Kingdom of Cambodia
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Project "Building Climate Resilience of Urban Systems through Ecosystem-Based Adaptation in the Asia-Pacific Region Project (Urban EbA Asia)"

Climate Vulnerability Mapping in Kep City

Prepared by: Dr. Oeurng Chantha, National Consultant
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Executive Summary

The objective of the report is to conduct the climate change risk and vulnerability assessment of Kep province and to identify the appropriate adaptation options for EbA interventions. Based on the climate vulnerability assessment, key findings are given as follows:

- Overall vulnerability to flash flood in the short-term and medium-term in the future, Prey Thum is the most vulnerable Sangkat, followed by Sangkat Ou Krasar and the Sangkat Kep (the less vulnerable one);
- Overall vulnerability to drought in both short-term and medium-term in the future in Kep city, Sangkat Kep is the most vulnerable Sangkat, followed by Sangkat Prey Thum and Sangkat Ou Krasar (the less vulnerable one);
- The overall shoreline erosion vulnerability Sangkats are in order: Prey Thum, Ou Krasar, and Kep; and
- Overall windstorm vulnerability in Kep city, these three Sangats are similarly vulnerable.

The adaptation options for EbA interventions in Kep province are proposed on the improvement of urban drainage system to reduce storm water, improvement of wastewater treatment plant, construction of sea dyke to project salinity intrusion that affects the rice fields, planting of mangrove to protect shoreline erosion, and building community ponds for drought resilience. Moreover, the training to build resilient capacity of the people is also proposed.

List of Abbreviations

ACI	Adaptive Capacity Index
ADB	Asian Development Bank
DEM	Digital Elevation Model
EbA	Ecosystem-based Adaptation
GDDP	Global Daily Downscaled Projections
GDP	Gross Domestic Product
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
LDCF	Least Developed Countries Fund
LULC	Land Use and Land Cover
MRC	Mekong River Commission
NASA	National Aeronautics and Space Administration
NCDD	National Committee for Sub-National Democratic Development
NEX	NASA Earth Exchange
NIS	National Institute of Statistics
MoE	Ministry of Environment
MOWRAM	Ministry of Water Resources and Meteorology
ODC	Open Development Cambodia
SEI	Sensitivity and Exposure Index
WFP	World Food Programme

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1 Introduction

1.1 Background

Building climate resilience of urban systems through Ecosystem-based Adaptation (EbA) in the Asia-Pacific region (project referred to as "Urban EbA Asia" in the text) is a four-year regional GEF-funded project of the Least Developed Countries Fund (LDCF), implemented by UN Environment. The project aims at reducing the vulnerability of poor urban communities in Asia-Pacific Least Developed

Countries (LDCs) to climate change impacts using Ecosystem-based Adaptation (EbA), with interventions in selected municipalities in Cambodia, Lao PDR, Bhutan, and Myanmar. Each country will benefit from the regional components that will include institutional strengthening and capacity building of city management authorities of pilot cities to plan and implement urban EbA as well as disseminate knowledge and public awareness on urban EbA in pilot cities.

In Cambodia, Kep City will benefit from specific EbA interventions under the second component of the project (CBD, 2009). The EbA interventions will be based on the recommendation from this assignment relate to the ecosystem assessment, livelihood improvement potential, socio-economic impacts including impacts on vulnerable groups, water shortage, proofing of infrastructure in the city, sustainable city, and so on.

1.2 Objective

The project aim at (1) conducting the climate change risk and vulnerability assessment, (2) collecting and updating data and information on biodiversity and ecology for the urban EbA intervention areas in Kep, (3) undertaking assessments to identify risks and adaptation needs of the urban communities to the effects of climate change at Kep City. The overall objective of the report is to conduct the climate change risk and vulnerability assessment of Kep province including the development of climate change models, climate impact analysis and identification of the appropriate adaptation options to provide EbA interventions at Kep province, especially Kep municipality. The product is to develop a report on adaptation needs for Kep province city and the potential for services from urban ecosystems. The output can contribute to meet the need that will be used as a basic for selecting the EbA options that will be implemented in the project.

2 Data and Methodology

2.1 Study Area Description

Kep is the smallest province of Cambodia, covering 336 km^2 with a population of 41,798 (NIS, 2019). The province has recently been assigned under new administrative division which consists of one municipality, Kep City and one district, Damnak Chang'aeur and has been recognized as the least populated province among the country. Figure 1 indicate the administrative boundary of the province as well as the boundary of our study area. The city has good road connections to the capital city of Cambodia, Phnom Penh (accessible by the National Road No.3 via Kampot province and the National Road No.2 via Takeo province) and Sihanoukville, home to the only deep seaport in Cambodia. The lowland paddy fields cover from the east to the lowland/upland mosaic in the west. The forest is located in the mountainous area of the western part of the Province (WFP, 2010). The temperature ranges from 17°C to 35°C and averages about 26°C. The area receives approximately 2216 mm of average annual rainfall (Municipality and Province Investment Information of Kep province, 2014).

The southern part of the province has an abundance of natural resources, fisheries, mangrove forests, and salt farms. The western part of the province has many mangrove forests and salt farms. For the most part, the northern and middle segments of the Province are covered by mountainous, productive land suitable for plantations, particularly high-quality pepper. Kep has a good potential for agriculture, fisheries, tourism, and seafood processing, and has abundant mountains with deep green jungles, mangrove forests and islands.

The territory of Kep province is divided into two districts:

- Damnak Chang'aeur, the largest district of the province and divided in two quarters – Angkaol to the west, and Pong Tuek at the east
- Kep Municipality: The municipality, located at the center of the Province, is subdivided into three communes: Sangkat Kep at the east of the Sangkat Kep, Sangkat Prey Thum in the middle, and Sangkat Ou Krasar at the west.

Kep was classified as the 8th most vulnerable province to climate change among all provinces in Cambodia due to its high hazard exposure and low adaptive capacity (Yusuf and Franscisco, 2010). The dominant feature of their vulnerability is their low adaptive capacity, ecological sensitivity, and higher exposure to climate hazards such as floods, droughts and windstorm.

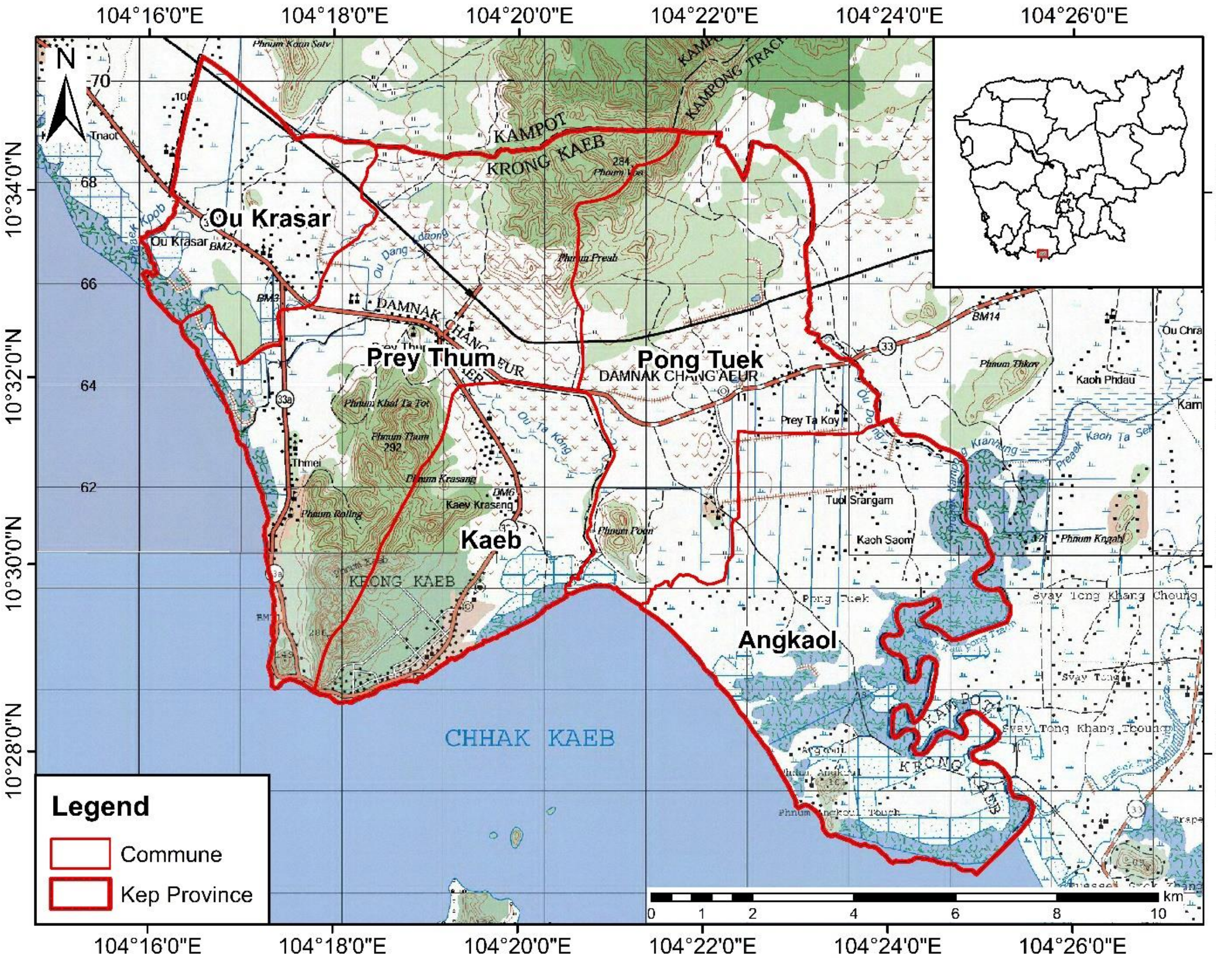


Figure 1: Commune maps of Kep province

2.2 Vulnerability Assessment Methods

Vulnerability is a multidimensional concept which varies across temporal and spatial scales and depends on economic, social, geographic, demographic, cultural, institutional, governance, and environmental factors (Thornton et al, 2006). As it needs to be considered across various dimensions, measuring vulnerability is complex (Gitz and Alexandre, 2012). There are different definitions of vulnerability to climate change, while there is little consensus about its precise meaning (Thomas, 2012). Even though the various definitions of vulnerability, most comprehensive and accepted is the definition by the Intergovernmental Panel on Climate Change (IPCC, 2000): The degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, including climate variability and extremes.

Vulnerability is a function of the character, magnitude, rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity. Thus, the vulnerability of any system is frequently considered as a function of three elements: exposure to a hazard, sensitivity to that hazard, and the capacity of the system to cope with and adapt or recover from the effects of those conditions, which are mostly referred to as adaptive capacity.

Exposure is the level and extent to which a system is exposed to significant climate change (Parry, 2007), and sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The effect may be direct (e.g., a change in crop yield in response to a change in the mean, range, or variability of temperature) or indirect (e.g., damages caused by an increase in the frequency of coastal flooding due to sea-level rise) (IPCC, 2000). Additionally, adaptive capacity is the ability or potential of a system to respond successfully to climate variability and change and includes adjustments in both behaviors and resources and technologies. The most widely used approach to the assessment of climate change vulnerability is based on the definition proposed by the IPCC. The vulnerability of a system can be defined as a function of the inter-relationship between three concepts (IPCC, 2000):

Vulnerability Index = f(Exposure, Sensitivity, Adaptive capacity)

Where:

- **Exposure**: "nature and degree to which a system is exposed to significant climatic variations";
- **Sensitivity**: "the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli"; and
- **Adaptive capacity**: "the ability of a system to adjust to climate change (including climate variability and extremes), to moderate the potential damage from it, to take advantage of its opportunities, or to cope with its consequences."

The relationship between these three components is outlined schematically in Figure 2.

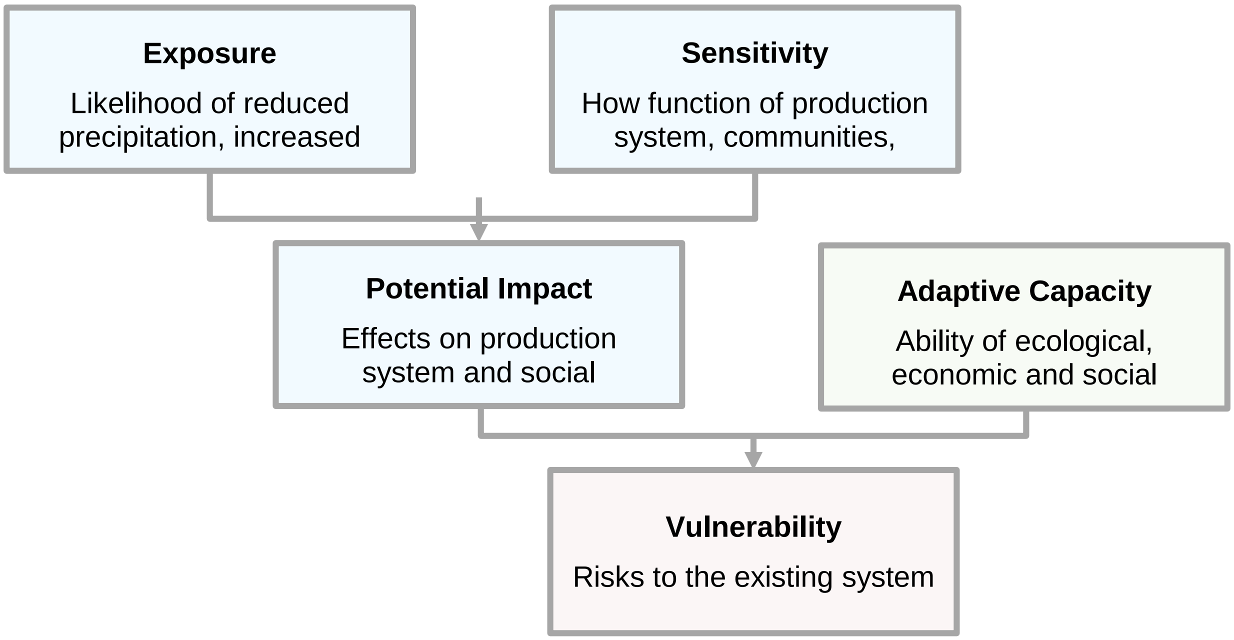


Figure 2: Key components of vulnerability, illustrating the relationship between exposure, sensitivity, and adaptive capacity.

Vulnerability is commonly comprised of three equally weighted metrics or components. Thus, the new modified formula for the vulnerability of the built environment (National Park Service, 2020).

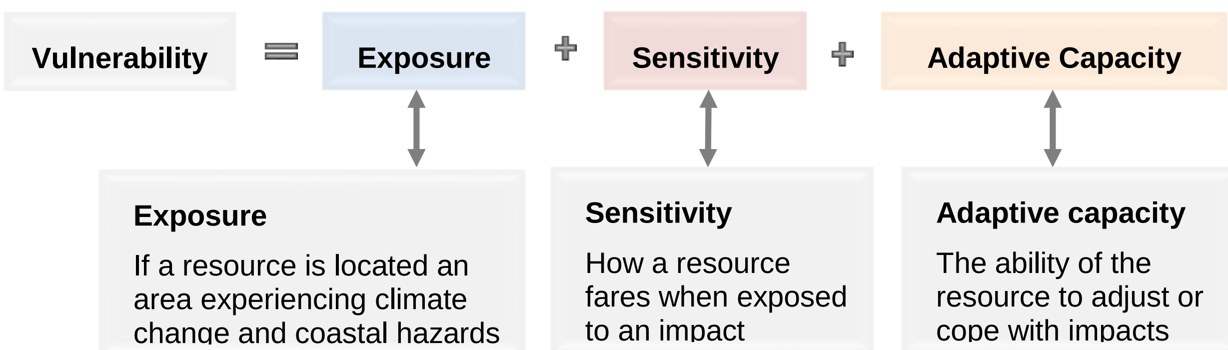


Figure 3: The new modified formula for the vulnerability assessments

2.2.1 Selection of Indicators

To assess the vulnerability of each hazard that does not appear to be modifying the subject, three components of vulnerability were included exposure, sensitivity, and adaptive capacity. Sub-groups of indicators were generated from the three level component of indicators. Only one index was generated for each hazard as exposure. Four groups of indicators were created for sensitivity, including Livelihood sensitivity, Natural sensitivity, Infrastructure sensitivity, and Human sensitivity. Five groups of indicators were generated for adaptive capacity, including Human adaptive capacity, Social capital adaptive capacity, Technological adaptive capacity, Economic adaptive capacity, and Infrastructural adaptive capacity.

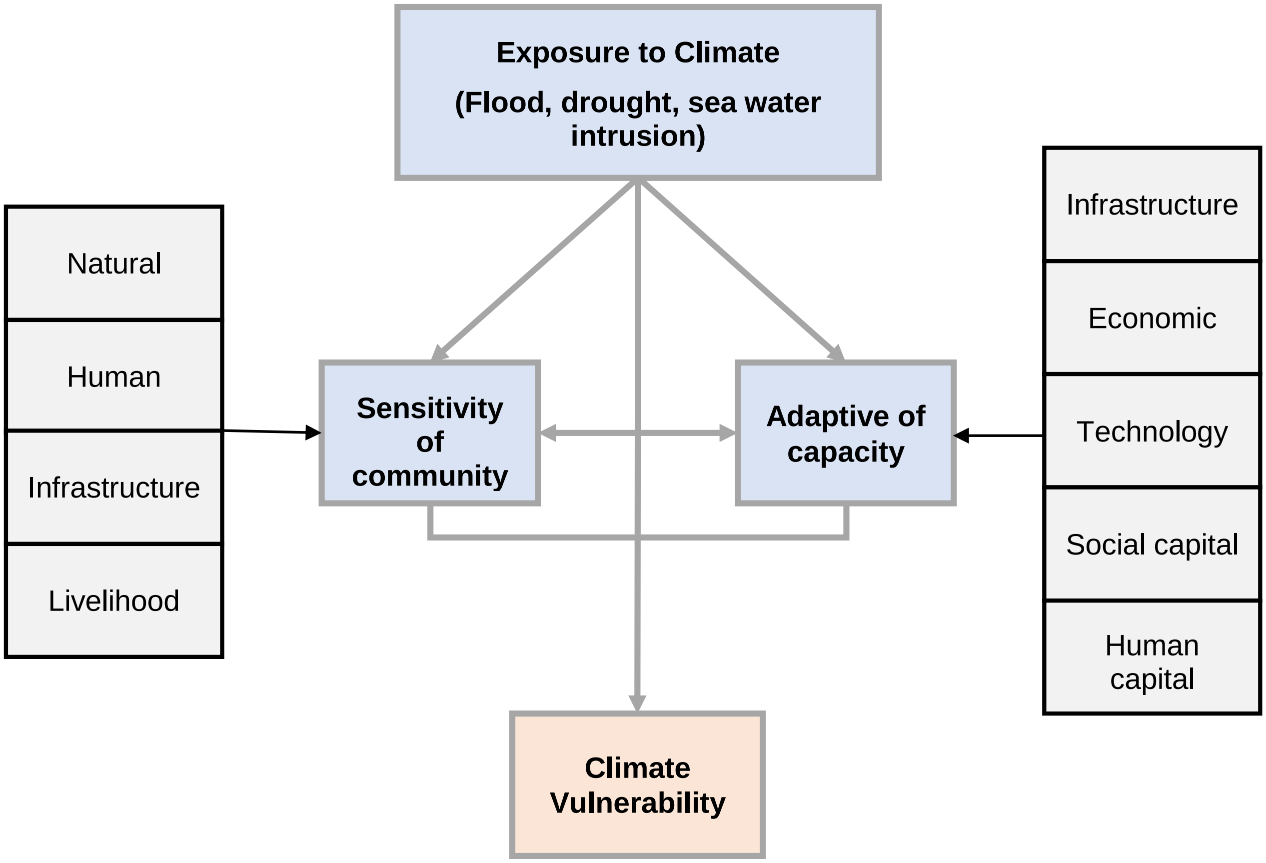


Figure 4: Various groups of indicators used to assess the vulnerability

The indicators from the empirical data were developed from sub-groups or level 4 indicators. Table 1 demonstrates how the overall vulnerability was evaluated. The overall vulnerability is the combination of the vulnerability from flash flood and drought.

Table 1: Indicators analytical framework for general relative vulnerability assessment

Level 1 Index	Level 2 Index	Level 3 Index	Level 4 Index
Climate Vulnerability	Exposure	Drought	1. Average annual amount of rainfall/drough
		Flash flood	2. 1-day maximum rainfall
		Shoreline erosion	3. Shoreline deteriotation
		Windstorm	4.Number of persons affected by heavy storms
	Sensitivity	Natural sensitivity	5. Commune area without forest cover
			6. Protected area to total commune area
			7. Low-lying (inundated) area to total commune area
			8. Mangrove area to shore area
		Human sensitivity	9. Commune population density
			10. Poverty rate
			11. Women-headed households
			12. Literacy Rate of lower secondary (aged 12-14)
			13. Literacy Rate of high school (aged 15-17)
			14. Male-female ratio
			15. Disability
		Infrastructure sensitivity	16. Unhygienic water for daily use
			17. Clean water acess
		Livelihood sensitivity	18. Laborers involving in agricultural sector
			19. Fish farm or shrimp
			20. Fishery involvment
	Adaptive capacity	Infrastructure indicators	21. Irrigated land
			22. Paved roads and concrete roads
			23. Households accesses to tap water
			24. Medical institutions
			25. Mangrove area to shore area
			26. Shoreline protection
		Technology indicators	27. Households has TVs
		Social capital indicators	28. Volunteer group in the commune
			29. Proportion of Pagodas
		Human indicators	30. Medical institutions
			31. Govt. primary schools

2.2.2 Weights

After the selection of indicators, they were defined to be either *Exposure*, *Sensitivity*, or *Adaptive capacity*. Then the analysis and development of the VI (vulnerability index) were done following four consecutive steps: *i) Quantifying the indicators*, *ii) Normalising the indicators* – making scaleless dependent, *iii) Assigning weights to the indicators*, and *iv) Aggregating indicators into vulnerability* *index*. Further explanation of each step comes as following (Gbetibouo et al, 2010, Ntajal, 2017, UNDP, 2006):

- **Step 1: Quantifying the indicators**. The numerical values of the selected indicators were mainly based on the general communal population and socio-economic dataset of the year 2017. Specific additional data was also collected from other primary and secondary data sources, field observations and measurements, and stakeholder perceptions from in-person interviews and workshops.

- **Step 2: Normalising the indicators**. Since the indicators hold different units (ha, meters, percentage, ton, etc.), they needed to be normalized, which means making them dimensionless in a unit, and prepare them to be in the same scale from 0 to 1, so that the comparison and aggregation can be made correctly. To do this conversion, we used this normalized formula:

  $$X_{i\_Normalised} = \frac{[X_i - Min(X_i)]}{[Max(X_i) - Min(X_i)]}$$

  (Where $X_{i\_Normalised}$: the X_i value after scale normalizing, X_i : individual indicator value, $Min(X_i)$: the lowest value of the indicator in the range, and $Max(X_i)$: the highest value of the indicator in the range).

- **Step 3: Assigning weights to the indicators**. The assigned value to each minor indicator was based on how important it plays in the vulnerability context, and it was known from the reviewed information, consultation with key stakeholders in the assessed sectors, and the knowledge of experts. The weight of each major indicator was computed with the following equation:

  $$w_j = \frac{n - r_j + 1}{\sum(n - r_j + 1)}$$

  (where *n*: the highest rank value of indicators; r_j : the rank of indicators, and w_j: the weight of indicators)

- **Step 4: Vulnerability index**. To produce the VI, we need to make *Sensitivity index and Exposure Index*, and *Adaptive Capacity Index*, deploying the following formulas:

  $$\text{Adaptive Capacity Index} = \sum_{i=1}^{n} W_i + AC_i$$

Where AC_i : each indicator assigned as the Adaptive Capacity; and W_i : weight assigned to each indicator.

$$\text{Sensitivity Index} = \sum_{i=1}^{n} W_i + \text{Sensitivity}_i$$

$$\text{Exposure Index} = \sum_{i=1}^{n} W_i + \text{Exposure}_i$$

Where $Sensitivity_i$ *and* $Exposure_i$: each indicator assigned as the Sensitivity and Exposure; and W_i : weight assigned to each indicator.

