Report on climate risk assessment of Battambang Municipality (D3.3)

CLIMATE RISK ASSESSMENT FOR SUBNATIONAL ADAPTATION AND ESTABLISHMENT OF A LOCAL CLIMATE INFORMATION SYSTEM FOR CLIMATE CHANGE ADAPTATION (LISA)

April 2023

Prepared for: **United Nations and MoE**
Prepared by: **ICEM**

DISCLAIMER

This document was prepared for the World Bank by an ICEM consultant team engaged to undertake the UN-CTCN project – *Climate risk assessment for subnational adaptation and establishment of a local climate information system for climate change adaptation (LISA) in Cambodia.* The views, conclusions and recommendations in the document are not to be taken to represent the views of the UN-CTCN.

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Suggested Citation	ICEM. 2023. Climate risk assessment of Battambang municipality. Prepared for UN-CTCN as part of the project *Climate risk assessment for subnational adaptation and establishment of a local climate information system for climate change adaptation (LISA) in Cambodia*.
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1 INTRODUCTION

Disaster and climate risk assessments that consider relevant hazards and vulnerabilities, and underlying risk drivers, are essential to provide evidence-based information and analysis to formulate disaster risk reduction and climate change adaptation plans and investments that are efficient and effective in reducing risk.[1] As part of the first priority for action, the Sendai Framework for Disaster Risk Reduction explicitly calls for systematic risk assessments to inform strategies and plans across all sectors: '*policies and practices for disaster risk management should be based on an understanding of disaster risk in all its dimensions of vulnerability, capacity, exposure of persons and assets, hazard characteristics and the environment'*.[2]

Disaster risk assessments are done through a standard overall process of risk identification, risk analysis and risk evaluation, which is customized depending on the specific focus or scale of the risk assessment.[3] Risk visualization refers to the presentation of risk information (on hazard, exposure and vulnerability) in various easy and user-friendly formats such as maps, diagrams, risk matrices, tables, online interactive platforms, infographics etc. with the aim to communicate and disseminate the risk information for use in planning, prioritization and decision-making on adaptation.

This *Climate Risk Assessment of Battambang Municipality* provides a socio-economic, hazard, climate change, impact and vulnerability profile for the city. The data and analysis of the report will be integrated into an online platform which will serve as a decision-support tool to facilitate hotspot identification and prioritization of investments in risk reduction, adaptation and resilience through the following questions:

- What are the key hazards for Battambang municipality that may cause major damage and losses to people, infrastructure and other urban assets?
- What do the climate change projections indicate for Battambang in terms of changes in precipitation and temperature?
- What assets including communities, critical infrastructure and other facilities are most likely to be exposed to and affected by these hazards? Where are they located?
- Where in the city are these hazards having the largest impact on a significant amount or size of the assets, meaning what are the exposure *hotspots* for each of these hazards?
- What capacities, within communities and institutions, exist to cope with these hazards or adapt to projected climate changes?
- Which assets are the most vulnerable to hazards and climate change and where are these located in Battambang municipality? Which hazards, assets and areas should be prioritized for risk reduction and adaptation?

This report is a deliverable under Output 3 of the *Technical Assistance (TA) on Climate risk assessment for subnational adaptation and establishment of a local climate information system for climate change adaptation (LISA) in Cambodia*. The TA is funded by the United Nations Climate Technology Centre and Network (UN-CTCN) and aims to design a web-based local climate information system, which can support adaptation planning and decision-making processes, and provide services for climate information delivery at the sub-national (local) level.

[1] UNDRR, 2017. *Words into Action: National Disaster Risk Assessment. Governance System, Methodologies and Use of Results.* Geneva, Switzerland.

[2] United Nations, General Assembly. 23 June 2015. *Sendai Framework for Disaster Risk Reduction 2015–2030*. A/RES/69/283.

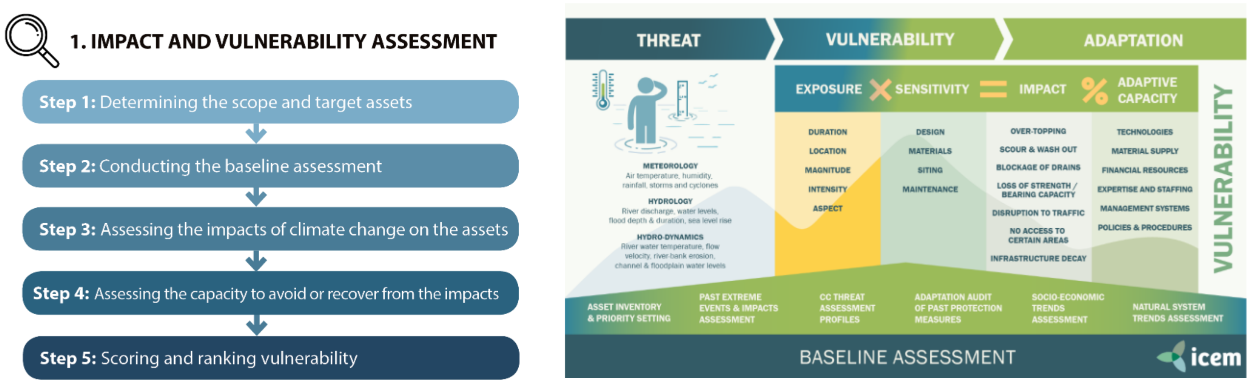
[3] ISO. 2009. *Risk management – Risk assessment techniques. International standard ISO31010.* International Organization for Standardization. Geneva, Switzerland.

2 METHODOLOGY

ICEM's *Climate Change Adaptation and Mitigation Methodology* (CAM) has been used to perform the risk assessment for Battambang municipality.[4] The CAM is a framework and tool for the analysis of climate and other natural hazard threats and impacts (phase 1), adaptation and mitigation planning (phase 2) and implementation and feedback (phase 3). ICEM has developed CAM specifically for the Asia Pacific Region and has extensively tested and refined this flexible and integrative method in other climate and disaster risk management projects in the region, in rural and urban contexts, for transboundary river basins, various critical infrastructure assets and multiple ecosystems.

Phase 1 of the CAM (Figure 1), the impact and vulnerability assessment, has been adapted and applied for the project's risk assessment.

Figure 1: Impact and vulnerability assessment process and framework



2.1 Terminology

The CAM uses the following key terms and definitions:

- *Hazard and threat:* A hazard is an existing source of danger that may cause harm, damage or loss or poses a danger to a system vulnerable to the hazard. A hazard is different from a threat in that a threat is a potential future event, such as the threat of landslide posed by a combination of heavy rains and a steep, unstable slope.
- *Exposure*: A measure of the extent to which the asset is exposed to existing hazards or potential threats. Exposure in the context of climate change is limited to potential climate threats. The exposure may depend upon the relevance of the threat (e.g., increase in temperature) to the type of asset and the extent to which the threat will increase (e.g., in intensity and frequency).
- *Sensitivity*: Sensitivity is the degree to which a system is affected, either adversely or beneficially, by climate variability or change. 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., damage caused by more frequent flooding due to increased water flows and volumes in rivers during extreme flood events).
- *Impact*: The effects of climate change on natural and human systems or assets. Often, reference to impacts refers also to secondary and tertiary consequences.

[4] A comprehensive CAM guide is available in English and Khmer. The guide lays out a step-by-step process for assessing climate change impacts and vulnerabilities and for preparing and implementing adaptation plans. The guide includes templates and matrices that can be used to record data, create plans, and assist with prioritizing adaptation measures.

- *Adaptive capacity*: The ability to adjust to climate change (including climate variability and extremes), to moderate potential damage, to take advantage of opportunities or to cope with the consequences.
- *Vulnerability*: Vulnerability is the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change (i.e., threats and hazards), including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity and its adaptive capacity.

2.2 Impact and vulnerability assessment

The CAM process has been applied as follows:

Step 1 – Determine the scope and target assets. The scope of the risk assessment in terms of hazards and threats, geographical area and assets has been defined through a series of consultations with national and city-level stakeholders and based on data availability. The risk assessment primarily focuses on riverine (fluvial) and rainfall-induced (pluvial) flood, riverbank erosion and drought, and the following assets in Battambang municipality: people, transport network, built-up area, and schools and health facilities. Other important hazards such as fire and heat waves are not included due to data unavailability.

Step 2 – Conducting a baseline assessment. An extensive socio-economic baseline assessment for Battambang municipality has been conducted based on review of official records and available literature, and information gathered from multi-stakeholder consultations.

Step 3 to 5 – Assessing impact, capacity and vulnerability. Data derived from available models, census and participatory mapping has been used to determine exposure, sensitivity and adaptive capacity of the selected assets. Each of these aspects of impact and vulnerability were reclassified into five classes (very low to very high) using a quintile analysis. To score impact and vulnerability, the following CAM matrices have been applied (Figure 2):

Figure 2: Matrices for scoring impact and vulnerability

Sensitivity of the asset	Exposure to hazard or threat: Very low	Low	Medium	High	Very high
Very high	Medium	Medium	High	Very high	Very high
High	Low	Medium	Medium	High	Very high
Medium	Low	Medium	Medium	High	Very high
Low	Low	Low	Medium	Medium	High
Very low	Very low	Low	Low	Medium	High

Adaptive capacity of the asset	**Impact** (exposure*sensitivity): Very low	Low	Medium	High	Very high
Very high	Medium	Medium	High	Very high	Very high
High	Low	Medium	Medium	High	Very high
Medium	Low	Medium	Medium	High	Very high
Low	Low	Low	Medium	Medium	High
Very low	Very low	Low	Low	Medium	High

The flood model used for the risk assessment was provided by the NGO People In Need (PIN) Cambodia, who performed pluvial flood modelling as part of the project '*Strengthening Climate Information and Early Warning Systems in Cambodia to Support Climate Resilient Development and Adaptation to Climate Change'*, implemented from August 2020 to January 2022 and funded by the Cambodia Climate Change Alliance (CCCA).[5] The data collection process consisted of four main activities: i) identification of

[5] PIN, NCDM. 2021. *Flood Mitigation Recommendations Report.* People in Need and the National Committee for Disaster Management, Phnom Penh, Cambodia.

benchmark; ii) road and topographic survey; iii) aerial survey of 3600 ha and cross section of the Sangker river; and iv) historical flood level survey. The data was used to develop an urban elevation profile, digital elevation model, digital surface model and digital terrain model. HECRAS software was used for producing the 2D flood model.

2.3 Limitations

Risk assessment is a process that does not result in a fixed final answer, but rather is a starting point and tool which delivers results to support decision-making. A risk assessment necessitates further detailed quantitative and qualitative analysis, particularly when performed over a short time and as more data becomes available. It also has a number of built-in limitations.

The risk assessment carried out for this project is based on available data and for Battambang there is only limited data available. For example, the only hazard model available was for flood, with the model only covering the center of the municipality (nine communes). For climate change, there was no downscaled information available, resulting in a limited number of values for the entire city and not allowing a deeper analysis, for example per village or specific hotspots in the municipality. In terms of sensitivity and capacity, the census data was only useful for measuring sensitivity and capacity of entire villages, with no information available for transport infrastructure, houses and critical facilities. For those assets, the analysis is limited to exposure analysis.

In addition to natural hazards and climate change, other biophysical pressures such as changing land use, infrastructure development, environmental degradation and anthropogenic influences should also be considered with additional study and integrated into a comprehensive qualitative assessment.

The risk assessment is largely a desk-based analysis, with limited and therefore incomplete field verification due to insufficient time and resources. It is recommended to perform more detailed CAM assessments for specific assets of importance for urban development in Battambang, using the risk assessment results as a starting point.

3 SOCIO-ECONOMIC BASELINE PROFILE

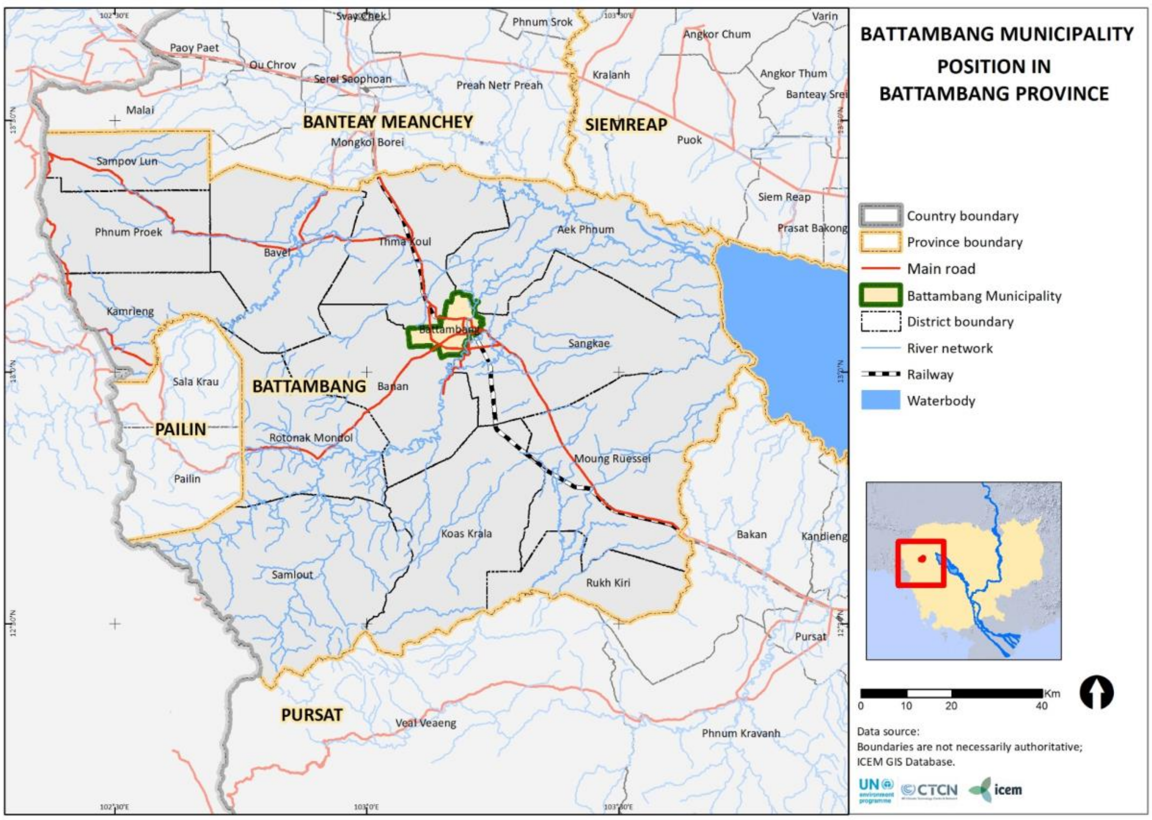
3.1 Overview

3.1.1 Administrative

Battambang province is situated in the northwest part of Cambodia, about 300 km from Phnom Penh via national road No 5. The province borders on Beanteay Meanchey and Siem Reap provinces in the north, and Pursat province in the south (Figure 3). The western boundary is formed by Pailin province and the border with Thailand. At its eastern tip, the province is connected to the Tonle Sap Lake.

The province covers an area of about 11,803 km^2, comprising 13 districts, Battambang municipality, 96 communes, and 741 villages.[6]

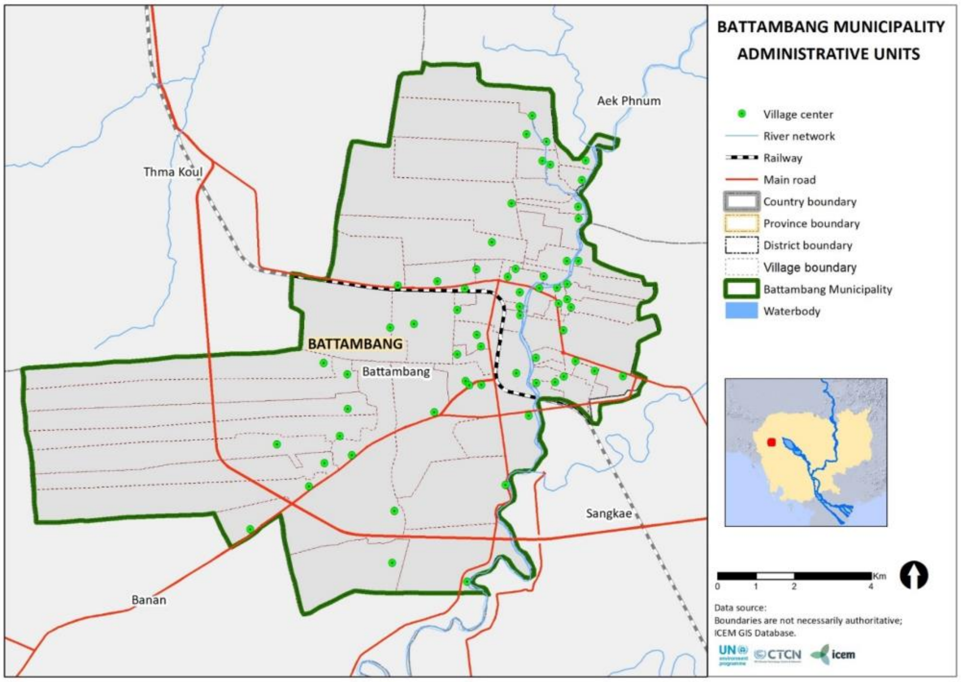
Figure 3: Battambang province, with the location of Battambang municipality



Battambang municipality, located in the center of the province and covering an area of 116km^2, is the second largest city of Cambodia, after Phnom Penh. **It consists of 10 communes (*sangkat*) with 62 villages** (Figure 4). Three of these are classified as rural (Kdol Doun Teav, O Mal, and Wat Kor), while seven are classified as urban (Prek Preah Sdech, Svay Por, Toul Ta Ek, Rattanak, O Char, Chamar Smrong, and Slaket).

[6] Try T. et al. 2015. *Situation Analysis and Needs Assessment Report for Rohal Soung Village and Battambang Province, Cambodia*. CGIAR Research Program on Climate Change, Agriculture and Food Security, Copenhagen, Denmark.

Figure 4: Battambang municipality: village boundaries and location of village centres



3.1.2 Population

Battambang municipality has a population of 164,823 people and 31,458 households (2019), mostly living in the central and eastern parts of the city (Figure 5 to Figure 8). The total female population in Battambang municipality is 83,806 (50.8% of the total population) (Figure 9), there are 23,811 girls (younger than 15 years) (Figure 10) and 5,345 female headed households (17% of the total households). Out of a total of 11,923 farmers, there are 5,054 women (42.4%). The population per village, with disaggregation for gender, is shown in Table 1 (per the 2019 census).

Table 1: Battambang population per village, with disaggregation for gender (2019)

Commune	Village	Households		Population				Farmers
		All	Female headed	Male	Female	Total	Girls	Women
Tuol Ta Aek	Ou Ta Kam Muoy	1,021	119	2,140	2,311	4,451	602	9
	Ou Ta Kam Pir	1,224	175	2,676	2,912	5,588	711	13
	Ou Ta Kam Bei	302	76	736	752	1,488	190	0
	Tuol Ta Aek	1,204	204	2,911	3,124	6,035	798	0
	Dangkao Teab	395	98	1,059	1,013	2,072	245	12
Preaek Preah Sdach	Preaek Preah Sdach	292	23	612	739	1,351	179	0
	Preaek Ta Tan	236	51	506	589	1,095	180	0
	Dabbei Meakkakra	783	156	1,882	2,118	4,000	446	0
	Ou Khcheay	326	82	985	1,028	2,013	382	0
	La Edth	260	63	727	742	1,469	188	0
	Num Krieb	172	69	769	769	1,538	238	0
	Baek Chan Thmei	311	38	733	869	1,602	285	0
	Chamkar Ruessei	346	18	929	902	1,831	322	0
Rotanak	Rumchek Muoy	470	70	1,455	1,481	2,936	391	0

Commune	Village	Households		Population				Farmers
		All	Female headed	Male	Female	Total	Girls	Women
	Rumchek Pir	182	50	625	598	1,223	229	0
	Rumchek Bei	308	37	627	708	1,335	289	32
	Rumchek Buon	941	182	1,575	1,605	3,180	531	30
	Rumchek Pram	181	40	629	613	1,242	218	0
	Souphi Muoy	265	35	733	707	1,440	245	9
	Souphi Pir	362	62	816	751	1,567	163	19
	Rotanak	450	45	1,191	1,342	2,533	528	0
Chamkar Samraong	Chamkar Samraong Muoy	1,115	156	3,017	2,969	5,986	747	258
	Chamkar Samraong Pir	1,117	110	2,434	2,584	5,018	463	165
	Voat Lieb	861	225	2,203	2,264	4,467	398	0
	Voat Rumduol	560	225	1,602	1,591	3,193	401	99
	Phka Sla	355	35	1,113	1,061	2,174	181	10
Sla Kaet	Sla Kaet	377	95	823	828	1,651	291	5
	Dam Spey	767	67	2,227	2,305	4,532	900	34
	Chrey Kaong	578	197	1,508	1,518	3,026	303	10
Kdol Doun Teav	Chong Preaek	299	58	631	712	1,343	219	98
	Kdol	347	57	665	705	1,370	165	0
	Ou Ta Nob	378	63	775	772	1,547	174	0
	Ta Pruoch	386	12	1,022	1,025	2,047	381	47
	Ta Koy	301	65	574	625	1,199	157	3
	Kantuot	293	65	620	763	1,383	210	2
	Thkov	344	81	781	820	1,601	165	19
OMal	OMal	209	43	489	444	933	111	52
	Dak Sasar	239	36	670	658	1,328	199	9
	Sala Balat	330	57	621	651	1,272	174	129
	Prey Dach	265	46	542	542	1,084	137	225
	Kouk Ponley	301	64	564	624	1,188	221	126
	Voat Roka	355	35	818	678	1,496	164	235
	Koun Sek	178	13	353	347	700	99	60
	Andoung Pring	387	86	772	751	1,523	249	74
	Boeng Reang	492	75	883	937	1,820	213	132
	Prey Roka	209	54	391	420	811	98	133
wat Kor	Wat Kor	902	152	1,971	2,050	4,021	366	583
	Chrab Krasang	865	160	1,930	2,005	3,935	295	677
	Ballang	478	80	1,207	1,553	2,760	509	344
	Khsach Pouy	562	142	1,268	1,404	2,672	344	605
	Damnak Luong	597	53	1,389	1,639	3,028	468	143
	Kampong Seima	445	41	1,307	1,415	2,722	479	329
Ou Char	Ou Char	660	151	2,237	2,469	4,706	490	20
	Prey Koun Sek	289	44	708	606	1,314	113	234
	Kab Kou Thmei	607	126	2,429	2,660	5,089	677	26

Commune	Village	Households		Population			Farmers	
		All	Female headed	Male	Female	Total	Girls	Women
	Andoung Chenh	453	60	1,221	1,074	2,295	152	20
	Anhchanh	478	96	1,349	1,489	2,838	396	5
	Ang	526	130	1,651	1,668	3,319	678	19
Svay Pao	Preaek Moha Tep	1,211	103	3,940	3,808	7,748	1,705	0
	Kampong Krabei	568	145	1,904	1,927	3,831	1,039	0
	Mphey Osakphea	568	51	2,262	2,131	4,393	804	0
	Kammeakkar	1,175	98	3,830	3,641	7,471	1,116	0
	TOTAL:	**31,458**	**5,345**	**81,017**	**83,806**	**164,823**	**23,811**	**5,054**

Figure 5: Population density within Battambang municipality (2020)

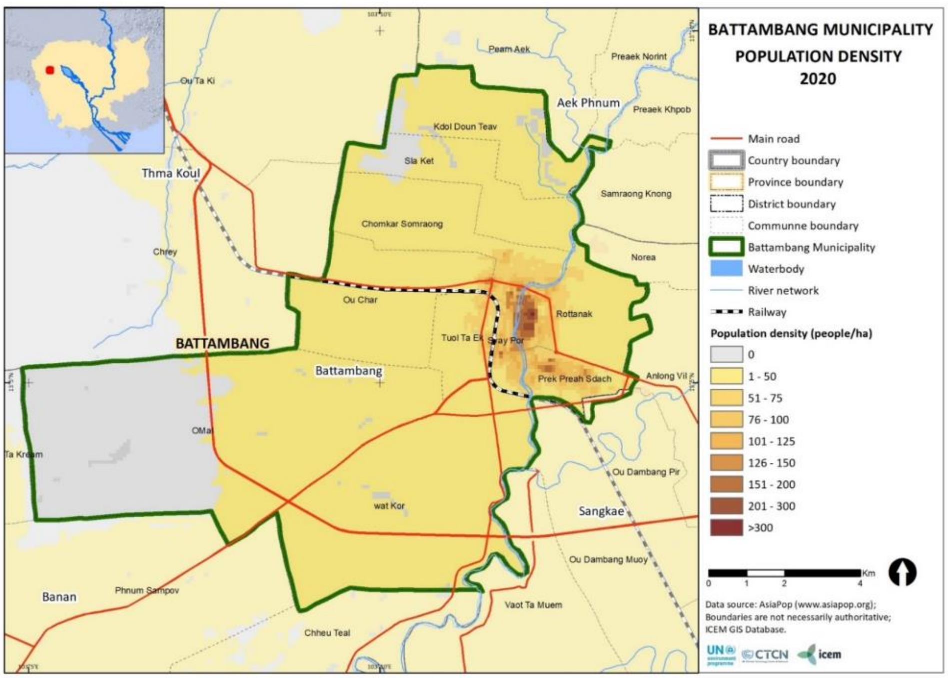


Figure 6: Population density within the central area of Battambang municipality (2020)

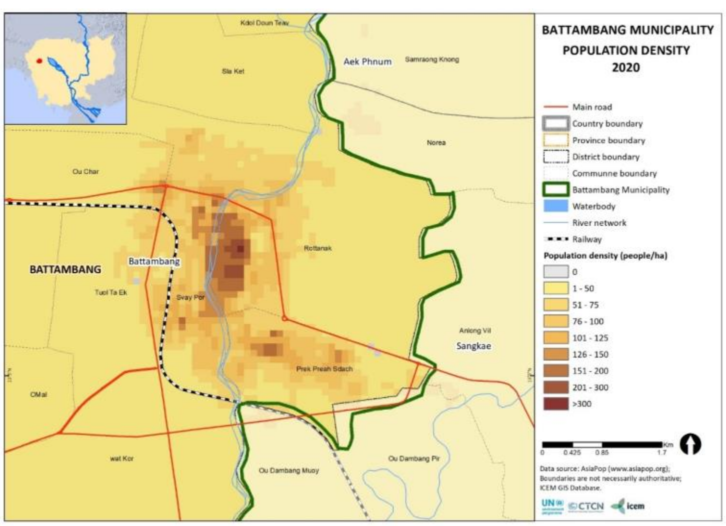


Figure 7: Battambang municipality: population per district (2019)

