with the beneficiaries of the study, i.e. the City of Can Tho, in order to allow updates and additional analysis of the model in the future.

Heat Wave Modelling: a heat wave module was developed for CLIMADA using the warm spell duration index (WSDI) for the simulation of stochastic heat wave indices using the RCA4 dataset. This heat wave model is applicable in any other area of the world.

Asset Valuation: In collaboration with all stakeholders, 8 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*

	Heat Wave		Pluvial/ Fluvial Floods		Tidal Floods	
	Sample size	Total (m USD)	Sample size	Total (m USD)	No / area / length	Total (m USD)
People	*551 912*		167 557		80 220	
Houses	*153 424*	1 970.98	46 619	589.15	22 292	275.36
Schools	*77*	279.31	58	205.55	25	55.50
Medical Facilities	*40*	653.62	22	394.91	6	29.97
Adm. Buildings	*51*	22.52	47	21.95	12	6.19
Road network	*1 097.4 km*	937.66	1 086.2 km	930.11	731.0 km	604.36
Electricity grid	*1 097.4 km*	6.58	1 086.5 km	6.52	729.1 km	4.37
Nat. Resources	*8 512 ha*	113.61	8 551 ha	115.56	8 268 ha	111.84
Total		1 051.75		2 263.76		1 087.61

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 and heat waves. 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. Consequently, two scenarios reflecting a mild and a strong climate change scenario (RCP 4.5 and RCP 8.5. respectively) are presented for each hazard in the following paragraphs.

The following figures show annual expected damage from tidal flood (Figure 1), pluvial/fluvial flood (Figure 2) and heat waves (Figure 3) in Can Tho for assets in USD (graph a and b) and for people (graph c and d). The first bar in yellow represents annual expected damage today. The second bar (economic development) represents the increase of the expected annual damage over the next 30 years due to economic development (for persons, it represents the expected population growth). The light red bar represents the additional annual expected damage due to climate change in Vietnam. Last, the red bar represents the total aggregated expected annual damage in 2050, when economic growth (and population growth) and climate change are considered.

2.2.1 Tidal Flood

The total expected damage from tidal flood for assets of USD 940k (2020) is expected to rise to 235% due to the strong economic growth and 65% due to climate change (94% with extreme climate scenario).

A total damage of USD 3.7m (USD 4m for extreme climate change scenario) is simulated for the time horizon 2050. The increase in annual expected damage in 2050 represents a rise of more than 300% in Can Tho, due both to economic growth (assets will be more valuable) and climate change (hazard will be more frequent and more intense). This large increase is mostly reflected by a strong economic growth prediction. In addition, flood events are expected to worsen in the coming decades. Regarding the population, more than 1,500 people are expected to be affected by floods annually in 2020. In line with a relatively low population growth in the area, an increase of the city population by 4% is expected in the future. More intensive climatic effects, in return are expected to affect more persons with an increase of 42% for a moderate climate and 44% for extreme climate. Consequently, taking economic growth as well as climate change into account ,a total of 2,253 people (2,296 for extreme climate) are expected to be affected annually in 2050, i.e. an increase of 46% and 49% compared to 2020.

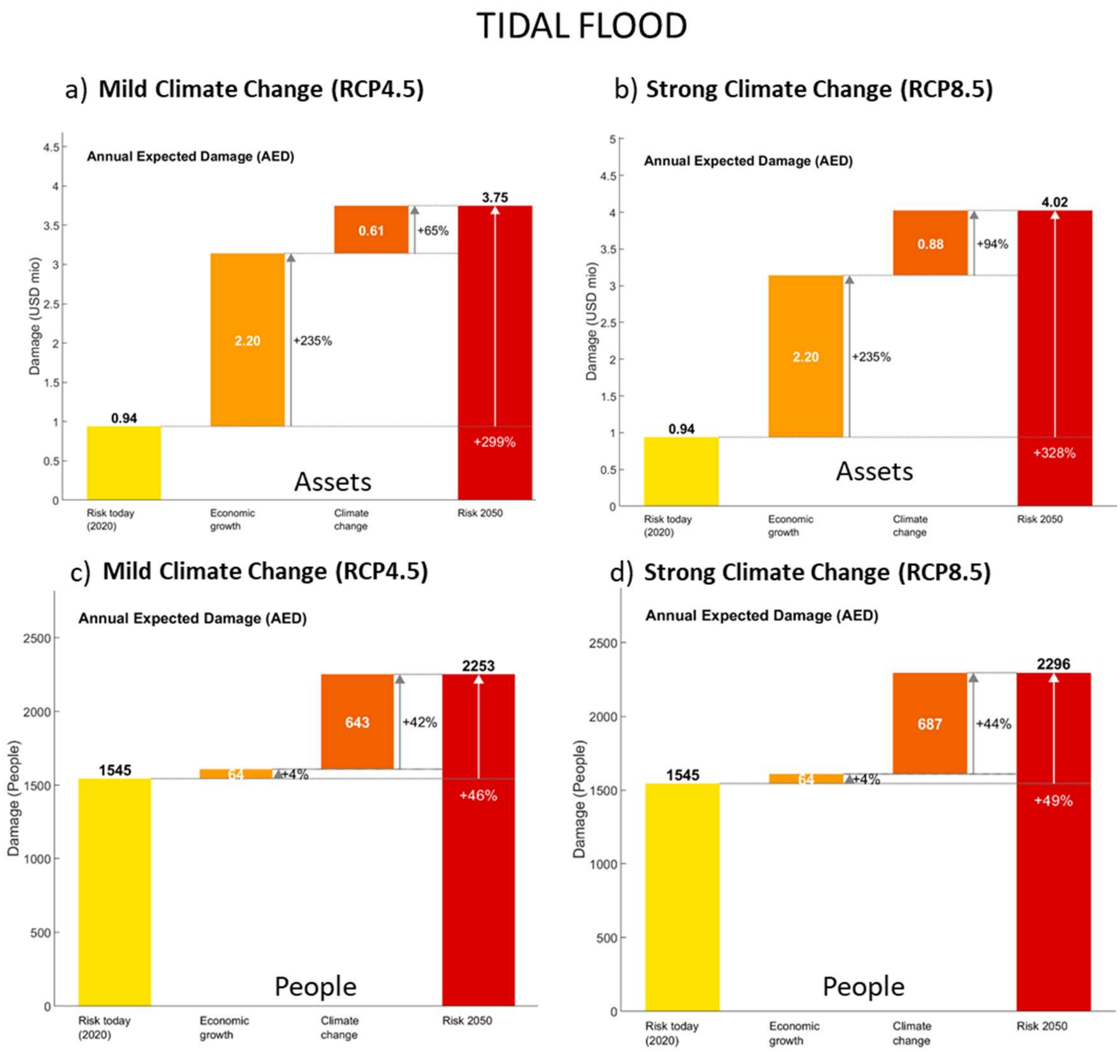


Figure 1: *Annual expected damage (AED) for Tidal Flood in Can Tho for Assets (graphs a & b in USD) and people affected (graph c & d in people).*