After the determination of the Adaptive Capacity index, Sensitivity index, and Exposure index that adhered to the vulnerability framework, the Vulnerability Index is defined and classified as following: Low: 0.00-0.30, Moderate: 0.31-0.50, High: 0.51-0.70, and Very high: 0.71-1.00. The generated Vulnerability Index values were jointed to Kep communal administrative dataset of geographical information system (GIS) to generate vulnerability maps.

2.3 Data Collection

2.3.1 Commune Database

We used the commune socio-economic and demographic dataset of the year 2016, which covers all the 24 provinces and Phnom Penh (1,646 communes) (NIS, 2016). This data source availability plays a critical role in the vulnerability assessment of Cambodia, including Kep province. The data was obtained from the National Institute of Statistics of the Ministry of Planning. The selected indicators using the national database at the sub-national level, including for adaptive capacity, including human adaptive capacity, social capital adaptive capacity, technological adaptive capacity, adaptive economic capacity, and infrastructural adaptive capacity.

2.3.2 Field Interview and data collection

Qualitative data concerning the vulnerability and adaptation assessment were collected through desk reviews, in-person interviews with the commune councils, and a focus group of provincial department officers (Provincial Department of Environment, Provincial Department of Public Works and Transport and Provincial Department of Water Resources And Meteorology), local people with key informants at a different geographical range and of the selected sectors.

2.4 Historical and Projected Climate Data and Analysis

2.4.1 Selected Historical Climate Data

Historical Rainfall and Temperature data: The rainfall and temperature data used in this study is from metadata of NASA Earth Exchange (NEX) Global Daily Downscaled Projections (GDDP) dataset daily and monthly averaged maximum temperature, minimum temperature, and precipitation. Each of the climate projections includes for the periods from 1950 to 2099 and Spatial resolution: 0.25 degrees x 0.25 degrees. Overall, NEX-GDDP data represents well the mean states of temperature and precipitation on a monthly scale but daily scale data show limitations (Raghavan, 2018). The data can be found and downloaded: https://nex.nasa.gov/nex/.

2.4.2 Projected Climate Change Dataset

*Projected Rainfall and Temperature data***:** The projected rainfall and temperature data used in this study is from metadata of NASA Earth Exchange (NEX) Global Daily Downscaled Projections (GDDP) dataset daily and monthly averaged maximum temperature, minimum temperature, and precipitation. Each of the climate projections includes for the periods from 1950 to 2099 and spatial resolution: 0.25 degrees x 0.25 degrees. The data can be found and downloaded: https://nex.nasa.gov/nex/.

Climate change scenarios: The climate change scenarios used in this study are consistent with the Mekong River basin and were carefully chosen from the completed list of available results from IPCC CMIP5 archive, as described by Kiem et al. (2013) and JBA (2014) for Mekong River Basin. The chosen results derive from the GFDL and IPSL general circulation models (GCMs), which were found to perform reasonably in terms of a monsoon climate. The GCMs used in this study represent:

1. A 'wetter overall' upper bound of projected future impacts **(GFDL-CM3)** a. Associated with an 8% increase in annual basin-wide rainfall in a medium emission, 2060 scenario. b. Associated with a 1.5^{o}C increase in annual temperature under a medium emissions 2060 scenario.

2. An 'increased seasonality' whereby a 'drier' dry season rainfall is combined with a 'wetter' wet season rainfall **(IPSL-CM5A-MR).** a. Associated with a 5% increase in annual basin-wide rainfall in a medium emission, 2060 scenario. (-11% in the dry season and +8% in the wet season). b. Associated with a 1.5^{o}C increase in annual temperature under a high emission 2060 scenario.

Two-time horizons (near-term future 2021–2040, called 2030s and medium-term future 2051-2070, call 2060s) were considered in this study, as these time horizons are being used by the Mekong River Commission (MRC) in other planning contexts. The selected GCMs have been combined with two emissions scenarios, RCP4.5: medium climate sensitivity and RCP8.5: high climate sensitivity, to provide a wide range of climate projection, as shown in Table 2.

Table 2: Climate Scenarios used for climate vulnerability assessments

No.	Type of scenarios		Emission scenarios	GCM	Climate sensitivity
	Level of change	Pattern of change			
Medium climate change scenarios					
3	Medium	Wetter oveall	RCP4.5	GFDL-CM3	Medium
4		Wetter wet seasons & drier dry seasons		IPSL-CM5A-MR	
High climate change scenarios					
5	High	Wetter oveall	RCP8.5	GFDL-CM3	High
6		Wetter wet seasons & drier dry seasons		IPSL-CM5A-MR	

3 Results and Findings

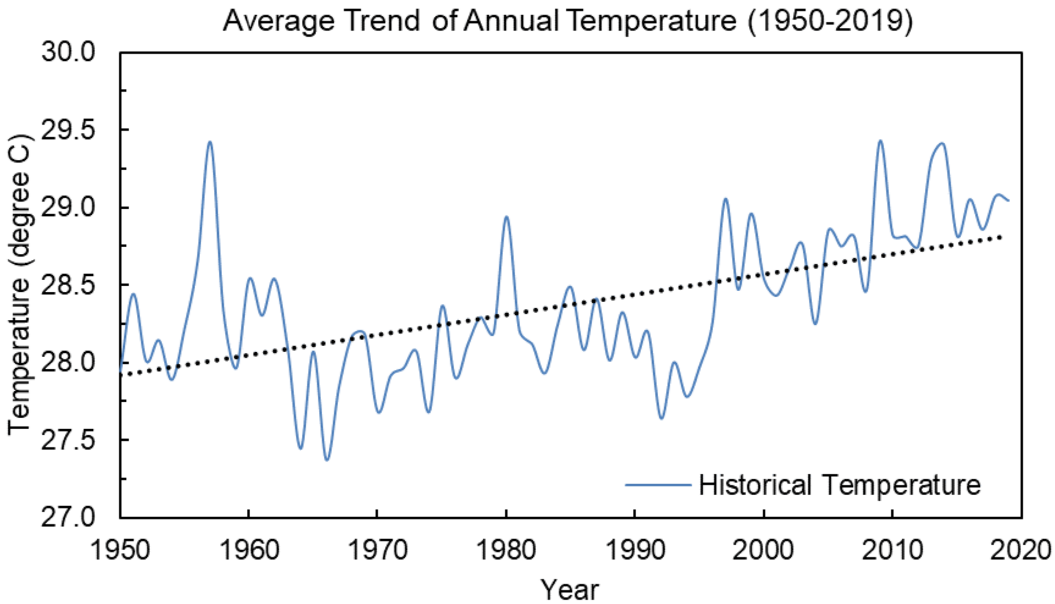
3.1 Observed and Projected Climate Change in Cambodia

3.1.1 Observed Climate Trends

Temperature Analysis:

With the accessibility constraints of long-term climate data, the analysis of the observed climate trends of this study was based on NASA Earth Exchange (NEX) Global Daily Downscaled Projections (GDDP) dataset sources for daily, monthly, averaged maximum and minimum temperature, and precipitation.

Figures 6 shows a trend of average annual temperature between 1950 and 2019, as illustrates; the average annual temperature fluctuated between 27^{o}C and 29.4^{o}C over the period. However, what to notice is that the figures have fluctuated with an upward trend from 27^{o}C in 1966 to 29.4^{o}C in 2009. This trend signifies that Kep's temperature has increased during this period with the baseline period.



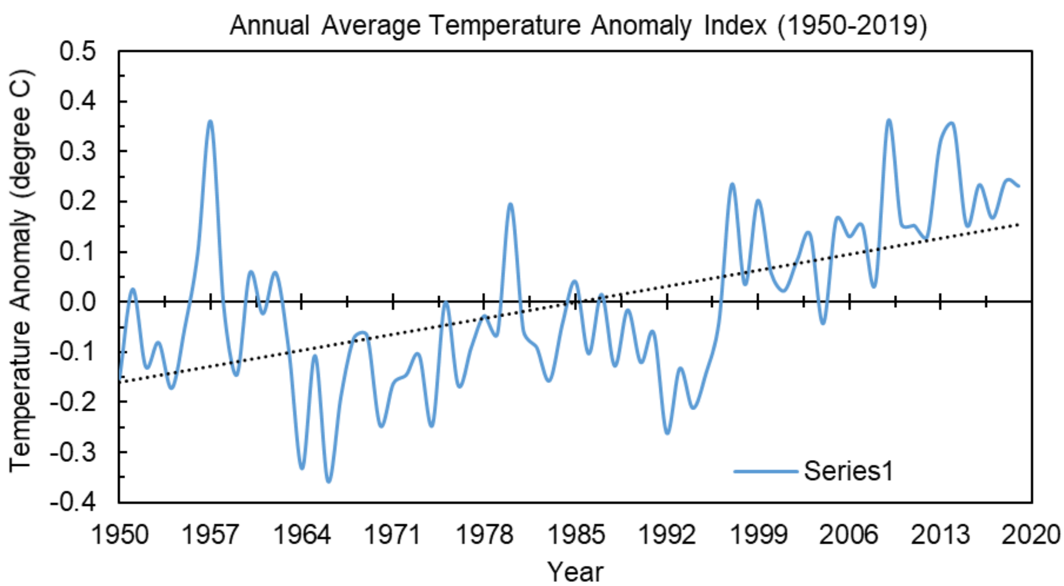


Figure 5: Trends of average annual temperature over Cambodia from 1950 to 2019 based on Nasa Earth Exchange data (NEX)

Spatial distribution or maps of historical average temperature in Kep province, measured over 70-year periods between 1950 and 2019, is shown in Figure 7. The average temperature fluctuated between 31.8^{o}C and 32.4^{o}C over the period in Kep province. The figure indicates that in the over commune in the map, Prey Thum and Ou Krasar commune, the average annual temperatures were significantly higher than those of other communes (AngKaol, Karp, and Pong Tuek).

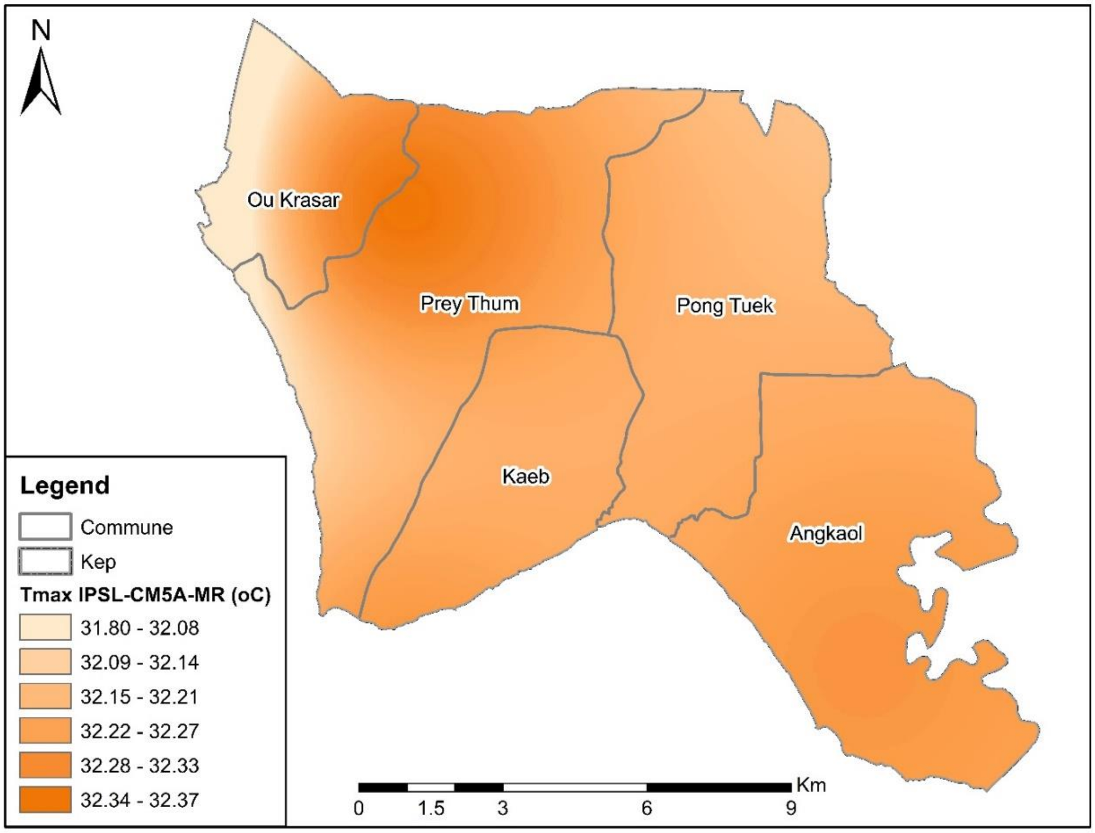


Figure 6: Historical average temperature in Kep province from 1950-2019

Rainfall Analysis:

The observed average annual rainfall between 1950 and 2019 is shown in Figures 8. Average annual rainfall arranged from 1632mm and 2937mm over the period. However, what to notice is that the figures fluctuated with an upward trend from 1632mm in 1966 to 2937mm in 2009. This trend signifies that Kep's rainfall has become higher during this period to the historical period.

Spatial distribution or maps of historical average rainfall in Kep province, measured over 70-year periods between 1950 and 2019, is shown in Figure 9. The average rainfall arranged between 2091mm and 2304mm over the period in Kep province. The figure indicates that in the over commune in the map, most of Ou Krasar and Prey Thum commune, the average annual temperatures were significantly higher than the other communes (AngKaol, Kap, and Pong Tuek).

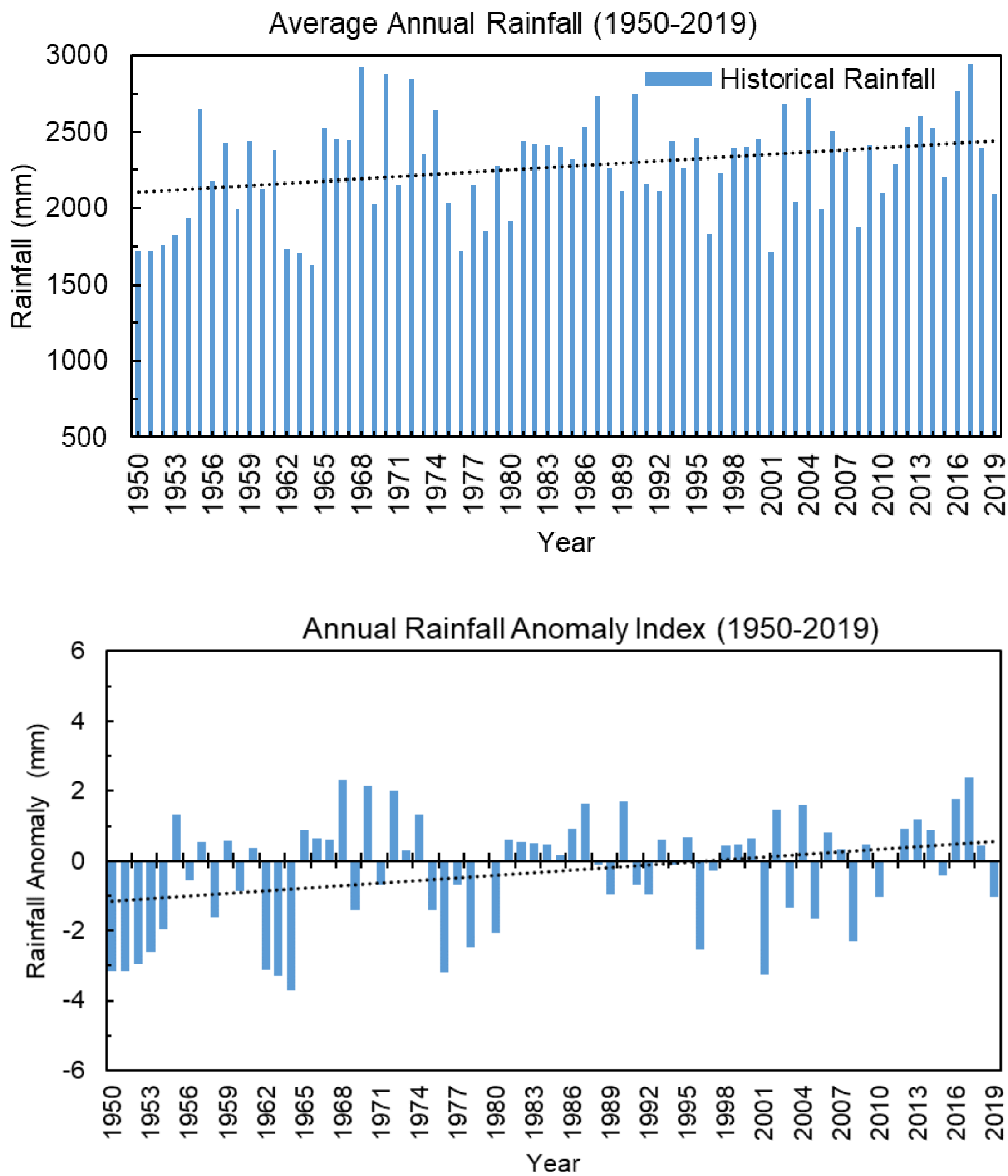


Figure 7: Trends of average annual rainfall over Cambodia from 1950 to 2019

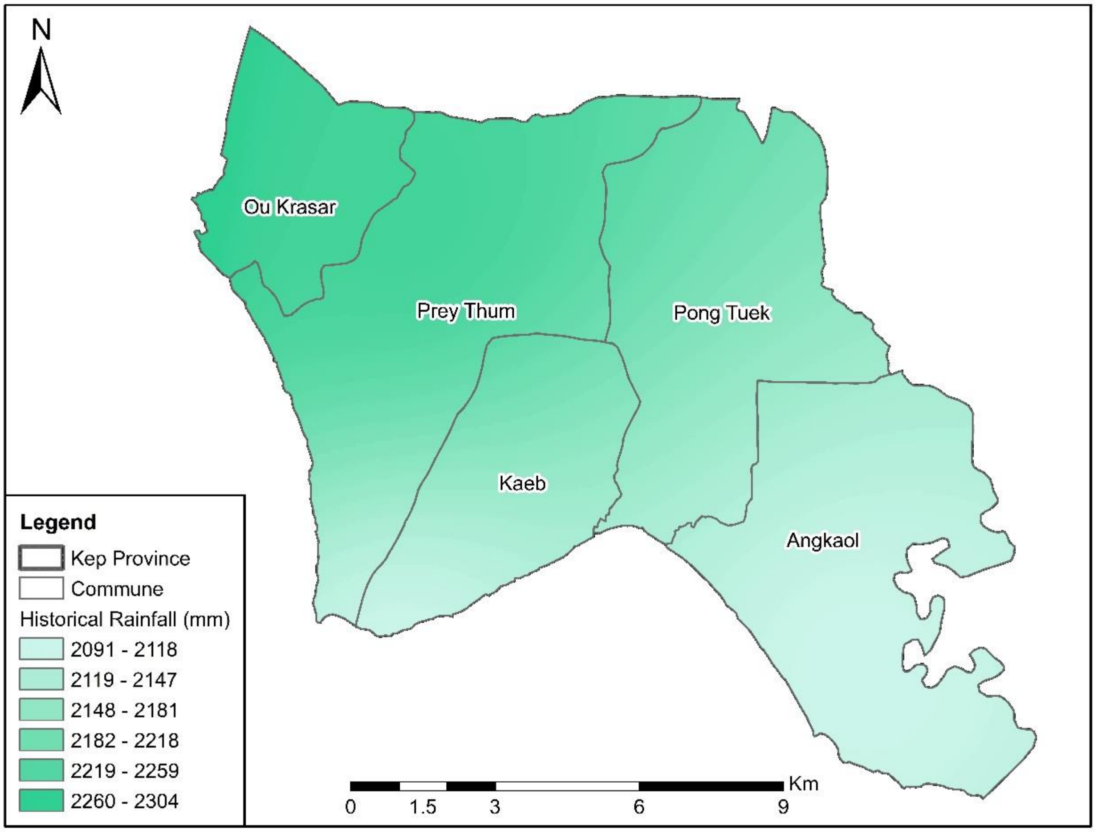


Figure 8: Historical average annual rainfall in the Kep province from 1950 to 2019

3.1.2 Projected Future Climate Change

The projections of climate change were analyzed based on the ensembled climate models with a projection extended up to the year 2100. The selected scenarios of GHG emissions pathways included RCP4.5 and RCP8.5 from the GFDL and the IPSL of general circulation models (GCMs)-see Section 2.4.2 for a detailed description of these climate models. With the selected climate variables of temperature and precipitation, the results of the analysis are illustrated in Figures 10 and 11. Figure 10 shows the observed and projected trends of changes in the average annual temperature up to 2100 based on the two climate change scenarios (RCP4.5 and RCP8.5) with both models (GFDL and IPSL), compared with the baseline period 1950-2019. It can be seen that the average annual temperature is projected to increase in both scenarios, with a more dramatic rise in the RCP8.5 with both models.

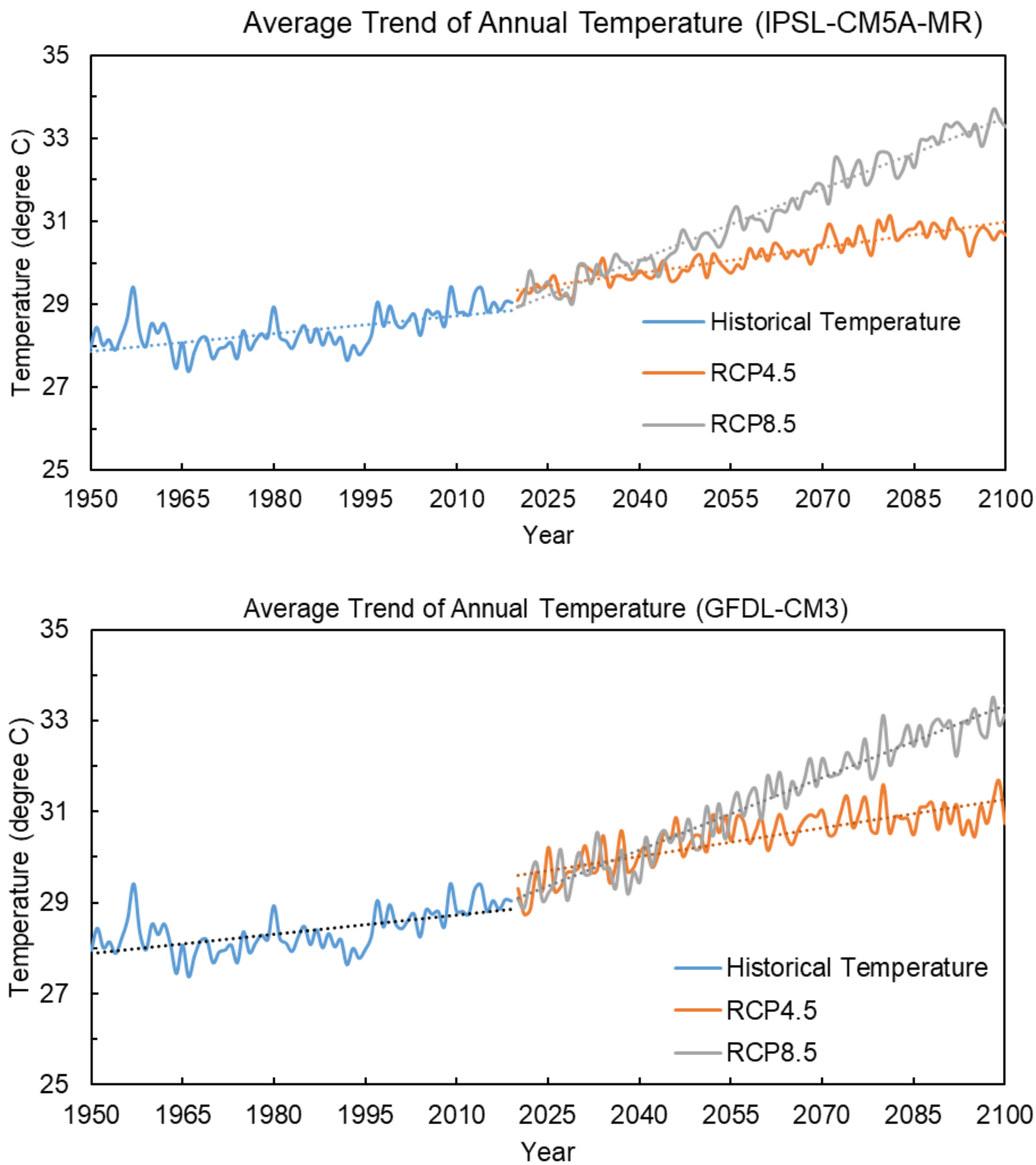
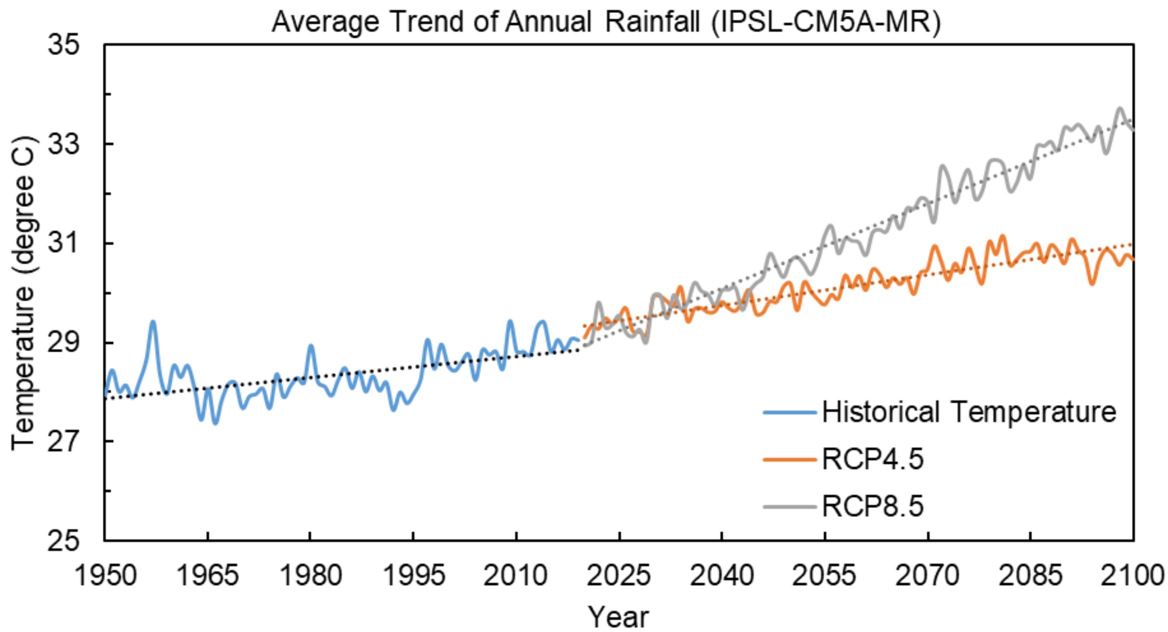


Figure 9: Historical and projected trends of changes in average annual temperature up to 2100 based on two different climate change scenarios (RCP4.5 and RCP8.5) and two models (GFDL-CM3 and IPSL-CM5A-MR).