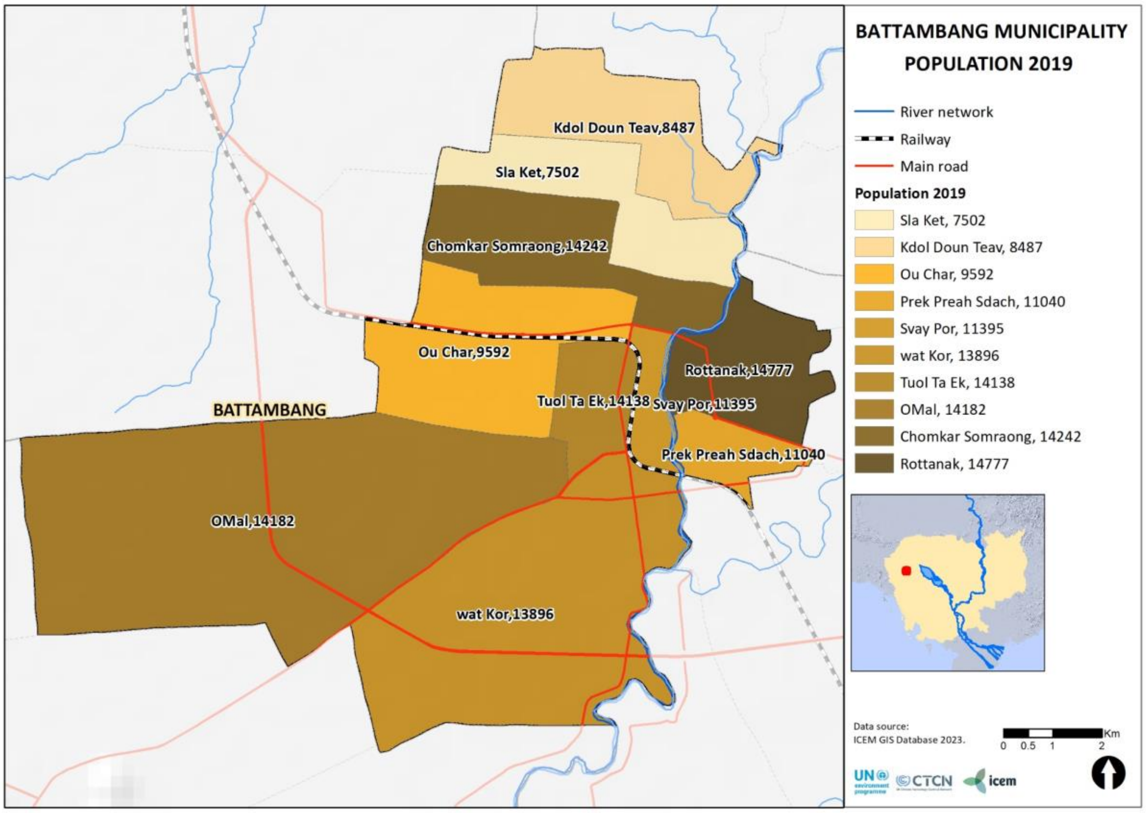


Figure 8: Battambang municipality: population per village (2019)

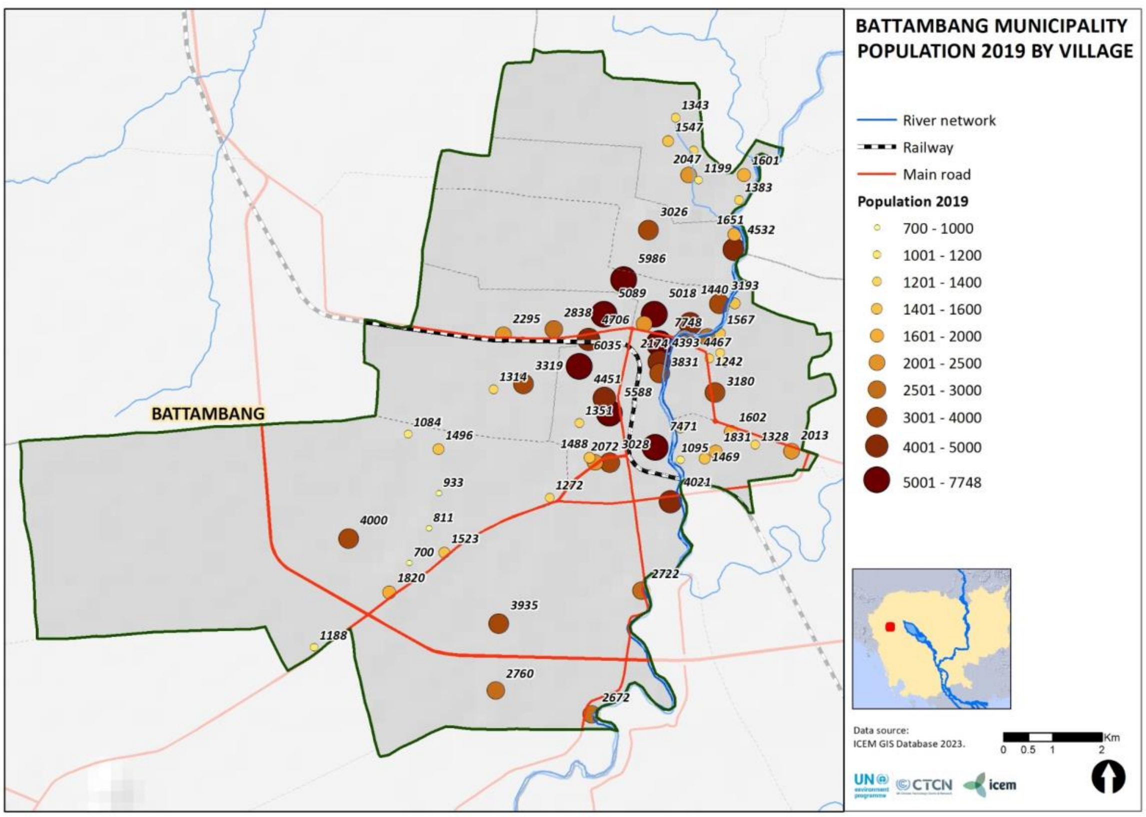


Figure 9: Battambang municipality: female population per village (2019)

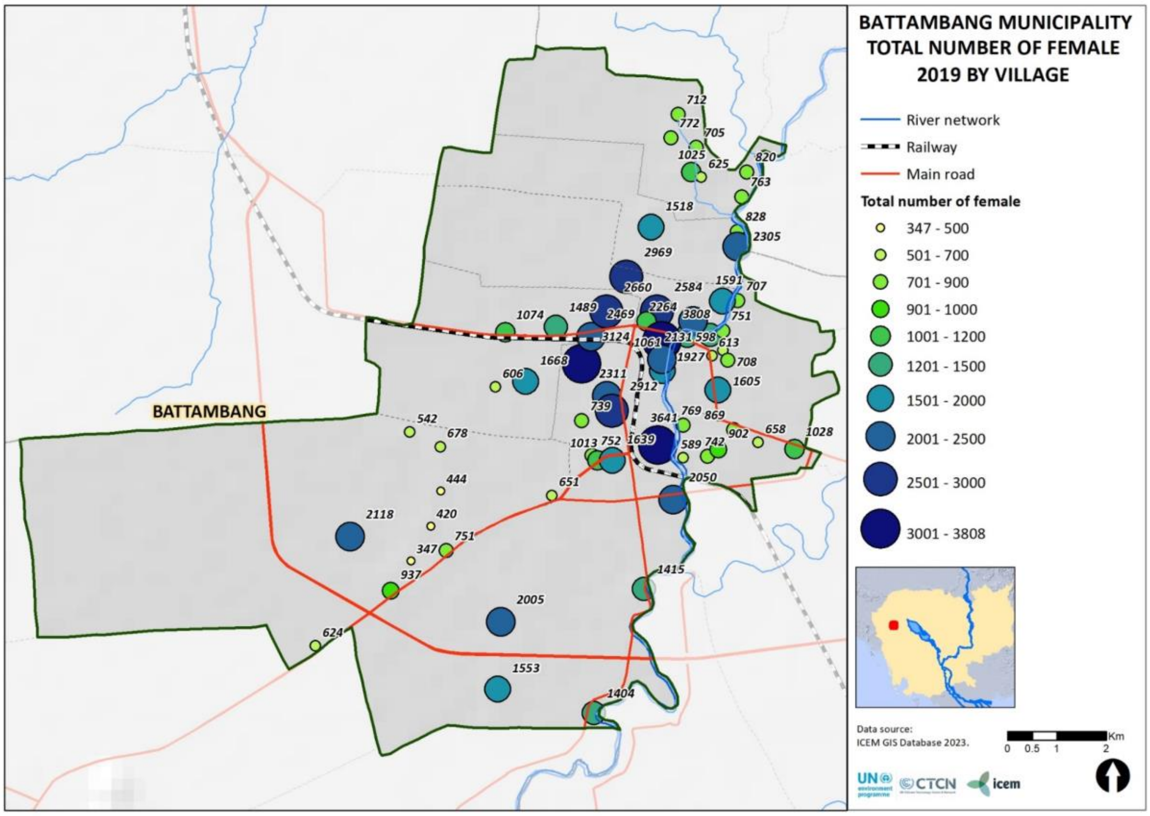
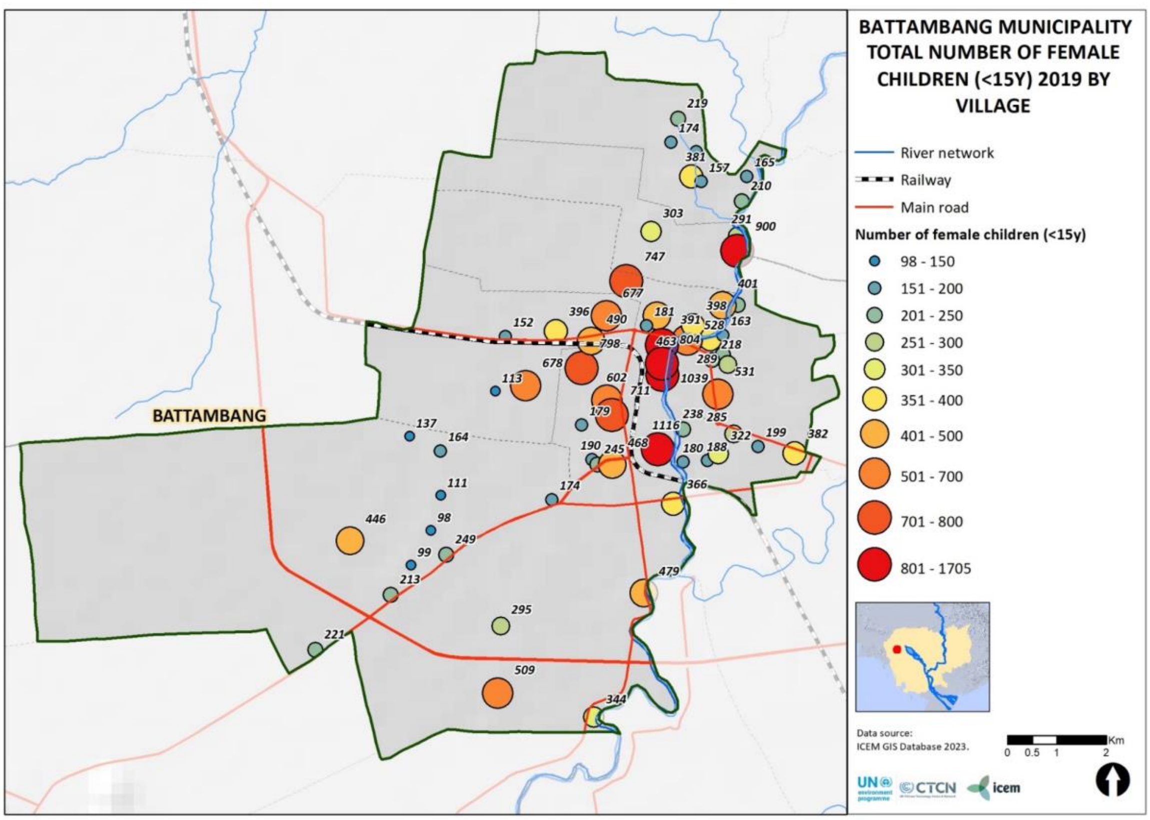


Figure 10: Battambang municipality: girls per village (2019)



3.1.3 Urban development

The economic vision for Battambang, according to the Battambang Land Use Master Plan (2008-2020), is to become the regional economic center for trade and investments for agro-industrial goods and services along the country's southern economic corridor.[7] As an economic hub of the northwest connecting to Phnom Penh and Thailand, **urbanization in the city has increased**. Battambang has seen a rapid growth over the recent decades, with the built-up area in the city expanding from approximately 1,500 hectares in 1990 to over 4,500 hectares in 2016 (Figure 11).[8] Urbanization in the city is at 3.28% per year[9] and its population is anticipated to grow by almost 70,000 people by 2030.[10]

Figure 11: Battambang municipality: urban areas

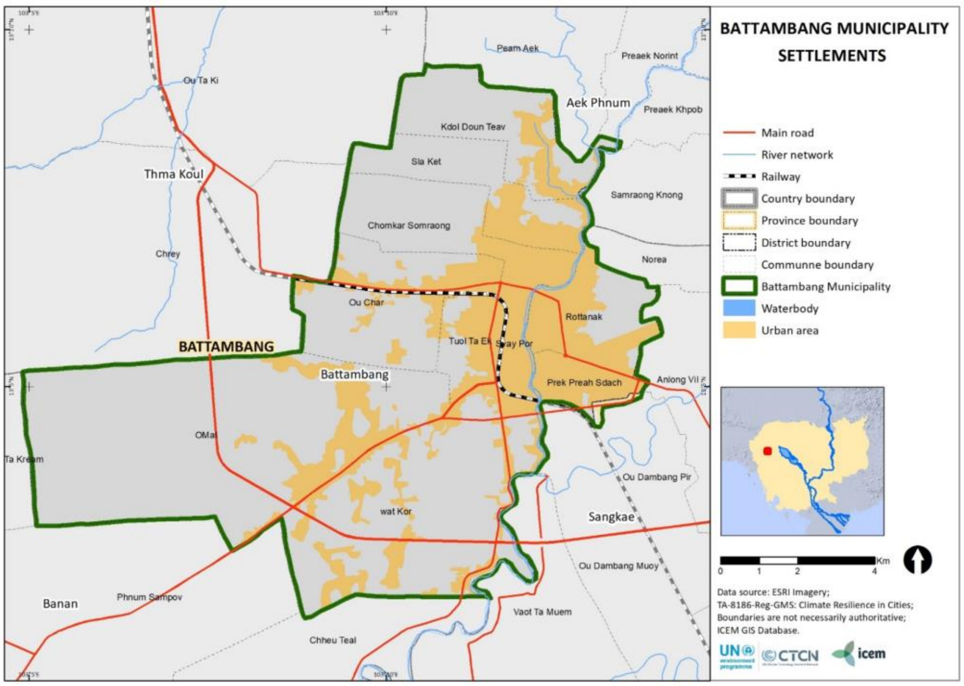
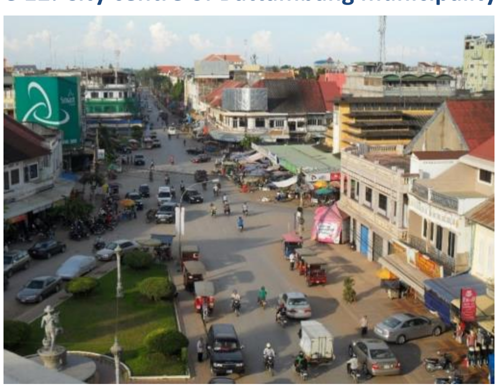


Figure 12: City centre of Battambang municipality



Source: Wikimedia Commons

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[7] Try T., Ibid.

[8] Ministry of Land Management, Urban Planning and Construction, 2016. *District & Municipal Land Use Master Plan and Land Use Plan Handbook*.

[9] The Urban Initiative. 2012. *Growing Pains: Urbanization and Informal Settlements in Cambodia's Secondary Cities.*

[10] UN ESCAP, UN Habitat. *Strategic Planning Workshop on Localizing the 2030 Agenda through Sustainable Urban Resource Management. Defining the Priority Area of Intervention*. Workshop Report. 24-25 June 2019, Battambang, Cambodia.

The municipality has a good transport network (Figure 12, Figure 13 and Figure 14), with the major roads traversing the city from east to west (National Road No. 5 connecting Sisophon, Poipet and Siem Reap) and east to south-west (National Road No. 57 connecting road No.5 to Battambang and Battambang to Pailin), one national railway line (from Phnom Penh to Sisophon) with a railway station in the city center, and several rural roads. The municipality also has an airport located in the east, but it is not used for commercial flights and only serves military purposes.

Figure 13: Battambang municipality: transportation network

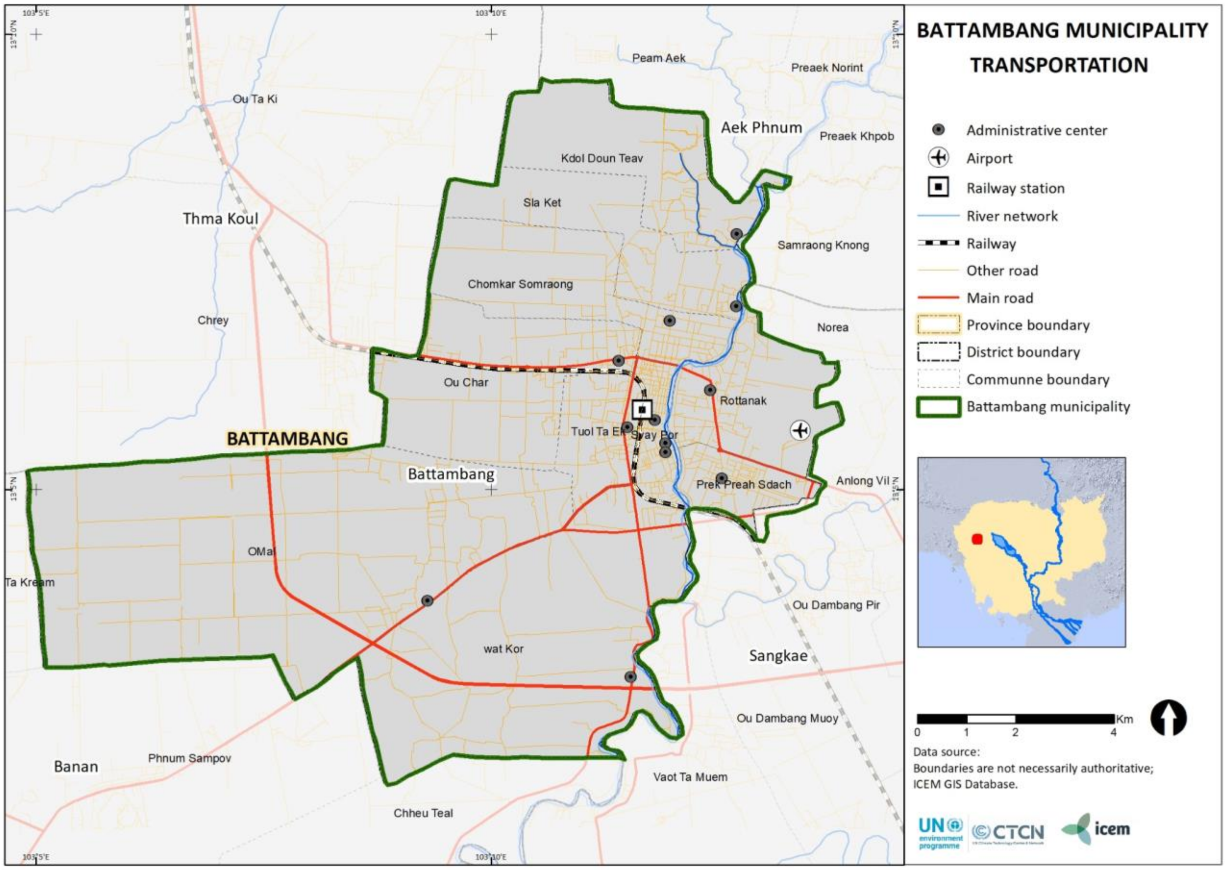


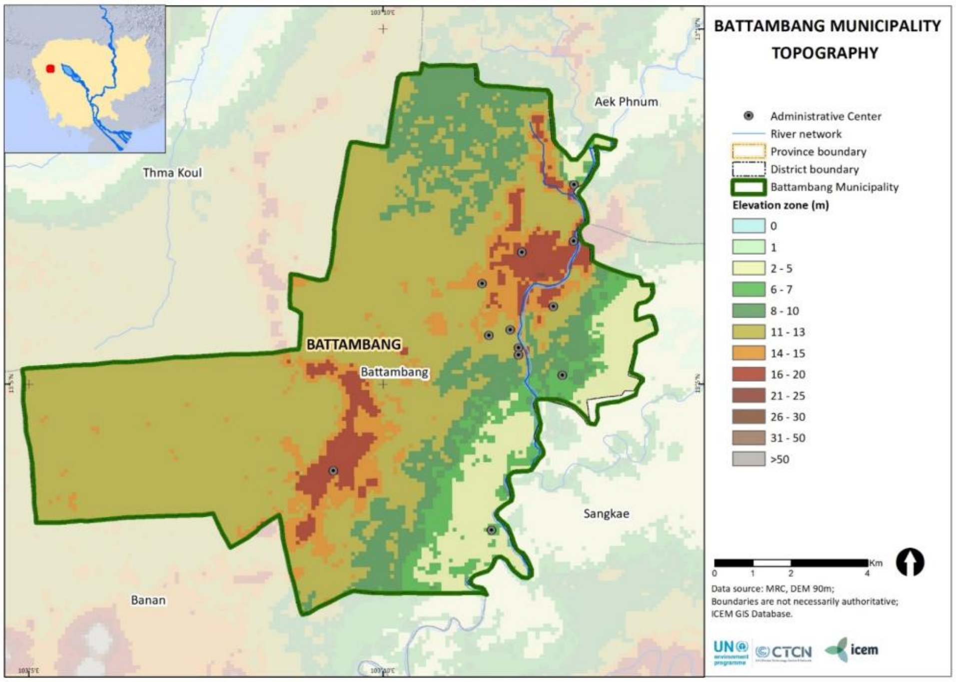
Figure 14: Battambang railway station and airport

Source: Wikimedia Commons / Khmer Times

3.1.4 Natural systems

Topography in **Battambang municipality is generally flat**, with the elevation in most parts being below 12 meter above sea level (Figure 15).

Figure 15: Battambang municipality: elevation zones



Battambang municipality is situated along the Sangkae/Sangker River (Figure 16). The river, around 250km long, originates in the Elephant and Cardamom Mountains at an elevation of 1,391m above mean sea level. It flows from south-west to north across Krong Battambang and joins the Stung Mongkol Borey river at Bac Prea village about 40 km downstream. It then flows a further 10km downstream before flowing into the Tonle Sap Lake. **Around 92% of Battambang municipality lies on the west bank of the Sangker river, including the main commercial and government establishments** (Figure 17).

Figure 16: Stung Sangker river basin

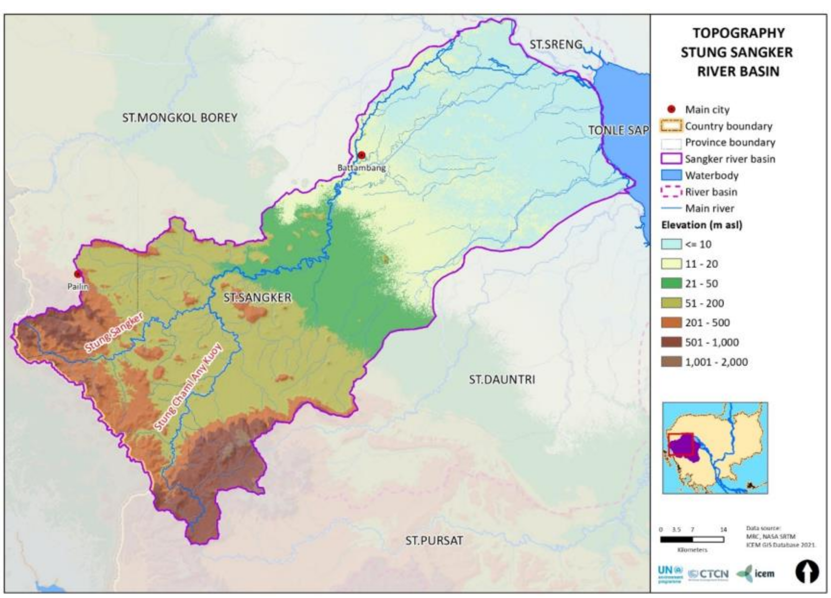
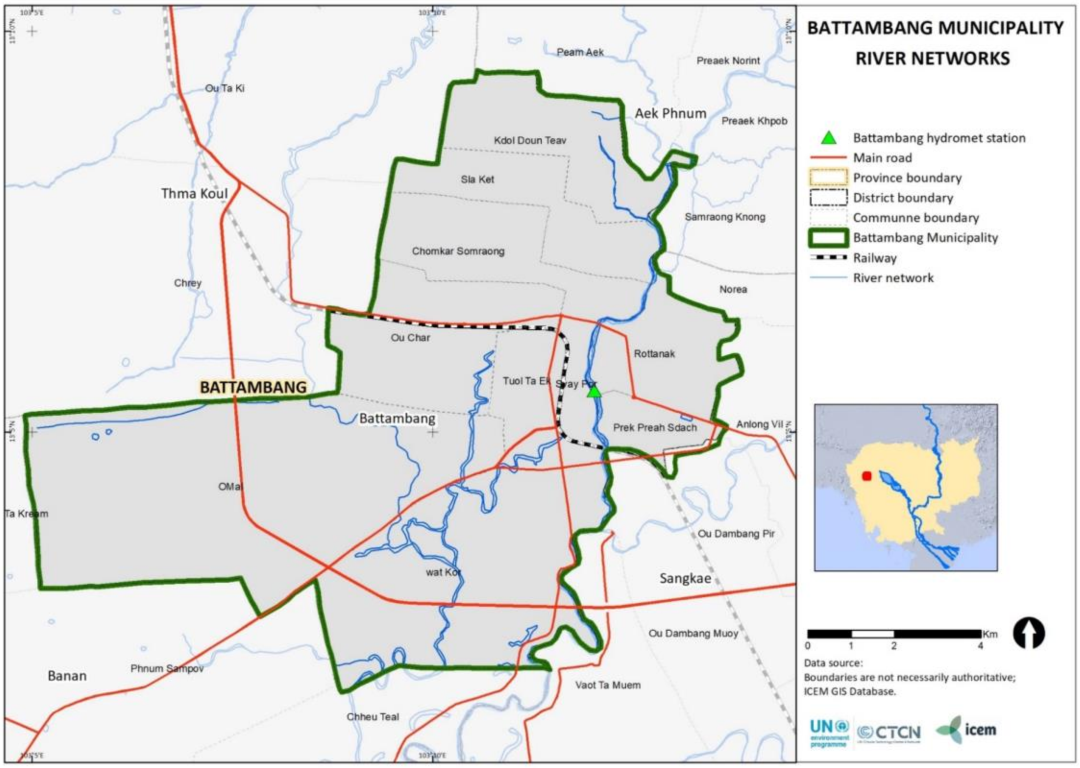
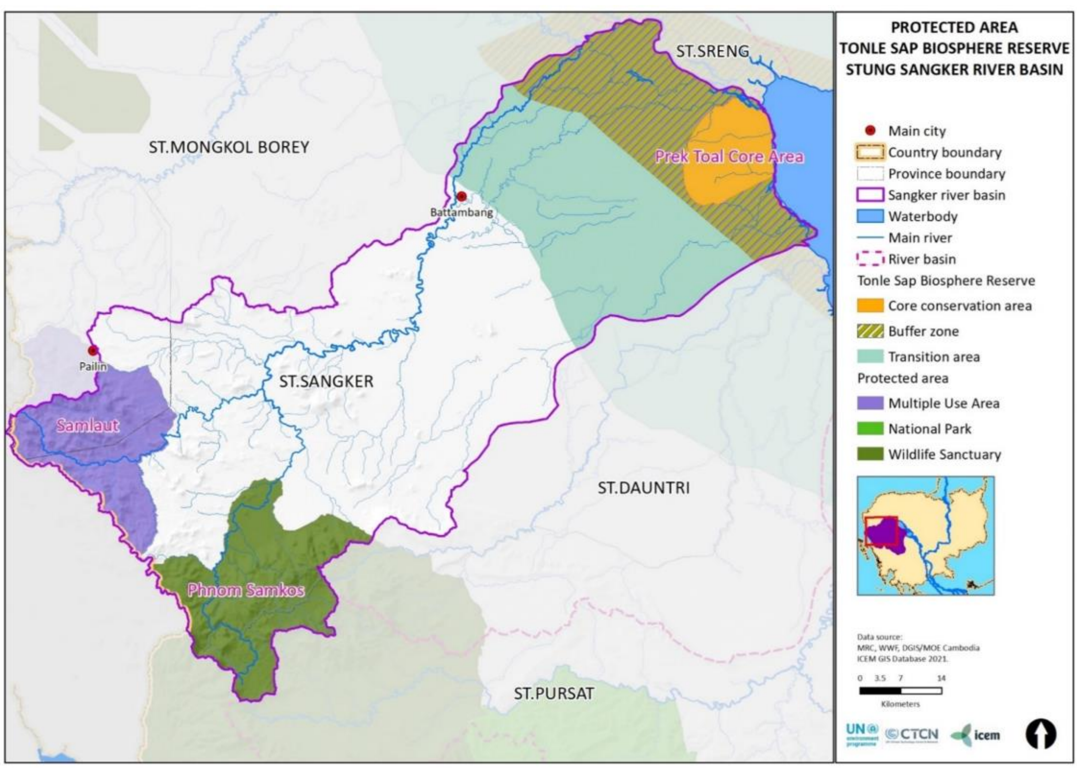


Figure 17: Battambang municipality: river network



While not in or near protected areas, to the north of Battambang lies the Tonle Sap Biosphere Reserve transition zone (Figure 18).

