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Centre on Water and Environment

CTCN - City Climate Vulnerability Assessment and Identification of Ecosystem based Adaptation Interventions- Lao PDR

Final Report

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CLIMATE TECHNOLOGY CENTRE & NETWORK

The expert in **WATER ENVIRONMENTS**

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CTCN - City Climate Vulnerability Assessment and Identification of Ecosystem based Adaptation Interventions- Lao PDR

Final Report

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CONTENTS

FIGURES

TABLES

APPENDICES

1 Executive Summary

This Draft Final Report contain the results from the CTCN funded study 'City Climate Vulnerability Assessment and Ecosystem Based Adaptation (EBA) Interventions' (Reference number 2016000024).

In Lao PDR, it is expected that the urbanisation will take place at a higher speed during the years to come. Climate change will put additional pressures on cities to cope with urbanization under a changing climate. Traditional urban solutions are likely to exacerbate the climate related problems, further encroaching on vital ecosystem services in the cities and surrounding peri-urban areas. Thus there is a need to rethink urban development approaches to include ecosystem based solutions to climate change adaptation.

The aim of this CTCN technical study was to provide the necessary information foundation to be able to recommend a set viable EBA options for 6 cities of Lao PDR: Luang Prabang, Vientiane, Paksan, Thakek, Kaysone Phomvihane/Savannakhet and Pakse. The technical assistance was requested by the National Designated Entity (NDE) of Laos, on behalf of the 6 cities listed above. In an extension of work, this CTCN technical assistance project will provide the necessary technical inputs for a formulation of a larger scale GCF proposal on implementing EBA interventions in Laos.

To identify the most suitable EBA intervention in an urban context, it was necessary to determine the anticipated climate change effects at city level. Furthermore, to inform the opportunities in, and vulnerability of ESS, it was necessary to conduct an assessment of ecosystem services and their vulnerability to climate change in the urban and peri-urban areas of the 6 cities. Thus the present study focused on following elements, to establish the necessary knowledge base for further action on implementation of EBA, and the formulation of the GCF proposal:

- Assessment of climate change impacts in the 6 cities
- Ecosystem services assessment, including existing ESS and their vulnerabilities
- Vulnerability assessment (vulnerability to main identified CC impact – floods)
- Identification of ecosystem-based adaptation options suitable for each city, based on several identified potential project sites

Further to the above assessments, the project also provides necessary inputs to GCF project documents, as agreed with the GCF project proposal consultant.

1.1 Climate change assessment for 6 cities

DHI estimated the impact of climate changes on meteorological variables including rainfall, evaporation, and temperature. Estimates of climate change impacts were developed for all six cities and also for upland catchment areas with potential to impact flooding and drainage in the cities.

The climate change impact estimates are based on local data sets, global data sets, and climate model projections. Downscaling and statistical correction were used to estimate how changes projected by climate models will impact at local scales and also to remove biases from climate model outputs.

For the analysis of changes in rainfall, the results suggest that the magnitude of *extreme events* will increase in future, and that the increases are projected to be greater at the end of the century, although there is a greater uncertainty in model projections. The results further suggest that there will be small increases in the *average rainfall* during the rainy season.

Analysis undertaken during this study also suggest that the average temperatures and evaporation will increase, with larger increases, but also greater uncertainty in the end-of-century projection. The results show similar tendencies in all of the six cities.

For both rainfall and temperature, the catchment based results show similar trends to those of city scale results, though the deviations from the baseline are less pronounced, primarily due to data and results being averaged.

1.2 Ecosystem services assessment

The identification of ecosystem services (ESS) in the 6 study cities was undertaken in a step-wise manner.

An initial assessment of ESS involved stakeholder consultation workshop and was focused on identifying ecosystem damages resulting from floods. Flooding was a particular focus of the analysis, as climate change projections identify flooding to be one of the most important threats to people and ecosystems in the 6 study cities, and a threat already today. The results from this first workshop were further elaborated on during the mid-term workshop during which the stakeholders from 6 cities analysed ESS specific for the selected potential project sites, and evaluate both, which ESS are damaged by floods, changing climate and human activities, and which ESS can help increase the adaptive capacity of the cities.

The identification and prioritization of those ESS that could be utilized in the project sites (via EBA interventions), focused on those ESS that mitigate or prevent flooding, store flood waters or in other ways could benefit/provide beneficial services to the population. Examples include land use types such as rice fields, natural depressions, and grasslands where storage/mitigation of floods can take place, meanwhile also delivering other benefits to the users.

1.3 Vulnerability assessment

The assessment of the sites identified by the cities showed that the combination of flood hazards and specific types of land cover (e.g. urban areas, rice fields) made the sites very vulnerable to floods, because rising water levels would cause direct impacts on these land types. For non-urban elements, rice fields were considered most sensitive to floods, but at the same time rice fields are considered effective in storing water during floods. The sensitivity is therefore related to the timing; if crops are still on the fields when the flood comes, the damage is very high, but if the crop has been secured before the flood the sensitivity of the rice field falls. For this study, timing of crops and floods have not been directly considered.

Overall, the vulnerability assessment has proved to be an effective tool to help highlighting potential problems and solutions when it comes to work with the different uses of the landscape as ecosystems, which can be used to mitigate flood damages and to increase benefits for the population.

1.4 Site selection

All sites were selected by the regional and local authorities without interaction with the consultant. It was the impression that sites had been selected based on actual flood events and with consultation with the people, who had suffered from the floods. In Luang Prabang the consultant was invited to a meeting with the local spokesmen, who explained the consequences of the floods and where they saw possibilities for mitigating the impacts.

The additional assessments carried out by C4 revealed that some of the sites have been selected for other projects, e.g. for ADB projects and the authorities have seen possibilities to work with EBA's in the same sites.

It must be stressed that the intention from the start of the project was to illustrate working with Ecosystem services and EBA's and relating it to sites without any promises of funding for any implementation, which has not been part of this project. DHI has therefore not spent time to investigate how the sites were selected.

1.5 Identification of priority ecosystem based adaptation options

The understanding of how an ecosystem-based adaptation (EBA) interventions could provide ecosystem services necessary for climate change adaptation, was facilitated by a number of exercises involving stakeholders.

During the September 2017 workshop the participants were taken through 3 steps of ecosystem service and appropriate EBA intervention exercises for each of the identified key sites in their respective cities (more details on the exercises can be found further in the report). The proposed sites were used to illustrate possibilities for implementation of concrete EBA interventions in the site by assessing ESS present, and impacted by climate change, as well as those necessary for flood climate change adaptation. The undertaken analysis thus has been able to deliver specific proposals for priority EBA interventions to be implemented in each site, estimated costing, siting of key elements as well as assessment of possible challenges to overcome in implementation. This information has been summarized in the city site descriptions.

The cities were given a long list of possible EBA's to work with for each of their sites, and in some cases added additional options suited specifically for the site in question. Since most attention of this project has been given to flood damage mitigation, most EBA interventions analysed and proposed were related to delivery of ESS that would help minimize impacts from floods e.g. re-forestation, which would reduce run-off and provide access to ecosystem services like firewood, plants and other goods from the forests. Other examples include watershed restoration, utilization of natural depressions and wetlands, as well as planting of grasses and plants for bank stabilization.

An important finding of the study has been the need to also address lack of or malfunctioning of conventional flood mitigation infrastructure in the cities. It was observed in several instances that lack of controlled flood water management (e.g. non-operational flood gates) prevented from optimal utilization of green spaces in a targeted manner. Thus many of the proposed EBA interventions involve a combination of green-grey measures. Further details of the exact measures proposed for each site are detailed in site descriptions. The site descriptions in cities also indicate potential upscaling potential based on climate change and vulnerability analysis.

2 Introduction

This report is the final document for the project

"**CTCN – City climate Vulnerability Assessment and Identification of Ecosystem based Adaptation interventions – Lao PDR**"

The project was carried out from spring 2016 to December 2017.

Overall scope of works

In 2016 Laos PDR requested CTCN to assist the country to find new ways to cope with climate changes and especially changes to flooding and droughts. Through CTCN, DHI was invited to develop an approach to engage with the Government of Laos and the six designated cities. The aim of the project was to enable Laos to work with green infrastructure elements as tools to create resilience in the urban and peri-urban areas. Special focus was put on identifying and using ecosystem services as tools, accepting that some ecosystem services are damaged by floods but can at the same time provide other services to the society. The change towards using green infrastructure elements in resilience planning must be seen as an eco-friendly method to help the ever-expanding urban development to cope with impacts from floods. The assessment should also look into whether the existing ecosystem services would be available under changed climate conditions.

Overview of visits and workshops held

DHI made a preliminary visit to the country in August 2016 and 3 identical workshops in Vientiane, Luang Prabang and Pakse were organised to help to identify positive and negative impacts during floods. In addition, a number of authorities and ministries were also visited to identify availability of data, masterplans and other sources of information to support the project.The outcome if these workshops provided the solid basis for the project and also provided the necessary basis for the Response Plan and for the interim workshops, held in January 2017, where all six cities were visited individually. As part of the city-based workshops, sites identified by the cities were visited and conditions on the site were discussed.

The workshop carried out in September 2017 had focus on linking identified ecosystem services to ecosystem-based interventions and each city had to consider which services were most relevant for their specific sites. DHI provided guidance but it was up to the cities to pick the most relevant services and also to put an overall financial frame for the interventions. The city-based work with the sites are provided in Appendix C of this report.

The final workshop in December 2017 provided an end to the project and delivered data to the cities and to the NDE. All cities had been given detailed hazard maps, land cover classifications and vulnerability maps and the cities had gone through their sites to assess whether the information provided in the final report was in line with local observations. The process of developing the different types of maps has been based on publicly available data and it has been up to the cities to assess the quality of the data provided. One of the cities suggested a change from one site to a new site, but it was considered being a task during the GCF project and not a subject for the present project. However, the principles for changing sites were discussed and it was agreed that there were no obstacles to change a site to a new site, if it was properly documented.

Approach utilized for conducting workshops

To develop a proper baseline for the project it was clear from the start that direct involvement of the authorities from the six cities and the ministry was absolutely necessary and from the first workshop in August 2016, representatives from the authorities participated in the identification of positive and negative impacts from floods and droughts. These observations were then used to identify ecosystems and ecosystem services and further to create an understanding of how elements in nature can provide services to the society and how to use the services to protect the society as well. All visits to Laos included visits to relevant authorities on both national and regional scale.

The approach used was to a large extent based on plenum and group work to gradually create a mutual understanding of the potentials to work with ecosystem-based adaptation interventions. It is important to underline that although sites have been selected as “work-areas”, this project has had no funds to provide for actual implementation and the sites have mainly been used to test and evaluate the use of potential EBA’s.

Engagement from the provinces in relation to sites and land-ownership.

During the last workshop in December 2017, the NDE presented 6 letters from the provincial governments. In order to implement the GCF project, the Department of Climate Change (DCC), on behalf of the responsible party of drafting the project proposal, has worked closely with the provincial authorities in identifying the sites, which could be used for the implementation of the GCF project. In the process of selecting project sites, the Department of Climate Change issued official letters to the 6 provinces involved in the project through its Provincial Natural Resources and Environment, which are the provincial focal points. The NDE requested the provincial authorities, together with the district authorities as well as the local communities, to discuss internally on the land issues for the potential implementation of GCF project. After the consultations, the provincial and district authorities and communities have agreed with the sites identified during this study. In addition, it was agreed that the implementation of EBA’s under the GCF project would not cause any problems or issues, which would affect the communities and populations. Hence, all the 6 provinces have endorsed approval letters of the project sites and the use of EBA’s in all the selected sites has been found acceptable and in line with, what is expected under the GCF Project. A copy of the 6 provincial letters of approval were shown during the final workshop.

Organization of this report

The final report reflects the requirements provided in the contract between DHI and CTCN and the structure reflects this. Besides executive summary and introduction the report provides input on

- Methodologies and data used and examples of results
- Assessment of the present and future climate conditions in the region
- Overview of the sites chosen by the cities
- Ecosystem services Assessment
- Vulnerability assessment
- Identification of Ecosystem-based adaptations
- Input to the Green Climate Fund project proposal

In addition, all descriptions of the sites, provided by the cities, has been included in the Appendix C.

3 Methods and approach

In the course of the project a wide range of available data sets with different levels of precision have been utilised. It was therefore necessary for the team to utilise the available data with caution and several assumptions had to be made, in order to make proper use of the data. However, despite of the variation in data quality, the various methods and approaches have provided a coherent and sufficient knowledge basis for establishing the project results and assessments.

The methods used for each of the tasks involved in the project are described below and the use of specific data are given in each of the sub sections.

3.1 Preliminary surveys on ecosystem services

To get information about ecosystem services, ES, DHI conducted a preliminary workshop in Vientiane in August 2016 with the aim of understanding which ES's were available, which were utilised by the population, and which were damaged by impacts such as flooding.

The method used to identify and assess the ES's was based on a participatory approach, where representatives from all 6 cities were invited to the workshop and where DHI facilitated discussions among the cities to come up with lists of ES's.

The participants were organised in groups and discussed the topic flood-related problems and damages. The main flood damages that the participants could think of were all noted in terms of headlines. Hereafter, the participants ranked the various damages in terms of importance with 'high' and 'low' being the outer bonds.

After the assessment of flood damages, the participants did a similar exercise to identify damages to ecosystem services. After noting the damages as headlines, these were prioritized.

The 6 cities came up with many similar types of flooding and ecosystem service damages, which was also expected. As flooding was the main cause of impacts, the type of damages were grouped in five sections, where some of the statements were in fact more related to the ecosystem services damage:

- Agriculture, forest and aquaculture (20 inputs)
- Economy and tourism (8 inputs)
- Geology (5 inputs)
- Infrastructure damages (24 inputs)
- People, property and health (33 inputs)

For the ES damages, the number of input was slightly lower and the inputs could also be grouped in five sections:

- Biology/habitats (11 inputs)
- Crops, wild and cultivated (26 inputs)
- Geology/soil (7 inputs)
- Protection and impacts (4 inputs)
- Water-related damages (10 inputs)

Damages to infrastructure are the most common denominators for the 6 cities and damages to important infrastructure elements like roads was mentioned most often, followed by power cuts and damages to private and public properties. For the ecosystem services, the impacts highest priority was water supply (whether from public supply systems or from contamination of private shallow wells), followed by loss of crops.

Only the city of Luang Prabang mentioned damages caused by droughts.

The overall assessment is described in the August 2016 Mission report.

3.2 Ecosystem Services Assessment

The ES identified in the preliminary workshop have through workshops in January 2017 and September 2017 been further assessed and grouped. This has mainly been done through individual assessments of specific areas, where the cities have identified damages on property and on ecosystem services. The use of specific sites has enabled the participants from the six cities to concentrate on the relevant ecosystem services within the project areas and also to get a better understanding of what ecosystem services are and how they can be utilised to benefit the society.

The identified ES's are provided in Chapter 6.

3.3 Climate Change impacts

DHI estimated impacts of climate change at city level in the six CTCN cities, along with associated upland catchment areas that may contribute to urban flooding in the cities. In addition, DHI developed estimates of climate change impacts on headwater catchment areas in the Mekong River basin. The purpose of the climate change assessment was to develop quantitative estimates of changes to meteorological and hydrological variables, in order to inform the vulnerability assessment and prioritization of ecosystem-based adaptation measures.

The climate change impact analysis estimated changes to three meteorological variables: rainfall, evaporation, and temperature. Because the primary climate-related focus of this CTCMN assistance is flooding, the analysis of changes to rainfall included an approach for estimating changes to extreme precipitation. The approaches used to estimate changes to evaporation and temperature estimated changes to average values.

Because of data and resource constraints, the climate change analysis did not estimate changes to river flows or catchment runoff. Developing quantitative estimates of changes to river flows and runoff would have required developing calibrated hydrological and hydraulic models of the Mekong River basin, along with side catchment areas with the potential to contribute to flooding in the six cities. This would have required data and resource inputs that are outside the scope of this project. Instead, estimates of changes to meteorological inputs in the headwater catchments of the Mekong and important side catchments are provided as a proxy for estimates of changes to flows and runoff.

3.4 Vulnerability assessment

The vulnerability assessment has been performed through a number of steps, where each step has been evaluated individually and results from each step has been combined to create the vulnerability assessment. The steps have been:

- Assessment of extent of flooding
- Assessment of the land cover
- Development of a sensitivity analysis
- Combining the three above to reach a vulnerability assessment

The data limitations in each of the steps are described below, but overall data from the authorities in Laos were not at a precision level that could be used directly. Therefore, it was decided to make use of internationally recognised public data.

3.4.1 Hazard assessment and mapping

The Hazard assessment was based on an assessment of the flood prone areas. A digital elevation model, based on the HAND system (Height above nearest drainage point[1]), has been used as a very first assessment of flood-prone areas. The application of the HAND method results in flooded areas which is derived from water levels above the nearest drainage point. The HAND analysis was made using a range from 0-10 meter of water level above an assumed zero flood condition. The approach is simple, but yet physically based as extrapolation of flooded areas would take into account the flow paths are determined with the digital elevation model. It must be underlined that the approach taken was the only feasible way to work with flood areas since there are no local LIDAR or other precise model available, which would otherwise have justified the application of e.g. an overland flood model. The shortcoming of the HAND method is that it is a static approach, wherefore any flow dynamics or event duration cannot be included and assessed.

Data for the HAND comes from 30-meter resolution results from the Shuttle Radar Topography Mission and released by NASA. It provides a digital elevation model, but it has limitations particularly in urban areas where infrastructure features are poorly resolved and results therefore only rough estimates. Further, the results from analysing the elevation in flat and hilly areas can also cause differences. Figure 3-1 contains the HAND map from Luang Prabang, where the hilly terrain shows that flooding mainly take place along the rivers and streams. Figure 3-2 shows a similar map from Pakse, where the land is relatively flat and flooding will cover larger areas. For the assessment of Thakek it was necessary to use an older 90-meter resolution model, since the 30-meter model gave erroneous results in the Thakek region.

For verification, the HAND model was compared with local information received from Laos. Although there were not complete compliances, it was decided that the data were sufficient for making what can be called preliminary maps of flood extent. Improvement of the information provided by the maps can be made by using specific records of flood events and their extent.

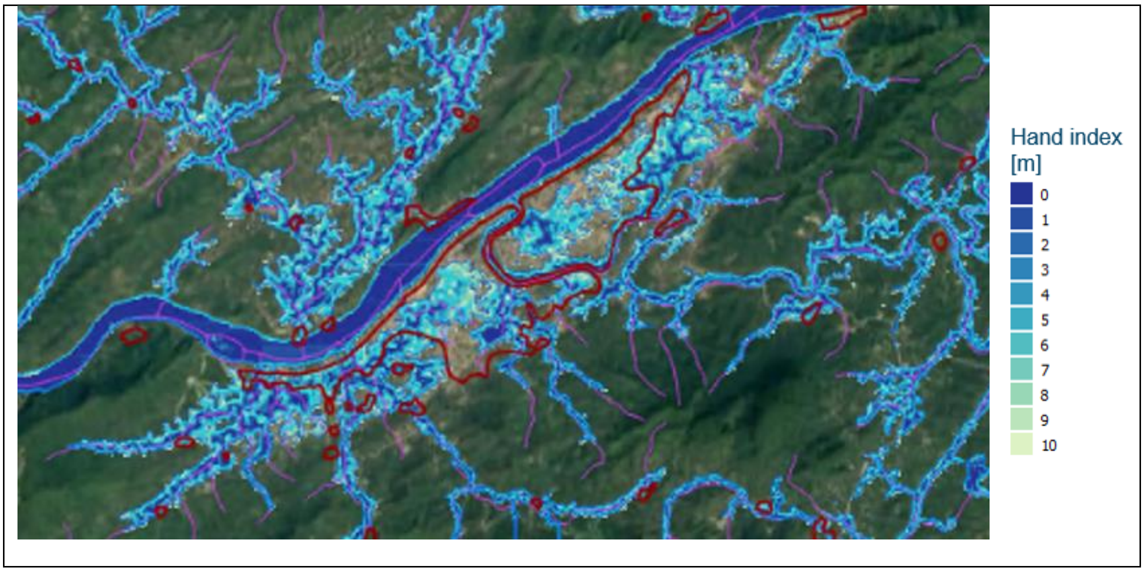


Figure 3-1 HAND map for Luang Prabang with index values. Red lines indicate built-up areas.

[1] Nobre et al (2011)

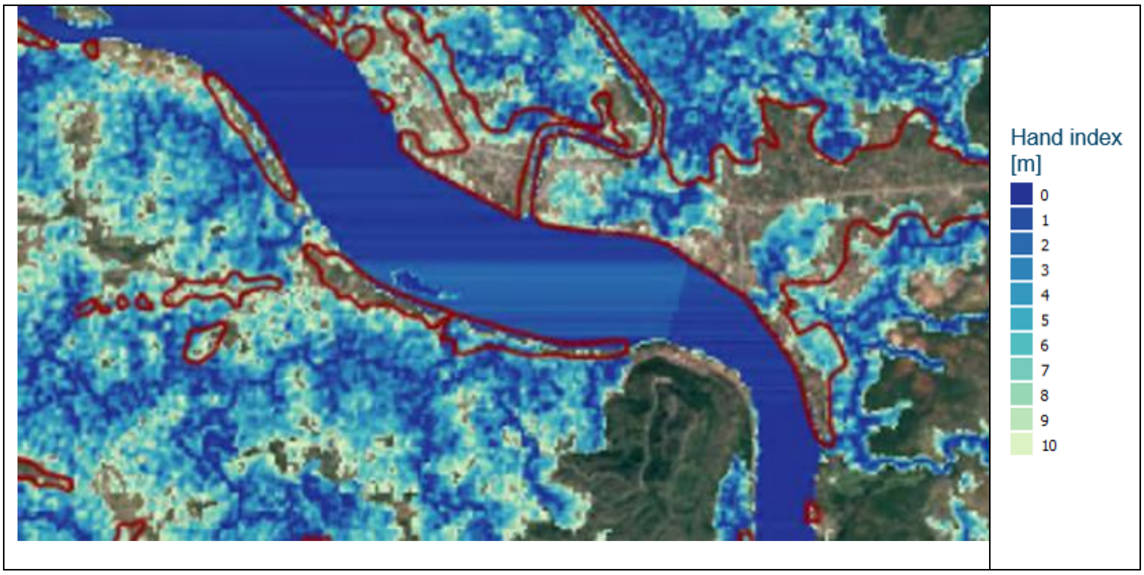


Figure 3-2 HAND-Index map for Pakse with index values. Red lines indicate built-up areas. The dark blue "0 m" indicates normal water level in both rivers and lakes. Areas with no colouring are more than 10 m above potentially flooded terrain.