Figure 10 demonstrates the observed and projected trends of changes in the average annual rainfall up to 2100 based on the two climate change scenarios (RCP4.5 and RCP8.5), compared with the baseline period 1950-2019. It can be seen that the average annual rainfall is projected to increase in both scenarios and models, with a more dramatic rise in the RCP8.5.



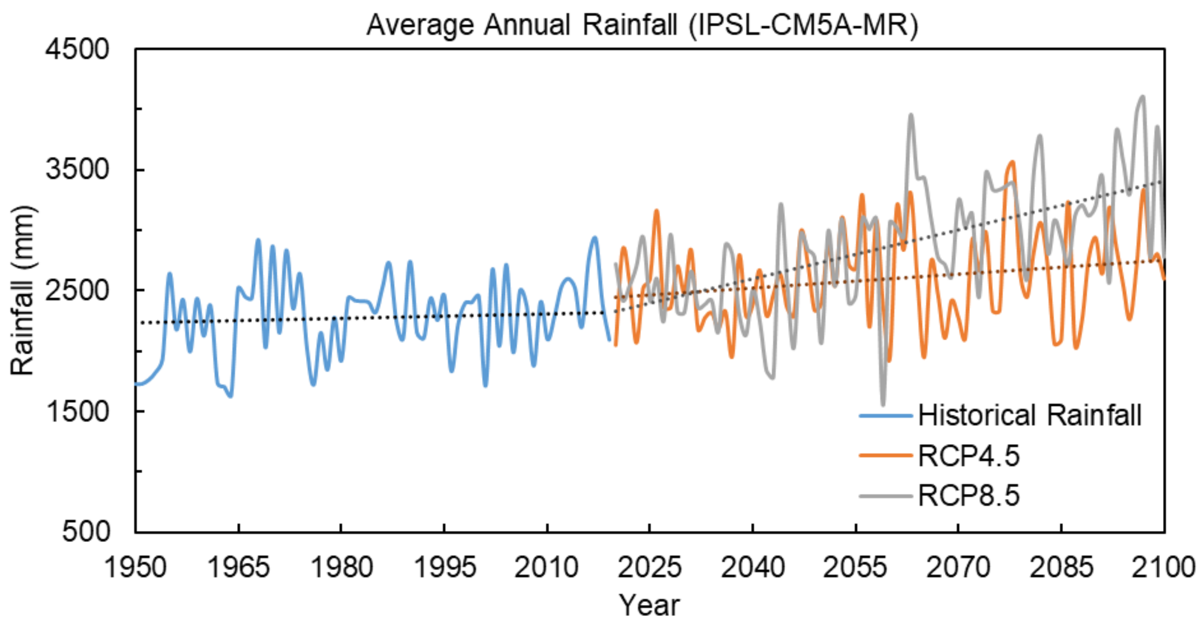


Figure 10: Historical and projected trends of changes in average annual rainfall up to 2100 based on two different climate change scenarios (RCP4.5 and RCP8.5), and two models (GFDL-CM3 and IPSL-CM5A-MR).

3.1.3 Projected Future Climate Change Comparing to Historical Climate

Figure 12 and Figure 13 demonstrates the maps of projected future climate change comparing to historical in average annual temperature for short-term (2021-2040: 2030s) and medium-term (2050-2070: 2060s) based on datasets of ensemble IPSL-CM5A-MR climate model for RCP4.5 and RCP8.5. By 2030s and 2060s or probably earlier and long-term, the annual temperature is expected to increase in both RCPs (RCP4.5 and RCP8.5) and both models (GFDL and IPSL). While the projection in RCP4.5 is likely to keep increasing up to 2°C by 2060s, and in RCP8.5, figures see a catastrophic, dramatic increase up to 3°C by 2060s. Overall, it is understood that a likely more significant increase in the average annual temperature is noticed in Prey Thum and Ou Krasar commune, and the figures in the RCP8.5 are more intent with both models. The long-term projection is expected to be higher in the average annual temperature. For the short-term by 2060s, the average annual temperature is projected to increase by 2.3°C in the north and around 1.1°C in the south, and both scenarios with both models are not noticeably different. However, in the long-term projection, it clearly illustrates that the rise in the average annual temperature would fall between 1.2°C and 3°C, with lower figures in the south. Significantly, by 2060s under RCP8.5 scenarios, it is expected to rise sharply, at between 2.5°C and 3°C throughout the country.

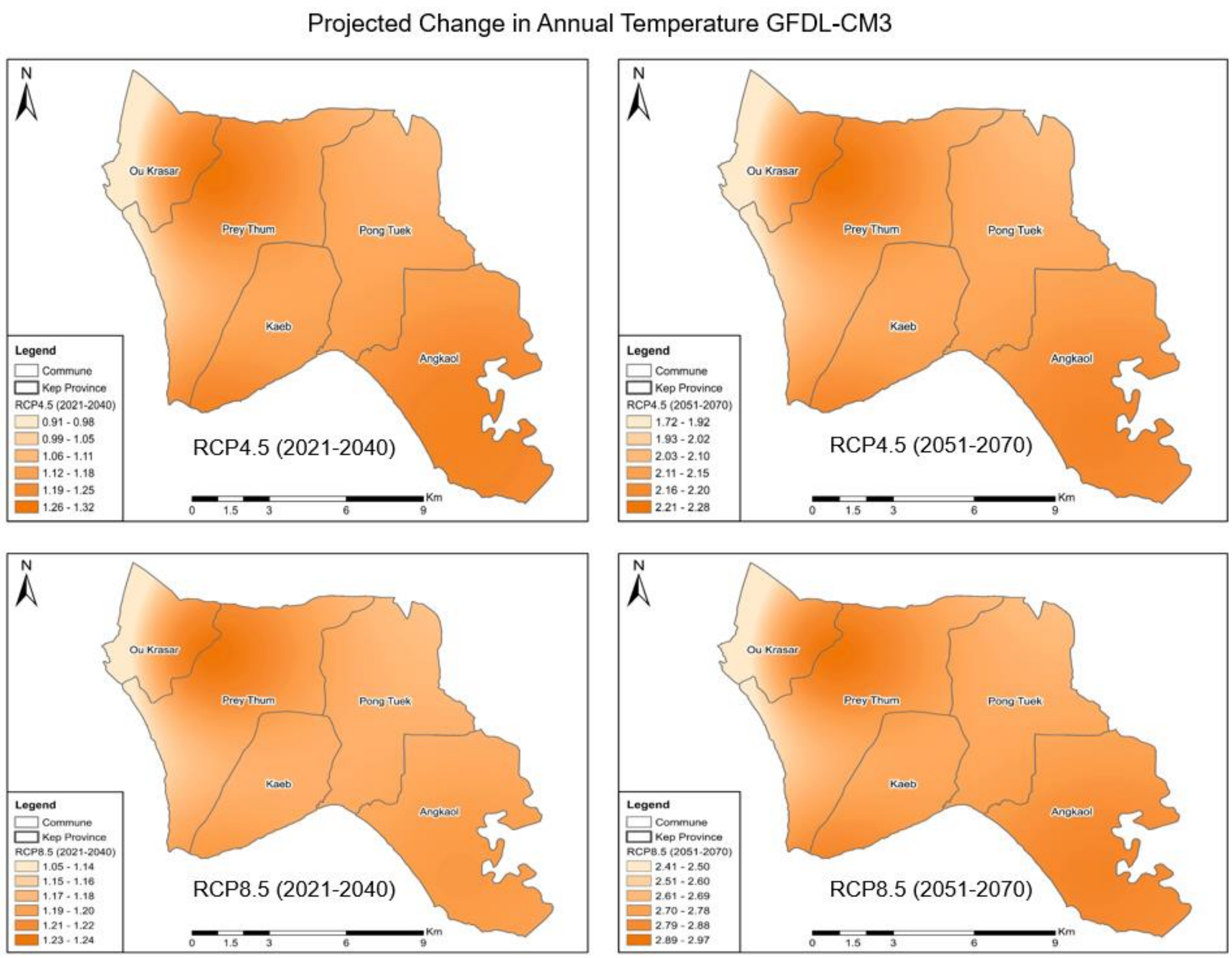


Figure 11: Maps of projected climate change (Projected - Historical) in average annual temperature for short-term (2021-2040) and medium-term (2050-2070) based on datasets of ensemble GFDL-CM3 climate model for RCP4.5 and RCP8.5.

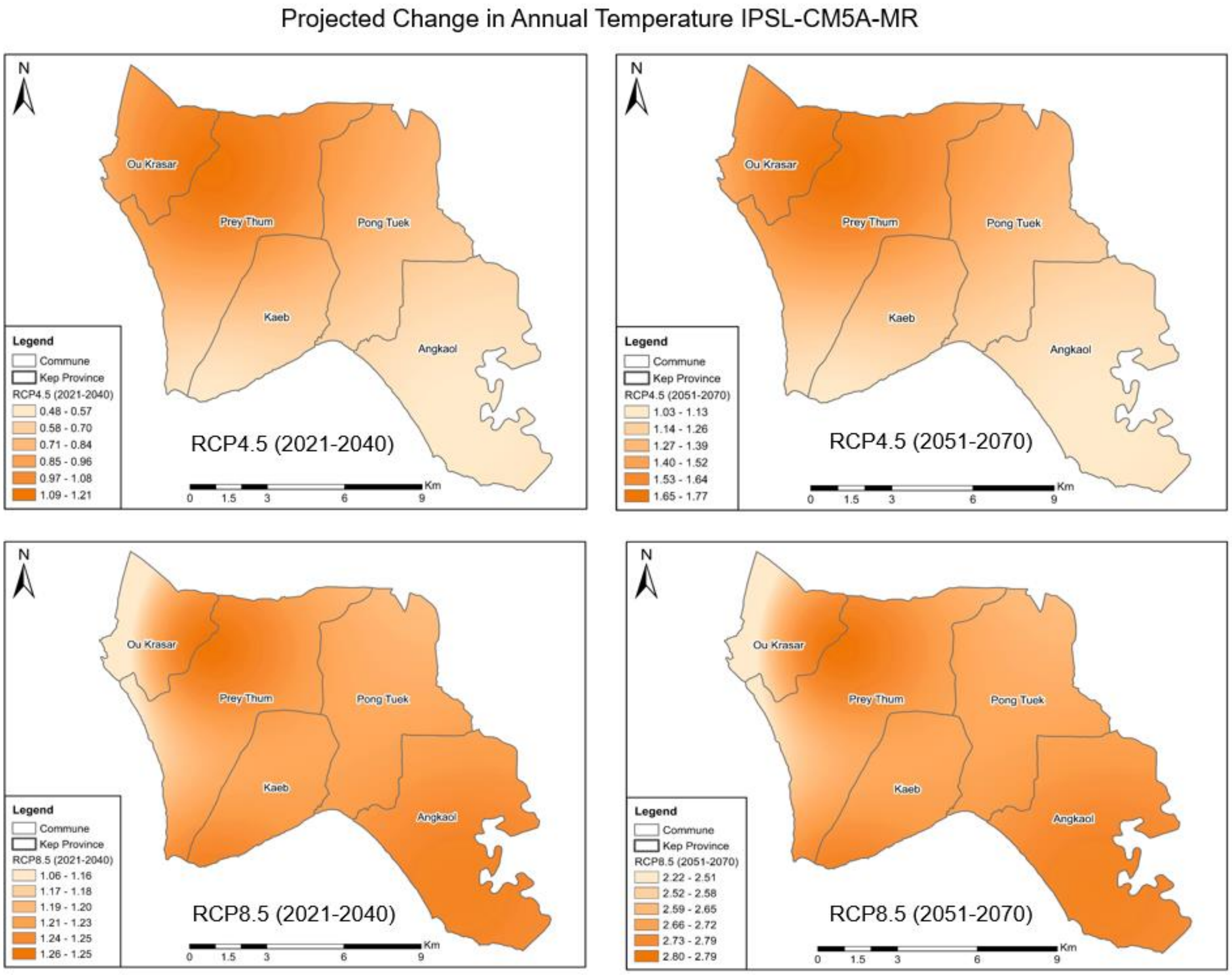


Figure 12: Maps of projected climate change (Projected - Historical) in average annual temperature for short-term (2021-2040) and medium-term (2050-2070) based on datasets of ensemble IPSL-CM5A-MR climate model for RCP4.5 and RCP8.5.

Figure 14 and Figure 15 show the maps of projected climate change (projected-historical) in average annual rainfall for short-term (2021-2040) and medium-term (2050-2070) based on datasets of ensemble IPSL-CM5A-MR climate model for RCP4.5 and RCP8.5. By 2030s and 2060s, the annual rainfall is expected to increase in both RCPs (RCP4.5 and RCP8.5) and both models (GFDL and IPSL). While the projection in RCP4.5 is likely to keep increasing up to 350mm by 2060s, and in RCP8.5, figures see a catastrophic, dramatic increase up to 31mm by 2060s. Overall, it is seen that a likely more significant increase in the average annual rainfall is noticed in Angkaol commune, and the figures in the RCP8.5 are differently more intent with both models in Ou Krasar commune. The long-term projection is expected to be higher in the average annual rainfall. For the short-term by 2060s, the average annual rainfall is projected to increase by 314mm in the north and around 350mm in the southern part of the province, and both scenarios with both models are not noticeably different.

However, in the long-term by the 2060s, the average annual rainfall is projected to increase by 311mm in the north and around 281mm in the southern part under both scenarios with both models.

Projected Change in Annual Rainfall GFDL-CM3

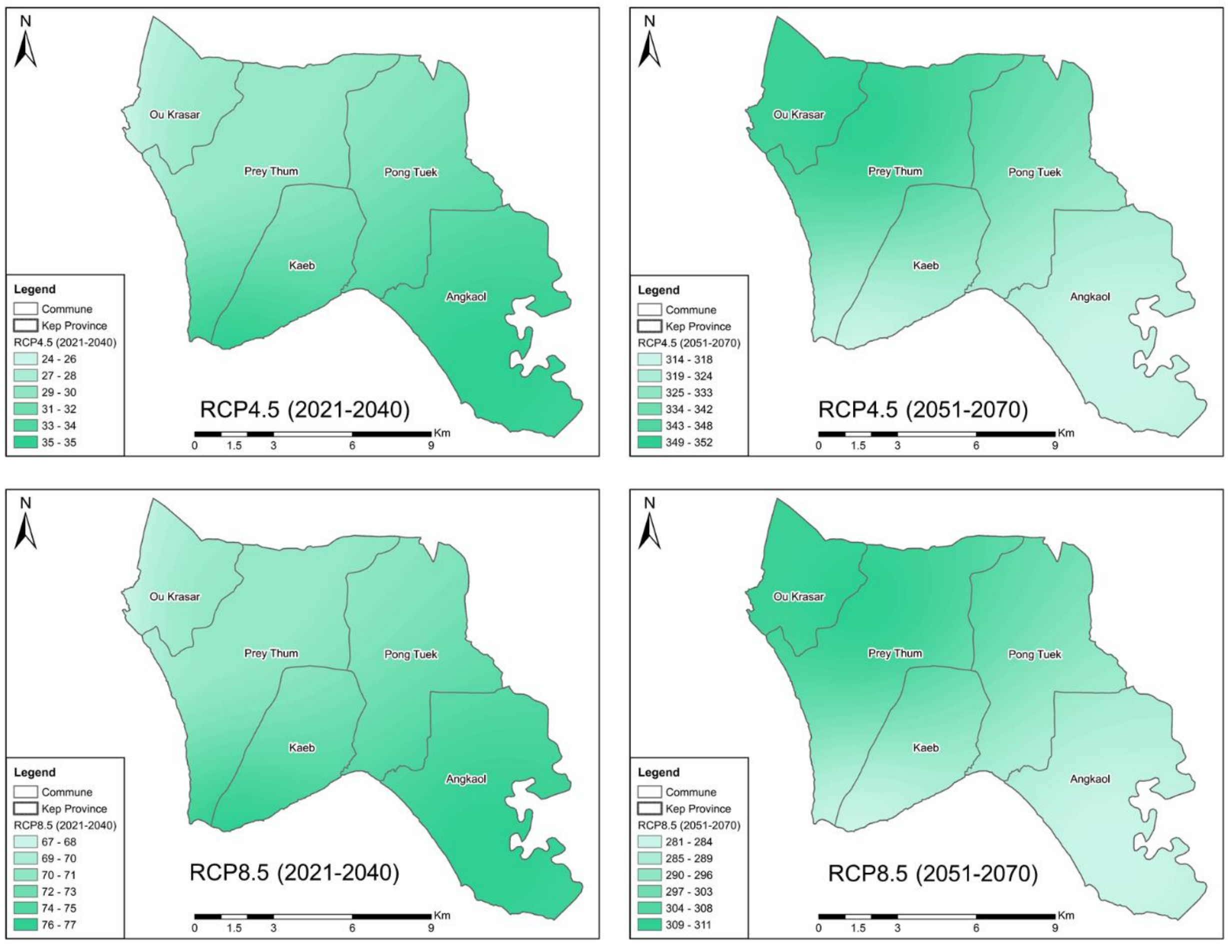


Figure 13: Maps of projected climate change (Projected - Historical) in average annual rainfall for short-term (2021-2040) and medium-term (2050-2070) based on datasets of ensemble GFDL-CM3 climate model for RCP4.5 and RCP8.5.

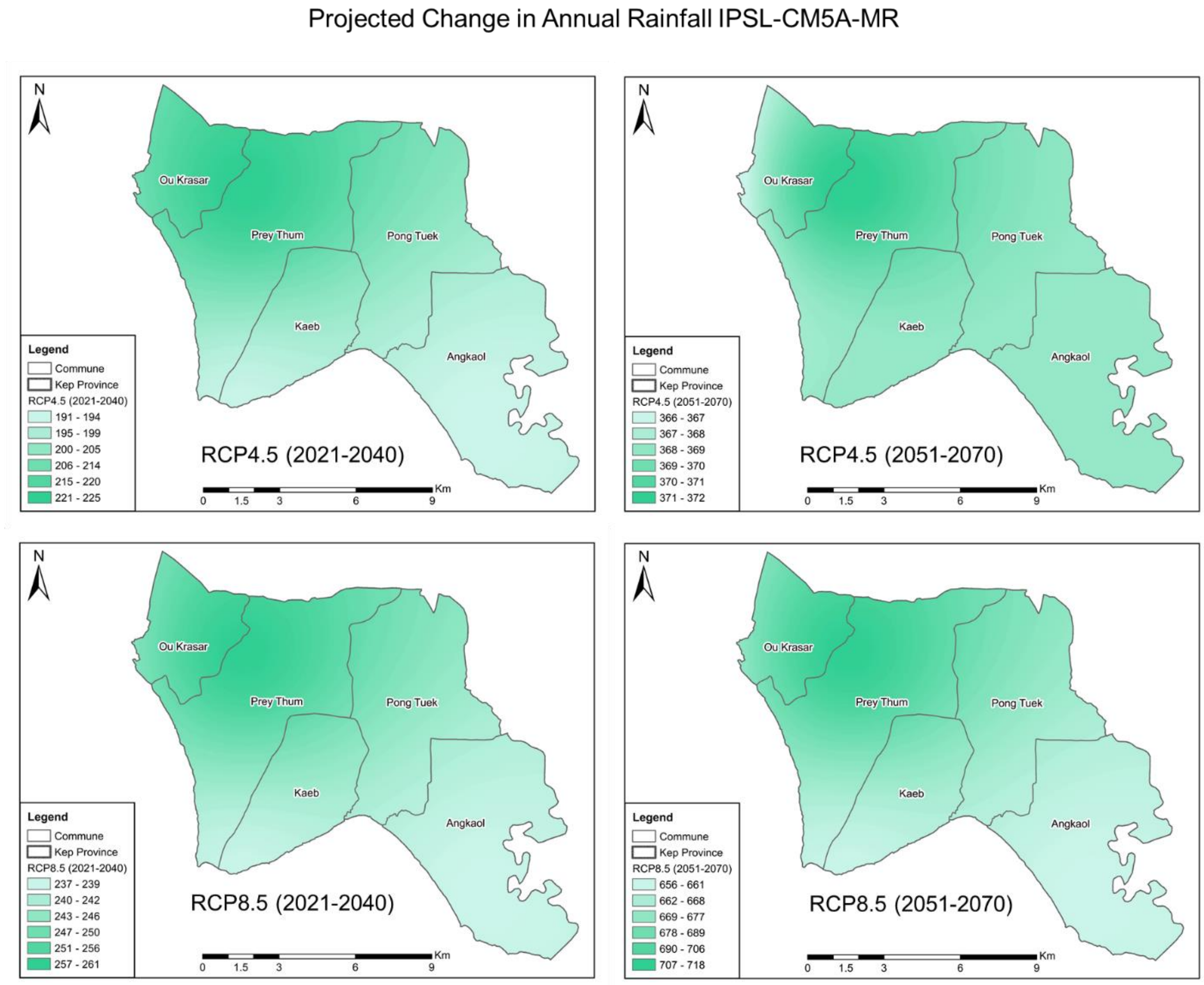


Figure 14: Maps of projected climate change (Projected - Historical) in average annual rainfall for short-term (2021-2040) and medium-term (2050-2070) based on datasets of ensemble IPSL-CM5A-MR climate model for RCP4.5 and RCP8.5.

