Economics of
Climate
Adaptation

Report 02

November 2020

Base Data Report

Cần Thơ, Vietnam

Flood Risk & Heat Waves

UNITED NATIONS
UNIVERSITY
UNU-EHS

Table of Contents

List of Tables

List of Figures

List of Acronyms

BMZ	German Ministry for Economic Cooperation and Development
CCA	Climate Change Adaptation
CCCO	Climate Change Coordination Office
CMIP5	Coupled Model Intercomparison Project Phase 5
CRO	Climate Resilience Office
ECA	Economics of Climate Adaptation
GCM	Global Climate Models
GSO	General Statistics Office Vietnam
HCMC	Ho Chi Minh City
ISF	InsuResilience Solutions Fund
IPCC	Intergovernmental Panel on Climate Change
KfW	German Development Bank
MPI	Ministry of Planning and Investment
UNFPA	United Nations Population Fund
UNU-EHS	United Nations University – Institute for Environment and Human Security

1. Context

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 regions 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 diverse 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 Can Tho City in the Mekong Delta of Vietnam to identify the most cost-effective measures to address floods and heat waves. The ISF is funded by German Development Bank KfW and commissioned by the German Ministry for Economic Cooperation and Development (BMZ). Currently, the Economics of Climate Adaptation (ECA) methodology is being implemented in three different countries (Vietnam, Honduras and Ethiopia).

The inception phase of the ECA study in Vietnam has been concluded with the definition of the scope of the project, including the target hazards to be addressed and the key assets to be considered. The most appropriate time horizon is being determined through the consultation with key stakeholders and in alignment of national and regional decisions and strategies. The present and following phases will determine the distribution of risk levels within the research area and evaluate different measures to mitigate such risk through a cost-benefit analysis. These phases will be supported by the modelling tool CLIMADA, which amongst others:

1) provides a comprehensive mapping of hazards, exposed assets and people and their specific vulnerability,
2) implements state-of-the-art probabilistic risk modelling techniques to integrate different economic development and climate impact scenarios, and
3) allows assessing a comprehensive portfolio of adaptation measures, quantifying the damage aversion potential and cost-benefit ratio for each measure.

This report will brief the reader on the state of data collection needed for running CLIMADA after thorough research with support from local authorities and other stakeholders.

The document is divided into five sections, the first two highlighting the most relevant factors regarding the selected hazard and assets in the selected study area. The third section presents future climate and socio-economic scenarios for a defined time-horizon. The fourth section presents a general overview of the collected data, with a quality assessment regarding their usability for the ECA study, as well as the proposed proxies for those data sets that are insufficient for running CLIMADA or might lead to too high uncertainties in the final results. The last section concludes and details the next steps.

2. Study Area & Selected Hazards

On January 10 in 2020, UNU-EHS, ISF, the Can Tho Climate Resilience Office, the Can Tho Climate Change Coordination Office (CCCO) and the People´s Committee of Can Tho City held an *ECA Inception Workshop*, to define the ECA study's scope and scale. Participants were asked to identify climate-related hazards that are of relevance for Can Tho. This identification process was followed by a ranking according to the severity of impacts. Based on a working group's ranking and a final validation in plenary, floods (tidal, pluvial, and fluvial) and heat waves were selected for the introduction to ECA. Nonetheless, a final decision on the study area could not be made and requested further consultation with key stakeholder groups. For this reason, a 'Scoping Consultancy', held from August to October 2020 in Can Tho, further examined the potential study area of the intended ECA study. In discussion with local experts and representatives of academia, three urban districts of Can Tho were selected. The study area as well as the selected hazards are described in the following sub-chapters.

2.1 Study Area Description

Can Tho's population counts approximately 1.23 million inhabitants as of 2019 and consists of five urban districts (Ninh Kieu, Binh Thuy, Cai Rang, O Mon and Thot Not) and four rural districts (Phong Dien, Thoi Lai, Vinh Thanh, Co Do)[1,2]. The urban core with its rapid urbanization is limited to three districts of Ninh Kieu, Binh Thuy and Cai Rang, which together account for 510.172 inhabitants. Can Tho, located the Hau River has an annual average temperature of 26.7°C and is characterized by many waterways. In total, Can Tho counts 158 rivers, channels and canals at various sizes, creating a network connected to two major rivers, the Hau and the Can Tho River. The section of the Hau River in Can Tho city is about 1,600 meter long and up to 350 m wide, and is lying in the transitional area to the tidal zone[3]. The river system in Can Tho mainly facilitates commercial activities, and is an important route for transporting goods, food and aquatic products. The dynamics between rapid urbanization, economic development and transformation are evident in Can Tho City and challenge the management of current and future hazards. Three urban districts have been selected and will be part of the ECA study:

Ninh Kieu district represents the most densely urbanised district accounting for 269.541 inhabitants and a population density of 9.221 inhabitants per square kilometre. Ninh Kieu hosts most of the central infrastructure such as governmental buildings, businesses, financial institutions, educational and health services, commercial hubs or service providers as well as parts of the university. In Ninh Kieu district, the Can Tho River represents a natural border to the neighbouring district Ca Rang.

Binh Thuy district is located north of Ninh Kieu and has next to its urban also peri-urban characteristics. Binh Thuy hosts a population of 142.309 inhabitants with a density of 2000 inhabitants per square kilometre. The district hosts industrial parks, a power plant and two airports of which one is the Can Tho

---

[1] Frouws, E., Frölke, R., Maarse, N., van den Heuvel, O., & Meijer, B. (2019). Polder system Can Tho City: Impact of the urban polder on Can Tho City.

[2] Garschagen, M. (2014). *Risky change? Vulnerability and adaptation between climate change and transformation dynamics in Can Tho City, Vietnam* (Vol. 15). Stuttgart: Steiner.

[3] Do, H. (2018). Can Tho City—Taking Advantage of Water Spaces in the Organization of Architectural Landscape and Climate Change Adaptation.

International Airport, established in 2010. Binh Thuy is one of the districts, where climate change has imposed the most significant impact on industrial areas[4].

Cai Rang district, located south of Ninh Kieu, hosts 98.322 inhabitants as of 2019 with a population density of 1.471 inhabitants per square meter. Cai Rang, with a peri-urban morphology is the most dynamic transforming district of Can Tho. Development master plans consider here new residential areas and industrial parks in the near future. These developments will shift the district from agricultural into non-agricultural land uses, with implications for future employment profiles[5]. A new port, named Cai Cui Port is in planning at the Hau River and will become a commercial gateway with capacities to handle large ocean freight vessels and to further expand Can Tho's ambitions to enhance market accessibility within the Mekong Delta and global markets.

Figure 1 shows a detailed map of the study area. The population count and density for each district based on a 2019 census is listed in Table 1 below. In addition, Annex 1 and Annex 2 includes maps for population count and density of each district and corresponding wards.
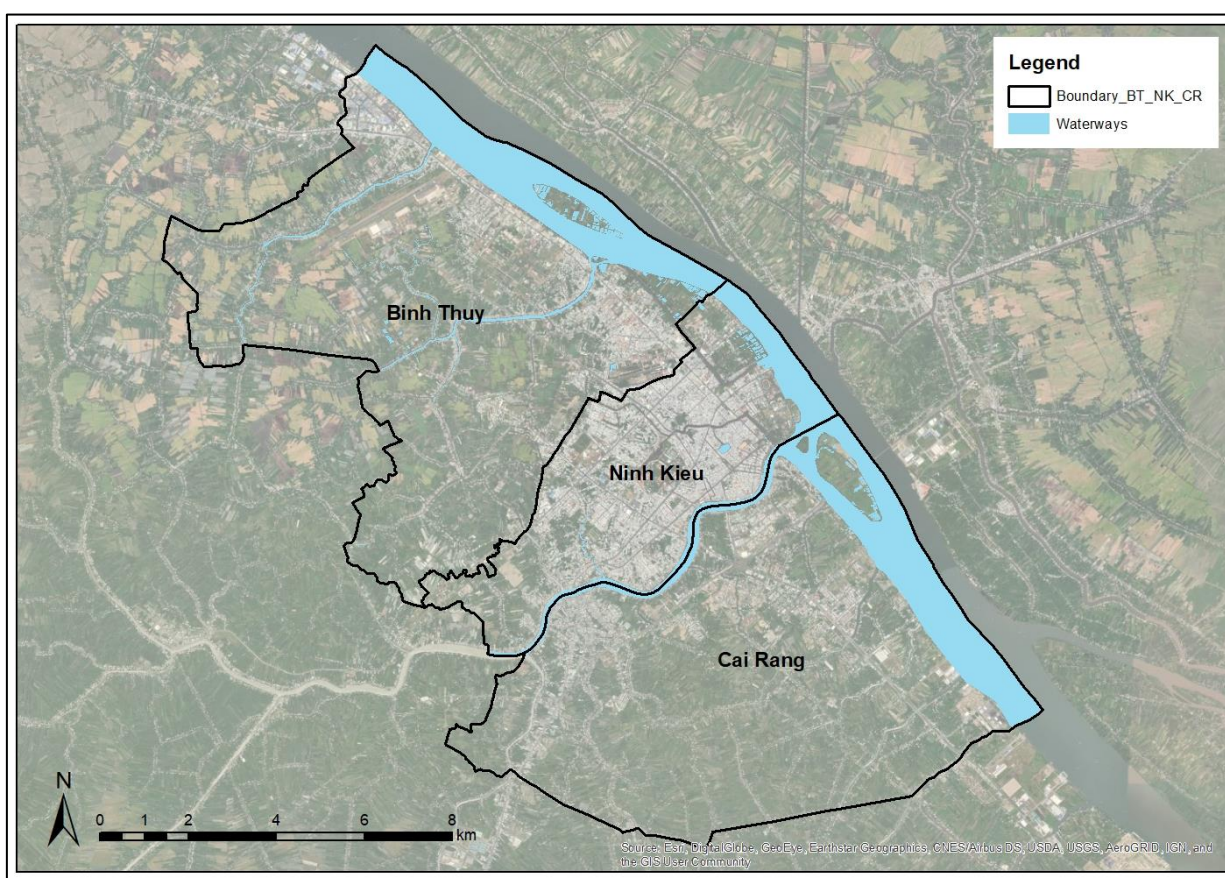
Figure 1: Overview of ECA Study Area - Binh Thuy, Ninh Kieu & Cai Rang district.

---

[4] Huynh, H. L. T., Do, A. T., & Dao, T. M. (2020). Climate change vulnerability assessment for Can Tho city by a set of indicators. *International Journal of Climate Change Strategies and Management*.

[5] Garschagen, M. (2014). *Risky change? Vulnerability and adaptation between climate change and transformation dynamics in Can Tho City, Vietnam* (Vol. 15). Stuttgart: Steiner.

Table 1: Population count of Ninh Kieu, Binh Thuy and Cai Rang district. Source: Census 2019.

District	Area (km²)	Population Count (2019)	Density (People/km²)
Ninh Kieu	29,23	269.541	9.221
Binh Thuy	71,13	142.309	2.000
Cai Rang	66,81	98.322	1.471

2.2 Relevance of Flood in Can Tho

Can Tho's topography altitudes between 0.6 to 1.2 m above sea level[6]. The central region of the Delta around Can Tho faces every year seasonal flooding events, often caused and influenced not only by a single flood regime but also by a combination of tidal floods from the sea, riverine floods from the upstream Mekong and strong precipitation (pluvial floods)[7,8]. The occurrence of floods with increasing severity become more damaging and unpredictable for the people and local governments, due to a multitude of factors such as climate change and rapid urban development[9].

There are a number of factors causing urban flooding in Can Tho City. The main factor of urban flooding are Mekong River upstream floods combined with the high-tide regime of the Eastern Sea, which usually occurs at the start and middle of the lunar month[10]. These factors can often occur combined with a third flood regime caused by rain. Rainfall is also a major factor causing urban flooding, in terms of timing and scale. 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[11]. Commonly, river discharges in Can Tho are high every season from September to November, whereas tidal flood often occur from October to January[12]. In 2008, 21 main streets were inundated to a depth up to 50 centimetres by high tides and a combination of heavy rains[13].

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[14]. Sewer overflows induced by floods also present an increased health

---

[6] Siddiqua, A. (2019) Emergence of Water Urbanism for Water Born "Can Tho". *Journal of Water Resource and Protection*, 11, 166-180.

[7] 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.

[8] Hung, N.N.; Degado, J.M.; Tri, V.K.; Apel, H. Floodplain hydrology of the Mekong delta, Vietnam. Hydrol. Processes 2012, 26, 674–686.

[9] Ibid.

[10] 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.

[11] Ibid.

[12] 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.

[13] 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.

[14] 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.

risk to the general population[15]. Also, rapid urbanization has reduced the natural infiltration of surface water and has decreased the natural reservoir capacities inside the city.

Can Tho evidenced several major flooding events in the past twenty years. In 2000, rainfall occurred earlier than usual in the rainy season and caused flooding in the lower Mekong River Delta with observed flood levels in Can Tho just 1-3 centimetres below a 40 year record level[16]. These floods inundated more than 110.000 houses and 26.000 hectares of rice paddies[17]. In 2008, 21 streets were inundated with depths between 30-50 centimetres, largely due to high tide, and heavy rainfall. On 5th October 2009, heavy rains (more than one hour) caused serious inundation to the city as well. The peak of the flood of October 2011 reached a water level of 2.15 meters, above Warning Scale III at 25cm, the highest level since 1940 and peaked the levels of year 2000[18]. This flood inundated almost the whole city as a result based on the combination of high tides and sea level rise[19]. Some parts of the city, close to the river, were inundated for several months, with the consequence of 27.000 houses inundated and a total economic loss of 11.3 million USD towards the city's infrastructure, businesses and agriculture[20].

A household survey conducted in 2009 in Can Tho indicated the number of flooded sites attributed to the causing flood regimes (see Table 2). This survey illustrates that especially the combination of rain and high tides results in high numbers of flooded sites.