2.2.2 Pluvial/Fluvial Flood

In Can Tho, the total expected damage from pluvial and fluvial flood combined for assets of USD 3.3m (2020) is expected to rise to 321% due to the strong economic growth and of 46% due to climate change (131% with extreme climate scenario). A total of USD 15.7m (USD 18.6m for extreme climate change scenario) are simulated for the time horizon 2050. The increase in annual expected damage by 2050 represents a rise of more than 360% in Can Tho, due both to economic growth (assets will be more valuable) and climate change (hazard will be more frequent and more intense). This large increase is mostly reflected by a strong economic growth prediction. In addition, flood events are expected to worsen in the coming decades. Regarding the population, more than 2,920 people are expected to be affected by floods annually in 2020. In line with relatively low population growth in the area, based on the analysis the number of people expected to be affected will increase by 10% in the future. More intensive climate change, in return is expected to affect more persons with an increase of 82% for a moderate climate and 120% for extreme climate. Therefore accounting for economic as well as climatic factors overall more than 5,600 people (6,700 for extreme climate) are expected to be affected annually in 2050, i.e. an increase of 92% and 130% compared to 2020.

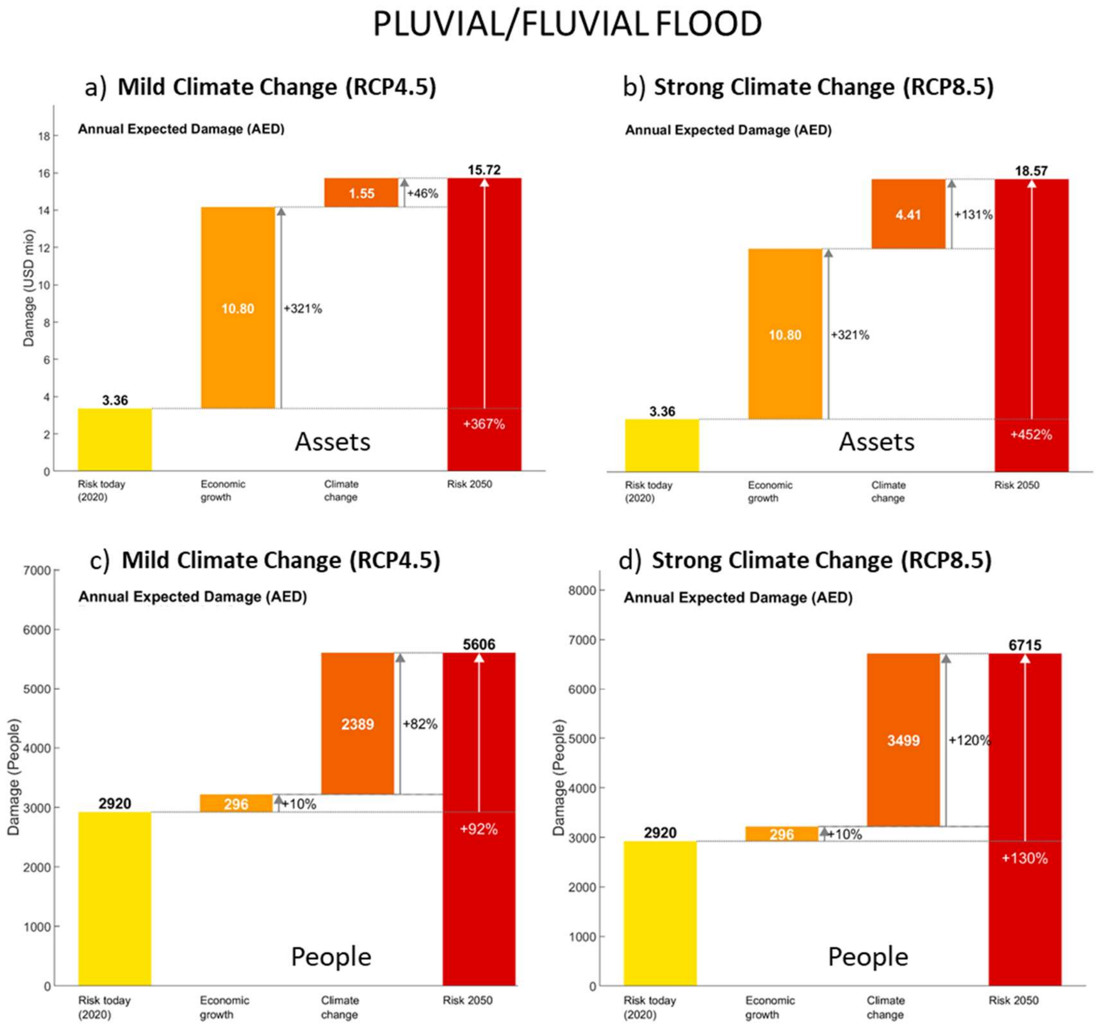


Figure 2: *Annual expected damage (AED) for Pluvial/Pluvial Flood in Can Tho for Assets (graph a & b in USD) and People affected (graph c & d in people).*

2.2.3 Heat Waves

For the city of Can Tho, a total expected damage from heat wave for assets of USD 87m (2020) are expected to rise to 222% due to the strong economic growth and to 36% due to climate change (148% with extreme climate scenario). Thus a total damage of USD 341m (USD 439m for extreme climate change scenario) is simulated for the time horizon 2050. The increase in annual expected damage in 2050 represents a rise of more than 400% in Can Tho, due both to economic growth (assets will be more valuable) and climate change (hazard will be more frequent and more intense). This large increase is mainly reflecting robust economic growth predictions for the City. In addition, heat wave events are expected to worsen in the coming decades.