3.2 Vulnerability Assessment

3.2.1 Flash Flood Vulnerability

Table 3 illustrates the weights generated from the vulnerability assessment method for the assessment of the vulnerability to flash flood. For sensitivity, the high weight was given to the natural sensitivity of the four main groups of indicators, and then human sensitivity, infrastructure sensitivity, and the smallest weight was given to livelihood Sensitivity. Similarly, with the adaptive capacity, the order weight was given to infrastructure, technology, social capital, and human capital adaptive capacity. More diverse weights were given to the specific indicators, for example, with the natural sensitivity; higher weight was given to the percentages of the commune covered by low-lying area, and non-forest than the proportion of the commune covered by the protected area. This is due to the opinion that low-lying areas and non-forest are more sensitive to flash flooding than the protected area.

Table 3: Weights for the flash flood vulnerability assessment

Level 4 Index	Weight	Level 3 Index	Weight	Level 2 Index	Weight	Level 1 Index
1. 1-day maximum rainfall	1	Flash flood	1	Exposure	0.33	Flash flood Vulnerability
2. Commune area without forest cover	0.30	Natural sensitivity	0.40	Sensitivity	0.33	
3. Protected area to total commune area	0.20					
4. Low-lying (inundated) area to total commune area	0.40					
5. Mangrove area to shore area	0.10					
6. Commune population density	0.11	Human sensitivity	0.30			
7. Poverty rate	0.18					
8. Women-headed households	0.25					
9. Literacy Rate of lower secondary (aged 12-14)	0.07					
10. Literacy Rate of high school (aged 15-17)	0.04					
11. Male-female ratio	0.14					
12. Disability	0.21					
13. Unhygienic water for daily use	0.33	Infrastructure sensitivity	0.10			
14. Clean water acess	0.67					
15. Laborers involving in agricultural sector	0.50	Livelihood sensitivity	0.20			
16. Fish farm or shrimp	0.17					
17. Fishery involvment	0.33					
18. Irrigated land	0.14	Infrastructure indicators	0.40	Adaptive capacity	0.33	
19. Paved roads and concrete roads	0.24					
20. Households accesses to tap water	0.29					
21. Medical institutions	0.19					
22. Mangrove area to shore area	0.10					
23. Shoreline protection	0.05					
24. Households has TVs	1	Technology indicators	0.10			
25. Volunteer group in the commune	0.33	Social capital indicators	0.20			
26. Proportion of Pagodas	0.67					
27. Medical institutions	0.67	Human indicators	0.30			
28. Govt. primary schools	0.33					

The below maps (Figure 16) show the exposure, sensitivity, and adaptive capacity to flash flood under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2030s. Ou Krasar and Prey Thum commune were considered to be highly exposed to flooding due to its percentages of the communes covered by low-lying area, and non-forest than the proportion of the communes covered by the protected area. In terms of sensitivity, the Prey Thum commune of the Kep province was classified as highly sensitive to flood. Having low adaptive capacity are Ou Krasar and Prey Thum commune.

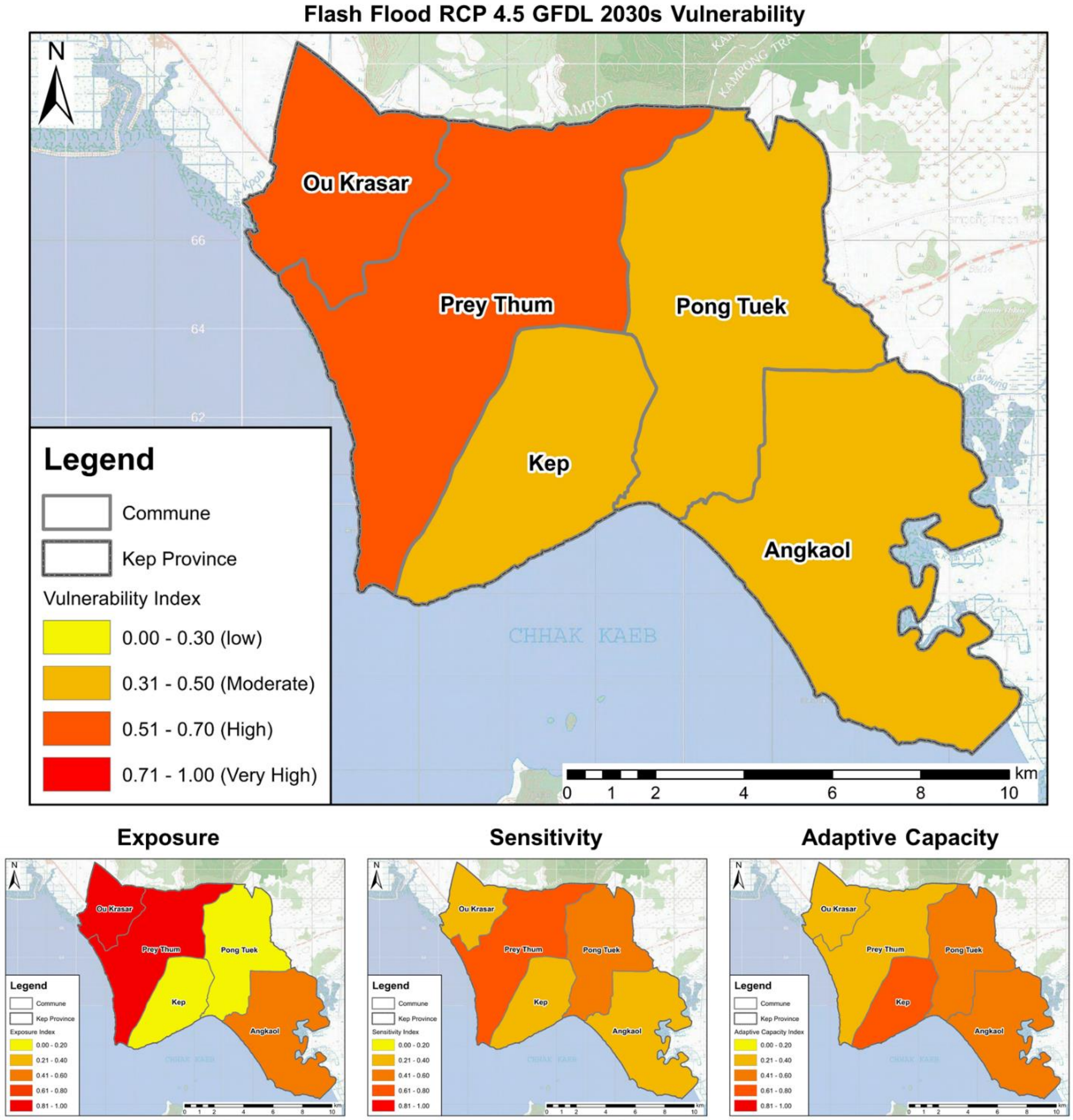


Figure 15: Maps of flash flood vulnerability in short-term (RCP4.5 GFDL 2030s) (top), exposure (bottom left), sensitivity (bottom middle), and adaptive capacity (bottom right)

The following map (top) highlights the vulnerability index to flash flood under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2030s across the Kep province. Ou Krasar and Prey Thum appear to be the most vulnerable commune given its high exposure to flooding that affected by the flash flood. Moreover, due to the low adaptive capacity in this region, it was classified as highly vulnerable. Thus, Ou Krasar and Prey Thum commune are highly vulnerable to flash flooding. However, the other three communes as Angkaol, Kep, and Pong Tuek are appeared to be low vulnerable communes that give their low exposure to flood that effect from the flash flood.

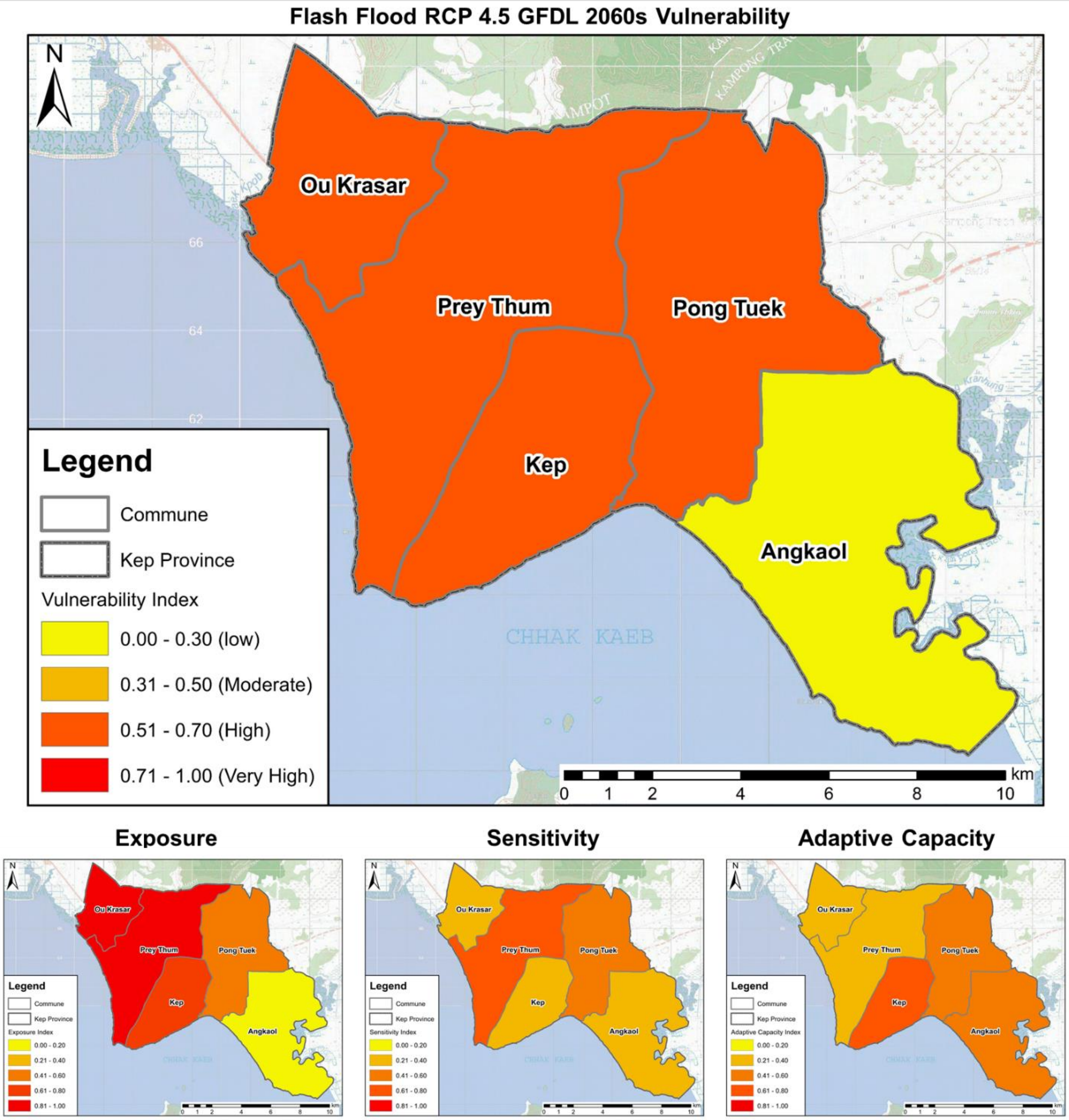


Figure 16: Maps of flash flood vulnerability in medium-term (RCP4.5 GFDL 2060s) (top), exposure (bottom left), sensitivity (bottom middle), and adaptive capacity (bottom right)

The following maps (Figure 17: bottom) show the index of exposure, sensitivity, and adaptive capacity to flash flood under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2060s. Angkaol and Pong Tuek are the two communes with the high exposure to flood. The sensitivity was similar to flash flood under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2060s where Prey Thum commune was classified to be the most sensitive region. In terms of adaptive capacity, most communes were classified as having the low and moderate adaptive capacity to floods as same as flash flood under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2060s.

Vulnerability to flash flood under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2060s was different vulnerability to flash flood under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2060s (Figure 17: above). Angkaol and Pong Tuek show to be the most vulnerable commune given its high exposure and low adaptive capacity to flood that effect from the flash flood. However, Ou Krasar, Kep, and Prey Tnum appear to below, and moderately vulnerable communes give their low and moderate exposure to flood that effect from the flash flood, respectively.

The additional flash flood vulnerability maps of various climate models and climate sensitivity (RCPs) for the short-term and medium-term future can be found in **Annex 3.**

3.2.2 Drought Vulnerability

The following Table 4 illustrates the weights generated from the vulnerability assessment method for the assessment of the vulnerability to drought. Overall, similarly, weights were given to the indicators as same as a flood. Insensitivity, lower weight was given to the infrastructure while the other three-livelihood, human, natural sensitivity were provided with high weights. This also means that the infrastructure is not very sensitive in drought conditions. With the specific indicators in natural sensitivity, the non-forest area was considered to be the most sensitive indicator compare to the protected area. Regarding the adaptive capacity, all four groups of indicators were offered high weight even though adaptive infrastructure capacity was considered to be slightly higher than the other three (human, social capital, and technology).

Table 4: Weights for the drought vulnerability assessment

Level 4 Index	Weight	Level 3 Index	Weight	Level 2 Index	Weight	Level 1 Index
1. Average annual amount of rainfall/drough	1	Drought	1	Exposure	0.33	Drought Vulnerability
2. Commune area without forest cover	0.67	Natural sensitivity	0.40	Sensitivity	0.33	
3. Protected area to total commune area	0.33					
4. Commune population density	0.11	Human sensitivity	0.30			
5. Poverty rate	0.18					
6. Women-headed households	0.21					
7. Literacy Rate of lower secondary (aged 12-14)	0.07					
8. Literacy Rate of high school (aged 15-17)	0.04					
9. Male-female ratio	0.14					
10. Disability	0.25					
11. Unhygienic water for daily use	0.33	Infrastructure sensitivity	0.10			
12. Clean water acess	0.67					
13. Laborers involving in agricultural sector	0.50	Livelihood sensitivity	0.20			
14. Fish farm or shrimp	0.33					
15. Fishery involvment	0.17					
16. Irrigated land	0.50	Infrastructure indicators	0.40	Adaptive capacity	0.33	
17. Households accesses to tap water	0.33					
18. Medical institutions	0.17					
19. Households has TVs	1	Technology indicators	0.10			
20. Volunteer group in the commune	0.33	Social capital indicators	0.20			
21. Proportion of Pagodas	0.67					
22. Medical institutions	0.67	Human indicators	0.30			
23. Govt. primary schools	0.33					

The following maps (Figure 18: bottom) show the index of exposure, sensitivity, and adaptive capacity to drought under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2030s. Angkaol is the commune with high exposure to droughts. The sensitivity to drought was similar to flood where Prey Thum commune was classified to be the most sensitive commune. In terms of adaptive capacity, more communes were classified as having a low adaptive capacity to drought similar floods (Ou Krasar and Prey Thum).

The following map (Figure 18: top) highlights the vulnerability index to drought under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2030s across the Kep province. Angkaol and Prey Thum expected to be the most vulnerable commune, given its high exposure to drought. Moreover, due to the low adaptive capacity among the communes in the area, it is classified as highly vulnerable. Thus, Angkaol and Prey Thum commune are highly vulnerable to drought. However, the other three communes, as Ou Krasar, Kep, and Pong Tuek are expected to be low vulnerable communes.

The additional drought vulnerability maps of various climate models and climate sensitivity (RCPs) for the short-term and medium-term future can be found in **Annex 4.**

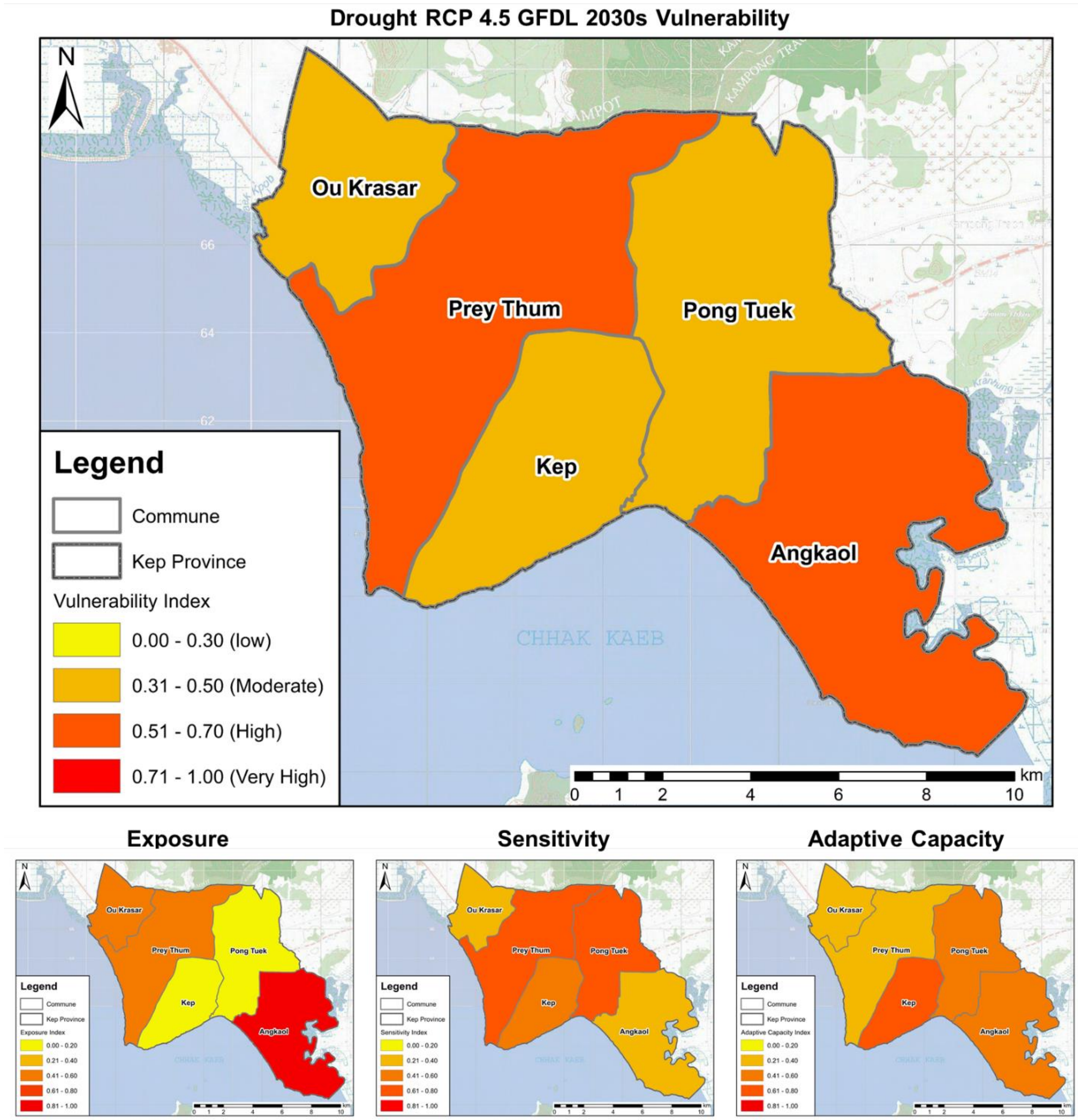


Figure 17: Maps of drought vulnerability in short-term (RCP4.5 GFDL 2030s) (top), exposure (bottom left), sensitivity (bottom middle), and adaptive capacity (bottom right)

The following maps bottom (Figure 19) show the index of exposure, sensitivity, and adaptive capacity to drought under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2060s. Kep commune is the commune with the hight exposure to droughts. The sensitivity to droughts was similar to flood where the Prey Thum commune is classified to be the most sensitive region. In terms of adaptive capacity, more communes were classified as having a low adaptive capacity to drought similar floods. Those are the ones located in Ou Krasar and Prey Thum.

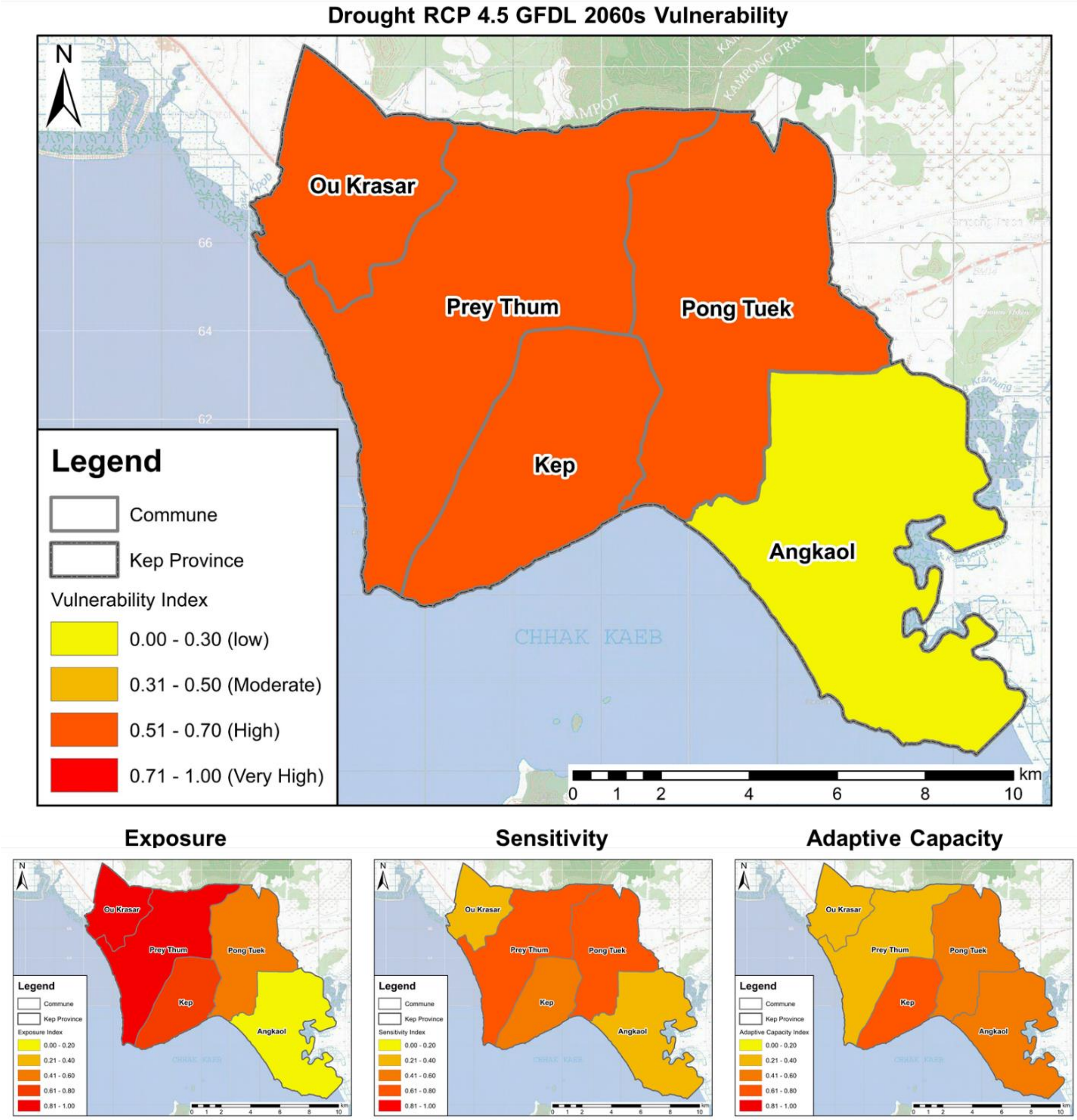


Figure 18: Maps of drought vulnerability in medium-term RCP4.5 GFDL 2060s vulnerability (top), exposure (bottom left), sensitivity (bottom middle), and adaptive capacity (bottom right)

The following map (Figure 19: top) highlights the vulnerability index to drought under scenarios climate change RCP4.5 model GFDL-CM3 with time horizon 2060s across the Kep province. Kep and Pong Tuek appear to be the most vulnerable commune given its high and very high exposure to drought, respectively. However, the other three communes, as Angkaol, Ou Krasar, and Pong Tuek, show to be low vulnerable communes given its low exposure to drought.

3.2.3 Shoreline Erosion Vulnerability

The following Table 5 illustrates the weights generated from the vulnerability assessment method for the assessment of the vulnerability to shoreline erosion. Overall, weights were given to the indicators as same as floods and drought. Insensitivity, lower weight was given to the infrastructure while the other three- livelihood, human, and natural sensitivity were provided with high weights. With the specific indicators in natural sensitivity, mangrove area to shore area. Regarding the adaptive capacity, all four groups of indicators were offered high weight even though adaptive infrastructure capacity was considered to be slightly higher than the other three (human, social capital, and technology).