Table 2: *Results of a 2009 flood survey in Can Tho City, indicating number of flooded sites per flood regime. Source: Can Tho People's Committee (2011)[21]*

No.	District	Cause of flood (flood regime)	No. of flooded sites
1	Ninh Kieu	Rain	12
		Rain and high tide	38
		Rain, high tide, upstream flood	11
		Sub-Total	**61**
2	Binh Thuy	Rain	5
		Rain and high tide	8
		Rain, high tide, upstream flood	4
		Sub-Total	**17**
3	Cai Rang	Rain	2
		Rain, high tide, upstream flood	13
		Sub-Total	**15**
Total		Rain	19
		Rain and high tide	46
		Rain, high tide, upstream flood	28
		Total (all flood regimes combined)	**93**

---

[15] Ibid.

[16] Huong, H. T. L., & Pathirana, A. (2013). Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam. *Hydrology and Earth System Sciences*, 17(1), 379.

[17] Ibid.

[18] Vo, D. T. (2018). Household economic losses of urban flooding: case study of Can Tho City, Vietnam. *Southeast Asia Review of Economics and Business*, 1(1).

[19] Can Tho Urban Development And Resilience Project, *Environmental And Social Impact Assessment (ESIA)*, People's Committee Of Can Tho City (2015).

[20] 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.

[21] Vo, D. T. (2018). Household economic losses of urban flooding: case study of Can Tho City, Vietnam. *Southeast Asia Review of Economics and Business*, 1(1).

The flooding of urban sites, mainly streets, cause damage and loss not only to physical infrastructures but also to livelihoods and businesses. Collapsed and damaged houses along riverbanks during flood periods mainly result from unsafe constructions. Some surveys also highlight critical numbers of schools affected from flood events. For example, up to more than 200 'flooded schools' were registered in 2000[22]. Flood also manifest in economic losses on household levels. A household survey from 2009, conducted in the urban center, i.e. Ninh Kieu district, found that the total annual economic losses caused by flooding during the year 2008 was VND 13.489.000 (approximately USD 642) per household. With a mean annual income of VND 121,638,000 (approximately USD 5792), the percentage of economic losses due to flooding in a household's income was approximately 11% per year[23]. It should be noted that a large amount (90%) of households' economic losses were indirect costs during a flood event, including own labour, missed work and lost revenues[24].

2.3 Relevance of Heat Waves in Can Tho

There is increasing scientific evidence that more frequent and intense extreme weather events such as high temperatures will occur in South-East Asia.[25] The Mekong Delta Region, consisting of 13 provinces in Vietnam, is considered one of the areas in South-East Asia most vulnerable to extreme hydro-meteorological events associated with climate change.[26] Studies indicated that the mean temperature in the central Mekong Delta Region increased by 0.5°C between 1978 and 2008, and the mean temperature is predicted to increase by up to 4°C by the year 2100, and the number of days that have an average temperature higher than 35°C will increase.[27] The increasing frequency and intensity of hazardous heat waves pose a serious risk to people, environment and economy. Heat waves can vary across different locations and at differing scales due to the variability of localised microclimates, resulting from different physical and built environments, socio-economic development, and adaptation strategies.[28] Especially in urban areas, such as Can Tho City, temperatures are generally higher, and *urban heat island* effects, may amplify the regional heat load during heat wave events. Urban heat island effects can be caused by multiple factors, including a low radiant heat loss in the urban canopy layer, changes in water balances and lower wind velocities compared to rural environments. Accordingly, local and regional climates can be significantly influenced by urbanization and other land-use changes.[29,30]

---

[22] Comprehensive Resilience Planning for Integrated Flood Risk Management for Can Tho, *Towards Sustainable Flood Management In Can Tho And Surrounding Areas – 2030*, World Bank, 2011.

[23] Vo, D. T. (2018). Household economic losses of urban flooding: case study of Can Tho City, Vietnam. *Southeast Asia Review of Economics and Business*, 1(1).

[24] Ibid.

[25] Intergovernmental Panel On Climate Change (IPCC). Climate Change 2013: The Physical Science Basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change. *Cambridge University Press*, 2014.

[26] Yusuf, A. A., & Francisco, H. (2009). Climate change vulnerability mapping for Southeast Asia.

[27] DONRE Can Tho (2009). Report on Environment Quality Monitoring: Can Tho City 10 years (1999-2008). Can Tho, Vietnam: Center of Natural Resources and Environment Monitoring (CNREM), Can Tho Department of Natural Resources and Environment (DONRE).

[28] Tran, D. N., Nguyen, V. T., Khan, A., Thai, P. K., Cunrui, H., Chu, C., & Phung, D. (2020). Spatial patterns of health vulnerability to heatwaves in Vietnam. *International journal of biometeorology*, 1-10.

[29] McGregor, G. R., Bessmoulin, P., Ebi, K., & Menne, B. (2015). *Heatwaves and health: guidance on warning-system development*. WMOP.

[30] Chaudhry, P., & Ruysschaert, G. (2008). Climate Change and Human Development in Viet Nam: A case study for how change happens. *Oxfam Policy and Practice: Climate Change and Resilience*, 4(1), 1-18.

Previous studies in the Mekong Delta mainly associated heat waves or the exposure of high temperatures with increases in the risk of water and vector-borne diseases, cardiovascular and respiratory diseases, and the risk of hospitalization among young and elderly people. For example, one study indicated that heat wave events caused a 12.9% increase in risk of hospitalization due to cardiovascular diseases in Ho Chi Minh City.[31] Another study in Ho Chi Minh City found significant effects of heat waves on hospitalization for elderly people and people with respiratory diseases.[32] In a multi-province study for the Mekong Delta, high temperatures were significantly associated with hospital admissions of young children and gastrointestinal infections.[33] For Can Tho City, one study counted 55 heat wave events (representing 292 days) between 2003-2013, with a daily average hospitalization of 30 admissions.[34]

2.4   Modelling Approach

Flood Modelling

As part of the novel flood modelling exercise, a team of international experts will work in close collaboration of the UNU-EHS team to i) provide better boundary conditions to the flood model using improved and high-resolution climate data, ii) model floods for the selected study areas using high-resolution topography data and updated boundary condition, and iii) validate the flood model outputs for large flood events.

The flood modelling experts will include the following outputs:

1. Modelling of pluvial, tidal and fluvial floods in the respective study area and production of flood maps (water depth) at 5 meter resolution (urban areas) and 30 meter resolution (rural areas) for 100yr, 50yr and 20r return periods. Alternative resolution can be discussed based on computational feasibility. The resolution might vary depending on data availability and computing feasibility. The highest resolution will be selected. A 2D flood model will be applied[35]. The 2D model has already been successfully applied in the region and will be extended to satisfy the research area selected for this study.

2. Flood maps (water depth) are produced for today's climate (1980-2015) and for two different climate scenarios (RCP4.5 and RCP8.5) for the time horizon 2050. Scenarios can be constructed using a mix between literature and the delta approach.

[31] Phung, D., Guo, Y., Thai, P., Rutherford, S., Wang, X., Nguyen, M., & Chu, C. (2016). The effects of high temperature on cardiovascular admissions in the most populous tropical city in Vietnam. *Environmental pollution*, 208, 33-39.

[32] Dang, T. N., Honda, Y., Van Do, D., Pham, A. L. T., Chu, C., Huang, C., & Phung, D. (2019). Effects of extreme temperatures on mortality and hospitalization in Ho Chi Minh City, Vietnam. *International Journal Of Environmental Research And Public Health*, 16(3), 432.

[33] Phung, D., Rutherford, S., Chu, C., Wang, X., Nguyen, M., Nguyen, N. H., & Huang, C. (2015). Temperature as a risk factor for hospitalisations among young children in the Mekong Delta area, Vietnam. *Occupational and Environmental Medicine*, 72(7), 529-535.

[34] 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.

[35] Apel, H. et al. (2016) Combined fluvial and pluvial urban flood hazard analysis concept development and application to Can Tho city, Mekong Delta, Vietnam. Nat. Hazards Earth Syst. Sci., 16, 941–961

Further information on the modelling parameters and input data will be detailed in the ECA Vulnerability Report.

Heat Wave Modelling

No universal definition of *heat wave* is suitable for the particular case of Vietnam. It is mainly because different temperatures often have varying impacts in different parts of the world or regions. Heat waves should therefore be defined using thresholds that correspond to local weather conditions and their impact on human health, built-up environments or natural ecosystems. For this reason, definitions often vary across studies in the form of the number of consecutive days that exceed a threshold temperature, the threshold temperature used, and severity. [36]

Taking into account the variance of heat waves in different locations, this study, will define heat waves by using the largely recognised ETCCDI index[37] which defines the number of days above the 90th percentile of T*max* temperature for a reference period. This index has the advantage that it does not use a reference temperature (e.g. 30°C) but is adapted to local condition. The ETCCDI is a recognised panel supported by the World Meteorological Organisation[38]. The warm spell duration index (WSDI)[39] can be derived from daily records from local weather stations (possibly refined with remote sensing data when necessary). Further information on input data will be detailed in the ECA Vulnerability Report.

---

[36] Tran, D. N., Nguyen, V. T., Khan, A., Thai, P. K., Cunrui, H., Chu, C., & Phung, D. (2020). Spatial patterns of health vulnerability to heatwaves in Vietnam. *International journal of biometeorology*, 1-10.

[37] See http://etccdi.pacificclimate.org/indices.shtml

[38] http://www.wmo.int/pages/prog/wcp/wcdmp/documents/WCDMP_72_TD_1500_en_1.pdf

[39] Peterson, T.C., 2005: Climate Change Indices. *WMO Bulletin*, **54 (2)**, 83-86.

3. Selection of Assets

A 'Scoping Consultancy', held from August to October 2020 in Can Tho, further examined the extent and scope of the intended ECA study. In discussion with local experts, consultants and representatives of academia, four asset categories were selected: *Public Assets*, *Housing*, *Vulnerable People* and *Natural Resources*. All asset categories are applied for flood risk, whereas people, road network and agriculture are analysed solely in connection with heat waves. This chapter will provide further information on each category and the respective sub-categories.

3.1   Public Assets

Public assets are often understood as critical infrastructure and therefore represent an important element in urban and peri-urban landscapes, such as Can Tho. Public assets offer fundamental services to urban and peri-urban businesses, industries and populations. Nonetheless, these assets are often exposed to extreme events, such as floods. In consultation with key stakeholders, the following public assets were selected for inclusion in the ECA study:

- Schools
- Medical Centres/Hospitals
- Administrative (Public) Buildings
- Electricity Grid
- Road Network

Table 3 shows the number of identified Schools (including kindergartens and nurseries), Medical Centers/Hosptials and Public Buildings for selected districts. A list for each of the three assets from Table 3 can be found in Annex 3. In addition, Figure 2 provides an overview of the exact lcoations of public assets, including the electricity grid and road network. In total, the study area will cover a road network of ca. 1101 kilometrs. Due to an inaccurate cartography of the overhead grid, we assume the same length identical to the road network.

Table 3: Publics Assets - Number of Schools, Medical Centres & Hospitals and Administrative (Public) Buildings. Based on consulting work from Dragon Mekong Institute.

District	Schools	Medical Centers/Hospitals	Administrative (Public) Buildings
Binh Thuy	15	8	8
Ninh Kieu	38	28	34
Cai Rang	16	4	9
TOTAL	**77**	**40**	**51**
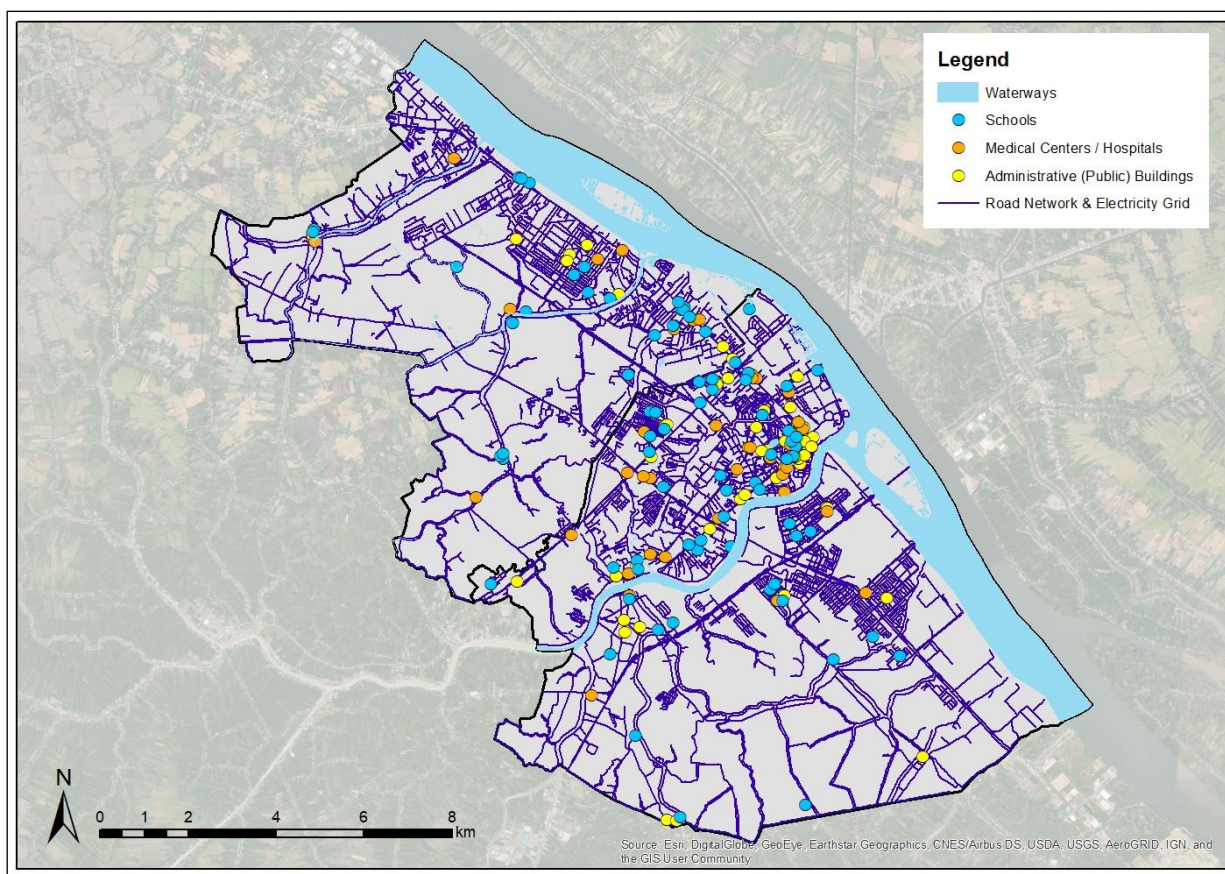
Figure 2: Overview and locations of selected public assets in Ninh Kieu, Binh Thuy and Cai Rang district.