Regarding the population, more than 540,000 people are expected to be affected by heat waves annually in 2020. In line with a relatively low population growth in the area, the number of affected people is expected to increase by 10% in the future. Increasing temperatures, in return, are expected to affect more persons with an increase of 6% for a moderate climate and 75% for extreme climate. A total of 630k people (1m for extreme climate) are expected to be affected annually in 2050, i.e. an increase of 16% and 85% compared to 2020.

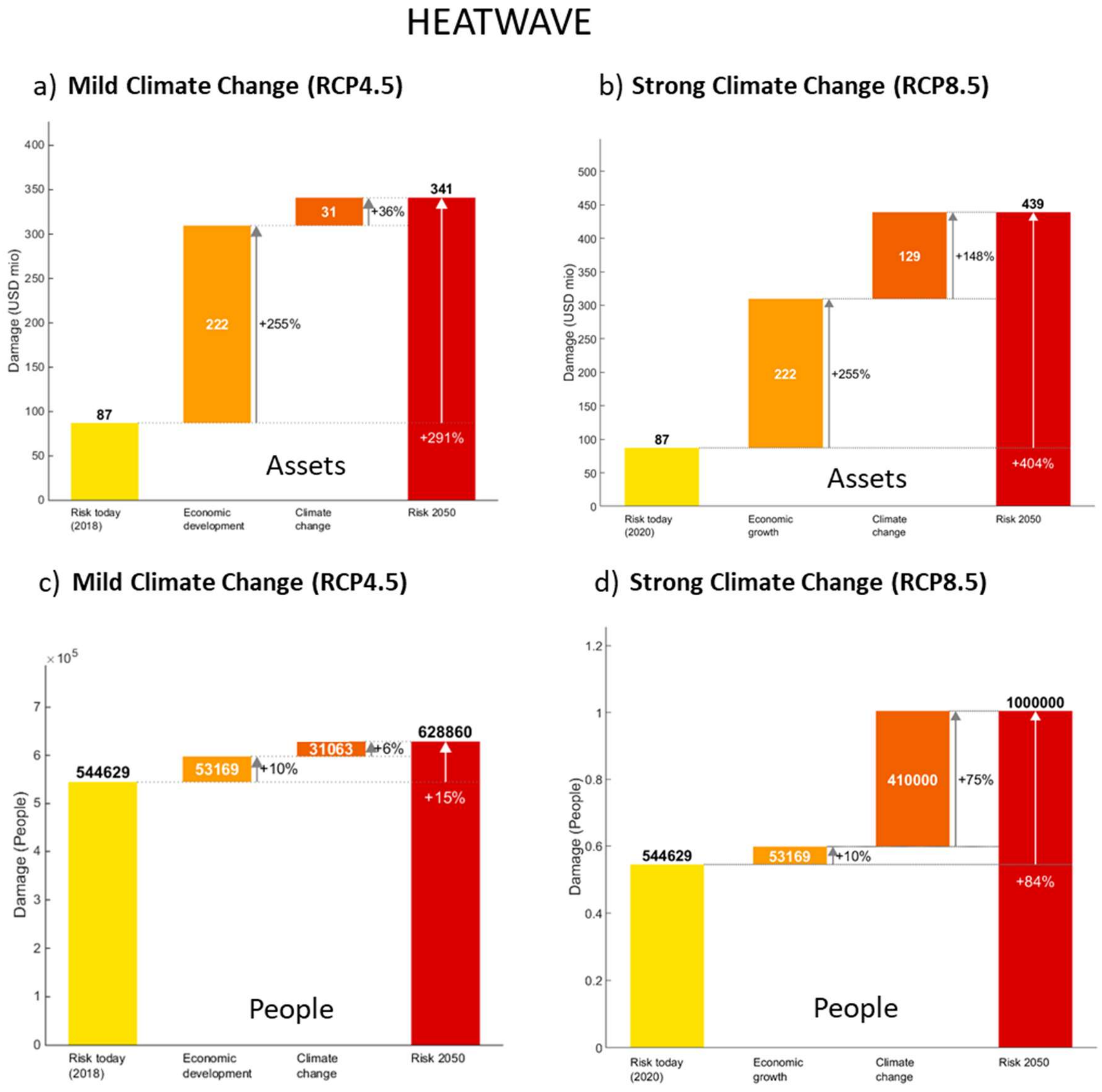


Figure 3: *Annual expected damage (AED) for Heat Wave in Can Tho for Assets (a & b in USD) and People (c & d in people)*

3 ADAPTATION OPTIONS

3.1 Measures Costing

Table 2: *Overview list of flood and heat wave adaptation measures for Can Tho.*

Measure	Total Cost in USD (30 years, incl. maintenance)	Hazard
1. Retention Reservoirs	1 150 825	pluvial-fluvial, tidal
2. Detention swales along roads	3 554 522	pluvial-fluvial, tidal
3. Improved solid waste management	1 566 192	pluvial-fluvial, tidal
4. Rehabilitation of existing drainage canals	3 185 343	pluvial-fluvial, tidal
5. Flood awareness campaign	1 165 758	pluvial-fluvial, tidal
6. Road spillways as bio-retention systems	9 414 001	pluvial-fluvial, tidal
7. Rain collection tanks for existing buildings	222 999	pluvial-fluvial
8. Mobile flood embankments	1 719 204	pluvial-fluvial, tidal
9. Flood wall	7 380 000	pluvial-fluvial, tidal
10. Flood protection storage facility (incl. sandbags)	921 557	pluvial-fluvial, tidal
11. Green Roofs	3 435 565	pluvial-fluvial, heat wave
12. Green spaces (Urban Forestry)	1 525 341	pluvial-fluvial, tidal, heat waves
13. White Roofs	2 658 463	heat wave
14. Cooling centers	4 439 100	heat wave
15. Climate smart agriculture	9 600 000	heat wave
16. Climate proofed standards for road design	1 980 250	heat wave
17. Index Insurance	(2 200 000 per year/flood) (500 000 per year/ heat wave)	pluvial-fluvial, tidal, heat waves
TOTAL[30]	53 919 120	all

[30] Excluding costs for Index Insurance

The adaptation measures were selected based on a comprehensive literature review and a consultation process with government officials from Can Tho City. In total, 37 adaptation measures were initially identified (referred to as "long list") and reduced to 17 (referred to as "shortlist") a transparent and participative selection process, including several stakeholder assignments and conducting a Multi-Criteria Analysis. A total of 17 measures were introduced to CLIMADA, and later six (6) were highlighted as optimal for the different forms of flood and three (3) for heat waves by the modelling platform. Out of these, a selected number of measures was further assessed during the pre-feasibility phase of the ECA study.