Table 5: Weights for the shoreline erosion vulnerability assessment

Level 4 Index	Weight	Level 3 Index	Weight	Level 2 Index	Weight	Level 1 Index
1. shoreline deteriotation	1	Shoreline erosion	1	Exposure	0.33	Shoreline Erosion Vulnerability
2. Mangrove area to shore area	1.00	Natural sensitivity	0.40	Sensitivity	0.33	
3. Commune population density	0.11	Human sensitivity	0.30			
4. Poverty rate	0.18					
5. Women-headed households	0.25					
6. Literacy Rate of lower secondary (aged 12-14)	0.04					
7. Literacy Rate of high school (aged 15-17)	0.07					
8. Male-female ratio	0.14					
9. Disability	0.21					
10. Unhygienic water for daily use	0.33	Infrastructure sensitivity	0.10			
11. Clean water acess	0.67					
12. Laborers involving in agricultural sector	0.50	Livelihood sensitivity	0.20			
13. Fish farm or shrimp	0.17					
14. Fishery involvment	0.33					
15. Irrigated land	0.20	Infrastructure indicators	0.40	Adaptive capacity	0.33	
26. Households accesses to tap water	0.33					
17. Medical institutions	0.27					
18. Mangrove area to shore area	0.13					
19. Shoreline protection	0.07					
20. Households has TVs	1	Technology indicators	0.10			
21. Volunteer group in the commune	0.33	Social capital indicators	0.20			
22. Proportion of Pagodas	0.67					
23. Medical institutions	0.67	Human indicators	0.30			
24. Govt. primary schools	0.33					

The map below (Figure 20) demonstrates the index of exposure, sensitivity, and adaptive capacity to shoreline erosion. Most of the communes in Kep province with high exposure to shoreline erosion. The sensitivity to shoreline erosion where Angkaol commune was classified to be the most sensitive region. In terms of adaptive capacity, more communes were classified as having the low and moderate adaptive capacity to shoreline erosion (Ou Krasar and Prey Thum).

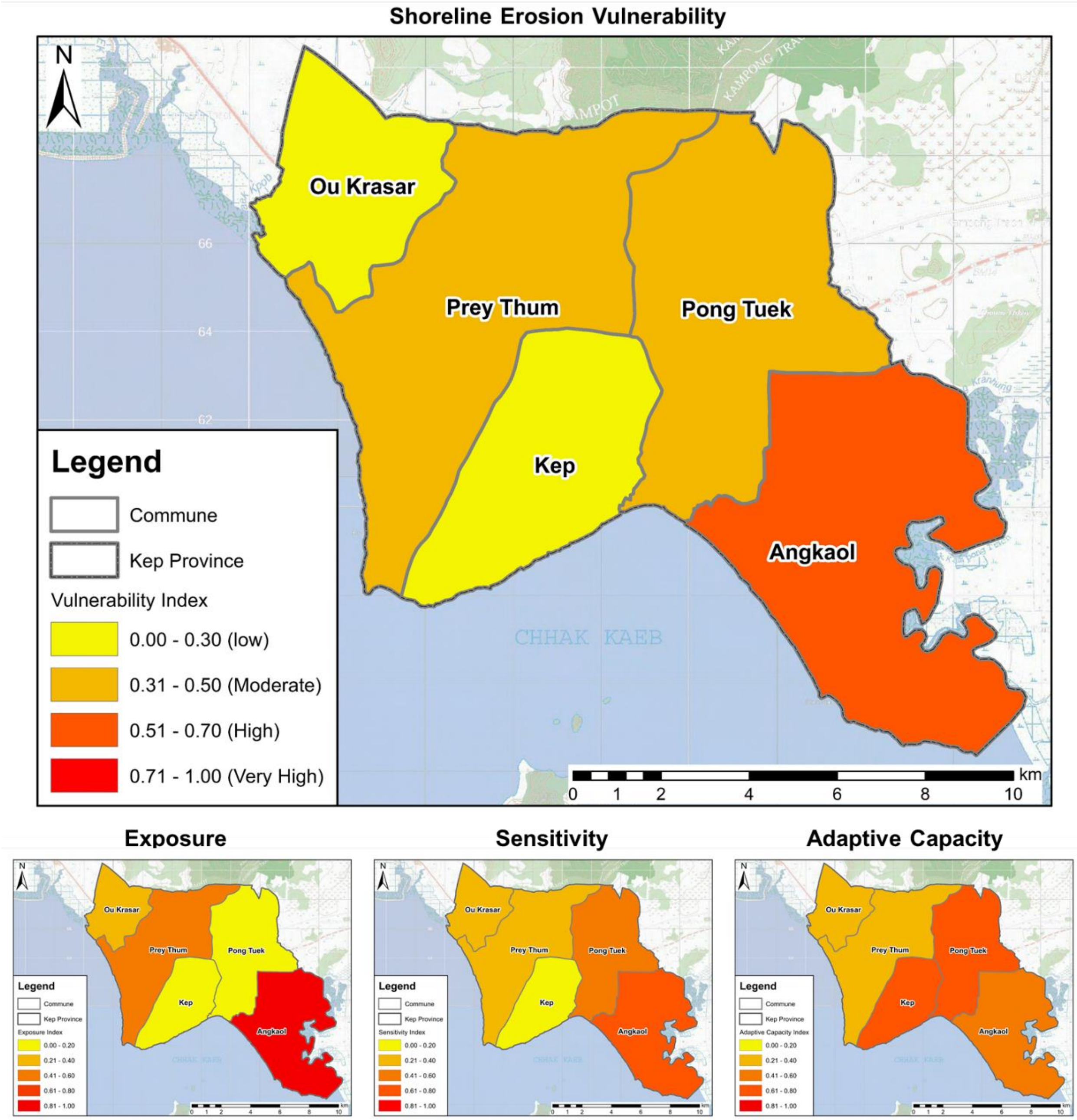


Figure 19: Maps of shoreline erosion vulnerability (top), exposure (bottom left), sensitivity (bottom middle), and adaptive capacity (bottom right)

The following map (Figure 20: top) highlights the vulnerability index to shoreline erosion. Angkaol is showing to be the most vulnerable commune given its high and very high exposure to shoreline erosion due to the commune have shoreline longer than the other three commune. However, Prey Thum and Pong Tuek communes are appearing to be moderately vulnerable communes given its low exposure to shoreline erosion, while Kep and Ou Krasar communes are performing to be low vulnerable communes give its low exposure to shoreline erosion.

3.2.4 Windstorm Vulnerability

The following Table 6 illustrates the weights generated from the vulnerability assessment method for the assessment of the vulnerability to windstorms. For sensitivity, the high weight was given to the natural sensitivity of the four main groups of indicators, and then human sensitivity, infrastructure sensitivity, and the smallest weight was given to livelihood Sensitivity. Similarly, with the adaptive capacity, the order weight was given to infrastructure, technology, social capital, and human capital adaptive capacity. The specific indicator natural sensitivity in which higher weight was given to the percentages of the commune area without forest area cover, mangrove area to shore area, and low-lying areas than the proportion of the commune covered by the protected area.

Table 6: Weights for the windstorm vulnerability assessment

Level 4 Index	Weight	Level 3 Index	Weight	Level 2 Index	Weight	Level 1 Index
1. Number of persons affected by heavy storms	1	Windstorm	1	Exposure	0.33	Windstorm Vulnerability
2. Commune area without forest cover	0.40	Natural sensitivity	0.40	Sensitivity	0.33	
3. Protected area to total commune area	0.10					
4. Low-lying (inundated) area to total commune area	0.20					
5. Mangrove area to shore area	0.30					
6. Commune population density	0.07	Human sensitivity	0.30			
7. Poverty rate	0.33					
8. Women-headed households	0.20					
9. Male-female ratio	0.13					
10. Disability	0.27					
11. Unhygienic water for daily use	0.33	Infrastructure sensitivity	0.10			
12. Clean water acess	0.67					
13. Laborers involving in agricultural sector	1.00	Livelihood sensitivity	0.20			
14. Irrigated land	0.33	Infrastructure indicators	0.40	Adaptive capacity	0.33	
15. Households accesses to tap water	0.20					
16. Medical institutions	0.27					
17. Mangrove area to shore area	0.13					
18. Shoreline protection	0.07					
19. Households has TVs	1	Technology indicators	0.10			
20. Volunteer group in the commune	0.67	Social capital indicators	0.20			
21. Proportion of Pagodas	0.33					
22. Medical institutions	0.67	Human indicators	0.30			
23. Govt. primary schools	0.33					

The map below (Figure 21) shows the index of exposure, sensitivity, and adaptive capacity to windstorm hazards. Most of the communes in Kep province with high exposure to windstorm hazards. The sensitivity to windstorm hazard where Angkaol and Pong Tuek commune are classified to be very high and highly sensitive regions, respectively. In terms of adaptive capacity, more communes are classified as having a low adaptive capacity to windstorm hazards. Those are the ones located in Ou Krasar and Prey Thum.

The following map (Figure 21: top) highlights the vulnerability index to windstorm hazards. Angkaol and Pong Tuek appeared to be the most vulnerable commune given its high and very high exposure to windstorm hazard due to the commune have shoreline longer than the other three communes. However, Kep and Prey Thum communes are displaying to be moderately vulnerable commune given its low exposure to windstorm hazard, while Ou Krasar communes are showing to be low vulnerable commune given its low exposure to windstorm hazard.

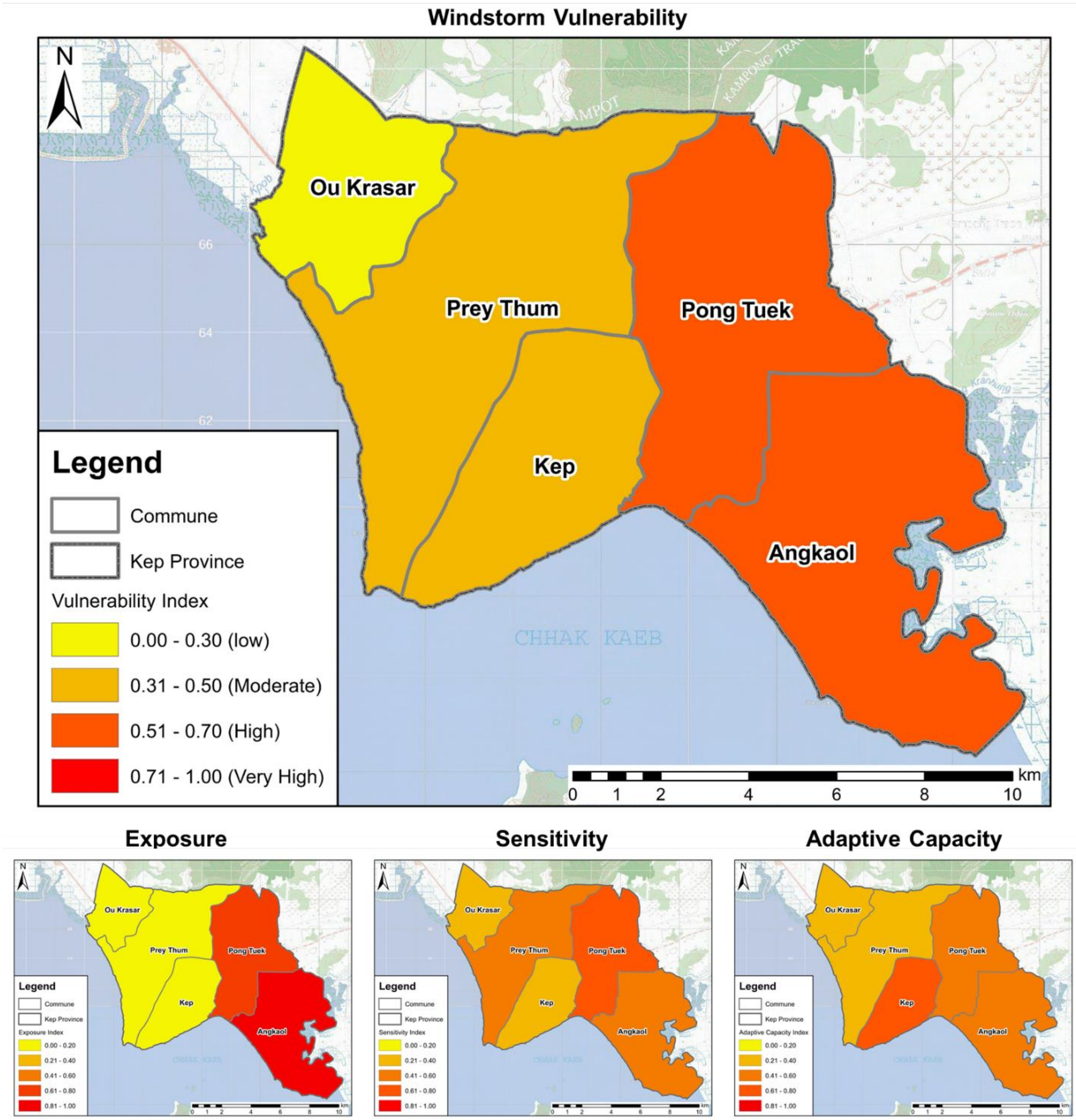


Figure 20: Maps of windstorm vulnerability (top), exposure (bottom left), sensitivity (bottom middle), and adaptive capacity (bottom right)

4 Summary of Climate Vulnerability in Kep City

Based on the recommendation related to the ecosystem assessment, livelihood improvement potential, socio-economic impacts including impacts on vulnerable groups, water shortage, proofing of infrastructure in the city, sustainable city, …etc, the study was scoped to Kep City. Kep Municipality (city), located at the center of the Kep province, is subdivided into three Sangkats (communes): Sangkat Kep at the east of the Sangkat Kep, Sangkat Prey Thum in the middle and Sangkat Ou Krasar at the west.

- *<u>Projected flash flood vulnerability in Kep City</u>*

The summary of the projected flash flood vulnerability in Kep City is presented in Table 7. The flash flood vulnerability in Kep City is reported for near-term future (short-term) 2021–2040 (2030s) and medium-term future (medium-term) 2051-2070 (2060s). The flash flood vulnerability in Kep City also presented based on the projected climate model (IPSL and GFDL) with two emissions scenarios (RCP4.5 & RCP8.5). The detail of the climate model and scenarios is described in Section 2.4.2.

In term of adaptive capacity, Kep has a stronger adaptive capacity to the flash flood than Prey Thum and Ou Krasar (these two Sangkats has similar adaptive capacity). The most sensitive Sangat is Prey Thum, following by Kep and Ou Krasar (these two Sangkats is similarly sensitive). Among these three Sangkats, overall, Sangkat Kep is the less exposure to flash-flood in both short-term and medium-term, follow by Prey Thum and Ou Krasar, respectively. Overall vulnerability to flash flood in the short-term and medium-term in the future, Prey Thum is the most vulnerable Sangkat, following by Sangkat Ou Krasar and the Sangkat Kep (the less vulnerable one).

Table 7: Summary of the short-term and medium-term flash flood vulnerability index in Kep City

Short-term Flash Flood Vulnerability							
RCP4.5 GFDL-2030s				RCP8.5 GFDL-2030s			
Commune	Kep	Ou Krasar	Prey Thum	Commune	Kep	Ou Krasar	Prey Thum
Exposure	0.12	1.00	0.98	Exposure	0.00	0.20	0.19
Sensitivity	0.32	0.31	0.63	Sensitivity	0.32	0.31	0.63
Adaptive capacity	0.68	0.36	0.40	Adaptive capacity	0.68	0.36	0.40
Vulnerability	**0.37**	**0.55**	**0.66**	**Vulnerability**	**0.33**	**0.29**	**0.40**
RCP4.5 IPSL-2030s				RCP8.5 IPSL-2030s			
Commune	Kep	Ou Krasar	Prey Thum	Commune	Kep	Ou Krasar	Prey Thum
Exposure	0.99	0.01	0.00	Exposure	1.00	0.81	0.78
Sensitivity	0.32	0.31	0.63	Sensitivity	0.32	0.31	0.63
Adaptive capacity	0.68	0.36	0.40	Adaptive capacity	0.68	0.36	0.40
Vulnerability	**0.66**	**0.23**	**0.34**	**Vulnerability**	**0.66**	**0.49**	**0.59**

Medium-term Flash Flood Vulnerability							
RCP4.5 GFDL-2060s				RCP8.5 GFDL-2060s			
Commune	Kep	Ou Krasar	Prey Thum	Commune	Kep	Ou Krasar	Prey Thum
Exposure	0.64	1.00	0.99	Exposure	0.35	1.00	0.98
Sensitivity	0.32	0.31	0.63	Sensitivity	0.32	0.31	0.63
Adaptive capacity	0.68	0.36	0.40	Adaptive capacity	0.68	0.36	0.40
Vulnerability	**0.54**	**0.55**	**0.67**	**Vulnerability**	**0.44**	**0.55**	**0.66**
RCP4.5 IPSL-2060s				RCP8.5 IPSL-2060s			
Commune	Kep	Ou Krasar	Prey Thum	Commune	Kep	Ou Krasar	Prey Thum
Exposure	0.00	0.37	0.36	Exposure	0.58	1.00	0.99
Sensitivity	0.32	0.31	0.63	Sensitivity	0.32	0.31	0.63
Adaptive capacity	0.68	0.36	0.40	Adaptive capacity	0.68	0.36	0.40
Vulnerability	**0.33**	**0.34**	**0.46**	**Vulnerability**	**0.52**	**0.55**	**0.66**

- *Projected drought vulnerability in Kep City*

Table 8 summarise the projected drought vulnerability in Kep City. The drought vulnerability in Kep City is reported for near-term future (short-term) 2021–2040 (2030s) and medium-term future (medium-term) 2051-2070 (2060s). The drought vulnerability in Kep City also presented based on the projected climate model (IPSL and GFDL) with two emissions scenarios (RCP4.5 & RCP8.5). Sangkat Kep has a higher adaptive capacity to drought events than Sangkat Prey Thum and Ou Krasar (these two Sangkats have similar adaptive capacity). However, Ou Krasar is the most sensitive area to drought. Among these three Sangkats, overall, Sangkat Prey Thum and Ou Krasar are expected to receive more exposure to drought in both short-term and medium-term than Sangat Kep. **Overall vulnerability to drought in both short-term and medium-term in the future in Kep city, Sangkat Kep is the most vulnerable Sangkat, following by Sangkat Prey Thum and Sangkat Ou Krasar (the less vulnerable one).**

Table 8: Summary of the short-term and medium-term drought vulnerability in Kep City

Short-term Drought Vulnerability							
RCP4.5 GFDL-2030s				RCP8.5 GFDL-2030s			
Commune	Kep	Ou Krasar	Prey Thum	Commune	Kep	Ou Krasar	Prey Thum
Exposure	0.10	0.54	0.52	Exposure	1.00	0.28	0.26
Sensitivity	0.50	0.30	0.61	Sensitivity	0.50	0.30	0.61
Adaptive capacity	0.68	0.38	0.40	Adaptive capacity	0.68	0.38	0.40
Vulnerability	**0.42**	**0.40**	**0.51**	**Vulnerability**	**0.72**	**0.31**	**0.42**
RCP4.5 IPSL-2030s				RCP8.5 IPSL-2030s			
Commune	Kep	Ou Krasar	Prey Thum	Commune	Kep	Ou Krasar	Prey Thum
Exposure	0.88	1.00	1.00	Exposure	0.34	0.00	0.01
Sensitivity	0.50	0.30	0.61	Sensitivity	0.50	0.30	0.61
Adaptive capacity	0.68	0.38	0.40	Adaptive capacity	0.68	0.38	0.40
Vulnerability	**0.68**	**0.55**	**0.66**	**Vulnerability**	**0.50**	**0.22**	**0.34**

Medium-term Drought Vulnerability							
RCP4.5 GFDL-2060s				RCP8.5 GFDL-2060s			
Commune	Kep	Ou Krasar	Prey Thum	Commune	Kep	Ou Krasar	Prey Thum
Exposure	0.66	1.00	0.99	Exposure	0.66	1.00	0.99
Sensitivity	0.50	0.30	0.61	Sensitivity	0.50	0.30	0.61
Adaptive capacity	0.68	0.38	0.40	Adaptive capacity	0.68	0.38	0.40
Vulnerability	**0.61**	**0.55**	**0.66**	**Vulnerability**	**0.61**	**0.55**	**0.66**
RCP4.5 IPSL-2060s				RCP8.5 IPSL-2060s			
Commune	Kep	Ou Krasar	Prey Thum	Commune	Kep	Ou Krasar	Prey Thum
Exposure	0.98	0.87	0.87	Exposure	0.66	1.00	0.99
Sensitivity	0.50	0.30	0.61	Sensitivity	0.50	0.30	0.61
Adaptive capacity	0.68	0.38	0.40	Adaptive capacity	0.68	0.38	0.40
Vulnerability	**0.71**	**0.51**	**0.62**	**Vulnerability**	**0.61**	**0.55**	**0.66**

- *Shoreline erosion vulnerability in Kep City*

The shoreline erosion in Kep city partly depends on the shoreline length, shoreline protection by the existing dike and/or mangrove area along the shoreline. Sangkat Prey Thum is the most exposure to shoreline erosion than Sangkat Ou Krasar and Kep. Sangkat Kep has more adaptive capacity to shoreline erosion than the other two Sangkats (these two Sangkats, Ou Krasar and Prey Thum, has similar adaptive capacity) since the protection was taken place. **The overall shoreline erosion vulnerability Sangkats are in order: Prey Thum, Ou Krasar, and Kep.**

Table 9: Summary of the shoreline erosion vulnerability in Kep City

Shoreline Erosion Vulnerability			
Commune	Kep	Ou Krasar	Prey Thum
Exposure	0.00	0.22	0.59
Sensitivity	0.15	0.36	0.33
Adaptive capacity	0.64	0.30	0.35
Vulnerability	**0.26**	**0.29**	**0.42**

- *Windstorm vulnerability in Kep City*

Due to the unpredictable and unforeseen windstorms in the future in this coastal area, the windstorm is based on the historical effect of windstorm in the area in Kep city, the area had shared similar exposure to windstorm. In-term of sensitivity, Sangkat Prey Thum is the most concerned Sangkat. Sangkat Kep has better adaptive capacity than two other Sangkat. **However, overall windstorm vulnerability in Kep city, these three Sangats are similarly vulnerable**.

Table 10: Summary of the windstorm vulnerability in Kep City

Windstorm Vulnerability			
Commune	Kep	Ou Krasar	Prey Thum
Exposure	0.11	0.00	0.08
Sensitivity	0.29	0.34	0.52
Adaptive capacity	0.66	0.36	0.36
Vulnerability	**0.35**	**0.23**	**0.32**

5 Conclusion

- Overall vulnerability to flash flood in the short-term and medium-term in the future, Prey Thum is the most vulnerable Sangkat, following by Sangkat Ou Krasar and the Sangkat Kep (the less vulnerable one);
- Overall vulnerability to drought in both short-term and medium-term in the future in Kep city, Sangkat Kep is the most vulnerable Sangkat, following by Sangkat Prey Thum and Sangkat Ou Krasar (the less vulnerable one);
- The overall shoreline erosion vulnerability Sangkats are in order: Prey Thum, Ou Krasar, and Kep; and
- Overall windstorm vulnerability in Kep city, these three Sangats are similarly vulnerable.