3.2   Housing

The ECA study will also include housing as an asset category. Following the census definition of 2009 and 2019, a dwelling is a construction used for housing, and includes three basic components: walls (or supporting columns), roof and floor. These components have been used to classify 'housing' based on construction materials[40]. On the basis of classifying construction materials by their 'sturdiness' and 'flimsiness' (see Annex 4), housing categories were identified and divided into four types: *permanent*, *semi-permanent*, *temporary* and *simple*.

Permanent housing includes dwellings for which the three main structural elements, supporting columns, roof and walls, all consist of sturdy construction material types. Semi-permanent housing indicates that two out of three structural elements are made of sturdy categories while temporary structures only have one of the three structural elements belonging to the sturdy category. Simple structures are those for which all three structural elements are classified as flimsy[41]. Table 4 shows the number of existing houses in Ninh Kieu, Binh Thuy and Cai Rang district, as well as the average dwelling area per household.

---

[40] *The 2019 Population and Housing Census,* Central Population and Housing Census
Steering Committee, Ha Noi, July 2019. The data collection of the 2019 Population and Housing Census took place from 1-25 April 2019.
[41] Ibid.

Table 4: *Number of residential houses in Ninh Kieu, Binh Thuy and Cai Rang district as of 2014, as well as average dwelling area (m²) per person per type of house in Can Tho City generally. Source: General Statistics Office (GSO) Vietnam under the Ministry of Planning and Investment (MPI).*

Housing Category	All districts	Ninh Kieu district	Binh Thuy district	Cai Rang district
Permanent	14.820	7.470	4.860	2.490
Semi-permanent	91.410	33.780	26.910	30.720
Temporary	15.240	5.430	4.590	5.220
Simple	5.400	1.740	1.350	2.310
TOTAL	126.870	48.420	37.710	40.740

Average dwelling area per person by house category in Can Tho (in m²)				
Total (avg.)	Permanent	Semi-permanent	Less-permanent	Simple-permanent
21,44	30,2	23,4	16,8	13,6

3.3   People

One important asset group are people. For this reason, the ECA study includes the general population of Ninh Kieu, Binh Thuy and Cai Rang district. Annex 1 includes a map of the population count and density. Ninh Kieu district counts the highest population density with 9.221 inhabitants per square kilometre compared to Cai Rang (1.471 inhabitants) and Binh Thuy (2000 inhabitants). Ninh Kieu district, located north of the junction of both Hau and Can Tho River, is most directly affected by floods. Along the rivers, water levels exceed the river banks for the time of the semi-diurnal high tides, causing inundations of short duration. These flood durations expand during flood season from September to November. Besides the two major rivers, a number of channels can be found in Ninh Kieu. In combination with high water levels of the rivers, inundation also occur by bank overtopping of these channels.[42] As Table 2 in Chapter 2.2 shows, Ninh Kieu was also most impacted by the floods in 2008, with the highest number of flooded sites compared to Binh Thuy and Cain Rang district.

Nonetheless, particular attention also applies to people living in communities that are located along the riverbanks, especially in Binh Thuy district. These communities require particular attention as their livelihoods strongly depend on riverine services that are prone to riverine or tidal floods and exposed to insufficient infrastructures, e.g. drainage and wastewater systems. Houses along the riverbanks are often temporal housing (informal settlements) and subject to bank erosion or clearance processes for public constructions, such as parks or green spaces. Studies that quantified these observed conditions along the riverbanks are not available. Only household surveys on economic losses[43] for flood events have been conducted in Ninh Kieu district, based on random sampling throughout the district (see Chapter 2.2) and lacked the focus on riverbanks. The results of ECA Vulnerability Report will provide more information on future flood levels in this particular area of the study area.

---

[42] Apel, H., Martínez Trepat, O., Hung, N. N., Chinh, D. T., Merz, B., and Dung, N. V.: *Combined fluvial and pluvial urban flood hazard analysis: concept development and application to Can Tho city, Mekong Delta, Vietnam*, Nat. Hazards Earth Syst. Sci., 16, 941-961, 10.5194/nhess-16-941-2016, 2016.

[43] Vo, D. T. (2018). Household economic losses of urban flooding: case study of Can Tho City, Vietnam. *Southeast Asia Review of Economics and Business*, 1(1).

3.4   Natural Resources

3.4.1   Agriculture

Aquaculture

Aquaculture, in particular fish farming has developed rapidly and became a key economic sector in Can Tho City. Pond cultivation is largely operated in areas along the Hau River which is sufficient for fresh water aquaculture. Species that are dominantly cultured are Tra Catfish and Basa (Pangasius) fish, accounting to 14.567 tons/year[44]. According to Can Tho's Fisheries Sub-Department, the area for farming aquatic species is about 2,300 ha, including 500 ha for intensive catfish production. Nonetheless the area of aquaculture in the study area accounts only to 82 ha.

Cash Crops

In the study area, 640 ha are used for cash crop production (see Figure 3). Cash cropping systems include vegetables such as cabbage, bean and corn which are mainly located in the sub-urban area of Cai Rang district (i.e. in Hung Thanh ward, Truong Thanh ward, Ba Lang ward) and Binh Thuy district (Long Hoa ward). These districts have an average bean production of 20.319 tons/year in 2019. In addition, corn was planted in the area on 124 ha yielding in 659 tons in 2019[45].

Orchards (Fruit Trees/Gardens)

Fruit trees/gardens are the most abundant agricultural land use in the study area, especially in Cai Rang district. The most commonly grown species are coconut, orange, mango, pomelo and longan, with a production of 1071 tons, 36200 tons, 2699 tons, 2235 tons and 253 tons respectively in year 2019[46].

Triple Rice Crops

The study area has normally different kinds of land use types. In terms of agricultural production, alluvial soil in Can Tho is highly fertile and very suitable for intensive agriculture. Triple rice cropping systems are mainly located in Binh Thuy district and partially in Cai Rang district. In 2019, Binh Thuy produced 13,621 tons of rice, and Cai Rang district 272 tons[47]. Rice is generally cultivated in three major cropping seasons during a year (therefore referred to as triple rice crops): winter-spring (from December to March), summer-autumn (from April to July), and autumn-winter season (from July to November), at 944 hectares, 895 hectares, 651 hectares respectively[48]. The double-rice cropping system has generally been replaced by a triple-rice system to boost rice production for food security and economic development.

---

[44] Can Tho Statistical Yearbook, 2019. Can Tho Statistical Publishing House.
[45] Ibid.
[46] Ibid.
[47] Ibid.
[48] Ibid.
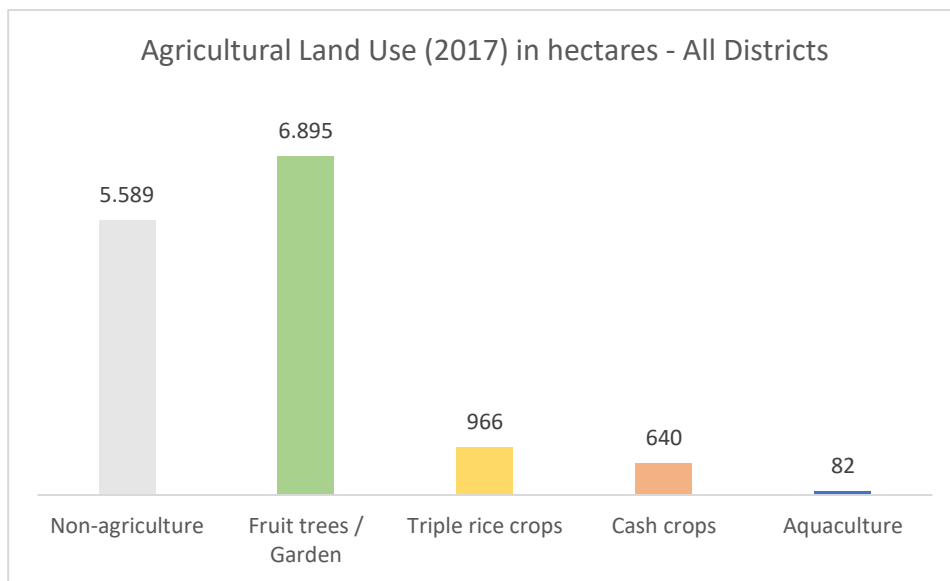
Figure 3: Agricultural land use (2017) in hectares (ha) combined for Ninh Kieu, Binh Thuy and Cai Rang district.
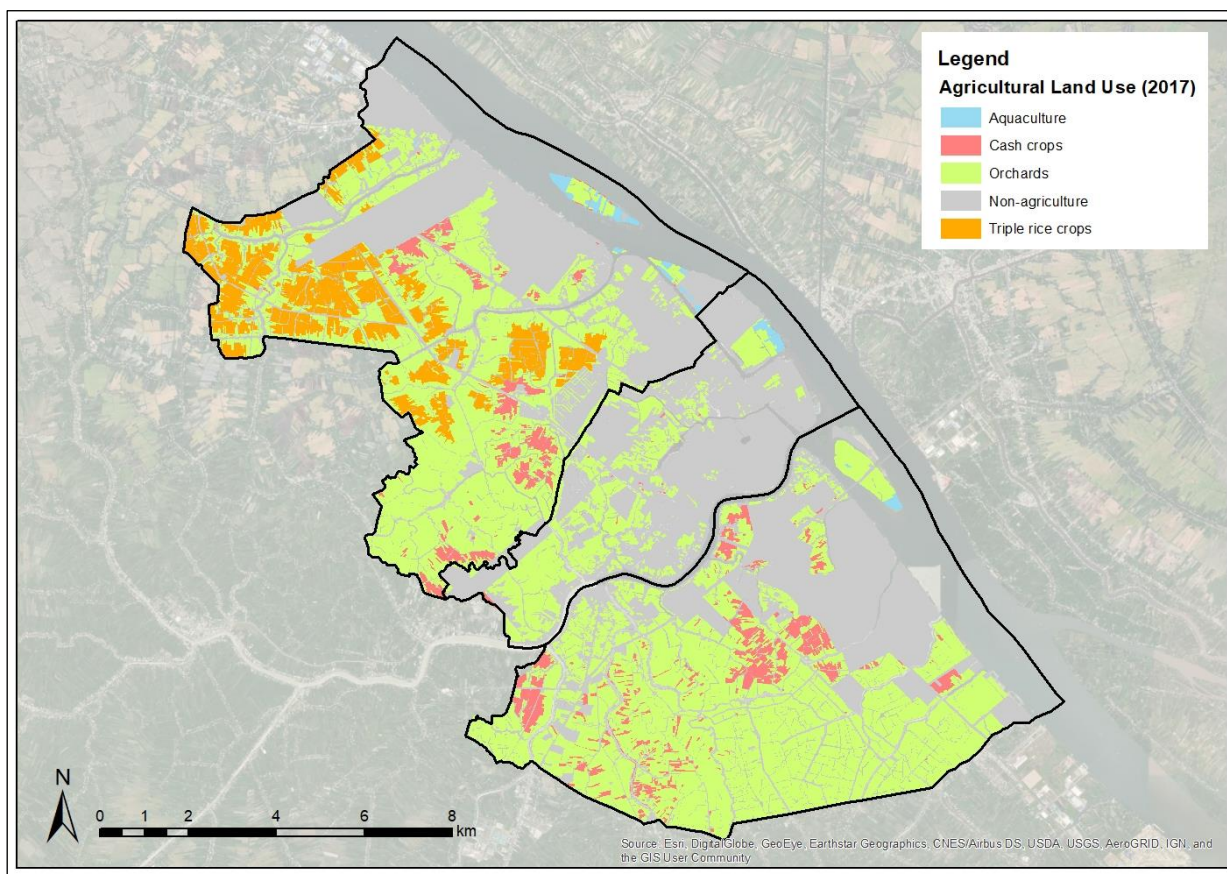
Figure 4: Overview of agricultural land use (2017) within study area. (Source: DoNRE, DRAGON Mekong Institute)

An overview of agricultural land use per district is provided in Annex 5.

