Reducing the Vulnerability of Cambodian Rural Livelihoods through Enhanced Sub-national Climate Change Planning and Execution of Priority Actions (SRL)

GIS Consultancy

FOR

VULNERABILITY MAPPING DEVELOPMENT

TECHNICAL REPORT

Submitted to

Project Management

Department of Climate Change (DCC) of the General Secretariat of the National Council for Sustainable Development (GSSD)

Ministry of Environment

Morodok Techo Building, Lot 503, Sangkat Tonle Bassac, Khan Chamkarmon, Phnom Penh, Cambodia

April 2018

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1. Introduction

1.1. Background

Climate change vulnerability is a core target issue which is needed to be assessed in the project entitled "Reducing the Vulnerability of Cambodian Rural Livelihoods through Enhanced Sub-national Climate Change Planning and Execution of Priority Actions (SRL)". The project has the objective to improve Sub-national administration systems affecting investments in rural livelihoods through climate sensitive planning, budgeting and execution. One of many tasks in the project, vulnerability identification through mapping is important for sub-national administration to put into consideration for development priority area. Climate change vulnerability map is a tool for identifying level of risk due climate related hazard and condition of community resilience. This report is trying to summary the working package for producing the map of vulnerability index. It describes the methodological framework, data acquisition and result discussion. The SRL project selected the target area for vulnerability assessment covers five district in Siem Reap province and five districts in Kampong Thom province. Vulnerability, flood and drought map of the ten targeted districts are the main outputs of the assignment. A variety of different environmental and socioeconomic input parameters are scaled, reclassified and weighted to provide best possible precision and accuracy during time of modeling required maps of hazards and their consequences. The results of the vulnerability map have been verified though field verification in selected district of both province and the map production have been improved several time after receiving comment from district and commune officials. The results of and full package of data, information, field verification survey which detailed in technical report will be help and supported for further planning decisions making for sub-national levels.

1.2. Task

The overall goal of the project is to improve quality of rural livelihood for the hazard-affected communities against current and future climate change impacts through the integration of technical and social aspects for development plan and implementation, and use climate change vulnerability map to identify risk and proper measure, risk management and prevention. The task for this GIS consultant work is to produce the map of vulnerability to identify risk on climate change impacts such as drought and floods. The maps are based-used to help and provide alert warning of the vulnerable areas and information with the climate change risk and their impacts in the target areas. The three main tasks are classified as followed:

1. Collect and analyze the existing data set including available topography, soil type, climate data and associated climate risks in ten target districts and its constituent communes.
2. Produce district vulnerability maps showing climate affected areas and population that are particularly vulnerable to climate disaster risks.

3. Facilitate a hands-on training on the district vulnerability assessment including the use of vulnerability maps for provincial and district administration officers, planning and budgeting committee (PBCs) and councilors at district commune level.

1.3. Objectives of Mapping

The result of mapping study is the map contained present climatic data/information and rural physical conditions to establish standardize guidelines which are formulated effectively to improve quality resilience and climate change adaptation options for the local administration and people. It's important for improving sub-national administration through providing the supportive tools for the hazard-affected communities against current climate change and/or natural disaster impacts for rural community. From these point of views, vulnerability map development is useful and significant in order to integrate the concept of climate change adaptation in the context of climate change reducing poverty in effective and efficient manners in rural Cambodia. Based on this approach the overall objective of the work can be described like followed:

1. To establish vulnerability maps for ten target districts located in Kampong Thom and Siem Reap

2. Present climatic data/information to support establish standardize guidelines which are formulated effectively to improve quality design and construction of rural facilities and climate change adaptation options of the local people.

2. Scope of work

2.1. Purpose and Scope of the Evaluation

The key component of the project consultation on vulnerability map development and map printing production process will be undertaken as in the following points:

1. The data collection and analysis process of the spatial and non-spatial data information focus only in Kampong Thom and Siem Reap provinces
2. ArcGIS Desktop package were used for data processing, analysis, generating of Vulnerability Map templates within mapping of full information cover in Kampong Thom and Siem Reap
3. The limitation of available data and information of climate impacts to physical structure and non-physical structures
4. The climate data and information currently available only from online global climate model especially meteorological data, drought and flood
5. Downscaling information and data from global and regional level into provincial and communal level, therefore the quality of data within information projection still has limitation use to support planning and decision making.

6. The vulnerability map use for rural infrastructure development need to be accepted and agreed from the consultation with all relevant stakeholders to ensure the quality of final map production.

2.2. Study Area

The study area is consisting of ten target districts which are located in the provinces of Kampong Thom and Siem Reap (**Figure 1**).

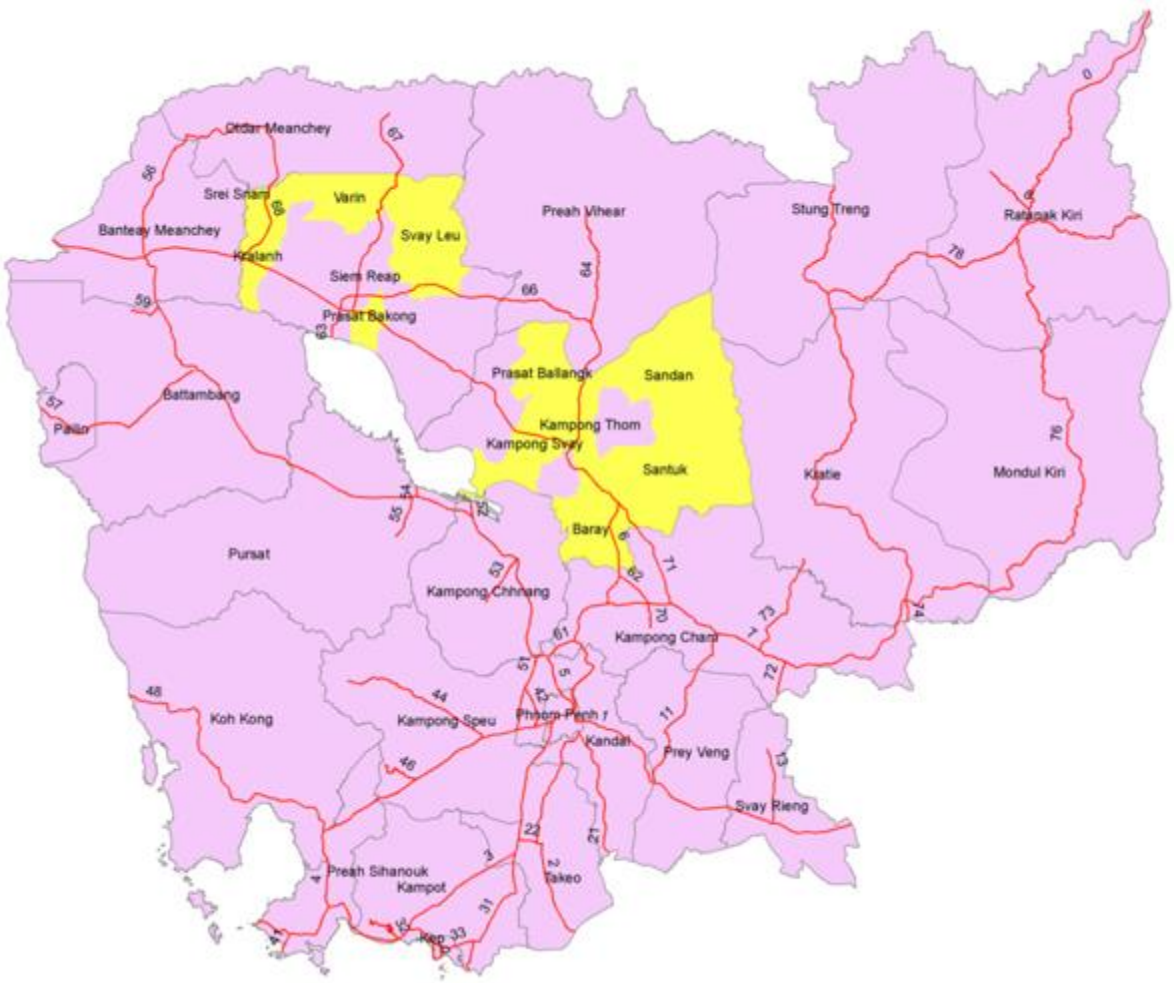

Figure 1: Study area and target districts in Kampong Thom and Siem Reap

3. Investigation Methodology

3.1. Factors of vulnerability

Vulnerability of climate change is caused by three different parameters which influence specific consequences and strength of various environmental hazards by themselves. While several climatic impacts can be only seen as one partly influence to the whole system, the sensitivity of the ecosystem itself as well as the degree of possible adaptive capacity will change the vulnerability in strength and it's regarding consequences. A high flood risk in certain areas with low amount of inhabitants or agriculture won't be equal pathogen to a low flood risk in areas with a huge inhabitant density and economic powership.

For better understanding, **Figure 2** will show the resulting scheme of vulnerability to climate change based on its three proportions. Beside of possible drought, one of the strongest and probable environmental hazards in the considered areas is the risk of possible floods.

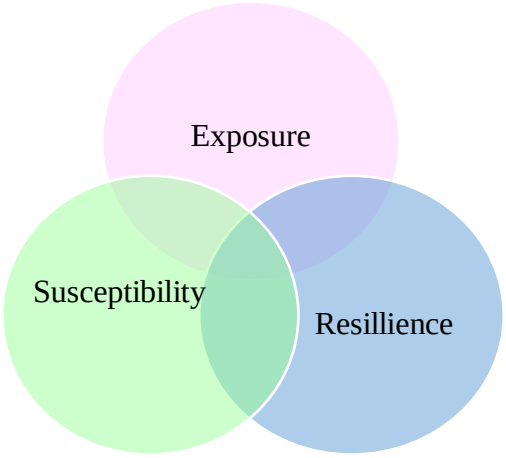

Figure 2: The relation of vulnerability to climate change consistent of its three parameters.

While the flood risk itself just consists on hydraulic and climatic properties, a few different approaches later of research in this regard the vulnerability to flood was described by the Seventh framework programme as followed (Seventh Framework Programme, 2011):

$$FVI = E + S - R$$

Where: *FVI: Flood vulnerability index*

E: Exposure

S: Susceptibility

R: Resilience

The summary between exposure and suspecibility minus amount of resilience can be seen as the summarized vulnerability to flood hazards. In this approach the adaptive capacities of the endangered communes themselves are not yet considered. The data usage is based on the indicators for defining exposure, susceptibility and resilience (see list of indicator in **Table 1**). For the certain target area, the indicators listed in Table 1 are used. Each indicator has own weighting. In this assignment, the results of the vulnerability will be based on climate hazards and use the expert opinion compare with commune chief based-questionnaire give the weight of relevant indicator. The weighting value was validated by joint discussion with village and commune officials through survey questionnaire. Existing physical information, survey information with the result of questionnaire from commune chiefs, land use, flood danger, drought data and other information will be combined into maps of the factors of vulnerability. By giving a vulnerability score to every commune, it is clear which communes are more vulnerable than others. The factors were combined into the vulnerability score and visualized with a map.

Table 1: Considered indicators on a commune level for vulnerability map

Proportions of vulnerability	Indicators
Exposure	• Population in hazard prone area • Land use • Flood risk • Drought risk
Susceptibility	• Social demographic/health • Awareness to climate change • Flood and drought protection • Infrastructure
Resilience	➢ **Social Resilience:** • Health - Health center - Emergency • Malnutrition - Sanitation - Family affected by environmental pollution - Average distance to drugstore - Average distance to hospital • Poverty - Number of poverty rate • Education - Illiterate per family - Average distance to primary school - Average distance to junior school - Average distance to senior school • Shelter - Concrete house - Electricity

	➢ **Coping Capacity:** • Security based on sum values of - Crime cases per year - Violence experienced households - Civil crime • Quality of consumed drinking water - Boiled drinking water - Filtrated drinking water - Purificated drinking water • Coping capacity of practiced agriculture - Number of families only one rice planting technology - Number of families who own irrigation systems

3.2. Methodological Framework

The previous section already explained the relation between hazard, sensitivity and adaption capacity as well as the numerical index for calculating a relative vulnerability of flood. One of the biggest challenges of this mapping approach is the requirement to reduce a nearly infinite amount of useable information into a numeric model without a notable loss of information. Numeric values are required to calculate specific dangers and hazards out of the comprehensive selected parameters. Therefore, a short overview about the working process is given in **Figure 3**.

One of the first steps in research will be the review of available literature for identifying potential dangers and hazards in the considered areas as well as their possible reasons and backgrounds. Furthermore, different community surveys should provide information about the local situations itself, current socioeconomic challenges and properties of the endemic people inside their rural areas. Paired with an amount of empiric knowledge it will be possible to identify determinants for hazards and risks of climate change as well as their adaptive requirements. In a next step, the necessary data can be collected, classified and weighted with different statistic factors dependent on their strength of impact. Following, the main step is the creation of a suiting model in ArcGIS, including calculation of every communal area of the selected districts and their local peculiarities based on extensive information of local people and the collected data.

In the final step those maps will be verified with already existing data and information to provide best possible accuracy in hazards probability. From the created maps it will be possible to compare the generated data with older information substance from previous local people awareness. Enhanced to map creation with a detailed precision, it can be possible to provide recommendations and advices based on endangered areas how to adapt to futural changes in a most suitable and economic way. The main outputs of this assignment are vulnerability map of 10 districts, flood and drought map.