6 EbA adaptation options related to the climate intervention for Kep City

Infrastructure

#	Propose Actions/options	Adaptation outcomes from EbA interventions	Proposed Location	Description		Estimated Price ($)	Responsible institution
				Quantity	Unit		
1	Stormwater drainage system - Closed drainage - Circle and/or triangular	- Reducing flash floods in the urban areas of Kep City - Sustain the resilience urban drainage - Reduce amount of solid waste attached with storm-water	Prey Thum and Kep Commune - Along the road #33A at the low area to Kep beach	5 000	meters	100,000	PDoPWT
2	Stormwater drainage system - Steep slope area using open channel - Near the hill using open channels	- Reducing flash floods in the urban areas of Kep City - Sustain the resilience urban drainage - Reduce amount of solid waste attached with storm-water	Prey Thum and Kep Commune - hill area	2 000	meters	60,000	PDoPWT
3	Box culvert to prevent the flood along the road #33.	- Reducing flash floods in the urban areas of Kep City - Sustain the resilience urban drainage - Reduce amount of solid waste attached with storm-water	Prey Thum and Ou Krasar Commune - Near Ou Krasar commune Hall - Near Prey Thum commune hall and bear Kep City hall	3	locations	50,000	PDoPWT
4	Separated wastewater collection using the closed conduit system	- Reducing flash floods in the urban areas of Kep City - Reduce the pollutant load to the sea. - Improve the environment and livelihood	Kep Commune	6 000	meters	120,000	PDoPWT
5	Function the existing wastewater treatment system	- Reduce the pollutant load to the sea - Improve the environment and livelihood	Prey Thum commune - Crab market - Kep beach	2	locations	200,000	Kep city administration And PDoE
6	Construct and connect the collecting system to wastewater treatment system using treatment plant	- Reduce the pollutant load to the sea - Improve the environment and livelihood	Kep Commune - Kep market	1	locations	100,000	Kep city administration And PDoPWT
7	Excavate and Renovate the exiting natural canal	- Reducing flash floods in the urban areas of Kep City	Prey Thum and Ou Krasar commune (Ou Pring canal)	5 000	meters	50,000	Kep city administration And PDoWRAM
8	Box culvert to prevent the flood in natural Canal	- Reducing flash floods	Ou Krasar commune	3	locations	30,000	Kep city administration , PDoPWT and PDoWRAM

9	Community ponds provide water for domestic use, livestock (50m x 50m x 4m).	- Reducing impact of the drought - Increase local agricultural production (vegetable) and daily water consumption, it will decrease the difficulties and time of women and children to take the water from the faraway water sources.	Angkaol Ou Krasar	4	locations	400,000	Kep city administration, PDoAFF
10	Construct the sea dyke	- Reducing salinity intrusion	Angkaol, 1000m Ou Krasar, 2000m	3 000	meters	100,000	Kep city administration
11	Mangrove planting in the rivermouth	- Reducing flood by reducing the effect of backwater from the sea.	Ou Krasar, Angkaol and Pong Tuek	3	locations	10,000	Kep province administration and PDoAFF
12	Introducing pilot scale on water saving irrigation technology	- Reducing impact of the drought - Increase local agricultural production (vegetable) and increasing the local economic	Ou Krasar, Angkaol and Pong Tuek	3	locations	60,000	Kep province administration and PDoAFF
13	Restoration and construction of irrigation system and road in Damnak Chang Er district	- Reduce impact of the drought - Increase local agricultural production (vegetable) and increasing the local economic - Improve accessibility for local people (Road improvement, mostly along the irrigation system	Damnak Chang Er district	4	meters	400,000	Kep province administration and DoRD

<u>Trainings</u>

#	Propose Actions/options	Adaptation outcomes from EbA interventions	Proposed Location	Description		Estimated Price ($)	Responsible institution
				Quantity	Unit		
1	Dissemination workshop and meeting on procedure for solid and liquid waste management with stakeholders	- Solid waste management and maintaining the stormwater and severage collecting system	All communes	2	times	4,000	Kep city administration And PDoE
2	Organizing frequent events training workshops and field visits to increase public awareness (including solid waste related which block the drainage system) to engage	- Reduced negative (and direct) impacts of climate change on livestock and crop production (mainly through physical damage) for household consumption	Ou Krasar, Prey Thum and Kep Commune	2	time	4,000	Kep city administration

	in maintaining resilient urban drainage system.						
3	Organizing the workshop on cooperation and sharing information related to water reservoir (Koun Sat and Ou Krasar reservoir) management by implementing integrated watershed management including through transboundary (Kep and/or Kompot province) cooperation.	- Reduced negative (and direct) impacts of climate change on livestock and crop production (mainly through physical damage) for household consumption	- Kep city: Multi-provincial departments related to water use (provincial department of agriculture and water resources) - Kep city and Kompot: management by implementing integrated watershed management between these two provinces.	2	time	4,000	Kep province, Kep city and PDoWRAM
4	Organizing the workshop on Ou Krasar reservoir conservation and water usage for sustainability during climate hazard events	- Reduced negative (and direct) impacts of climate change on livestock and crop production (mainly through physical damage) for household consumption	Ou Krasar Prey Thum and Kep Commune	1	time	3,000	PDoWRAM
5	Organizing the workshop and demonstration on solid waste management to sustain the stormwater and wastewater drainage system	- Reduced negative (and direct) impacts of climate change on livestock and crop production (mainly through physical damage) for household consumption	Ou Krasar and Prey Thum and Kep Commune.	2	time	4,000	PDoE
6	Develop a practical guideline and workshop for flash flood and drought for provincial staff and local authority	- Reduce the damage and loss of properties - Technologies that will enable cost-effective	Kep city administration and provincial departments	1		5,000	Kep city administration And PDoE
7	Mainstream the practical guideline on flood and drought through on-site training for each commune with participants from local people.	- Reduced negative (and direct) impacts of climate change on livestock and crop production (mainly through physical damage) for household consumption	Ou Krasar and Prey Thum and Kep Commune.	2	time	4,000	Kep city administration And PDoE
8	Workshop and training on water saving irrigation technology to provincial department and staff	- To ensure that there is ownership of the intervention from the local communities and sustainability after the project ends - Ensure that there is liaison with the different stakeholders, and that these individuals receive and	Ou Krasar and Prey Thum and Kep Commune	1	time	3,000	Kep city administration And PDoAFF

		pass on relevant information in a timely- and language-sensitive manner.					
9	Training on water saving for agriculture practices; implementation of agriculture practices (e.g. agroforestry and soil conservation) to improve climate change adaption	- To ensure that there is ownership of the intervention from the local communities and sustainability after the project ends - Ensure that there is liaison with the different stakeholders, and that these individuals receive and pass on relevant information in a timely- and language-sensitive manner.	Ou Krasar Prey Thum and Kep Commune.	2	time	4,000	PDoAFF
10	Storm and emergency evacuation meeting point signs and preparing the gathering space	- Reduce the loss of assets of coastal communities and infrastructure located by physically protecting the communities against stronger and more frequent storms - Reduce the saltwater intrusion to inland and nearby farmland.	Ou Krasar Prey Thum and Kep Commune	15	locations	1,500	Kep city administration

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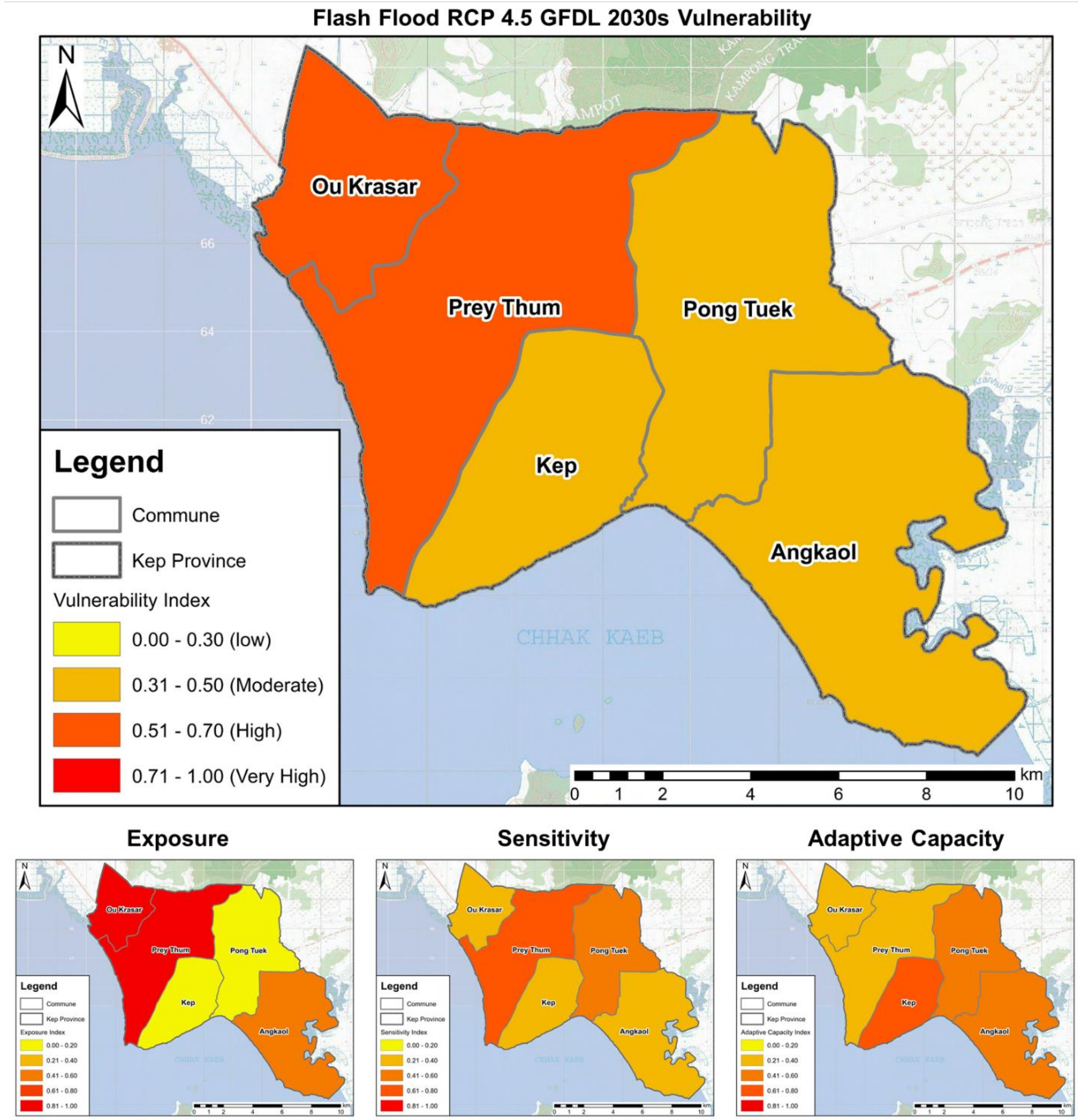
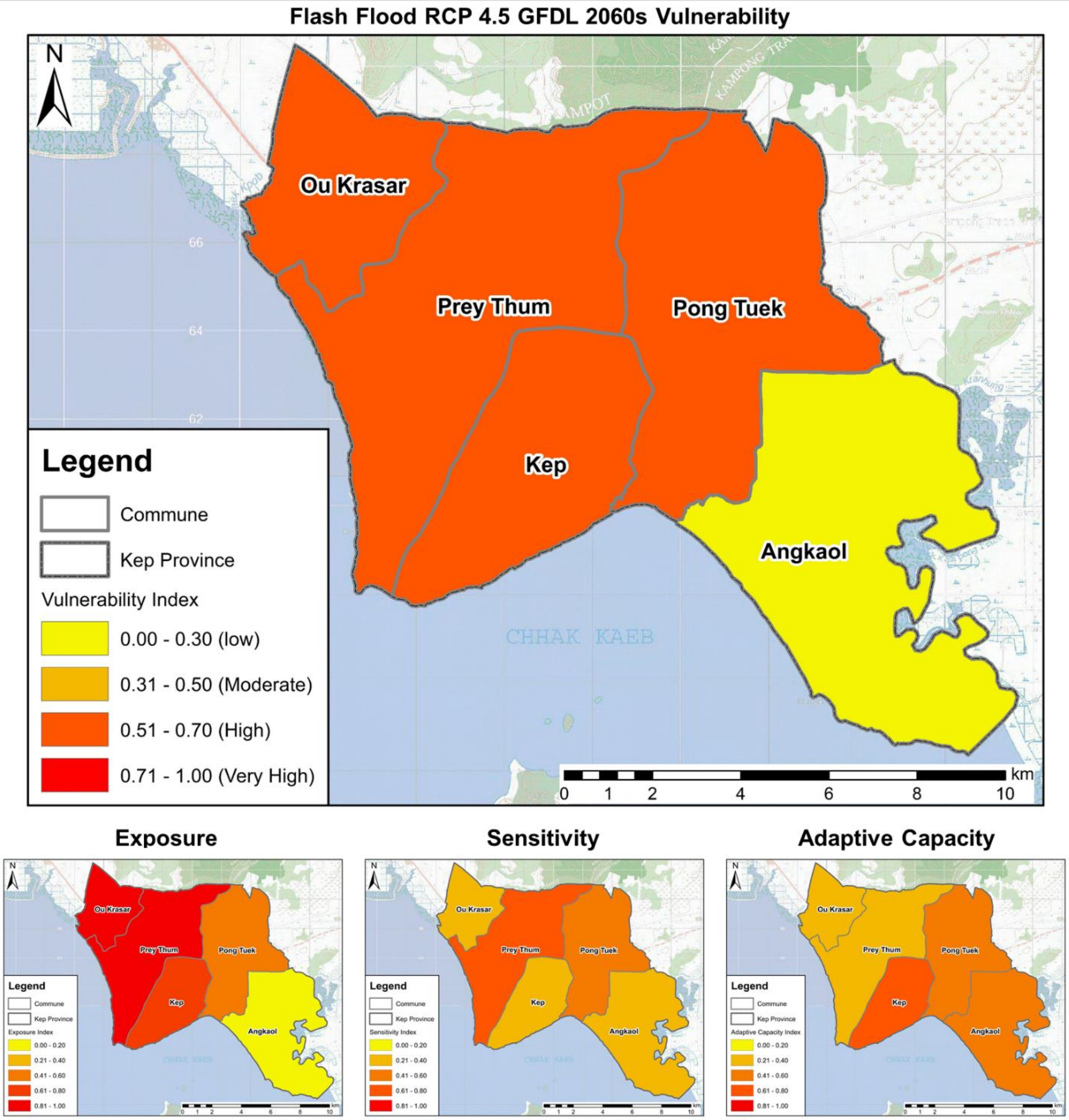
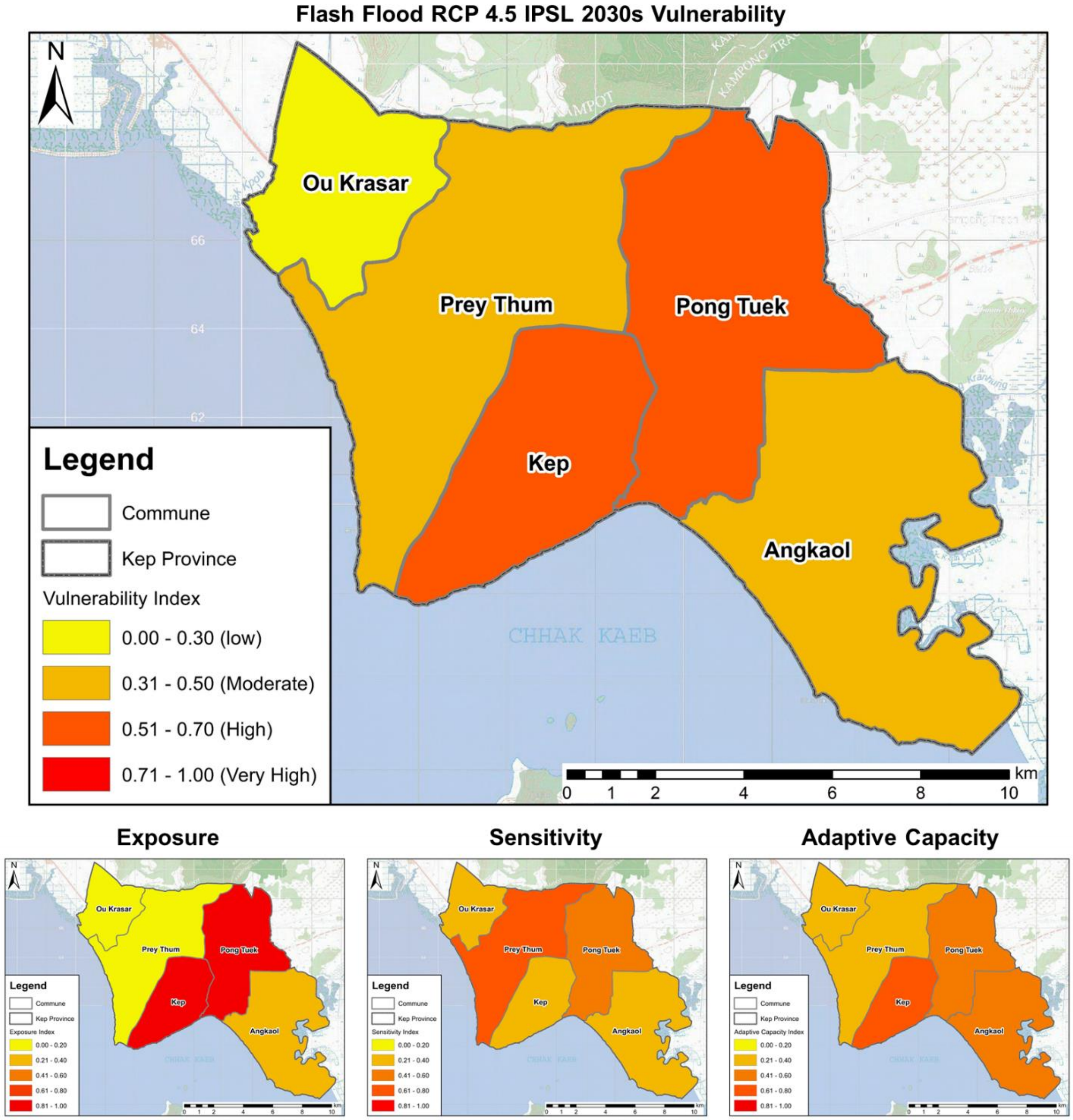
Annex 1: Flash flood vulnerability maps



Flash flood vulnerability in Kep province: In the short-term future, 2021–2040 (2030s), for GFDL model with Medium climate sensitivity (RCP 4.5)



Flash flood vulnerability in Kep province: In the medium-term future, 2051–2070 (2060s), for GFDL model with high climate sensitivity (RCP 4.5)



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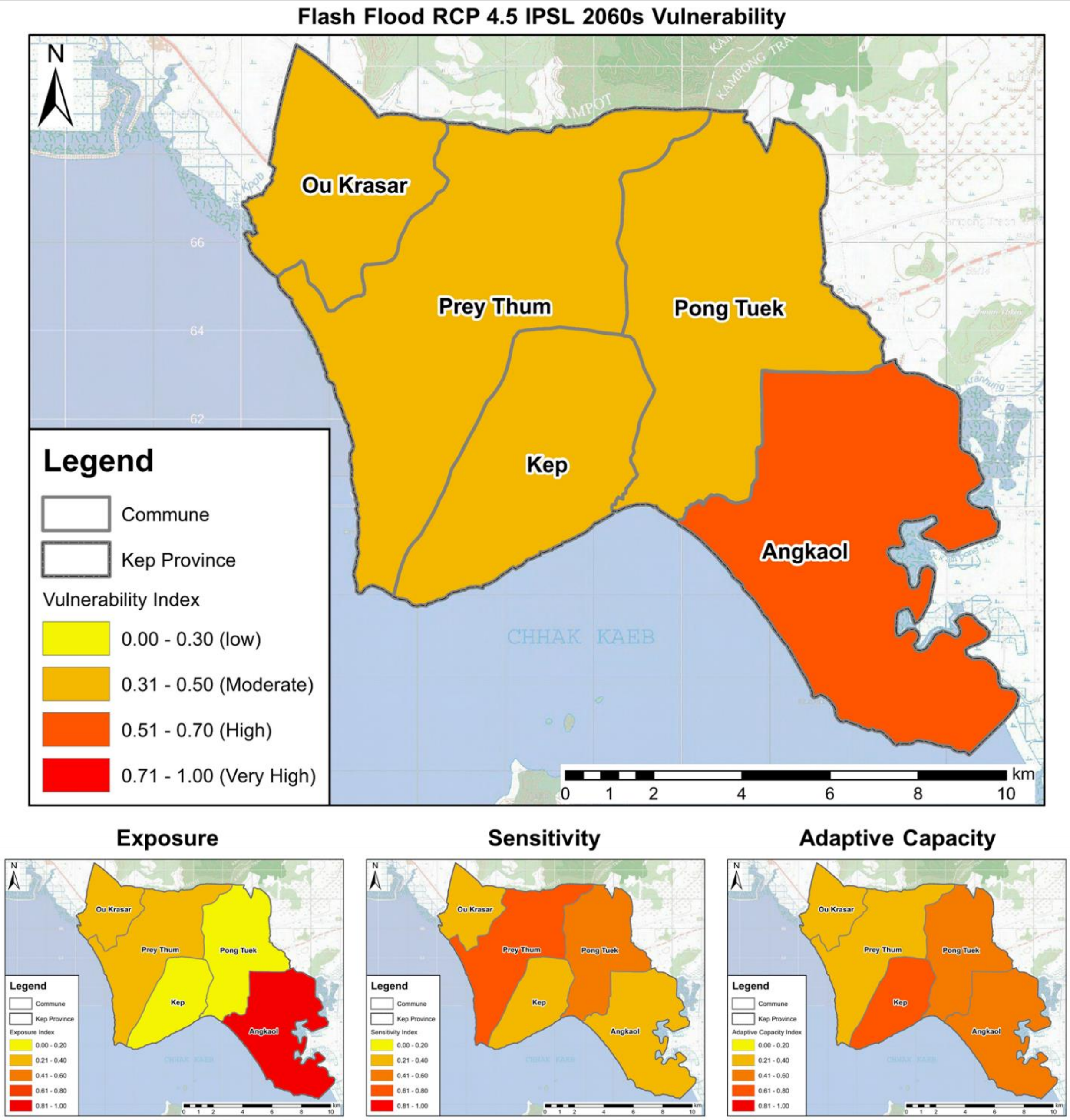
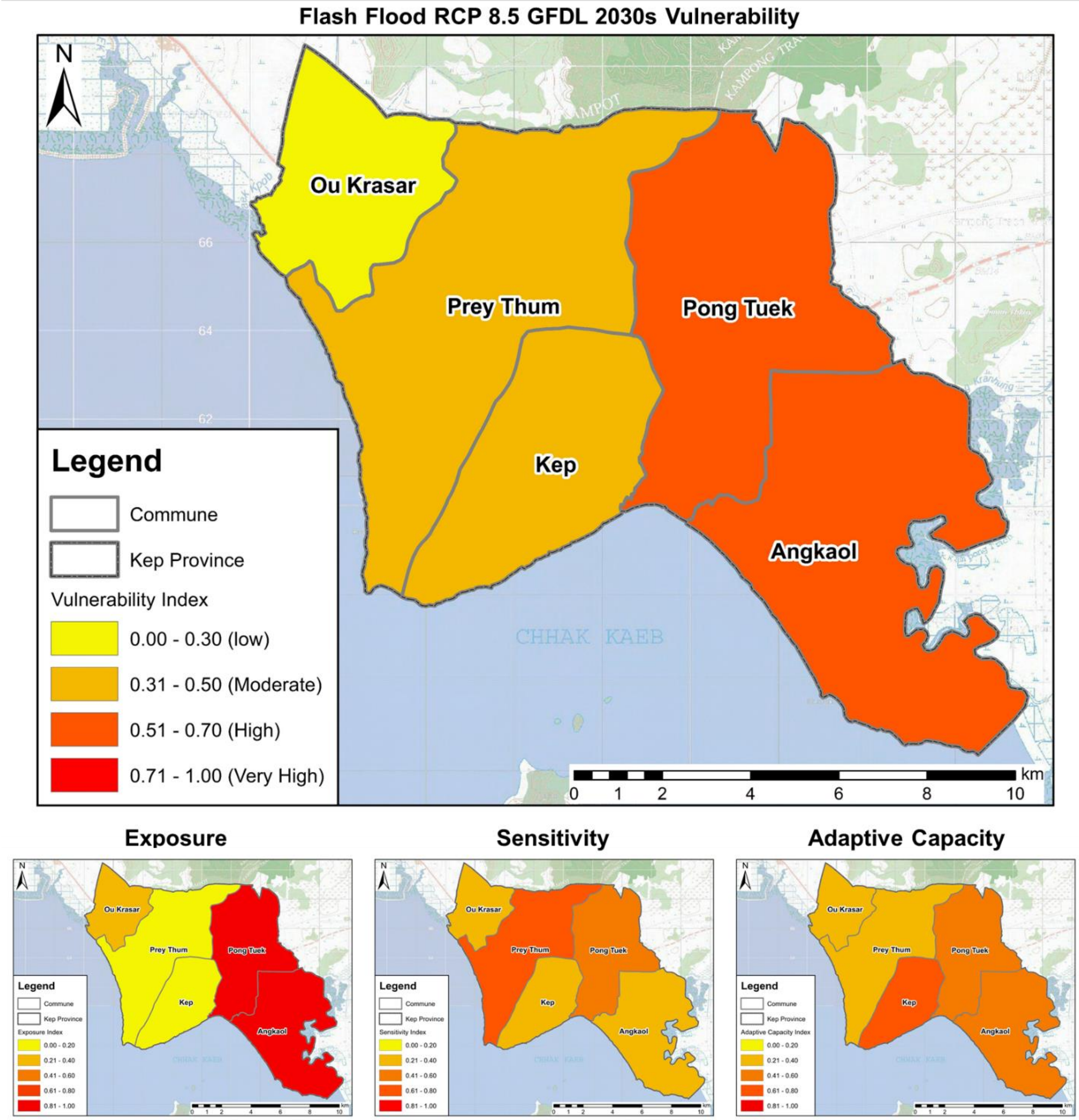
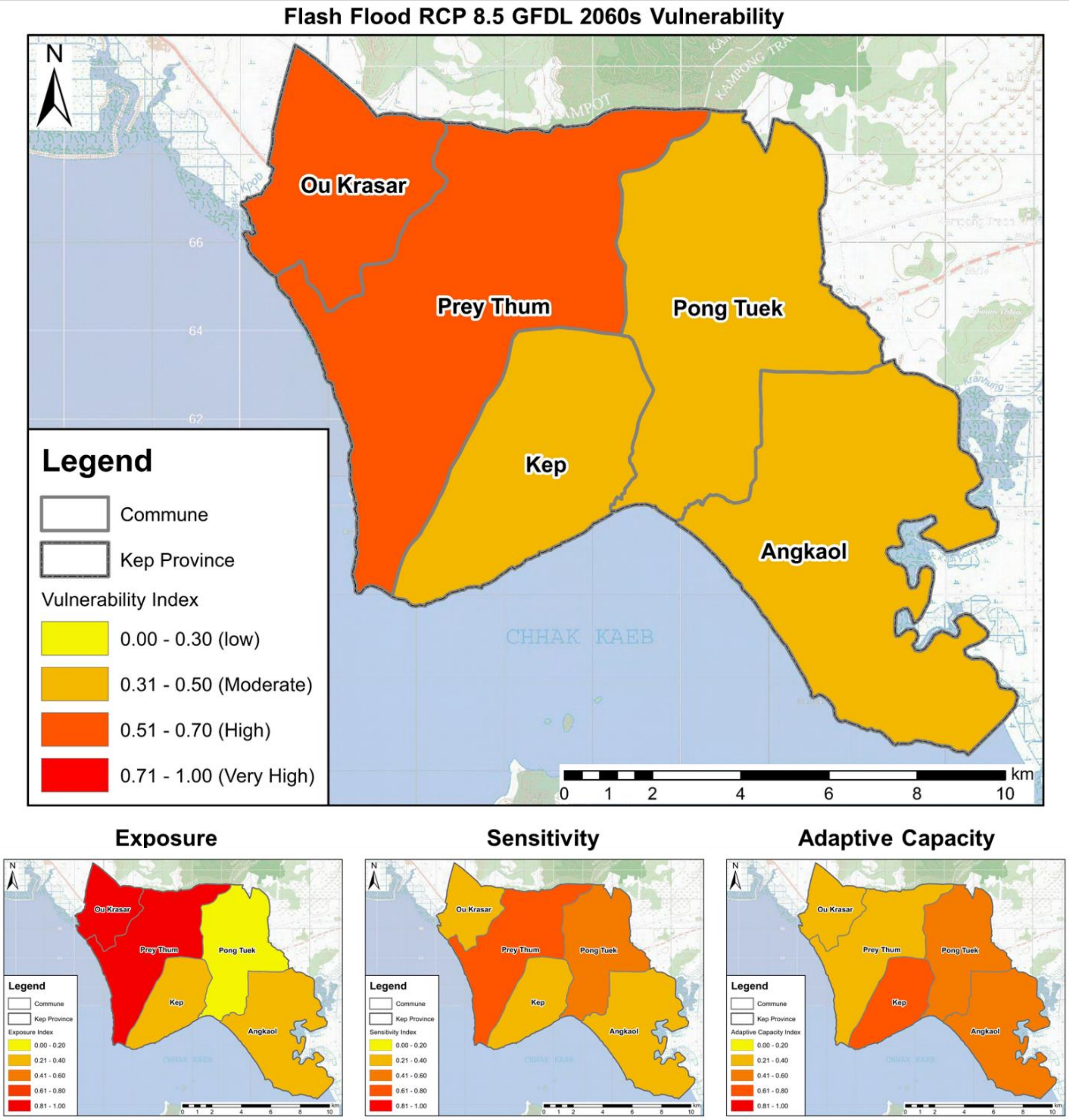