3.4.2 Green Spaces

As of Figure 5, 416 ha of green spaces have been selected in total for inclusion in the ECA study. The selected green spaces consist mainly of parks, conservation landscapes, such as natural green spaces along riverbanks or natural conservation zones, areas of natural reservoirs or water retention[49]. Ninh Kieu, Binh Thuy and Cai Rang are the most urbanised districts in Can Tho. Therefore some spaces in the districts can be considered as spaces with a multipurpose function between recreation and aesthetic purposes such as, flower gardens, green pedestrian trenches along streets, rivers and canals.
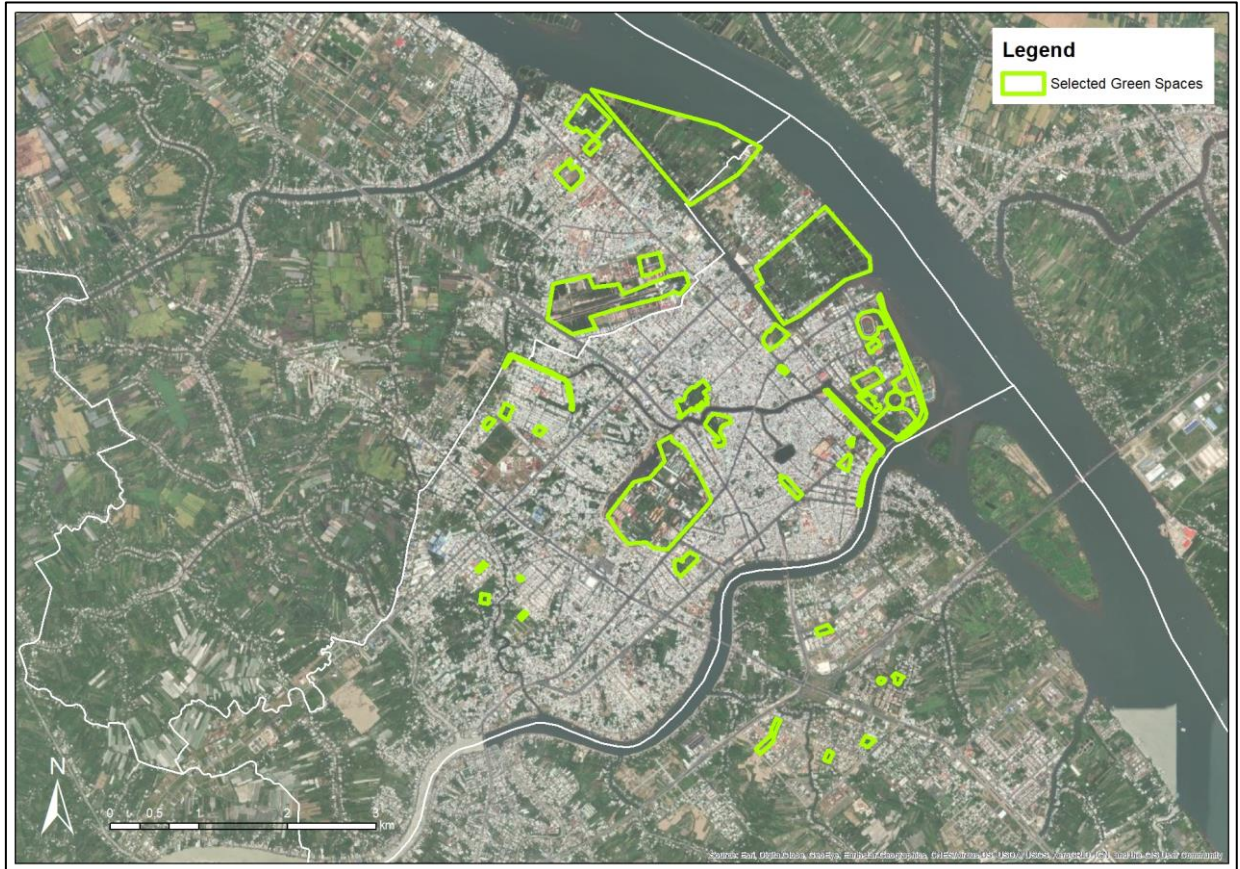
Figure 5: *Selected green spaces prone to regular flooding in Ninh Kieu, Binh Thuy and Cai Rang district.*

---

[49] Can Tho People Committee, 2013. The Master plan of Can Tho city to 2030 and vision to 2050 (approved in 2013, Decision 1515/QĐ-TTg).

4. Scenario Development

4.1 Socio Economic Scenario

4.1.1 Introduction

Being the demographic and economic centre of the Mekong River Delta Can Tho provides central services in education, health, commerce and trade as well as growing industrial zones. Graduating to a centrally managed class 1[50] urban area in 2009, Can Tho and its leadership gained more independence and responsibility. Can Tho however is also one of only five cities whose plans and policies are being controlled and approved by the Vietnamese national Government emphasising the city's national importance.[51] This development followed the Master Plan on Socio-Economic Development of Can Tho City in the 2006 – 2020 period, which outlines a number of objectives to strengthen Can Tho's economic development with high efficiency and competiveness in both domestic and world markets. It outlines, for instance, a restructuring goal of the local economy with a (new) focus on industry and construction sector and related investment into high and clean technologies.[52] It further highlights investment goals into traffic infrastructure on several levels, i.e. national highways, railway systems, the seaport cluster as well as upgrading the national waterways. Beyond that, and to further strengthen its national as well as regional role, goals regarding public health and education are being highlighted. This is later again confirmed by the subsequent Master Plan on Socio-Economic Development of Can Tho City through 2020, with a vision toward 2030, which foresees a restructuring toward a service-industry-high-tech agriculture economy after 2020.[53] The time horizon has been set to the period from 2020-2050 based on the consultative process[54].

4.1.2 Population Growth Scenario

Can Tho, as one of the key economic centres of Vietnam and specifically the Mekong River Delta region, will experience as much as most cities and regions in Vietnam, further population growth over the coming decades. The General Statistics Office (GSO) of Vietnam together with the United Nations Population Fund (UNFPA) in 2016 published the *Vietnam Population Projection 2014 - 2049*[55] which is based on the 2009 Population and Housing Census and updated with 2014 Intercensal Population and

---

[50] Cities in Vietnam are ranked according to six classes: Special, I, II, III, IV, and V, based on a point based systems consisting of six indicator groups. These are: 1) Functions of an urban centre; 2) Population size; 3) Population density; 4) Non-agricultural labour; 5) Urban infrastructure facilities; 6) Urban architecture and landscape. For further detail please refer e.g. to L.M. Son. (2020). *Rethinking City Classification System in Vietnam: Towards Urban Sustainability and People-Centered Development*. VNU Journal of Science: Policy and Management Studies, Vol. 36, No. 2(2020) 81-91.

[51] DiGregorio, M., Phong, T., Garschagen, M., Tyler, S. (2016). *A political economy of urbanisation and climate risk in Vietnam*. 10.13140/RG.2.1.1880.7283.

[52] The Prime Minister of Government. (2007). *Approving the Master Plan on Socio-Economic Development of Can Tho City in the 2006-2020 Period*. No: 21/2007/QD-TTg. Hanoi. Vietnam

[53] The Prime Minister of Government. (2013). *Decision No. 1533/QD-TTg of August 30, 2013, approving the master plan on socio-economic development of Can Tho city through 2020, with a vision toward 2030*.

[54] The decision for the time-horizon of 2020-2050 has been part of a consultative process (incl. Dragon Mekong Institute and key experts) and was based on the *Government Resolution 59-NQ/TW on Building and developing Can Tho City till 2030 with vision until 2045* (2020).

[55] GSO and UNFPA. (2016). *Vietnam Population Projection 2014 – 2049*. Vietnam News Agency Publishing House, Ha Noi, Vietnam.

Housing Survey. The projections are divided into different categories: national, urban/rural, socio-economic region, and provinces and cities. The report further provides estimates for three different fertility scenarios: low, medium, and high variants. Since with increasing level of detail, i.e. province and city level, and with longer the projection periods the projection results become less precise sub-national projections were only carried out until 2039.

For Can Tho a steady population increase is expected until 2039 although with a decreasing growth rate converting toward an annual average of just around 0.3% over the period of 2034-39. Since the estimates for the Mekong River Delta region are the lowest among the provincial projections (and actually reach a value just below 0% in 2034) and the observed growth rate pattern in Can Tho matches the national *low variant* growth rate estimates, those shall be applied to the *medium variant* population estimates until 2049 and extrapolated until 2050, this study's time horizon. Following that, the in **Figure 6** displayed growth rate can be observed.

Based on those estimates the population of Can Tho will grow from 1.309 million inhabitants to about 1.437 million from 2020 to 2050 resulting in an average annual growths rate of about 0.31%.
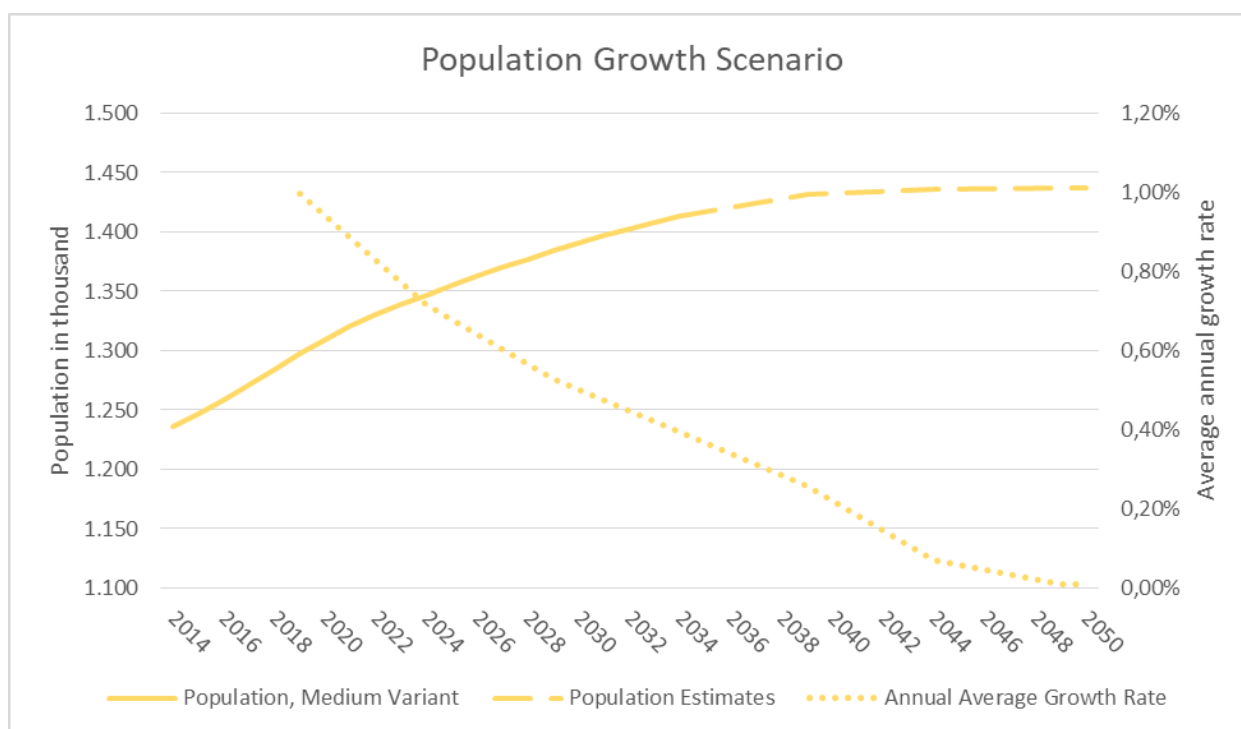
Figure 6: *Population Growth Scenario Can Tho. Population estimates (solid line and dashed line) on the left axis in thousand; Annual average population growth rate (dotted line) on the right axis in percent. Source: Authors' own compilation based on data from GSO and UNFPA (2016)*

4.1.3   Economic Growth Scenario

As the largest city in the Mekong River Delta and one of the largest cities in Vietnam Can Tho plays a key role for the local as well as national economic development. Following the ambitious Master Plan on Socio-Economic Development of Can Tho City in the 2006-2020 Period it was aimed to restructure the local economy by reducing the share of the 'agriculture-forestry-fisheries' sector (3.7%) and the 'service'

(42.5%) sector to the benefit of the 'industry-construction' (53.8%) sector.[56] Part of this plan is, among other areas, significant investment in transport infrastructure, e.g. ports and overland connections on roads- and rail networks, as well as the education and health sectors. Following those plans Can Tho became a centrally managed class 1 urban area providing its leadership with more responsibilities and independence regarding its planning of urban and economic development.[57] Since however no recent data on economic development of the city are available, e.g. from a potential follow up document on the Master Plan on Socio Economic Development mentioned above on the time after 2020, this analysis will employ national estimates provided by the Economist Intelligence Unit, which predicts an average annual growth rate of 4.6% for the period of 2020-2050.[58] Although the recent global economic disruption caused by the COVID-19 pandemic and the measures to combat the pandemic has and further will affect the local and the Vietnamese economy as a whole, long term growth paths are still expected as those effects can be expected to be only temporary. Since the economy of Can Tho City is one of the drivers of the economic development of the country and since the most recent Master Plans are outlining a shift toward more space efficient and profitable industries, e.g. service and high-tech industries, these national estimates shall serve as proxy values for the city's economic growth.

4.1.4 Discount Rate Scenario

With regard to the employed discount rate again data provided by the World Bank were chosen.[59] Since data on the GDP deflator are available since 1985 those are preferred over the CPI data available only from 1995. A second advantage of the GDP deflator is that prices of all goods and services produced domestically are being reflected rather than a limited and fixed basket of goods as reflected in the CPI. However, the analysis of both reveals only little deviations. Assuming a polynomial growth path of the third degree (cubic), proving to have a reasonably high goodness of fit of R^2=0.97 and higher than e.g. a linear or a quadratic function, for the GDP deflator index (base year 2010) results in an average annual increase of 3.91%. Figure 7 displays both, the assumed path of the GDP deflator (left axis, solid and dashed lines) as well as its growth rate (right axis, dotted and smaller dashed lines).[60]

---

[56] The Prime Minister of Government. (2007). *Approving the Master Plan on Socio-Economic Development of Can Tho City in the 2006-2020 Period*. No: 21/2007/QD-TTg. Hanoi. Vietnam

[57] DiGregorio, M., Phong, T., Garschagen, M., Tyler, S. (2016). *A political economy of urbanisation and climate risk in Vietnam*. 10.13140/RG.2.1.1880.7283.