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.

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

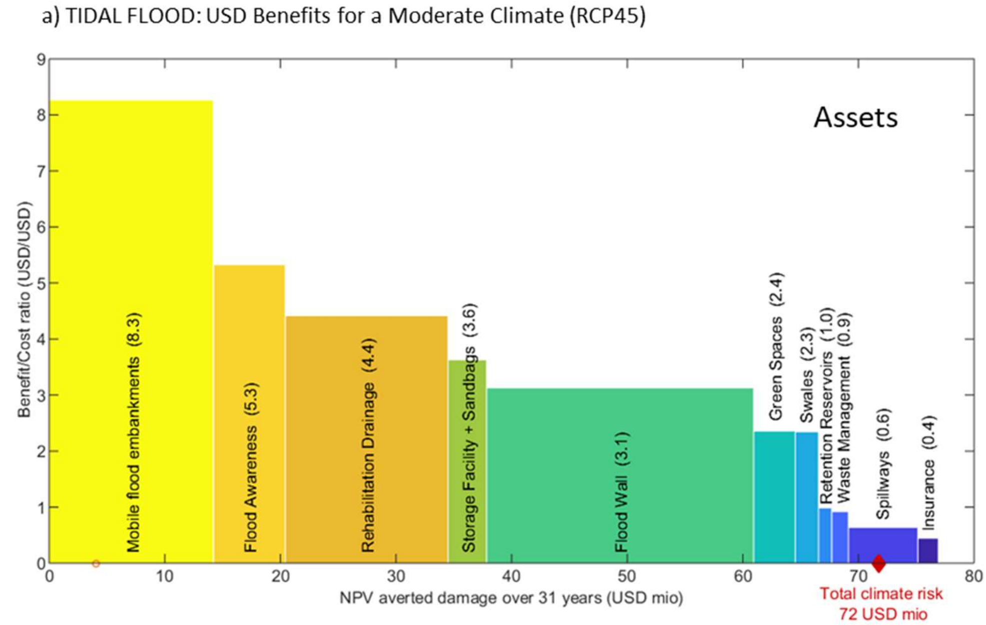
3.2.1 Tidal Flood

Figure 4 a) and b) displays impacts of measures applied to assets and people in Can Tho under moderate climate scenario. In the case of tidal flood risk, a large number (13) of measures were selected for the cost-benefit analysis. Low cost infrastructural measures, such as “Mobile flood embankments” (20% reduction of total climate risk)[31] or “Rehabilitation of Drainage” (20% reduction of total climate risk) are efficient in terms of averted damage, with each of them showing a good cost-benefit ratio for each invested dollar. These measures, although being cost-efficient, have a low adaptation/mitigation impact with exception of “Flood wall” (32% reduction of total climate risk). All measures combined without overlapping effect and without insurance may avert more than USD 75 m of future damage.

Figure 4 b) presents the impact of measures on affected persons in Can Tho for tidal flood risk. All measures altogether are expected reduce the number of affected persons by almost 15,000 per invested 1,000 USD. It means that the measures selected for assets are beneficial for people as well, protecting

[31] For the moderate RCP45 scenario

all 11,300 people at risk. Nevertheless, only three measures are beneficial for population, namely "Flood Awareness" (25% reduction of total climate risk), "Waste management" (32% reduction) and "Mobile flood embankments" (16% reduction). "Mobile flood embankment" and "Flood awareness" are both effective and beneficial at protecting assets and population, and they should therefore be considered.



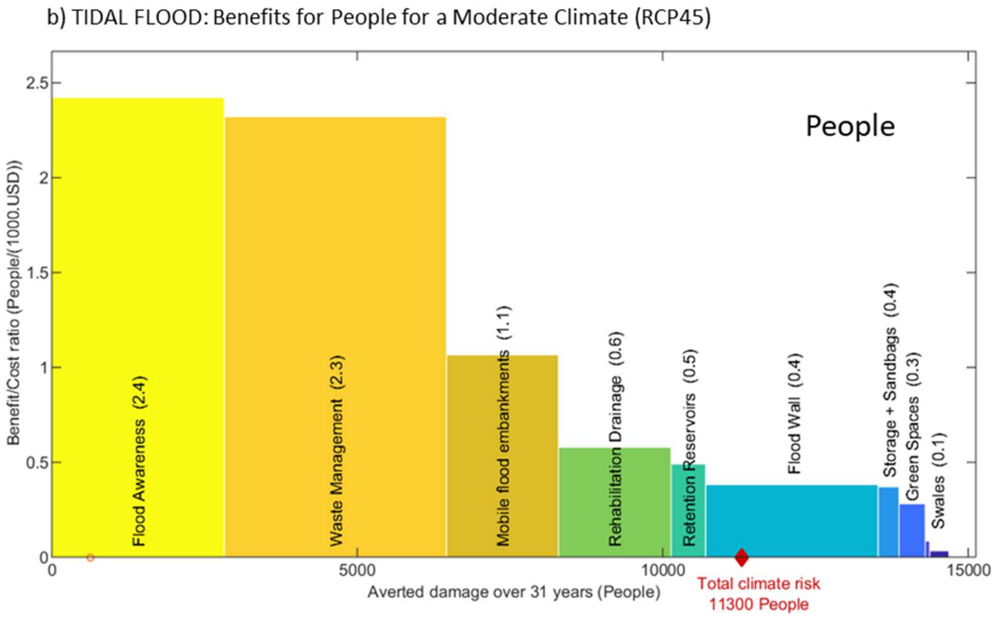


Figure 4: *Adaptation cost curve for assets damage for Tidal Flood in a) USD and b) people for a moderate climate scenario.*