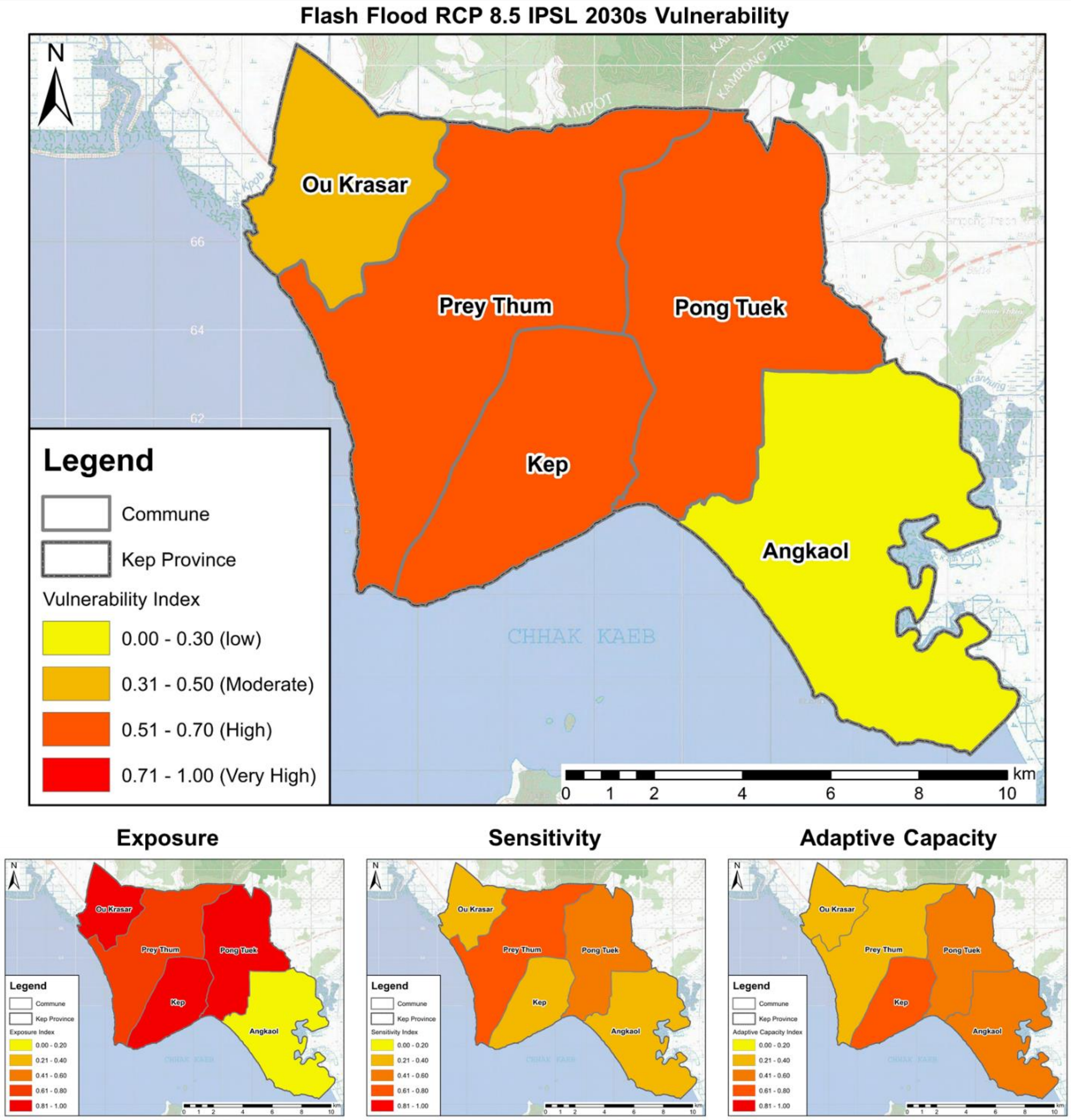
Flash flood vulnerability in Kep province: In the medium-term future, 2051–2070 (2060s), for IPSL model with high climate sensitivity (RCP 4.5)



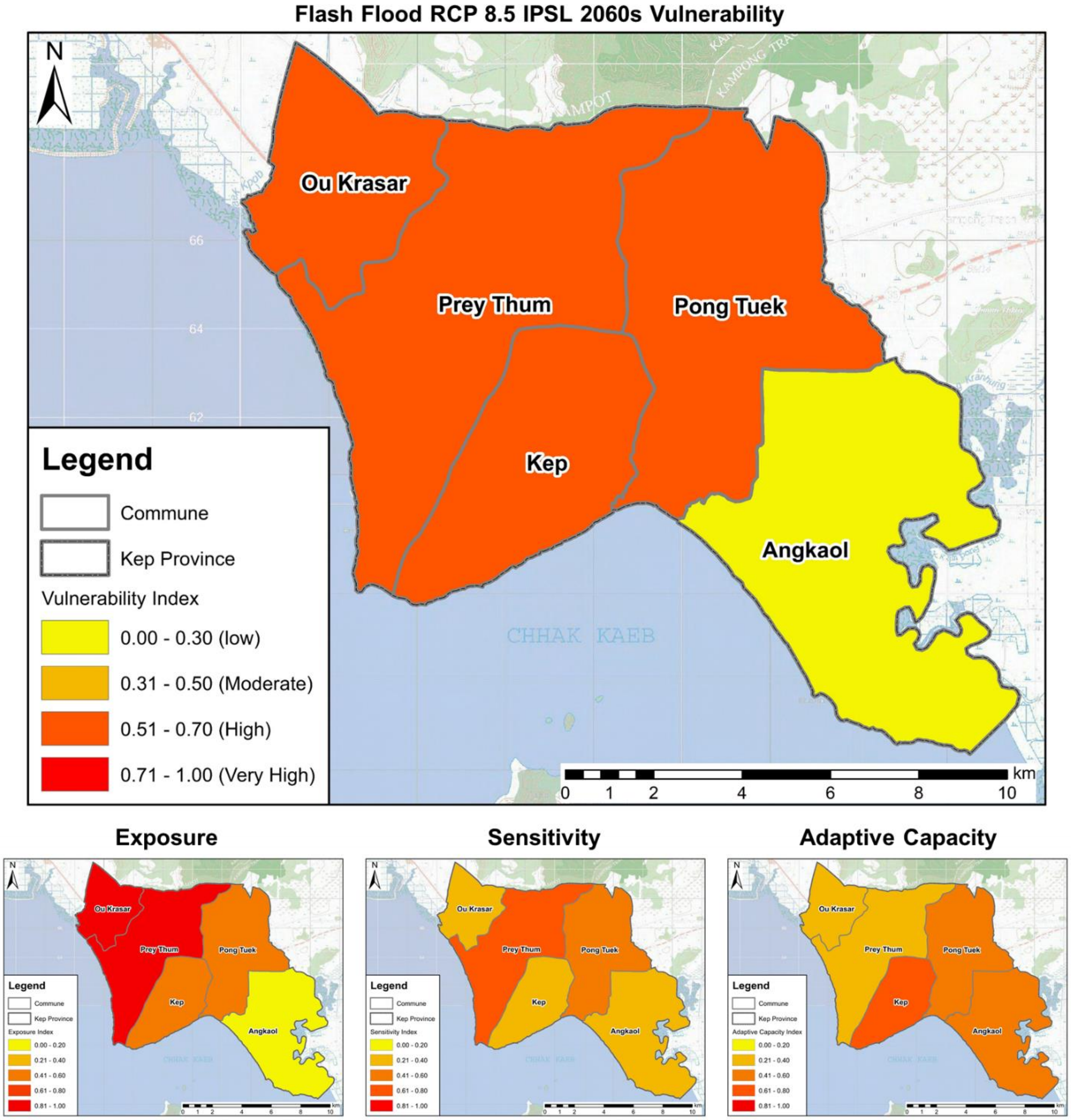
Flash flood vulnerability in Kep province: In the short-term future, 2021–2040 (2030s), for GFDL model with High climate sensitivity (RCP 8.5)



Flash flood vulnerability in Kep province: In the medium-term future, 2051–2070 (2060s), for GFDL model with high climate sensitivity (RCP 8.5)

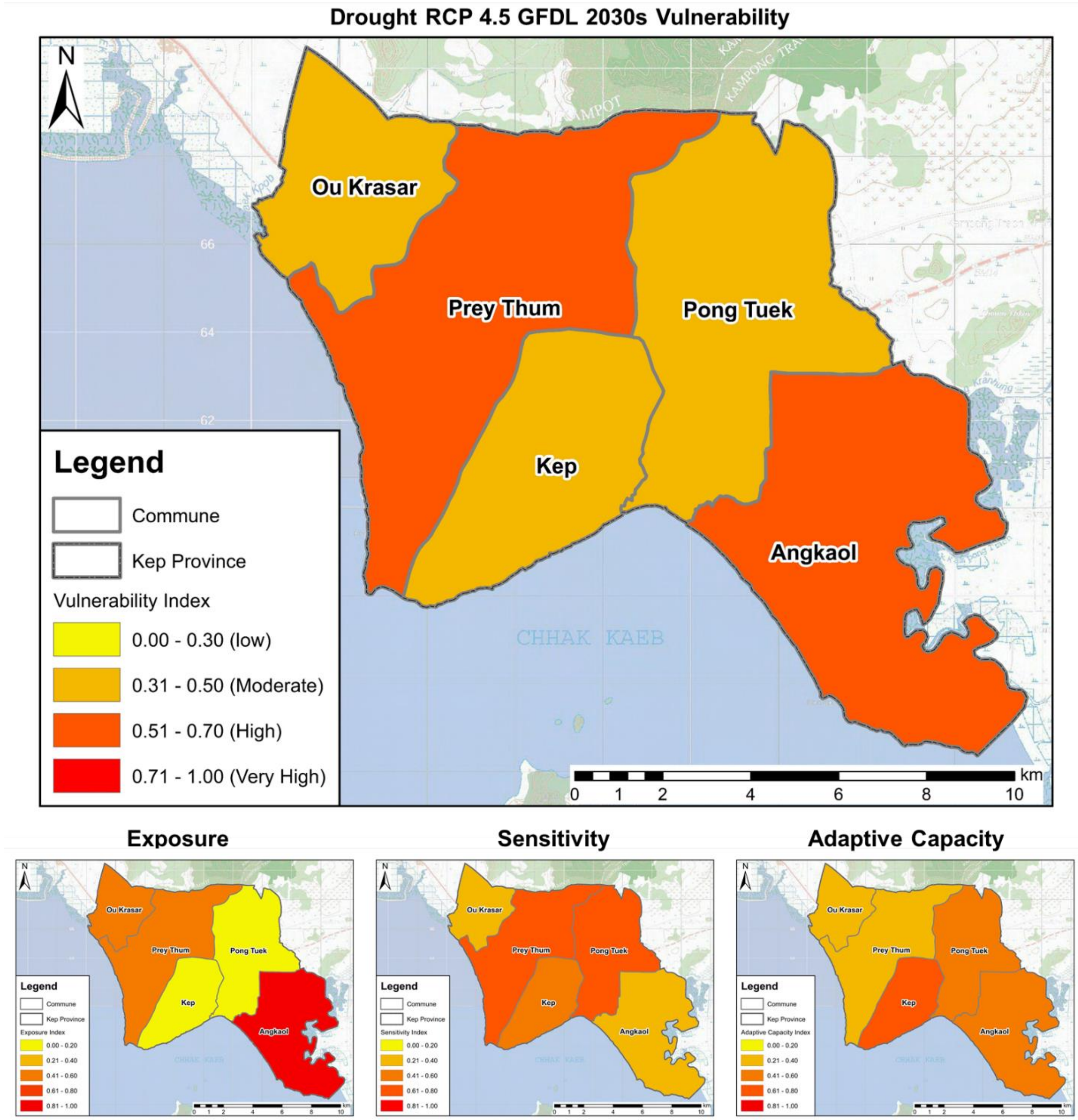


Flash flood vulnerability in Kep province: In the short-term future, 2021–2040 (2030s), for IPSL model with High climate sensitivity (RCP 8.5)

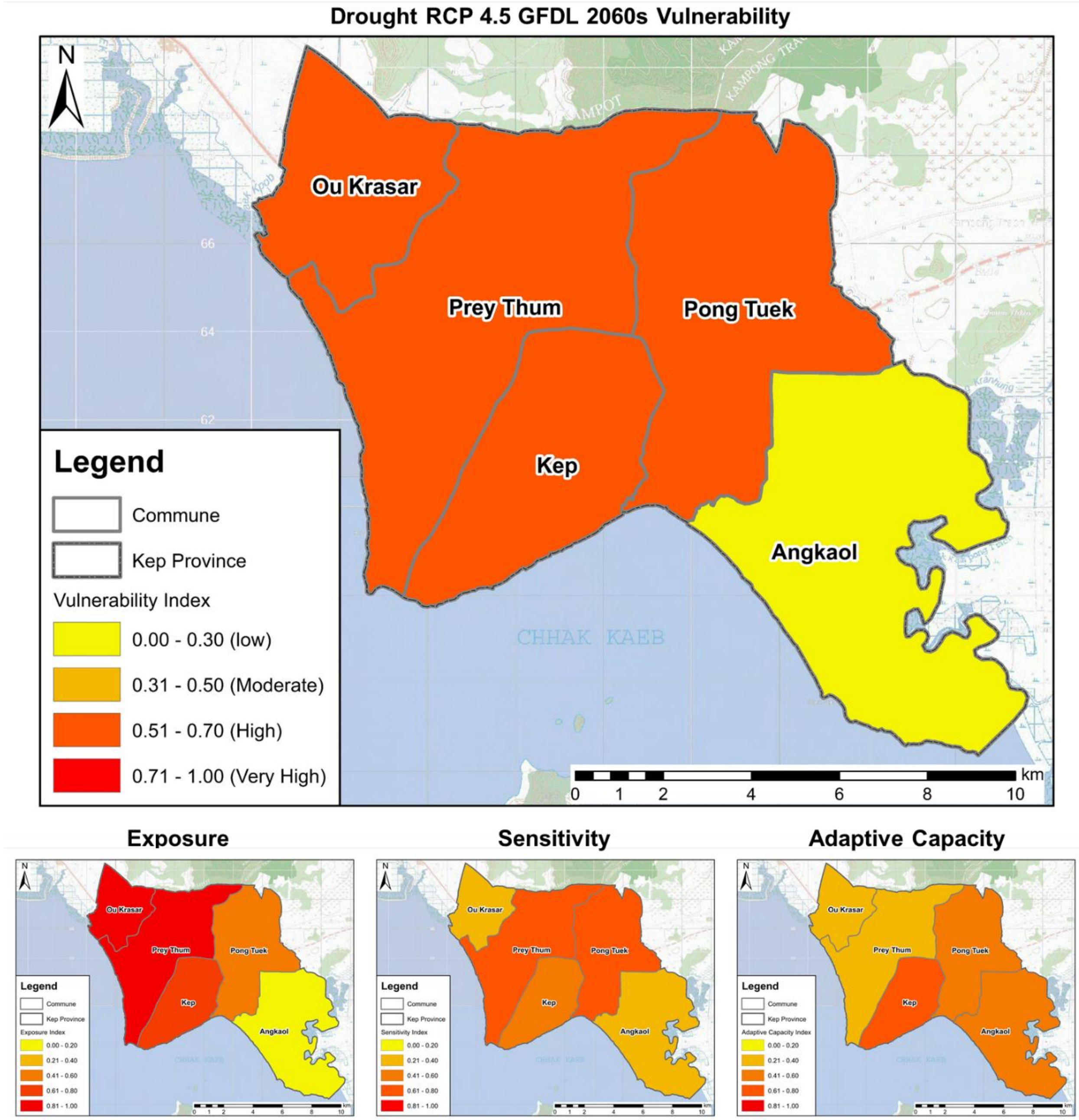


Flash flood vulnerability in Kep province: In the medium-term future, 2051–2070 (2060s), for IPSL model with high climate sensitivity (RCP 8.5)