[58] EIU. (2020). Vietnam. Economy: Long-term outlook. Retrieved on 22.10.2020, from http://country.eiu.com/article.aspx?articleid=90072792&Country=Vietnam&topic=Economy&subtopic=Long-term+outlook&subsubtopic=Long-term+outlook&aid=1&oid=1160072699>

[59] World Bank. (2020). World Development Indicators. GDP deflator (base year varies by country). Retrieved 21.10.2020, from https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS?locations=VN

[60] The observed gap between the recorded past annual growth rate and the estimated growth rate stems from the indirect approximation via the index rather than the growth rate itself. However, since CLIMADA employs the annual average rate rather, this is negligible.
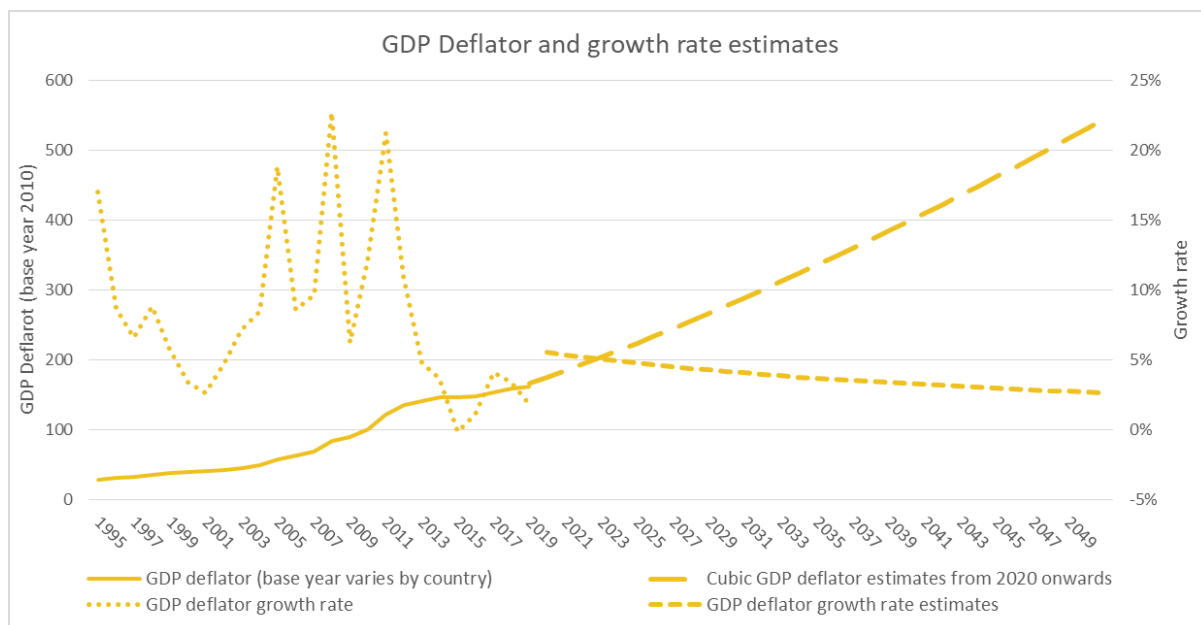
Figure 7: *Discount rate Scenario: GDP Deflator. Source: Authors' own compilation based on data from World Bank (2020).*

4.1.5   Socio-Economic Scenario Definition

Due to limitations with regard to data on a sub-national level, national proxies are being applied for economic growth and the discount rate scenario while for the population scenario official city-level projections are being extended using national estimates. Finally, the following parameters of the socio-economic scenario will be applied in CLIMADA:

- Average annual population growth rate: 0.31%
- Average annual economic growth rate: 4.6%
- Discount rate: average annual rate of 3.91%

4.2   Climate Scenarios

4.2.1   Introduction

The objective of this section is to review different climate scenarios for Vietnam. The following section will comment on projections of future climate in East Asia and Vietnam. It will focus on several aspects of climate scenarios in the areas related to precipitation and sea level rise highlighting scientific consensus and actual debates.

4.2.2   Overview

The potential increase in flood intensity and probability is among the most severe impacts that climate change poses to delta cities[61]. This is most relevant for the tropics, where the combined effects of sea

---

[61] Hunt, A., & Watkiss, P. (2011). Climate change impacts and adaptation in cities: A review of the literature. Climatic Change, 104(1), 13 -49. https://doi.org/10.1007/s10584-010-9975-6

level rise (SLR) and of a fast-growing population and economy pose a challenge to the liveability of densely inhabited cities of low-lying deltas[62].

The Mekong Delta, with its extreme low mean elevation (0.8 m)[63] is one of the globally most vulnerable deltas to climate change and sea-level rise. Recent climate impact projections revealed an intensification in magnitude[64] and frequency of extreme floods in the Mekong River basin. The Fifth Assessment Report of the Intergovernmental Panel on Climate Change predicted an increase of 17–38 cm in tidal level along the coast by mid-century[65]. Updated values show even a stronger rise of 43-84cm depending on the scenario[66]. Presently, flooding occurs annually in HCMC, often due to a combination of heavy rainfall, discharge from upstream reservoirs, and storm surges coinciding with high tide. This phenomenon is tied to the summer monsoon, when the easterlies discharge moisture from the East Sea, implying even higher water levels in extended areas, and stalling the drainage valves system of the city. This causes economic damage and nuisance to daily life and business, and considerable intangible losses due to traffic congestion. The number of people and the values of assets exposed to coastal flooding are among the highest in the world[67].

4.2.3   Current Climate Trends in Vietnam

At the global and regional scales, a substantial number of studies have investigated and documented the changing patterns of climatic variables across space and time[68,69]. In recent decades, Vietnam annual and seasonal observed trends in mean near-surface temperature indicate overall warming of 0.3°C per decade[70]. Total annual rainfall is dominated by a negative trend in five out of eight climatic zones[71]. Changes in climate have also intensified the incidence and magnitude of extreme events such as floods, droughts and typhoons[72].

Long-term significant trends in rainfall and temperature patterns were recently identified in areas with very high proportion of agricultural land, particularly for rice production such as the Mekong River deltas[73]. Changes in the rainfall and temperature patterns are very likely to have serious impacts on rice

[62] McGranahan, G., Balk, D., & Anderson, B. (2007). The rising tide: Assessing the risks of climate change and human settlements in low elevation coastal zones. Environment and Urbanization, 19(1), 17-37. https://doi.org/10.1177/0956247807076960

[63] Minderhoud, L. Coumou, G. Erkens, H. Middelkoop, E. StouthamerMekong delta much lower than previously assumed in sea-level rise impact assessments Nat. Commun., 10 (2019), p. 3847

[64] L.P. Hoang, M.T.H. van Vliet, M. Kummu, H. Lauri, J. Koponen, I. Supit, R. Leemans, P. Kabat, F. LudwigThe Mekong's future flows under multiple drivers: how climate change, hydropower developments and irrigation expansions drive hydrological changes Sci. Total Environ. (2018), 10.1016/j.scitotenv.2018.08.160

[65] Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change Geneva, Switzerland (2014), p. 151

[66] Oppenheimer, M., B.C. Glavovic , J. Hinkel, R. van de Wal, A.K. Magnan, A. Abd-Elgawad, R. Cai, M. Cifuentes-Jara, R.M. DeConto, T. Ghosh, J. Hay, F. Isla, B. Marzeion, B. Meyssignac, and Z. Sebesvari, 2019: Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities. In: IPCC Special Report on the Ocean and Cryosphere in a Changing Climate [H.-O. Pörtner, D.C. Roberts, V. Masson-Delmotte, P. Zhai, M. Tignor, E. Poloczanska, K. Mintenbeck, A. Alegría, M. Nicolai, A. Okem, J. Petzold, B. Rama, N.M. Weyer (eds.)]. In press

[67] Kuenzer, C., V. Heimhuber, J. Day, O. Varis, T. Bucx, F. Renaud, L. Gaohuan, V. Q. Tuan, T. Schlurmann, W. Glamore (2020) Profiling resilience and adaptation in mega deltas: A comparative assessment of the Mekong, Yellow, Yangtze, and Rhine deltas. Ocean & Coastal Management, Volume 198, 105362, ISSN 0964-5691, https://doi.org/10.1016/j.ocecoaman.2020.105362

[68] S. Kundu, D. Khare, A. Mondal, P.K. MishraAnalysis of spatial and temporal variation in rainfall trend of Madhya Pradesh, India (1901–2011) Environ. Earth Sci., 73 (2015), pp. 8197-8216, 10.1007/s12665-014-3978-y

[69] W.-H. Nam, E.-M. Hong, G.A. BaigorriaHow climate change has affected the spatio-temporal patterns of precipitation and temperature at various time scales in North Korea Int. J. Climatol., 36 (2016), pp. 722-734

[70] D.Q. Nguyen, J. Renwick, J. McGregor(2013) Variations of surface temperature and rainfall in Vietnam from 1971 to 2010 Int. J. Climatol

[71] Kien Nguyen Duc, Tiho Ancev, Alan Randall (2019) Evidence of climatic change in Vietnam: Some implications for agricultural production, Journal of Environmental Management, Volume 231, 2019, Pages 524-545, ISSN 0301-4797, https://doi.org/10.1016/j.jenvman.2018.10.011.

[72] S. Kundu, D. Khare, A. Mondal, P.K. MishraAnalysis of spatial and temporal variation in rainfall trend of Madhya Pradesh, India (1901–2011) Environ. Earth Sci., 73 (2015), pp. 8197-8216, 10.1007/s12665-014-3978-y

[73] ibid

cultivation and productivity during the growing season due to the warming across the country and the surplus or deficit of rainfall in certain areas. It is consequently expected that climate change will have adverse effects on the agricultural sector, including rice production in many regions of Vietnam. It is expected that changes in the climate patterns will influence the frequency and intensity of future floods but also water scarcity[74].

4.2.4 Global Climate Models

Global Climate Models (GCMs) are used to project changes in the Earth's climate. The prevailing generation of models associated with the fifth Assessment Report from IPCC (AR5) from the Coupled Model Intercomparison Project Phase 5 (CMIP5), includes more than 40 models from more than 20 modelling centres. Unsurprisingly, with such a disparate set of processes, locations, and variables, few models can stand out consistently, in either a positive or negative way, in such a variety of contexts[75]. It is difficult to apply the raw data of GCMs at a local scale without downscaling due to their relatively coarse resolution[76]. The CORDEX, or Coordinated Regional Climate Downscaling Experiment, offers global coordination for developing high-resolution climate projections and precipitation models by downscaling GCMs to Regional Climate Models (RCMs)[77].

While the number of dynamical regional climate downscaling studies in Southeast Asia is limited[78], most available literatures focused on changes in mean precipitation[79]. Compared to the average climatic values, precipitation extremes have larger impacts to the ecosystem and many aspects of human society. To date, with 14 ensemble members, CORDEX-SEA is considered as the most comprehensive regional multi-model climate downscaling simulation over Southeast Asia[80]. Although the ensembles show a bias towards extreme precipitation, downscaling in Vietnam is consistent with most RCMs (especially RegCM4 and RCA4)[81].

In this ECA study, extreme precipitation are highly relevant, and we recommend, based on the latest results, to use projections from the CNRM-CM5-RegCM4 model used by the Vietnam National University.

4.2.5 Climate Scenario Definition

In this study, it is important to decide which scenarios and what GCMs should be used for future simulation. However, there is no consensus on which of the four Representative Concentration Pathways (RCPs; RCP2.6, RCP4.5, RCP6, or RCP8.5) is most likely; the IPCC considers all RCPs to be within the likely range of actual radiative forcing. Although RCP4.5 is widely used, we believe it would be prudent to plan for additional less optimistic scenarios. Henceforth, for this analysis, RCP4.5 and RCP8.5

---

[74] Nguyen Van Khanh Triet, Nguyen Viet Dung, Long Phi Hoang, Nguyen Le Duy, Dung Duc Tran, Tran Tuan Anh, Matti Kummu, Bruno Merz, Heiko Apel (2020) Future projections of flood dynamics in the Vietnamese Mekong Delta, Science of The Total Environment, Volume 742, 2020, 140596, ISSN 0048-9697, https://doi.org/10.1016/j.scitotenv.2020.140596.

[75] Rios, R., Taddia, A. and Grunwaldt, A. (2016). Climate Change projections in Latin America and the Caribbean. Report. IDB, New York. 32pp

[76] Feyissa, G., Zeleke, G., Bewket, W., & Gebremariam, E. (2018). Downscaling of future temperature and precipitation extremes in Addis Ababa under climate change. Climate, 6(3). https://doi.org/10.3390/cli6030058

[77] Pinto, I., Lennard, C., Tadross, M. (2016). Evaluation and projections of extreme precipitation over southern Africa from two CORDEX models. Climatic Change 135. 655–668. https://doi.org/10.1007/s10584-015-1573-1

[78] Supari, Fredolin Tangang, Liew Juneng, Faye Cruz, Jing Xiang Chung, Sheau Tieh Ngai, Ester Salimun, Mohd Syazwan Faisal Mohd, Jerasorn Santisirisomboon, Patama Singhruck, Tan PhanVan, Thanh Ngo-Duc, Gemma Narisma, Edvin Aldrian, Dodo Gunawan, Ardhasena Sopaheluwakan (2020) Multi-model projections of precipitation extremes in Southeast Asia based on CORDEX-Southeast Asia simulations, Environmental Research, Volume 184, 109350, ISSN 0013-9351, https://doi.org/10.1016/j.envres.2020.109350

[79] ibid

[80] F. Tangang, et al. (2020) Projected Future Changes in Rainfall in Southeast Asia Based on Multi-Model Simulations of CORDEX Southeast Asia, submitted for publication

[81] Supari, Fredolin Tangang et al. (2020) Multi-model projections of precipitation extremes in Southeast Asia based on CORDEX-Southeast Asia simulations, Environmental Research, Volume 184, 109350, ISSN 0013-9351, https://doi.org/10.1016/j.envres.2020.109350

are selected simply because they are most consistent. As discussed above, we suggest using CNRM-CM5 in combination with the RegCM4 RCM, whenever available for future simulation of precipitation.

5. Data Collection and Evaluation

This section presents the availability of data necessary for this study. Different type of data is necessary and ranges from meteorological data, population data, asset and damage data, spatial data, socio-economic data to climate data. All data were subject to drastic quality control and stored in a dedicated database to avoid redundancy. Table 5 below presents the different data types along with their source, availability and an evaluation of their quality (Green: good quality and suitable for the study; Yellow: Medium quality. Data needs to be updated; Red: Insufficient quality for the study). Where data is of insufficient quality or need additional work, we have indicated possible proxies and their sources. All proxies are acquired and are evaluated as of good quality for this study. In the case of this ECA study, almost all data were obtained from key partners based in Can Tho and literature, publicly available or accessible in scientific journals. An important key partner during the base data collection process was the Research Institute for Climate Change (DRAGON Mekong Institute), which is subordinated to Can Tho University.