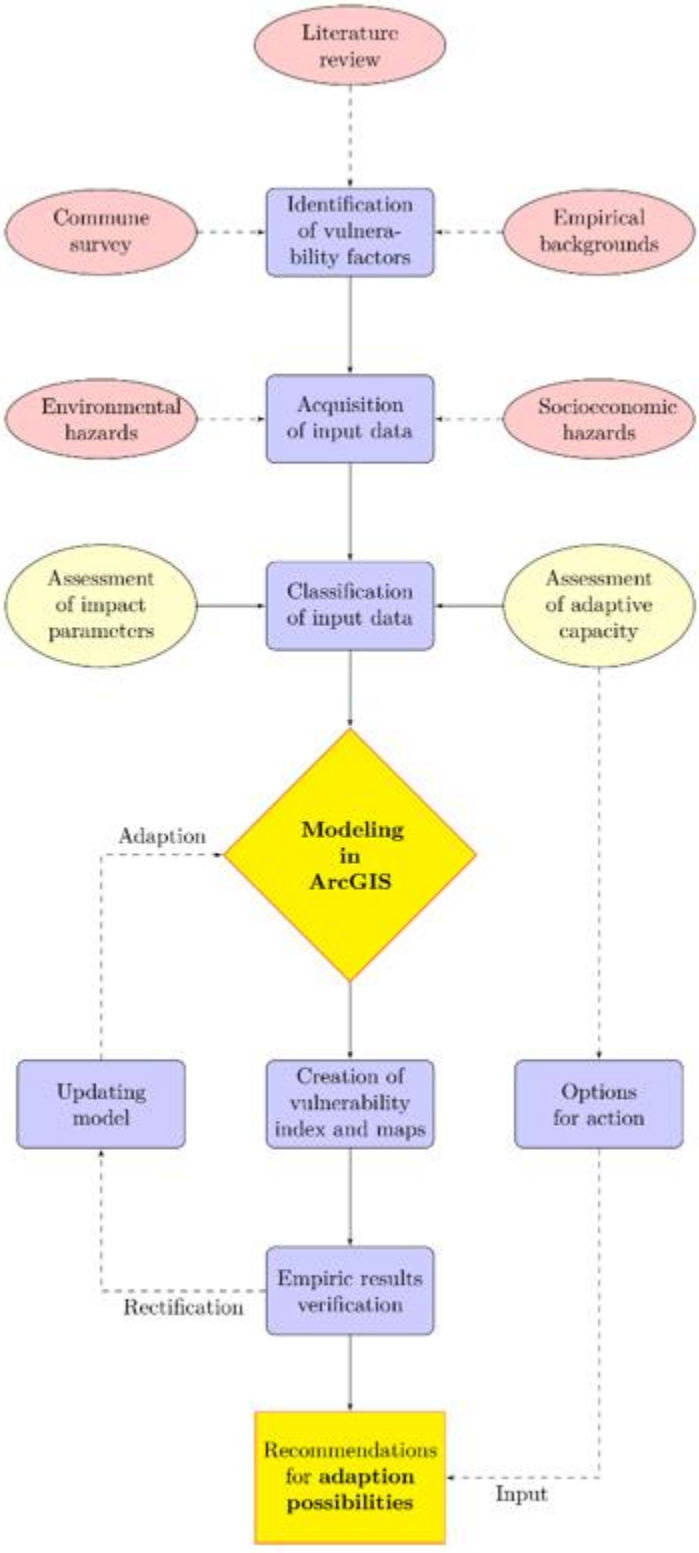

Figure 3: Scheme of research chronology to create vulnerability maps based on environmental impacts and socioeconomic adaptive capacity

3.3. Data Acquisition

The vulnerability to climate hazards and risks of climate change was based on multiple different input parameters which can be classified into the two main categories of risks and overall resilience. The poorer a commune the less powerful its social property and the less endurant its adapting capacity in consequence. On the other side the socioeconomic power and coping capacity should provide information about external factors and business intensity including land use, state of culturing technology as well as amount of used technology. Specific parts of utilized data was taken from a requested governmental tabular file which contained social and economic properties of all individual villages of Cambodia. This socio-economic data survey by ministry of planning in 2015 (CDB 2015). To create maps on a commune-based level of scale all villages of communes in target provinces have been calculated by hand to extract the required data. Hereby the executed calculations were separated into sum parameters and average parameters for every contained commune of the two target provinces of Kampong Thom and Siem Reap. This step provided the possibility of choosing values with increased significance to the intended creation of socioeconomic vulnerability and resilience. In contrast several types of additional GIS-data have been included.

Hereby the utilized data was collected by a variety of different online sources. In following the providing organizations of acquired input data are listed in **Table 2**: Listing of input data for modeling process:

Table 2: Listing of input data for modeling process

Data type	**Organization**	**URL**
Drought	University of Tokyo	http://wtlab.iis.u-tokyo.ac.jp/DMEWS/Cambodia
Flood	European Commission	https://global-surface-water.appspot.com/download
Land type	World Food Programme	https://geonode.wfp.org/layers/geonode
Poverty/malnutrition	World Food Programme	https://geonode.wfp.org/layers/geonode
Social properties	Ministry of Interior	Internal files

3.4. Data Processing

- Drought Data

Basic risk exposure data for the climate hazards consisted on two main dangers: The risk of drought and the risk of flood. Hereby the drought input data from the Institute of Industrial Science at the University of Tokyo was available in form of non-georeferenced and combined raster image files with symbolization of repeating annual and reoccurring drought risk areas. In a first step the combined raster file has been georeferenced and extracted to the spatial size of the target provinces Kampong Thom and Siem Reap to increase its handling and processing velocity in the destination area. Afterwards the data was resampled in an intermediate stage to increase the cell size resolution of the raster pixels to match the later on standardized cell size of 20 x 20 m of the later on mapping resolution. In a last step the file was reclassified to match the desired target classification of ten possible exposure categories. In a next step therefore it was possible to use this pre-treated data for the later on calculation of the final hazard exposure. The calculation of the drought risk is displayed in **Figure 4**: Calculation of drought risk:

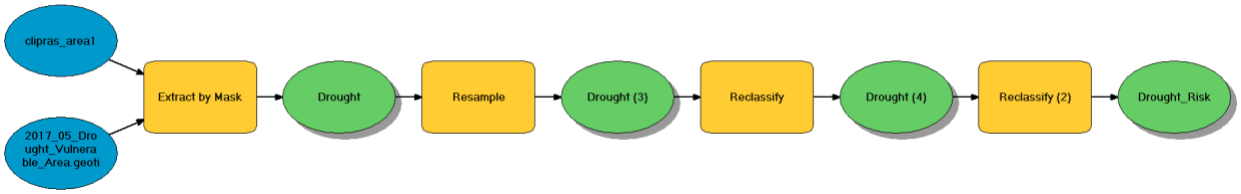

Figure 4: Calculation of drought risk

Based on the calculation of the drought risk by using GIS tool, the flood risk map was produced with the rating of potential risk from low to high (**Figure 5**). The coloring for drought risk level is described in the **Table 3**. The five level of risk are corresponding to abnormally dry, moderate drought, server drought, extreme drought, and exceptional drought.

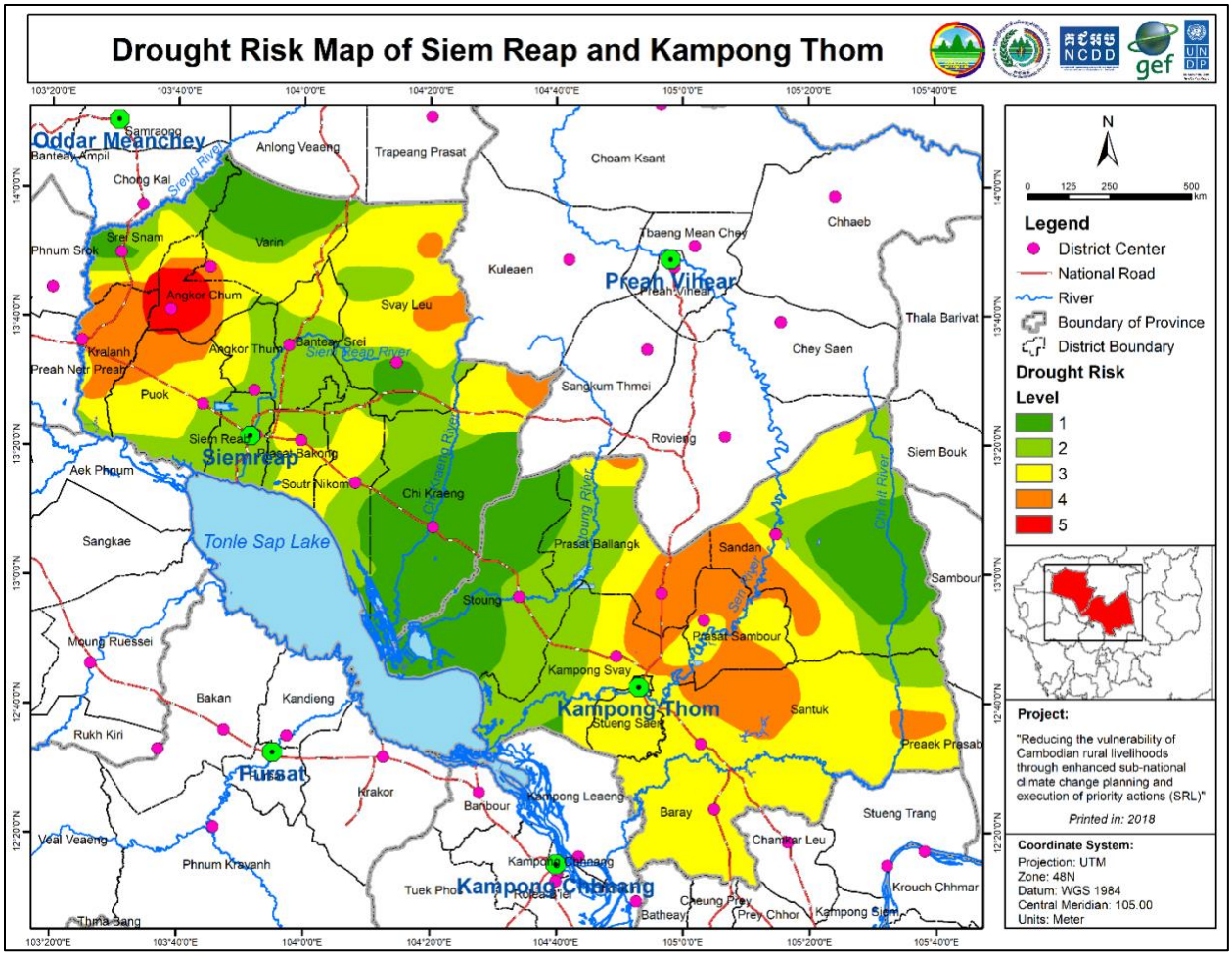

Figure 5: Map of drough risk in Siem Reap and Kampong Thom

Table 3: Drought risk level description

Level	Description	Possible Impacts
1	Abnormally Dry	- Going into drought: short-term dryness slowing planting, growth of crops or pastures - Coming out of drought: some lingering water deficits pastures or crops not fully recovered - Soil moisture and large class fuel moistures are high and do not contribute much to fire intensity
2	Moderate Drought	- Some damage to crops, pastures - Streams, reservoirs, or wells low, some water shortages developing or imminent - Voluntary water-use restrictions requested - Lower litter and duff layers are drying and beginning to contribute to fire intensity

3	Severe Drought	- Crop or pasture losses likely - Water shortages common - Water restrictions imposed - Fire intensity
4	Extreme Drought	- Major crop/pasture losses - Widespread water shortages or restrictions - Lower litter and duff layers actively contribute to fire intensity and will burn actively
5	Exceptional Drought	- Exceptional and widespread crop/pasture losses - Shortages of water in reservoirs, streams, and wells creating water emergencies - Often associated with more severe drought with increased wildfire occurrence. Intense, deep burning fires with significant downwind spotting can be expected. Live fuels can also be expected to burn actively at these level

- Flood Data

While the drought data was provided as a non-georeferenced image file in contrast the flood data from a data pool of the European Commission was separated into six different flood properties already containing georeferencing control information. Hereby all available data was used to calculate the final flood risk based on different weighting factors of every single property. The used data for calculating the final flood risk consisted of the following six flood properties:

1. Flood extent (areas where flood has ever been existent)
2. Flood transitions (to clarify the flood behavior if increasing or decreasing on areas in chronological observation)
3. Flood seasonality (to consider typically flooded areas and assume them with a lower risk due to already existent knowledge and handling routine)
4. Flood occurrence (in relative classification of occurrence density and occurrence velocity)
5. Flood reoccurrence (in relative classification of flood decreasing velocity)
6. Flood change (to quantify the qualitative data and classification of flood transitions)

For generating the flood risk maps in a first step all flood raster files have been projected into the form now on used projection type WGS 1984 zone 48N to reach the highest possible precision for target areas in Southern East Asia. In a next step all flood files have been extracted and clipped to the outside contour of the two target provinces Kampong Thom and Siem Reap. Subsequently the files with their scaling range from 0 to 100 have been reclassified into the previously mentioned scoring value system from 1 to 10. Hereby the data package for flood transitions contained eleven

different flood properties based on the following data: Permanent water, New permanent water, Lost permanent water, Seasonal water, New seasonal water, Lost seasonal water, Seasonal to permanent water, Permament to seasonal water, Ephmeral permanent water, Ephmeral seasonal water, and No water.