3.2.2 Fluvial/Pluvial Flood

Figure 5 a) and b) displays impacts of measures applied to assets and people in Can Tho under a moderate climate scenario. In the case of pluvial/fluvial flood risk, a large number (13) of measures were selected for the cost-benefit analysis. Infrastructural measures, such as "swales" (16% impact reduction for moderate scenario) and low-cost approaches such as "Mobile flood embankments" (30% impact reduction) or “Rehabilitation of Drainage” (34% reduction of total climate risk) are efficient in terms of averted damage, and show a good cost-benefit ratio for each invested dollar. For Can Tho, all measures are cost-efficient, and account altogether for more than USD 650 m of averted damage, if combined without overlapping effect and with insurance. In addition, it should be mentioned that “Flood Walls” reduce expected future losses to a great extent as well (to a greater extent than e.g. swales). Yet as a flood wall is associated with less benefits for each dollar invested, this measure is less beneficial than e.g. swales.

Figure 5 b) presents the impact of measures on affected persons in Can Tho for pluvial/fluvial flood risk. All measures, altogether are expected to reduce the number of affected persons by almost 2m per invested 1,000 USD. It means that measures selected for assets remain have the potential to protect population at risk. All measures but one are beneficial for people with, namely “Waste management” (12% impact reduction), “Flood Awareness” (8% impact reduction) and “Swales” (10% impact reduction) showing the highest cost-benefit ratio. “Mobile flood embankment” (10% impact reduction) is also very efficient and might be considered while discussing measures that protect both population and assets. Therefore, “Swales”, “Mobile flood embankments”, “Rehabilitation of drainage”, “Flood awareness”, and “Waste management” should be considered for adaptation planning in Can Tho.

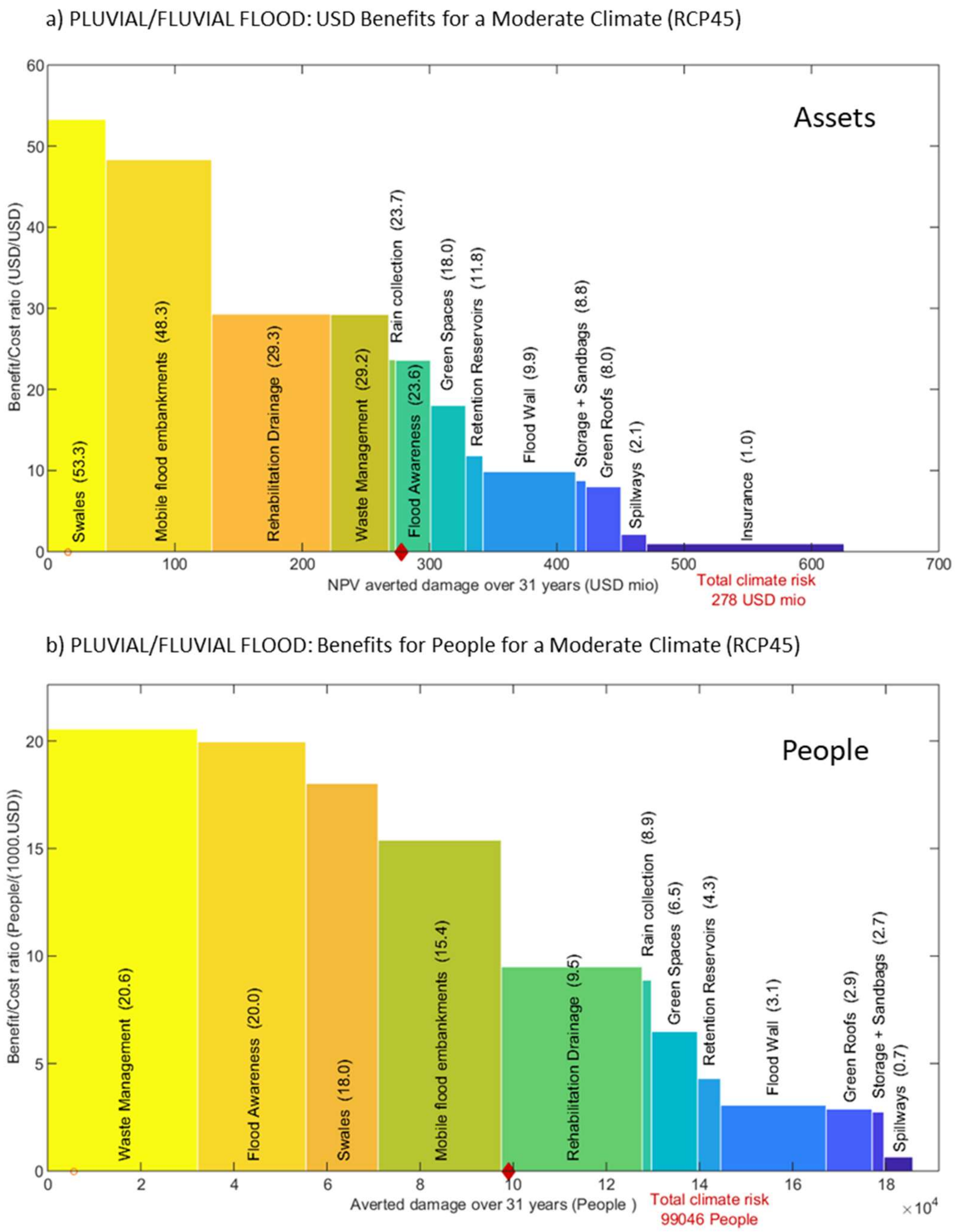


Figure 5: *Adaptation cost curve for Pluvial/Fluvial Flood a) assets and b) people for a moderate climate scenarios.*

3.2.3 Heat Waves

Figure 6 a) and b) displays the impacts of measures applied to assets and people in Can Tho under moderate climate scenario. In the case of heat wave risk, a reduced number (6) of measures were selected for the cost-benefit analysis. Low cost infrastructural and green measures, such as "Green roofs" or "White roofs" are generally less efficient in terms of averted damage but show a good cost-benefit analysis for each invested dollar. "Climate smart agriculture" shows the best cost-benefit ratio for assets in Can Tho. In Can Tho all measures are cost efficient and account altogether to more than

USD 350 m of averted damage, if combined without overlapping effect and without insurance. It means that all measures combined, even with insurance, are not enough to cover the expected damages in the region.