Figure 18: Protected areas in the Stung Sangker river basin and near Battambang



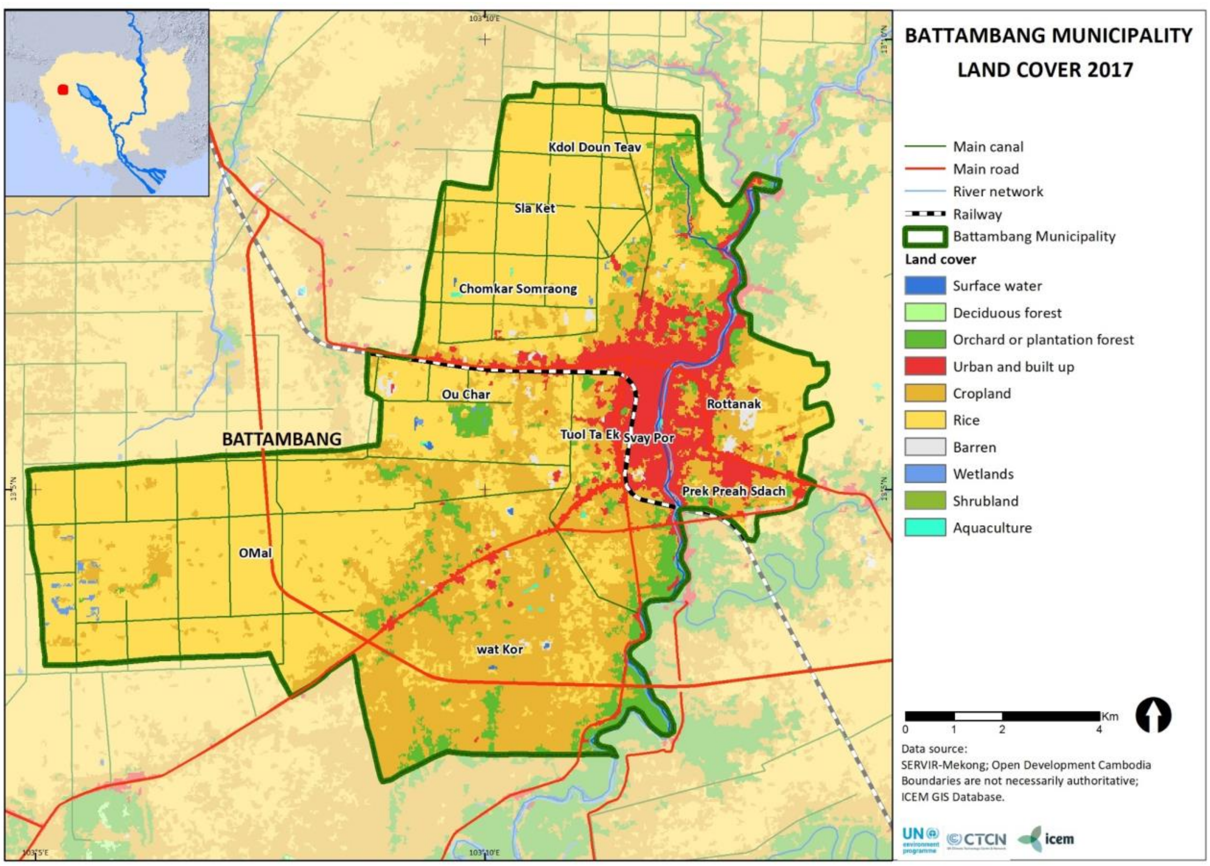
3.1.5 Land use

The major land use in Battambang municipality is agriculture, which occupies more than 74% or 8,558 hectares of the total land area of the city (Figure 19). The province and municipality have fertile land due to its location near the Tonle Sap Lake. Agriculture is predominantly rain-fed, with irrigation largely undeveloped despite the proximity of the Sangker river. Agriculture – wet-season rice, vegetable, livestock, and poultry farming – is the main economic activity in the province. **However, the sector provides only 7.3% of all employment, with 70.7% of employment in services** (including processing agricultural produce) and 1.9% in manufacturing.[11] Only 11,923 people or 7.2% of the total population are farmers, including 5,054 women, with most of the farmers living in Wat Kor (2,681), OMal (1,175), Chamkar Samraong (532) and Ou Char (324) communes.

The residential zone and residential-with-agricultural zone combined represent an area of more than 1,800 hectares or almost 16% of the total area; the main residential zone is concentrated in the city center, while the residential-with-agriculture zones are situated within the sub-urban areas along small to medium roads close to the city border limits and in the south-west.[12]

Forest is degrading across the entire Battambang province, with forest cover reduction in 2019 estimated at 20% over the previous 10 years.[13]

Figure 19: Land use within Battambang municipality (2017)



[11] World Bank. 2018. *Cambodia: Achieving the Potential of Urbanization*.
[12] Try T., Ibid.
[13] According to the Ministry of Environment, forest cover data in Battambang province was reduced by 20% for 10 years. Cambodia Climate Change Alliance, 2022. *Flood Mitigation Recommendations Report.*

The 2030 land use plan envisions a further expansion of the residential and commercial areas and a reduction of agricultural land (Figure 20 and Figure 21).

Figure 20: Land use plan for Battambang for 2030: overall municipality

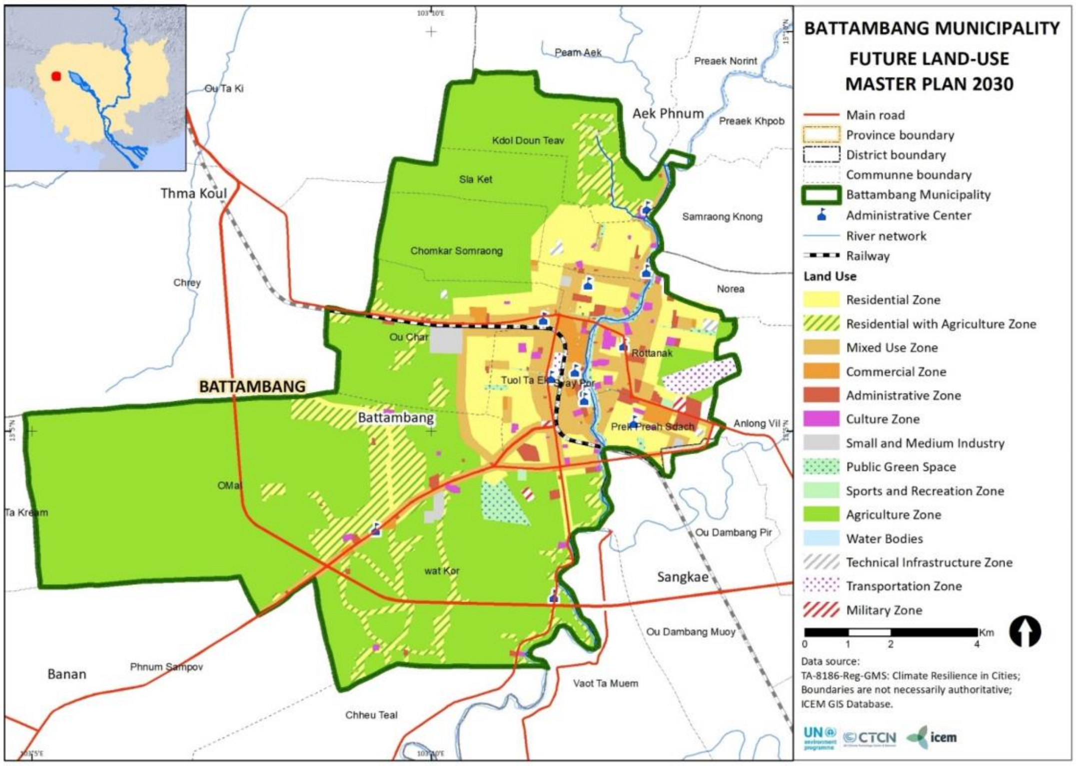
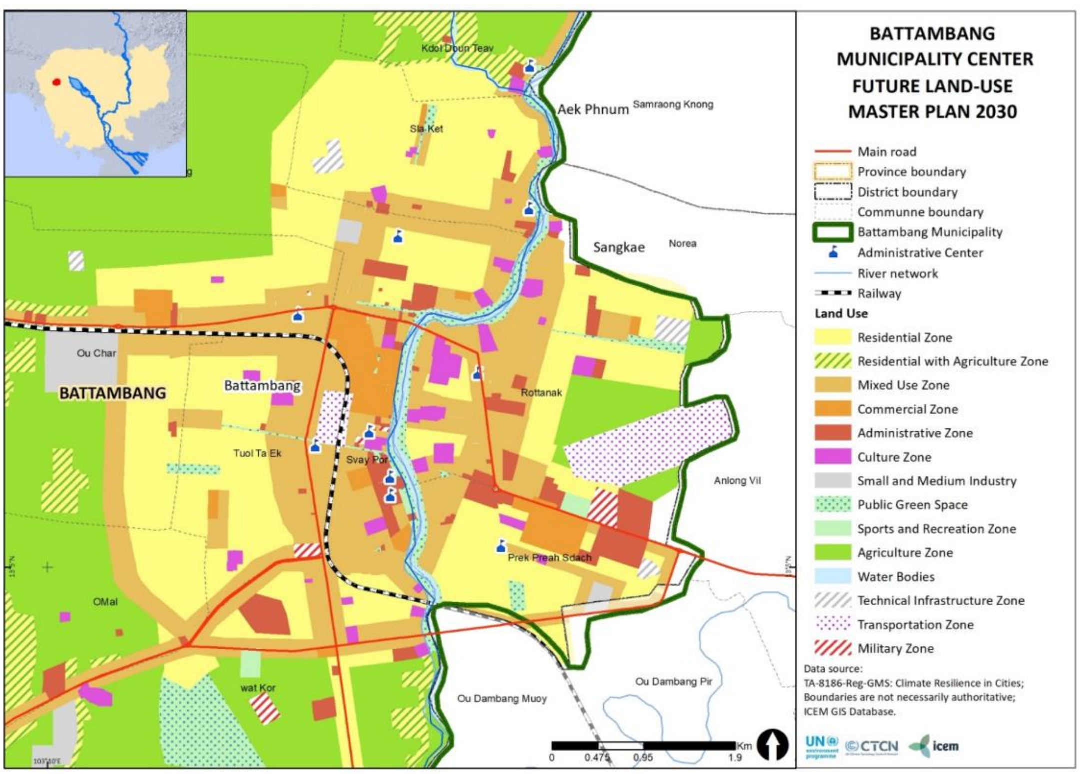


Figure 21: Land use plan for Battambang for 2030: centre of the city



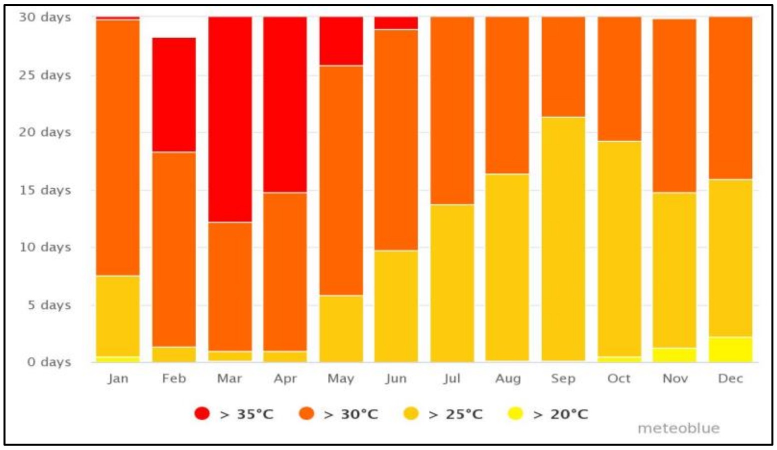
4 HAZARD AND CLIMATE CHANGE THREATS

4.1 Climate baseline

4.1.1 Temperature

The hot season in Battambang lasts for two months, from March to April, with an average daily high temperature above 34°C. The hottest month of the year in Battambang is April, with an average high of 35.5°C and low of 26°C. The cool season lasts for 6 months, from July to January, with an average daily high temperature below 31°C. The coolest month of the year in Battambang is December, with an average low of 21°C and high of 30°C. Figure 22 shows the maximum temperature in Battambang.[14]

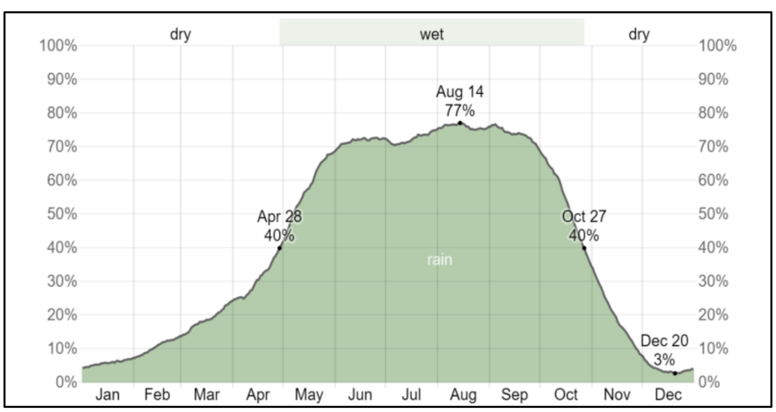
Figure 22: Maximum temperature in Battambang



4.1.2 Rainfall

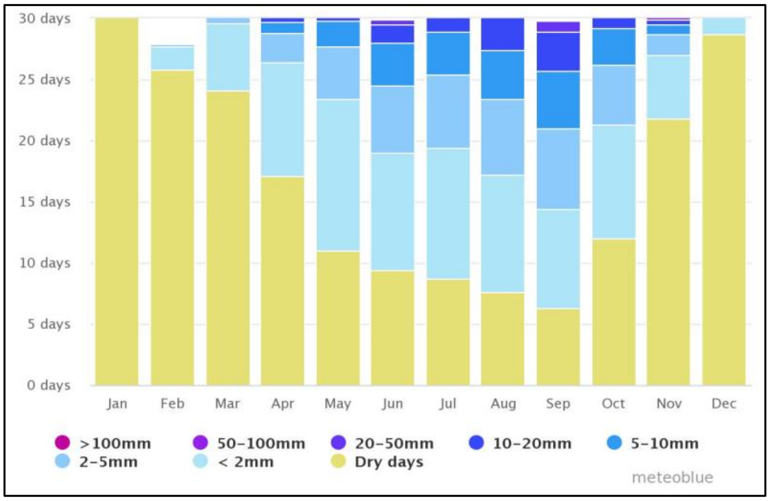
Annual rainfall at the Battambang municipality hydromet station is about 1,350 mm. Battambang experiences extreme seasonal variation in monthly rainfall (Figure 23 and Figure 24). **The wet season lasts six months, from May to October**, with a greater than 40% chance of a given day being a wet day. The month with the most wet days in Battambang is August, with an average of 23.5 days of precipitation. The dry season lasts 6 months, from November to April. The month with the fewest wet days in Battambang is December, with an average of 1.1 days of precipitation.[15]

Figure 23: Daily chance of precipitation in Battambang (source: weatherspark.com)



[14] The climate diagrams are based on 30 years of hourly weather model simulations. Source: www.meteoblue.com
[15] Source: www.weatherspark.com

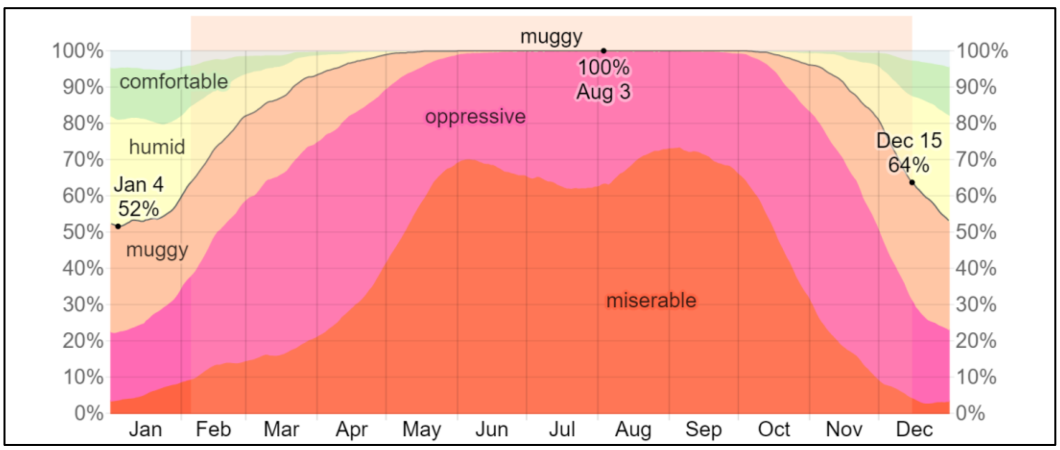
Figure 24: Rainfall in Battambang



4.1.3 Humidity

Humidity typically varies significantly between night and day. Lower dew points feel drier and higher dew points feel more humid. The muggier period of the year lasts for 10 months, from February to December, during which time the comfort level is muggy, oppressive, or miserable at least 64% of the time (Figure 25).[16]

Figure 25: Humidity comfort level in Battambang

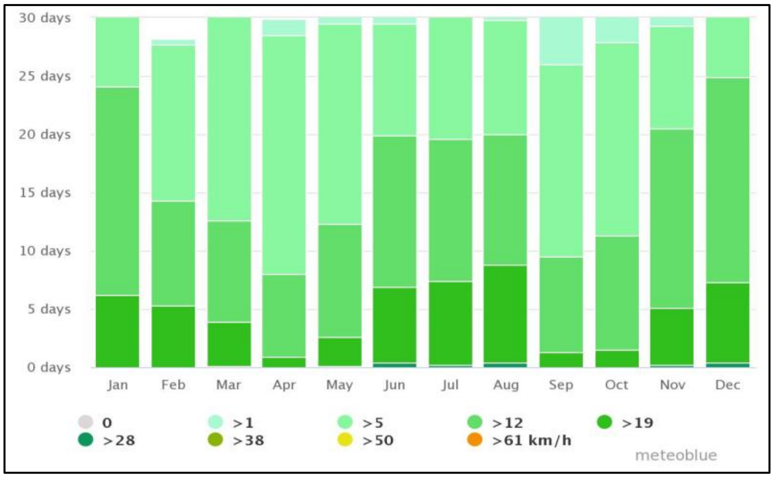


4.1.4 Wind speed

The monsoon creates steady strong winds from December to April, and calm winds from June to October (Figure 26). The windier part of the year lasts for 4 months, from May to September, with average wind speeds of more than 9.4 km per hour. The windiest month of the year in Battambang is July, with an average hourly wind speed of 11 km per hour. The calmer time of the year lasts for 8 months, from September to end of May. The calmest month of the year in Battambang is October, with an average hourly wind speed of 8 km per hour.

[16] Source: www.weatherspark.com

Figure 26: Average wind speed in Battambang



4.2 Hazards

The Ministry of Environment's Second National Communication confirmed that **Battambang province is the most vulnerable province to drought and second-most vulnerable to floods in the country**, based on historical damage data.[17]

4.2.1 Flood

Battambang municipality – and especially the city center - experiences flooding and periodic inundation annually during the rainy season period, affecting services, transport networks and people's livelihoods. According to the Provincial Water Resource Department in Battambang, a river water level above 12.5 meters high can flood major parts of the city.[18] Pluvial floods are having increasingly devastating damages and losses due to the higher exposure caused by rapid urban growth and underdeveloped drainage facilities. Flooding also happens along the rail line because capacity reduction of drainage canals was blocked by new constructions and filled with sediment[19], and several national roads have been built without proper drainage systems.[20]

Historical floods occurred in Battambang municipality in 2000, 2006, 2011, 2013 and 2015 (Table 2). Historical records show that the 2011 floods, with observed water levels of up to 13.95 meters, affected 31,458 people in the entire province (7,111 households in 31 communes in 9 districts), inundated 52,503 hectares, and destroyed 36,266 hectares of rice fields. The 2013 floods, which reached a historical height of 14.2 meters, affected 346,408 people in the entire province (74,160 families in 132 communes) (Figure 27).[21] The flooding caused the destruction of 16 irrigation schemes with a total 31,072 m of main canals, 1,247 m of dikes and 15 construction sites. The total cost of repair was estimated at US$ 700,000.[22]

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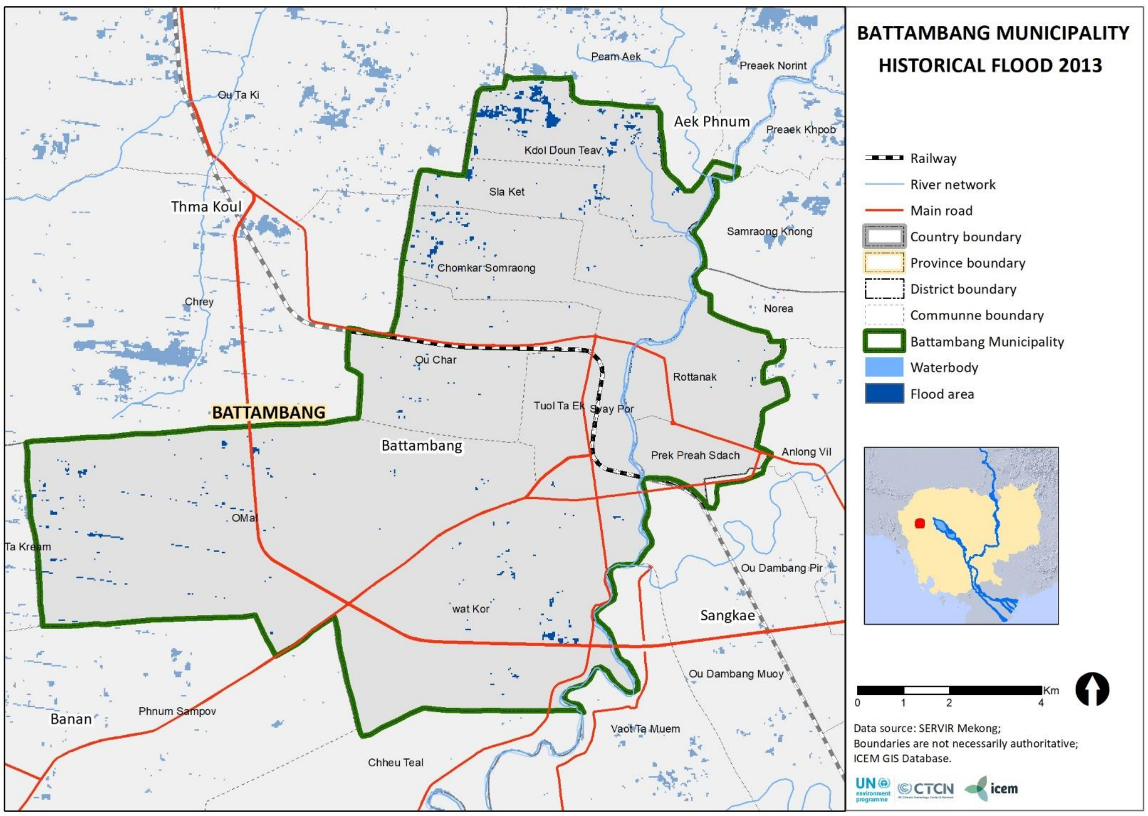
[17] Ministry of Environment, Kingdom of Cambodia. 2015. *Cambodia's Second National Communication. Submitted under the United Nations Framework Convention on Climate Change.*
[18] Try T., Ibid.
[19] CDIA and ADB, 2010. *Battambang Urban Improvements to Mitigate Climate Change, Cambodia*. Cities Development Initiative in Asia (CDIA) and Asian Development Bank (ADB): Manila
[20] Try T., Ibid.
[21] Urban Climate Resilience in Southeast Asia Partnership (URCSEA), 2015. *Report on Identification of Case Study Site: Battambang Municipality, Battambang Province, Cambodia*.
[22] Try T., Ibid.