3.4.2 Land Cover Classification analysis

The land use data which was made available for the consultant was either too coarse in resolution as these were national level data, and often they did not match with observed data from e.g. satellite images. In addition, several of the data were outdated and did not reflect the rapid urban growth in some of the cities.

Therefor a land cover classification analysis was carried out for all cities based on satellite images from Sentinel 2, covering two seasons. The resolution of the images was 10x10 meters.

City	Image I, date	Image II, date
Vientiane	28th November 2016	16th February 2017
Luang Prabang	13th March 2016	29th September 2016
Pakse	12th November 2016	2nd March 2017
Kaysome Phomvihane / Savannakhet	25th December 2016	5th March 2017
Thakek	25th December 2016	5th March 2017
Paksan	25th December 2016	24th January 2017

The classification was developed by identifying different types of typical land covers, while keeping the number of classes limited for practical reasons.

The following 11 classes were identified:

- Forest (deciduous)
- Agriculture (none-specific crops)
- Bare soil

- Forest (coniferous)
- Rubber (Plantation)
- Rice paddies (irrigated naturally)
- Irrigated rice (Irrigated by pumping in the dry season)
- Roads
- Urban (built-up areas)
- Water (Rivers, lakes, streams)
- Grassland

The distinction between the rice paddies and the irrigated rice came from analysing the images, which revealed that limited areas are used for rice paddies, which are irrigated during the dry season with water pumped in from rivers and reservoirs.

With a resolution of 10x10 meters the method cannot identify small houses or sections of roads, but overall the results are suitable for further use in the overall vulnerability analysis. An example is provided below.

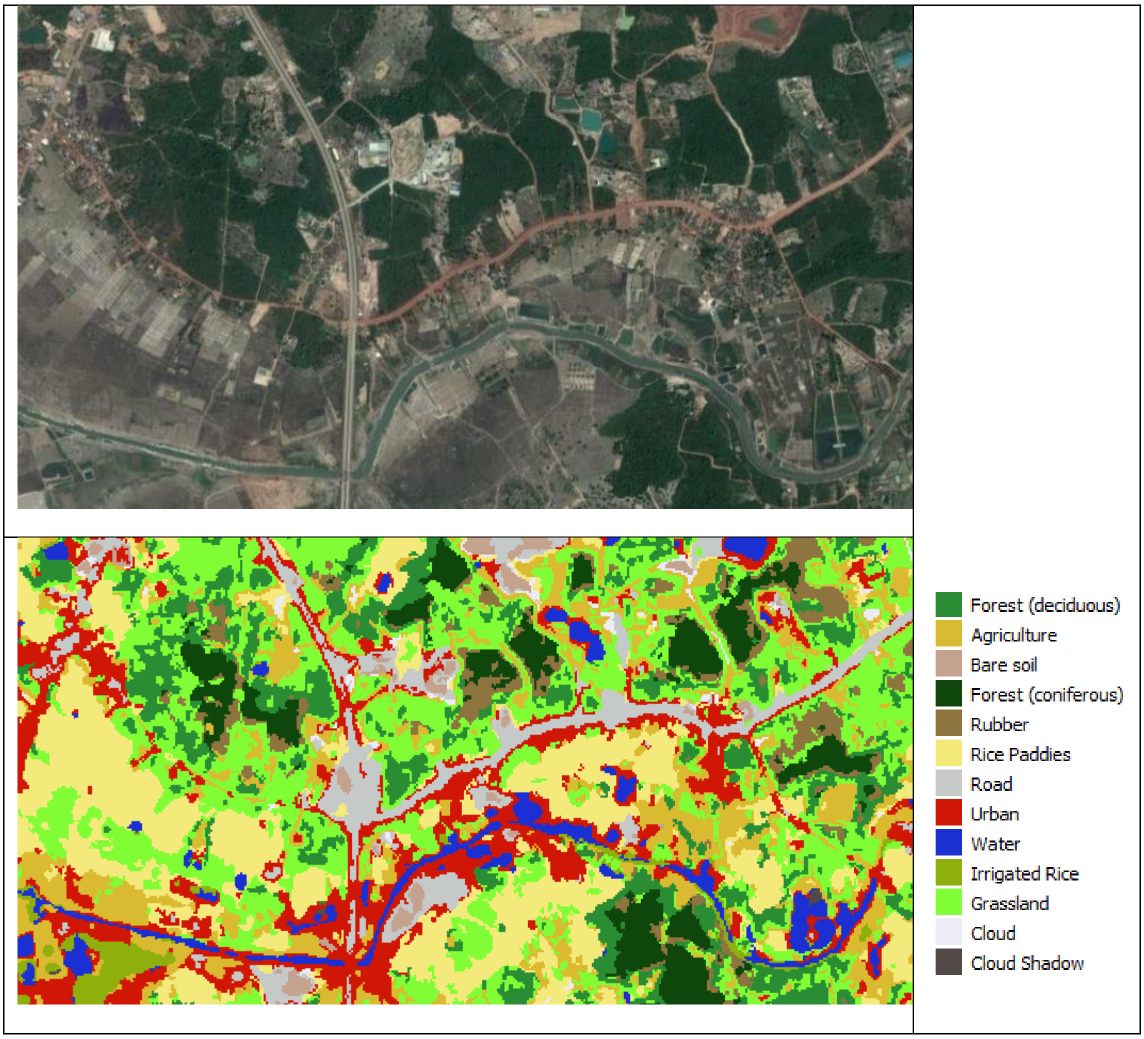


Figure 3-3 Example from the land cover classification.

3.4.3 Sensitivity assessment

The sensitivity assessment is based on looking at the various land covers and for each land cover type, a sensitivity rank has been applied, as shown in Table 3-1. The rank was set according to expected damages done by flooding, and was based on subjective expectations and extracts from the workshop results, where the sensitivity of various land covers were discussed. Both types of rice were initially put under Rank 2, but during the workshop in September 2017, the city delegates argued that rice should belong to the class with high sensitivity.

Table 3-1 Sensitivity rank for the land cover classes

Raster value	Sensitivity Rank	Classes
3	High	Agriculture, Rice (paddies and irrigated), Roads, Urban, Rubber
2	Medium	Grassland
1	Low	Water, Bare soil, Forests (Coniferous/deciduous)

For the flood map (HAND-system), the level of flooding was divided into four categories, where flood sites with water levels above 10 m was not taken into the calculation. The four categories are shown in Table 3-2. The exposure codes are skewed towards high frequencies of flooding, putting 3-meter bands to high and medium exposure (0 – 2,99 m and 3 – 5,99 m) and 4 meters for low exposure (6 – 9,99 m).

Table 3-2 Exposure code for flooding, based on the HAND-method.

HAND Index, m	Exposure code	Exposure text
0,0 – 2,99 m	3	High exposure, flooded often
3,0 – 5,99 m	2	Medium exposure, flooded less often
6,0 – 9,99 m	1	Low exposure, flooded seldom
Above 10	NULL	Very low, not taken further

3.4.4 Vulnerability assessment and mapping

The vulnerability assessment was carried out with the use of the ranking of the sensitivity of the land covers and the exposure codes from the flooding and put into a matrix, shown in Table 3-3 below. The outcome is based on multiplication of the ranks and the codes and then the vulnerabilities are divided into three categories; Low, Medium and High.

Table 3-3 The vulnerability matrix (above) and the operational levels (below)

		Land cover rank: 1= low sensitivity, 3= high sensitivity		
	Code/Rank	**1**	**2**	**3**
Exposure code for flooding: 1 = low, 3 = high risk	**1**	**1**	**2**	**3**
	2	**2**	**4**	**6**
	3	**3**	**6**	**9**

Vulnerability	
1	LOW
2	LOW
3	LOW
4	MEDIUM
6	MEDIUM
9	HIGH

When the vulnerability assessment is transferred to GIS, the results appear like the example from Paksan, shown below in Figure 3-4.

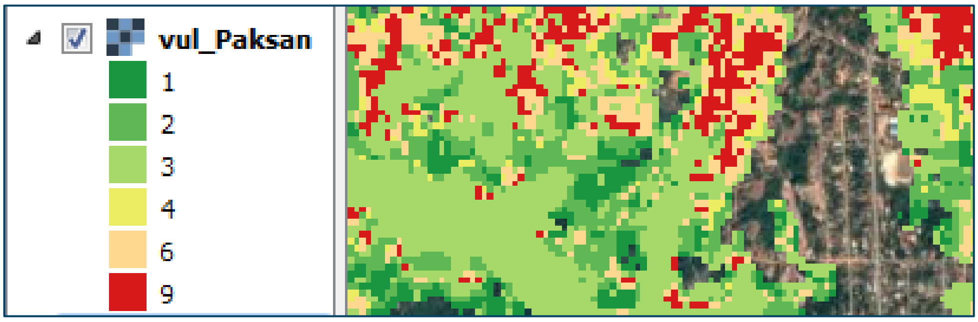


Figure 3-4 Example of a GIS-based vulnerability analysis from Paksan.

3.5 Ecosystems-based adaptation interventions

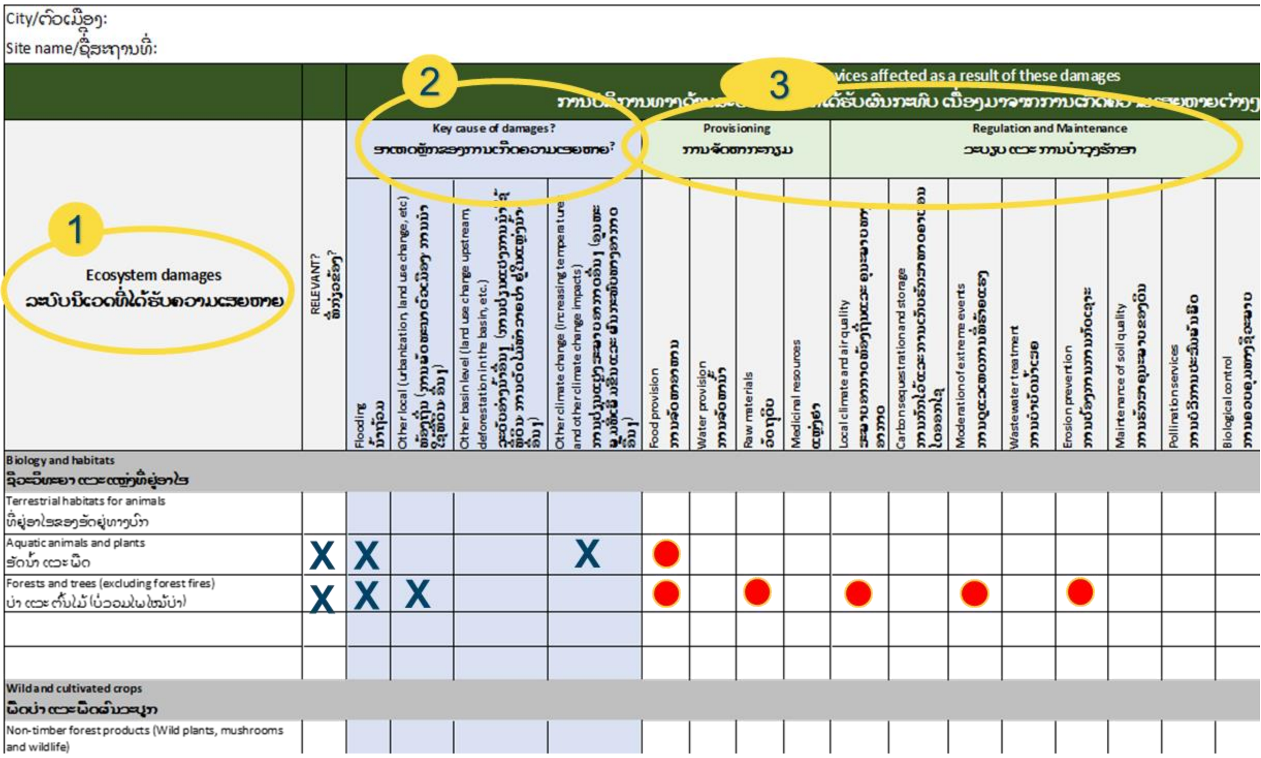
The identification of ecosystem-based adaptation interventions necessary and suitable for each city and selected flood site, builds on the work carried out in the earlier stages of the project. These include two key analysis outcomes from the first two workshops of the project, namely a) the assessment of key damages resulting from floods and b) key ecosystem services damaged by floods.

In addition to this, a separate capacity building session in September 2017 workshop was devoted to strengthening the understanding of participants of the dual role of ecosystem services in the selected sites. Firstly, that key ecosystem services *are being damaged* by floods, but also that ecosystem services *provide* increased resilience to floods and key socioeconomic benefits (Cf. Chapter 6). This step has been important part of the project development, in order to increase the participants understanding of the importance of ESS and to translate the conceptual understanding of the ecosystem services to pragmatic examples of how ecosystem services interact with local socioeconomic activities (such as fishing, agriculture, irrigation, grazing, etc.).

For identification of the specific ecosystem-based adaptation options for each site, participants were introduced to, and asked to evaluate a range of possible EBA interventions for the flood response in the key sites in their city. The selection and prioritization of the EBA interventions was linked to the previous assessments of the ESS, ensuring that the EBA interventions address the specific ESS damages in the site.

Thus the EBA intervention selection and prioritization was carried out through 3 steps of group discussions (each city discussing their selected key sites in the group):

<u>Exercise 1.</u> Identification of the damages of ecosystems experienced in the key site, the key causes of that damage (flooding, but also other factors such as land conversion, climate change) and consequently the resulting damages to ecosystem services. Schematic example outcome of the analysis below:

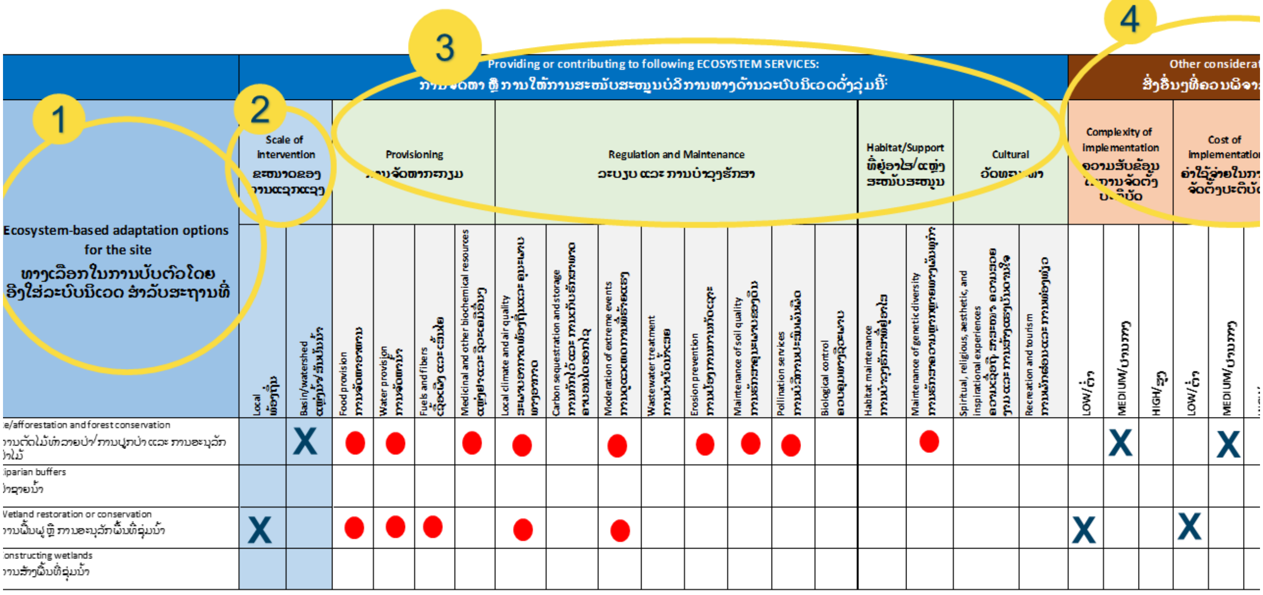


<u>Exercise 2</u>. Group discussions and presentations of outcomes and selection of 2-3 EBA interventions for further analysis. The key considerations for selection are that the selected EBA options are relevant for flood protection but also provides ESS identified in Exercise 1.

<u>Exercise 3</u>. Detailed assessment and prioritization of the selected EBA interventions based on the following criteria:

- ✓ Necessary scale of the intervention for best impact (local or basin)
- ✓ ESS that the selected EBA can provide (flood protection, but also environmental and socioeconomic ESS benefits)
- ✓ Expected complexity of implementation (feasible in reality?)
- ✓ Estimated cost of implementation
- ✓ Timeframe to achieve the desired ESS benefits (short to long term).

Schematic presentation of the analysis outcome can be seen below:



The above three exercises resulted in selection of 1-3 priority EBA interventions for each key site based on the assessment of criteria described above. In addition, each city provided the location of the proposed key sites and approximate mapping of key features of the proposed EBA interventions.

4 Assessment of Climate Change Impacts (Activity 1)

DHI estimated the impact of climate change on meteorological variables including rainfall, evaporation, and temperature. Estimates of climate change impacts were developed for the six cities and also for upland catchment areas with potential to impact flooding and drainage in the cities. Because of the importance of Mekong River flows for flooding and urban drainage, estimates of changes to meteorological variables were also developed for headwater catchments in the upper part of the basin.

The climate change impact estimates are based on local data sets, global data sets, and climate model projections. Downscaling and statistical correction were used to estimate how changes projected by climate models will impact at local scales and also to remove biases from climate model outputs. Because of the importance of flooding in this CTCN assistance, the projection of rainfall changes includes estimates of changes to extreme rainfall. The projection of changes to evaporation and temperature is limited to estimation of changes to average values.

4.1 Collection and harmonization of key data sets

The data set used to estimate climate change impacts was developed by DHI in collaboration with the NDE. The data set was assembled from local sources and globally-available data sets. Local data were used for impact assessment at city level, while global data sets were used to estimate impacts on upland and headwater catchment areas. In addition, a set of climate change projections was assembled from regional climate model experiments for the East Asia region.

4.1.1 Rainfall data

Rainfall data were obtained from local sources and from the CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) global data set. Local rainfall data were obtained for each of the six cities. The CHIRPS data set (Funk et al., 2015), was used to develop rainfall estimates for upland catchment areas and for headwater catchments in the Mekong basin.

Rainfall data obtained from local sources are displayed in .

Table 4-1 Local rainfall data

Location	Time step	Start of record	End of record
Luang Prabang	Daily	1 Jan 1986	31 Dec 2015
Vientiane	Daily	1 Jan 1986	31 Dec 2015
Paksan	Daily	1 Jan 1986	31 Dec 2015
Thakhek	Daily	1 Jan 1988	31 Dec 2015
Savannakhet	Daily	1 Jan 1988	31 Dec 2015
Pakse	Daily	1 Jan 1986	31 Dec 2015

The CHIRPS data set is a global rainfall data set that incorporates satellite imagery and station data to create a gridded rainfall time series. The data is available on a 0.05° grid and covers the period from 1 January 1981 to 30 June 2017 on a daily time step.

CHIRPS data were used to develop estimates of rainfall for side catchments and headwater catchments in the upper Mekong River basin. Side catchments are side catchment areas with potential to contribute to urban flooding, either by overbank flooding or by constraining discharges from the urban drainage system during high-flow periods. Headwater catchments in the upper Mekong basin contribute to elevated water levels downstream, which can also impact urban drainage.

Side catchment areas with potential flooding impacts were identified for four cities: Luang Prabang, Paksan, Thakhek, and Pakse. No side catchment areas were identified for Vientiane of Savannakhet because neither city is located next to a tributary catchment large enough to impact urban flooding by either of the mechanisms mentioned above. A map of the four side catchment areas is presented in .