Four categories which have been mentioned as useful were separated from the other categories by reclassifying the non-used data as no data and setting calculation specific values to the instrumental properties in a first step. The further included data of the transitions file about lost flood areas and decreasing water impoundments was not considered as necessary for calculation of future flood risk areas.

Like mentioned in the previous section about drought risk the final flood file is consisting on different flood exposures in form of numeric values from one to ten. To combine the final flood map every single input parameter has been reclassified from its initial values from 0 to 100 to 0 to 10 and adjusted by individual weighting factors for increasing or decreasing its impact efficiency when merging to a combined file. While the remaining flood properties have been overlaid to calculate intermediate values based on every properties value the transitions file went into the final raster file without further manipulation of the values. To combine the remaining flood properties for risk identification, the following weighting factors have been applied: Flood seasonality (20 %), Flood recurrence (20 %), Flood occurrence (30 %), and Flood change (30 %). Afterwards the previously mentioned flood properties of the transitions file have been merged with the newly generated flood file consisting on the upper four categories to create the final flood risk map which were classified risk level. To avoid comma-decimal classification numbers the target file was reclassified into the final scoring categories from one to 4 again to equalize its extent to the drought risk data (**Figure 6**). Later on the flood risk could be used for the final natural hazard exposure calculation based on the sum of flood and drought.

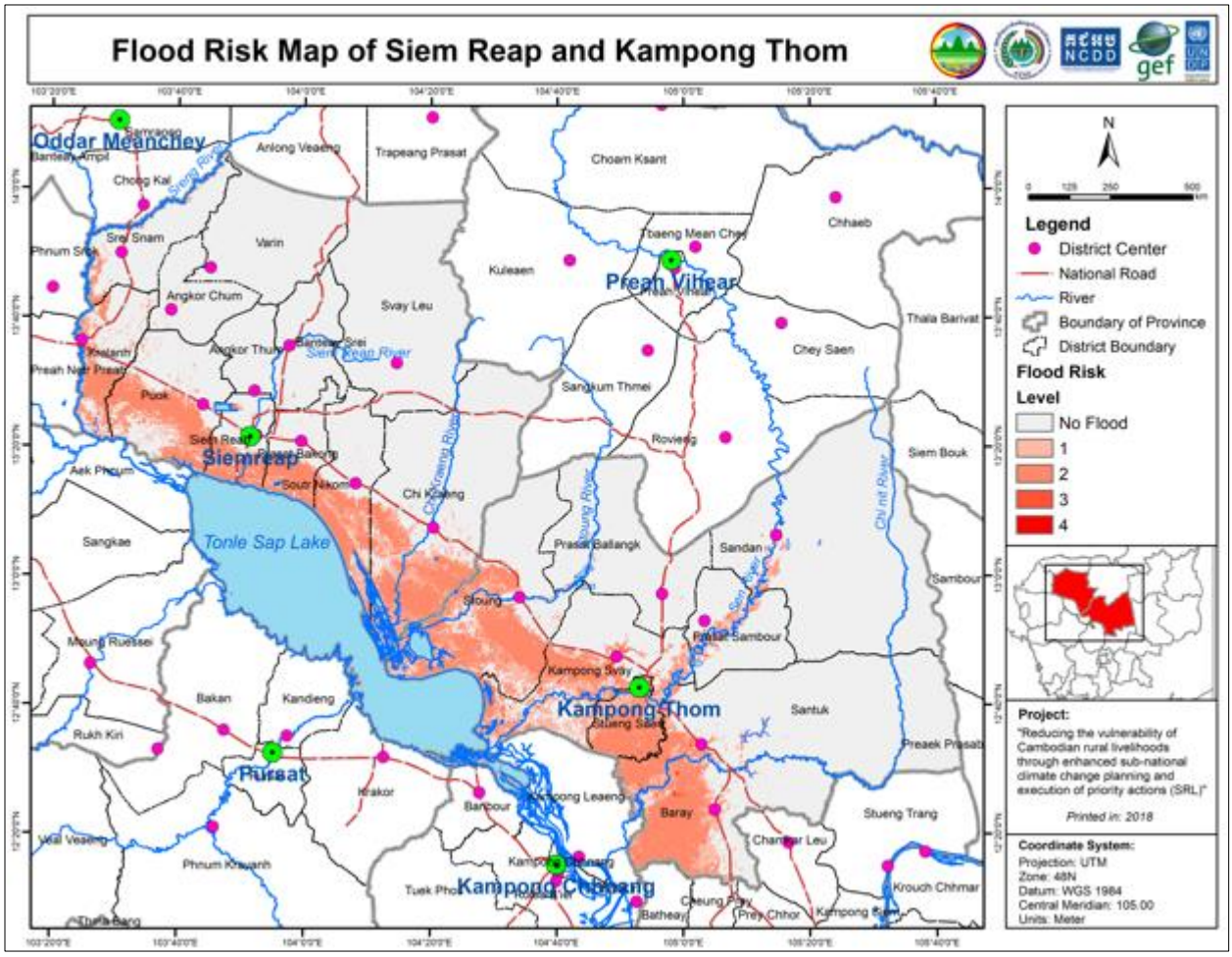

Figure 6: Flood risk map in Siem Reap and Kampong Thom

To identify the location and understand condition of flood. The table below describes the level of flood risk which are classified in to abnormally, moderate, server and extreme (**Table 4**). However, the flood risk map above shows all flood prone area have from level of risk from abnormally to moderate only. There is only some dots indicates severe risk and just little with extreme condition.

Table 4: Flood risk level description

Level	Description	Possible Impacts
1	Abnormally	- Going into flood: short-term flood can tangible physical damage to agriculture, infrastructure, public utilities, housing, structure and assets - Coming out of flood: Loss of income. Cleaning and sanitation crops not fully recovered
2	Moderate	Damage to crops Harmful to rural road thin surface

		Damage Streams, reservoirs, or water supply (wells), Intangible: loss of life, health effects and environment Industrial production losses Temporary relocation
3	Severe	- Agricultural and industrial production losses likely - Damage to rural road thin surface - Food aid within water sanitation common - Relocation people to ground safety
4	Extreme	- Increased vulnerability of survivors - Fully damage crop, infrastructure, public utilities, housing, structure and assets - Alert and need support from national and international rescue volunteer team. - Need Emergency planning during and after flooded

- Economic power and vulnerability based on type of land use

To describe the vulnerability of currently practiced agriculture in the target areas an amount of specific land use data has been utilized for calculation of economic challenges caused by climate change. The data was taken from a public accessible data pool of the World Food Programme. Hereby ten different types of agricultural practice have been projected, extracted with the target area extent and converted into one single numerical scored raster file. Hereby the cropland areas had to be extracted to single land use types first. Afterwards an additional field was added to the attribute table of all land use types while every land use character got specified with a target value from 1 to 10, depending on its vulnerability. The land-use data was classified as follows (see **Table 5:** Land use data and its classification):

Table 5: Land use data and its classification

Land usage type	**Numerical value of vulnerability**
Paddy Field	10
Garden Crop	9
Field Crop	8
Swidden Agriculture	7
Village Garden Crop	6
Rice Floating	5
Inland-water	4
Wetland	3
Protected Area	2
Grass Land	1

In the end all specified values have been merged together into one file and got reclassified while no data values have been set as zero to avoid colorless areas in the final map (**Figure 7**).

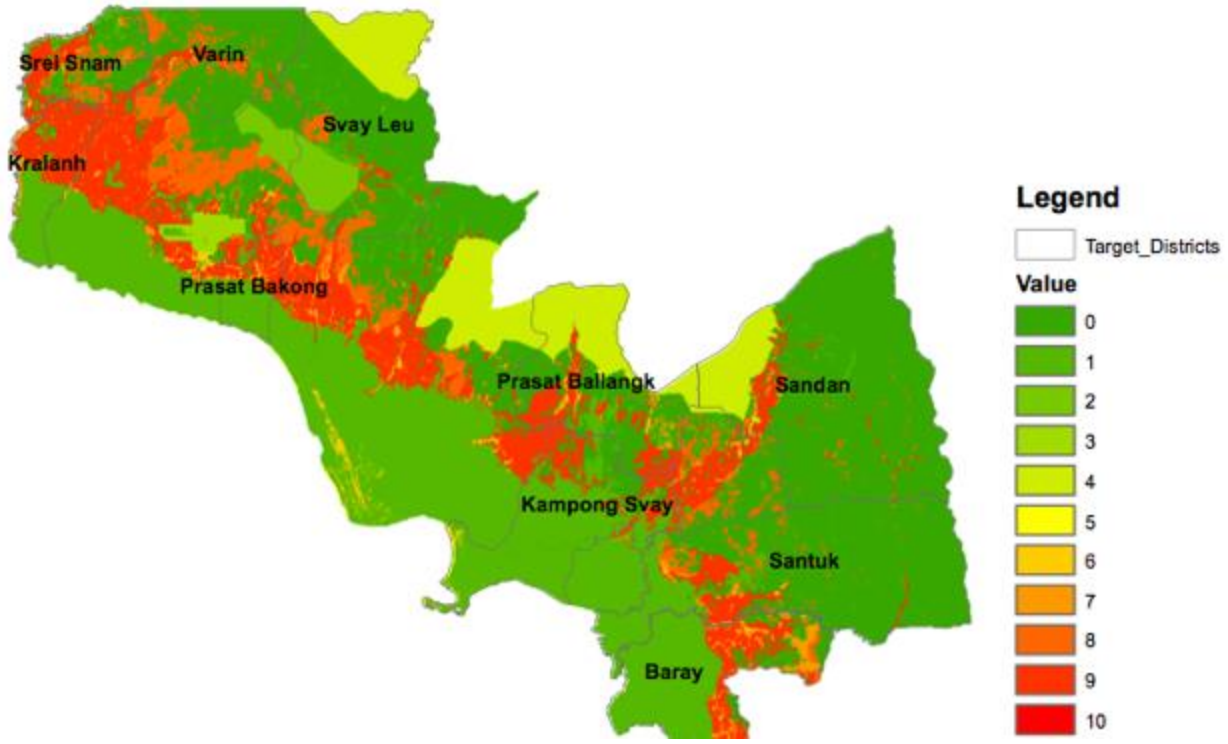

Figure 7: Vulnerable Land use in the Target Area

- Coping Capacity

For consideration of different livelihoods, the coping capacity based on regional deviating properties has been calculated. Hereby three main categories have been created based on the following single input data which was overlaid to the final main category:

1. Security based on sum values of
    a. Crime cases per year (40 %)
    b. Violence experienced households (40 %)
    c. Civil crime (20 %)
2. Quality of consumed drinking water based on sum values of
    a. Boiled drinking water (35 %)
    b. Filtrated drinking water (30 %)
    c. Purificated drinking water (35 %)
3. Coping capacity of practiced agriculture based on average values of
    a. Number of families who apply only one rice planting technology (50 %)
    b. Number of families who own irrigation systems (50 %)

Afterwards all three main categories have been summarized and reclassified into the target values from 1 to 10. The weighting of each factor for the overlaying the coping capacity was improved based on the field verification.

- Social resilience

In a last step of investigation about regional strength on communal level the social resilience was calculated with a variety of different input parameters. Hereby the focus was set on socioeconomic properties like education, health support, poverty and malnutrition. The data was taken from a requested tabular file from NCCD. Again there were four main categories specified based on the following features:

1. Average amount of households with shelter
2. Implementation of education facilities based on
    a. Average distance to primary school (30 %)
    b. Average distance to junior school (20 %)
    c. Average distance to senior school (10 %)
    d. Average amount of illiterate people (40 %)
3. State of health support based on
    a. Average amount of drugstores in commune (15 %)
    b. Average amount of sanitation facilities in commune (25 %)
    c. Average amount of families endangered by garbage pollution (5 %)
    d. Average amount of hospitals in commune (15 %)
    e. Intensity of malnutrition in commune (40 %)
4. Poverty level of commune

In the end all four categories have been overlaid into one final resilience raster file. Hereby the weighting of the single properties was set as follows:

- Education implementation (20 %)
- State of health (30 %)
- Families with good shelter (30 %)
- Commune poverty (20 %)

It noticed that the weighting percentage for overlaying each category, was modified and changed according to the result from field verification. Coping capacity and resilience have been combined for the showing the strength of communities to the disaster. The combination of the data was then spatially displayed with the rating in the maps (**Figure 8**).