Table 5: *Summary of data collected, quality assessment and supplementary sources when relevant.*

Data Item	Availability	Source	Quality	Proxy	Proxy Source
1. Impacts of past flood events					
1.1 Asset values					
1.1.1 Public assets	Yes	DRAGON Mekong Institute (consulting work)	(1) Road Networks of 6 different classes; (2) Drainage System: Storm & waste water sewers; (3) Residential houses – four types; (5) Schools (Kindergarten, Nursery- , Primary-, Secondary Schools, Colleges); (6) Medical Centres/Hospitals; (7) Administrative Buildings; (8) Electricity Grid, (9) Industrial Parks/Residential areas; (10) Water supply network		
1.1.2 Population	Yes	Can Tho Statistical Yearbook 2019 / General Statistics Office Vietnam	The information on average population; sex Ratio; population by housing type, life expectancy, etc. for each ward in 3 districts (ECA study area).		
Census	Yes	Can Tho Statistical Yearbook 2019 / General Statistics Office Vietnam	Census of 2009 & 2019; Population count and density for each ward in Ninh Kieu, Binh Thuy and Cai Rang district.		
1.2 Historical damages	Yes	DRAGON Mekong Institute (consulting work)	Information on *damages/direct economic impacts* are scarce, mainly based on scientific literature or singular household surveys. Precise information of 52 flooded streets available for 2016-2018, incl. flood time & duration, flood depth and flood regime. Flood maps available (heavily flooded >0.4m / medium flooded <0.4m / slightly flooded <0.2m)	'*Natural Disaster Reports'* of Can Tho available for 2014-2019 (in Vietnamese). Source for additional information on impacted assets and economic impacts. Further translation of documents required.	People's Committee Can Tho

1.2.3 Population (lives affected by flood)	No			*'Natural Disaster Reports'* of Can Tho available for 2014-2019 (in Vietnamese). Source for additional information on impacted assets and economic impacts. Further translation of documents required.	People's Committee Can Tho
2. Remote sensing					
2.1 High resolution satellite images	No			Satellite images with high resolution (preferably 0.3-1 meters)	• DRAGON Mekong Institute/ Can Tho University • UNU-EHS' own database
3. Meteorological Data					
3.1 Precipitation	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	Daily precipitation data available for 2000--2018 perceived from the Dragon Institute (consulting work). In addition, Can Tho Airport Gauge Data available for precipitation, hourly, 15 years (1965-1970, 1973-1975, 2014-2019)USAF-WBAN_ID Station Name: *489125 9999 Can Tho.*		
3.2 Temperature	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	Temperature data (avg, min, max) available for 2000-2014 perceived from the Dragon Institute (consulting work). In addition, Can Tho Airport Gauge Data available for air temperature, 15 years (1965-1970, 1973-1975, 2014-2019).USAF-WBAN_ID Station Name: 489125 9999 Can Tho.		
3.3 Extreme Temperatures	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	Can Tho Airport Gauge Data available for extreme temperatures, 15 years (1965-1970, 1973-1975, 2014-2019).USAF-WBAN_ID Station Name: 489125 9999 Can Tho. Counts the number of days with maximum temperature of 32.2°C (90 F) or higher.		

3.4 Relative Humidity	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	Relative (daily) humidity data available for 2000-2012 perceived from the Dragon Institute (consulting work). In addition, Can Tho Airport Gauge Data available for relative humidity, hourly, 15 years (1965-1970, 1973-1975, 2014-2019).USAF-WBAN_ID Station Name: 489125 9999 Can Tho.		
3.5 Evaporation	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	Evapotranspiration data (daily) available for 2008-2018.		
3.6 Water level & Discharges	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	Water level (Hau River): daily data from 1998 – 2018; Monthly water discharge (Hau River) from 2008-2013 and 2015 and 2018.		
3.7 Tides of Hau River	No			Data available at two tide-monitoring stations in Can Tho & Dinh An	Both station operated by Mekong River Commission (MRC)
4. Soil Data					
4.1 Types of soils	No		Only a brief description available. Precise GIS data are not available.	Soil map of Ninh Kieu, Binh Thuy & Cai Rang district	• FAO • Can Tho University • DoNRE
5. Administrative Areas					
5.1 Political-Administrative Division	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	Administrative boundaries of selected district and their respective wards is available in GIS format.		
6. Socio-economic factors					
6.2 Employment / additional income sources	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	Information on 14 different employment sectors in Can Tho available, including unemployment rates (as of 2019)		
6.3 Evolution of wealth (GDP per capita/ CPI	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	Development of income and consumer price index		

6.4 Economic growth	Yes	World Bank Database / Economist Intelligence Unit (EIU)	Projections of GPD growth rates for 2020-2050.		
7. Households					
7.1 Type / size of housing/houses	Yes	General Statistics Office Vietnam / Census 2009 & 2019	Type of housing in based on four classification types: permanent, semi-permanent, temporal, simple.		
7.2 Household conditions (number of members and housing conditions)	Yes	General Statistics Office Vietnam / Census 2009 & 2019	Information on number of households and household size in each district. Average floor area per household by district.		
7.3 Emigration/Immigration	Yes	General Statistics Office Vietnam / Census 2009 & 2019	Information on net emigration and immigration rate for Can Tho		
9. Cadastre and Land Use (GIS)					
9.1 Land use	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University MoNRE	• Agricultural Land Use (2017) available in GIS • Current Land Use (2014) only PDF format • Planned Land Use (2020 & 2030) only in PDF format	• Digitalization from PDF format possible • Request access to GIS files	• People's Committee Can Tho
9.2 Cadastre	Yes	People's Committee Can Tho	2014 Urban cadastre in pdf format. Urban land values at main roads available, sub-roads and residential as well as resettlement areas in the 3 districts		
9.3 Residential Buildings	Yes	DLR (WISDOM Project)	Building footprints derived from Quickbird images (2012) are available for Can Tho City. Nonetheless, recently build building are not covered.	Extract building footprints from recent satellite images.	• UNU-EHS
10. Infrastructure (GIS)					
10.1 Health Centers/Hospitals	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	GIS locations available for hospitals in study area		

10.2 Road Network	Yes	• DRAGON Mekong Institute (consulting work)/ Can Tho University • Open Street Map (OSM) Data	Road network (main & secondary roads)		
10.3 Drainage System	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	Drainage System available for Binh Thuy and Ninh Kieu	Drainage system for Cai Rang needed (if existent or in planning)	
10.4 Schools/Education	Yes	DRAGON Mekong Institute (consulting work)/ Can Tho University	GIS location of schools/educational facilities available		
10.5 Electricity Grid	No		A plan of the existing electricity grid for the whole city is not available.	Road Network	Open Street Map Database
11. Strategies and policies of the regions					
11.1 Relevant Strategies/Government Resolutions	Yes	• Government Resolution 59-NQ/TW on Building and developing Can Tho City till to 2030 with vision until 2045 (2020) • Master Plan for Socio-Economic Development of Can Tho City through 2020 with vision 2030 (2013) • Master plan of the Can Tho City till 2030 and with a vision to 2050 (Decision No: 1515/QD-TTg) • Government Resolution 120 /NQ-CP on Sustainable and Climate-Resilient Development of the Mekong Delta of Vietnam • Can Tho City Strength Diagnostic, Resilient Cities Programme, WBG, 2014 • Designing for Nature-Based Infrastructure in Can Tho, Resilience Accelerator, 100RC, 2019 • Can Tho Climate Change Activities Strategy in the Period 2015-2030, Can Tho's People's Committee, 2015 • Mekong Delta Plan, Long-term Vision and Strategy			

6. Conclusion and Next Steps

This report describes the state of data availability and data collection to run CLIMADA. It presents a general overview of the collected data, with a quality assessment regarding their usability for the ECA study, as well as the proposed proxies for those data sets that are insufficient for running CLIMADA or might lead to too high uncertainties in the final results. The inception phase of the ECA study in Vietnam defined the scope, including hazards, key assets, and the time horizon. This report documents and discusses data availability and quality for this purpose. Suggestions of possible proxies are made for unavailable data and data of insufficient quality. In some occasions, high-quality subnational data remain a challenge. The data presented here is of sufficient quality to successfully run CLIMADA. An exception must be made for the future flood model of Can Tho. Potential datasets for a potential combined flood model, including different flood regimes, still needs to be consulted and assessed in particular. Further, this document showcases hazard and assets selections in the study area along with final recommendations for climate and socio-economic scenarios to be included in CLIMADA.

The overall results of the database report are summarised below:

1) A systematic review of available data and collection of proxies whenever necessary for running CLIMADA
2) Visualization and final recommendations on hazards and assets selection
3) Development of climate and socio-economic scenarios based on the latest research

Specific results of the report include:

Hazard: Floods (fluvial, pluvial and tidal) and heat waves are selected and simulated for today and in the future for the area of Can Tho City.

Study Area: In particular, Ninh Kieu, Binh Thuy and Cai Rang district of Can Tho City are the defined study area for the ECA study. These urban and peri-urban districts consist 28 wards and a total population count of 421.682 inhabitants.

Time Horizon: Based on discussions with key stakeholders and in alignment with (regional) key government decisions and strategies[82] the defined time horizon for the ECA study is defined for 30 years, from year 2020 to 2050.

---

[82]

- Master plan of the Can Tho City till 2030 and with a vision to 2050 (Decision No: 1515/QD-TTg)
- Government Resolution 59-NQ/TW on Building and developing Can Tho City till to 2030 with vision until 2045 (2020)
- Master Plan for Socio-Economic Development of Can Tho City through 2020 with vision 2030 (2013)

Assets: Following the Inception Report and an additional 'scoping consultancy' in cooperation with the DRAGON Mekong Institute of Can Tho University, the assets listed below are supported by the collected data and displayed in this report:

- People & Vulnerable Groups
- Public Assets
  - Schools
  - Medical Centres/Hospitals
  - Administrative (Public) Buildings
  - Electricity Grid
  - Road Network
- Housing
- Natural Resources
  - Agriculture
    - Aquaculture
    - Cash Crops
    - Fruit Trees/Gardens
    - Triple Rice Crops
  - Green Spaces/Areas

Data availability: The availability of the data is presented in this report. All data were subject to drastic quality control and stored in a dedicated database to avoid redundancy. We have selected and presented alternatives for missing data. In addition to the data gathered has been verified and validated accordingly in a series of validation workshops together with key stakeholders.

Special note on COVID-19 risk assessment: In the current pandemic context, the ECA Study Team has conducted a thorough risk assessment for the project. According to our current knowledge we estimate how the current situation might impact the timeline and deliverable of the ECA study in Vietnam. A separated detailed brief will be shared with stakeholders. The overall risk assessment level is estimated to be "medium" with an expected 3-4 months delay compared to the initial schedule. Delays are mostly caused by travel restrictions. We offer several mitigation options including digital workshops and delayed final delivery workshops. An updated time plan is provided in Annex 6.

Concrete next steps include:

Data Validation Workshop: A short online workshop will take place in January 2021 to inform about the development of the ECA study in Vietnam. In case an online workshop will not be feasible (i.e. due to internet blockades or limited bandwidth) alternative modes are being evaluated.

A long list of adaptation measures: A long list of possible adaptation measures will be prepared and discussed with stakeholder during a short online workshop in February 2020. After this workshop, a shortlist of measures will be selected for introduction into CLIMADA.

Valuation of assets: Selected assets will be given monetary values, using different methods. Values and methods will be documented in the vulnerability report.

Damage functions: Using available historical damages, desk research and expert interviews, the relationship between different flood regimes affecting Can Tho and the potential damage will be

quantified by so-called damage functions. Details about damages functions will be explained in the vulnerability report.

Simulation in CLIMADA: In this step, assets values and location, as well as damage functions, will be introduced in CLIMADA for simulation. The combined flood model will be validated as a next step. Adaptation measures and climatic and socio-economic scenarios are also added to the model. Calibration and validation of the model are essential steps that will be performed, using historical events. Simulation of future flood events will document the effectiveness of the shortlist of adaptation measures.

Vulnerability Report: The vulnerability report is expected to be circulated in April/May 2021. It will include the simulations and results of CLIMADA, the results of the combined flood model, and a ranking of recommended adaptation measures for Ninh Kieu, Binh Thuy and Cai Rang district of Can Tho. It details decisions made for every step and makes recommendations on the best measures. Uncertainties linked to the modelling exercise are also discussed.

ANNEXES

Economics of
Climate
Adaptation

ANNEX 1: Population Count & Density (2019)
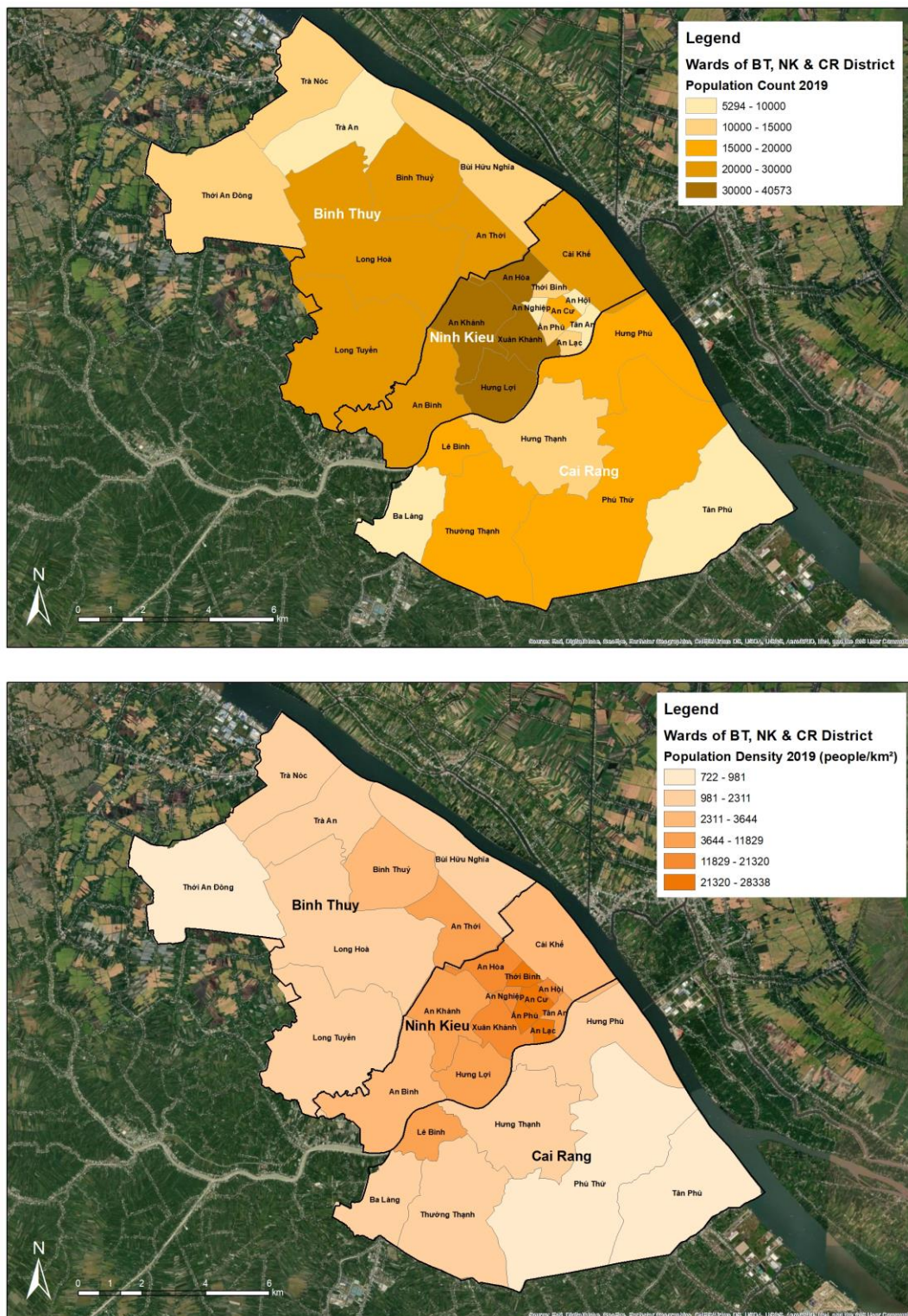
Figure 8: Population count (top) & density (bottom) for Ninh Kieu, Binh Thuy and Cai Rang district, incl. wards. Source: Census 2019.