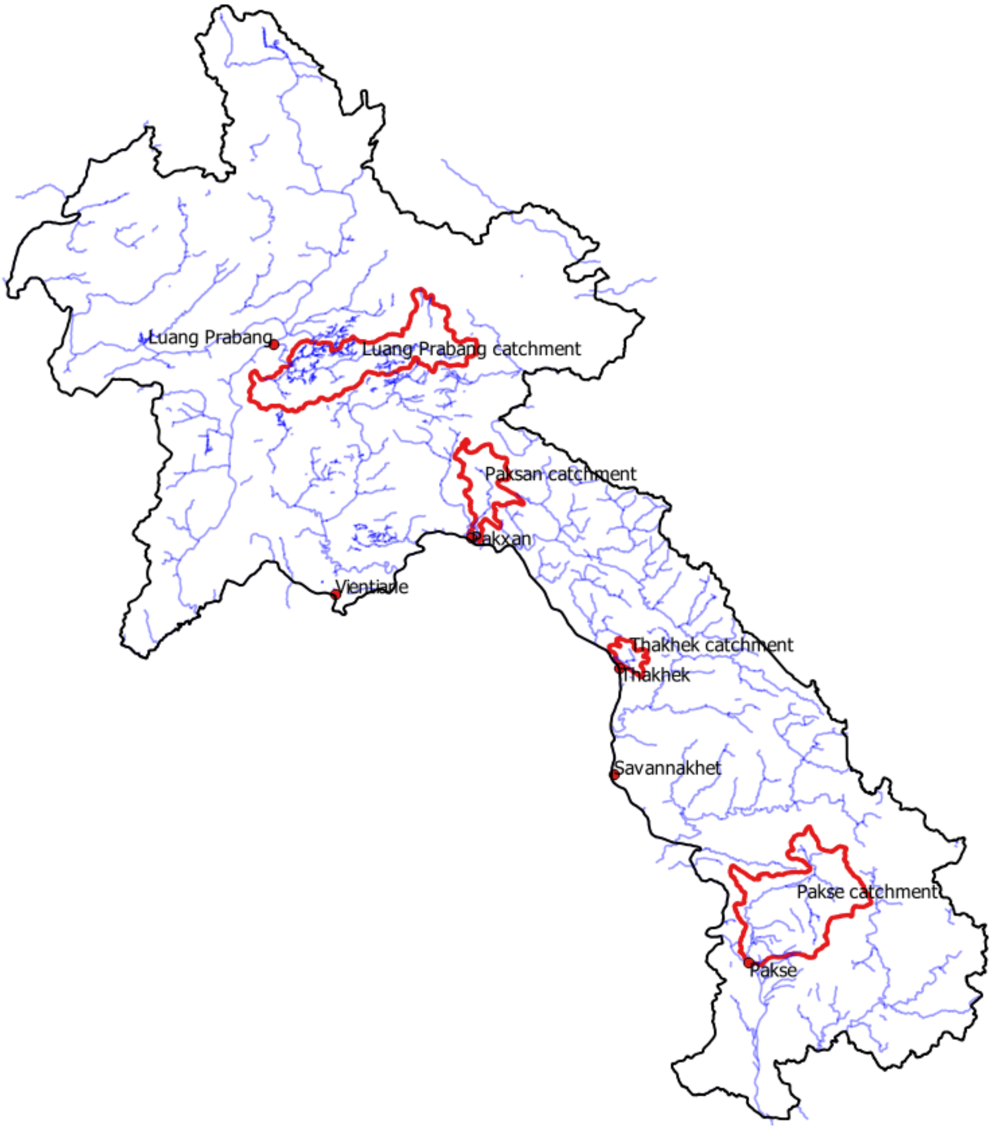


Figure 4-1 Side catchment areas with potential to impact urban flooding

The headwaters of the Mekong River basin upstream of Luang Prabang were divided into three areas. The three headwater subcatchments are displayed in .

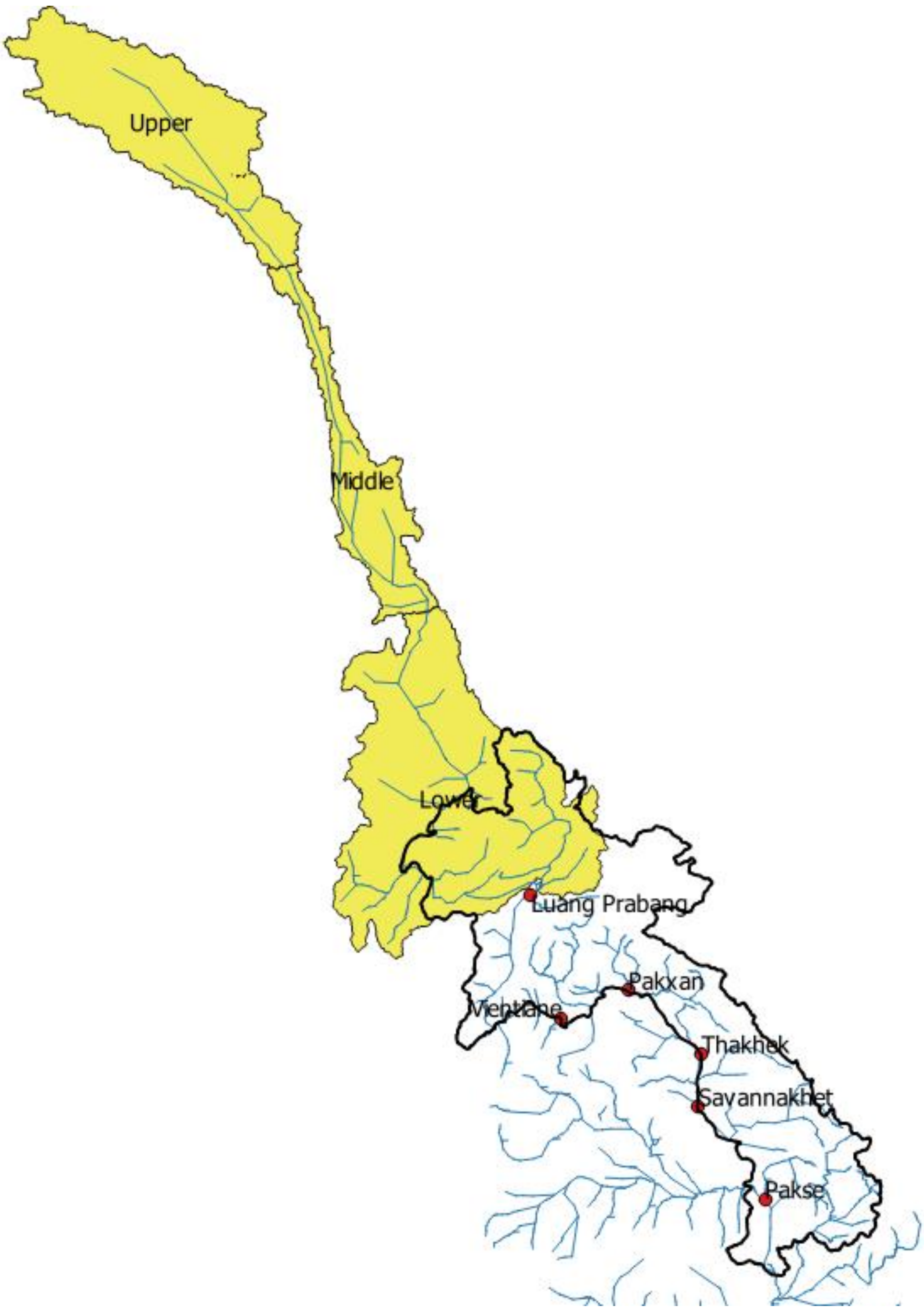


Figure 4-2 Upper Mekong headwater catchment areas

For both the side catchments and the headwater catchment areas, rainfall estimates were developed by taking a weighted average of CHIRPS grid cells intersecting each catchment area.

4.1.2 Temperature data

Temperature data were obtained from local sources and from the CRU global data set. Local temperature data were obtained for each of the six cities. The CRU data set (Harris, Jones, Osborn, & Lister, 2014), was used to develop temperature estimates for upland side catchment areas and for headwater catchments in the Mekong basin.

Temperature data obtained from local sources are displayed in . Local temperature data were not available for Paksan or Savannakhet.

Table 4-2 Local temperature data

Location	Time step	Start of record	End of record
Luang Prabang	Daily	1 Jan 1986	31 Dec 2015
Vientiane	Daily	1 Jan 1986	31 Dec 2015
Thakhek	Daily	1 Jan 1990	31 Dec 2015
Pakse	Daily	1 Jan 1986	31 Dec 2015

The CRU data set (Climate Research Unit) is a global climate data set consisting of observed station data interpolated on to a 0.5° global grid. The data set is updated on a regular basis and currently covers the period from 1 January 1901 to 30 June 2017 on a monthly time step.

The CRU data set was used to develop time series records of temperature for upland side catchment areas and for headwater catchments in the Mekong basin. The upland side catchment and headwater catchment areas are the same as those described in . Time series were estimated by taking a weighted average of CRU grid cells intersecting each of the catchment areas. Because the CRU data set consists of monthly data, the catchment temperature time series are also monthly.

4.1.3 Evaporation data

Evaporation data were obtained from the CRU global data set. No local evaporation data were made available to the project team.

Evaporation data provided by CRU consist of estimates of potential evaporation calculated from other meteorological variables including temperature, vapour pressure, cloud cover, and wind speed. The evaporation data provided by CRU are therefore derived values. Details of the calculation procedure are provided in Harris et al. (2014).

The CRU data set was used to develop time series records of evaporation for upland side catchment areas and for headwater catchments in the Mekong basin. No evaporation values were estimated for cities because the 0.5° CRU grid was considered too coarse for estimating local values. The upland side catchment and headwater catchment areas are the same as those described in . Time series were estimated by taking a weighted average of CRU grid cells intersecting each of the catchment areas. Because the CRU data set consists of monthly data, the evaporation time series are also monthly.

4.1.4 Climate model projections

Climate models are used to project how the climate will evolve in the future in response to changes in greenhouse gas concentrations and other forcings. Climate model projections were used in this project to estimate how meteorological variables might change under future conditions. This section gives an overview of the climate model data sets used in this analysis. Methods used to project climate model output to city or catchment scales are described in .

The climate model projections used in this project are outputs of regional climate models (RCMs). RCMs simulate the atmosphere overlying a portion of the Earth’s surface, in contrast to global climate models (GCMs), which simulate the entire atmosphere. Because of computational constraints, the computational grid size typically found in GCMs is too coarse to simulate some processes that are important for rainfall, such as orographic precipitation. Therefore, RCMs have been developed to provide a finer discretization of the atmosphere and land surface than is possible with GCMs. RCMs use GCM outputs as boundary conditions.

The project uses RCM outputs disseminated by CORDEX (Giorgi, Jones, & Asrar, 2009) which coordinates and evaluates regional climate modelling efforts by partner research organizations. Outputs from RCMs of the CORDEX East Asia region have been used. A map of the CORDEX East Asia region is displayed in

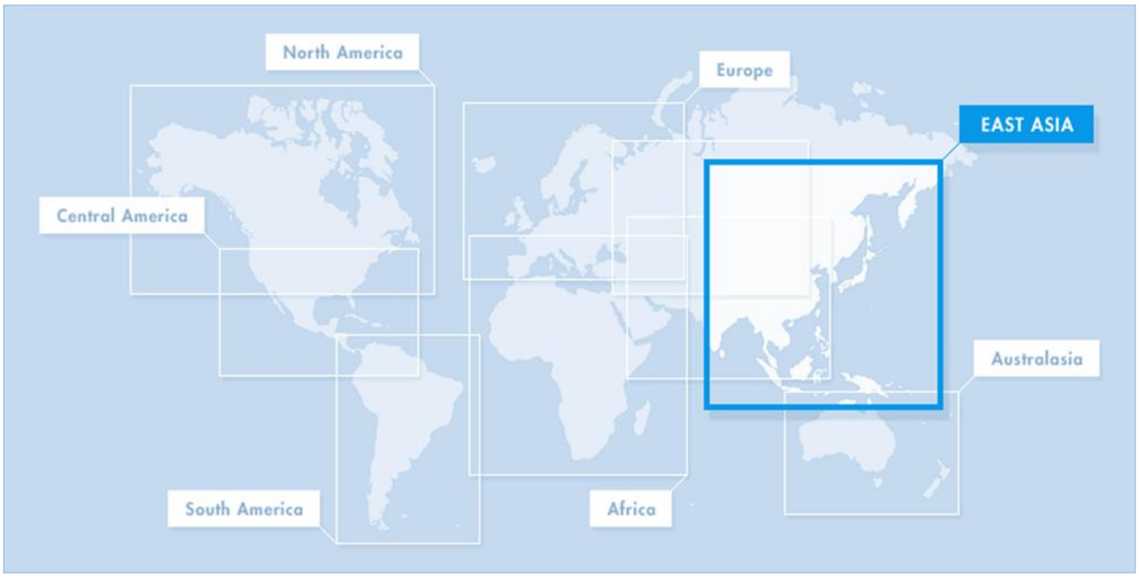


Figure 4-3 CORDEX East Asia model domain

At the time of project implementation, results from a total of six different RCM models were available through CORDEX for the East Asia region. However, five of the six model results are based on boundary conditions from a single GCM: HadGEM2-AO (Martin et al., 2011). The other RCM model result available through CORDEX is from HIRHAM5 (Bøssing Christensen et al., 2007), which uses boundary conditions from the GCM ECEARTH (Hazeleger et al., 2012).

Only two of the six RCMs available through CORDEX were used to develop climate projections in this analysis. Because five of the RCMs are associated with HadGEM2-AO, only one of these, HadGEM3-RA (Davies et al., 2005), was selected in order to conserve resources for other project activities. Results from ECEARTH-HIRHAM5 were also used A comparsion of results from the five RCMs associated with HadGEM2-AO is given in Park et al. (2016).

A total of five timeseries of results were obtained for each RCM. A simulation of the historical climate was obtained for each model, covering the period from 1986 to 2005. In addition, four projections of the future climate were obtained, two projecting conditions in mid-century (2046-2065) and two projecting end-of-century conditions (2081-2100). The two projections for each future period are based different assumptions about how greenhouse gas concentrations will evolve in the future, as defined in the IPCC’s Representative Concentration Pathways scenarios (Pachauri et al., 2014). One uses the RCP4.5 scenario, which assumes declining greenhouse gas emissions, while the other uses the RCP8.5 scenario, which assumes that greenhouse gas emissions will mostly increase to the end of the century. A summary of all RCM results used in the analysis is given in .

Table 4-3 Summary of RCM results used in climate change analysis

GCM	RCM	Simulation period	Greenhouse gas concentration scenario
HadGEM2-AO	HadGEM3-RA	1986-2005	Historical
HadGEM2-AO	HadGEM3-RA	2046-2065	RCP4.5
HadGEM2-AO	HadGEM3-RA	2046-2065	RCP8.5
HadGEM2-AO	HadGEM3-RA	2081-2100	RCP4.5
HadGEM2-AO	HadGEM3-RA	2081-2100	RCP8.5
ECEARTH	HIRHAM5	1986-2005	Historical
ECEARTH	HIRHAM5	2046-2065	RCP4.5
ECEARTH	HIRHAM5	2046-2065	RCP8.5
ECEARTH	HIRHAM5	2081-2100	RCP4.5
ECEARTH	HIRHAM5	2081-2100	RCP8.5

4.2 Assessment of climate change at city and catchment level

Data and climate model results described in were used to develop projections of meteorological variables at city and catchment level. These projections are developed through statistical post-processing that estimates changes to meteorological variables based on RCM projections.

4.2.1 Statistical post-processing

The RCM models described in do not include all local-scale processes involved in precipitation generation (Maraun et al., 2010). In addition, the RCMs use a spatial grid size of ~50 km^2, which is too coarse for estimating local changes. Therefore, an additional statistical post-processing step is used to remove biases from RCM results and downscale to local scales.

Two different post-processing approaches are used: one for rainfall and another for evaporation and temperature. Because this assistance focuses on flooding, the approach used for estimating changes to rainfall estimates how the frequency and magnitude of extreme rainfall events may change in the future. The approach used for estimating changes to temperature and evaporation estimates changes to average values only.

4.2.1.1 Rainfall

Changes to rainfall are estimated using change factor quantile mapping (Sunyer Pinya et al., 2015). The method is applied using the following steps:

1. Climate model outputs and observed time series are grouped by month. For each month, daily rainfall values are sorted by size to produce an empirical cumulative probability distribution.
2. Each cumulative distribution is divided into increments. For the climate model outputs, an average daily rainfall is estimated for each increment of the distribution.

3. The ratio of average daily rainfall in the future climate model simulation to the historical climate simulation is estimated for each increment of the cumulative distribution. The resulting set of ratios are called “change factors”.
4. Each value of the observed time series is multiplied by the change factor associated with that value’s month and cumulative distribution increment.

4.2.1.2 Temperature and evaporation

Changes to temperature and evaporation are estimated using the change factor of mean method (Sunyer Pinya et al., 2015). The method is applied using the following steps:

1. Climate model outputs and observed time series are grouped by month. For the climate model outputs, average values are estimated for each month.
2. The ratio of average temperature (or evaporation) in the future climate model simulation to the historical climate simulation is estimated for each month. The resulting set of ratios are called “change factors”.
3. Each value of the observed time series is multiplied by the change factor associated with that value’s month.

4.3 Results

This section presents estimates of changes to rainfall, temperature, and evaporation. Because similar changes are projected for the six cities as well as the upland and headwater catchment areas, results are presented for one representative city and catchment only. The representative city is Pakse and the representative side catchment is the Pakse side catchment. Results from other cities and catchments are presented in Appendix A.

Each indicator plot compares four climate projections to an observed baseline. In addition, an average of the four projections is presented. The four projections presented in each plot represent the four possible combination of RCM and RCP scenario (). Projections for the two projection periods (2046-65 and 2081-2100) are presented separately.

4.3.1 Rainfall

The presentation of changes to rainfall includes changes to extremes and changes to average values. Changes to extremes are estimated using the following two indicators:

- **Annual maximum time series:** This indicator is a time series of the maximum daily rainfall event for each year of the observed rainfall time series. The indicator compares observed annual maximum rainfall events to projected maximum events.
- **Duration curve of monthly maximum time series:** This indicator is a sorted list of maximum daily rainfall for each month of the observed time series. The indicator compares observed monthly maximum rainfall events to projected maximum events.

Changes to average values are estimated using the following indicator:

- **Average monthly rainfall:** This indicator is a series of 12 values, each giving the average rainfall for a month of the year.

4.3.1.1 Pakse city

4.3.1.1.1 Annual maximum time series

Annual maximum time series for Pakse city are compared in Figure 4-4 and Figure 4-5. The figures suggest that the magnitude of extreme events will increase in the future. Increases are projected to be greater at the end of the century, although there is a greater range of uncertainty in model projections.

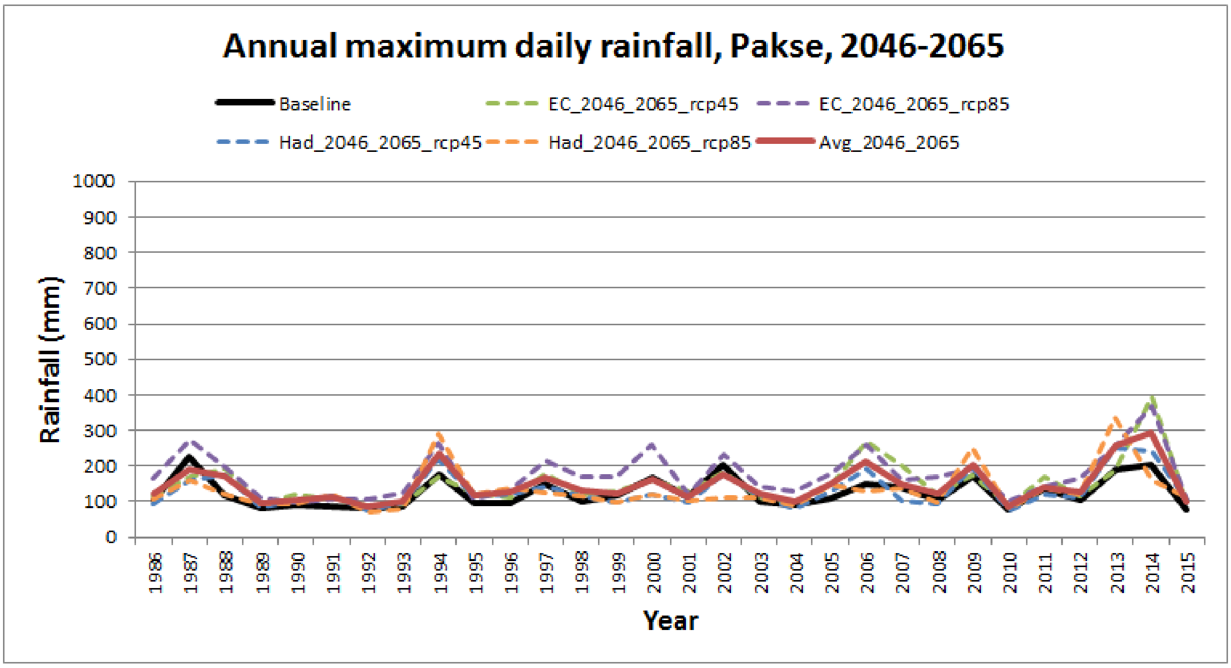


Figure 4-4 Annual maximum daily rainfall, Pakse city, 2046-2065

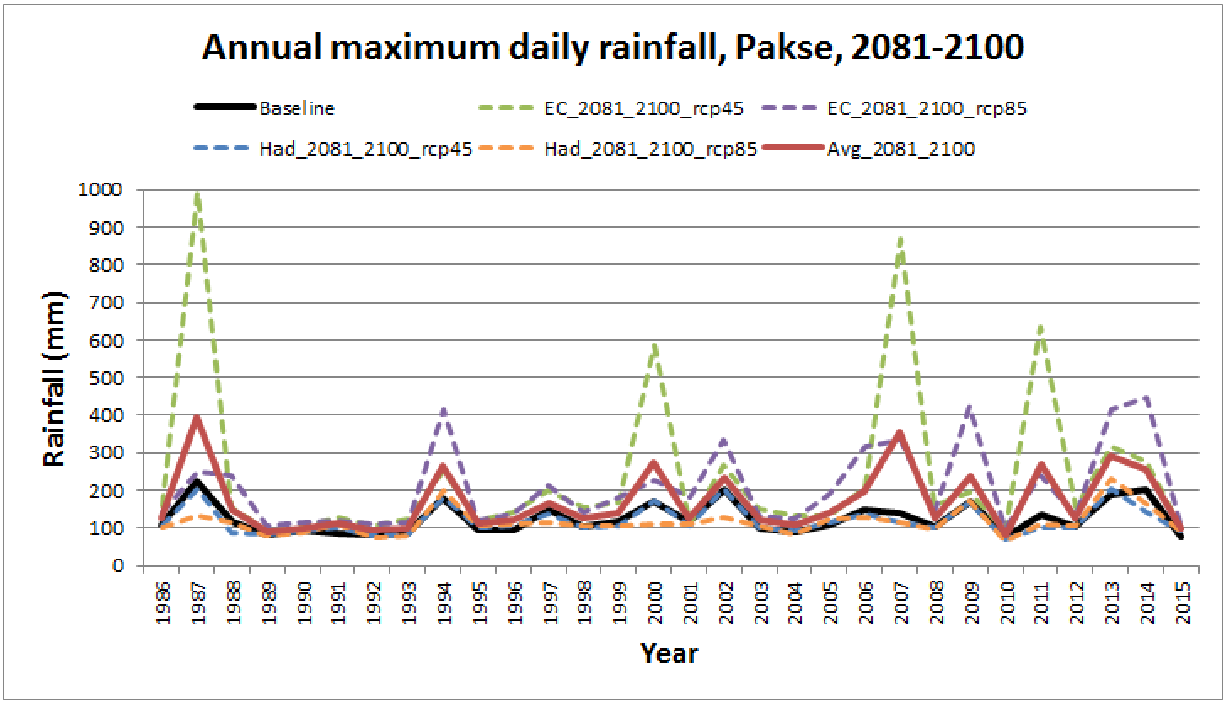


Figure 4-5 Annual maximum daily rainfall, Pakse city, 2081-2100

4.3.1.1.2 Duration curve of monthly maximum rainfall time series

Frequencies of monthly maximum rainfall amounts are compared in Figure 4-6. Only the ensemble average is presented. The figure suggests that extreme events will be more likely in the future.