Table 2: Maximum water level and flow at Battambang station, from 1999 to 2013

Year	Max annual water level (m)	Annual flood (m^3/s)	Year	Max annual water level (m)	Annual flood (m^3/s)
1999	12.37	634	**2006**	13.71	1,125
2000	13.44	1009	**2007**	13.5	1,034
2001	12.14	569	**2008**	12.14	569
2002	11.59	433	**2009**	12.08	552
2003	13.02	846	**2010**	11.12	337
2004	12.08	552	**2011**	13.95	1,235
2005	13.39	988	**2012**	12.79	715
			2013	14.2	

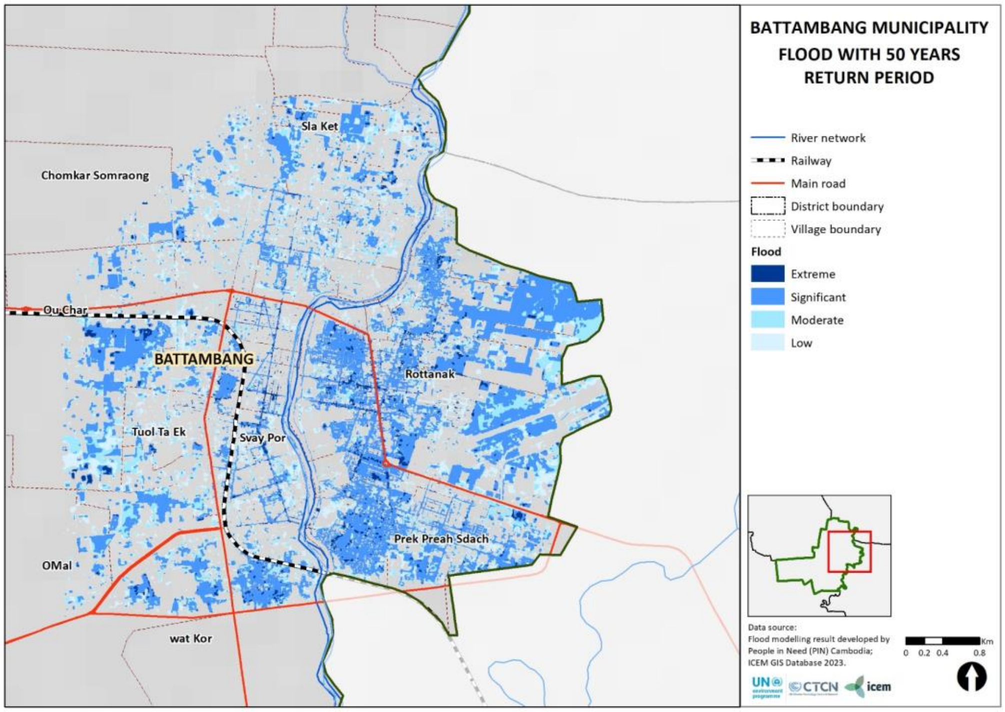
Figure 27: Historical flood in Battambang municipality in 2013[23]



Based on the modelled flood, carried out by PIN Cambodia, most rainfall-induced flood occurs to the east of the Sangker river, draining north-east ward through the agricultural lowland and artificial drainage channels (Figure 28).[24] Some inundation does occur within the urban areas along the roads, although this is primarily under 25 cm depth. According to the model, the areas with the highest flood hazard level include Prek Preah Sdach, Rottanak, Wat Kor, Norea, Anlong Vil, Toul Ta Ek and Chomkar Somraong communes. When considering the location of people in the area, **the communes with the largest flood exposure for people include Prek Preah Sdach, Wat Kor, Rottanak, Chomkar Somraong, Toul Ta Ek, and Svay Por communes**.

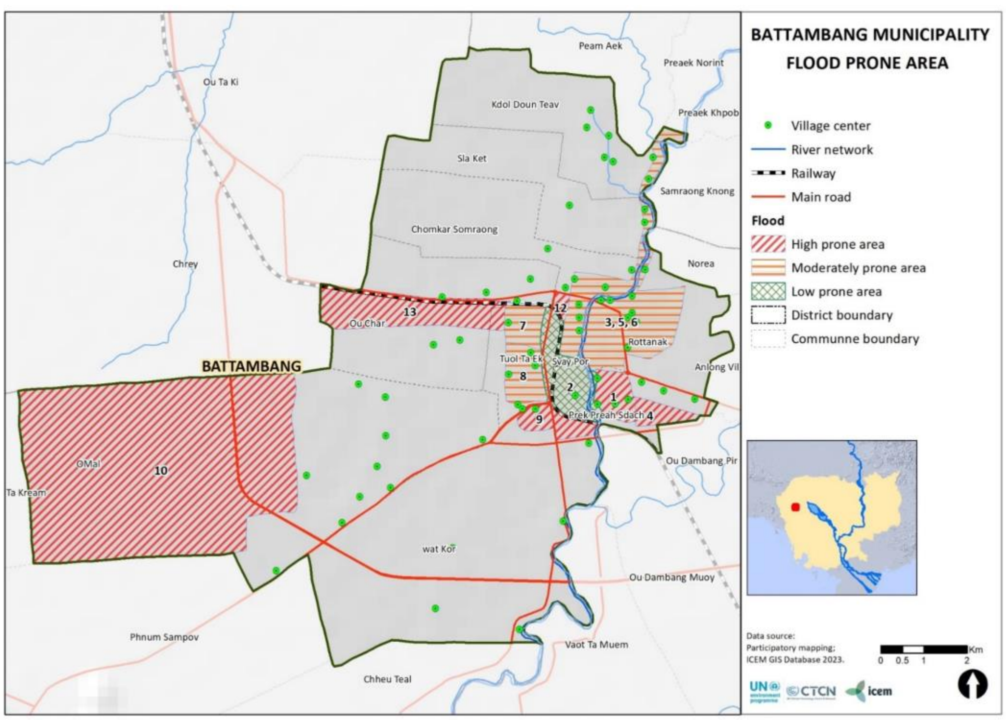
[23] Open Development Cambodia. Cambodia flood-prone areas 2013. Last accessed in January 2023.
[24] PIN, NCDM. 2021. *Flood Mitigation Recommendations Report.* People in Need and the National Committee for Disaster Management, Phnom Penh, Cambodia.

Figure 28: Modelled flood hazard level, for Battambang's city center



In January 2023, ICEM conducted a participatory mapping exercise with municipal authorities to map flood hotspots in Battambang. Figure 29 shows the **participatorily identified flood hotspot areas** for Battambang municipality, using categories of highly-, moderately- and low-prone areas. The hotspots show areas that have experienced riverine or rainfall-induced floods according to the municipal authorities. **The flood hotspots are mainly located in the center of the city, along the northern section of the railway and in OMal commune.**

Figure 29: Flood hotspot areas in Battambang city, as identified by municipal stakeholders in January 2023



The assets at risk as well as the cause, duration, depth and frequency of flooding in these hotspots are provided in Table 3.

Table 3: Identified flood hotspot information, as provided by municipal stakeholders in January 2023

No.	Category	Assets at risk	Cause of flood	Flood duration	Flood depth	Flood frequency
1	High	Houses, Muslim temple, statue	Blockage of outlet of stormwater way	1-2 weeks	0.7 m	Every year
2	Low	Informal housing	-	-	-	-
3	Moderate	Provincial park	-	-	-	-
4	High	Residential area	Blockage of outlet of stormwater way	1-2 weeks	0.7 m	Every year
5	Moderate	Residential area, school, clinic	-	-	-	-
6	Moderate	Houses, residential area, market, commercial area	-	-	-	-
7	Moderate	Houses, residential area, school, temple	-	-	-	-
8	Moderate	Houses, residential area, school, temple	-	-	-	-
9	High	Houses, residential area, health center, school, temple	Lack of stormwater release system	1-2 weeks	0.6 m	Every year
10	High	Houses, residential area, school, rice fields, flood reservoir	Water flow from upstream reservoir in Kamping Pouy, Sneng	1 month	1.5 m	Every year
11	Low	-	Low for flood, more prone to riverbank collapse	-	-	-
12	High	Market, residential area	Flood water coming out of the drainage	3-7 days	0.5 m	Once in 5-6 years
13	High	Houses, residential area	Blockage and shallowness of water releasing canals	1-2 weeks	0.7 m	Every year

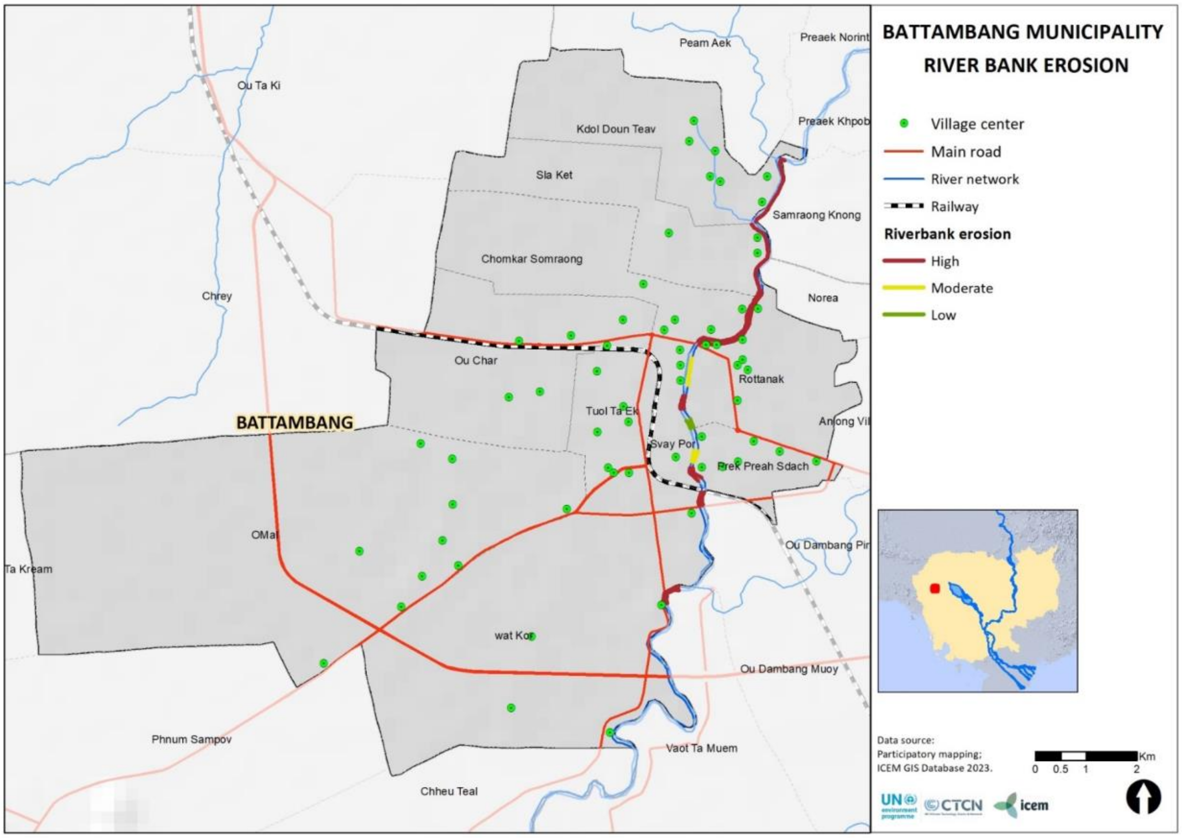
4.2.2 River bank erosion

Erosion along the Sangker river has also been identified as a key hazard by municipal stakeholders at the participatory mapping workshop organized by ICEM in January 2023. The identified riverbank erosion hotspots, categorized from high to moderate to low, are shown in Table 4 and Figure 30. **A total of 43km of river bank in the city is considered by stakeholders as highly prone to erosion.**

Table 4: Kilometres of riverbank in Battambang city prone to erosion

Commune	High	Moderate	Low	Total km in erosion prone area
Chomkar Somraong	8.29	0.45		8.74
Kdol Doun Teav	4.22			4.22
Prek Preah Sdach	2.72	1.05	0.79	4.56
Rottanak	10.40	1.38	0.79	12.57
Sla Ket	6.83			6.83
Svay Por	5.81	2.15	0.79	8.75
Tuol Ta Ek	0.31			0.31
Wat Kor	4.35	0.08		4.43
Ou Char	0	0	0	0
OMal	0	0	0	0
Total	**42.92**	**5.10**	**2.37**	**50.39**

Figure 30: Riverbank erosion hotspot areas in Battambang city



4.2.3 Drought

Drought is an increasing hazard threat for Battambang province, especially between December and March when Battambang receives very little rainfall with about 5.6% of the annual total. Drought most commonly occurs in the following districts: Moung Ruessei, Rukh Kiri, Banan, Koas Kralor , Rotanak Mondul, Sam Lout, Bavel, Phnom Proek, Kamrieng, and Sampov Loun.[25]

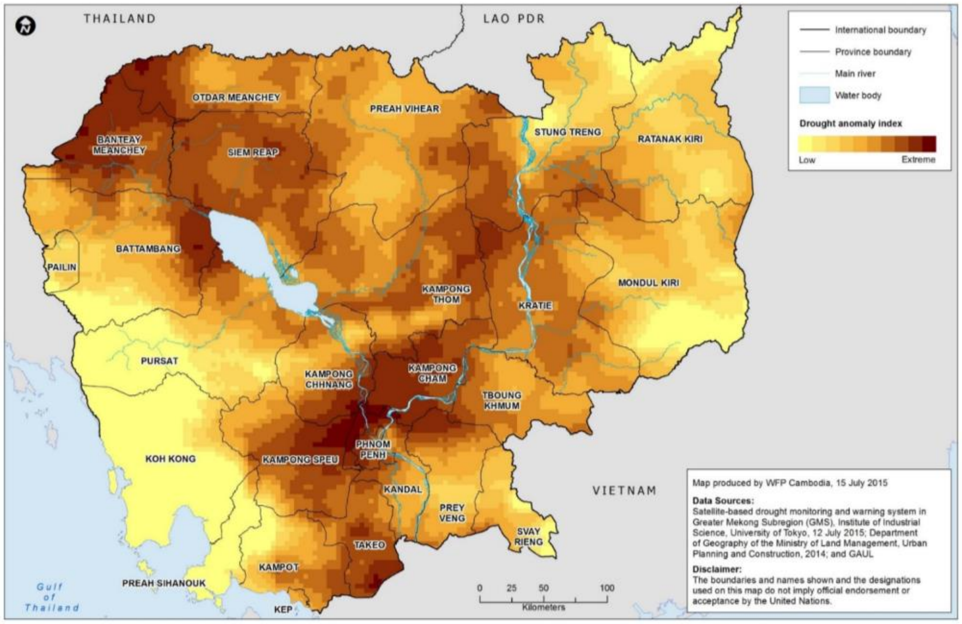
Severe droughts in Battambang occurred during the dry season of 2011- 2012, 2014-2015, 2016-2017, 2017-2018 and 2018-2019 (Table 5 and Figure 31).

Table 5: Rainfall in the period of December to March in Battambang, from 2010 to 2019

Year	Rainfall in period of December to March (mm)	Year	Rainfall in period of December to March (mm)
2010-2011	94.9	**2015-2016**	13.9
2011-2012	134.2	**2016-2017**	164.6
2012-2013	21.6	**2017-2018**	127.2
2013-2014	89.2	**2018-2019**	110.0
2014-2015	137.8		

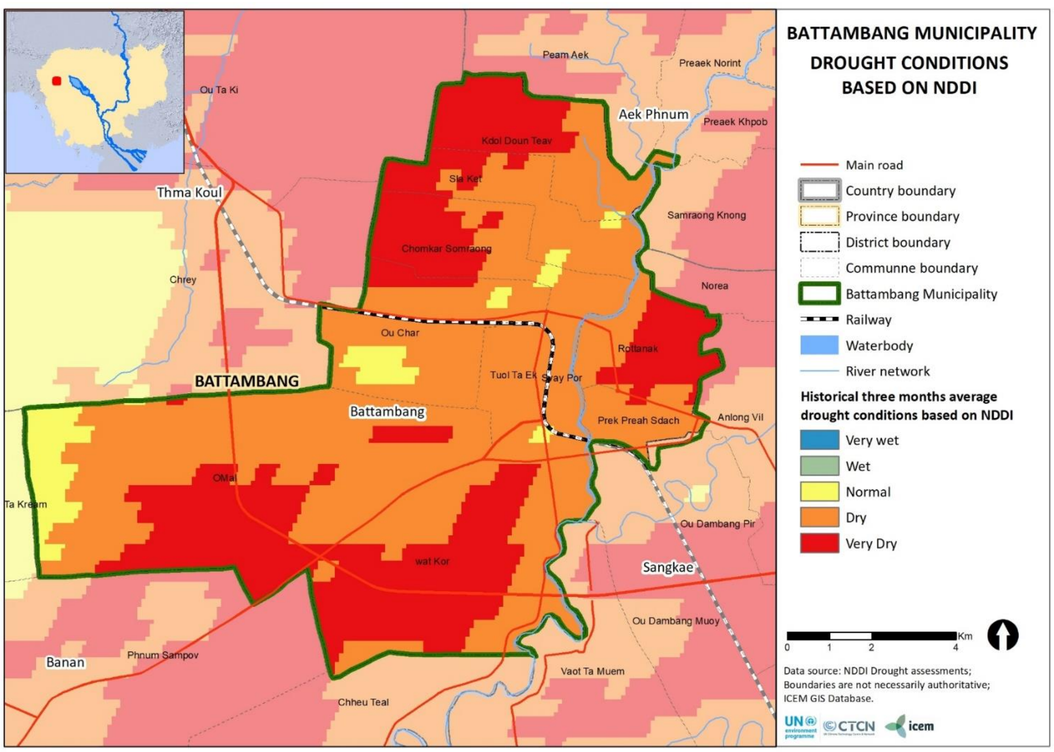
[25] MOE, ADB, WB and Hatfield Consultants. 2013. *Synthesis Report on Vulnerability and Adaptation Assessment for Key Sectors Including Strategic and Operational Recommendations.* PPCR Project-Phase 1. Phnom Penh.

Figure 31: Drought in 2015 affecting Battambang: drought intensity as of 12 July 2015[26]



Historical drought for Battambang municipality, based on the normalized difference drought index, show that various parts of the city have experienced dry to very dry drought conditions, such as the south-western, north-western and eastern parts (Figure 32).

Figure 32: Historical drought conditions in Battambang municipality



[26] WFP. Originally published on 15 July 2015. Last accessed on 12 December 2022. https://reliefweb.int/map/cambodia/cambodia-drought-intensity-12-july-2015

4.3 Climate change

4.3.1 Projections

Climate change is changing the frequency and severity of flood and drought events and creating new challenges for water security. The Mekong River Commission climate change projections used three GCMs and a range of scenarios for the Lower Mekong Basin. The IPSL-CM5A-MR model gives the greatest seasonal variability in results and is described here using the RCP 8.5 scenario. Spatial resolution of the data is approximately 1km (0.008333 degree). The baseline period is 1986-2005, future time horizons is available for every year up to 2100.

Table 6: Projected changes to average rainfall and maximum temperatures by 2050

	Baseline	2050s	Change
Average annual rainfall	1,295 mm	1,320 mm	+1.9 %
Total rainfall in wet season	1,044 mm	1,092 mm	+4.6 %
Total rainfall in dry season	250 mm	228 mm	-8.8 %
Average annual maximum temperature	32.1 °C	33.7 °C	+1.6 °C
Average maximum temperature in wet season	31.9 °C	33.6 °C	+1.7 °C
Average maximum temperature in dry season	32.4 °C	33.7 °C	+1.3 °C

As shown in Table 6, projections for the wet season (Figure 33 and Figure 34) show precipitation in Battambang municipality projected to increase with around 4.6%. In the wet season, temperatures are projected to increase with 1.7^{o}C. **Increased rainfall in wet season is likely to increase the severity and duration of floods.**

Battambang city is expected to be significantly hotter and wetter in the wet season and hotter and drier in the dry season. During the dry season (Figure 35 and Figure 36) precipitation by 2050 is projected to decrease of around 8.8%. On the other hand, average maximum temperatures during the dry season are projected to increase across the sub-basin by around 1.3^{o}C. **Reduced rainfall and increased temperatures during the dry season are likely to increase the severity and duration of droughts.**

Figure 33: Precipitation during the wet season in Battambang by 2050

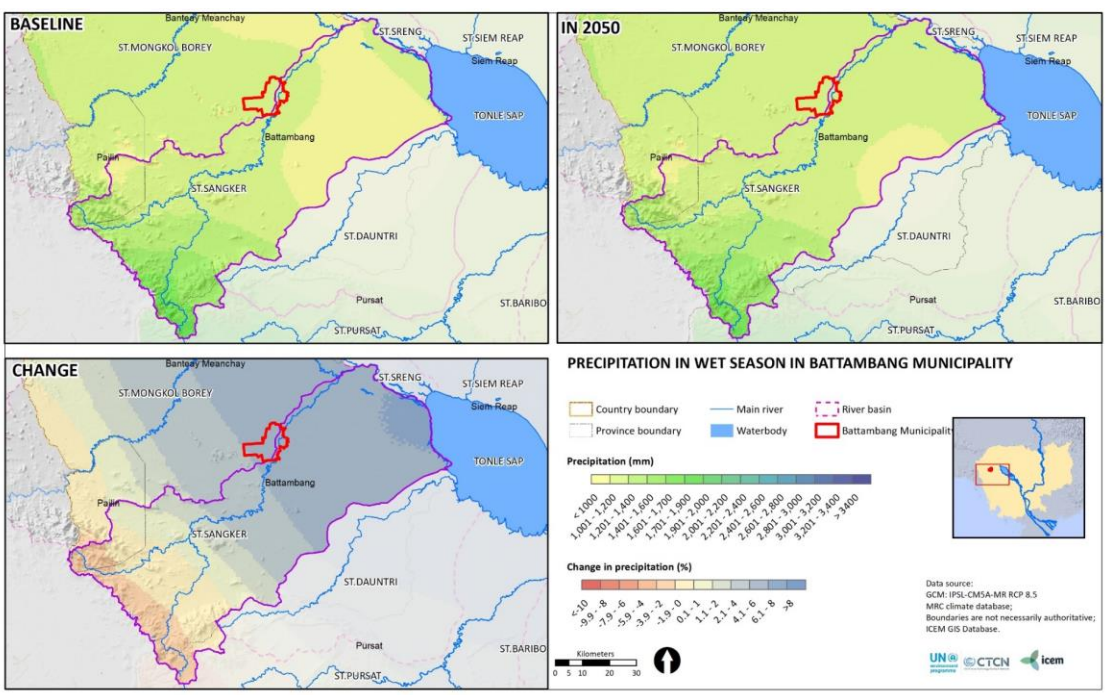


Figure 34: Change in average maximum temperature in the wet season in Battambang by 2050

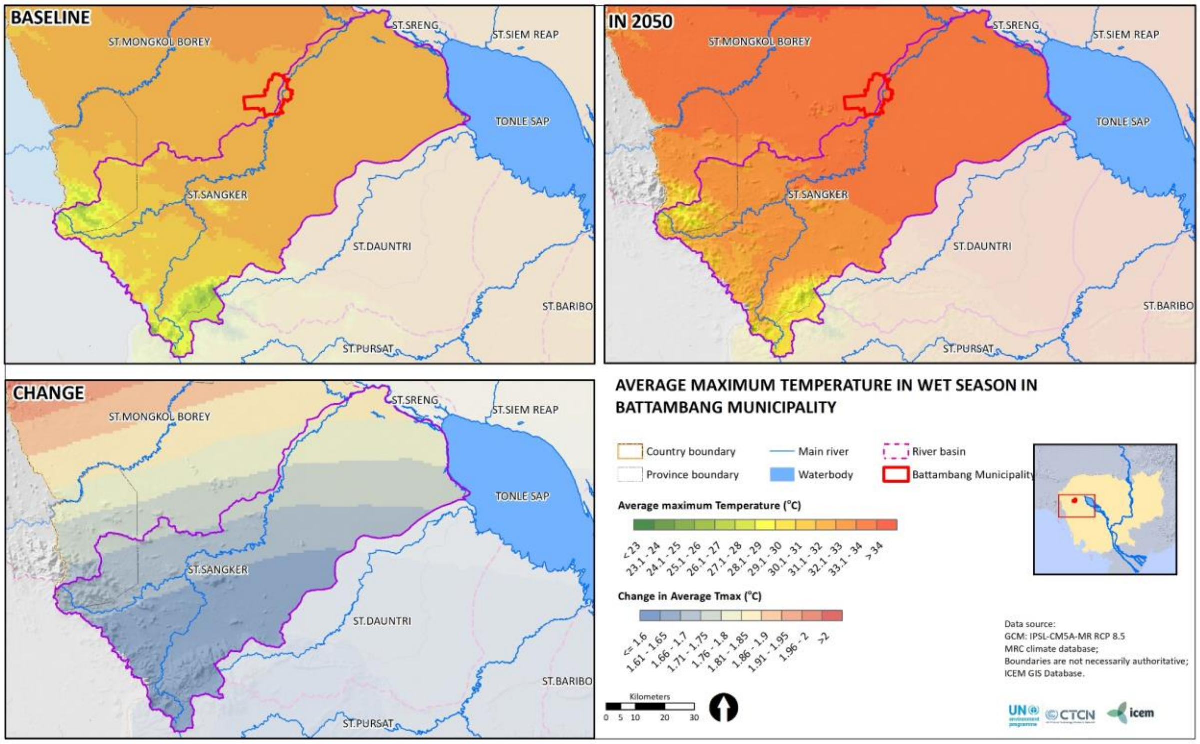


Figure 35: Change in precipitation during the dry season in Battambang by 2050

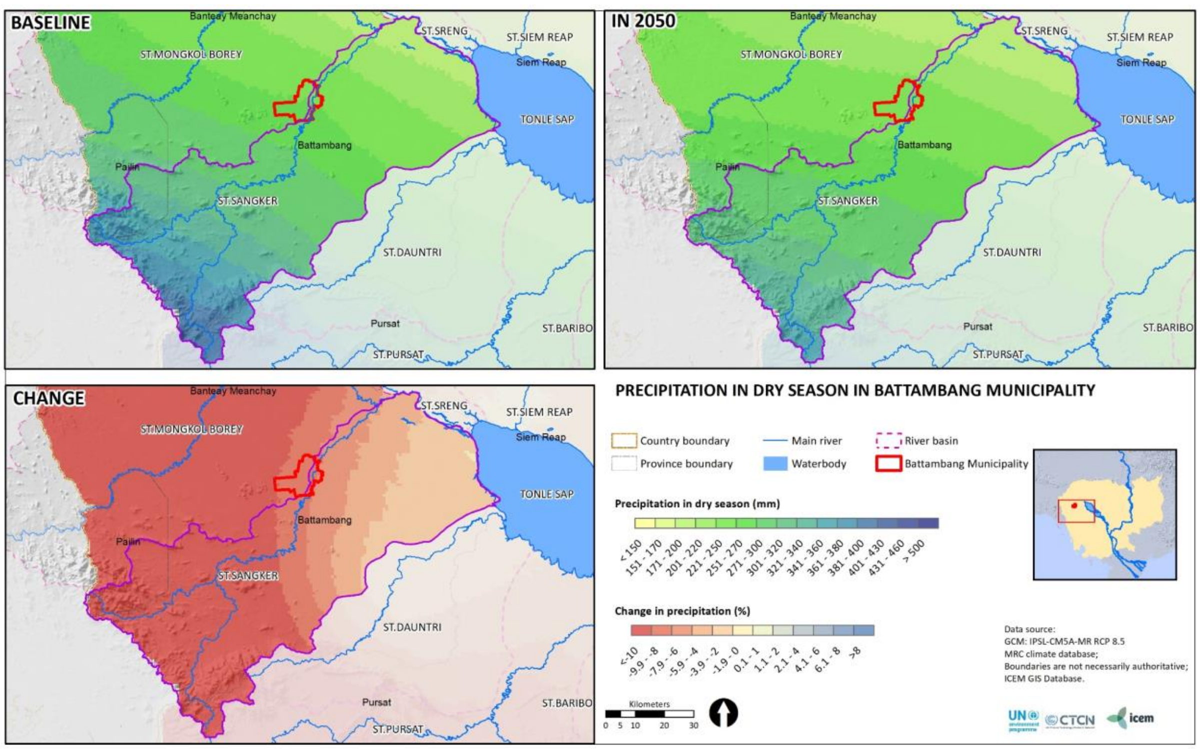
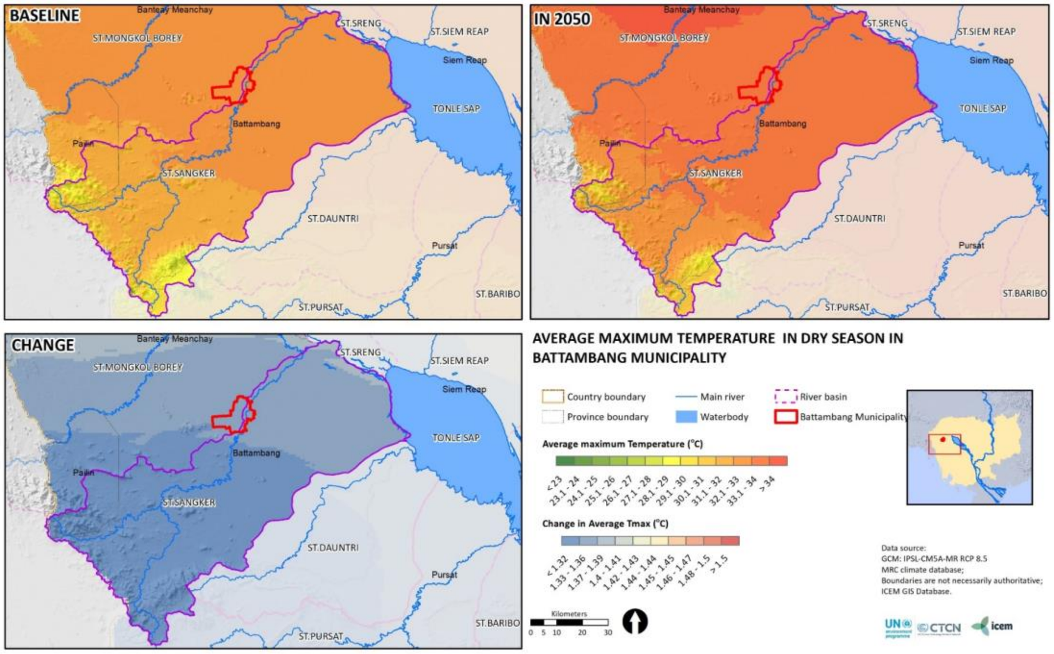