Figure 6 b) presents the impact of measures on affected persons in Can Tho for heat wave risk. All measures account altogether to a reduction of almost 1.5m affected persons per invested 1,000 USD. It means that measures selected for assets have the potential to protect population at risk. Nevertheless, all measures combined together cover only a small part of the potentially affected population, and indicate therefore a large protection gap when it comes to heat wave. "White roofs" and "Cooling Centers" are the most beneficial measures.

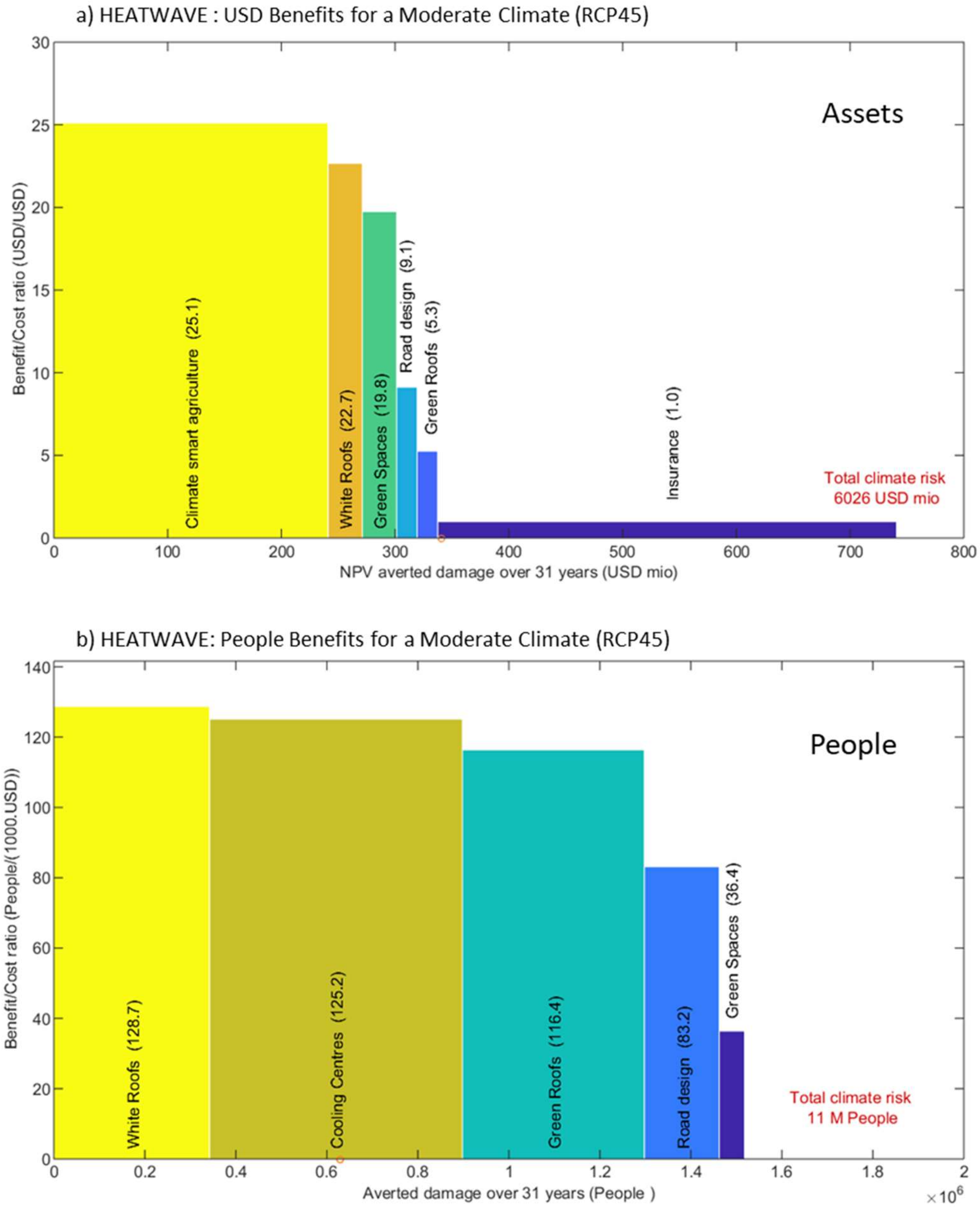


Figure 6: *Adaptation cost curve for assets damage for Heat Wave for moderate climate a) assets and b) population*

3.3 Spatial Distribution of Benefits

3.3.1 Tidal and Pluvial/Fluvial Flood

The figures below illustrate the spatial distribution of benefits on selected assets resulting from the respective measure as indicated. Due to limitations in the hazard resolution, the highlighted areas of benefit are only indicative and not to be understood as exact locations. The benefits are presented as the annual averted damages averaged over the here relevant period of 31 years. In Figure 7 and Figure 8, for instance, the benefits of the rehabilitation of drainage for housing for tidal and pluvial fluvial floods is being displayed. It highlights that the measure can have very different benefits depending on the location of the assets considered.