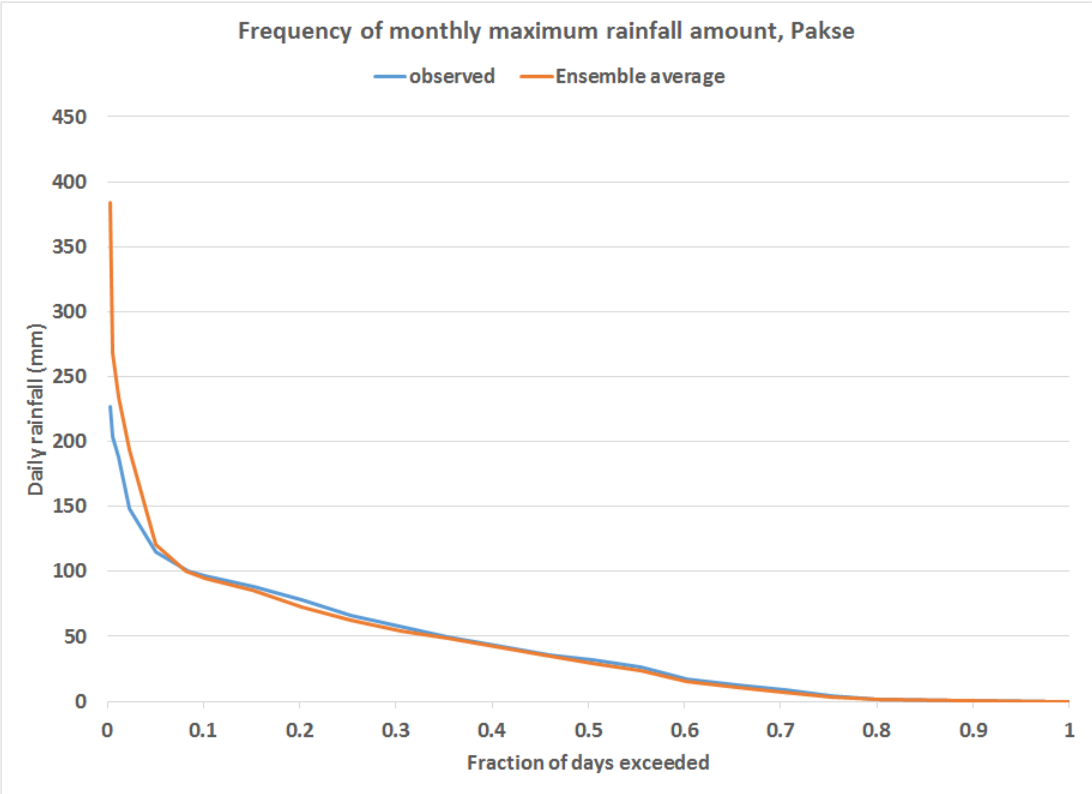


Figure 4-6 Comparison of distribution of monthly maximum rainfall amount, Pakse

4.3.1.1.3 Average monthly rainfall

Average monthly rainfall values are compared in Figure 4-7 and Figure 4-8. The figures suggest small increases in average rainfall during the rainy season.

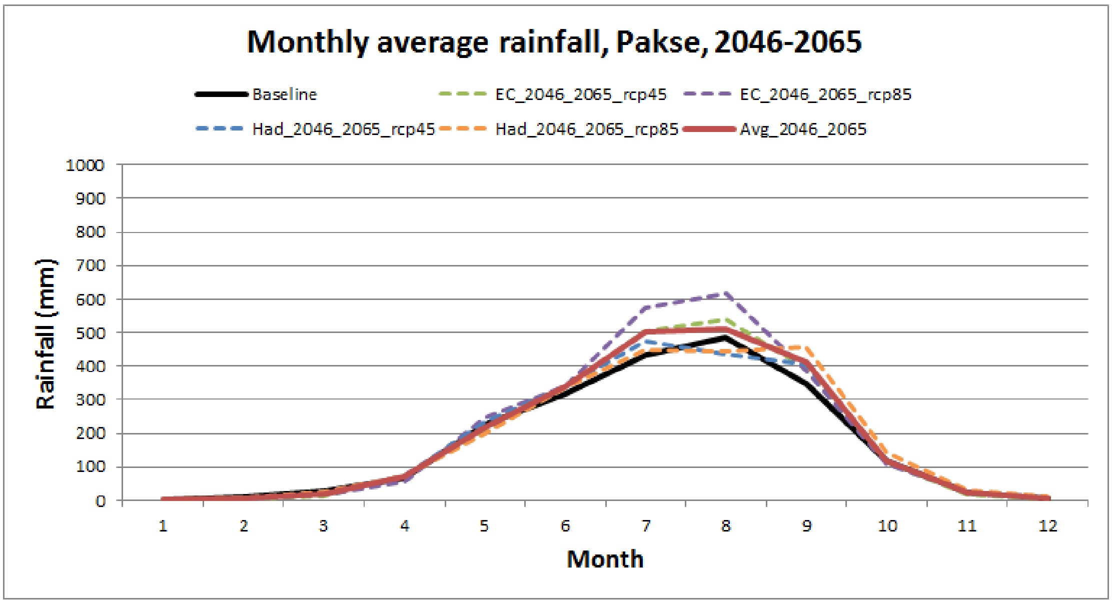


Figure 4-7 Average monthly rainfall, Pakse, 2046-2065

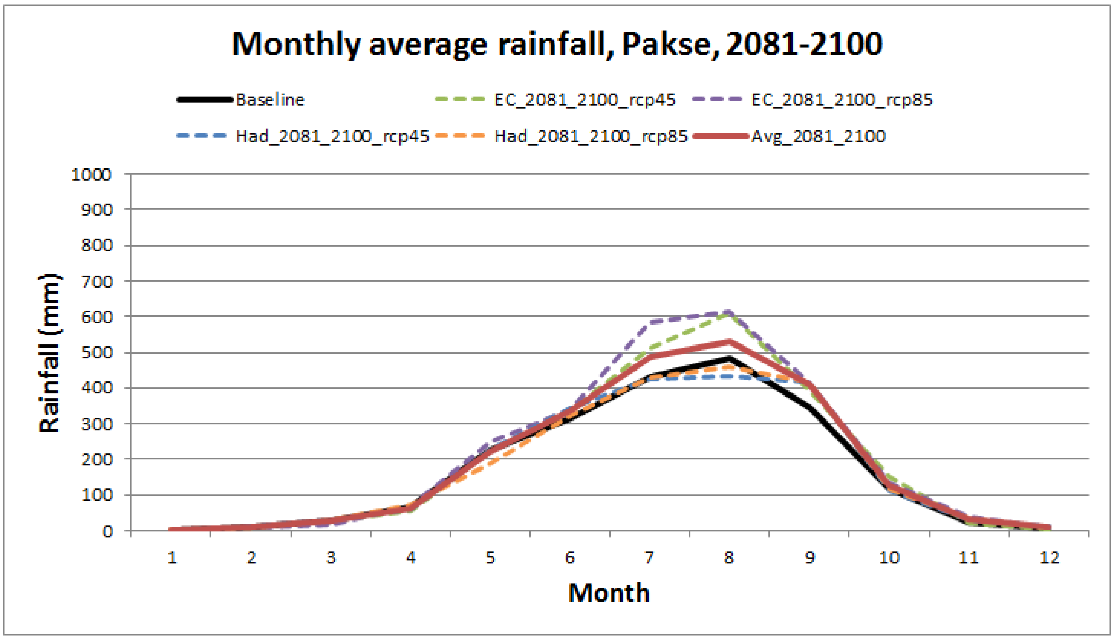


Figure 4-8 Average monthly rainfall, Pakse, 2081-2100

Average values and changes are given in table format in Table 4-4 and Table 4-5. The change factors given in the tables are multiplicative.

Table 4-4 Average monthly rainfall, Pakse, 2046-2065

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	2.8	10.0	27.2	67.6	224.5	314.9	432.8	484.4	345.8	119.0	23.9	4.5
Ensemble average	1.9	5.5	21.1	69.8	218.1	338.3	500.5	509.7	410.3	120.3	23.2	6.9
Change factor	0.68	0.55	0.78	1.03	0.97	1.07	1.16	1.05	1.19	1.01	0.97	1.54

Table 4-5 Average monthly rainfall, Pakse, 2081-2100

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	2.8	10.0	27.2	67.6	224.5	314.9	432.8	484.4	345.8	119.0	23.9	4.5
Ensemble average	1.8	9.4	25.9	63.8	222.6	335.0	488.0	529.7	411.4	127.0	30.7	8.3
Change factor	0.63	0.94	0.95	0.94	0.99	1.06	1.13	1.09	1.19	1.07	1.29	1.85

4.3.1.2 Pakse catchment

4.3.1.2.1 Annual maximum time series

Annual maximum timeseries for Pakse catchment are displayed in Figure 4-9 and Figure 4-10. The figures suggest that changes to extemes are likely to be less pronounced at larger catchment scales because the impacts of local extreme rainfall events are averaged over a larger area.

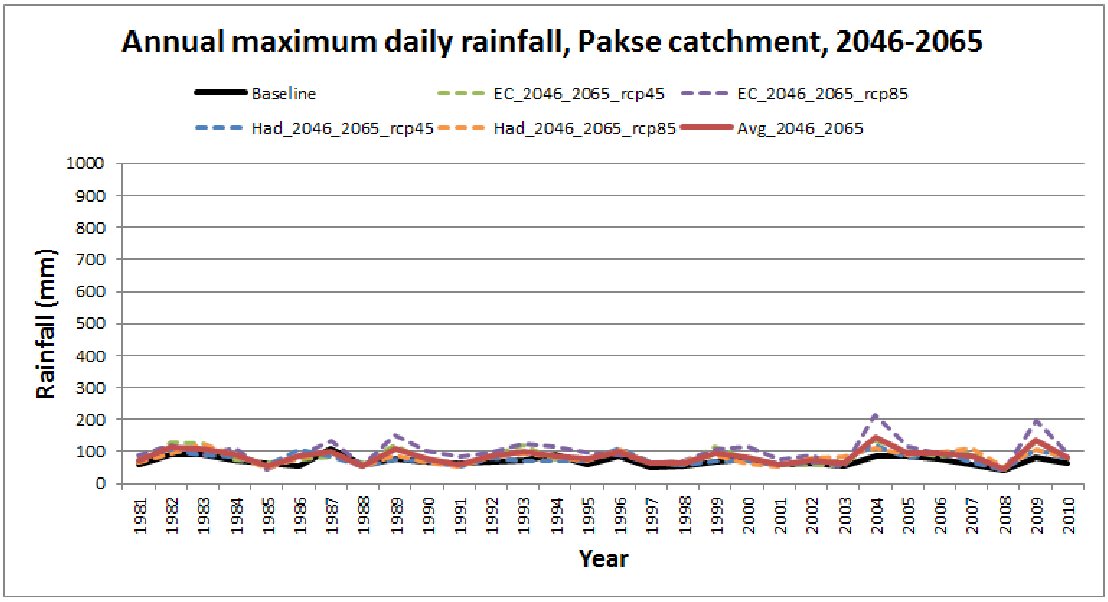


Figure 4-9 Annual maximum daily rainfall, Pakse catchment, 2046-2065

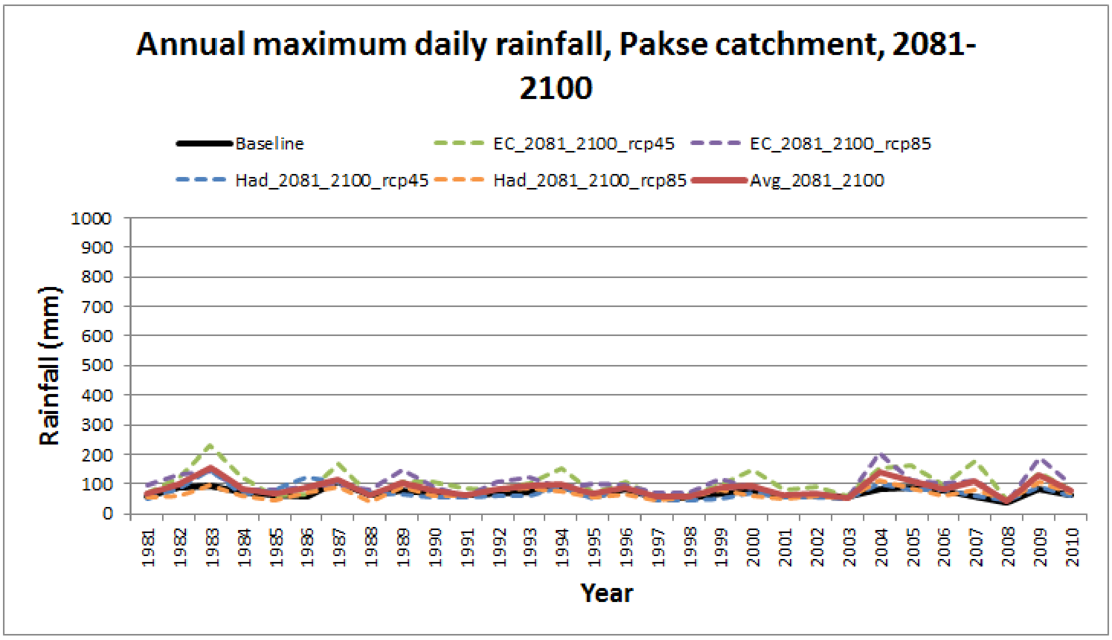


Figure 4-10 Annual maximum daily rainfall, Pakse catchment, 2081-2100

4.3.1.2.2 Duration curve of monthly maximum rainfall time series

Frequencies of monthly maximum rainfall amounts are compared in Figure 4-11. Only the ensemble average is presented. The figure suggests that extreme events will be more likely in the future, although the projected change is not as significant as the change projected for Pakse city.

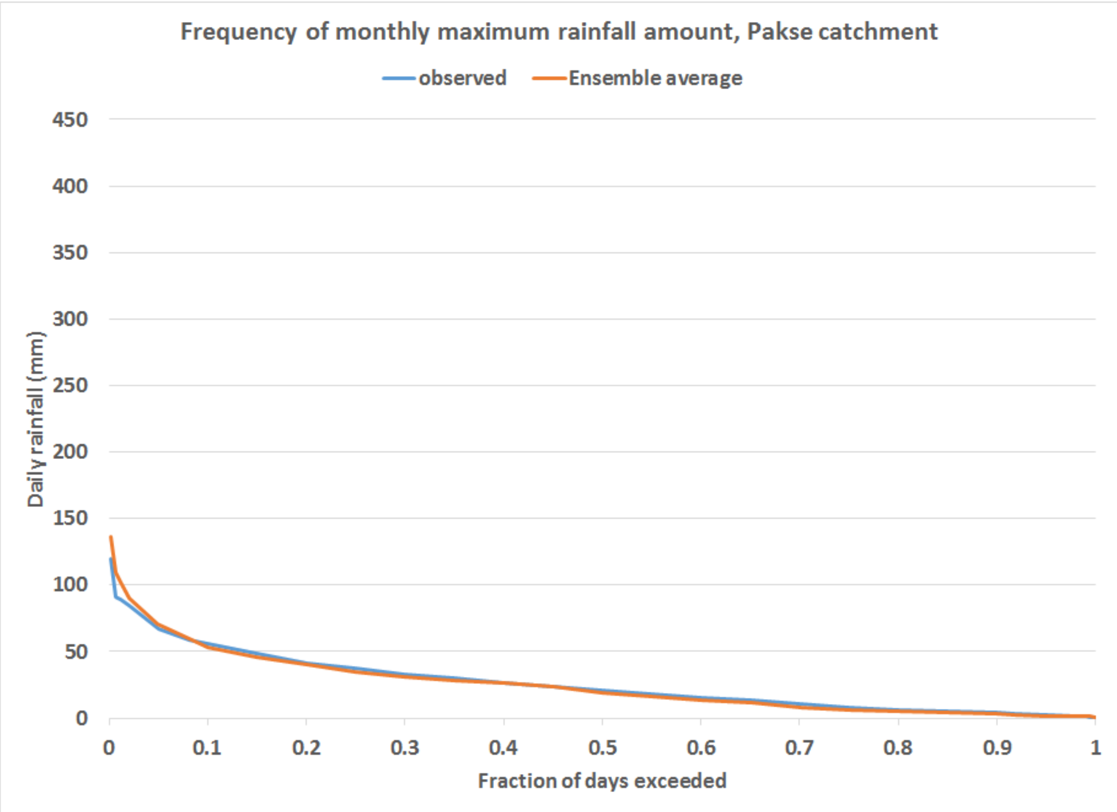


Figure 4-11 Comparison of distribution of monthly maximum rainfall amount, Pakse catchment

4.3.1.2.3 Average monthly rainfall

Projections of monthly average rainfall for Pakse catchment are displayed in Figure 4-12 and Figure 4-13. The figures suggest that significant changes to average rainfall are unlikely at larger scales.

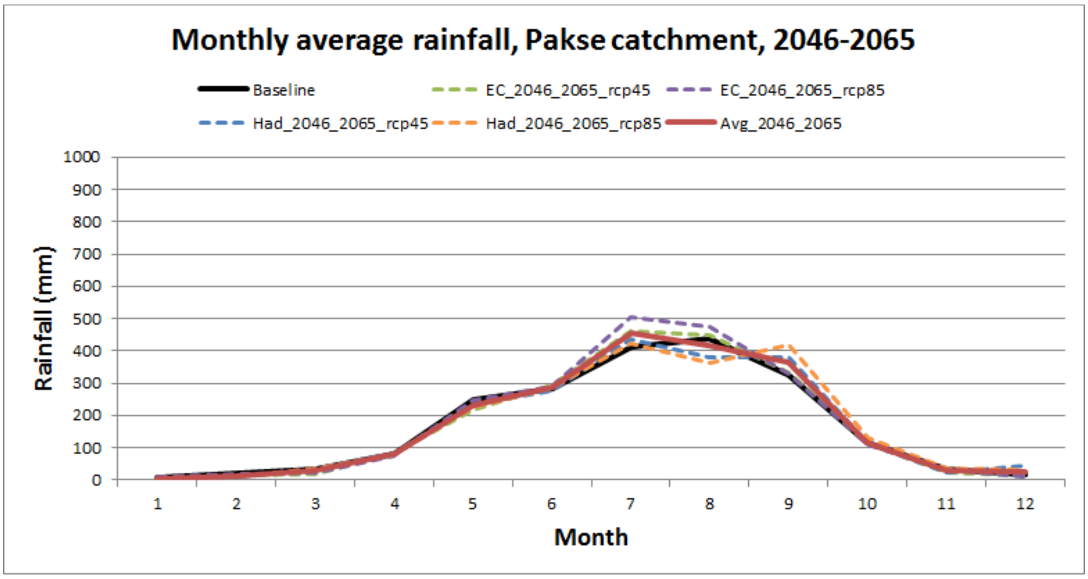


Figure 4-12 Average monthly rainfall, Pakse catchment, 2046-2065

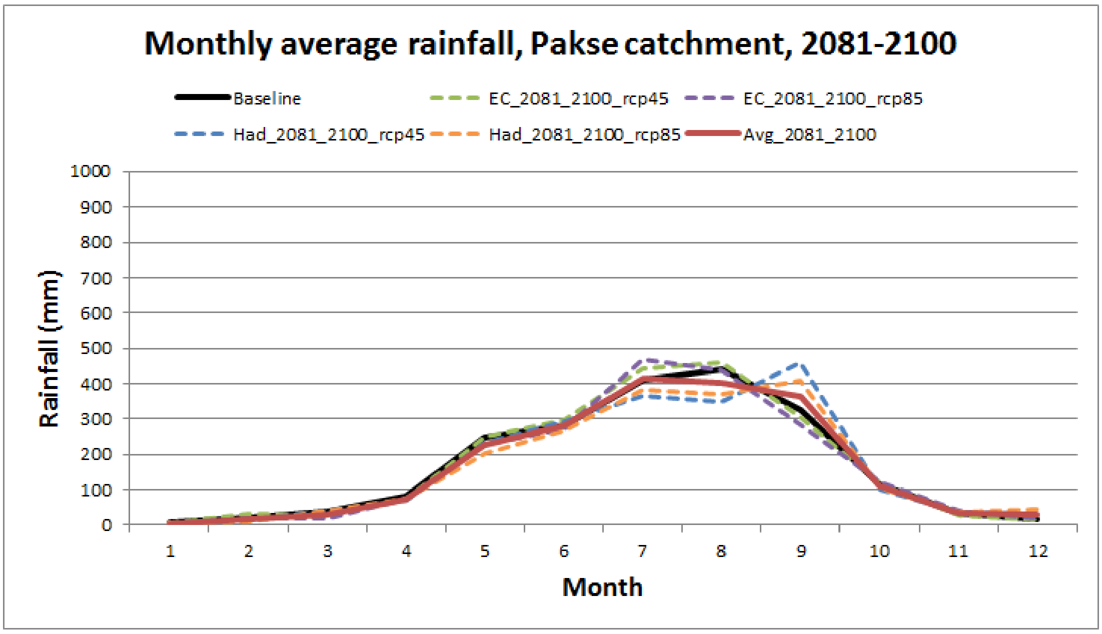


Figure 4-13 Average monthly rainfall, Pakse catchment, 2081-2100

Average values and changes are given in table format in Table 4-6 and Table 4-7. The change factors given in the tables are multiplicative.