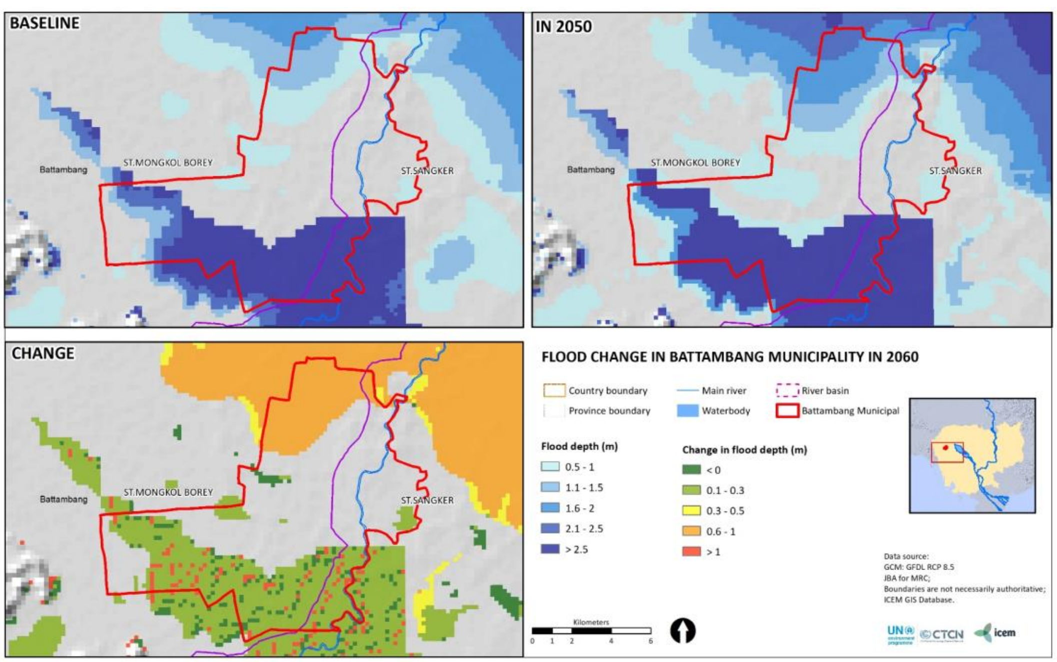
Figure 36: Average maximum temperatures during the dry season in Battambang by 2050



4.3.2 Impact on hazards

Figure 37 shows the flood depth for a 1-in-100 years return period flood event in Battambang city modelled by JBA flood.[27] **The maximum flood depth in Battambang city is 5.4m in the baseline period, with a projected increase to 5.6m in 2050s due to climate change.**

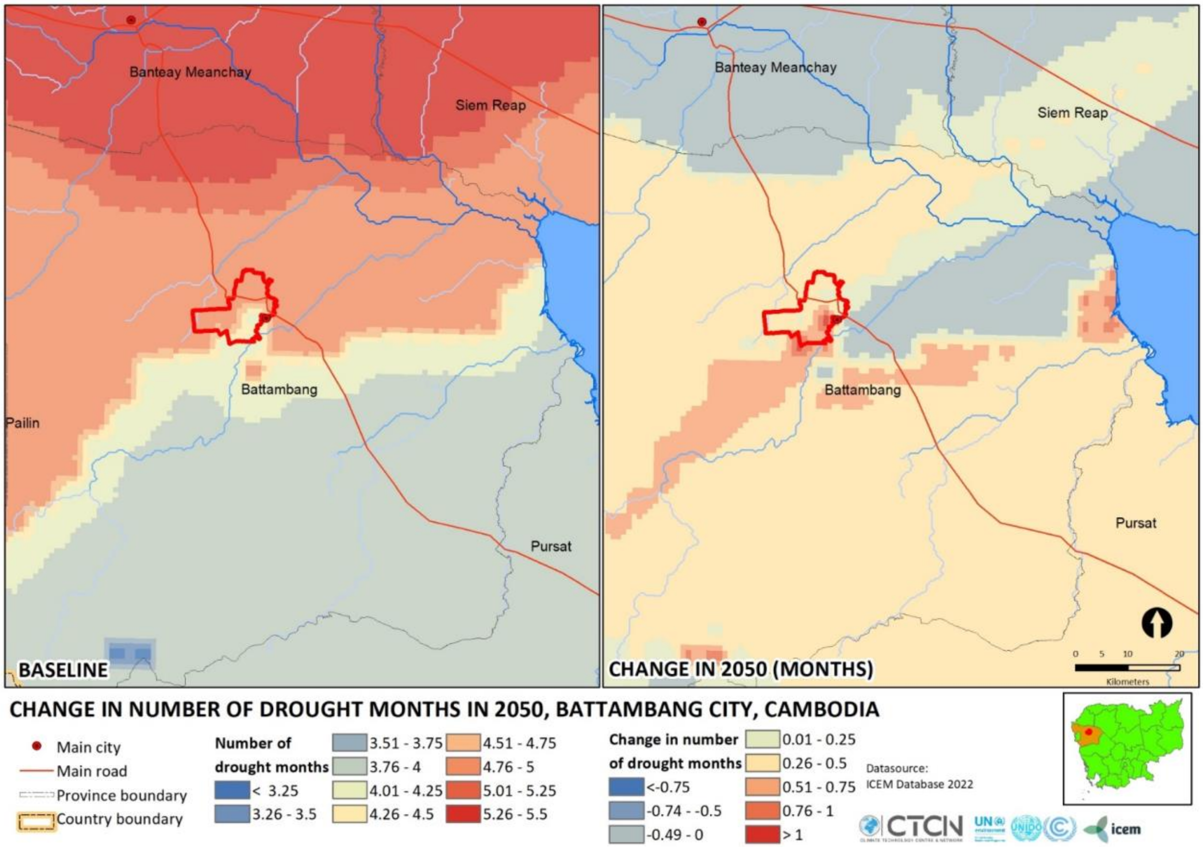
Figure 37: Modelled flood risk in Battambang municipality



[27] JBA Consulting, 2016. *Enhancement of Basin-wide Flood Analysis and Additional Simulations under Climate Change to provide datasets for Impact Assessment and MASAP preparation.*

The number of drought months is projected to increase by 0.4 drought months in 2050s (Figure 38).

Figure 38: Drought months in Battambang city baseline and changes in 2050s



5 IMPACT AND VULNERABILITY ASSESSMENT

5.1 Rainfall-induced floods

5.1.1 Exposure to rainfall-induced floods

The exposure to floods for villages, built-up area, roads, railway and schools and health facilities was calculated based on the pluvial flood hazard map developed by PIN combined with available census and global data. The overall results are described in this section, while the detailed CAM results are provided in Appendix 2.

5.1.1.1 Exposure of villages

Determining the exposure of villages has been done in two ways: by looking at the location of the village centre and whether it's located in a flood prone area, and by calculating the total area in the entire village exposed to various flood hazard levels. For 15 villages located in the southwest of the municipality, there is no PIN model data available, so exposure could not be calculated.

In terms of the village centres, **40 out of the 62 village centres (64.5%) in Battambang municipality can be considered as prone to flood**, with 10 village centres located in an extremely prone flood area, 10 in a significantly prone, 10 in a moderately prone and 10 in a low prone area (each 16.1% of the total number of villages) (Table 7 and Figure 39).

21 of the 40 village centres exposed to flood are located in Rottanak (8), Prek Preah Sdach (7) and Tuol Ta Ek (6) communes, which also have the highest number of village centres extremely prone to floods.

Table 7: Battambang municipality: village centres located in flood prone areas

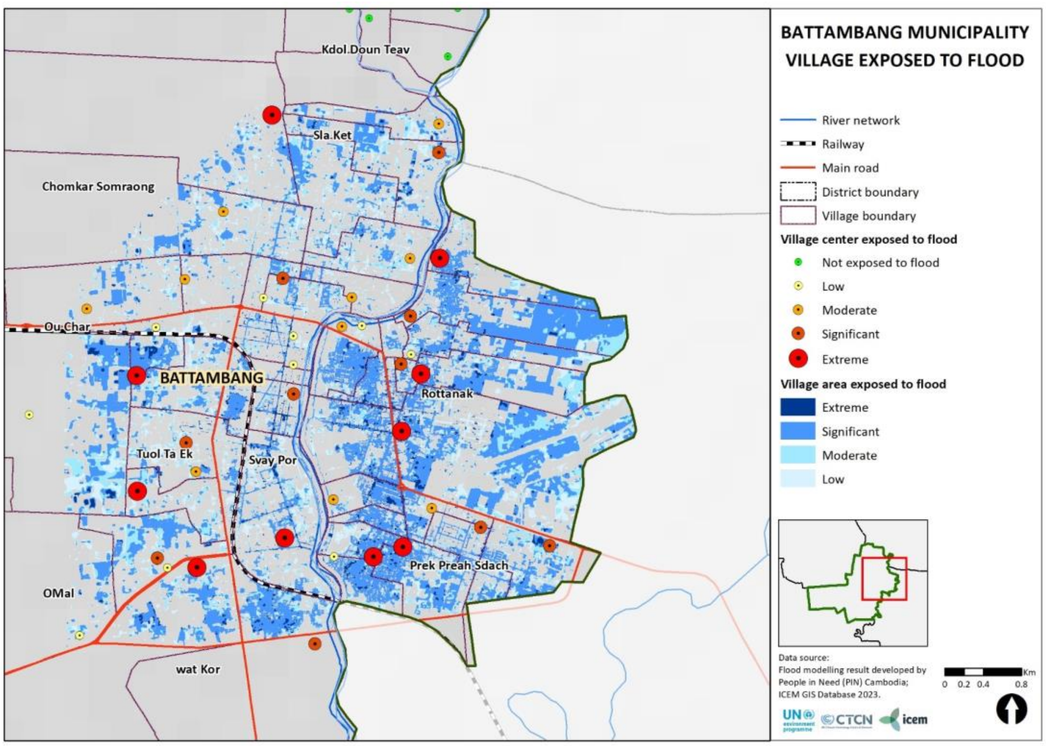
Commune	Flood hotspots (no. of village centres)				Number of village centres exposed	Total number of villages	% exposed out of total
	Extreme	Significant	Moderate	Low			
Chomkar Somraong	-	1	3	1	5	5	100%
Kdol Doun Teav	-	-	-	-	0	7	0%
OMal	-	-	-	1	1	7	14.3%
Ou Char	-	-	2	1	4	6	66.7%
Prek Preah Sdach	2	2	2	1	7	7	100%
Rottanak	3	2	1	2	8	8	100%
Sla Ket	1	1	1	-	3	3	100%
Svay Por	1	1	-	2	4	4	100%
Tuol Ta Ek	2	2	1	1	6	6	100%
wat Kor	1	1	-	-	2	6	33.3%
Total	**10**	**10**	**10**	**10**	**40**	**62**	**64.5%**

In terms of the actual village area exposed, **1,070.9ha (9.3% of the entire municipality) is exposed to various levels of flood**, with 40.5ha (0.4%) to extreme flood levels, 587.8ha (5.1%) to significant flood levels, 207.6ha (1.8%) to moderate flood levels and 234.9ha (2%) to low flood levels (Table 8). **Rottanak, Prek Preah Sdach and Tuol Ta Ek communes, in the center of the municipality, have the highest percentage of land and highest total land area exposed to flood**, with Rottanak having the highest area of extremely prone and significantly prone flood areas, 14.4ha and 240ha respectively.

Table 8: Battambang municipality: area of the village located in flood prone areas

Commune	Flood hotspots (ha)				Total area exposed	Total area of the commune	% exposed area out of total
	Extreme	Significant	Moderate	Low			
Chomkar Somraong	0.9	28.6	19.8	26.6	75.9	877.15	8.6%
Kdol Doun Teav	-	-	-	-	0	921.1	0.0%
OMal	0.2	6.0	2.8	3.8	12.9	3,759.14	0.3%
Ou Char	1.8	22.2	15.2	21.1	60.3	1,193.38	5.1%
Prek Preah Sdach	7.6	95.2	21.5	22.3	146.5	285.69	51.3%
Rottanak	14.4	240.0	59.7	55.7	369.8	682.37	54.2%
Sla Ket	2.5	44.0	22.5	31.5	100.5	764.59	13.1%
Svay Por	5.4	28.1	13.7	20.3	67.5	217.25	31.1%
Tuol Ta Ek	5.2	83.4	40.8	43.0	172.4	371.41	46.4%
Wat Kor	2.7	40.3	11.7	10.6	65.3	2,479.07	2.6%
Total	**40.5**	**587.8**	**207.6**	**234.9**	**1,070.9**	**11,551.2**	**9.3%**

Figure 39: Battambang municipality: villages centres exposed to flood



Applying the CAM to the total area of the village exposed[28], the exposure of the village to flood can be scored from very low to very high and visualized as shown in

Figure 40: 10 villages (16%) have a very high, 10 villages (16%) a high, 10 villages (16%) a medium, 13 villages (21%) a low and 4 (7%) villages a very low exposure to flood (Figure 41). **62,329 people or 37.8% of the total population is highly to very highly exposed to rainfall-induced floods**, including 30.565 male,

[28] The PIN flood model's 4 hazard classes (extreme to low) were reclassified into the CAM's 5 very low-to-very high classes.

31,764 female and 9,208 girls. The majority of the villages with high to very high exposure are in Prek Preah Sdach (5), Rottanak (5), and Tuol Ta Aek (3) communes.

Figure 40: Battambang municipality: village area exposed to flood

Note: villages and communes in the south and west of the municipality are coloured grey as there was no data available from the PIN flood hazard model for these villages.

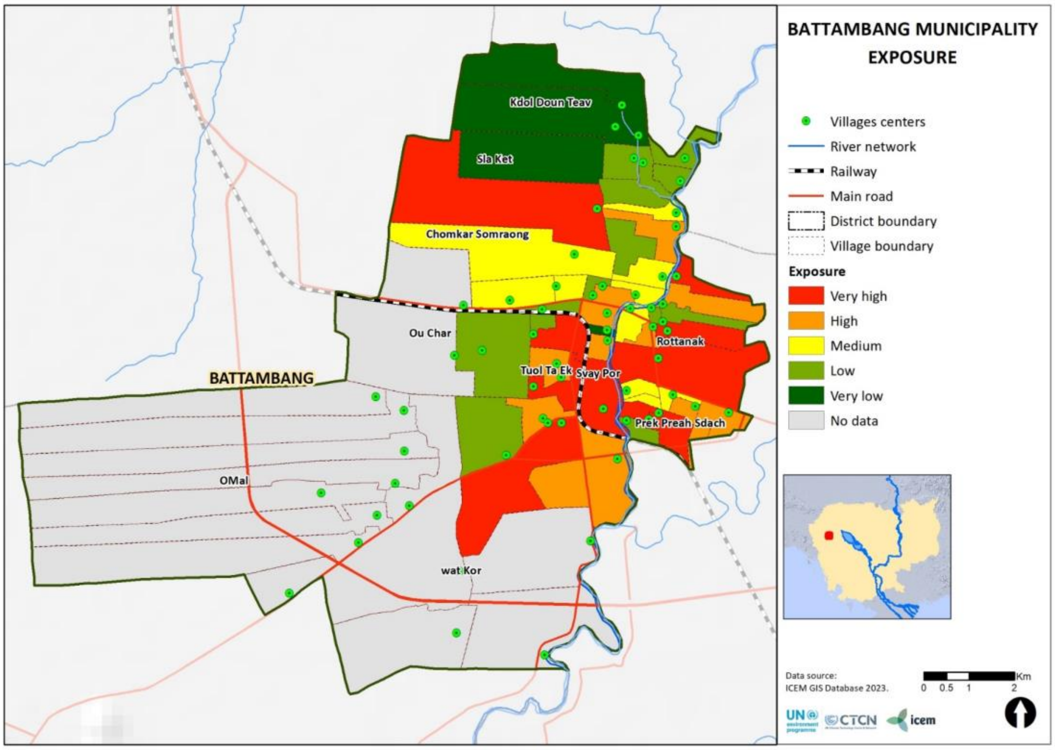
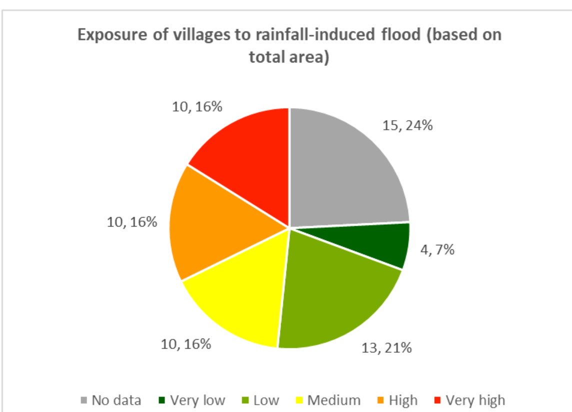


Figure 41: Battambang municipality: villages exposed to flood



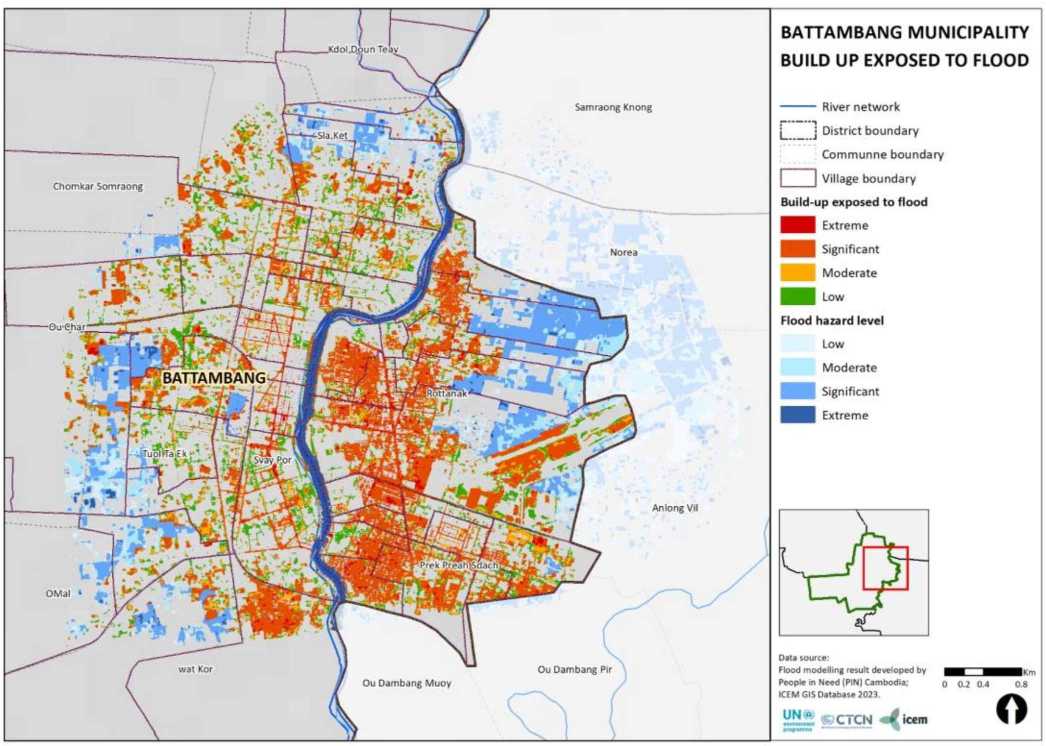
5.1.1.2 Exposure of built-up area

Using 2009 land use data, **741.3ha of built-up area (24.8% of the total) in Battambang municipality are exposed to rainfall-induced flood**, with 31.6ha of built-up area extremely prone, 399.4ha significantly prone, 137.3 moderately prone and 173ha low prone to floods (Table 9 and Figure 42). **The communes with the highest percentage of built-up area exposed to flood are Prek Preah Sdach and Rottanak**, 54.8% and 51.7% respectively, with Rottanak having the largest built-up area exposed to extreme and significant flood hazard levels.