ANNEX 2: Population count for districts & wards (2019)

Table 6: *Population count of Ninh Kieu, Binh Thuy and Cai Rang, incl. respective wards. Source: Census 2019.*

Ninh Kieu District		Binh Thuy District		Cai Rang District	
Ward	*Pop. count*	*Ward*	*Pop. count*	*Ward*	*Pop. Count*
Cai Khe	23.648	Binh Thuy	21.409	Le Binh	18.154
An Hoa	31.614	Tra An	9.579	Hung Phu	17.325
Thoi Binh	13.291	Tra Noc	14.951	Hung Thanh	13.042
An Nghiep	7.462	Thoi An Dong	11.874	Ba Lang	6.052
An Cu	17.286	An Thoi	28.447	Thuong Thanh	15.926
An Hoi	6.853	Bui Huu Nghia	11.979	Phu Thu	20.024
Tan An	5.294	Long Hoa	21.941	Tan Phu	7.799
An Lac	11.867	Long Tuyen	22.129		
An Phu	12.766				
Xuan Khanh	32.388				
Hung Loi	39.864				
An Khanh	40.573				
An Binh	26.635				
TOTAL	**269.541**		**142.309**		**98.322**

ANNEX 3: List of Selected Public Assets (Buildings)

Table 5: *List of selected Public Assets (Administrative buildings, Schools, Medical centres/Hospitals)*

1. Administrative (Public) Buildings

#	Name (Vietnamese)	Name (English)	District
1	Vien kiem sat nhan dan TPCT	People's Procuracy of Can Tho City	Ninh Kieu
2	UBND phuong Tan An	People's Committee of Tan An Ward	Ninh Kieu
3	So ngoai vu TPCT	Department of Foreign Affairs of Can Tho city	Ninh Kieu
4	Hoi Lien Hiep phu nu TPCT	The Women's Association of Can Tho city	Ninh Kieu
5	UBND phuong An Cu	People's Committee of An Cu Ward	Ninh Kieu
6	Phong canh sat PCCC TP Can Tho	Fire and Rescue Police Department of Can Tho city	Ninh Kieu
7	So TNMT TP Can Tho	Department of Natural Resources and Environment of Can Tho city	Ninh Kieu
8	So cong thuong TPCT	Department of Industry and Trade of Can Tho city	Ninh Kieu
9	So KH&ĐT TP Can Tho	Department of Planning and investment of Can Tho city	Ninh Kieu
10	UBND phuong An Nghiep	People's Committee of An Nghiep Ward	Ninh Kieu
11	So ngoai vu TPCT	Department of Foreign Affairs of Can Tho city	Ninh Kieu
12	UBND phuong Xuan Khanh	People's Committee of Xuan Khanh Ward	Ninh Kieu
13	UBND phuong An Hoi	People's Committee of Xuan Khanh Ward	Ninh Kieu
14	Chi cuc Thue quan Ninh Kieu	Tax department of Ninh Kieu district	Ninh Kieu
15	Thanh uy TP Can Tho	Party Commitee of Can Tho	Ninh Kieu
16	So Tu phap TP Can Tho	Department of Justice of Can Tho city	Ninh Kieu
17	Toa an Nhan dan TP Can Tho	Can Tho city People's Court	Ninh Kieu
18	Toa an Nhan dan quan Ninh Kieu	Ninh Kieu district People's Court	Ninh Kieu
19	Cong an Phuong An Hoa	Police department of An Hoa ward	Ninh Kieu
20	Cong an Phuong Cai Khe	Police department of Cai Khe ward	Ninh Kieu
21	Quan Uy Ninh Kieu	Party Commitee of Ninh Kieu district	Ninh Kieu
22	UBND Thanh pho Can Tho	People's Committee of Can Tho city	Ninh Kieu
23	So GTVT Tp Can Tho	Department of transportation of Can Tho city	Ninh Kieu
24	So NN&PTNT Can Tho	Department of Agriculture And Rural Development of Can Tho	Ninh Kieu
25	VTV Can Tho	Vietnam Television of Can tho city	Ninh Kieu
26	UBND Phuong An Binh	People's Committee of An Binh Ward	Ninh Kieu
27	Toa an Nhan dan TP Can Tho	Can Tho city People's Court	Ninh Kieu
28	So KH va CN Can Tho	Depart ment of Science and Technology of Can Tho	Ninh Kieu
29	Cong an phuong An Cu	Police department of Cai Khe ward	Ninh Kieu
30	Cong an quan Ninh Kieu	Police department of Cai Khe ward	Ninh Kieu
31	Cong an TP CT	Police department of Can Tho city	Ninh Kieu
32	UBND Phuong An Khanh	People's Committee of An Khanh Ward	Ninh Kieu
33	Cong an Phuong An Khanh	Police department of An Khanh ward	Ninh Kieu
34	Cong an Phuong An Binh	Police department of An Binh ward	Ninh Kieu

35	UBND phuong Hung Phu	People's Committee of Xuan Khanh Ward	Cai Rang
36	UBND phuong Phu Thu	People's Committee of Xuan Khanh Ward	Cai Rang
37	UBND Phuong Tan Phu	People's Committee of Tan Phu Ward	Cai Rang
38	UBND Phuong Hung Thanh	People's Committee of Hung Thanh Ward	Cai Rang
39	UBND phuong Le Binh	People's Committee of Le Binh Ward	Cai Rang
40	Quan uy Cai Rang	Party Commitee of Cai Rang	Cai Rang
41	Toa an Nhan dan quan Cai Rang	Cai Rang district People's Court	Cai Rang
42	Cong an phuong Thuong Thanh	Police department Thuong Thanh	Cai Rang
43	UBND Phuong Thuong Thanh	People's Committee of Thuong Thanh	Cai Rang
44	UNBD Phuong Binh Thuy	People's Committee of Binh Thuy Ward	Binh Thuy
45	Chi cuc Thi hanh an Dan su quan Binh Thuy	Department of Civil Judgment Enforcement of Binh Thuy district	Binh Thuy
46	UBND Phuong Thoi An Dong	People's Committee of Thoi An Dong Ward	Binh Thuy
47	Cong an Phuong Thoi An Dong	Police department of Thoi An Dong ward	Binh Thuy
48	Toa an Nhan dan quan Binh Thuy	Binh Thuy district People's Court	Binh Thuy
49	UBND quan Binh Thuy	People's Committee of Binh Thuy Ward	Binh Thuy
50	Cong an quan Binh Thuy	Police department of Binh Thuy Ward	Binh Thuy
51	UBND phuong Tra An	People's Committee of Tra An Ward	Binh Thuy

2. Medical Centres & Hospitals			
#	Name (Vietnamese)	Name (English)	District
1	Benh vien Da Khoa Trung Uong CT	Can Tho Central General Hospital	Ninh Kieu
2	Benh vien quoc te Phuong Chau	Phuong Chau international hospital	Ninh Kieu
3	Benh vien tim mach TPCT	Can Tho Cardiovascular Hospital	Ninh Kieu
4	Tram y te phuong An Hoa	Medical Center of An Hoa Ward	Ninh Kieu
5	Benh vien da khoa TP Can Tho	Can Tho General hospital	Ninh Kieu
6	Benh vien quan y 121	121 Military Hospital	Ninh Kieu
7	Benh vien Da Lieu Can Tho	Can Tho Dermatology Hospital	Ninh kieu
8	Benh vien Nhi dong Can Tho	Can Tho Children's Hospital	Ninh Kieu
9	Benh vien mat - Rang ham mat TP. Can Tho	CanTho Eye and Odonto- Stomatology Hospital	Ninh Kieu
10	Benh vien Tai mui hong TP Can Tho	Can Tho Ear, Nose and Throat hospital	Ninh Kieu
11	Benh vien Y hoc co truyen Can Tho	Can Tho Traditional Medicine Hospital	Ninh Kieu
12	Benh vien Huyet hoc Truyen mau TPCT	Can Tho hematology blood transfusion hospital	Ninh Kieu
13	Benh vien Da khoa Hoa Hao - Can Tho	Hoa Hao General hospital	Ninh Kieu
14	Benh vien Phu san TP. Can Tho	Can Tho Obstetrics and Gynecology Hospital	Ninh Kieu

15	Tram Y te Phuong Xuan Khanh	Medical Center of Xuan Khanh Ward	Ninh Kieu
16	Tram Y te Phuong An Binh	Medical Center of An Binh Ward	Ninh Kieu
17	Tram y te Phuong An Cu	Medical Center of An Cu Ward	Ninh Kieu
18	Tram Y te phuong An Hoa	Medical Center of An Hoa Ward	Ninh Kieu
19	Tram y te Phuong An Hoi	Medical Center of An Hoi Ward	Ninh Kieu
20	Tram Y te phuong An Khanh	Medical Center of An Khanh Ward	Ninh Kieu
21	Tram Y te phuong An Lac	Medical Center of An Lac Ward	Ninh Kieu
22	Tram Y te Phuong An Phu	Medical Center of An Phu Ward	Ninh Kieu
23	Tram y te Phuong Cai Khe	Medical Center of Cai Khe Ward	Ninh Kieu
24	Tram y te phuong Hung Loi	Medical Center of Hung Loi Ward	Ninh Kieu
25	Tram y te phuong Tan An	Medical Center of Tan An Ward	Ninh Kieu
26	Tram Y te phuong Bui Huu Nghia	Medical Center of Bui Huu Nghia Ward	Ninh Kieu
27	Benh vien Hoan My Cuu Long	Hoan My Cuu Long Hospital	Ninh Kieu
28	Benh vien Ung buou TP Can Tho	Can Tho oncology hospital	Ninh Kieu
29	Tram Y te phuong Ba Lang	Medical Center of Ba Lang Ward	Cai Rang
30	Tram y te phuong Hung Phu	Medical Center of Hung Phu Ward	Cai Rang
31	Tram Y te phuong Hung Thanh	Medical Center of Hung Thanh Ward	Cai Rang
32	Tram Y te phuong Le Binh	Medical Center of Le Binh Ward	Cai Rang
33	Benh vien Tam Duc Can Tho	Tam Duc hospital	Binh Thuy
34	Tram Y te phuong An Thoi	Medical Center of An Thoi Ward	Binh Thuy
35	Tram Y te phuong Binh Thuy	Medical Center of Binh Thuy Ward	Binh Thuy
36	Tram Y te phuong Long Hoa	Medical Center of Long Hoa Ward	Binh Thuy
37	Tram Y te phuong Long Tuyen	Medical Center of Long Tuyen Ward	Binh Thuy
38	Tram Y te Phuong Thoi An Dong	Medical Center of Thoi An Dong Ward	Binh Thuy
39	Tram y te phuong Tra Noc	Medical Center of Tra Noc Ward	Binh Thuy
40	Benh vien da khoa quan Binh Thuy	General hospital Binh Thuy District	Binh Thuy

3. Schools (incl. kindergartens, nursery- , primary-, secondary school)		
#	**Name (Vietnamese)**	**Name (English)**	**District**
1	Truong THCS Luong The Vinh	Luong The Vinh Secondary school	Ninh Kieu
2	TT Ngoai ngu - Tin hoc TP Can Tho	Can Tho Computer training and foreign language center	Ninh Kieu
3	Truong Tieu hoc An Binh 1	An Binh 1 Primary school	Ninh Kieu
4	Truong Trung cap GTVT mien Nam	Southern Transport Vocatinal School	Ninh Kieu
5	Khu 3 - ĐHCT	Can Tho University – Campus III	Ninh Kieu

6	Truong THCS Doan Thi Diem	Doan Thi Diem Secondary school	Ninh Kieu
7	Truong THPT Phan Ngoc Hien	Phan Ngoc Hien High school	Ninh Kieu
8	Truong tieu hoc Thoi Binh 1	Thoi Binh 1 Primary school	Ninh Kieu
9	Truong cao dang y te Can Tho	Can Tho Medical College	Ninh Kieu
10	Truong THCS An Khanh	An Khanh Secondary school	Ninh Kieu
11	Truong THPT An Khanh	An Khanh High school	Ninh Kieu
12	Truong cao dang KT-KT Can Tho	Can Tho Technical Economic College	Ninh Kieu
13	Truong THCS An Thoi	An Thoi Secondary school	Ninh Kieu
14	Dai hoc Can Tho - Khu II	Can Tho University	Ninh Kieu
15	Truong Tieu hoc Cai Khe 2	Cai Khe 2 Primary school	Ninh Kieu
16	Truong Dai hoc KT-CN Can Tho	Can Tho University of engineering and technology	Ninh Kieu
17	Truong Cao dang du lịch Can Tho	Can Tho Vocational Tourism College	Ninh Kieu
18	Truong Tieu hoc Vo Truong Toan	Vo Truong Toan Primary school	Ninh Kieu
19	Truong Cao dang Can Tho	Can Tho College	Ninh Kieu
20	Truong Dai hoc Y Duoc Can Tho	Can Tho University of Medicine and Pharmacy	Ninh Kieu
21	Truong Van Hoa Nghe Thuat Can Tho	Can Tho College of Art Culture	Ninh Kieu
22	Truong Trung cap Pham Ngoc Thach	Pham Ngoc Thach college	Ninh Kieu
23	Dai hoc Can Tho - Khu 1	Can Tho University – Campus I	Ninh Kieu
24	Truong THCS An Hoa 2	An Hoa 2 Secondary school	Ninh Kieu
25	Truong THCS Chu Van An	Chu Van An Secondary school	Ninh Kieu
26	Truong pho thong Thai Binh Duong	Thai Binh Duong High school	Ninh Kieu
27	Truong pho thong nang khieu TDTT Can Tho	Can Tho High School for the Gifted Student	Ninh Kieu
28	Truong Tieu hoc Le Quy Don	Le Quy Don Primary school	Ninh Kieu
29	Truong Tieu hoc Tran Quoc Toan	Tran Quoc Toan Primary school	Ninh Kieu
30	Truong Tieu hoc To Hien Thanh	To Hien Thanh Primary school	Ninh Kieu
31	Truong THPT Nguyen Viet Hong	Nguyen Viet Hong High school	Ninh Kieu
32	Truong THCS Tran Ngoc Que	Tran Ngoc Que Secondary school	Ninh Kieu
33	Truong Tieu Hoc Nguyen Hien	Nguyen Hien Primary school	Ninh Kieu
34	Truong THPT Chau Van Liem	Chau Van Liem High school	Ninh Kieu
35	Truong Tieu hoc Mac Dinh Chi	Mac Dinh Chi Primary school	Ninh Kieu
36	Truong Mam Non Trang Ti	Trang Ti Kindergarten	Ninh Kieu