Table 4-6 Average monthly rainfall, Pakse catchment, 2046-2065

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	6.1	21.0	35.6	80.4	247.3	283.7	411.6	440.0	326.3	114.8	33.2	18.4
Ensemble average	5.4	13.5	28.3	79.5	229.8	286.6	456.2	416.8	365.6	115.7	28.1	24.2
Change factor	0.89	0.64	0.79	0.99	0.93	1.01	1.11	0.95	1.12	1.01	0.85	1.32

Table 4-7 Average monthly rainfall, Pakse catchment, 2046-2065

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	6.1	21.0	35.6	80.4	247.3	283.7	411.6	440.0	326.3	114.8	33.2	18.4
Ensemble average	4.5	18.4	30.8	73.1	227.9	281.4	413.8	402.6	365.1	109.1	34.0	27.6
Change factor	0.75	0.88	0.87	0.91	0.92	0.99	1.01	0.92	1.12	0.95	1.02	1.51

4.3.2 Temperature

The presentation of changes to temperature consists of changes to average values only. Changes to average values are estimated using the following indicator:

- **Average monthly temperature:** This indicator is a series of 12 values, each giving the average temperature for a month of the year.

4.3.2.1 Pakse city

Average temperatures for Pakse are compared in Figure 4-14 and Figure 4-15. The figures suggest that average temperatures will increase, with larger increases and greater uncertainty in the end-of-century projection.

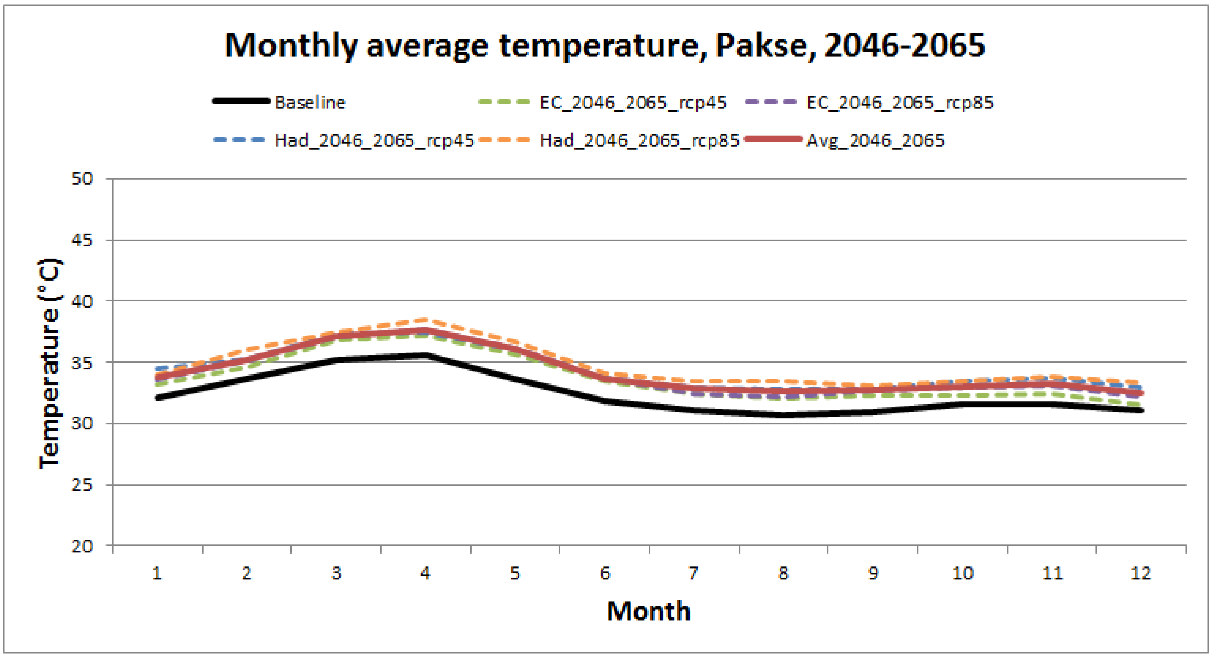


Figure 4-14 Average monthly temperatures, Pakse city, 2046-2065

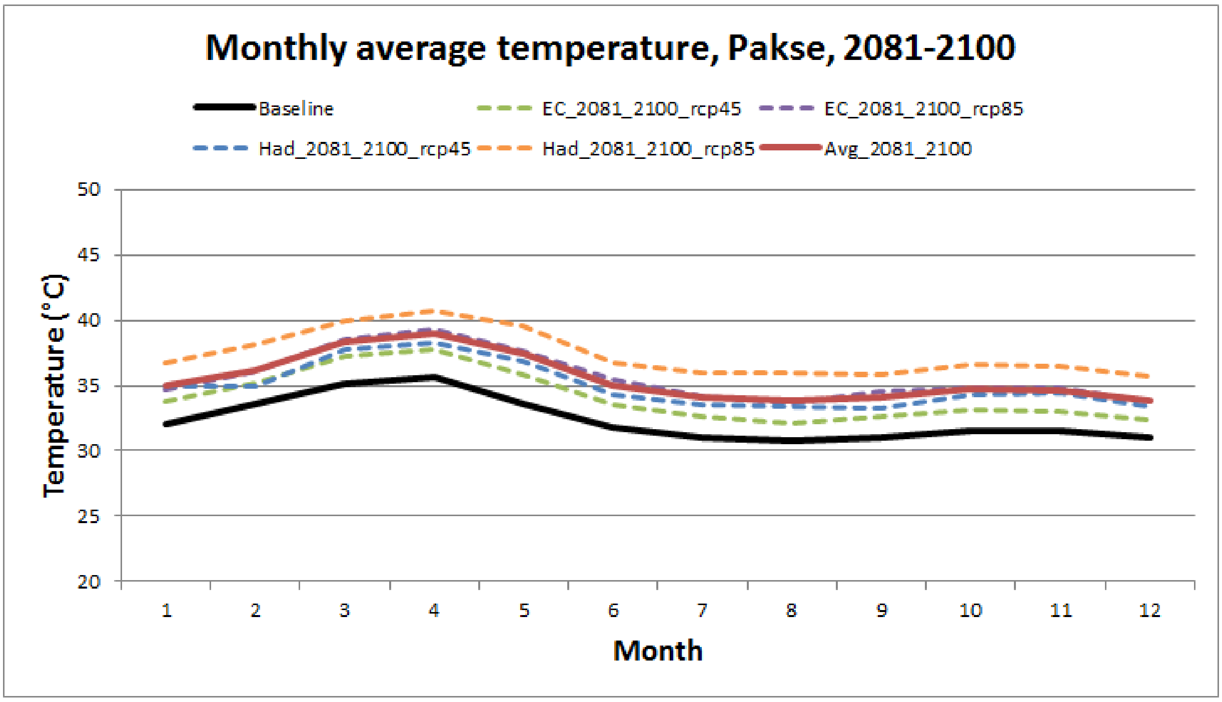


Figure 4-15 Average monthly temperatures, Pakse city, 2081-2100

Average values and changes are given in table format in Table 4-8 and Table 4-9. The change factors given in the tables are additive.

Table 4-8 Average monthly temperatures, Pakse city, 2046-2065

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	32.1	33.6	35.2	35.6	33.6	31.8	31.0	30.7	31.0	31.5	31.6	31.1
Ensemble average	33.8	35.3	37.2	37.7	36.2	33.7	32.8	32.6	32.7	33.1	33.3	32.5
Change factor	1.72	1.66	2.02	2.08	2.52	1.85	1.78	1.89	1.74	1.52	1.66	1.45

Table 4-9 Average monthly temperatures, Pakse city, 2081-2100

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	32.1	33.6	35.2	35.6	33.6	31.8	31.0	30.7	31.0	31.5	31.6	31.1
Ensemble average	35.0	36.1	38.4	39.0	37.5	35.0	34.1	33.8	34.1	34.7	34.7	33.8
Change factor	2.97	2.50	3.21	3.38	3.84	3.20	3.05	3.06	3.09	3.17	3.07	2.76

4.3.2.1.1 Pakse catchment

Average temperatures for Pakse catchment are compared in Figure 4-16 and Figure 4-17. The figures suggest that temperature changes will be smaller at the catchment scale, again because of averaging effects.

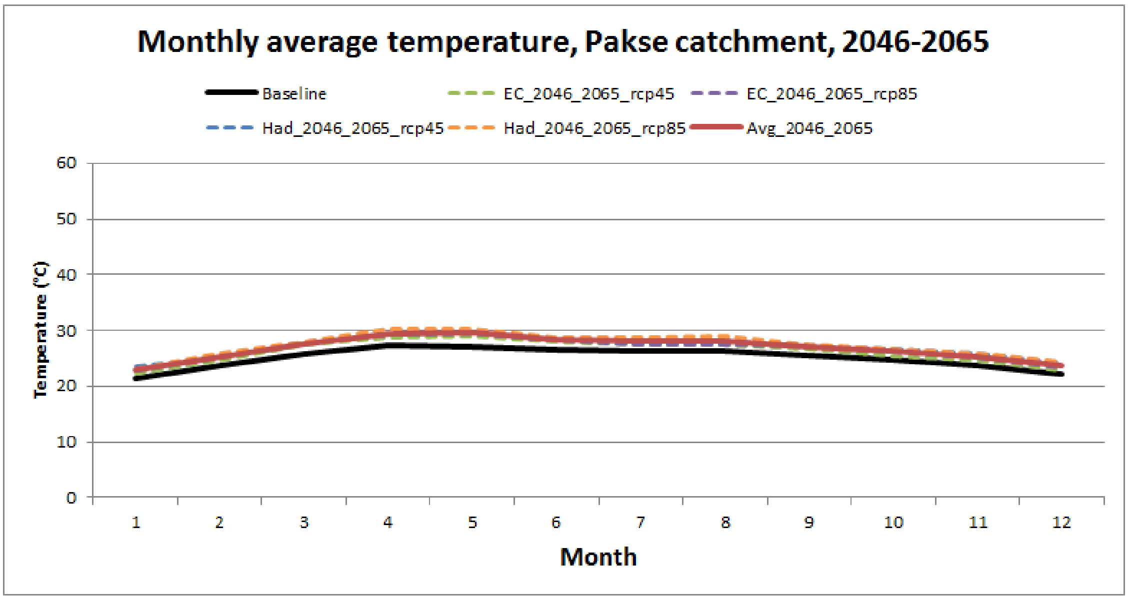


Figure 4-16 Average monthly temperatures, Pakse catchment, 2046-2065

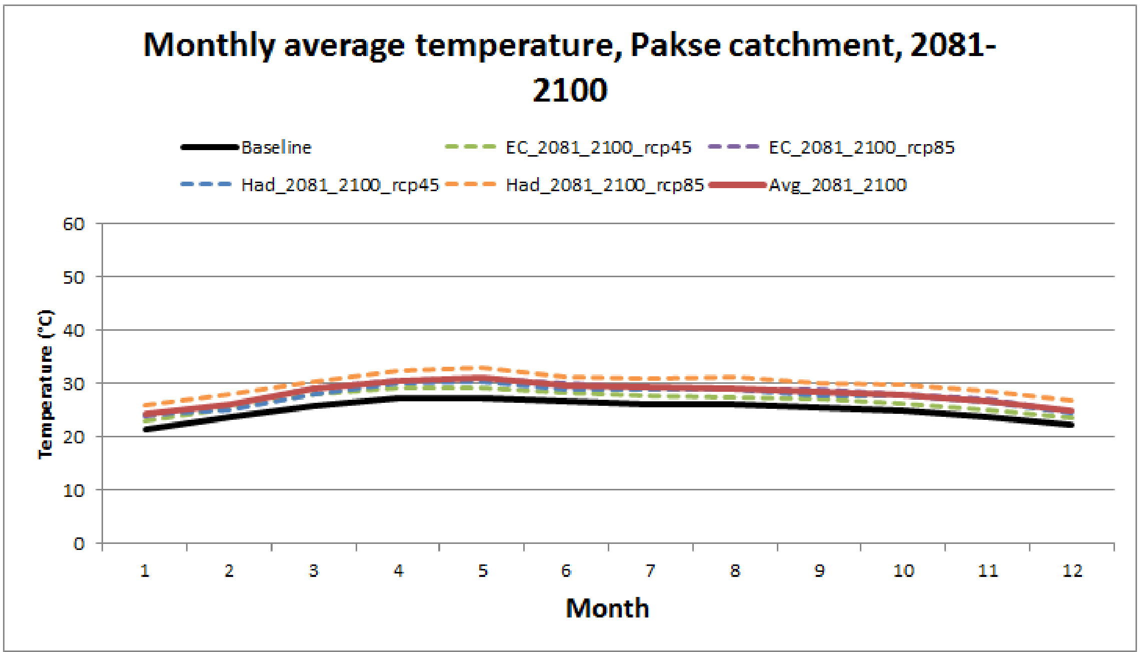


Figure 4-17 Average monthly temperatures, Pakse catchment, 2081-2100

Average values and changes are given in table format in Table 4-10 and Table 4-11. The change factors given in the tables are additive.

Table 4-10 Average monthly temperatures, Pakse catchment, 2046-2065

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	21.3	23.6	25.7	27.2	27.2	26.6	26.2	26.2	25.6	24.8	23.7	22.2
Ensemble average	23.0	25.2	27.7	29.3	29.7	28.3	28.0	28.0	27.1	26.2	25.3	23.6
Change factor	1.64	1.57	2.00	2.07	2.49	1.79	1.73	1.81	1.58	1.47	1.60	1.39

Table 4-11 Average monthly temperatures, Pakse catchment, 2081-2100

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	21.3	23.6	25.7	27.2	27.2	26.6	26.2	26.2	25.6	24.8	23.7	22.2
Ensemble average	24.2	26.1	28.9	30.6	31.0	29.6	29.2	29.1	28.5	27.9	26.8	24.9
Change factor	2.90	2.43	3.20	3.42	3.82	3.09	2.98	2.94	2.95	3.14	3.04	2.72

4.3.2.2 Evaporation

The presentation of changes to evaporation consists of changes to average values only. Changes to average values are estimated using the following indicator:

- **Average monthly potential evaporation:** This indicator is a series of 12 values, each giving the average potential evaporation for a month of the year.

Changes to evaporation are presented for Pakse catchment only because estimates of evaporation are not available for Pakse city.

4.3.2.2.1 Pakse catchment

Projections of changes to average daily potential evapotranspiration are displayed in Figure 4-18 and Figure 4-19. The figures suggest that evaporation will increase, with larger increases and greater uncertainty projected for the end-of-century simulation.

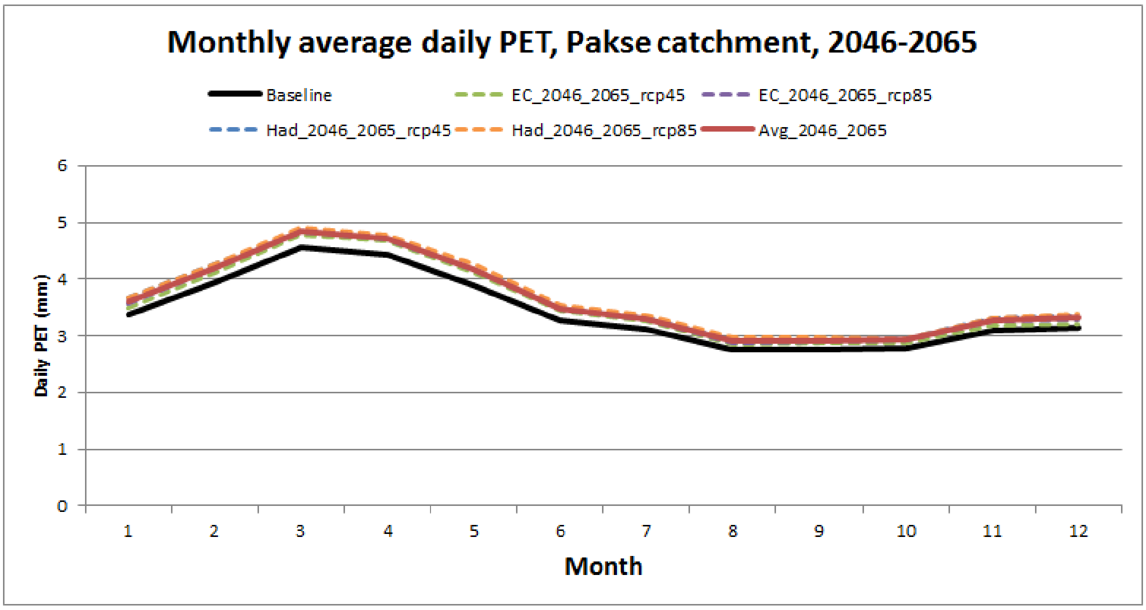


Figure 4-18 Average monthly daily PET, Pakse, 2046-2065

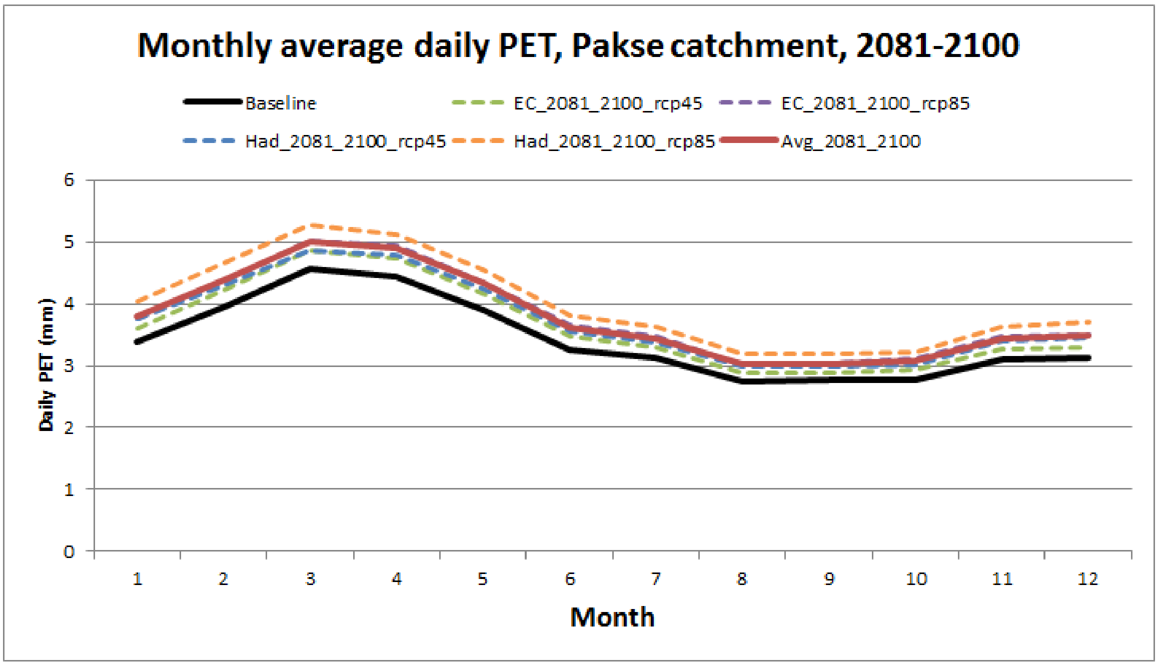


Figure 4-19 Average monthly daily PET, Pakse, 2081-2100

Average values and changes are given in table format in Table 4-12 and Table 4-13. The change factors given in the tables are multiplicative.