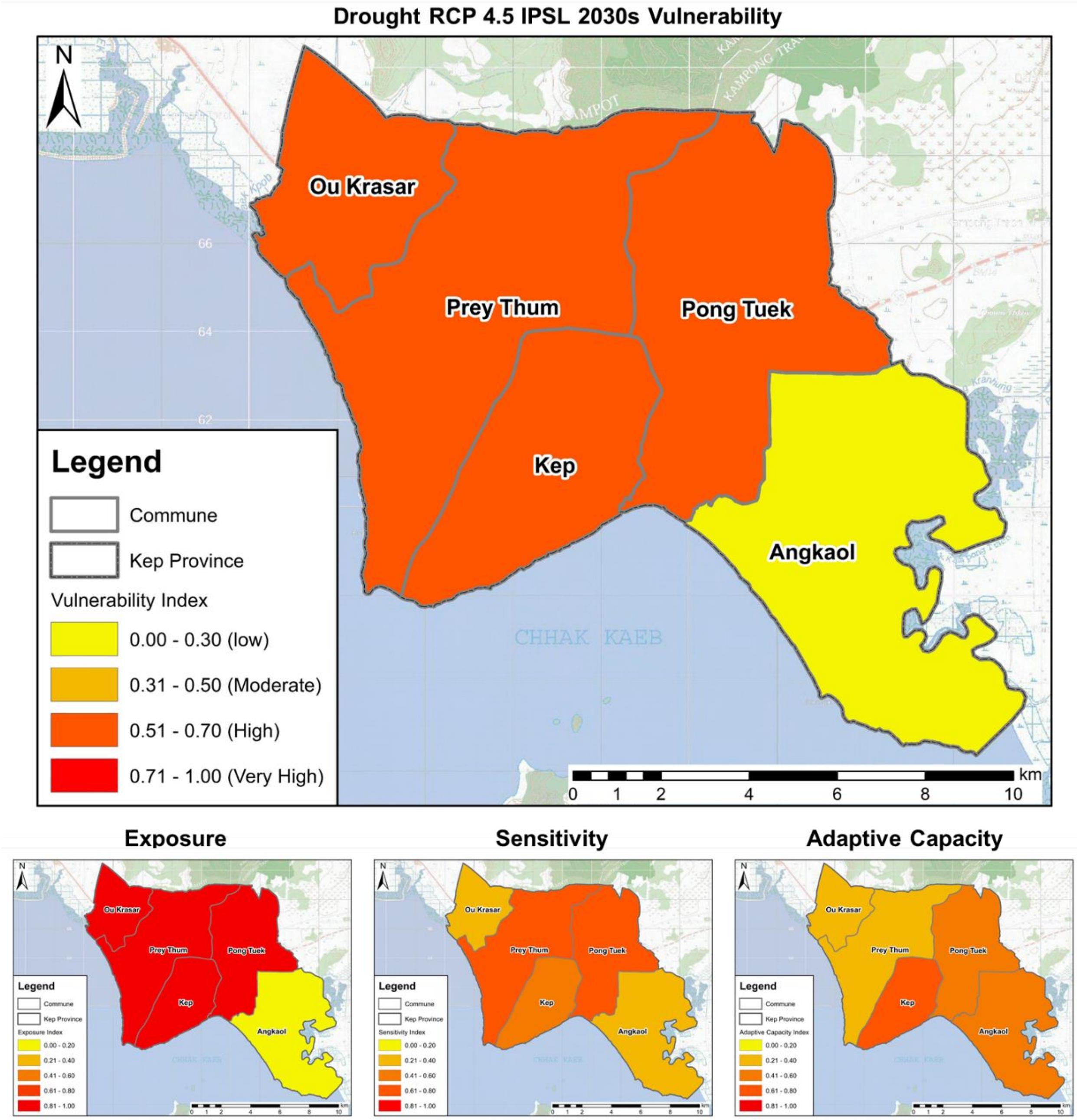
Annex 2: Drought vulnerability maps



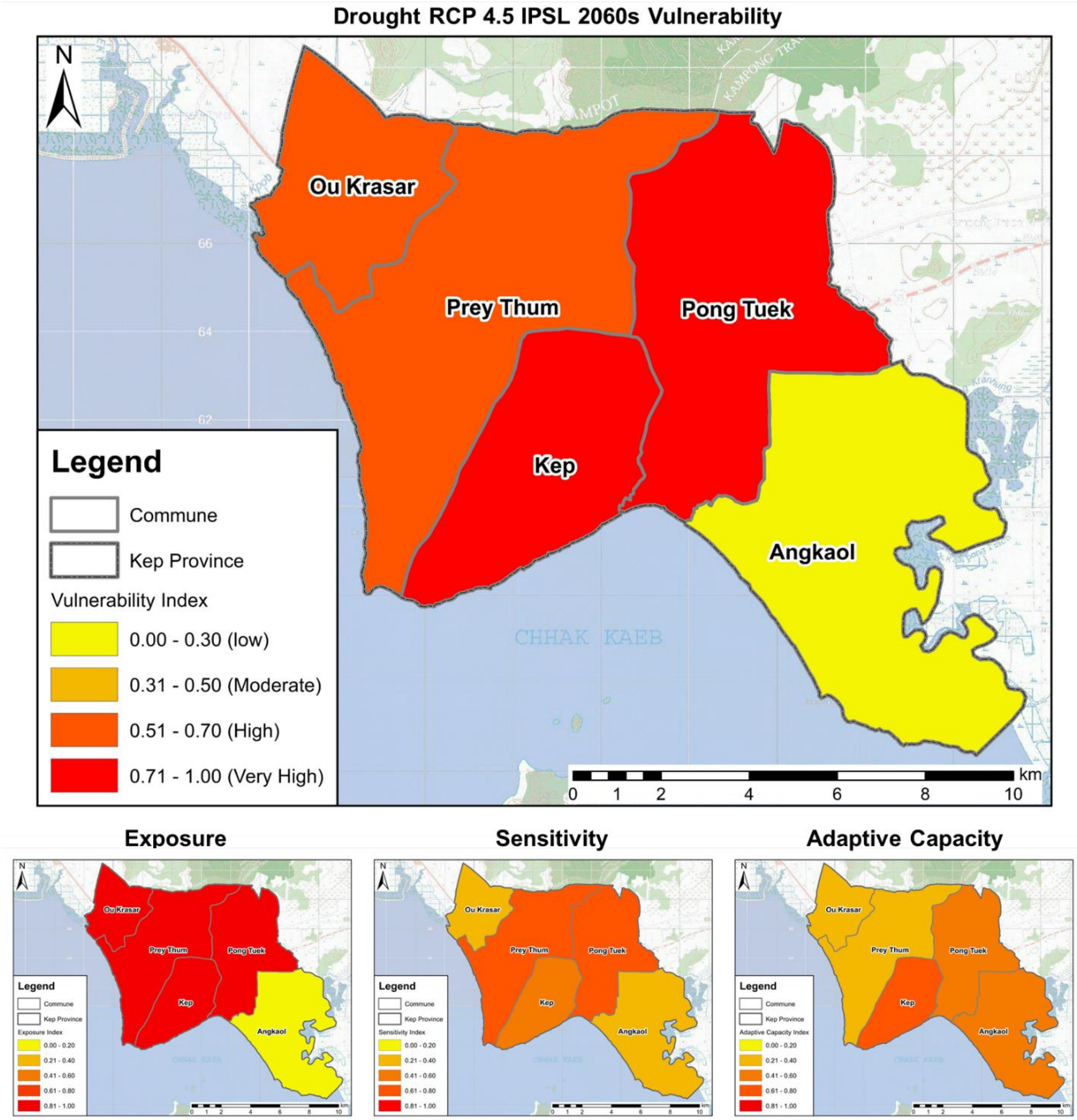
Drought vulnerability in Kep province: In the short-term future, 2021–2040 (2030s), for GFDL model with Medium climate sensitivity (RCP 4.5)



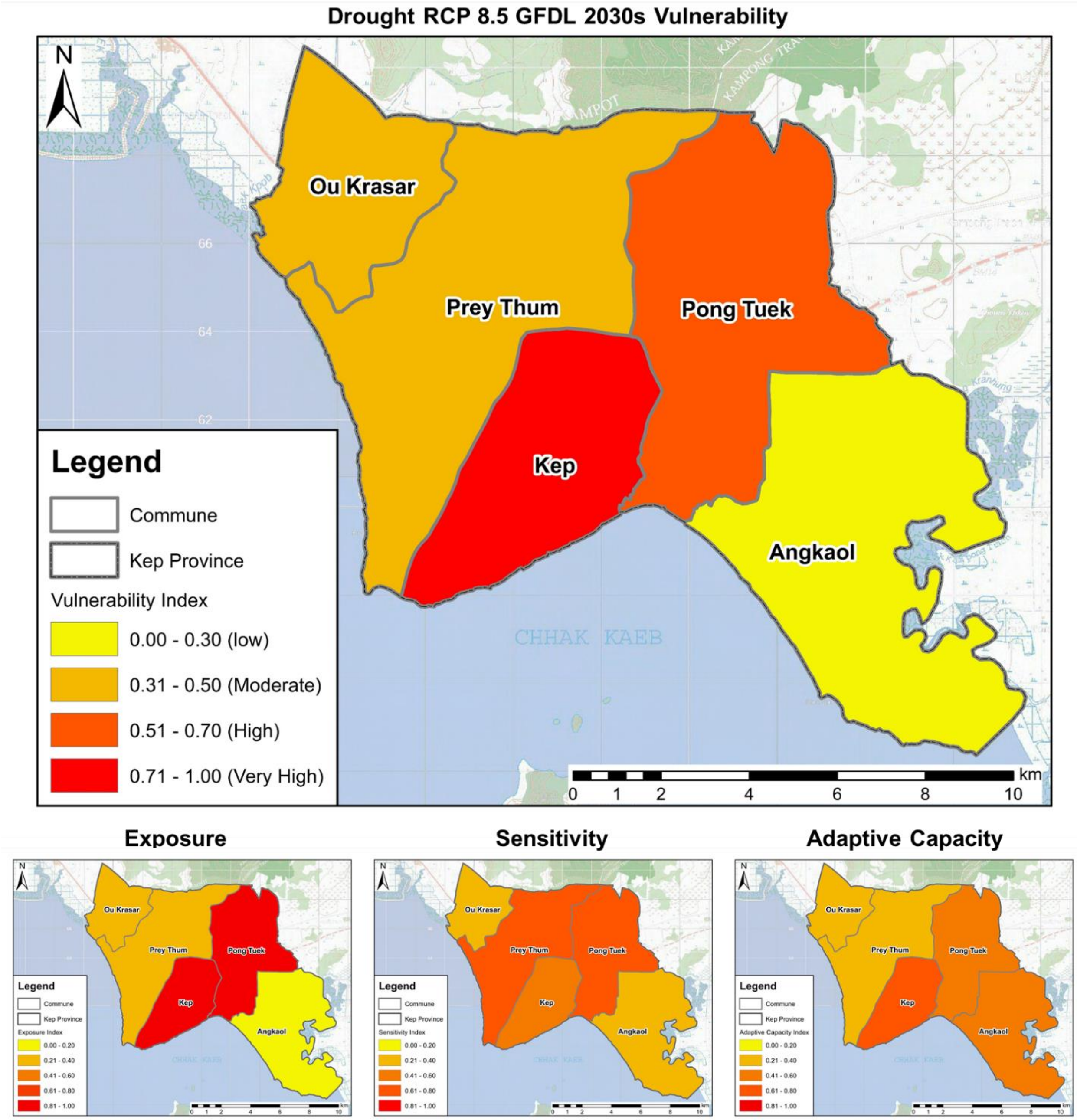
Drought vulnerability in Kep province: In the medium-term future, 2051–2070 (2060s), for GFDL model with Medium climate sensitivity (RCP 4.5)



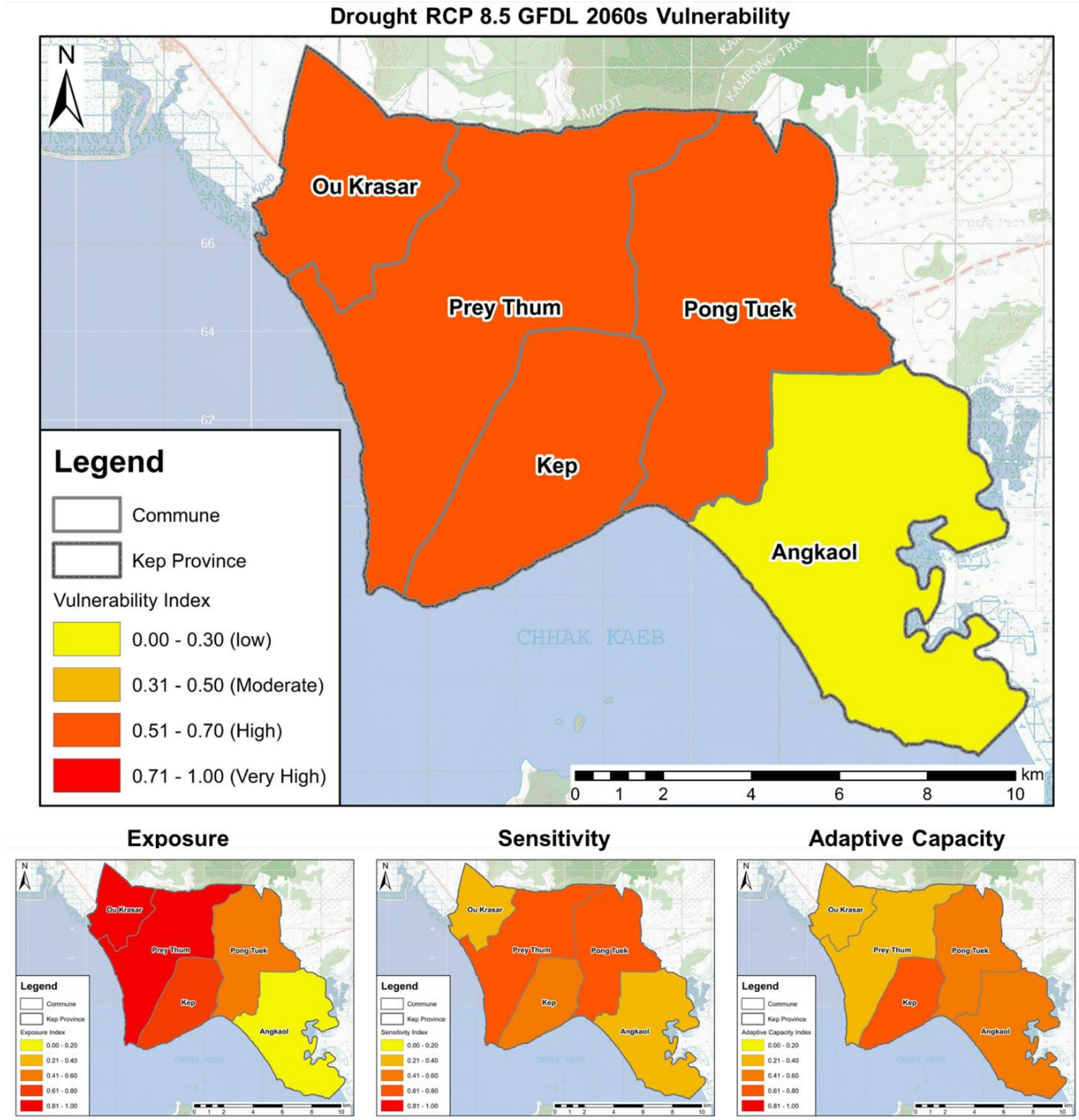
Drought vulnerability in Kep province: In the short-term future, 2021–2040 (2030s), for IPSL model with Medium climate sensitivity (RCP 4.5)



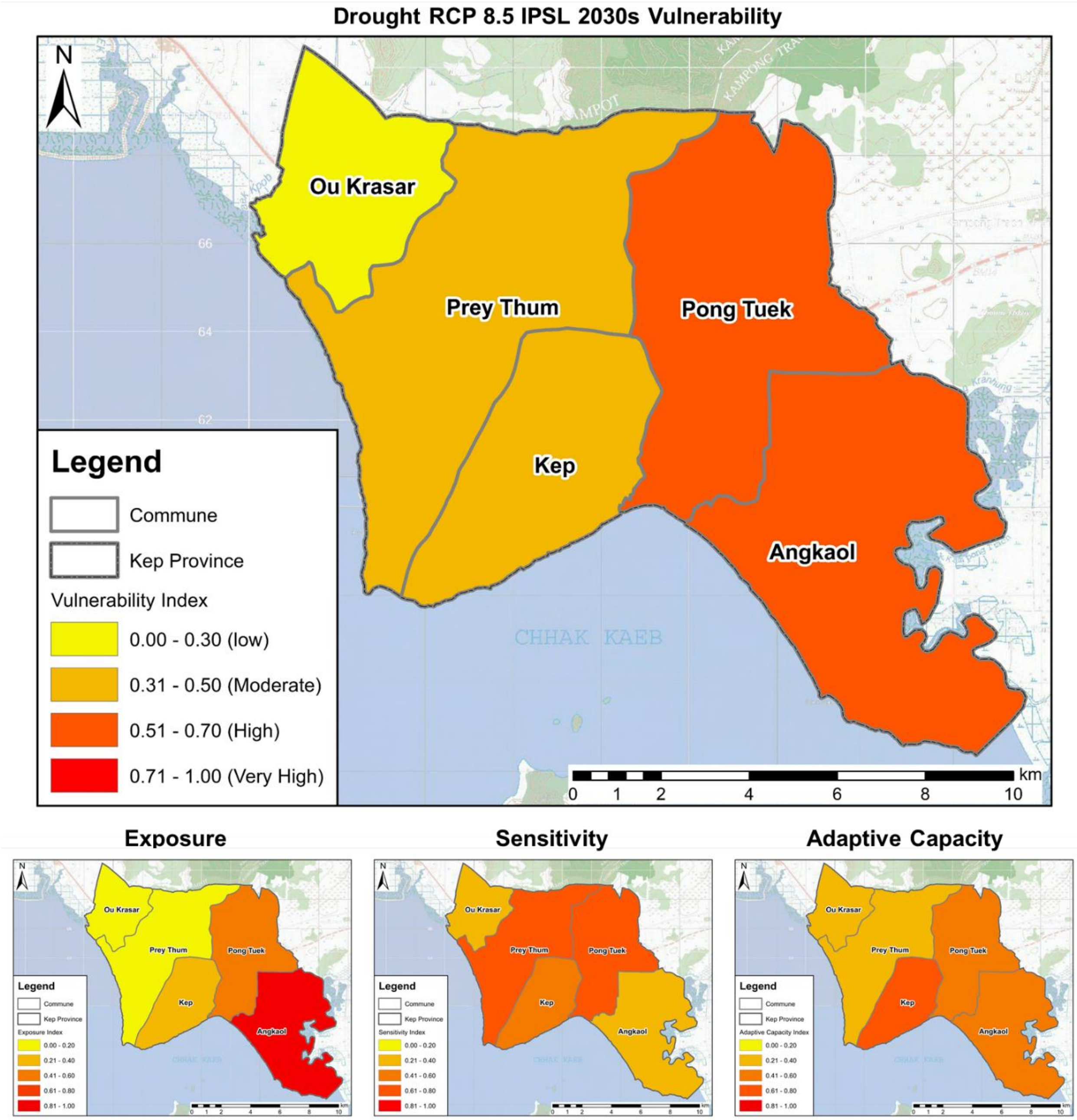
Drought vulnerability in Kep province: In the medium-term future, 2051–2070 (2060s), for IPSL model with Medium climate sensitivity (RCP 4.5)



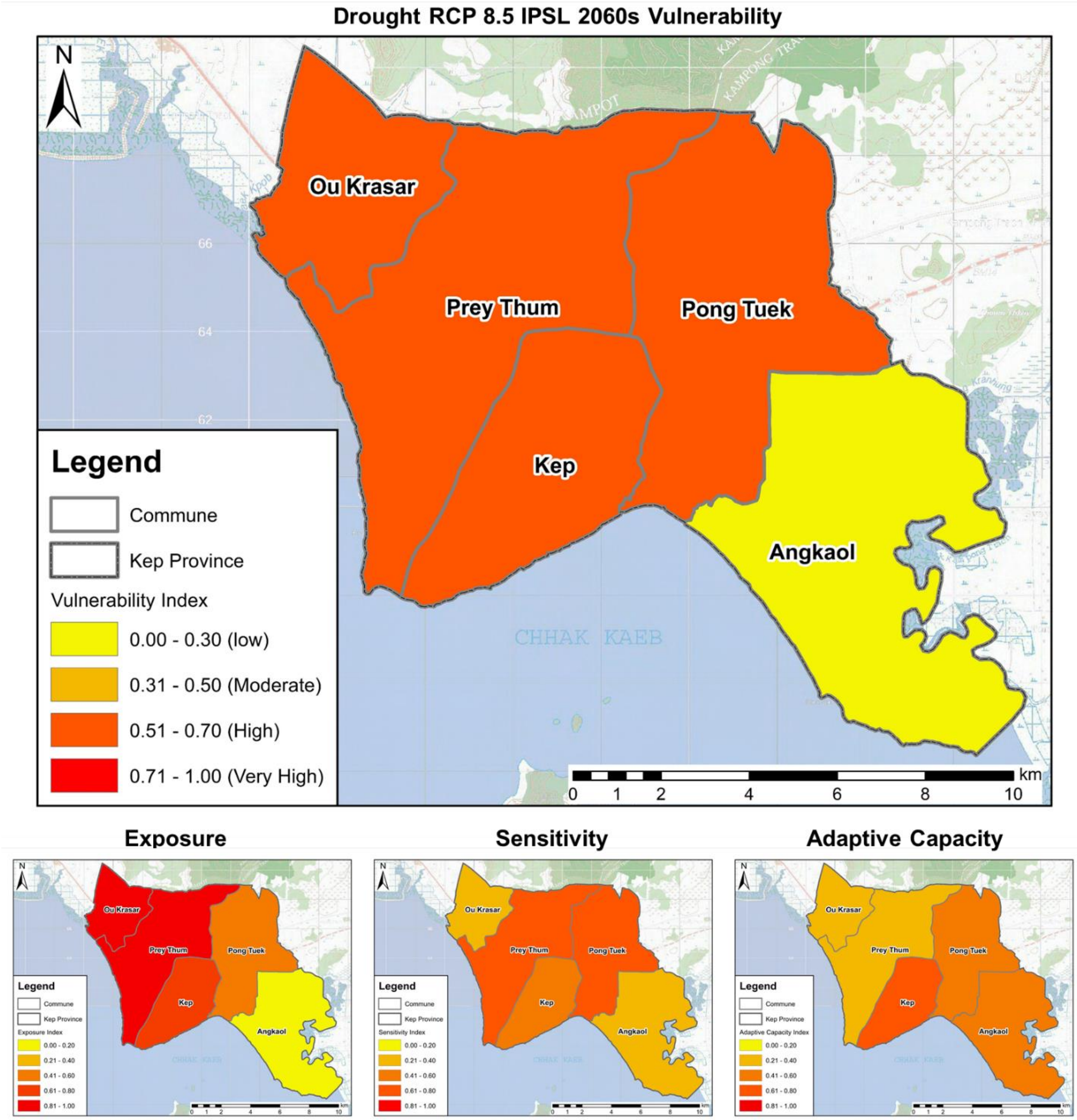
Drought vulnerability in Kep province: In the short-term future, 2021–2040 (2030s), for GFDL model with High climate sensitivity (RCP 8.5)



Drought vulnerability in Kep province: In the medium-term future, 2051–2070 (2060s), for GFDL model with High climate sensitivity (RCP 8.5)

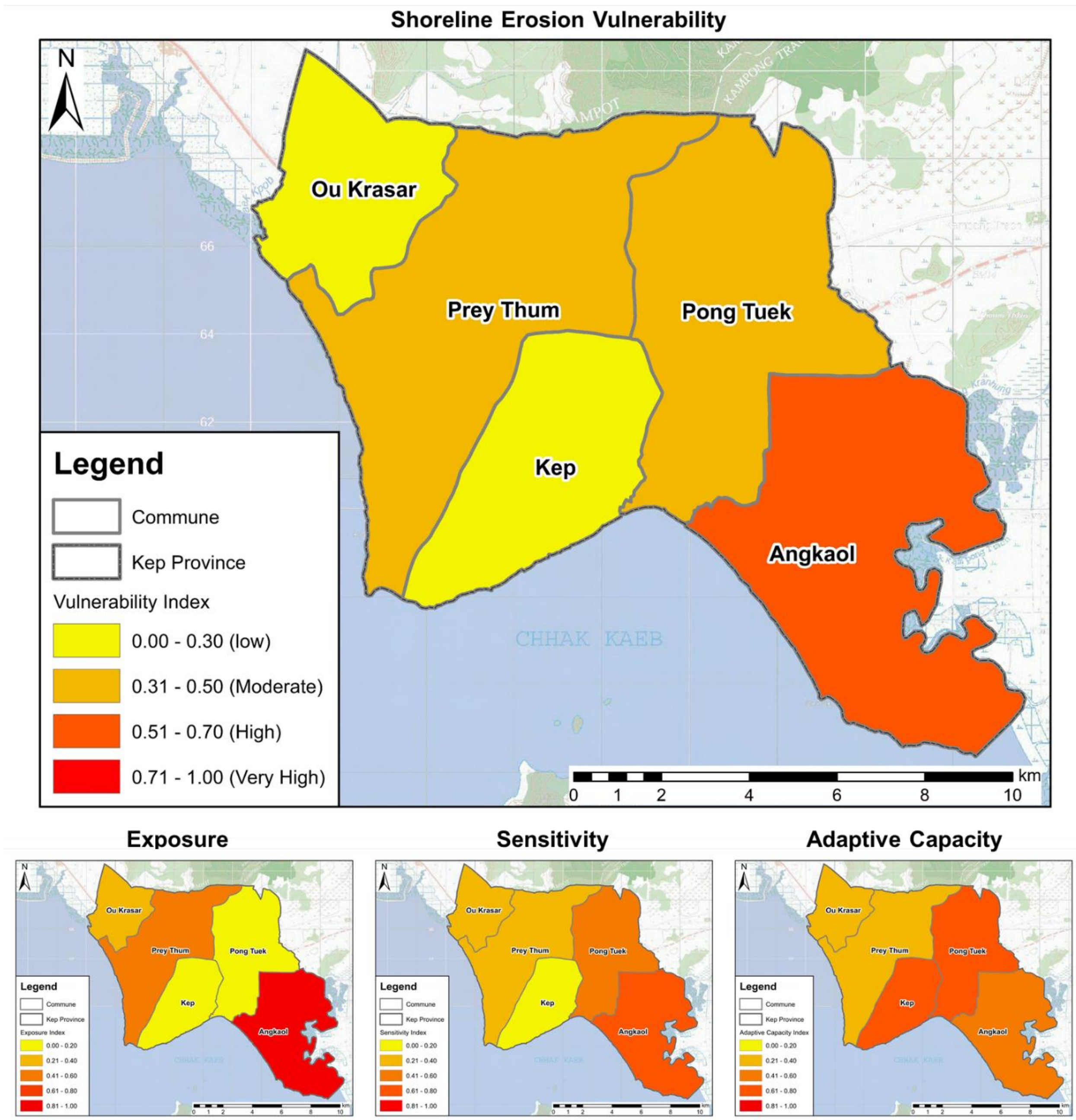


Drought vulnerability in Kep province: In the short-term future, 2021–2040 (2030s), for IPSL model with High climate sensitivity (RCP 8.5)



Drought vulnerability in Kep province: In the medium-term future, 2051–2070 (2060s), for IPSL model with High climate sensitivity (RCP 8.5)

Annex 3: Shoreline erosion vulnerability maps



Annex 4: Windstorm vulnerability maps