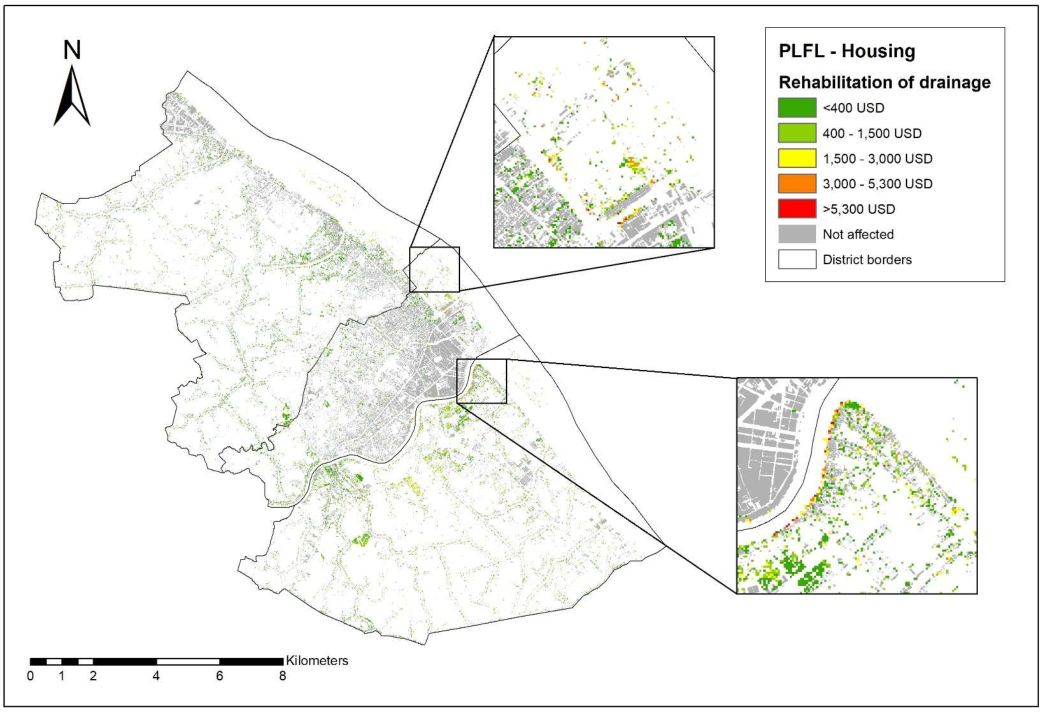


Figure 7: *Spatial location of benefits for rehabilitation of drainage for housing (Pluvial/Fluvial Flood Risk)*

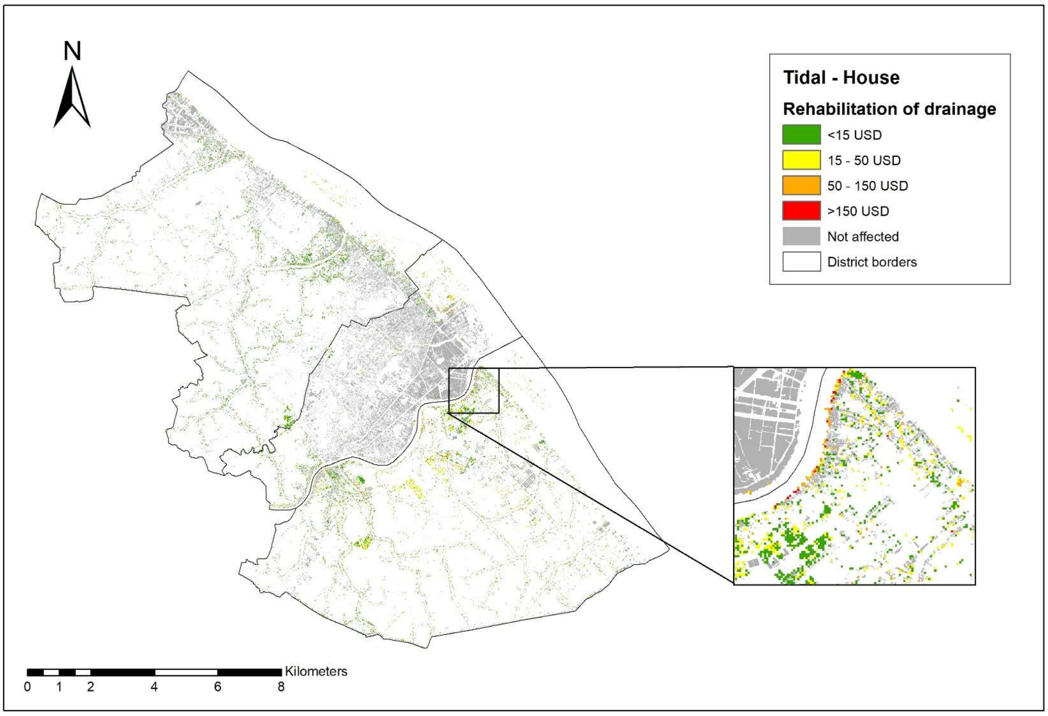


Figure 8: *Spatial location of benefits for rehabilitation of drainage for housing (Tidal Flood Risk)*

3.3.2 Heat Waves

Figure 9 and Figure 10 below illustrate the spatial distribution of benefits on selected assets resulting from the respective measure to protect assets and the population of Can Tho against heat waves as indicated. Due to limitations in the hazard resolution, the highlighted areas of benefit are only indicative and not to be understood as exact locations. The benefits are presented as the annual averted damages averaged over the here relevant period of 31 years for selected measures and assets.