Table 4-12 Average monthly daily PET, Pakse, 2046-2065

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	3.4	4.0	4.6	4.4	3.9	3.3	3.1	2.7	2.8	2.8	3.1	3.1
Ensemble average	3.6	4.2	4.8	4.7	4.2	3.5	3.3	2.9	2.9	2.9	3.3	3.3
Change factor	1.06	1.06	1.06	1.06	1.07	1.07	1.06	1.06	1.06	1.05	1.06	1.06

Table 4-13 Average monthly daily PET, Pakse, 2081-2100

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	3.4	4.0	4.6	4.4	3.9	3.3	3.1	2.7	2.8	2.8	3.1	3.1
Ensemble average	3.8	4.4	5.0	4.9	4.3	3.6	3.4	3.0	3.0	3.1	3.4	3.5
Change factor	1.12	1.11	1.10	1.10	1.11	1.11	1.10	1.10	1.10	1.10	1.11	1.11

4.3.3 Summary of climate change projections

The climate change analysis suggests that the following are likely in the future:

- Overall changes to rainfall amounts likely to be small, but significant increases to the frequency and intensity of extreme events are likely.
- Changes to extreme rainfall likely to be more significant at local scales.
- Significant increases in average temperatures and evaporation are likely.

5 Site selection

An important exercise in the project has been for each of the cities to identify and describe one or more sites, where flooding is a problem and where the use of ecosystem services could be used to mitigate damages and create a higher level of resilience, while at the same time also looking at which ecosystem services were provided by the flooding. Each city did choose a main project side and additional sites were also identified. All sites have been described to a smaller or larger extent and all are presented in Appendix C.

It appeared that the sites chosen for this project were already identified previously and that the selection criteria for the sites to some extent were done on the basis of the history of resent events on the sites. When visiting one of the sites in Luang Prabang, the flood problems were explained by the local committee.

For several sites it was obvious that mitigation could not entirely be achieved by the use of ecosystem services, as there would also be a need for relatively small investments in e.g. replacement or building of flap-gates to prevent back-flow of water from e.g. Mekong River or other local rivers into the hinterland, but combining the “grey” infrastructure with “Green” infrastructure seemed to be the solution.

It was emphasised several times that even though the cities identified sites for mitigation, the selection was only of preliminary status and a final selection would be the task under a potential future Green Climate Fund project.

Table 5-1 Overview of the sites selected by the cities.

City	Site name
Vientiane	Ban Dontiou (key site)
	Ban Dong Xang Hin, Xaythany (additional site)
Thakek (Khammouan)	Nong Bua – Huay Simung (key site)
	Huag Naly and Huay Nangsord (additional site)
Kaysome Phomvihane	Huay LongKong, the Thahae village (key site)
	Huoy Kylamung, Hua Muang village (additional site)
Pakse	Ban Tha Ha (key site)
	Ban Ke (additional site)
Paksan, Bolikhamaxy	Nong Peung (key site)
	Ban Thabo village (additional site)
Luang Prabang	Kok Ngiew (Key site)
	Huay Mow (additional site)

6 Ecosystem Services Assessment (Activity 2)

An important part of this project has been to identify ecosystem services and assess these in the Lao context. It was obvious from day one that damages caused by flooding are by far the most distressing factor in all six cities. The floods are mainly caused by rising of the Mekong and from the effects of a rising Mekong that prevents tributaries to discharge to the Mekong, thereby initiating flooding along the banks of the tributaries. Droughts were also discussed, but only very few damages were caused by droughts.

During the different workshops from this project, the understanding of ecosystem services and their use grew and the workshop in September 2017 clearly showed how to work with these systems

6.1 Identification of Ecosystem Service Indicators

The identification of ecosystem services and their indicators has been carried out through several steps, where the initial steps were taken during the preliminary workshop in August 2016.

In the initial step, damages caused by flooding were identified. Hereafter the damages to ecosystem services were identified as well. Table 6-1 below shows the initial lists of damages, experienced in the six cities. Most of the damages are tied to infrastructure and to a lesser extent to ecosystems. The time-wise extent of many of the damages were closely linked with the extent of the floods, typically from weeks to months. The direct damages to e.g. accessibility of roads seemed to last typically for 2-4 weeks, but damages to e.g. electricity supply could last much longer. A closer look at the damages also indicate that there are overlapping damages, but for the process, it was decided to include all inputs, since it also showed that there were different views on how damages were felt.

Table 6-1 Matrix with flood damages, ranked with highest priorities on top and with indications of which cities experienced the damages.

Flooding damages	VTE	PKS	LPB	SVK	PAK	THK
Inconvenience in public and private transportation	x				x	
Electricity polls falling over, cutting the supply	x		x	x		x
Dirty residential areas (smell, dirt)	x			x	x	x
Damaged sanitation /toilets	x					
Rice production inhibited periodically	x	x				
Damage to houses and public property			x	x	x	x
Poor water quality in wells	x					
Water supply problems (sedimentation)			x	x		
Water supply system cannot operate during flooding						x
Landslides	x	x				
Soil erosion			x			
Bank erosion				x		
Loss of school time (no access to school during flooding)	x	x	x			x
Teaching material damaged			x			x
Affecting drainage systems	x			x		x
Damaged irrigation systems	x	x				
Damaged roads	x			x	x	x

Flooding damages	VTE	PKS	LPB	SVK	PAK	THK
Damage to bridges			x			
Difficult livelihood	x	x			x	x
Water-borne diseases (dengue fever)	x	x	x	x	x	x
Poor quality of food	x	x				
Loss of crop yield		x	x	x	x	x
Loss of poultry and pigs					x	x
Affect house hold income	x	x	x			
Inconveniences for residents			x			
Affecting state budget for repairing damages	x	x			x	
Poor quality of water	x	x				
Affect mental health	x	x				
General health problems			xD			
Traffic congestion	x	x	x			
Shortage of state budget to rehabilitate ecosystems	x	x	x			
Impacts on tourism and temples			x			x
Impacts to livestock activities	x	x	x			x
Impacts on aquaculture				x		
Damaged forest	x	X				
Affect habitats	x	x				
Affect culture	x	x				
Salt from salt factory impacts drinking water during flooding				x		

The indications given in the table above were then discussed and served as input to assessing damages to ecosystem. Based on an introduction to ecosystem services provided by the consultant, the participants formulated a range of damages to identified ecosystems and their services, and the findings are presented in Table 6-2.

Table 6-2 Damages to ecosystems

Damages to Ecosystem services	VTE	PKS	LPB	SVK	PAK	THK
Impacts on rubber tree plantations	x	x				
Loss of trees for landslide protection			x			
Food supply chain affected	x	x				
Changes in water flow	x	x				
Changes in water quality			x			X
Reduced biodiversity	x	x				
Less firewood				x		
Change of water channel corridor (change in the physical place of the river channel)	x	x			x	
Damage to non-timber forest products	x	x		x		
Erosion	x	x			x	
Affecting the agriculture: Impacts on seeds, livestock, Products, Crops, vegetables	x	x		x		
Decrease in wild plants and wildlife			xD[2]	x		
Affect insect habitats	x	x		x		
Lack of budget to prevent bank erosion	x	x				
Ruining habitats (??)	x	x				
Fewer food sources for livestock			xD			
Damage to vegetables and herbs	x	x				
Damage to aquatic animals	x	x				

[2] D = drought

Damages to Ecosystem services	VTE	PKS	LPB	SVK	PAK	THK
Damage to aquatic plants			x			
Damaged fish cages	x	x				
Flooded fish farms	x	x				
Damage to natural mushroom	x	x				
River bank erosion	x	x				
Soil fertility goes down				x	x	
Affected water plants (Green plants or water facilities ??)	x	x				
Affected green areas	x	x				
Damaged wells and drinking water facilities	x	x		x		
Forest fires			xD			
Trees die due to higher temperatures			xD			
Shallow fish-filled pools disappear during flooding			x			

The results from Table 6-2 have been grouped into functional classes in Table 6-3 below.

Table 6-3 Damages to ecosystems, grouped in functional classes, with priorities.

Priority	Eco system damages	VTE	PKS	LPB	SVK	PAK	THK
	Biology/Habitats						
13	Affect insect habitats	x	x		x		
6	Reduced biodiversity	x	x				
15	Ruining habitats (??)	x	x				
18	Damage to aquatic animals	x	x				
19	Damage to aquatic plants			x			
29	Trees die due to higher temperatures			xD			
	Crops, wild and cultivated						
9	Damage to non-timber forest products	x	x		x		
11	Affecting the agriculture: Impacts on seeds, livestock, Products, Crops, vegetables	x	x		x		
1	Impacts on rubber tree plantations	x	x				
3	Food supply chain affected	x	x				
12	Decrease in wild plants and wildlife				x		
14	Lack of budget to prevent bank erosion	x	x				
17	Damage to vegetables and herbs	x	x				
20	Damaged fish cages	x	x				
21	Flooded fish farms	x	x				
22	Damage to natural mushroom	x	x				
25	Affected water plants (Green plants or water facilities ??)	x	x				
7	Less firewood				x		
16	Fewer food sources for livestock			xD			
30	Shallow fish-filled pools disappear during flooding			x			
	Geology, soil						
10	Erosion	x	x			x	
23	River bank erosion	x	x				
24	Soil fertility goes down				X	x	
	Protection, impacts,						

Priority	Eco system damages	VTE	PKS	LPB	SVK	PAK	THK
26	Affected green areas	x	x				
2	Los of trees for landslide protection			x			
28	Forest fires			xD[3]			
	Water related damages						
8	Change of water channel corridor (change in the physical place of the river channel)	x	x			x	
27	Damaged wells and drinking water facilities	x	x		x		
4	Changes in water flow	x	x				
5	Changes in water quality			x			x

6.2 Identification and prioritization of ecosystem services in the six cities

The identification and prioritization of the most appropriate ecosystem services that could be used on the project sites, identified by the six cities can be condensed to those services that can absorb, store or prevent flooding, and those services that could benefit/provide services to the population. This means that landuses like rice fields, grassland and other landuses, are areas, where storage/mitigation of floods can take place. Storage/mitigation in urban areas are only useful to a lesser degree, although flood water can pro-actively be conveyed in designated streets and gutters. If flash-floods dominates, such as is the case in selected areas in in Luang Prabang, the ecosystem services would include a sustainable maintenance of the forest-cover in the uphill areas above the village. The same ecosystem service would also be the choice for mitigating the flash floods, hitting the main road in Luang Prabang as well.

The negative impacts on the ESS from flooding will often be counterbalanced by positive impacts as well. Although flooding may cause negative impact on e.g. the standing crop on rice fields, the flooding increases groundwater recharge, deposits nutrients and organic matter on the fields, replenishes small waterbodies with fresh water and provides water to the vegetation in an area. Flooding may also bring various fish, shellfish and other valuable food items into the flooded areas, where they can be utilised by the population.

Overall, ecosystem services being prioritised for mitigating floods were mainly concentrated on land under cultivation and here rice fields were highest in priority, since the rice fields were the most abundant land cover type in and around the cities. Bringing these fields into active ecosystems would require new ways to control the water entering the fields.

[3] D = Drought

7 Vulnerability Assessment (Activity 3)

The vulnerability assessment was carried out through a number of steps, where each step provided input to the final assessment. The approach used looked at the flooding, the land cover classification and the sensitivity of how infrastructure and ecosystem services were impacted by the flooding. From interviews it came out that the annual flooding had a duration of approximately 4-5 weeks with annual variations.

The flood hazard maps for 5 of the 6 cities were based on digital information with grid size of 30x30 meter, but for Thakek it was necessary to use an older digital model with 90x90 m grid size. It should be noted that the data used for the production of maps and assessments can be regarded as preliminary and not in a quality that can be used as a basis for e.g. construction of new dikes and other features. It is proposed that future in-depth assessments be based on locally obtained LIDAR surveys to increase precision of base-maps such as elevation maps.

A section for each city and its sites is given below, showing the place of the site(‘s), the flood hazard map, the land cover classification map and the vulnerability map. A short description of the sites and special observations are given for each site, whereas the full site description is provided in Appendix C. The demarcation of the sites is done very coarse and should only be seen as an indication to enabling a zoom to the areas.

7.1 Vientiane – Xaythany District

The two sites in Vientiane is to the North of the main city and both can be classified as peri-urban / rural and they are adjacent to each other, as shown in Figure 7-1. The description provided in Appendix C indicates that flooding occur annually in both areas, which are crossed by small streams. The green space is used for rice paddies and for gardens.

Figure 7-1 Vientiane; overview of the two project sites

7.1.1 Hazard mapping – Vientiane

The flood hazard map, shown in Figure 7-2, indicates that both sites are in low-lying areas, where flooding happens when the flood levels rises. Only a few places in the sites are lying higher than 10 meters. The outline of the small streams are clearly shown in the map and it is the areas next to the streams, which are most often flooded. Most of the built-up areas in the Ban Dontieu site are raised above the open land and are thus not so flood prone. The same conditions are found in the Ban Dong Xang Hin site.

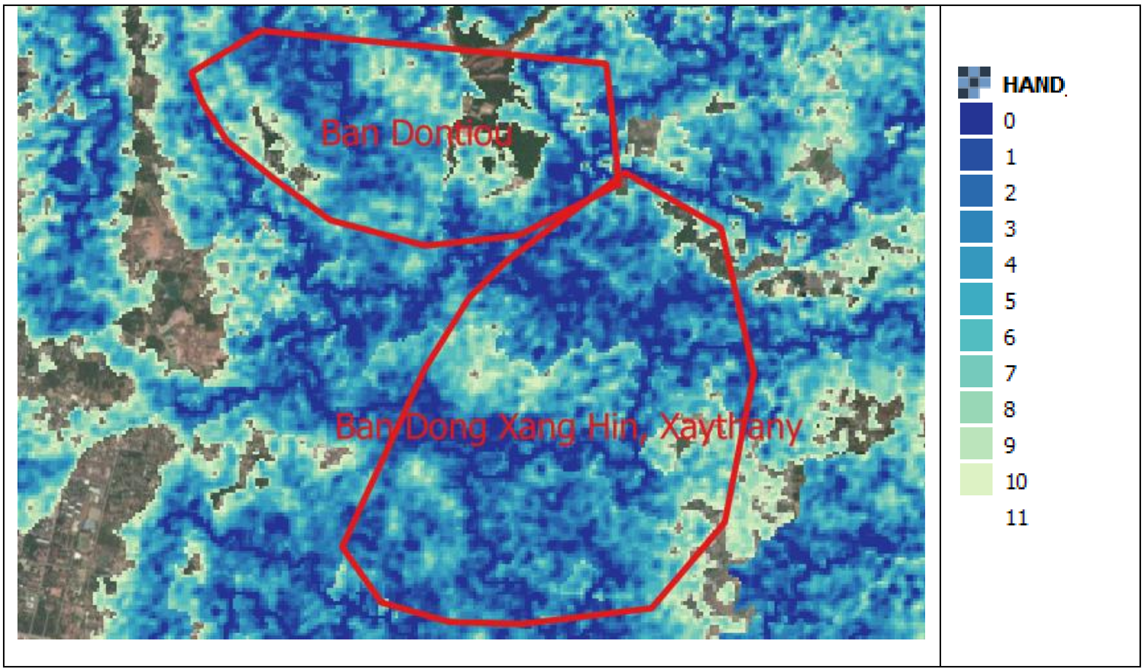


Figure 7-2 Vientiane; Flooding hazard map (0 = open water, 1-11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded)

7.1.2 Sensitivity mapping – Vientiane

The land cover classification, shown in Figure 7-3, states that both sites have urban concentrations and spread-out houses along the main roads. For the Ban Dontieu site, it is mainly forest and grassland with some areas with rice, whereas rice is among the dominating land covers in the Ban Dong Xang area. The grassland and forests are not as flood-sensitive as the rice areas and the urban areas

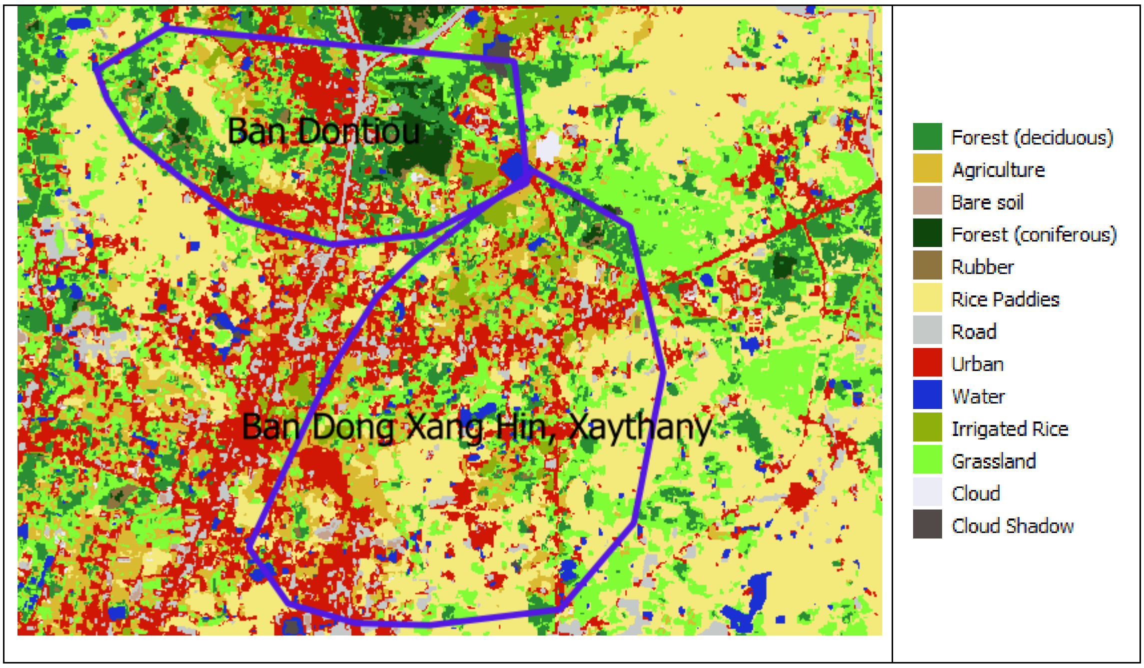


Figure 7-3 Vientiane; Land cover classification

7.1.3 Vulnerability mapping – Vientiane

The vulnerability assessment of the two sites shows that the differences in dominating land covers have direct impact on the vulnerability, cf. Figure 7-4. The Ban Dontieu site has relatively large areas, where the vulnerability is considered low, whereas the Ban Dong Xang site has substantial areas where the vulnerability is considered medium or high.

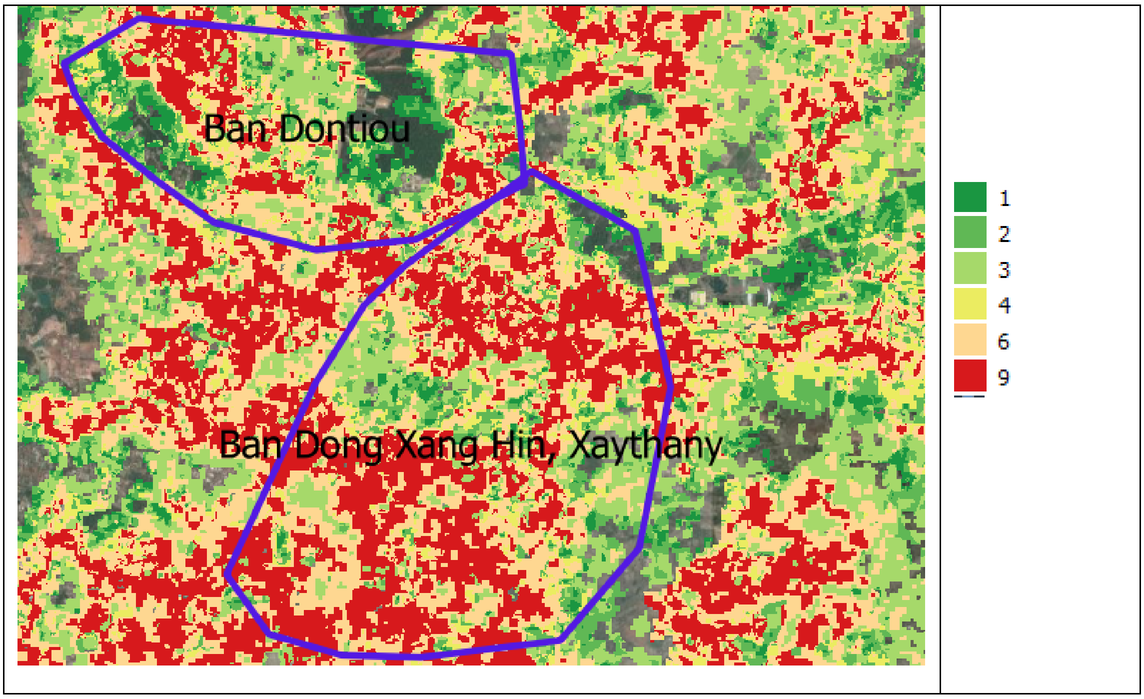


Figure 7-4 Vientiane; Vulnerability map (1-3 low, 4+6 medium, 9 high)

7.2 Thakek (Khammouan)

The site in Thakek, Huay Paksimung, is situated south of the main city along the Mekong River. It is a combined rural / peri-urban area with several smaller villages. Rising water level in Mekong is the main cause for the flooding in the area.