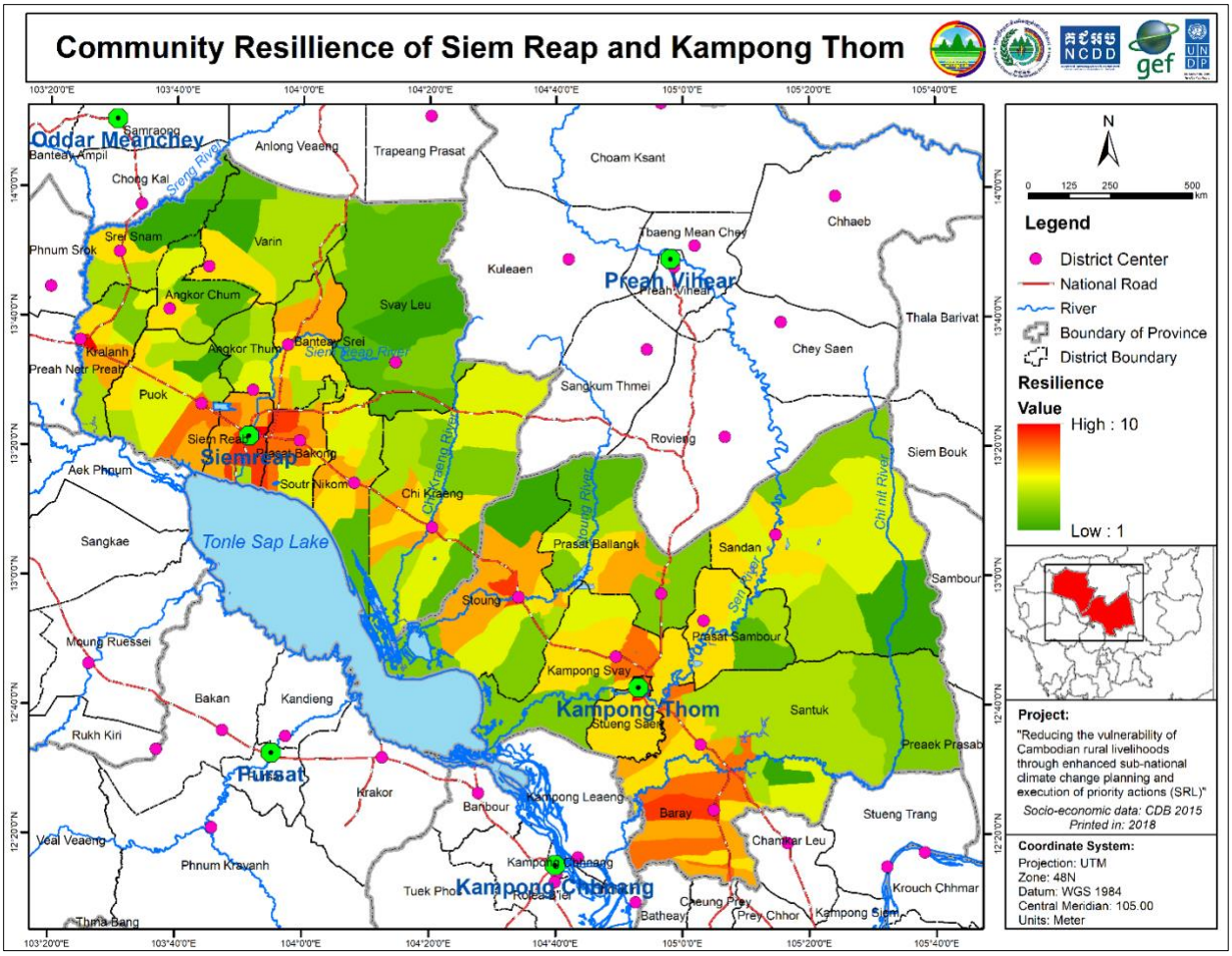

Figure 8: Community resilience in the target area

- Final calculation of the vulnerability

The final vulnerability map depending on hazards and risks of climate change could be calculated by summarizing the values of flood risk, drought risk and land usage vulnerability and later on subtraction of the sum of social resilience and coping capacity from the previous value. With a correct classification of the five input parameters low values will represent a strong economic and social situation with relatively low risks to flood and drought. In contrast, high values clarify endangered areas with either high risk to climate hazards or lower resilience and coping capacity. In the very end the final map of vulnerability was clipped by every single target district to generate final maps on district based scale. The final maps for combination of social resilience, coping capacity, drought or flood risk and land use vulnerability are produced. For the intended mapping process all property files with an outside extent of the target provinces have been added into a layout. Afterwards the final maps have been exported as *.tiff-files which are included in the present report.