Table 9: Battambang municipality: built up area located in flood prone areas

Commune	Flood hotspots (ha)				Total area exposed	Total area of the commune	% exposed area out of total
	Extreme	Significant	Moderate	Low			
Chomkar Somraong	0.76	28.39	19.53	26.19	74.86	228.63	32.7%
Kdol Doun Teav	-	-	-	-	0	152.53	0%
OMal	0.02	0.39	0.27	0.39	1.07	347.1	0.3%
Ou Char	1.42	15.73	10.2	15.85	43.2	338.18	12.8%
Prek Preah Sdach	7.52	93.79	21.29	22.1	144.7	263.84	54.8%
Rottanak	11.58	144.73	28.04	31.91	216.27	418.56	51.7%
Sla Ket	1.43	24.47	14.22	19.78	59.9	242.61	24.7%
Svay Por	5.39	28.06	13.65	20.3	67.4	208.34	32.4%
Tuol Ta Ek	1.83	36.34	21.54	29.22	88.92	242.87	36.6%
Wat Kor	1.66	27.51	8.53	7.29	44.99	460.62	9.8%
Total	**31.61**	**399.39**	**137.27**	**173.03**	**741.3**	**2,903.29**	**24.8%**

Figure 42: Battambang municipality: built up area exposed to flood



5.1.1.3 Exposure of the transportation network

In terms of exposure of roads (using 2023 OpenStreetMap data), 11km of main roads (20.6% of the total) and 155.4km of other roads (26.9% of the total) in Battambang municipality are exposed to rainfall-induced flood (Table 10, Table 11 and Figure 43). 0.59km of main roads and 8.71km of other roads are exposed to extreme, 5.58km of main roads and 76.52km of other roads to significant, 1.86km of main roads and 28.21km of other roads to moderate and 2.95km of main roads and 41.96km of other roads to low flood hazard levels. **OMal and Rottanak communes have the most km of main roads exposed, while Rottanak, Svay Por and Prek Preah Sdach communes have the most km of other roads exposed.**

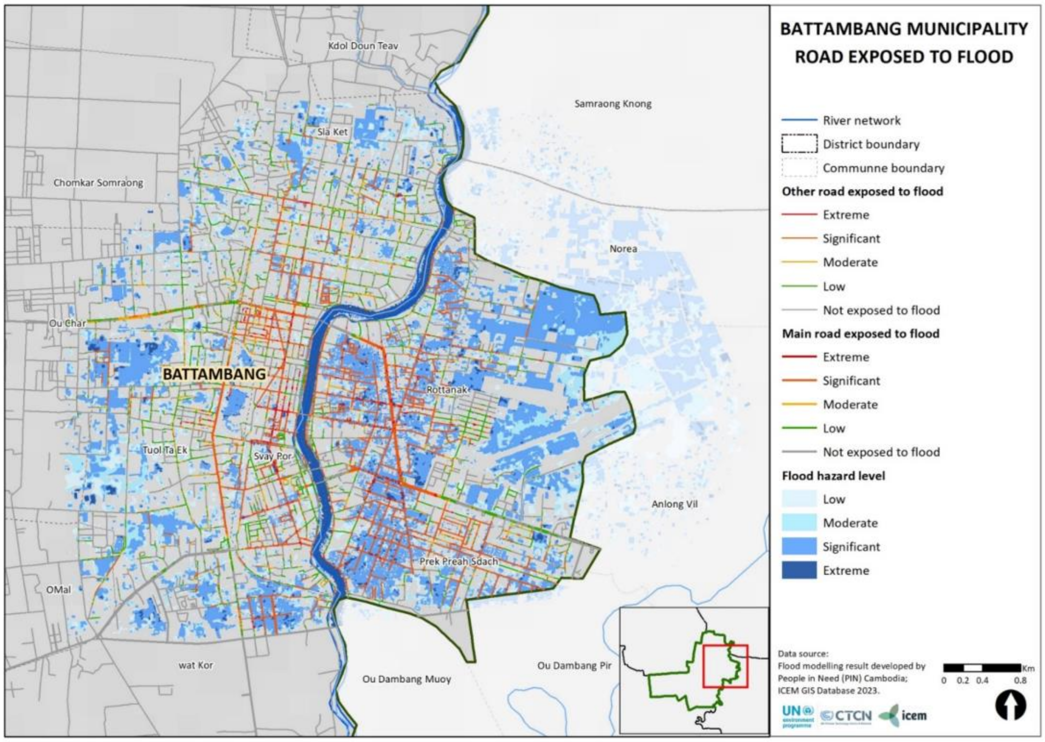
Table 10: Battambang municipality: sections of main roads located in flood prone areas

Commune	Flood hotspots (km)				Total km of main roads exposed	Total km of main roads	% exposed out of total
	Extreme	Significant	Moderate	Low			
Chomkar Somraong	0.01	0.05	0.03	0.01	0.09	0.09	100%
Kdol Doun Teav	-	-	-	-	0	15.19	0%
OMal	-	0.48	1.05	1.35	2.89	6.91	41.8%
Ou Char	0.41	1.36	0.04	0.05	1.86	2.09	88.9%
Prek Preah Sdach	0.03	0.62	0.17	0.09	0.9	1.16	77.3%
Rottanak	0.01	1.85	0.23	0.14	2.23	2.65	84.2%
Sla Ket	0.02	0.57	0.18	0.41	1.18	20.27	5.8%
Svay Por	-	-	-	-	0	0	0%
Tuol Ta Ek	0.11	0.66	0.16	0.9	1.83	4.88	37.5%
wat Kor	-	-	-	-	0	0	0%
Total	**0.59**	**5.58**	**1.86**	**2.95**	**10.98**	**53.25**	**20.6%**

Table 11: Battambang municipality: sections of other roads located in flood prone areas

Commune	Flood hotspots (km)				Total km of main roads exposed	Total km of main roads	% exposed out of total
	Extreme	Significant	Moderate	Low			
Chomkar Somraong	0.21	6.96	4.73	5.91	17.81	56.78	31.4%
Kdol Doun Teav	-	-	-	-	0	35.92	0%
OMal	-	0.25	0.26	0.47	0.97	99.64	1%
Ou Char	0.04	1	2.1	3.76	6.9	74.09	9.3%
Prek Preah Sdach	1.7	18.89	3.73	4.42	28.74	39.17	73.4%
Rottanak	2.51	23.34	4.55	7.51	37.91	65.37	58%
Sla Ket	0.26	3.91	3.05	4.95	12.16	41.76	29.1%
Svay Por	3.51	13.32	4.89	7.21	28.94	44.08	65.7%
Tuol Ta Ek	0.33	6.03	4.19	6.46	17	36.2	47%
wat Kor	0.15	2.82	0.72	1.26	4.96	85.27	5.8%
Total	**8.71**	**76.52**	**28.21**	**41.96**	**155.4**	**578.28**	**26.9%**

Figure 43: Battambang municipality: road sections exposed to flood

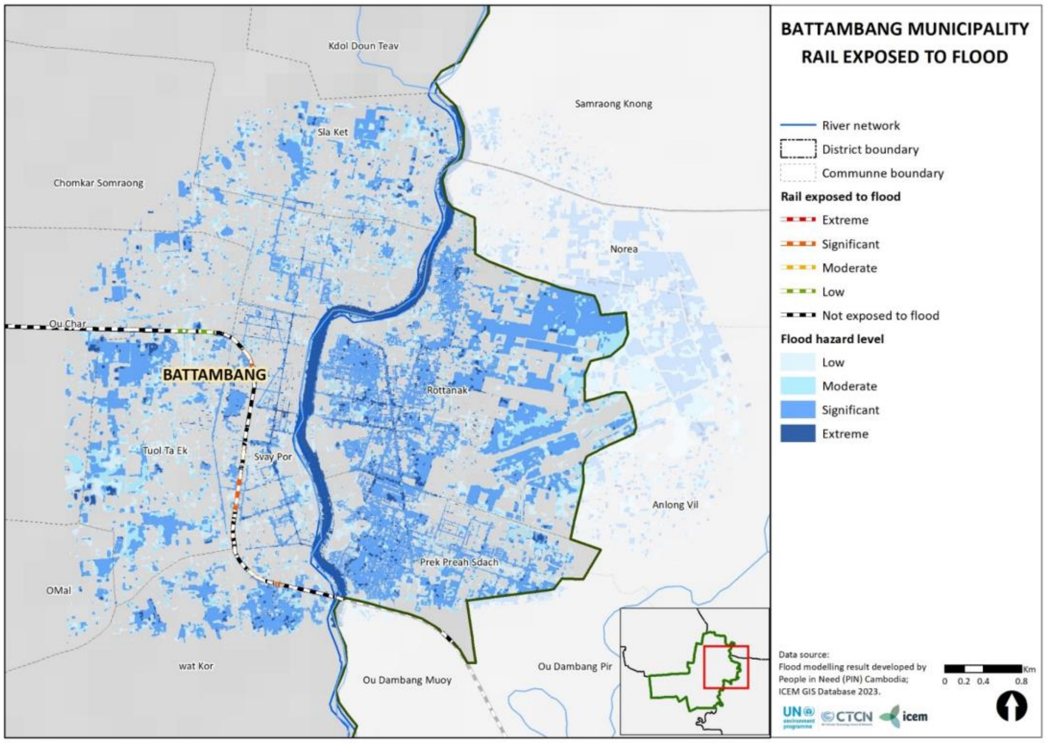


In terms of the railway, **1.82km out of the total 8.96km (20.4%) of railway traversing the municipality is exposed to rainfall-induced floods** (Table 12 and Figure 44). Svay Por commune has the longest km of railway exposed, with 0.95km exposed to mostly significant and moderate flood hazard levels.

Table 12: Battambang municipality: sections of the railways located in flood prone areas

Commune	Flood hotspots (km)				Total km of railway exposed	Total km of railway	% exposed out of total
	Extreme	Significant	Moderate	Low			
Ou Char	-	-	0.01	0.05	0.06	4.36	1.4%
Svay Por	0.02	0.58	0.21	0.14	0.95	2.38	40%
Tuol Ta Ek	0.02	0.06	0.03	0.36	0.46	1.00	46.3%
wat Kor	0.02	0.12	0.09	0.13	0.35	1.03	34.2%
Prek Preah Sdach	-	-	-	-	0	0.19	0%
Total	**0.05**	**0.76**	**0.33**	**0.68**	**1.82**	**8.96**	**20.4%**

Figure 44: Battambang municipality: railway sections exposed to flood



5.1.1.4 Exposure of schools and health facilities

In terms of critical services and facilities used before and during disaster events, **25 schools (33.3% of the total) and 3 health facilities (33.3%) are exposed to rainfall-induced flood**, with 2 schools located in extremely prone flood areas, 9 schools and 2 health facilities in significantly prone, 2 schools in moderately prone and 12 schools and 1 health facility in low prone areas (Table 13, and Figure 45). **4 out of 7 schools in Prek Preah Sdach commune are exposed to significant flood hazard levels**, while all health facilities in Svay Por and Tuol Ta Ek communes (1 each) are exposed to significant flood hazard levels.

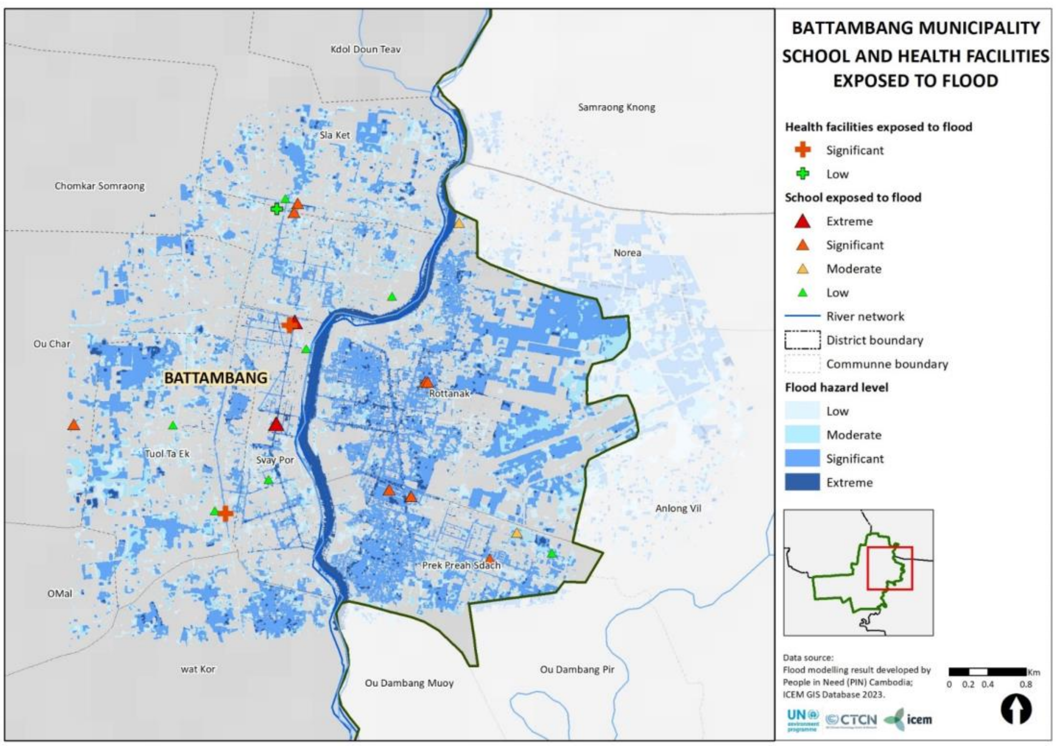
Table 13: Battambang municipality: schools located in flood prone areas

Commune	Flood hotspots (no. of schools)				Number of schools exposed	Total number of schools	% exposed out of total
	Extreme	Significant	Moderate	Low			
Chomkar Somraong	-	1	-	1	2	3	66.7%
Kdol Doun Teav	-	-	-	-	-	9	0%
OMal	-	-	-	-	-	11	0%
Ou Char	-	1	-	-	1	8	12.5%
Prek Preah Sdach	-	4	1	2	7	7	100%
Rottanak	-	2	1	-	3	9	33.3%
Sla Ket	-	1	-	1	2	4	50%
Svay Por	2	-	-	5	7	9	77.8%
Tuol Ta Ek	-	-	-	3	3	4	75%
wat Kor	-	-	-	-	-	11	0%
Total	**2**	**9**	**2**	**12**	**25**	**75**	**33.3%**

Table 14: Battambang municipality: health facilities located in flood prone areas

Commune	Flood hotspots (no. of health facilities)				Number of facilities exposed	Total number of facilities	% exposed out of total
	Extreme	Significant	Moderate	Low			
Chomkar Somraong	-	-	-	1	1	3	33.3%
Kdol Doun Teav	-	-	-	-	-	1	0%
OMal	-	-	-	-	-	1	0%
Ou Char	-	-	-	-	-	0	0%
Prek Preah Sdach	-	-	-	-	-	0	0%
Rottanak	-	-	-	-	-	0	0%
Sla Ket	-	-	-	-	-	1	0%
Svay Por	-	1	-	-	1	1	100%
Tuol Ta Ek	-	1	-	-	1	1	100%
wat Kor	-	-	-	-	-	1	0%
Total	**0**	**2**	**0**	**1**	**3**	**9**	**33.3%**

Figure 45: Battambang municipality: schools and health facilities exposed to flood



5.1.2 *Sensitivity of villages to rainfall-induced floods*

Sensitivity is the degree to which an asset or system will be affected by, or responsive to the exposure to hazards and climate change. For this risk assessment, sensitivity has been identified per village and for social parameters such as proportion of vulnerable groups (female headed households, children and elderly), proportion of people with farming as their main livelihood, and access to sanitation, using 2019 census data. Sensitivity could not be assessed for the transport network, built-up area and schools and health facilities because there is no data available.

In terms of the sensitivity to hazards and climate change (as defined through the selected parameters), **the population in 15 out of the 62 villages (24%) in Battambang municipality can be considered as very highly sensitive to floods**, in 21 villages (34%) as highly sensitive, in 12 villages (19%) as medium sensitive, and in 14 villages (23%) as very lowly sensitive (Figure 47). See Figure 46 for a detailed overview of the scoring of the villages on all the five sensitivity parameters. The communes with the largest number of villages that are highly or very highly sensitive are OMal (7 villages), Ou Char (5) and wat Kor (5).

Figure 46: Battambang municipality: sensitivity per village, as defined by 5 parameters

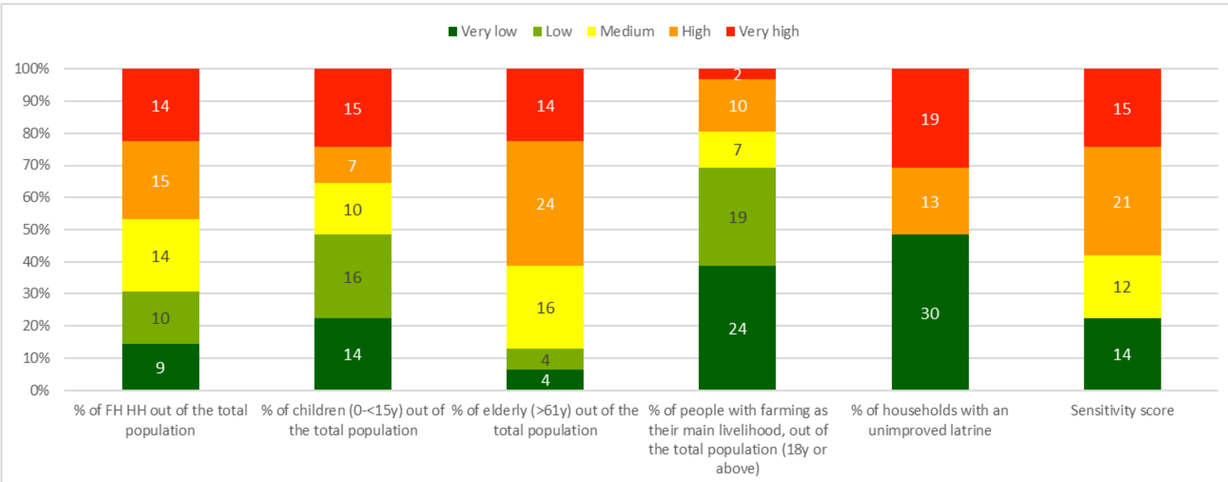
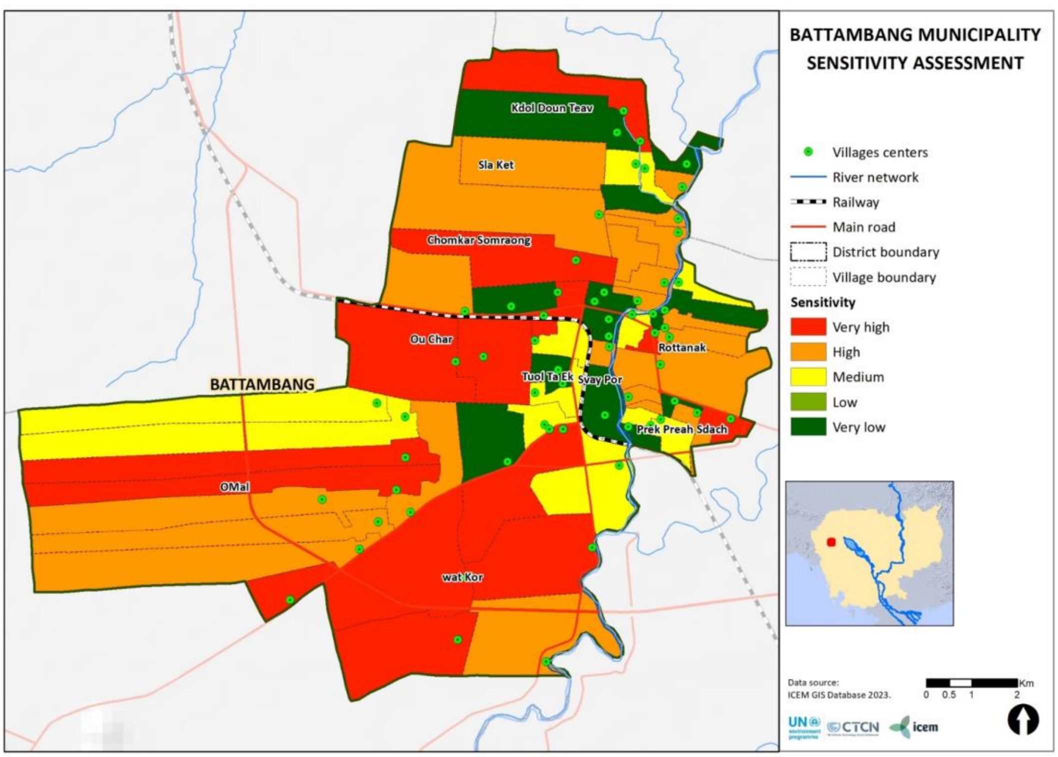


Figure 47: Battambang municipality: sensitivity per village to rainfall-induced floods



5.1.3 Impact of rainfall-induced floods for villages

Impact refers to the effects of hazards and climate change on natural and human systems or assets. Impact is a combination of the exposure and the sensitivity of systems or assets to specific hazards and threats.

From the CAM analysis, **11 out of the 62 villages (18%) in Battambang municipality are potentially very highly impacted by rainfall-induced floods**, 8 (13%) highly impacted, 17 (27%) medium impacted, 9 (15%) lowly impacted and 2 (3%) very lowly impacted (Figure 48 and Table 15). Impact levels are variable across the municipality (Figure 49), with Prek Preah Sdach and Rottanak communes having the highest number of villages highly to very highly impacted, 5 and 4 villages respectively.

Figure 48: Results of flood exposure, sensitivity and impact analysis for villages

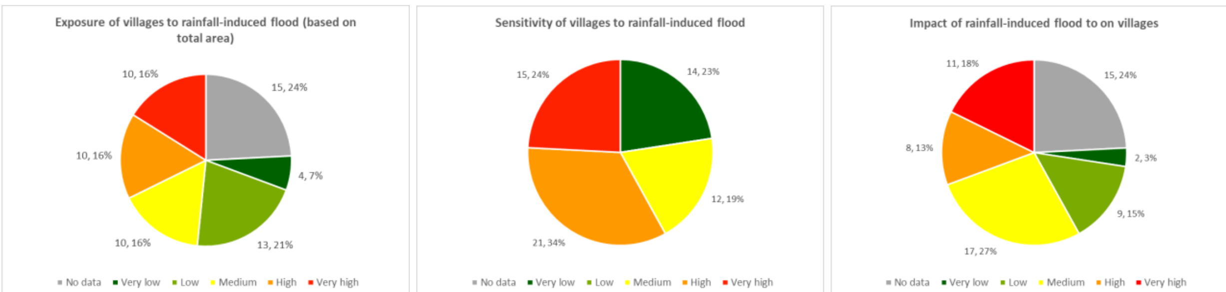
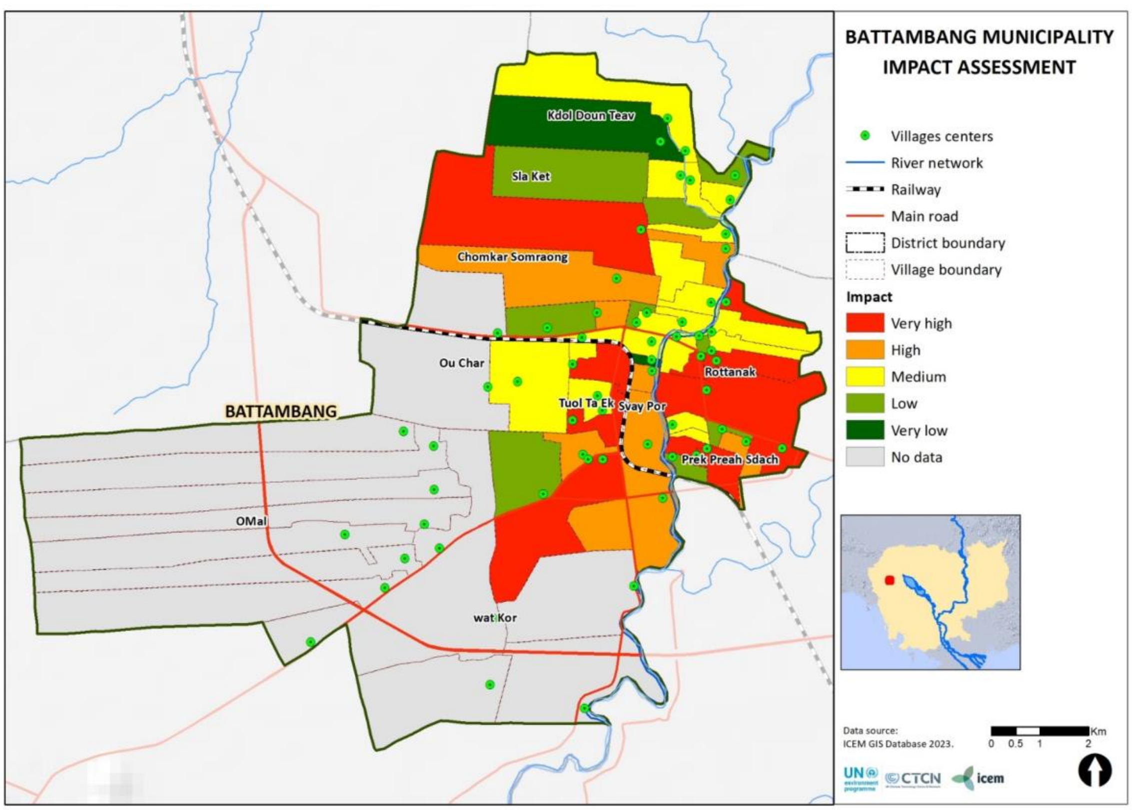


Table 15: Results of flood exposure, sensitivity and impact analysis for villages

CAM dimensions	Number of villages					
	Very low	Low	Medium	High	Very High	No data
Exposure	4	13	10	10	10	15
Sensitivity	14	0	12	21	15	0
Impact	2	9	17	8	11	15

Figure 49: Battambang municipality: impact per village for rainfall-induced floods



5.1.4 Adaptive capacity of villages to manage flood

Adaptive capacity is the ability to adjust to hazards and climate change threats, to moderate potential damage, to take advantage of opportunities or to cope with the consequences. For this risk assessment, adaptive capacity has been identified per village and for social parameters such as literacy levels, access to clean water for consumption, and distance to key services such as health and education, using 2019 census data. Adaptive capacity could not be assessed for the transport network, built-up area and schools and health facilities because there is no data available.

In terms of the adaptive capacity to hazards and climate change (as defined through the selected parameters), **the population in 34 out of the 62 villages (55%) in Battambang municipality can be considered as having very high capacity for dealing with floods**, 15 (24%) having high capacity, 10 (16%) having medium capacity, 1 (2%) having low capacity and 2 (3%) having very low capacity. See Figure 46 for a detailed overview for scoring on all the four sensitivity parameters. **Capacity is the lowest for the most southern located villages in wat Kor commune** (Figure 51).

Figure 50: Battambang municipality: adaptive capacity per village, as defined by 4 parameters

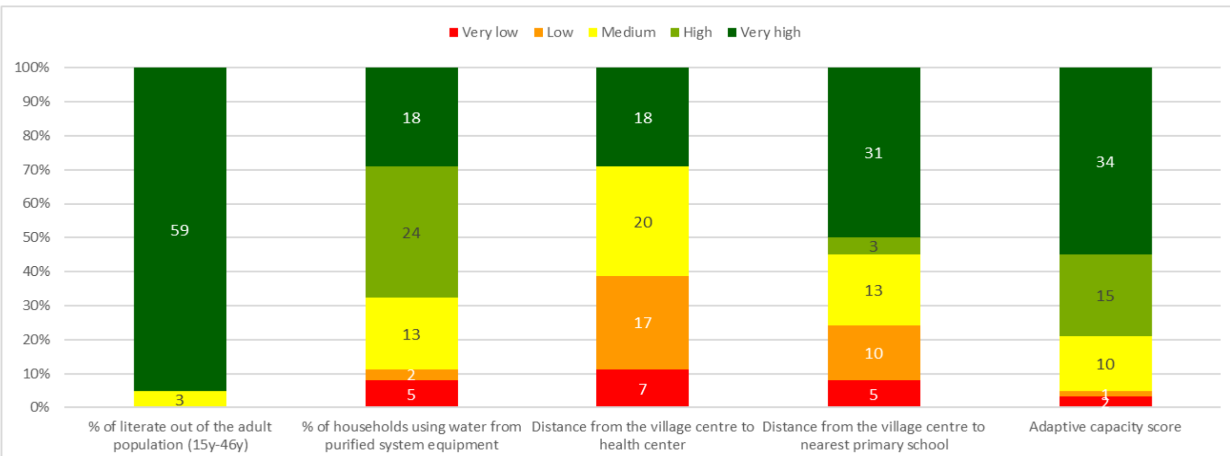
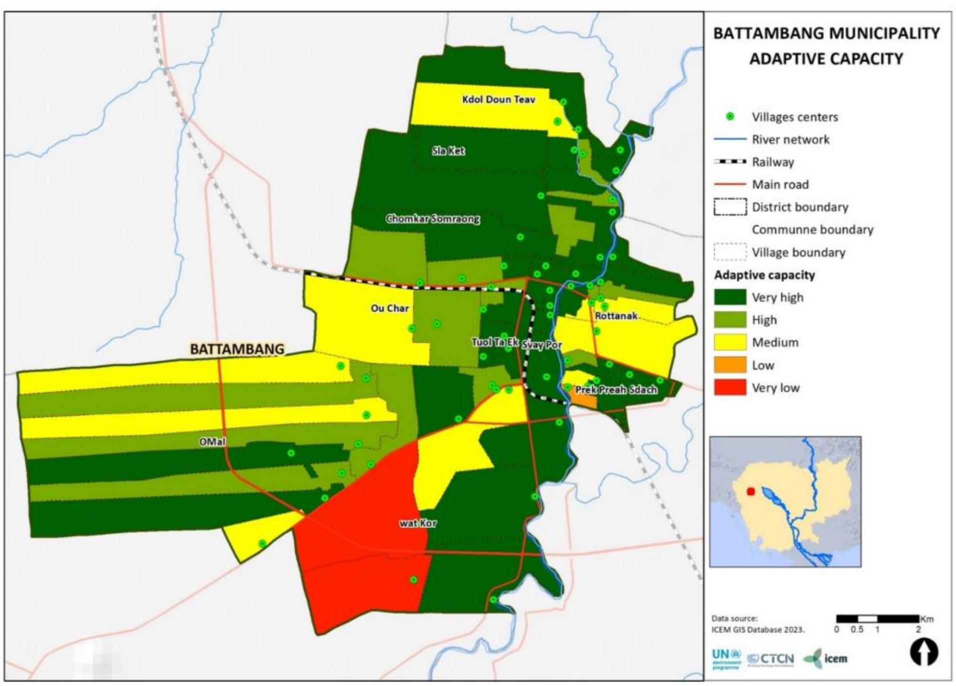


Figure 51: Battambang municipality: adaptive capacity per village for rainfall-induced floods



5.1.5 Vulnerability of villages to rainfall-induced flood

Vulnerability is the degree to which a system or asset is susceptible to, and unable to cope with, adverse effects of hazards and climate change. Vulnerability is a function of the exposure of a system or asset, its sensitivity and its adaptive capacity.