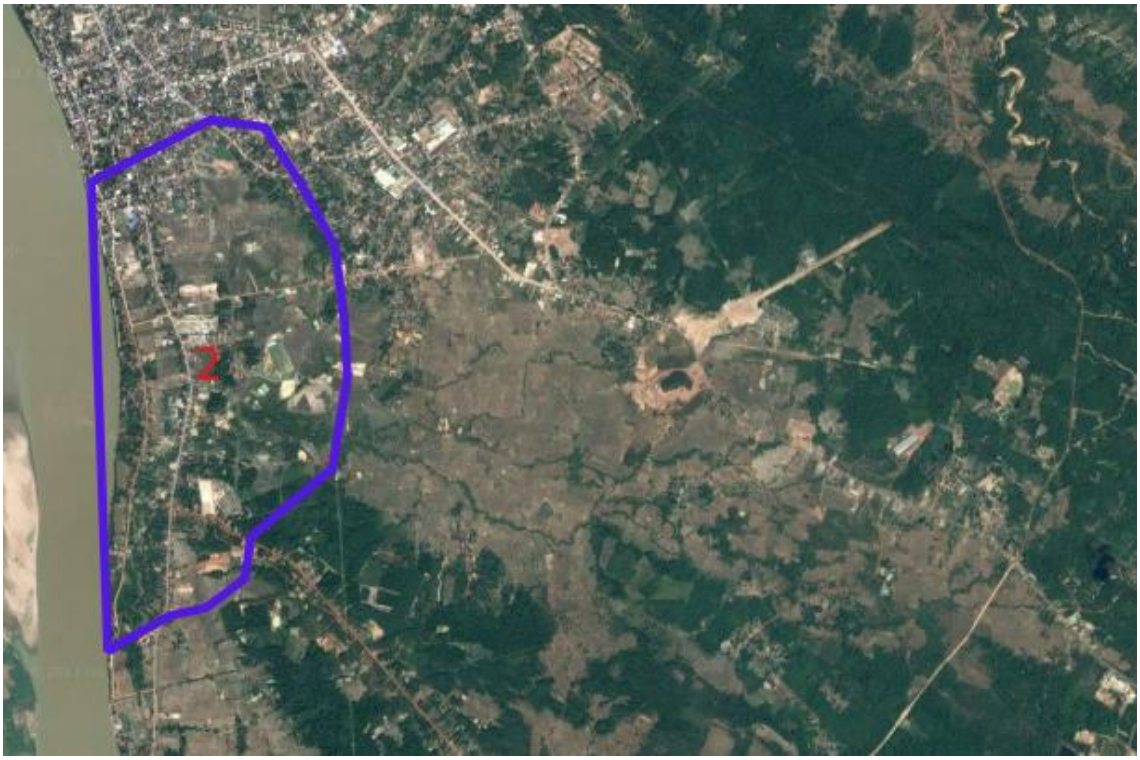


Figure 7-5 Thakek; overview of the two project sites

7.2.1 Hazard mapping – Thakek

The flood map for Thakek has been made with a different digital elevation model than the one used for the other 5 cities. The change to the 90x90 m grid model was done, since the 30x30 meter model did not provide a trustworthy baseline for the Hazard map. The coarser hazard map has also made the vulnerability map coarser than for the other cities. A hazard map is shown in Figure 7-6.

The project area is mainly subject to flooding along the streams and small rivers, but a major part of the project area is also subject g is very narrow several places, but according to field information from visiting the area, the dike is never overtopped during heavy floods.

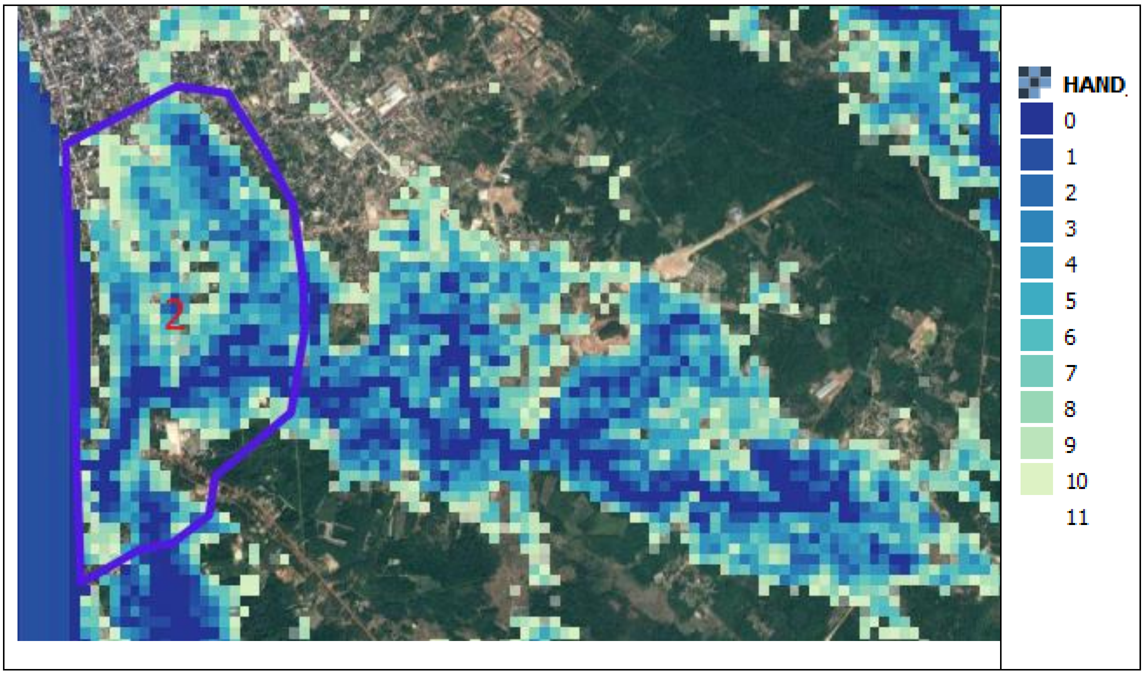


Figure 7-6 Thakek; Flooding hazard map (0 = open water, 1-11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded)

7.2.2 Sensitivity mapping – Thakek

The project site, Nong Bua – Huay Simung, is a typical site along the Mekong River. The site is behind the Mekong dike and impacts from flooding comes from the Mekong itself and from stormwater from the catchment. The main land cover are rice fields, grassland and a few clusters of forest. There are fringes of dwellings along the North-south road through the site. The land covers are shown in Figure 7-7.

The urban areas and the rice fields are the most sensitive elements in the project site and this will have an influence on the vulnerability of the area.

7.2.3 Vulnerability mapping – Thakek

The vulnerability map for the site is very coarse due to the use of a digital elevation model, 9 times less detailed than the one used for the other sites in this project and the results must be taken with care. The vulnerability map is shown in Figure 7-4 and it indicates that the most vulnerable areas are scattered and falls along the western and the eastern borders of the site.

The results indicate that the available digital elevation models do not provide background data that can be used for a proper vulnerability mapping and the conclusion for this site is that a better DEM is needed if the methodology for developing vulnerability maps in this project can be replicated for the Thakek site.

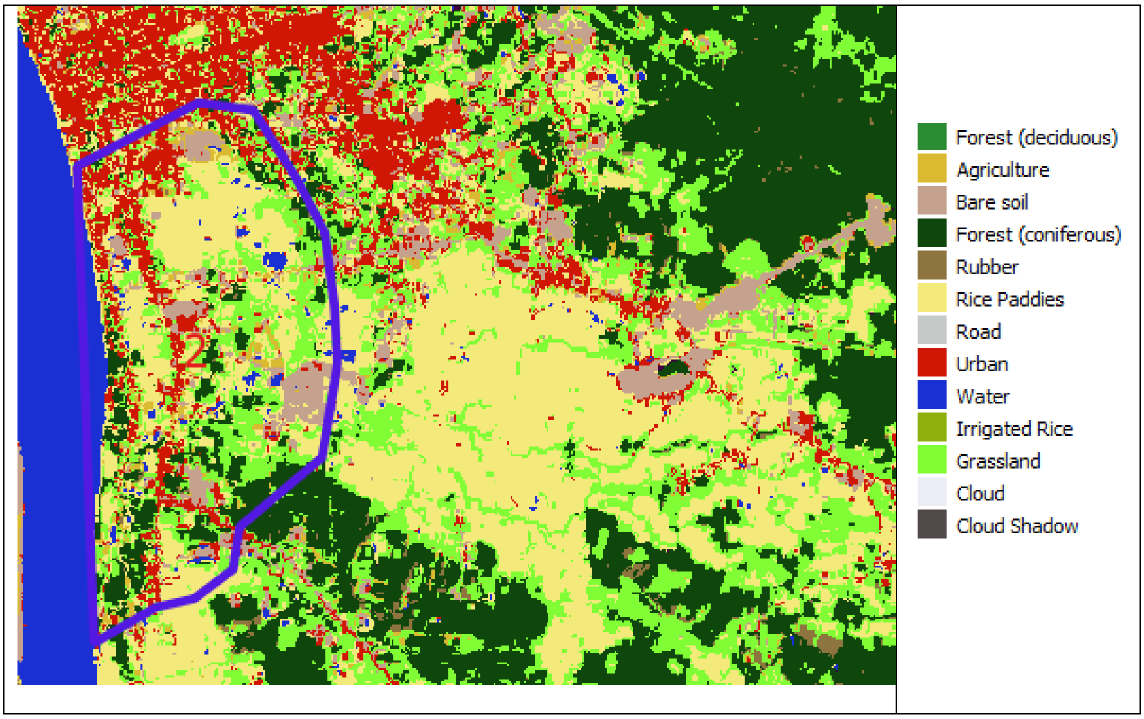


Figure 7-7 Thakek; Land cover classification

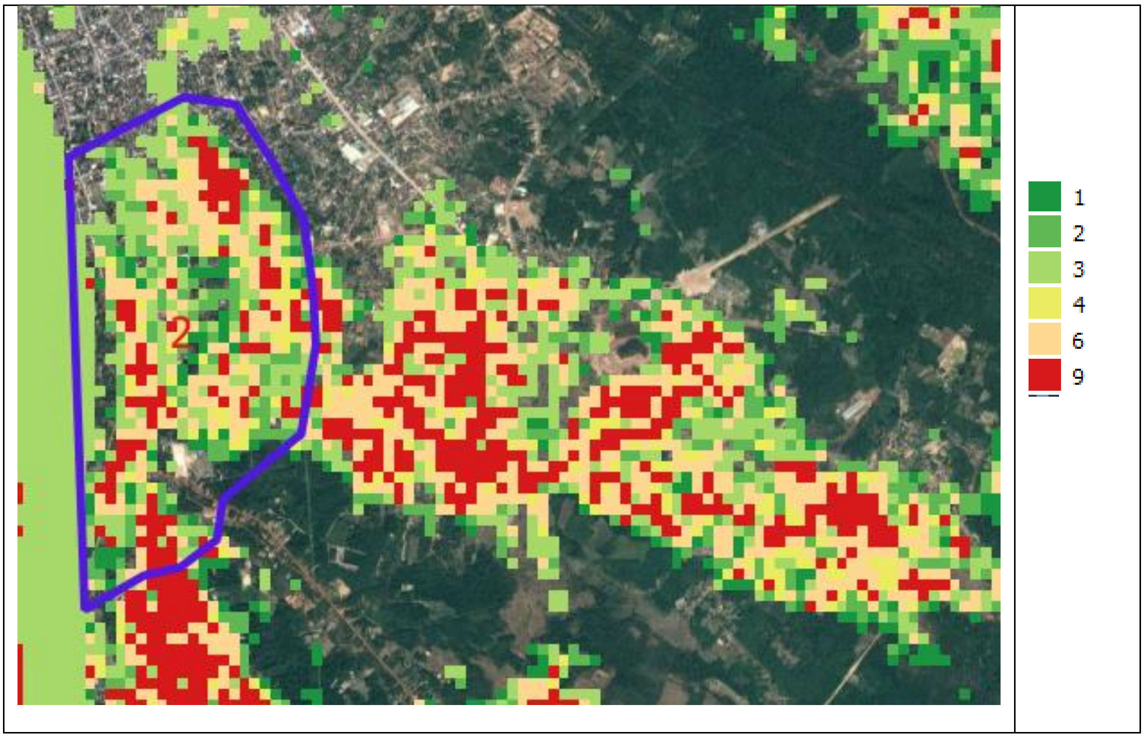


Figure 7-8 Thakek; Vulnerability map (1-3 low, 4+6 medium, 9 high)

7.3 Savannakhet / Kaysome Phomvihane

In Kaysome Phomvihane city there are two sites south and north of the city as shown in Figure 7-9. The southern site 1 at the Thahea village, which is along the small river Huay Long Kong, is impacted from floods, when the river overflows in the rainy season. The water comes from the upper catchment and passes both urban and rural areas towards the outlet to the Mekong River.

The Northern site 2 is at the village Nakea, along the stream Huoy Nongdouan. Flooding comes from heavy rains and from urban development, which has taken the natural absorption capacity out of the area.

7.3.1 Hazard mapping – Kaysome Phomvihane

At site 1 the main flood prone areas are along the Huay Long Kong stream, which are low-lying and only 1-2 meters above the stream (Cf. Figure 7-10). The flooding comes from the upstream area, where dense urban build-up has led to a faster runoff into the stream. The project site is in the lower part of the catchment, where the stream mainly to the east is surrounded by fields with rice and vegetables. The houses and dwellings along the road to the Northeast are also lying in flood prone areas and may suffer impacts from floods.

At site 2 the area slopes down from the east towards the west along the Mekong river and this area along the stream Huay Nong Douan is low-lying and highly flood prone. Only a few meters of rise in the river level will eventually flood the area. However, it has to be stressed that the HAND model is not capable to identify narrow dikes, which may in fact protect houses along the river. The development of villages and other activities in the area has led to additional pressure on the stream and the frequency of flooding has increased and will continue to increase. The project site is shown in Figure 7-11.

Figure 7-9 Kaysome Phomvihane; overview of the two project sites

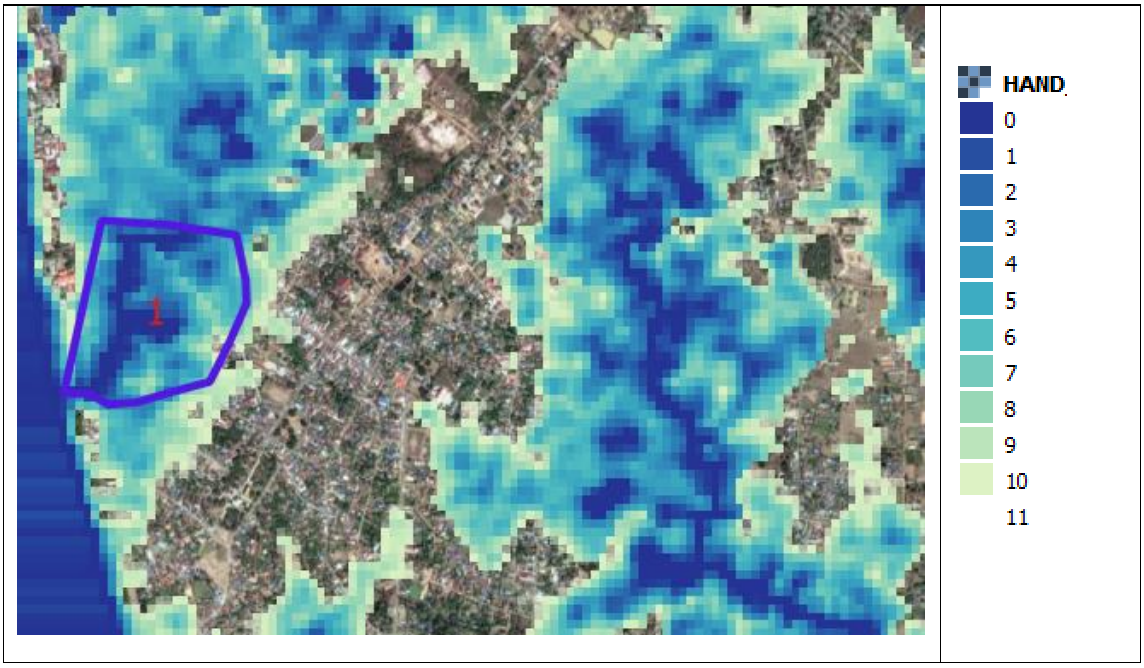


Figure 7-10 Kaysome Phomvihane, Site 1; Flooding hazard map (0 = open water, 1-11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded)

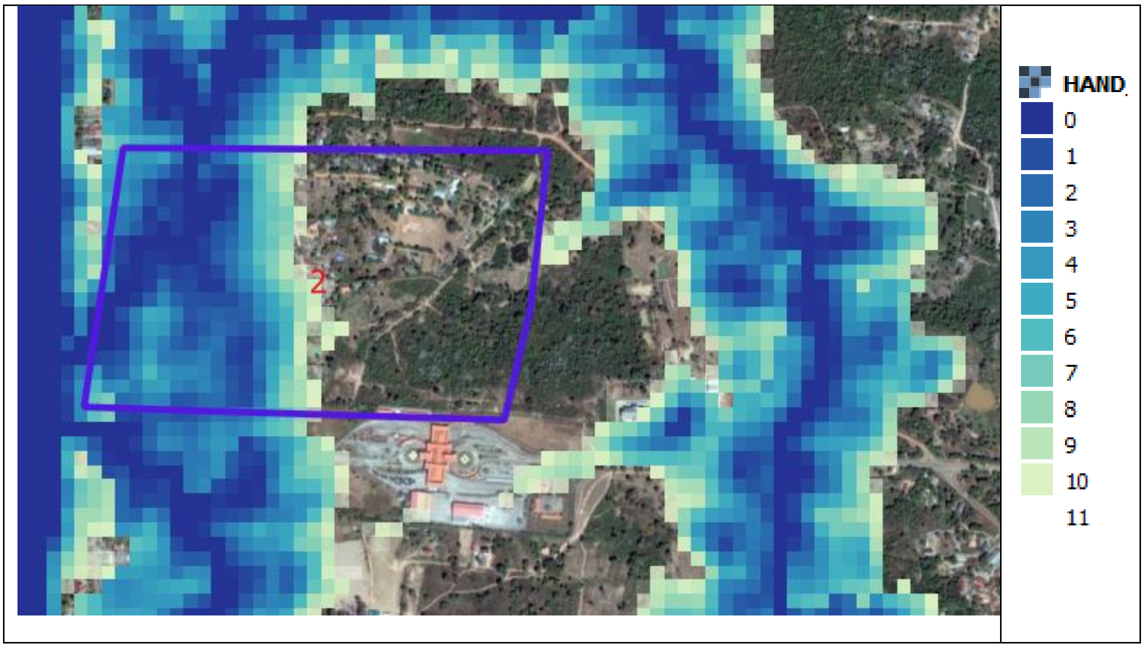


Figure 7-11 Kaysome Phomvihane, Site 2; Flooding hazard map (0 = open water, 1-11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded)

7.3.2 Sensitivity mapping – Kaysome Phomvihane

The area at Site 1 is mostly occupied by either urban structures or rice field, covering approx. 70% of the area and both classes are with the highest sensitivity (Cf Figure 7-12). The rest of the area is covered by patches of grass land and forests. The high percentage of land cover classes in the highly sensitive group indicates that floods in this site will cause damages to these two land cover classes. The extent of the damage will be determined by the elevation of the sub-sites.

The land cover at Site 2 shows a fringe of urban structure towards the Mekong River and then scattered urban/housing areas in the rest of the site (Cf. Figure 7-13). Just south of the site, there are large areas occupied with urban and road development from the toll station. There are large areas with rice fields towards the west and scattered rice fields and grass land towards the east, intertwined with patches of forest. The urban and the rice areas are the most sensitive elements inside the project area.