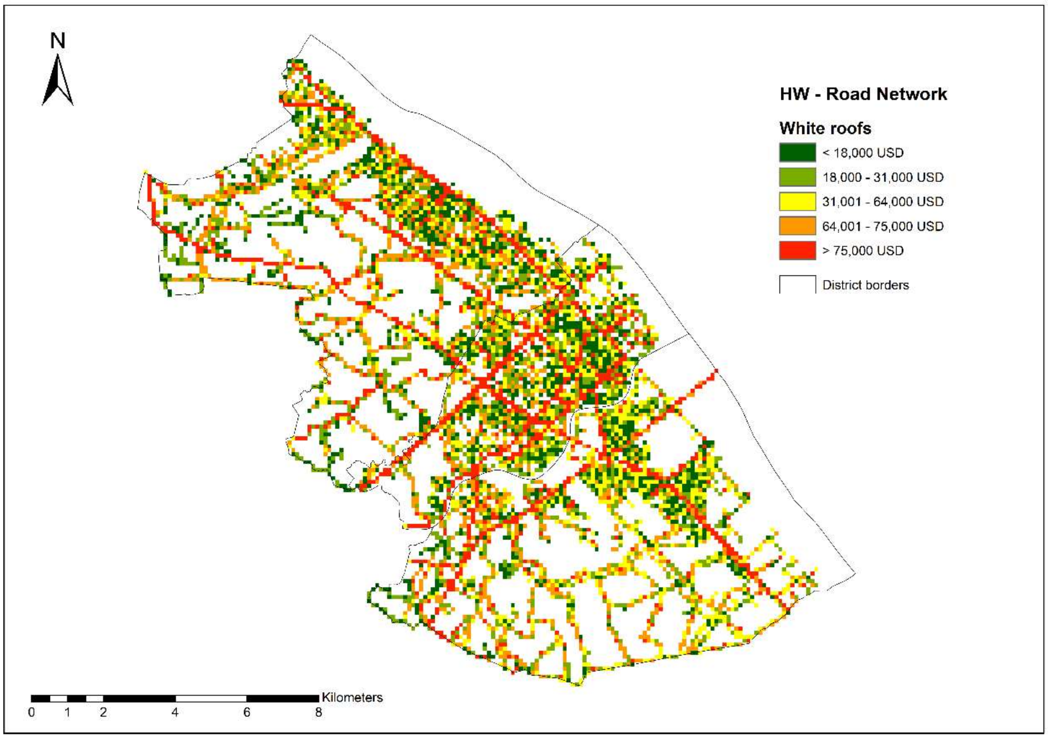


Figure 9: *Spatial location of benefits of white roofs for road networks (Heat Wave Risk)*

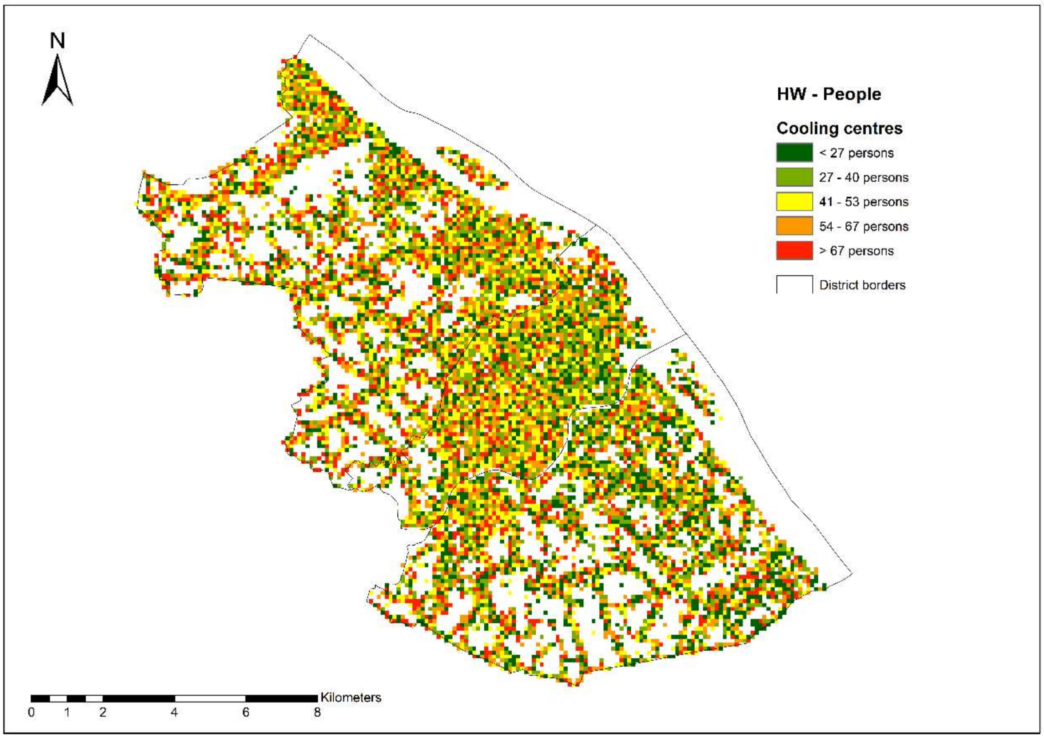


Figure 10: *Spatial location of benefits of cooling centers on people (Heat Wave Risk)*

4 NEXT STEPS

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

In its first part, this report recalls decisions made in coordination with all stakeholders regarding the scenarios (climatic and economic) to be applied and what assets should be considered in the analysis. During several workshops and webinars, a portfolio of measures (from a long list to a short list) have been discussed. Values have been validated by stakeholders' concertation and expert interviews.

Further, this report presents the results, assumptions and limitations of the development of a flood and heat wave model for the region of Can Tho. The flood model developed for the purpose of this report provides a unique improvement in resolution and quality to the simulation of different types of floods in the region. The heat wave model is based on internationally recognised indices and has been developed for the purpose of this study. Its integration into CLIMADA, a modelling platform, provides an estimation of impacts of future heat wave risk impact for the selected assets. By 2050, flood and heat wave damages in Can Tho are expected to rise by a fourfold (Flood and Heat Wave), due to both, economic growth (assets will be more valuable) and climate change (hazards will be more frequent and more intense).

The introduction of a selection of adaptation measures provides insights for the development of a sound climate adaptation portfolio under the selected scenarios. When compared to other measures, green measures and grey measures provide the best return on investment, while offering a good protection against future climatic risks. These measures are listed below:

TIDAL and PLUVIAL/FLUVIAL FLOOD:

a. "Mobile flood embankment" It is intended to introduce mobile flood embankment systems for a length of 3 km. For this, 30 hose modules with a diameter of 1.1 meter and length of 100 meters are needed.
b. "Flood awareness" Activities to prepare against flood should be planned in advance. Through flood preparedness programmes, understanding and awareness regarding the flood events is strengthened among the local community. Community members

are a focal point of preparedness programmes, therefore, informing the public and providing training for flood preparedness is vital

c. "Rehabilitation of drainage" These effects can increase the efficiency of the canal in moving water. Hence increasing the conveyance. In total, ca. 68 km are subject of a rehabilitation monitoring, with varying pipe/canal diameters from 0.4 to 1.2 meters.

HEAT WAVE:

a. "Cooling Centers"
b. "Climate Smart Agriculture"
c. "White Roofs"

This measure “Cooling Centers” was evaluated at the pre-feasibility level and was considered technically feasible considering regulations, technological feasibility, location, resources, and sustainability. In general, being cost-efficient, the measures also have co-benefits such as reducing adverse health effects, reduced mobility problems, increased employment and productivity, increased school attendance and performance, and increased income. Potential negative effects have been also explored. These measures were evaluated at the pre-feasibility level and were considered feasible towards local regulations, technological requirements, location, resources, and sustainability.

Economics of Climate Adaptation

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