From the CAM assessment, **5 out of the 62 villages (8%) in Battambang municipality are very vulnerable to rainfall-induced floods**, 6 villages (10%) highly vulnerable, 16 villages (26%) medium vulnerable, 19 villages (31%) lowly vulnerable, and 1 village (1%) very lowly vulnerable (Figure 52 and Table 16). **23,475 people (14.2% of the total population), including 11,509 male and 11,966 female, are considered highly to very highly vulnerable to rainfall-induced floods**. **The majority of the very highly and highly vulnerable villages are in Rottanak and Prek Preah Sdach communes**, with 4 villages in each (Figure 53).

Figure 52: Results of flood impact, capacity and vulnerability analysis for villages

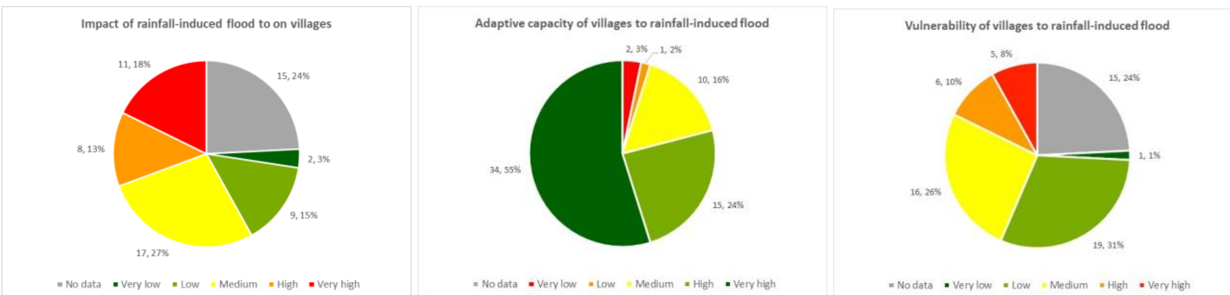
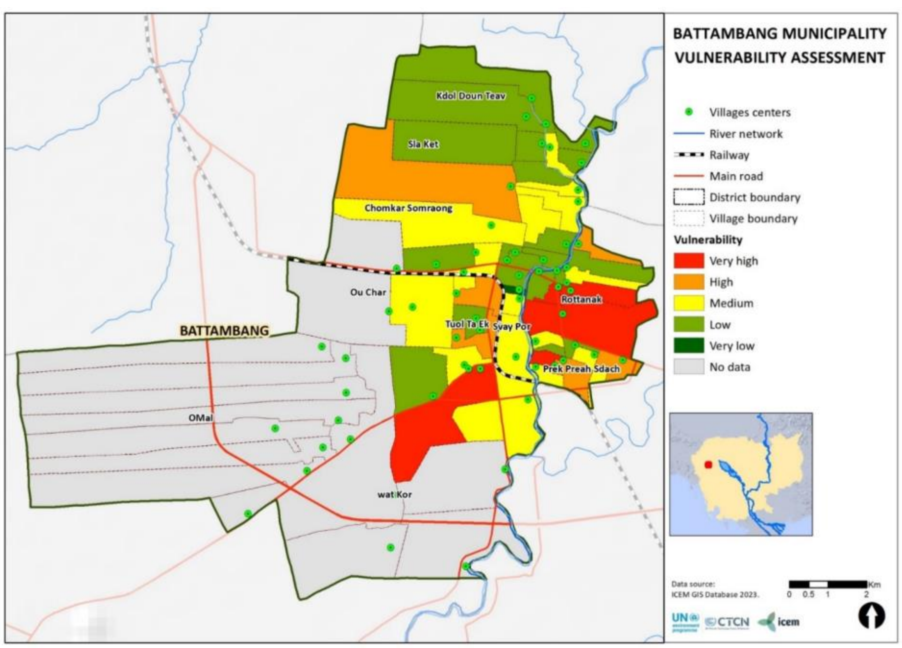


Table 16: Results of flood impact, capacity and vulnerability analysis for villages

Note: the colour-coding for the very low to very high classes for adaptive capacity should be reversed, as follows: very high (dark green) to very low (red).

CAM dimensions	Number of villages					
	Very low	Low	Medium	High	Very High	No data
Impact	2	9	17	8	11	15
Adaptive capacity	2	1	10	15	34	0
Vulnerability	1	19	16	6	5	15

Figure 53: Battambang municipality: vulnerability of villages to rainfall-induced floods



In terms of gender, **11,966 women (14.3% of all women) and 3,560 girls (15% of all girls) are considered highly to very highly vulnerable to rainfall-induced floods**, based on the CAM assessment (Table 17, Figure 54 and Figure 55). 236 women farmers (4.7% of all women farmers) are considered highly to very highly vulnerable. The highest number of high to very highly vulnerable women lives in Rotanak (3,633 women), Preaek Preah Sdach (3,411), Tuol Ta Aek (1,765), Sla Kaet (1,518) and wat Kor (1,518) communes. The highest number of high to very highly vulnerable girls lives in Rotanak (1,283 girls), Preaek Preah Sdach (1,071), wat Kor (468), Tuol Ta Aek (435) and Sla Kaet (303) and communes.

Vulnerability of men, women and girls is high to very high mainly because of high to very high impact (as a combination of exposure and sensitivity). Adaptive capacity levels are generally high to very high for most people in Battambang, except in some villages in wat Kor commune.

Table 17: Women and girls' vulnerability to floods, per village

Note: Each of the dimensions of vulnerability have been scored according to five classes: very low (VL), low (L), medium (M), high (H) and very high (VH). Where there is no data available, mainly for impact and vulnerability, 'Not Available' (NA) has been used.

Commune	Village	Impact	Adaptive capacity	Vulnerability	Women	Girls	Women farmers
Tuol Ta Aek	Ou Ta Kam Muoy	M	VH	L	2,311	602	9
	Ou Ta Kam Pir	M	VH	M	2,912	711	13
	Ou Ta Kam Bei	H	H	VH	752	190	0
	Tuol Ta Aek	VH	VH	M	3,124	798	0
	Dangkao Teab	M	H	VH	1,013	245	12
Preaek Preah Sdach	Preaek Preah Sdach	VH	VH	H	739	179	0
	Preaek Ta Tan	L	L	M	589	180	0
	Dabbei Meakkakra	H	VH	M	2,118	446	0
	Ou Khcheay	VH	VH	H	1,028	382	0
	La Edth	VH	VH	H	742	188	0
	Num Krieb	M	H	M	769	238	0
	Baek Chan Thmei	L	VH	L	869	285	0
	Chamkar Ruessei	VH	M	VH	902	322	0
Rotanak	Rumchek Muoy	L	H	L	1,481	391	0
	Rumchek Pir	M	H	M	598	229	0
	Rumchek Bei	VH	M	VH	708	289	32
	Rumchek Buon	VH	M	VH	1,605	531	30
	Rumchek Pram	VH	M	VH	613	218	0
	Souphi Muoy	VH	VH	H	707	245	9
	Souphi Pir	M	VH	L	751	163	19
	Rotanak	M	VH	L	1,342	528	0
Chamkar Samraong	Chamkar Samraong Muoy	H	VH	M	2,969	747	258
	Chamkar Samraong Pir	M	VH	L	2,584	463	165
	Voat Lieb	M	VH	L	2,264	398	0
	Voat Rumduol	M	VH	L	1,591	401	99
	Phka Sla	L	VH	L	1,061	181	10
Sla Kaet	Sla Kaet	M	H	M	828	291	5
	Dam Spey	H	VH	M	2,305	900	34
	Chrey Kaong	VH	VH	H	1,518	303	10

Commune	Village	Impact	Adaptive capacity	Vulnerability	Women	Girls	Women farmers
Kdol Doun Teav	Chong Preaek	M	VH	L	712	219	98
	Kdol	L	VH	L	705	165	0
	Ou Ta Nob	VL	M	L	772	174	0
	Ta Pruoch	M	VH	L	1,025	381	47
	Ta Koy	M	H	M	625	157	3
	Kantuot	M	VH	L	763	210	2
	Thkov	L	VH	NA	820	165	19
OMal	OMal	NA	M	NA	444	111	52
	Dak Sasar	NA	VH	NA	658	199	9
	Sala Balat	L	VH	L	651	174	129
	Prey Dach	NA	M	NA	542	137	225
	Kouk Ponley	NA	M	NA	624	221	126
	Voat Roka	NA	H	NA	678	164	235
	Koun Sek	NA	H	NA	347	99	60
	Andoung Pring	NA	H	NA	751	249	74
	Boeng Reang	NA	VH	NA	937	213	132
	Prey Roka	NA	H	NA	420	98	133
wat Kor	Wat Kor	H	VH	M	2,050	366	583
	Chrab Krasang	NA	VL	NA	2,005	295	677
	Ballang	NA	VL	NA	1,553	509	344
	Khsach Pouy	NA	VH	NA	1,404	344	605
	Damnak Luong	VH	M	VH	1,639	468	143
	Kampong Seima	NA	VH	NA	1,415	479	329
Ou Char	Ou Char	M	H	M	2,469	490	20
	Prey Koun Sek	NA	M	NA	606	113	234
	Kab Kou Thmei	H	VH	M	2,660	677	26
	Andoung Chenh	NA	H	NA	1,074	152	20
	Anhchanh	L	H	L	1,489	396	5
	Ang	M	H	M	1,668	678	19
Svay Pao	Preaek Moha Tep	L	VH	L	3,808	1,705	0
	Kampong Krabei	H	VH	M	1,927	1,039	0
	Mphey Osakphea	VL	VH	VL	2,131	804	0
	Kammeakkar	H	VH	M	3,641	1,116	0
				TOTAL:	**83,806**	**23,811**	**5,054**

Figure 54: Results of the vulnerability assessment overlaid with data on total number of women per village

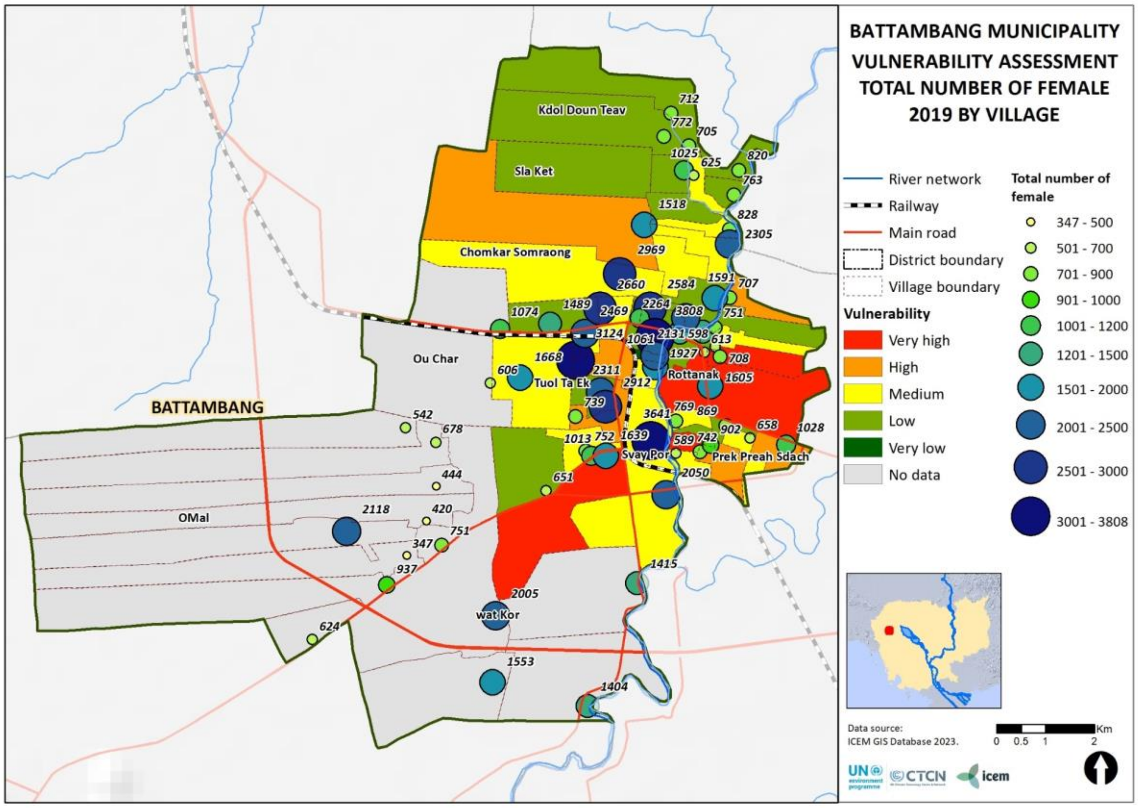
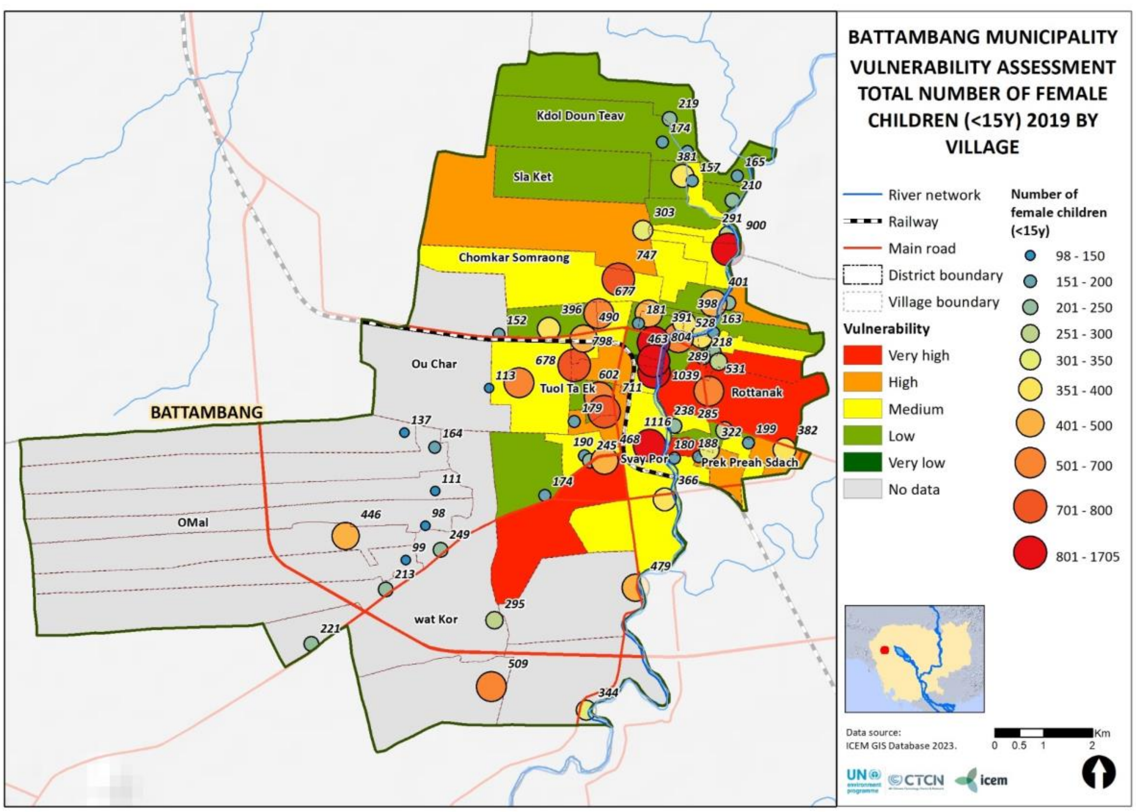


Figure 55: Results of the vulnerability assessment overlaid with data on total number of girls per village



5.2 Drought

5.2.1 Exposure to drought

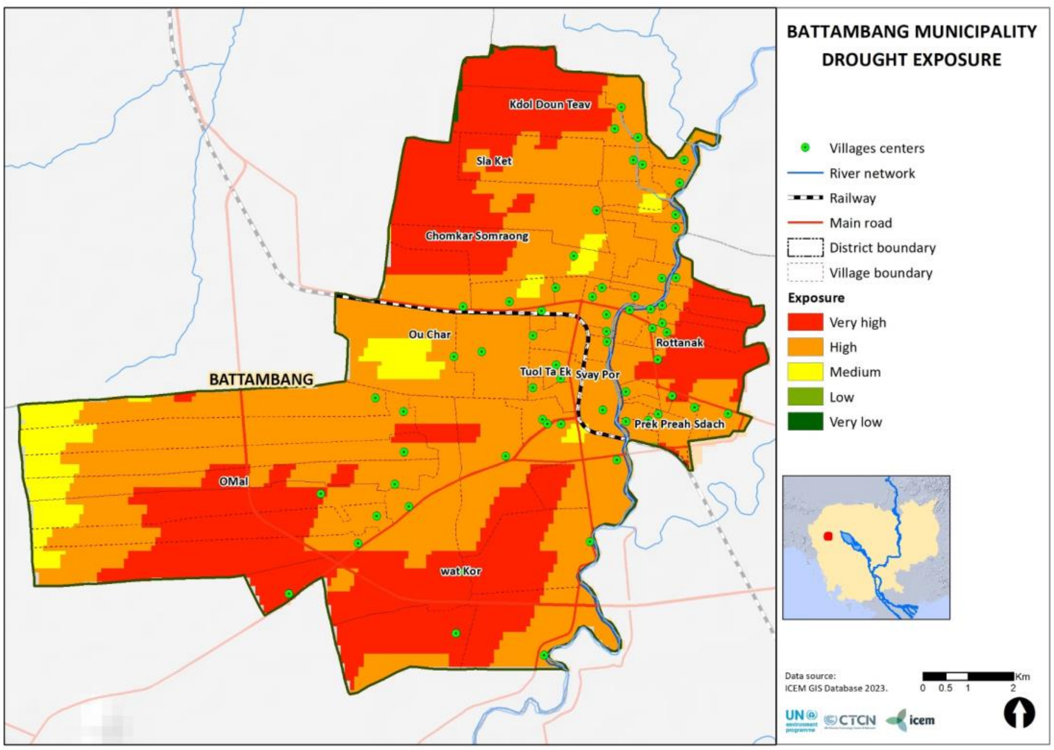
The exposure to drought was calculated for land as an asset (using 2017 SERVIR-Mekong land use data[29]) and based on the drought hazard map (using the normalized differentiated drought index, as shown in Figure 32).

Exposure to drought is high to very high for all land in the municipality, with **112.8km² or 95.1% of the total land exposed to high to very high drought levels** (Table 18 and Figure 56). None of the land is exposed to low or very low levels of drought.

Table 18: Battambang municipality: total land area exposed to drought

Exposure	Land area (km²)					Total land area (km²)
	Very low	Low	Medium	High	Very High	
Number	0.0	0.0	5.8	72.6	40.2	118.6
Percentage	0.0	0.0	4.9%	61.2%	33.9%	100.0%

Figure 56: Battambang municipality: land exposed to drought



5.2.2 Sensitivity of land to drought

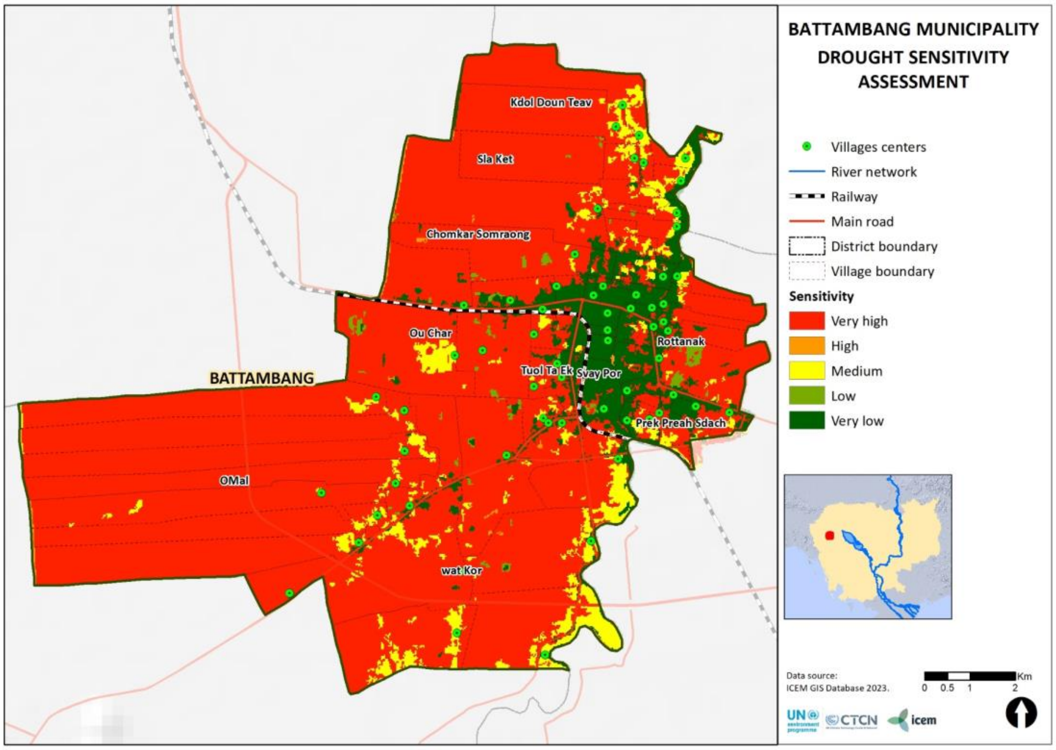
Sensitivity of land to drought was calculated based on the following assumptions of the various land uses and how they may be affected by drought and climate change: crop land, rice and wetland (very high sensitivity); aquaculture (high); orchard or plantation forest (medium); barren (low); and surface water and urban and built-up land (very low). The results are shown in Table 19 and Figure 57. **98.9km² or 83.4% of all land in Battambang municipality can be considered as very highly sensitive to drought.**

[29] USAID-NASA-ADPC Land Cover Portal. Last accessed on 20 April 2023.

Table 19: Battambang municipality: total land area sensitive to drought

Sensitivity	Land area (km²)					Total land area (km²)
	Very low	Low	Medium	High	Very High	
Number	11.5	0.7	7.3	0.2	98.9	118.6
Percentage	9.7%	0.6%	6.2%	0.2%	83.4%	100.0%

Figure 57: Battambang municipality: sensitivity of land to drought



5.2.3 *Impact of drought on land*

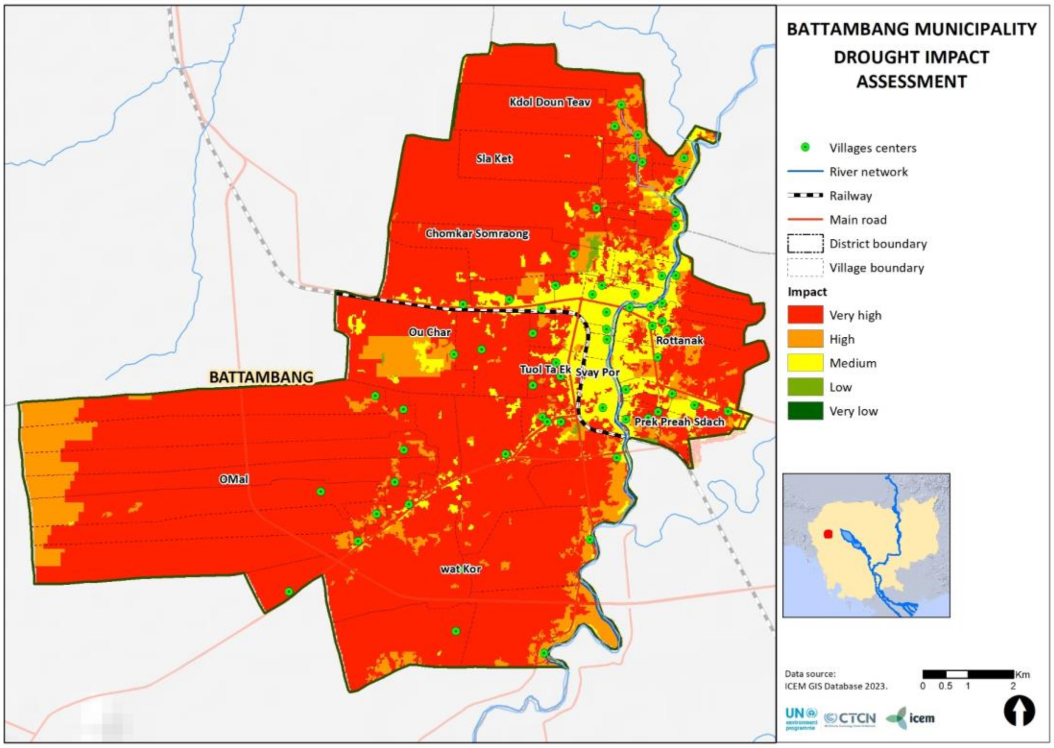
Combing the exposure and the sensitivity of land shows us the potential impact of drought.

Based on the CAM assessment, **94.3km² or 79.5% of all land in Battambang is potentially very highly impacted by drought** and 12.5km² or 10.5% highly impacted (Table 20 and Figure 58). There is a negligible amount of land lowly or very lowly impacted by drought.

Table 20: Battambang municipality: total land area potentially impacted by drought

Impact	Land area (km²)					Total land area (km²)
	Very low	Low	Medium	High	Very High	
Number	0.0	0.2	11.6	12.5	94.3	118.6
Percentage	0.0%	0.2%	9.8%	10.5%	79.5%	100.0%

Figure 58: Battambang municipality: potential impact of drought for land uses



6 CONCLUSION

Battambang municipality, the second largest city in Cambodia, is susceptible to several hydro-meteorological hazards such as flood, drought, fire and heatwaves. Floods in particular happen every year and have a devastating impact on the city's services, transport networks and people's livelihoods. On top of that, climate change is making the city wetter in the wet season and drier in the dry season, increasing the severity and duration of floods as well as droughts.