4. Vulnerability Map Production

4.1. Overall Vulnerability Index

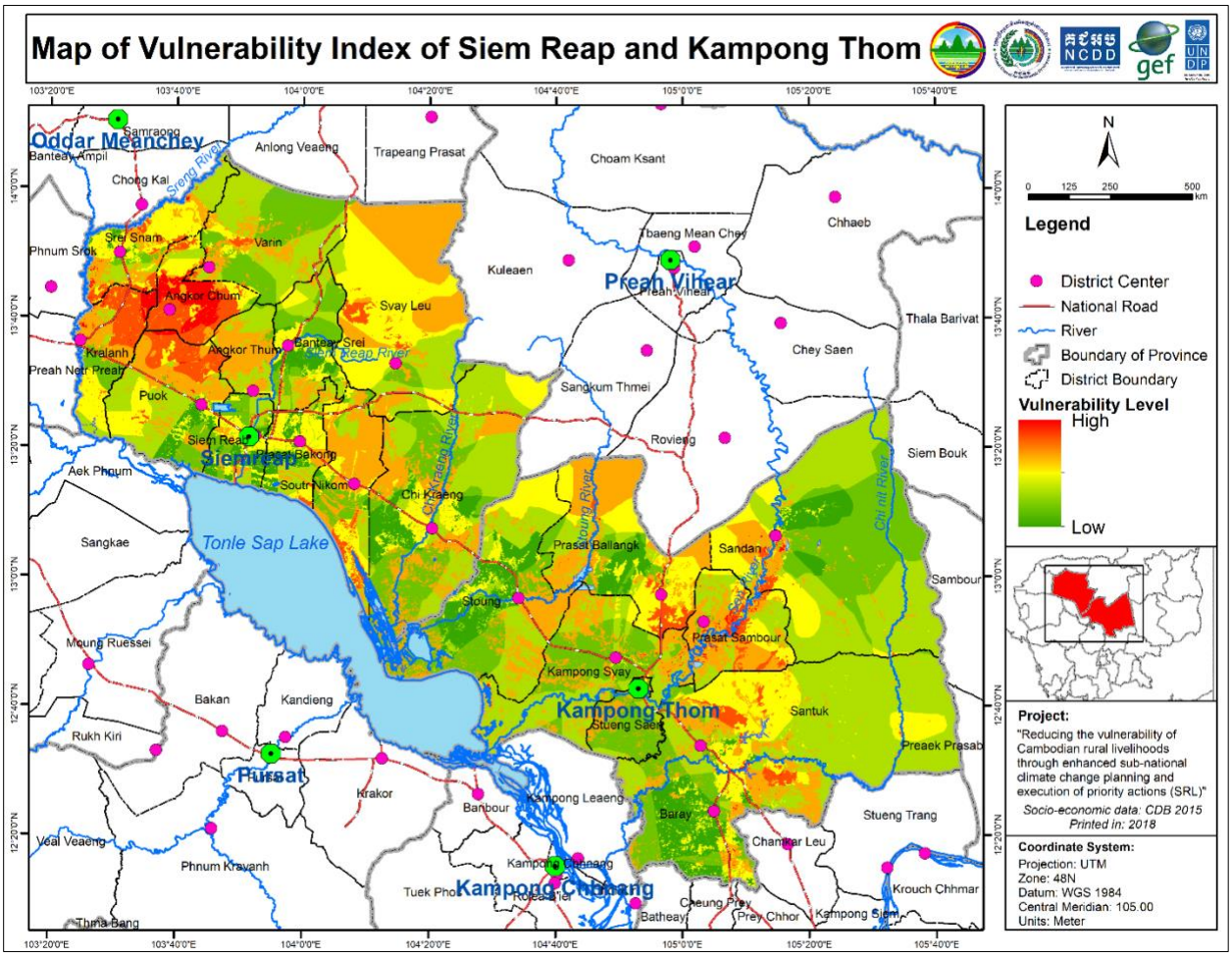

Figure 9: Vulnerability Index of Siem Reap Province and Kampong Thom Province

4.2. District-based Vulnerability in Kampong Thom

1. Baray District

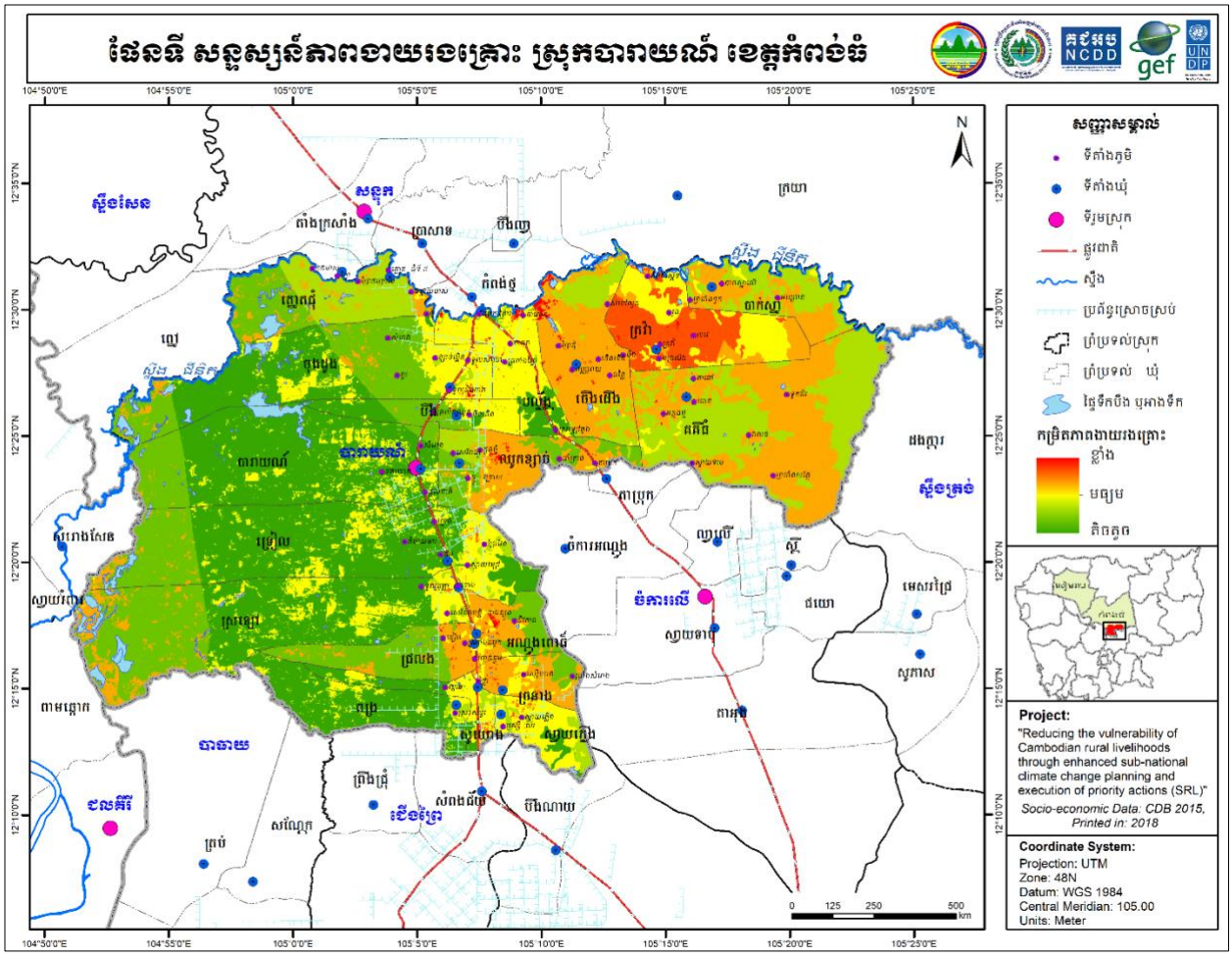

Figure 10: Vulnerability index of Baray district, Kampong Thom province

2. Kampong Svay District

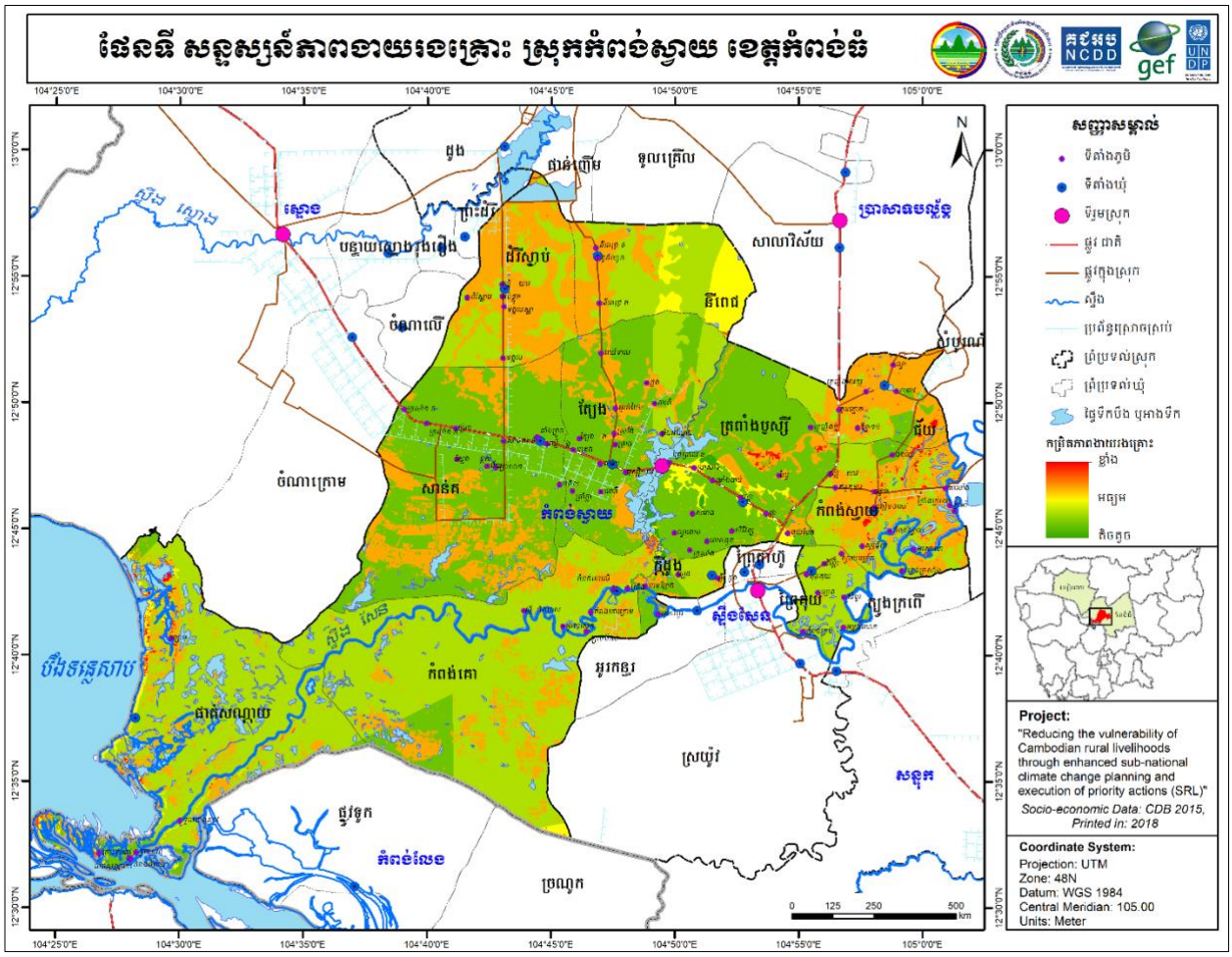

Figure 11: Vulnerability index of Kampong Svay district, Kampong Thom province

3. Prasat Ballangk District

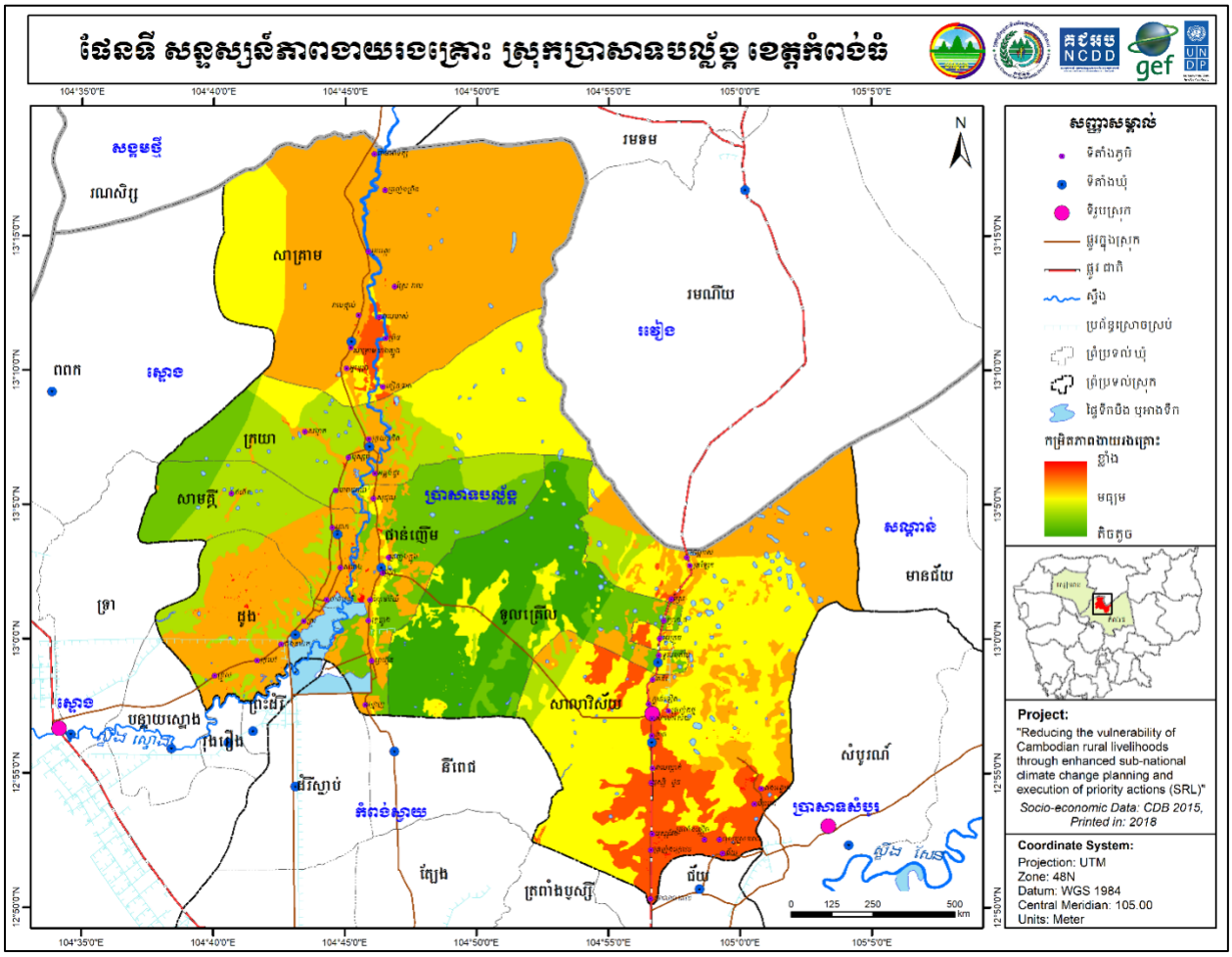

Figure 12: Vulnerability Index of Ballangk district, Kampong Thom Pronvince

4. Sandan District

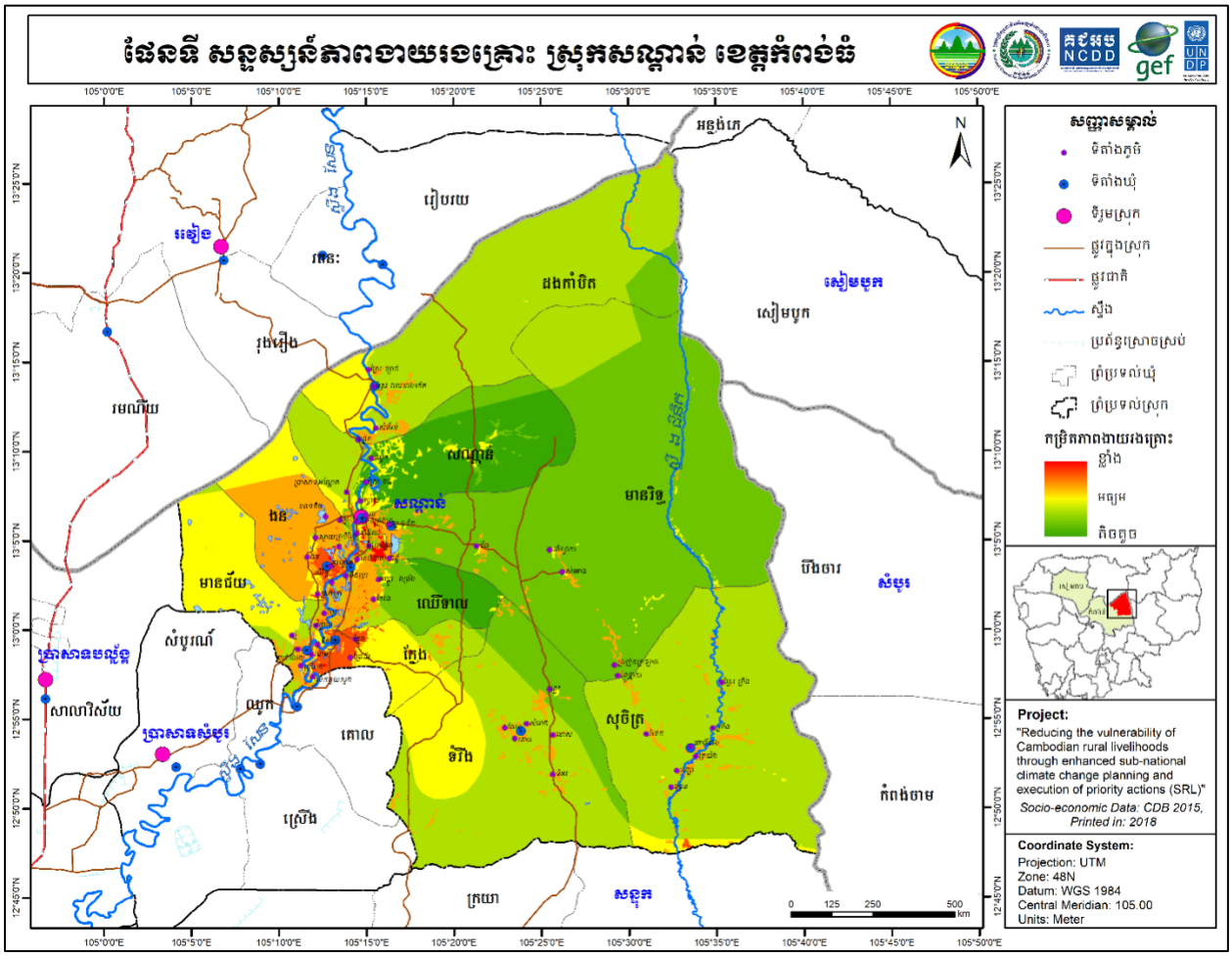

Figure 13: Vunerability Index of Sandan district, Kampong Thom province

5. Santuk District

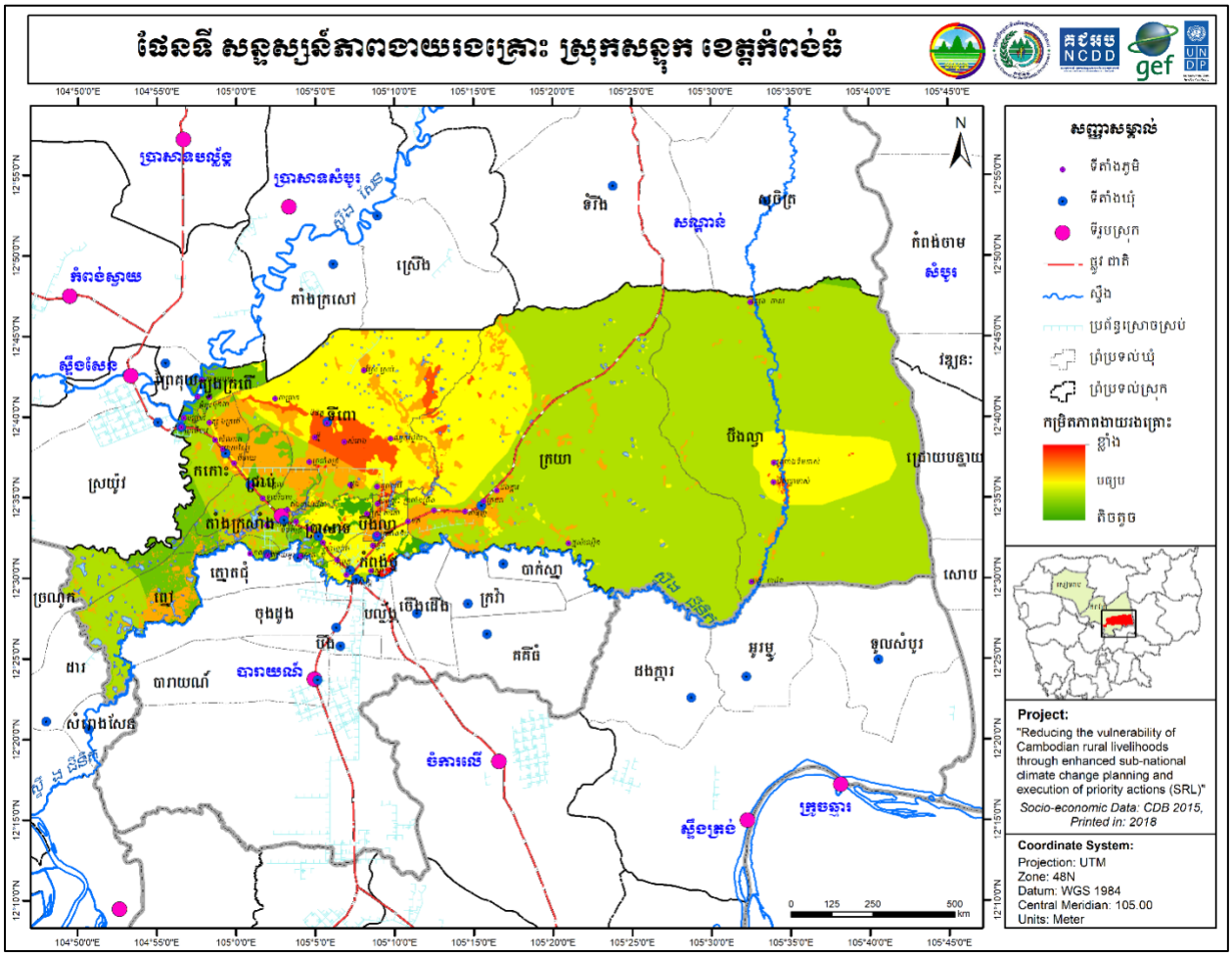

Figure 14: Vulnerability index of Santuk district, Kampong Thom province

4.3. District-based Vulnerability in Siem Reap

1. Kralanh District

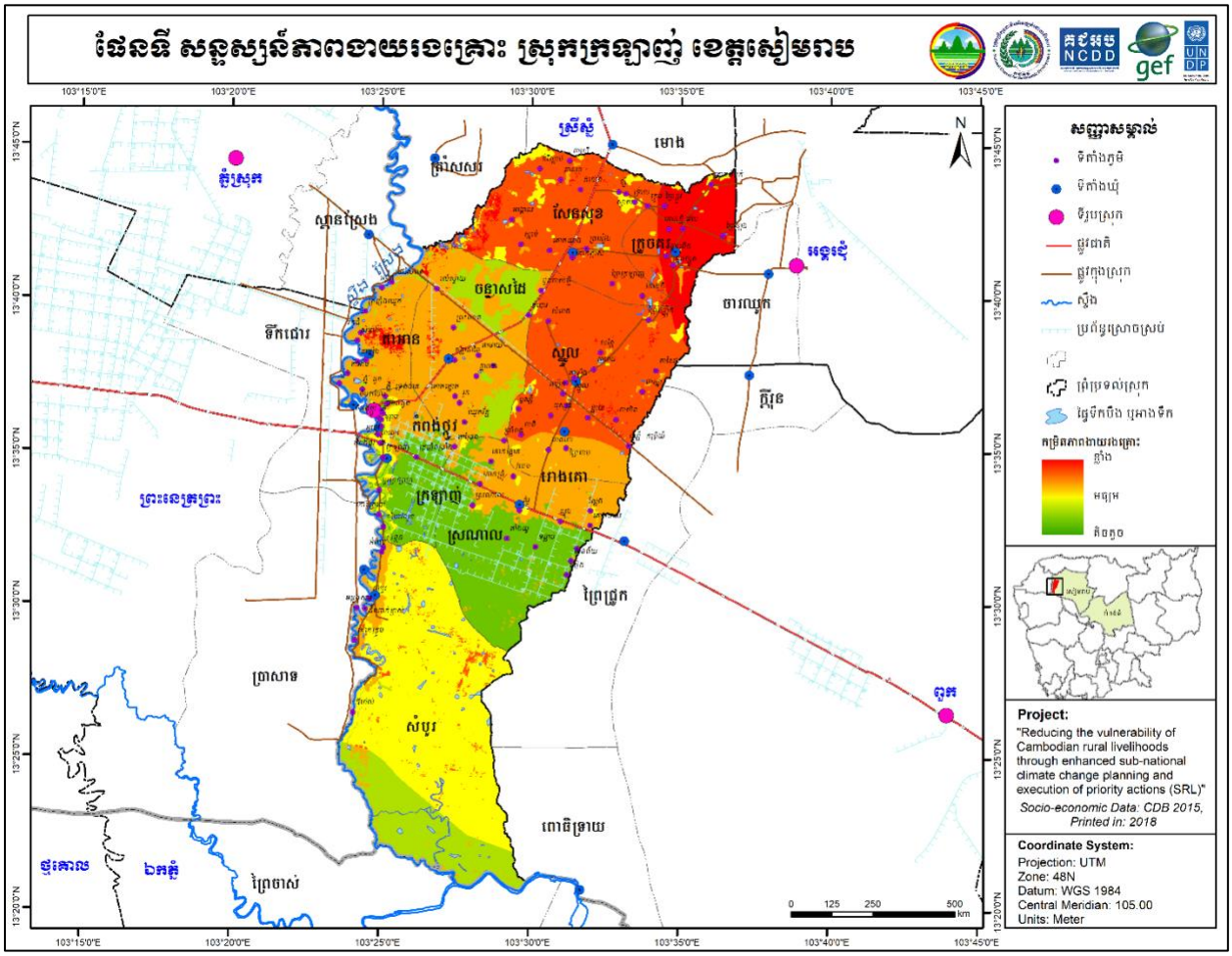

Figure 15: Vulnerability index of Kralanh district, Siem Reap province

2. Prasat Bakong District

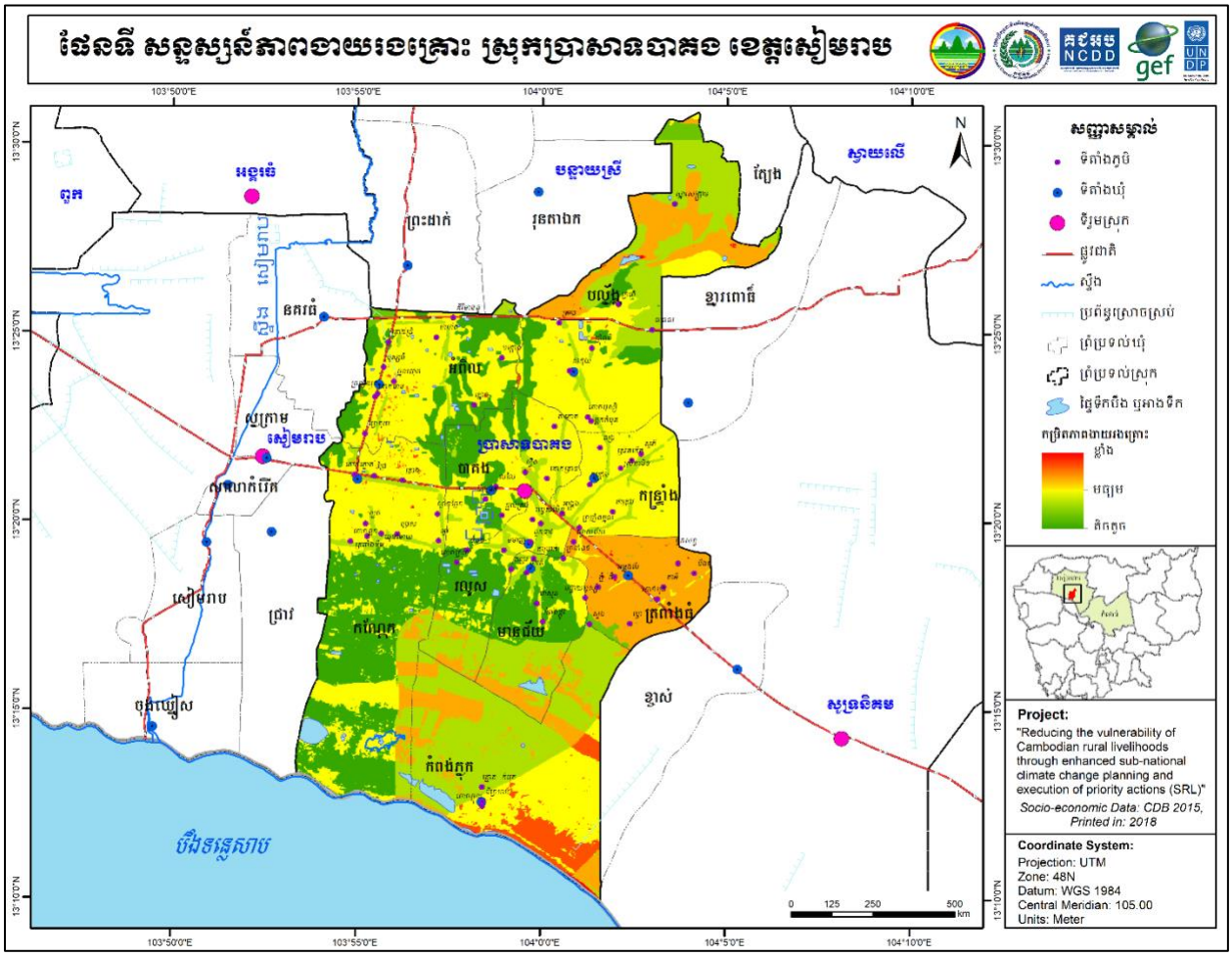

Figure 16: Vulnerability index of Prasat Bakong district, Siem Reap province

3. Srei Snam District

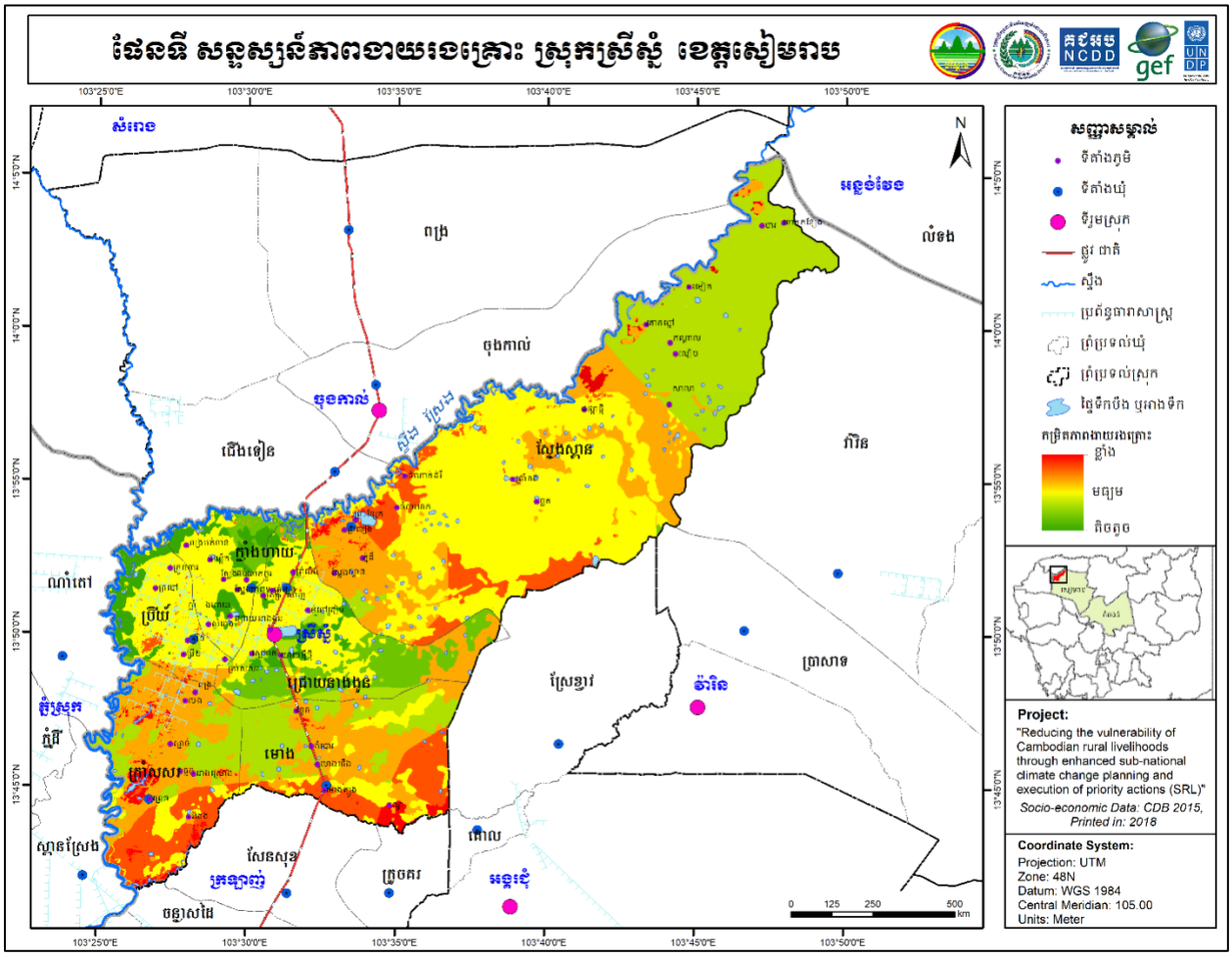

Figure 17: Vulnerability index of Srei Snam district, Siem Reap province

4. Svay Leu District

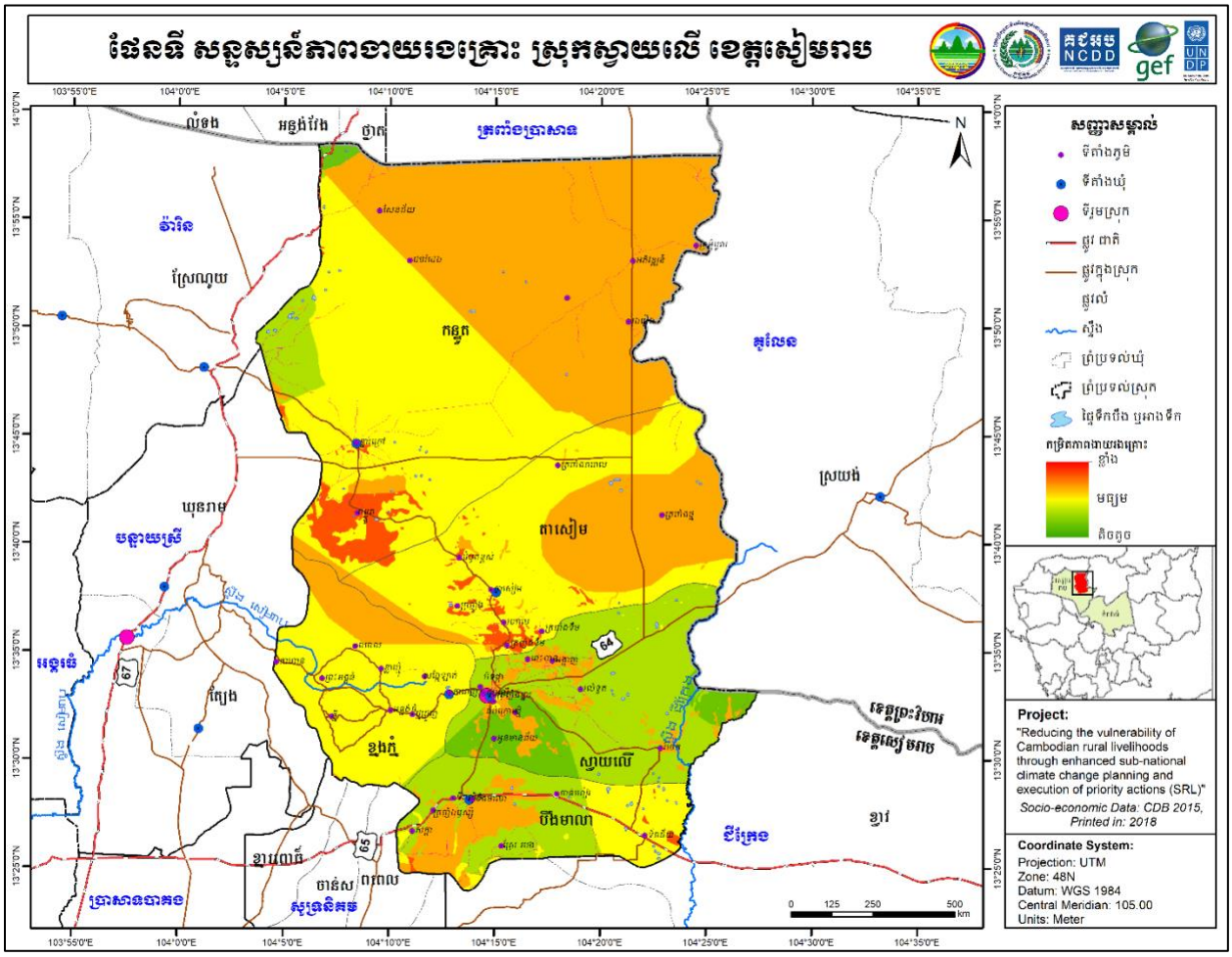

Figure 18: Vulnerability index of Svay Leu district, Siem Reap province

5. Varin District

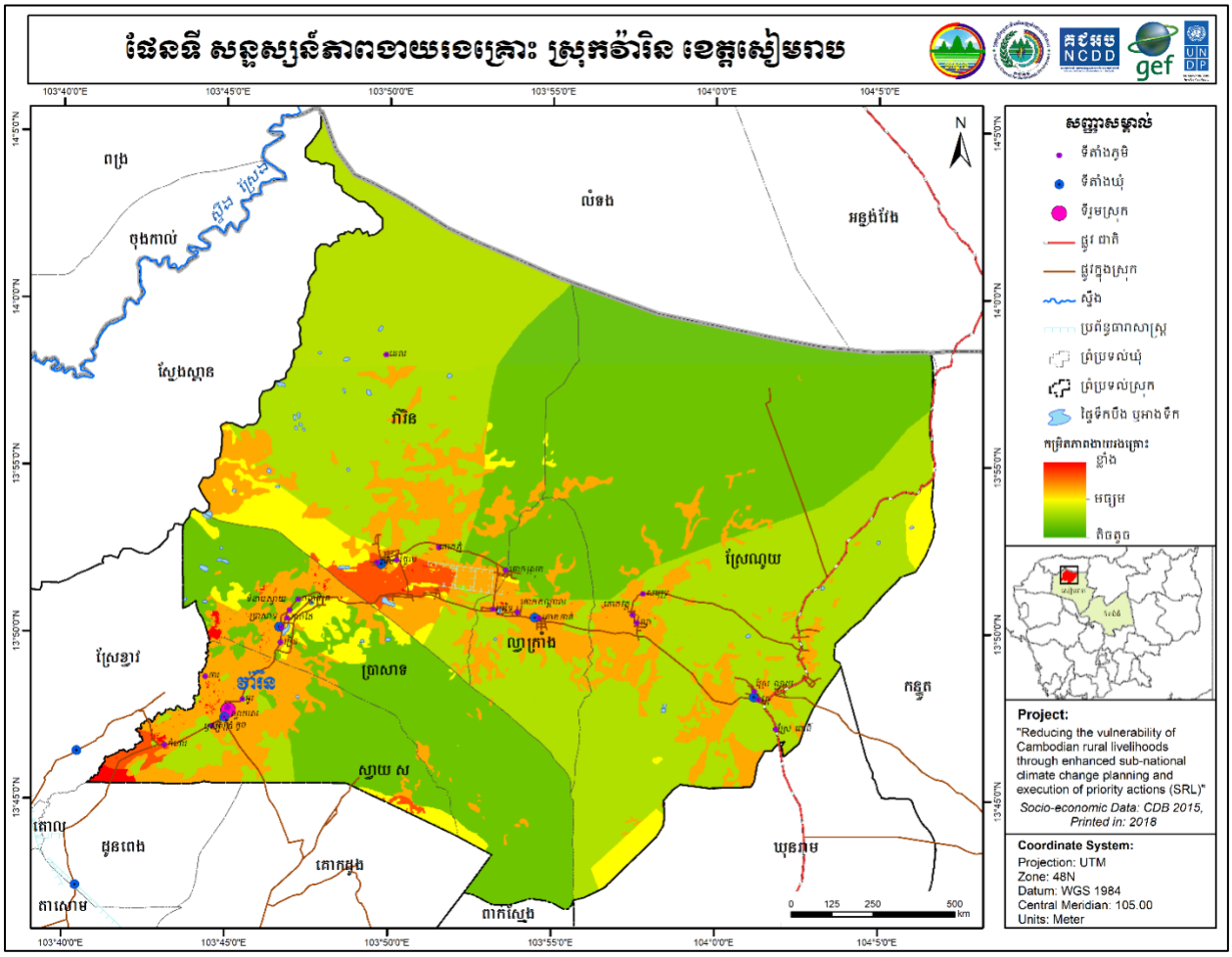

Figure 19: Vulnerability index of Varin district, Siem Reap province

It should be reminded that, all 10 district vulnerability index maps have been introduced and explained to the officials from target districts and communes. At first, the vulnerability index map together with flood and drought maps were introduced to the local officials during the field verification in Siem Reap and Kampong Thom province. The maps were used to compare with the hand-drawing district map of flood and drought. The comparisons were acceptable between the disaster risk map which sketched by local authorizes. Secondly, all district vulnerability index maps were discussed and checked again by the districts and commune's officials during DVA and Vulnerability Maps Training Workshop which was conducted on 21-22 March 2018 in Phnom Penh. The map productions have been improved based on the suggestion and comments from participants representing to all 10 districts of target provinces. The third presentation of the GIS work for vulnerability mapping was carried out during the 2nd Climate Change Awareness Training and Gender Mainstreaming for Sub-National Councilors which was conducted at Kampong Thom on 26 March 2018 and Siem Reap Province on 28 March 2018. From these three activities of checking, the maps have been finalized with some improvement to make it becomes user friendly.

5. Field Verification

5.1. Description of Fieldwork

Field verification for vulnerability mapping in selected target communes and districts in both Siem Reap Province and Kampong Thom Province.

The fieldwork is intended to consult and validate of primary result on vulnerability maps with selected commune and corresponding districts. The consultation with sub-national administration is also armed to verify the weighting of risk combination for local vulnerability rating. Aside from expert's opinion, the input from responsible governors directly on place are also very important to get qualified information for planning. During the meeting with districts and commune, the vulnerability map, flooded map and drought were compared with the manual sketch map of flood and drought risk that were made by the local governor. Then, the discussion was executed by using an extensive discussion questionnaire with 3 communes which was selected by a detections of high vulnerable area with relation to specific properties of the target areas. Afterwards the collected data can be classified and transferred into the model. Based on the questionnaire it is possible to provide a qualified information to correct the existing GIS-model, what will strengthen the accuracy of the calculated results. Briefly, the main activity in fieldwork were:

- Presentation on the primarily result of vulnerable map
- Comparing the primarily result with the sketch map of flood and drought hazard which mad by local district
- Discussion on Survey questionnaire

➢ **Field Verification in Siem Reap**

- ***Summary of Activity in Fieldwork:***

The fieldwork in Siem Reap was conducted from 07 to 10 February 2018. There are three selected target communes which are Slaeng Spean commune in Srei Snam district, Snuol commune in Kralanh district, and Varin commune in Varin district, to carry out the verification survey with village and commune officials.

- In Srei Snam district, the meeting was conducted both in the district hall and then in Slaeng Spean commune hall. In Srei Sam district hall, the meeting was arranged to show the GIS work and to compare the GIS vulnerability map with sketches map of disaster risk which made by local common chief and district official expert. After finishing the meeting in Srei Snam district hall, the group work moves to Slaeng Spean commune hall where the meeting was conducted and chaired by communed chief with participation from village chiefs and common council members. This communal meeting started with the opening of commune

chief and then the GIS expert introduce the GIS work for vulnerability map through presentation and a long with question. After the presentation which showed the primary result of GIS vulnerability and disaster mapping, all participants enjoyed to compare the vulnerability map between GIS mapping and manually sketching by commune and district officials. Then, all participant discussed on validating questionnaires to provided qualitative responses. At the end, the commune chief closes the meeting and followed by group photo.

- In Kranlanh district, the meeting also conducted both in district hall and Snuol commune hall. The activity and process of the meeting was the same as in Srei Snam district and Slaeng Spean commune.

- In Varin district, the meeting was conducted only in Varin commune hall. However, the official from Varin district hall aslo participated to the meeting. This communal meeting in Varin opened by commune chief and then the GIS expert introduce the GIS work for vulnerability map through presentation and a long with open question. The presentation was made to introduce the method used in scientific work for making the vulnerability map and showed the primary result of GIS vulnerability and disaster mapping including flood and drought. After that, the meeting did comparison the vulnerability map between GIS mapping and manually sketching by commune and district officials. Then, all participant discussed on validating questionnaires to provided qualitative responses. The meeting was ended by closing remark from commune chief and followed by group photo.

- ***Summary of Result and Conclusion:***

The comparison of GIS map and sketch map all districts were very similar but the sketch maps showed only flood and drought. For drought information in the sketch map was unclear because the the method to make it was that the commune chief asked to the village chief if the local people complain about lacking of water to use for farm or domestic. It means that they feel lack of water only if they do farming during dry season. For the flood map are very similar between GIS map and sketch map. Based on the questionnaire response, it shows that those three selected communes are really in high vulnerability. However, the title of sketch map was written as vulnerability map but it shows only flood and drought. They did not include the factor of resilient which based on other factor of socio-economic and others. In overall, all the district appreciates with the result of GIS map that show consistent with their knowledge and experience.

➢ **Field Verification in Kampong Thom**

- ***Summary of Activity in Fieldwork:***