37	Truong Mam non Hoa Cuc	Hoa Cuc Kindergarten	Ninh Kieu
38	Truong ĐH Nam Can Tho	Nam Can Though University	Ninh Kieu
39	Truong THPT Tran Dai Nghia	Tran Dai Nghia High school	Cai Rang
40	Truong THCS Hung Phu	Hung Phu Secondary school	Cai Rang
41	Truong Dai hoc Tay Do	Tay Do University	Cai Rang
42	Truong THCS Le Binh	Le Binh Secondary school	Cai Rang
43	Truong THCS Hung Thanh	Hung Thanh Secondary school	Cai Rang
44	Truong Tieu hoc Hung Thanh	Hung Thanh Primary school	Cai Rang
45	Truong tieu hoc Le Binh 2	Le Binh Primary school	Cai Rang
46	Truong Tieu hoc Phu Thu 1	Phu Thu 1 Primary school	Cai Rang
47	Truong Tieu hoc Thuong Thanh	Thuong Thanh Primary school	Cai Rang
48	Truong Tieu hoc Phu Thu 3	Phu Thu 3 Primary school	Cai Rang
49	Truong Pho Thong Viet My	Viet My high school	Cai Rang
50	Truong Mam non Hung Thanh	Hung Thanh Preschool	Cai Rang
51	Truong THPT Nguyen Viet Dung	Nguyen Viet Dung High school	Cai Rang
52	Truong THCS Phu Thu	Phu Thu Secondary school	Cai Rang
53	Truong Mam non Ngoi Sao 2	Ngoi Sao 2 Kindergarten	Cai Rang
54	Truong THCS Thuong Thanh	Thuong Thanh Secondary school	Cai Rang
55	Truong Trung cap Y Duoc MeKong	Mekong Medicine School	Binh Thuy
56	Truong Trung cap Canh sat nhan dan III	Police Academy III	Binh Thuy
57	Truong Trung cap Cong an nhan dan	Police Academy	Binh Thuy
58	Truong Trung Cap Dai Viet TPCT	Dai Viet Technical school	Binh Thuy
59	Truong Trung cap Hong Ha TPCT	Hong Ha Technical school	Binh Thuy
60	Truong THPT Bui Huu Nghia	Bui Huu Nghia High school	Binh Thuy
61	Truong THCS Binh Thuy	Binh Thuy Secondary school	Binh Thuy
62	Truong Tieu hoc An Thoi 1	An Thoi 1 Primary school	Binh Thuy
63	Truong THPT Binh Thuy	Binh Thuy High school	Binh Thuy
64	Truong THCS Long Tuyen	Long Tuyen Secondary school	Binh Thuy
65	Truong Tieu hoc Long Tuyen 2	Long Tuyen 2 Primary school	Binh Thuy
66	Truong mam non Long Tuyen	Long Tuyen P Kindergarten	Binh Thuy
67	Truong Tieu hoc Long Hoa 3	Long Tuyen 3 Primary school	Binh Thuy
68	Truong Man non Long Hoa	Long Hoa Kindergarten	Binh Thuy
69	Truong Man Non Huong Duong	Huong Duong Kindergarten	Binh Thuy

70	Truong Cao Dang Kinh te Doi Ngoai Can Tho	Can Tho College of Economy and Relation	Binh Thuy
71	Truong Tieu hoc Tra An	Tra An Primary school	Binh Thuy
72	Truong THCS Tra An	Tra An Secondary school	Binh Thuy
73	Truong THCS Long Hoa	Long Hoa Secondary school	Binh Thuy
74	Truong Tieu hoc Binh Thuy	Binh Thuy Primary school	Binh Thuy
75	Truong THCS Thoi An Dong	Thoi An Dong Secondary school	Binh Thuy
76	Truong Tieu hoc Thoi An Dong	Thoi An Dong Primary school	Binh Thuy
77	Truong tieu hoc Binh Thuy 2	Binh Thuy 2 Primary school	Binh Thuy

ANNEX 4: Classification of Housing Construction Material

In order to assess the quality of residential housing in Vietnam, the 2019 Population and Housing Census questionnaire was designed to collect information on the main construction materials used for houses. The table below presents the classification used in the 2009 and 2019 Population and Housing Census.

Table 7: Methods for Classifying Housing Based On Construction Materials In The 2009 And 2019 Population And Housing Census. Source: https://www.gso.gov.vn/en/population-and-houses-census/

	Main material of supporting columns	Main material of roof	Main material of walls
Sturdy	1. Steel-reinforced concrete 2. Brick/stone 3. Iron/steel/solid wood	1. Steel-reinforced concrete; 2. Tile (cement, terra cotta)	1. Steel-reinforced concrete 2. Brick or stone masonry 3. Wood/metal
Flimsy	4. Scrap wood/ bamboo 5. Other	3. Sheeting (fibrocement/ metal); 4. Leaves/straw/tar paper; 5. Other	4. Mud/lime/straw 5. Slabs/bamboo screen/ planks 6. Other

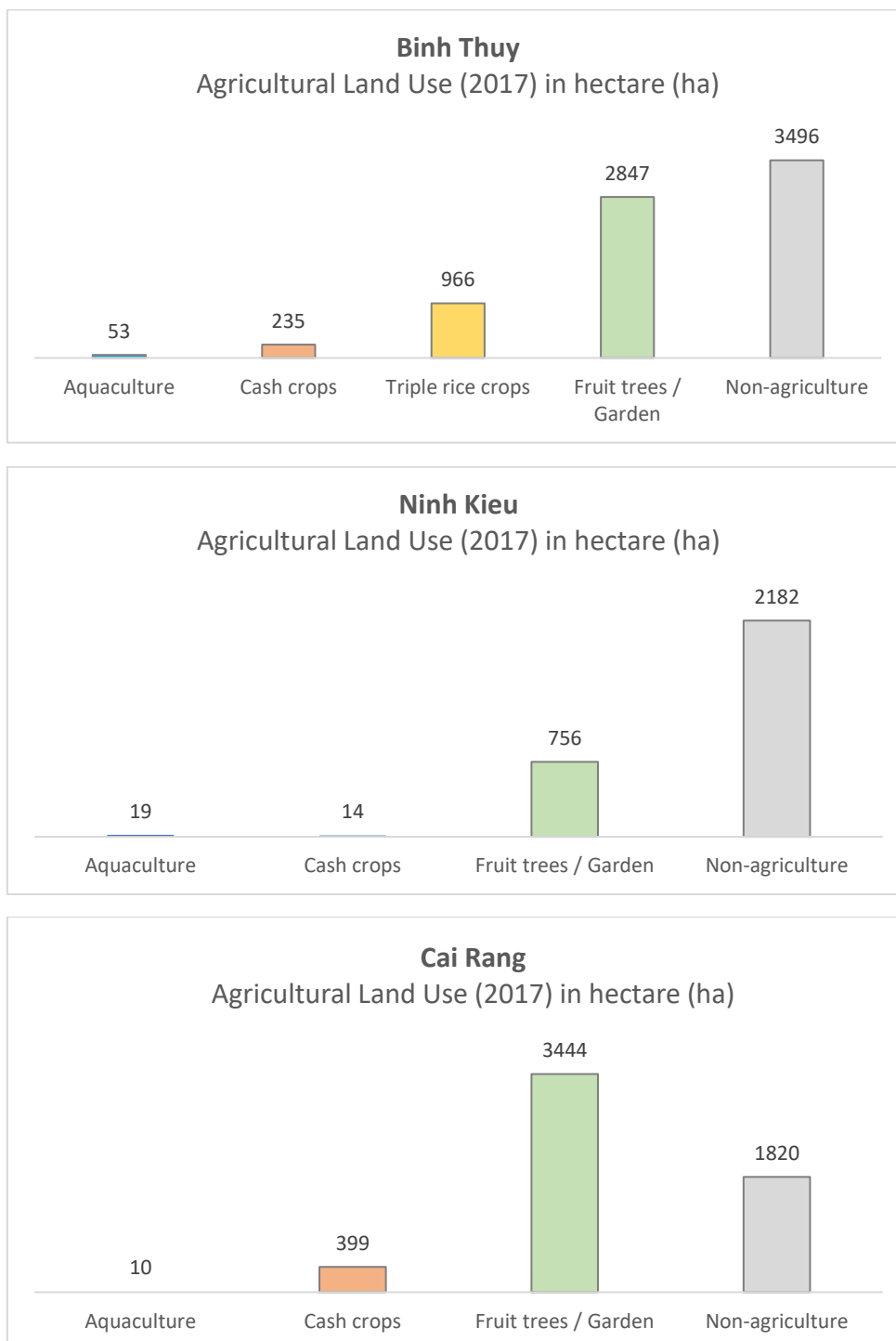# ANNEX 5: Agricultural Land Use (2017) per District

Figure 9: *Agricultural land use (2017) in hectare (ha) of Binh Thuy, Ninh Kieu and Cai Rang district.*

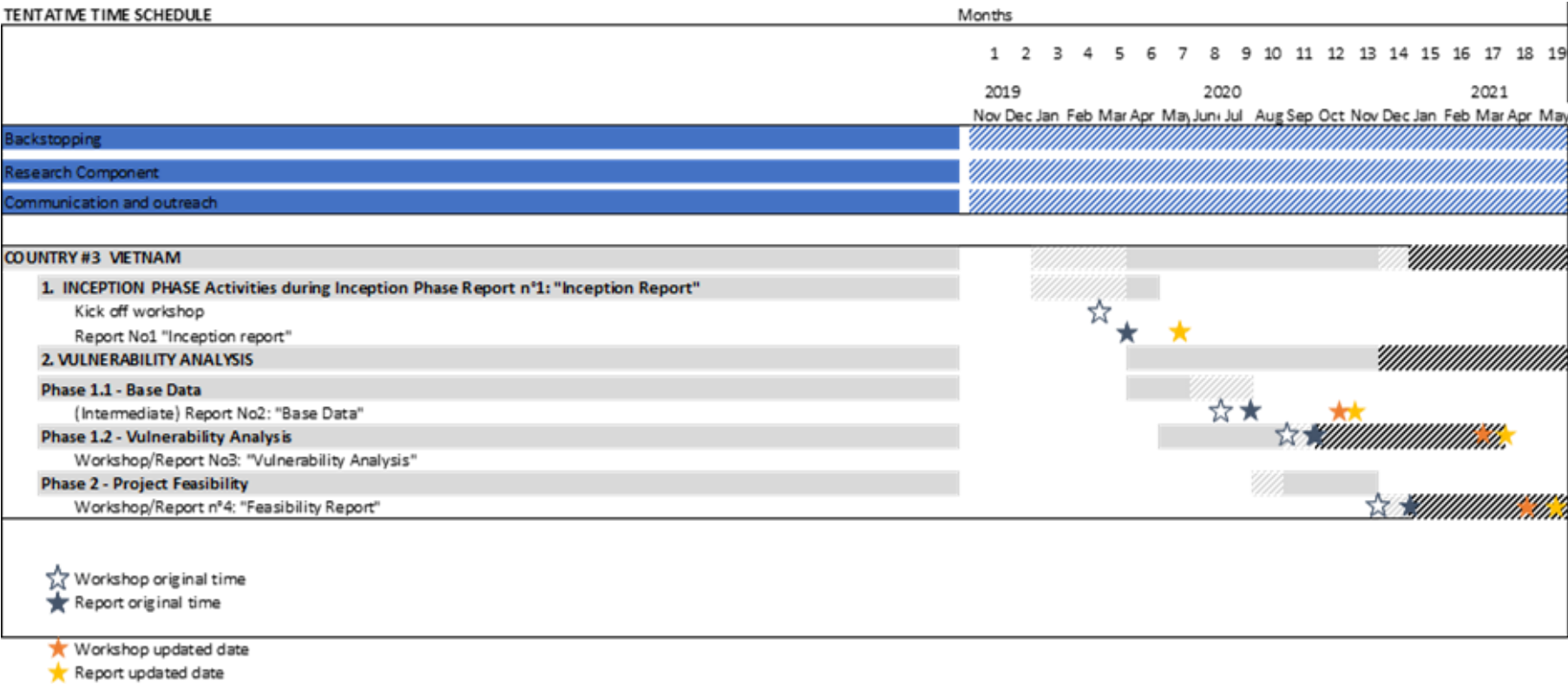# ANNEX 6: Updated Time Plan for the ECA Study

Figure 10: Updated time schedule for the ECA Study in Vietnam, indicating new tentative dates for workshops and deliverables respectively by orange and yellow stars (original dates are white and blue).

Authors: Eike Behre, Florian Waldschmidt, Alvaro Rojas, David Daou, Zita Sebesvari, Sönke Kreft and Maxime Souvignet

Economics of
Climate
Adaptation