A risk assessment was carried out for various systems and assets in Battambang municipality to determine the impact and vulnerability for rainfall-induced (pluvial) floods and drought. The risk assessment concluded that:

Flood:

- 32% of all the villages in Battambang municipality is highly to very highly exposed to rainfall-induced floods. That accounts for 62,329 people (38% of the total population), including 30.565 male, 31,764 female and 9,208 girls.
- The majority of the villages with high to very high exposure are in Prek Preah Sdach, Rottanak, and Tuol Ta Aek communes.
- Exposure is set to increase with climate change, as rainfall during the wet season is expected to increase to 1,092 mm by 2050 (a 4.6% increase).
- The largest total land area exposed to flood is in Rottanak, Tuol Ta Ek and Prek Preah Sdach communes, with Rottanak commune considerably higher than all other communes;
- 741.3ha of the city's built-up area (25% of the total) is exposed to rainfall-induced flood, of which 431ha is exposed to significant or extreme flood hazard levels. The communes with the highest total built-up area exposed to flood are Prek Preah Sdach and Rottanak communes, with Rottanak having the largest built-up area exposed to extreme and significant flood hazard levels;
- 11km of main roads (21% of the total) and 155.4km of other roads (27% of the total) are exposed to rainfall-induced flood, of which 6.2km of main roads and 85.2km of other roads are exposed to significant or extreme flood hazard levels;
- 1.8km out of the total 9km (20%) of railway in the municipality is exposed to rainfall-induced floods, with 0.8km exposed to significant or extreme flood hazard levels;
- 25 schools (33% of the total) and 3 health facilities (33%) are exposed to rainfall-induced flood, with 11 schools and 2 health facilities exposed to significant or extreme flood hazard levels. 4 out of 7 schools in Prek Preah Sdach commune are exposed to significant flood hazard levels;
- 58% of all the villages is highly sensitive to hazards and climate change, while 79% of all the villages has high to very high adaptive capacity to cope with the hazards and climate change. Sensitivity is the highest in villages in OMal and Ou Char communes, while capacity the lowest in wat Kor commune.
- For the villages with high exposure and high sensitivity, the impact of rainfall floods is high. Potential impacts include inundation and damage of houses and infrastructure, loss of crops, reduced access to markets and services, disruption of economic activities, and unsafe water and sanitation conditions.
- 18% of all villages is considered highly to very highly vulnerable to rainfall-induced floods. The majority of the very highly and highly vulnerable villages are in Rottanak and Prek Preah Sdach communes. 27,446 people (16% of the total population) living in these villages, including 13,347 male, 14,099 female and 4,069 girls, can therefore be considered highly to very highly vulnerable.

Drought:

- Exposure to drought is high to very high for all land in Battambang municipality, with 112.8km^2 or 95% of the total land exposed to high to very high drought levels. Several parts of the city have experienced dry to very dry drought conditions, such as the south-western, north-western and eastern parts.

- 98.9km^2 or 83% of all land in Battambang municipality can be considered as very highly sensitive to drought.
- 94.3km^2 or 80% of all land in Battambang is potentially very highly impacted by drought and 12.5km^2 or 11% highly impacted.

Further data collection and qualitative assessment are required to strengthen the risk assessment results. However, the findings from this risk assessment can already support the prioritization of adaptation investments, in a context of limited resources.

APPENDIX 1: RESULTS OF A CLIMATE IMPACT AND VULNERABILITY ASSESSMENT FOR 7 COMMUNES IN BATTAMBANG MUNICIPALITY CONDUCTED IN 2017

This appendix shows the results of a qualitative climate impact and vulnerability assessment conducted in February-April 2017 for 7 communes in Battambang, all located west of the Sangker river: **wat Kor, O Mal, Tuol Ta Ek, Ou Char, Chomkar Somraong, Sla Ket and Kdol Doun Teav.**[30] The CAM was applied as methodology for this assessment. Three hazard and climate change threats were considered: **rainfall-induced flood, riverine flood and drought.** The assessment focused on drainage and irrigation canals within those communes, its exposure and sensitivity to projected climate change, the likely impact of those changes, and the capacity of the stakeholders to respond to those impacts.

Overall, the results show that the 7 communes are highly exposed to rainfall-induced and riverine floods, and has medium-high exposure to droughts (Table 21). The adaptive capacity of the municipality is rated low to medium. Consequently, the municipality is considered vulnerable to rainfall and riverine floods, with medium-level vulnerability to droughts. These results are explained below.

Vulnerability to rainfall-induced floods

The seven communes were assessed to be highly exposed to rainfall-induced floods. They experience heavy rainfall during the wet season (around 1,095 mm) and are located on a low-lying, relatively flat ground, which makes natural drainage of rainwater difficult. This exposure is set to increase with climate change, as rainfall during the wet season is expected to increase to 1,182 mm by 2050 (an 8% increase).

The communes are also highly sensitive to rainfall floods, primarily due to the lack of an adequate sewer network (with only 17% of the central area to the west of the river connected). In addition, many drains, open canals (including Kampong Siema canal) and natural streams lack discharge capacity because they are blocked by new buildings and commercial establishments, clogged with solid wastes dumped by local residents, and overgrown with plants and algae. The lack of effective wastewater treatment facilities (with existing waste water treatment plant treating only 50-400 m^3 of wastewater per day) leads to mixing of wastewater and flood water, with consequent negative health impacts. Most economic activities are affected (particularly agriculture), many households are not flood-proof, and non-road transport is non-existent. Sensitivity is also heightened by high levels of poverty: poor households – particularly 47 slum households living on the canal – are extremely sensitive to floods due to reduced mobility, inadequate housing and reliance on economic activities that are halted by floods (e.g. working as street vendors and motorcycle taxies).

Due to a combination of high exposure and high sensitivity, the impact of rainfall floods is rated as high. Impacts include (among others) halting of many economic activities, inundation and damage of homes and infrastructure, reduced access to markets and various facilities, destruction of crops and unsanitary living conditions, and increase in water-borne diseases.

The seven communes are assessed as having low adaptive capacity to rainfall floods. Improving drainage west of Sangke river is not included in current (2017) government plans or proposed projects. A large share of the population west of the river (including Ou Char, Tuol Ta Ek, O Mal and Wat Kor, and large sections of Sla Ket and Chomkar Somraong communes) is not connected to the existing waste water treatment plant or the new waste water treatment plant proposed, meaning that wastewater in these

[30] ICEM. 2018. *TA 8179-CAM: Mainstreaming Climate Resilience into Development Planning – Package 1, Feasibility Study: Battambang Western Greenbelt Adaptation Project (Battambang Province).* Prepared for Ministry of Environment and Asian Development Bank.

areas will continue to be mixed with flood water for the foreseeable future. The arrangements for canal maintenance and related financing appear to be non-existent.[31]

Due to a combination of high exposure, high sensitivity and low adaptive capacity, the seven targeted communes are considered to be highly vulnerable to rainfall-induced floods.

Vulnerability to riverine floods

The seven communes were assessed to be highly exposed to riverine floods. They are located on the banks of the Sangker river, which is an alluvial river (meaning that the elevation along the river bank is higher than that of the town centre). Sangker river water level of 12.5 m or higher is sufficient to cause riverine flooding in the city as water overflows the river banks.[32] Severe riverine floods occurred in 1993, 1994, 2006, 2011 and 2013, with depth up to 1 m and lasting up to seven days.

The existing 2 km of river embankment protection (from the highway bridge to H.E. Sor Kheng bridge) were constructed in 2007. Due to strong currents and heavy downpours during the rainy season, 170 m of protection structures have been severely damaged.[33] Consequently, there are sections where the inundated water freely flows from the river to the town centre, further exacerbating exposure.[34]

The sensitivity of the seven communes to riverine floods is similar to rainfall floods, and hence also rated as high. Notably, drainage of flood waters into the Sangker river is an option during rainfall floods, but not during riverine floods.

Due to a combination of high exposure and high sensitivity, the impact of riverine floods is rated as high. The impacts of riverine floods are similar to those of rainfall floods, but also include erosion of river banks.

As with rainfall floods, the seven communes are assessed as having low adaptive capacity to riverine floods. This is due to lack of plans to improve the drainage system and wastewater treatment west of the Sangker river in the foreseeable future, and the existing (2017) lack of arrangements for canal maintenance and related financing.

Due to a combination of high exposure, high sensitivity and low adaptive capacity, the seven targeted communes are considered to be highly vulnerable to riverine floods.

Vulnerability to droughts

The seven communes are assessed as being highly exposed to droughts. During the dry season, they experience high maximum temperatures (around 32.6°C) and lack of rainfall (235 mm). The late onset of the wet season is also frequent. The most recent droughts occurred in 2014 and 2015, lasting 3-4 months. This exposure is set to increase with climate change, with maximum dry-season temperatures expected to increase to 34.5°C by 2050, and dry-season rainfall is expected to decrease slightly (to 234 mm).

The sensitivity of the seven communes to droughts is rates as medium. Rain-fed agriculture accounts for 75% municipality's area. Less than 1% of the agricultural land is irrigated because irrigation infrastructure is largely undeveloped, despite the proximity of the Sangker river. Existing infrastructure (2017) which can potentially be used for irrigation – natural streams and open canals, including Kampong Siema – lack discharge capacity because they are blocked by buildings, clogged with solid waste, and overgrown with

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[31] Field visits, including conversation with Battambang municipal government on 24 October 2017.

[32] ADB. 2015. *Building Urban Resilience in Battambang, Cambodia.* Volume 5 of the Resource Kit for Building Resilience and Sustainability in Mekong Towns. Prepared by ICEM for the Asian Development Bank and Nordic Development Fund.

[33] MPWT. 2012. *Resettlement Plan - CAM: Greater Mekong Subregion Corridor Towns Development Project, Battambang Wastewater Treatment*.

[34] ADB. 2012. *Project Manual - Kingdom of Cambodia: Greater Mekong Subregion Southern Economic Corridor Towns Development Project.*

plants and algae. These potential sources of irrigation water are also polluted with wastewater due to inadequate wastewater treatment. Blockage of the water intake at both ends of the Kampong Siema canal due to bank collapse, disrepair of the pumping station, and disrepair of canal culverts further prevent the use of Sangke river waters for irrigation. The municipality also lacks green space, resulting in high degrees of heat stress for its residents. However, the sensitivity to drought is reduced by the fact that agriculture is the main source of income for only 27.2% of municipality's residents, which is low compared to rural areas.

Due to a combination of high exposure and medium sensitivity, the impact of droughts is rated as medium. The impacts include loss of agricultural production and livestock due to lack of water and late planting of rice, with consequent food insecurity and loss of farming income.[35] Droughts also decrease the quality of water in existing canals, making it unsuitable for irrigation.

The target communes are considered to have medium adaptive capacity to droughts. There are no existing government plans (2017) for improving irrigation infrastructure in the municipality, and arrangements for maintaining the existing canals (including Kampong Siema) appear to be non-existent. However, the municipality is experiencing rapid urbanization with significant growth in the number of markets, clinics, hotels and guesthouses over the last decade.[36] This trend is expected to continue, further reducing the dependence of households on agriculture (and thus reducing their sensitivity to drought).

Due to a combination of high exposure, medium sensitivity and medium adaptive capacity, the targeted communes are considered to have medium-level vulnerability to droughts.

[35] For example, according to Chomkar Somraong commune council, the 2014-2015 droughts reduced rice production for 20% of households in the commune. According to Kdol Doun Teav commune council, the drought impacted 150 ha of wet-season rice crop by forcing households to shift to short-duration rice when the rain finally came (consultations held in October 2017).
[36] EGIS. 2016. *TA-8556 REG: Supporting the Cities Development Initiative for Asia—Prefeasibility Study and Preliminary Engineering-PWSSP (47285-001)*. Appendix H5: Preliminary Design Report - Battambang Subproject.

Table 21: Results of a 2017 impact and vulnerability assessment of 7 communes in Battambang municipality

Asset	Threat	Interpretation of threat	Exposure	Sensitivity	Impact	Impact summary	Adaptive Capacity	Vulnerability
wat Kor, O Mal, Tuol Ta Ek, Ou Char, Chomkar Somraong, Sla Ket, Svay Por and Kdol Doun Teav communes	Rainfall flood	• Regular occurrence during the wet season (Jun-Dec) • Caused by intensive rainfall and exacerbated by the low absorptive capacity • Flood depth of up to 0.5m, lasting up to seven days • Severity expected to increase with climate change due to increased rainfall during the wet season (up by 8% by 2050)	H	H	H	• Inundation and damage of homes and infrastructure • Flooding and erosion of the majority of urban roads, reducing access to markets and various facilities (schools, hospitals, temples), increasing road maintenance costs and halting economic activity • Destruction of crops (particularly in lowland areas) and damage to soil quality • Erosion of town canals, reducing drainage • Flood debris blocking and causing sedimentation of drainage systems, reducing their discharge capacity • Unsanitary living conditions, particularly for floods that last more than 5 days • Increase in water-borne diseases and diseases spread by mosquitos (malaria, dengue fever)	L	H
	Riverine flood	• Occurs when Sangke river water level rises to 12.5 m or higher, which is sufficient to cause water overflows of the river banks. • Exacerbated by 170 m of river embankment protection being damaged, meaning there are sections where the inundated water freely flows from the river to the town centre. • Occurred in 1993, 1994, 2006, 2011 and 2013 • Depth up to 1 m and lasting up to 20 days. • Severity expected to increase with climate change due to increase n wet-season rainfall in the upper catchment (increasing maximum discharge by 16% by 2050)	H	H	H	• Halting of economic activities • Inundation and damage of homes and infrastructure • Flooding and erosion of the majority of urban roads, reducing access to markets and various facilities (schools, hospitals, temples) and increasing road maintenance costs • Destruction of crops (particularly in lowland areas) and damage to soil quality • Erosion of banks of Sangke river and town canals, reducing drainage • Flood debris blocking and causing sedimentation of drainage systems, reducing their discharge capacity • Unsanitary living conditions, particularly for floods that last more than 5 days • Increase in water-borne diseases and diseases spread by mosquitos (malaria, dengue fever)	L	H

Asset	Threat	Interpretation of threat	Exposure	Sensitivity	Impact	Impact summary	Adaptive Capacity	Vulnerability
	Drought	• Caused by the lack of rainfall during November-May and frequent delay of the wet season • Exacerbated by the lack of irrigation infrastructure and lack of green space • Most recently occurred in 2014 and 2015, lasting 3-4 months • Severity expected to increase with climate change due to increases in temperature (+1.9°C) and decreases in rainfall (-0.5%) during the dry season by 2050	H	M	M	• Loss of agricultural production and livestock, leading to decreased food security and reduced farmer incomes • Decrease in the quality of water in town canals (making it unsuitable for irrigation). • Heat stress for residents due to lack of green space	M	M

APPENDIX 2: DETAILED RISK ASSESSMENT RESULTS PER VILLAGE

Table 22 provides the detailed results per village of the vulnerability assessment. Vulnerability has been assessed as a combination of sensitivity, exposure, impact and adaptative capacity using the following function: *vulnerability = impact (=exposure*sensitivity) / adaptive capacity*. Data derived from available models, census and participatory mapping has been used to determine exposure, sensitivity and adaptive capacity of the selected assets. Each of these aspects of impact and vulnerability were reclassified into five classes (very low to very high) using a quintile analysis. To score impact and vulnerability, CAM matrices have been applied (Figure 2).[37]

Each of the dimensions of vulnerability have been scored according to five classes: very low (VL), low (L), medium (M), high (H) and very high (VH). Where there is no data available, mainly for flood exposure, impact and vulnerability, 'Not Available' (NA) has been used.

Table 22: Detailed scores on vulnerability for each of the villages

Commune	Village	Sensitivity						Flood exposure	Impact	Adaptive capacity					Vulnerability
		% of FH HH out of the total population	% of children (0-<15y) out of the total population	% of elderly (>61y) out of the total population	% of people with farming as their main livelihood, out of the total population (18y or above)	% of households with an unimproved latrine	Sensitivity			% of literate out of the adult population (15y-46y)	% of households using water from purified system equipment	Distance from the village centre to health center	Distance from the village centre to nearest primary school	Adaptive capacity	
Chamkar Samraong	Chamkar Samraong Muoy	M	M	H	M	VH	VH	M	H	VH	H	VH	M	VH	M
	Chamkar Samraong Pir	L	VL	M	L	H	VL	H	M	VH	H	VH	VH	VH	L
	Phka Sla	L	VL	H	VL	VL	VL	L	L	VH	H	M	H	VH	L
	Voat Lieb	VH	VL	VH	VL	H	H	M	M	VH	VH	M	M	VH	L
	Voat Rumduol	VH	L	M	L	H	H	M	M	VH	H	L	VH	VH	L
Kdol Doun Teav	Chong Preaek	H	H	M	M	VH	VH	VL	M	VH	H	L	VH	VH	L
	Kantuot	H	M	M	L	H	H	L	M	VH	VH	VH	VH	VH	L
	Kdol	M	L	H	VL	VH	H	VL	L	VH	M	M	VH	VH	L
	Ou Ta Nob	M	L	H	L	VL	VL	VL	VL	VH	H	VL	L	M	L

[37] A comprehensive CAM guide is available in English and Khmer. The guide lays out a step-by-step process for assessing climate change impacts and vulnerabilities and for preparing and implementing adaptation plans. The guide includes templates and matrices that can be used to record data, create plans, and assist with prioritizing adaptation measures.

Commune	Village	Sensitivity								Adaptive capacity					
		% of FH HH out of the total population	% of children (0-<15y) out of the total population	% of elderly (>61y) out of the total population	% of people with farming as their main livelihood, out of the total population (18y or above)	% of households with an unimproved latrine	Sensitivity	Flood exposure	Impact	% of literate out of the adult population (15y-46y)	% of households using water from purified system equipment	Distance from the village centre to health center	Distance from the village centre to nearest primary school	Adaptive capacity	Vulnerability
	Ta Koy	H	L	H	L	VL	M	L	M	VH	H	L	M	H	M
	Ta Pruoch	VL	VH	VL	L	H	M	L	M	VH	H	L	VH	VH	L
	Thkov	H	VL	H	L	VL	VL	L	L	VH	H	VH	VH	VH	L
Ou Char	Andoung Chenh	L	VL	VH	L	VH	H	NA	NA	VH	M	L	VH	H	NA
	Ang	VH	VH	H	L	VL	VH	L	M	VH	H	VL	VH	H	M
	Anhchanh	H	L	H	VL	VL	VL	M	L	VH	H	M	M	H	L
	Kab Kou Thmei	H	M	H	L	VH	VH	M	H	VH	H	M	VH	VH	M
	Ou Char	H	VL	VH	L	VH	VH	L	M	VH	VH	L	M	H	M
	Prey Koun Sek	M	M	VH	VH	VH	VH	NA	NA	VH	H	VL	VL	M	NA
OMal	Andoung Pring	H	VH	M	M	VL	H	NA	NA	VH	M	VH	L	H	NA
	Boeng Reang	M	L	M	M	VH	H	NA	NA	VH	M	VH	VH	VH	NA
	Dak Sasar	M	M	VH	H	VL	H	NA	NA	VH	M	M	VH	VH	NA
	Kouk Ponley	H	VH	M	H	VL	VH	NA	NA	VH	VL	L	VH	M	NA
	Koun Sek	VL	M	M	H	VH	H	NA	NA	VH	L	VH	M	H	NA
	OMal	H	VL	H	M	VH	VH	NA	NA	VH	L	M	M	M	NA
	Prey Dach	M	L	M	VH	VL	M	NA	NA	VH	VL	L	VH	M	NA
	Prey Roka	VH	VL	VH	H	H	VH	NA	NA	VH	M	M	M	H	NA
	Sala Balat	M	L	L	M	VL	VL	L	L	VH	H	L	VH	VH	L
	Voat Roka	L	L	H	H	VL	M	NA	NA	VH	VL	M	VH	H	NA
Preaek Preah Sdach	Baek Chan Thmei	L	M	M	VL	VL	VL	M	L	VH	VH	M	VH	VH	L
	Chamkar Ruessei	VL	VH	L	VL	VH	M	VH	VH	VH	H	L	L	M	VH
	Dabbei Meakkakra	H	VL	H	VL	VH	H	H	H	VH	VH	M	VH	VH	M

Commune	Village	Sensitivity								Adaptive capacity					
		% of FH HH out of the total population	% of children (0-<15y) out of the total population	% of elderly (>61y) out of the total population	% of people with farming as their main livelihood, out of the total population (18y or above)	% of households with an unimproved latrine	Sensitivity	Flood exposure	Impact	% of literate out of the adult population (15y-46y)	% of households using water from purified system equipment	Distance from the village centre to health center	Distance from the village centre to nearest primary school	Adaptive capacity	Vulnerability
	La Edth	VH	L	VH	VL	VL	M	VH	VH	VH	H	L	VH	VH	H
	Num Krieb	VH	H	VH	VL	VL	H	M	M	VH	VH	M	VL	H	M
	Ou Khcheay	VH	VH	L	VL	VH	VH	H	VH	VH	H	VH	M	VH	H
	Preaek Preah Sdach	VL	L	VH	VL	H	M	VH	VH	VH	VH	M	H	VH	H
	Preaek Ta Tan	H	H	VL	VL	VL	VL	L	L	M	M	L	L	L	M
Rotanak	Rotanak	L	VH	H	VL	VL	M	M	M	VH	H	L	VH	VH	L
	Rumchek Bei	L	VH	VL	L	VH	H	VH	VH	VH	VH	L	VL	M	VH
	Rumchek Buon	H	H	H	L	VL	H	VH	VH	VH	H	VL	M	M	VH
	Rumchek Muoy	M	L	H	VL	VL	VL	L	L	VH	VH	M	L	H	L
	Rumchek Pir	VH	VH	H	VL	VL	H	L	M	VH	M	M	M	H	M
	Rumchek Pram	H	VH	VH	VL	VH	VH	H	VH	VH	M	L	L	M	VH
	Souphi Muoy	L	H	VH	L	VL	M	VH	VH	VH	VH	M	VH	VH	H
	Souphi Pir	M	L	M	L	VL	VL	H	M	VH	H	VH	H	VH	L
Sla Kaet	Chrey Kaong	VH	VL	H	L	H	H	VH	VH	VH	H	VH	VH	VH	H
	Dam Spey	VL	VH	M	L	VH	H	H	H	VH	H	VH	M	VH	M
	Sla Kaet	VH	M	L	L	H	H	M	M	VH	M	VH	L	H	M
Svay Pao	Kammeakkar	VL	M	H	VL	VL	VL	VH	H	VH	VH	M	VH	VH	M
	Kampong Krabei	VH	VH	M	VL	VL	H	H	H	VH	VH	M	VH	VH	M
	Mphey Osakphea	VL	VH	H	VL	VL	VL	VL	VL	VH	VH	VH	L	VH	VL
	Preaek Moha Tep	VL	VH	H	VL	VL	VL	L	L	VH	VH	VH	VH	VH	L
Tuol Ta Aek	Dangkao Teab	VH	VL	M	L	VH	H	L	M	VH	VH	M	VL	H	VH
	Ou Ta Kam Bei	VH	L	VH	VL	VL	M	H	H	VH	VH	L	L	H	VH

Commune	Village	Sensitivity								Adaptive capacity					
		% of FH HH out of the total population	% of children (0-<15y) out of the total population	% of elderly (>61y) out of the total population	% of people with farming as their main livelihood, out of the total population (18y or above)	% of households with an unimproved latrine	Sensitivity	Flood exposure	Impact	% of literate out of the adult population (15y-46y)	% of households using water from purified system equipment	Distance from the village centre to health center	Distance from the village centre to nearest primary school	Adaptive capacity	Vulnerability
	Ou Ta Kam Muoy	L	M	VL	VL	VL	VL	H	M	VH	M	VH	VH	VH	L
	Ou Ta Kam Pir	M	L	VH	VL	VH	H	M	M	M	H	VH	VH	VH	M
	Tuol Ta Aek	M	L	M	VL	H	M	VH	VH	VH	VH	M	VH	VH	M
Wat Kor	Ballang	M	VH	M	H	H	VH	NA	NA	M	VL	VL	M	VL	NA
	Chrab Krasang	H	VL	H	H	H	VH	NA	NA	VH	VL	VL	VL	VL	NA
	Damnak Luong	VL	H	VH	M	VH	VH	VH	VH	VH	H	VL	L	M	VH
	Kampong Seima	L	H	H	H	H	VH	NA	NA	VH	M	VH	VH	VH	NA
	Khsach Pouy	VH	VL	H	H	VL	H	NA	NA	VH	M	VH	VH	VH	NA
	Wat Kor	M	VL	H	H	VL	M	H	H	VH	VH	L	VH	VH	M

APPENDIX 3: VULNERABILITY ASSESSMENT FIELD REPORT TEMPLATE

The following template can be used by municipal stakeholders to conduct a vulnerability assessment in the field, for specific assets such as infrastructure, services or communities. Step-by-step guidance on how to apply the template is available in English and Khmer.

CLIMATE CHANGE THREATS	DESCRIPTION OF THREATS
Change and shift in regular climate Increase/decrease in temperature Increase/decrease in precipitation Increase/decrease in flow **Change and shift in events** Riverine flooding Extreme localised pooling/flooding Flash floods Storms Landslides Droughts	**DESCRIPTION OF THREATS** circle relevant threat in list provided and describe how it relates to the target system and its components.

EXPOSURE Description	**SCORE**
SENSITIVITY Description	**SCORE**
IMPACT Description	**SCORE**
ADAPTIVE CAPACITY Description	**SCORE**
VULNERABILITY SCORE: Refer to guiding matrix to help identify the vulnerability score	

Impact Scoring Matrix

Sensitivity of system to climate threat	Exposure of system to climate threat: Very Low	Low	Medium	High	Very High
Very High	Medium	Medium	High	Very High	Very High
High	Low	Medium	Medium	High	Very High
Medium	Low	Medium	Medium	High	Very High
Low	Low	Low	Medium	Medium	High
Very Low	Very Low	Low	Low	Medium	High

VULNERABILITY ASSESSMENT MATRIX:

System:
Major components:
1.
2.
3.
4.
5.

Threat	Interpretation of Threat	Exposure	Sensitivity	Impact	Impact Summary	Adaptive Capacity	Sensitivity
Change and shift in regular climate	Written description of how the threat relates to the system	Refer to table			Written explanation of impact and explanation for score	Refer to table	
Change and shift in events							

1 *Include footnotes*
2
3
4

Summary

Threat	Exposure	Sensitivity	Impact Level	Adaptive Capacity	Vulnerability
1					
2					
3					

Concluding statement

Command area least vulnerable to increased temperature and rainfall whilst intake most vulnerable to flash floods. The main canal is more vulnerable to sedimentation and landslide problems.

Vulnerability Scoring Matrix

Adaptive Capacity \ Impact	Very Low Inconvenience (days)	Low Short disruption to system function (weeks)	Medium Medium disruption to system function (months)	High Long term damage to system, property (years)	Very High Loss of life, livelihood, or system integrity
Very Low Very limited institutional capacity and no financial resources	Medium	Medium	High	Very High	Very High
Low Limited institutional capacity and limited access to technical and financial resources	Low	Medium	Medium	High	Very High
Medium Growing institutional capacity and access to technical and financial resources	Low	Medium	Medium	High	Very High
High Sound institutional capacity and good access to technical and financial resources	Low	Low	Medium	Medium	High
Very High Exceptional institutional capacity and abundant access to technical and financial resources	Very Low	Low	Low	Medium	High

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