The fieldwork in Kampong Thom was conducted from 11 to 14 February 2018. There are also three selected target communes to carry out the verification survey with village and commune officials. (1) Krava commune in Baray district, (2) Ti Pou commune in Santuk district, and (3) Sala Visai commune in Prasat Ballangk district.

- In Baray district, the meeting was conducted in Krava commune hall. Krava is found to be most vulnerable Baray district. In Krava commune hall, the meeting was arranged to show the GIS work and to compare the GIS vulnerability map with sketches map of disaster risk which made by local common chief and district official expert. The meeting was chaired by communed chief with participation from village chiefs and common council members. This communal meeting started with the opening of commune chief and then the GIS expert introduce the GIS work for vulnerability map through presentation and a long with question. After the presentation which showed the primary result of GIS vulnerability and disaster mapping, all participants did comparison the vulnerability map between GIS mapping and manually sketching by commune and district officials. Then, all participant discussed on validating questionnaires to provided qualitative responses. At the end, the commune chief closed the meeting and followed by group photo. The comparison indicated very good agreement between disaster map by GIS expert and sketched map

- In Santuk district, the meeting also conducted in Ti Pou commune hall. The activity and process of the meeting was the same as meeting and discussion in Krava commune of Baray district. Based on the questionnaire response, it noticed that the risk of flood in Ti Pou commune is not so that hight. Only drought is reported to happened a lot and everywhere in the commune. Regarding to livelihood of the local people is relatively better.

- In Prasat Ballangk district, the meeting was conducted only in Sala Visai commune hall. However, the official from Prasat Ballangk district hall also participated to the meeting. This communal meeting in Sala Visai was opened by commune chief and then the GIS expert introduce the GIS work for vulnerability map through presentation and a long with open question. The presentation was made to introduce the method used in scientific work for making the vulnerability map and showed the primary result of GIS vulnerability and disaster mapping including flood and drought. After that, the meeting did comparison the vulnerability map between GIS mapping and manually sketching by commune and district officials. Then, all participant discussed on validating questionnaires to provided qualitative responses. The meeting was ended by closing remark from commune chief.

- ***Summary of Result and Conclusion:***

The comparison of GIS map and sketch map of all three districts were very similar except the vulnerability in Ti Pou commune of Santuk district. The sketch maps showed only flood and drought. For drought information in the sketch map of all district was unclear because the production method was that commune chief asked to the village chief if the local people complain about lacking of water to use for farm or domestic. It means that they think they impacted by drought only if they do farming during dry season and lack of water to irrigate. The flood maps are very similar between GIS map and sketch map however, the flood map in Ti Pou commune needs to be slightly modified. Based on the questionnaire response, it shows that Krava commune and Sala Visai communes are really in high vulnerability but for Ti Pou communes need to be revised and check the input data from social factors. Again, the title of sketch maps was written as *vulnerability map* but it highlighted only flood and drought. They did not include the factor of community resilience which based on factors of socio-economic and others. In overall, all the majority of district and commune official appreciates with the result of GIS map that show

consistent with their knowledge and experience. However, the GIS expert needs to revise the weight of vulnerability combination. The responses from questionnaire help to redefine little to the weight of disaster risk and lead to have good vulnerability combination.

6. Conclusion and Recommendation

6.1. Conclusion

During this research approach, various different information and input parameters will be collected, reclassified and shrinked into calculable parameters for mathematic creation of a map model based on numeric values. The biggest challenge will be the implementation of providing best possible accuracy without a remarkable loss of informational details and deepness. This can be guaranteed by a long-term validation of the classification of input parameters as well as their weighting factors in further calculation. Misleading outputs will be corrected and adapted in a second approach of validation. Therefore, the model can be adjusted and calibrated during further executions by influencing its input and its calculation format in a legal and suitable way. The maps production have been improved after receiving some comment from sub-national officer thought training session and though digital checking. The ultimate maps should contain a maximum of possible precision. At all there will be final geographic maps including output of vulnerability consistent of flood and drought. Based on those maps it will be possible to provide better informational background for further adaptive implementations. Also, there is room for improvement of the data collection with the questionnaire, and the method vulnerability assessment.

6.2. Recommendation

The result for mapping study is the map contained present natural hazard information and rural resilience, which are very important to improve and facility adaptation measure of the local people. The creation of vulnerability map should be combined not only hazard areas but resilience of commune also need to put into consideration in order to have equity development priority. For further action in the project, it is recommended to take the result of vulnerability map for identifying the priority area to implement the project for strengthening resilience of people in the high vulnerable. It is recommended to extend the vulnerability study for the projection scenario of climate change impact in the context of lower Mekong basin in order to improve quality of rural infrastructures for the hazard-affected communities against current climate change and/or natural disaster impacts for rural community.

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Appendix

Questionnaire use for field verification to interview the local district and commune officials

	សំនួរ	ចំឡើយ	ភាពសំខាន់	យោបល់ផ្សេងៗ
1	តើអ្នកកត់សំគាល់ឃើញថាឃុំរបស់អ្នកស្ថិតក្នុងតំបន់ងាយរងគ្រោះដោយទឹកជំនន់ដែរទេ?	ចាទ សូម្បីពេលទឹកជំនន់តិចតួចក៏ឃុំខ្ញុំរងប៉ះពាល់ដែរ  មិនធ្លាប់ទេសូម្បីពេលទឹកជំនន់ធំកើតឡើងក៏ឃុំខ្ញុំមិនរងប៉ះពាល់ដែរ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	
2	តើអ្នកធ្លាប់កត់សំគាល់ឃើញមានកើតគ្រោះរាំងស្ងួតដែរទេក្នុងឃុំរបស់អ្នក?	ចាទធ្លាប់សូម្បីពេលនៅខែវស្សាក៏ឃុំខ្ញុំទទួលរងប៉ះពាល់ដែរ  មិនធ្លាប់ទេសូម្បីពេលខែប្រាំងក៏ឃុំខ្ញុំមិនរងប៉ះពាល់ដែរ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	
3	បើប្រៀបធៀបទៅឃុំដទៃក្នុងស្រុកនេះ តើឃុំអ្នកមានបញ្ហាប្រឈមនឹងគ្រោះមហន្តរាយខ្លាំងឬទេ?	ប្រឈមខ្លាំងជាងឃុំដទៃក្នុងស្រុកនេះ  មិនសូវប្រឈមទេទោះបីកន្លែងផ្សេងប្រឈមខ្លាំងក៏ដោយ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	

	សំនួរ	ចំឡើយ	ភាពសំខាន់	យោបល់ផ្សេងៗ
4	តើនៅក្នុងឃុំរបស់អ្នក អ្នកគិតថាប្រជាពលរដ្ឋយល់ដឹងអំពីមហន្តរាយដែលកើតឡើងពាក់ព័ន្ធនឹងការប្រែប្រួលអាកាសធាតុដែរទេ?	មិនសូវយល់ដឹងប៉ុន្មានទេបើប្រៀបធៀបទៅឃុំផ្សេង  យល់ដឹងខ្លាំងដែរ លើតែអ៊ូរឿងប្រែប្រួលអាកាសធាតុ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	
5	តើអ្នកធ្លាប់ទទួលការផ្សព្វផ្សាយឬជូនដំណឹងពីការប្រុងប្រយ័ត្ន និងត្រៀមខ្លួនចំពោះគ្រោះមហន្តរាយដែលត្រូវបានព្យាករណ៍នៅក្នុងតំបន់?	មិន ធ្លាប់ទេ ទាល់តែកើតឡើងនិងរងផលប៉ះពាល់ទើបដឹង  ធ្លាប់ហើយទទួលបានការនែនាំបានត្រឹមត្រូវ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	
6	តើអ្នកគិតថាកត្តា ចាស់ជរា ឬកូនច្រើន ឬជំងឺដង្កាត់ភ្ជាប់ ជាឧបសគ្គដែលប្រជាជនភាគច្រើនក្នុងឃុំអ្នកពិបាកនឹងបង្កើនជីវភាពដែរទេ?	បាទ មានប្រជាពលរដ្ឋច្រើនណាស់ប្រឈមនឹងបញ្ហានេះ  ទេ ប្រជាពលរដ្ឋក្នុងឃុំខ្ញុំមិនសូវមានបញ្ហានេះប្រឈមទាំងនេះទេ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	

	សំនួរ	ចំឡើយ	ភាពសំខាន់	យោបល់ផ្សេងៗ
7	បើប្រៀបធៀបទៅតំបន់ដទៃក្នុងស្រុកនេះតើអ្នកគិតថាឃុំអ្នកមានហេដ្ឋារចនាសម្ព័ន្ធប្រសើរជាងទេ?	ទេ ឃុំខ្ញុំមិនទាន់មានហេដ្ឋារចនាសម្ព័ន្ធប្រសើរដូចឃុំផ្សេងទេ  បាទ ដាក់ស្តែងឃុំខ្ញុំមានផ្លូវថ្នល់ ប្រឡាយទឹង ល្អជាងឃុំដទៃក្នុងស្រុកនេះ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	
8	តើអ្នកគិតថាប្រជាពលរដ្ឋក្នុងឃុំងាយនឹងទទួលបានសេវាសុខភាពនៅគ្រប់គ្រប់គ្នាទេ?	ទេ ឃុំខ្ញុំមណ្ឌលសុខភាពនៅឆ្ងាយបើប្រៀបទៅនឹងឃុំដទៃហើយប្រជាពលរដ្ឋពិបាកធ្វើដំណើរទៅណាស់  បាទ មណ្ឌលសុខភាពនៅជិតហើយប្រជាពលរដ្ឋភាគច្រើនមកទទួលបានសេវាកម្ម	សំខាន់ខ្លាំង  សំខាន់តិចតួច	

	សំនួរ	ចំឡើយ	ភាពសំខាន់	យោបល់ផ្សេងៗ
9	តើអង្គាធមូលដ្ឋានមានផ្តល់ជាវិធានការការពារពីគ្រោះថ្នាក់ទឹកជំនន់ និងគ្រោះរាំងស្ងួតដែរទេ?	ទេ ឃុំខ្ញុំមិនមានវិធានការ និងការវិនិយោគដើម្បីការពារពីគ្រោះទឹកជំនន់ និងគ្រោះរាំងស្ងួតនោះទេ។ ហើយឃុំយើងត្រូវការ  បាទ ការពារដោយឃុំ និងស្រុក ហើយពួកគេវិនិយោគគ្រប់គ្រាន់ ដូចជាប្រព័ន្ធបង្ហូរទឹកចេញ ម៉ាស៊ីនបូមទឹក អាងស្តុកទឹក	សំខាន់ខ្លាំង  សំខាន់តិចតួច	
10	តើអ្នកតែងតែរៀបចំរួចរាល់ហើយសំរាប់ការពារគ្រោះទឹកជំនន់ និងគ្រោះរាំងស្ងួតនៅមូលដ្ឋានរបស់អ្នក?	ទេ គ្រួសារខ្ញុំមិនដែលបានរៀបចំគិតគូរអំពីគ្រោះទឹកជំនន់ និងគ្រោះរាំងស្ងួតនោះទេ បាទ គ្រួសារខ្ញុំតែងតែបានគិតគូរអំពីការត្រៀមខ្លួនសំរាបទប់ទល់នឹងគ្រោះមហន្តរាយនោះ	សំខាន់ខ្លាំង សំខាន់តិចតួច	

	សំនួរ	ចំឡើយ	ភាពសំខាន់	យោបល់ផ្សេងៗ
11	បន្ទាប់ពីមានគ្រោះមហន្តរាយនោះ កើតឡើងម្តងៗ តើមានជួបបញ្ហាការប្រើប្រាស់ទឹកទេដូចជាទឹកពិសារគ្មានអនាម័យ គ្មានសោទឹកស្អាត?	អោយតែមានទឹកជំនន់និងរាំងស្ងួតកើតឡើងតិចតួចក៏ដោយ ក៏អ្នកស្រុកខ្ញុំជួបបញ្ហាទឹកស្អាតជានិច្ច  មិនមានបញ្ហាទឹកស្អាតកើតឡើងទេបន្ទាប់ពីមានទឹកជំនន់និងរាំងស្ងួត ព្រោះយើងបានរៀបចំទុកដាក់ និងមានវិធានការល្អ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	
12	ពេលមានគ្រោះមហន្តរាយកើតឡើងហើយតើឃុំអ្នកមានអគ្គិសនីប្រើប្រាស់ទេ?	អគ្គិសនីដាច់រហូតទោះមិនមានគ្រោះមហន្តរាយកើតឡើង  អគ្គិសនីនៅតែដំណើរការល្អក្នុងឃុំ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	

	សំនួរ	ចំឡើយ	ភាពសំខាន់	យោបល់ផ្សេងៗ
13	តើមានសេវាជួយដូចជាការគាំទ្រ ឥរិការពីផ្នែកណាមួយដែរឬទេបន្ទាប់ពីមានគ្រោះមហន្តរាយកើតឡើងនៅក្នុងឃុំស្រុកនេះ?	មិនមានការជួយណាមួយទេ  មានការជួយពីអង្គការក្រៅរដ្ឋាភិបាល និងរដ្ឋាភិបាលតាមរយៈកម្មវិធីមួយចំនួន	សំខាន់ខ្លាំង  សំខាន់តិចតួច	
14	តើការអប់រំមូលដ្ឋានរបស់អ្នក មានភាពល្អប្រសើរដែរទេ? មានកូនៗអ្នករស់នៅឃុំរបស់អ្នកបានចូលរៀនច្រើន ហើយបានខ្ពស់ៗដែរទេ?	សកម្មភាពអប់រំនៅមូលដ្ឋានមានសភាពមិនសូវល្អ ហើយក្មេងៗភាគច្រើនមិនបានចូលសាលា  ការអប់រំនៅទីនេះមានការវិវត្តល្អប្រសើគួរអោយកត់សំគាល់ ហើយក្មេងៗច្រើនដែលបានចូលរៀន និងបន្តការសិក្សាទៅទីក្រុងបានច្រើន	សំខាន់ខ្លាំង  សំខាន់តិចតួច	

	សំនួរ	ចំឡើយ	ភាពសំខាន់	យោបល់ផ្សេងៗ
15	តើអ្នកយល់ឃើញថាមានសកម្មភាពអំពើហឹង្សា ចោរលួច ក្នុងទំនើងកើតមានការកើនឡើងទៅពីមួយឆ្នាំទៅមួយឆ្នាំនៅតំបន់នេះ ហើយបើប្រៀបទៅនឹងឃុំផ្សេងមិចដែរ?	មានការកើនឡើងដែរ  ឃុំខ្ញុំនេះមានសន្តិសុខល្អណាស់ប្រើប្រៀបទៅឃុំផ្សេង	សំខាន់ខ្លាំង  សំខាន់តិចតួច	
16	តើអ្នកយល់ថាប្រជាពលរដ្ឋក្នុងឃុំរបស់អ្នកមានអាហារហូបចុកគ្រប់គ្រាន់ ហើយចេះផលិតផលិតផលកសិកម្មដោយខ្លួនឯង ហើយភាពតម្រើនមិនទិញទំនិញជាស្បៀងអាហារពីក្រៅមកទេ?	ឃុំយើងពិបាកក្នុងការធ្វើកសិកម្ម ហើយពិបាកផលិតស្បៀងអាហារបើប្រៀបទៅកន្លែងផ្សេង  ឃុំខ្ញុំមានការផលិតអាហារស្បៀងនិងផលិតផលកសិកម្មបានផលល្អជាងគេ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	

	សំនួរ	ចំឡើយ	ភាពសំខាន់	យោបល់ផ្សេងៗ
17	តើអ្នកគិតថាផ្ទះដែលសាងសង នៅក្នុងភូមិឃុំនេះមានសភាពរឹងមាំល្អទេ? ហើយពេលមានព្យុះភ្លៀងខ្លាំងម្តងៗតើមានរលំដួលច្រើនទេ?	មិនសូវរឹងមាំទេ ដោយសារប្រជាជនមិនសូវមានលុយធ្វើអោយមាំ ហើយងាយដួលរំលំផ្ទុះធ្លាយ  ភាគច្រើនបងប្អូនប្រជាពលរដ្ឋធ្វើបានមាំល្អអាចទប់ទល់បានជាមួយអាកាសធាតុអាក្រក់ផ្សេងៗ	សំខាន់ខ្លាំង  សំខាន់តិចតួច	