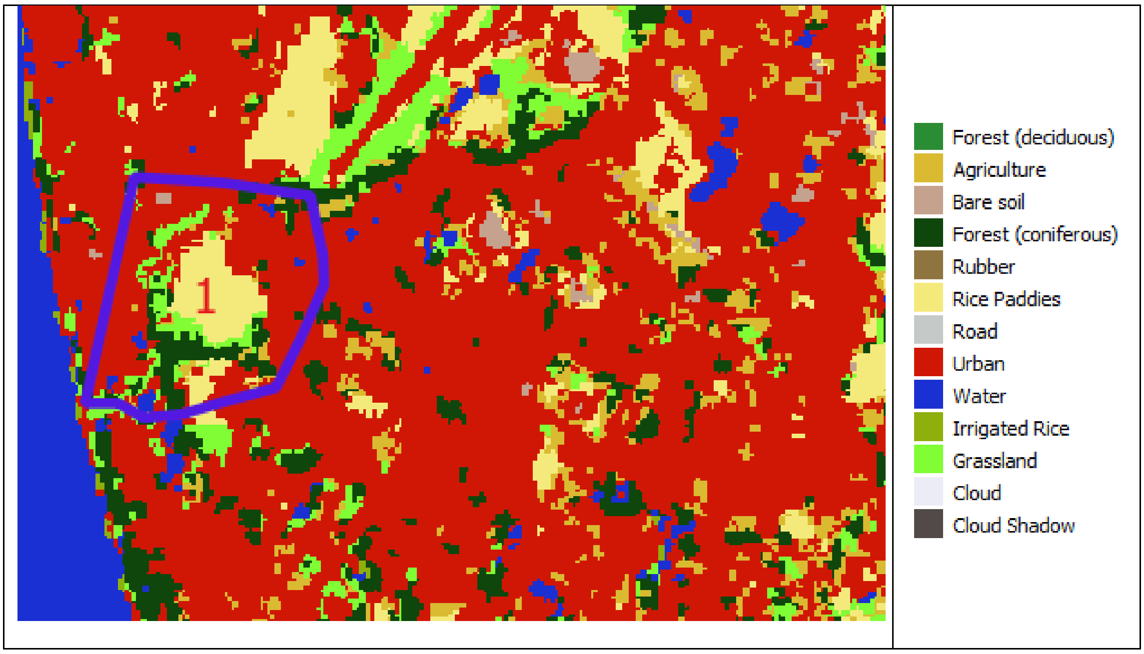


Figure 7-12 Kaysome Phomvihane, Site 1; Land cover classification

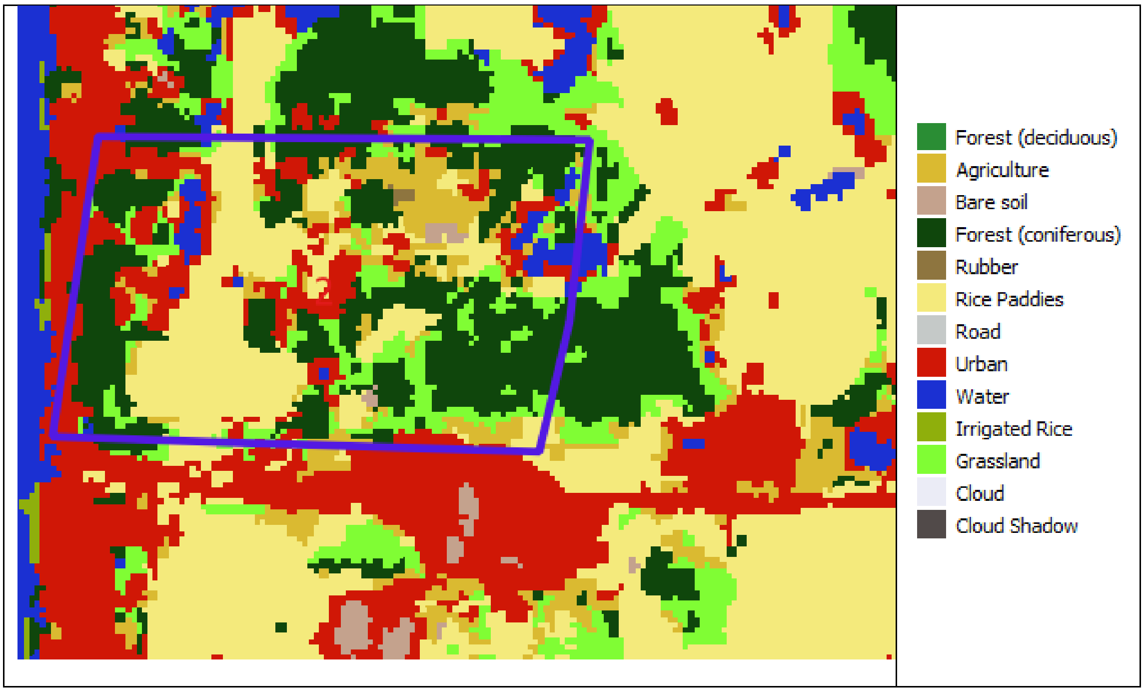


Figure 7-13 Kaysome Phomvihane, Site 2; Land cover classification

7.3.3 Vulnerability mapping – Kaysome Phomvihane

As shown in the description of the sensitivity of the different land cover classes, Site 1 is very vulnerable to floods, mainly due to large areas with rice and urban sprawl. As indicated in the hazard map, most of the site is low-lying and therefore very flood prone, the urban sprawl along the edges and across the site also increases the vulnerability of the area. A rough estimate gives 80-90 % of the area as medium and high vulnerability. The map is shown in Figure 7-14.The vulnerability assessment for Site 2, shown in Figure 7-15, indicates that the eastern part is not impacted by floods at all, due to high elevation above the Mekong River, whereas the western part with the urban areas and rice fields show high vulnerability. Reduction interventions will have to be implemented in the catchment to reduce the inflow of water in the Huay Nong Douan.

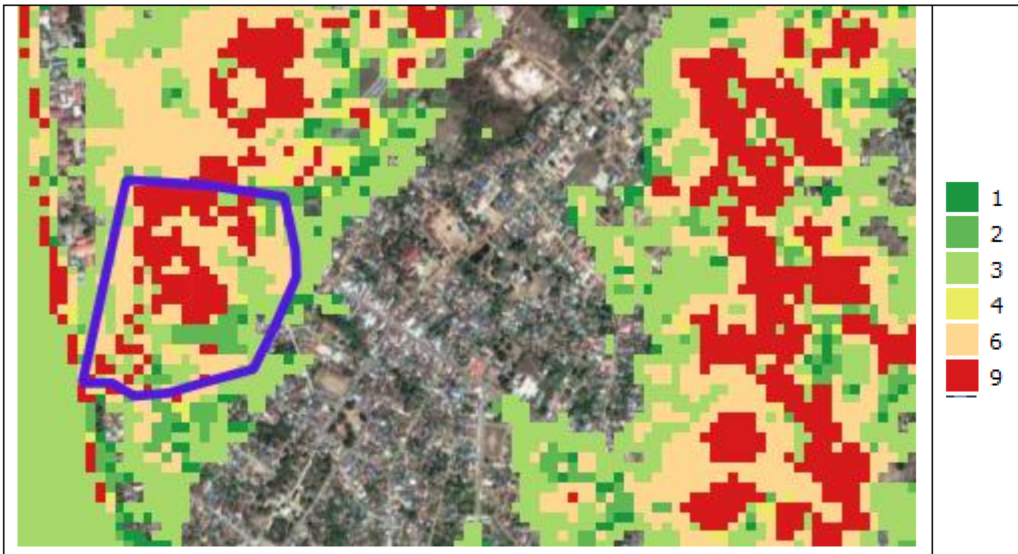


Figure 7-14 Kaysome Phomvihane, Site 1; Vulnerability map (1-3 low, 4+6 medium, 9 high)

Figure 7-15 Kaysome Phomvihane, Site 2; Vulnerability map (1-3 low, 4+6 medium, 9 high)

7.4 Pakse

The authorities of Pakse have identified 3 sites with one directly along the Mekong (site 1) and two sites along the Se Done River (Sites 2 and 3), Cf. Figure 7-16. All three sites are flood prone, but through different mecanisms.

Figure 7-16 Pakse; overview of the three project sites

7.4.1 Hazard mapping – Pakse

Site 1 is a relativly large area south of the main road, as shown in Figure 7-17

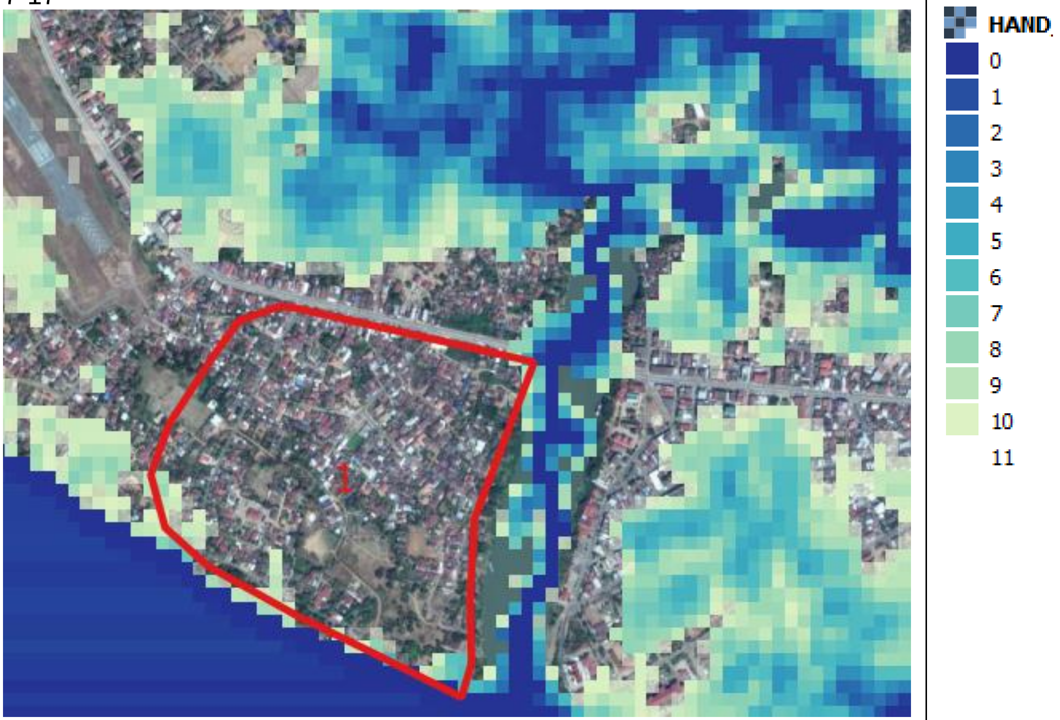


Figure 7-17. It is an urban area with some open grasslands and rice field scattered. A small stream runs through the site and drains out to the Mekong River through a flap-gate. The gate is broken and rising water levels in Mekong forces water back into the area. This reason for flooding is not reflected in the hazard map, which indicates that the area is not at all at risk as the area in general is 10 meter or more above the Mekong River. The hazards identified are thus caused by water intrusion from the Mekong and the inability of the small stream to drain the area properly.

Site 2 is a small area along the Se Done River, where the drainage from the area goes through a broken flap-gate (Cf. Figure 7-18). During high water levels in Mekong River, the discharges from Se Done River is reduced and water is forced upstream and consequently also into all smaller sub-catchments. The dike along the river will protect the hinterland until a certain water level, but flooding of the hinterland through the non-functional flap-gate, exacerbated by the run-off from the sub-catchment, will take place annually.

Site 3 shows the same trends as Site 2, but there are no protective structures preventing water from the Se Done to be forced into the catchment. The landscape on the eastern side of the river is low-lying and therefore easily flooded and at present difficult to protect.

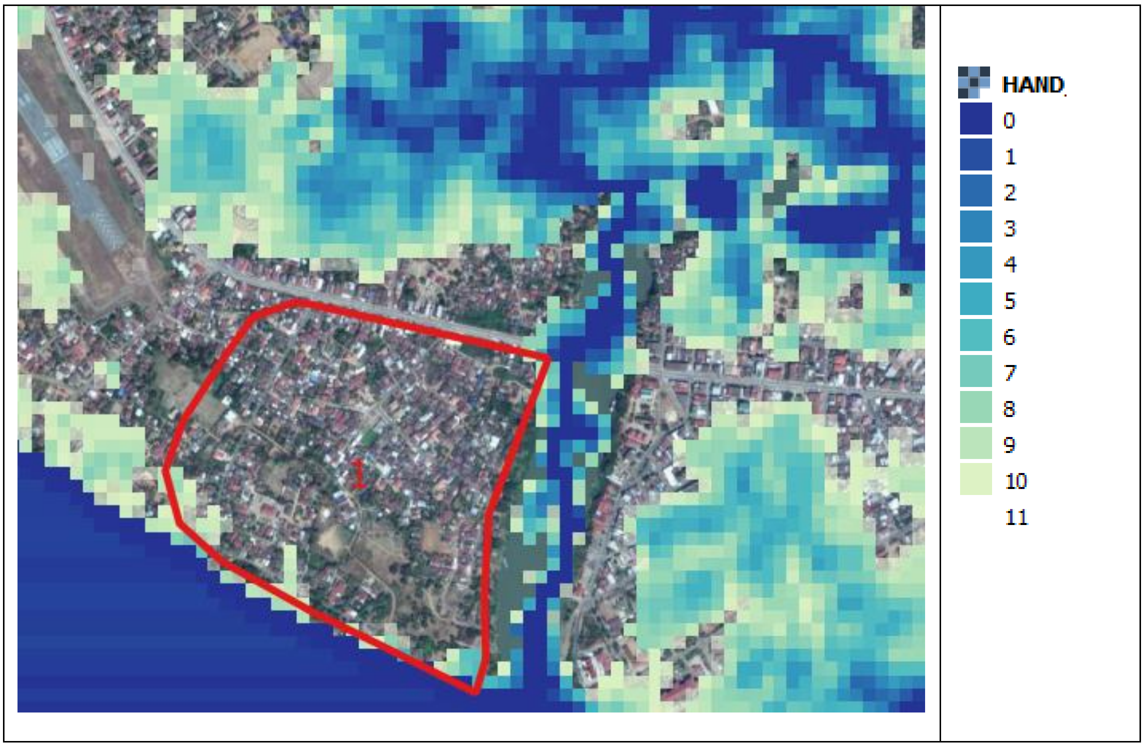


Figure 7-17 Pakse, Site 1; Flooding hazard map (0 = open water, 1-11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded)

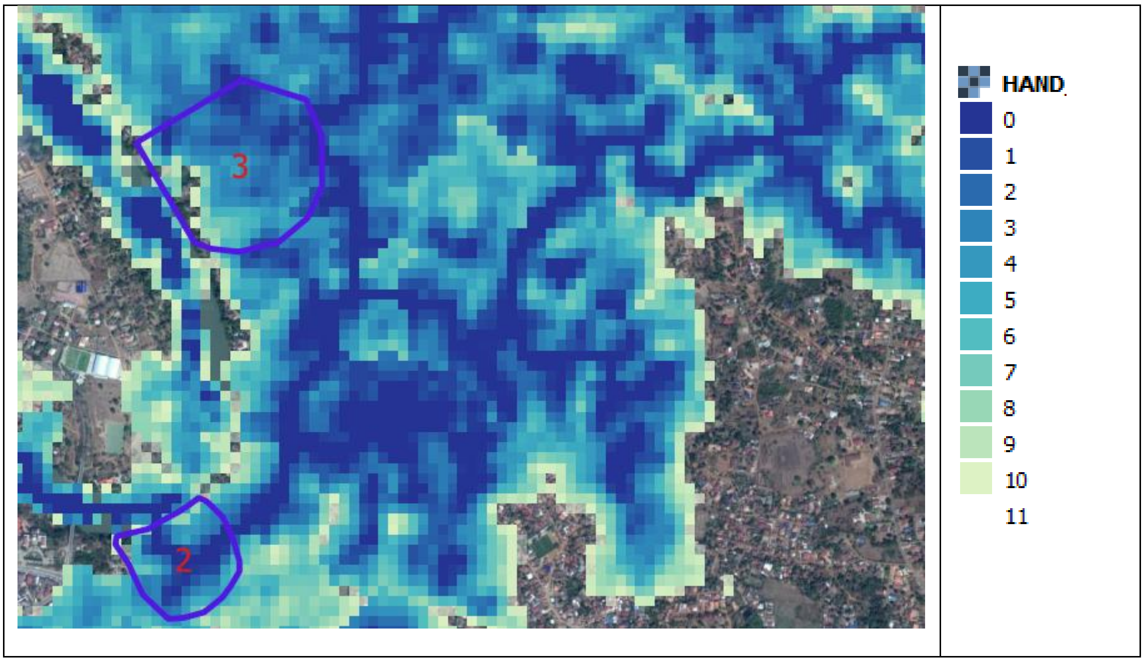


Figure 7-18 Pakse, Sites 2+3; Flooding hazard map (0 = open water, 1-11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded)

7.4.2 Sensitivity mapping – Pakse

The land cover in Site 1 is approximately covered by urban sprawl with grasslands taking up the rest of the area. The urban areas are obviously very sensitive to flooding. According to the authorities, the area receives run-off from the areas north of the main road, which indicates additional pressure on the area (Cf. Figure 7-19).

Urban sprawl is also the main feature for Site 2 as seen in Figure 7-20. The drainage area for Site 2 is probably larger than indicated in the figure, which also indicate that a larger area may be flooded. The rest of the area is covered by forest and grasslands, which are not as sensitive as the urban areas.

The area associated with Site 3 is also expected to be larger than indicated. The area is dominated by grassland and a smaller peri-urban area. The overall sensitivity of the area is mainly medium to low with the urban sprawl as highly sensitive to flooding.

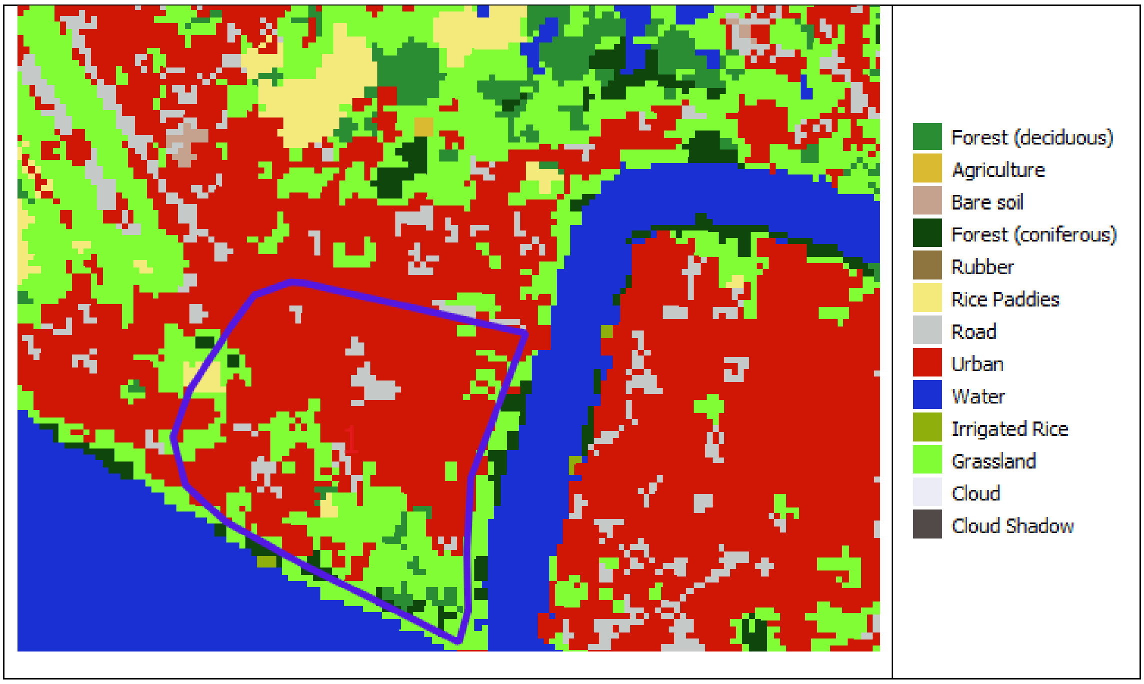


Figure 7-19 Pakse, Site 1; Land cover classification

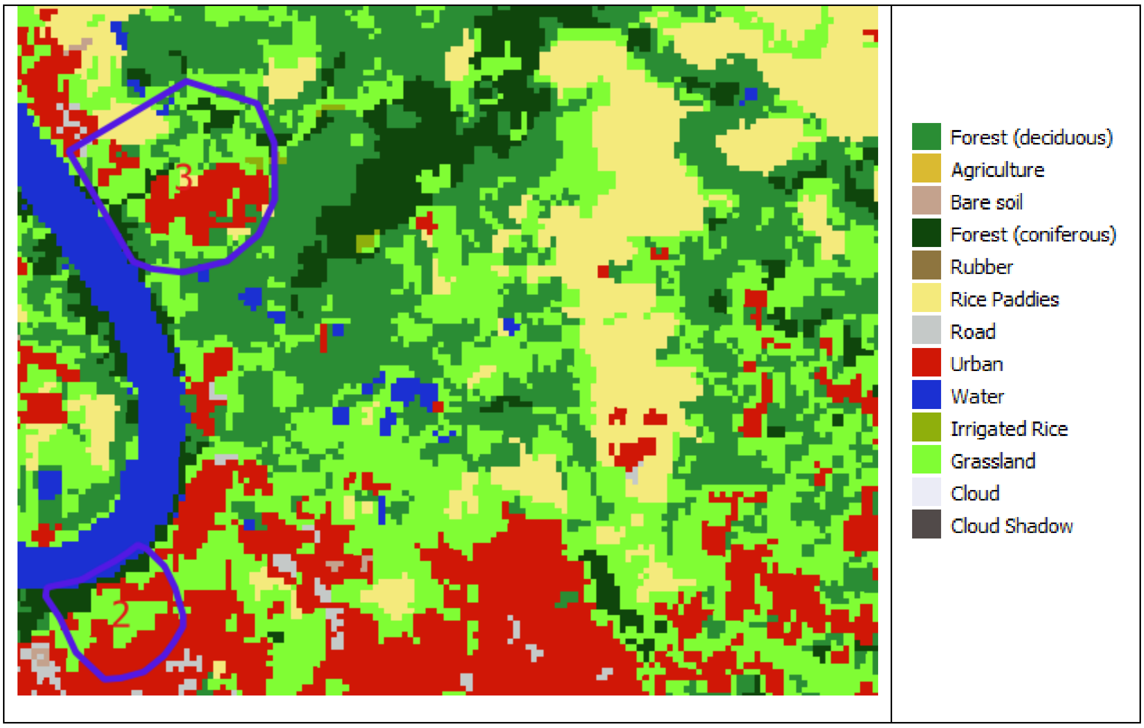


Figure 7-20 Pakse, Sites 2+3; Land cover classification

7.4.3 Vulnerability mapping – Pakse

If the vulnerability for Site 1 should only be based on the map, as shown in Figure 7-21, there are no problems, but the physical structure of the area, combined with the information that the catchment is larger than indicated, and that the main problem is caused by a non-functional flap-gate, flooding is still a main factor for the area. Even with a functional flap-gate, the drainage from the catchment may cause flooding and thus increase the vulnerability of the area, especially for the urban sector of the site.

The vulnerability of Site 2 shows that approximately 80% of the area is classified as highly or medium vulnerable (Cf. Figure 7-22), but it also seems as if the hinterland is less vulnerable and could be used to mitigate the flooding damages to the urban sprawl. A fixing of the flap-gate will significantly reduce the impacts in the area.

Most of the Site 3 is classified as low to medium vulnerable with only high vulnerability for the urban areas. However, a closer look at the land cover classification indicates that the agricultural areas has been classified as rice fields, although the areas look more like grass lands, which have a lower vulnerability (Compare Figure 7-16 with Figure 7-22). A re-classification of the site would lead to a lower vulnerability for the whole area.

Figure 7-21 Pakse, Site 1; Vulnerability map (1-3 low, 4+6 medium, 9 high)

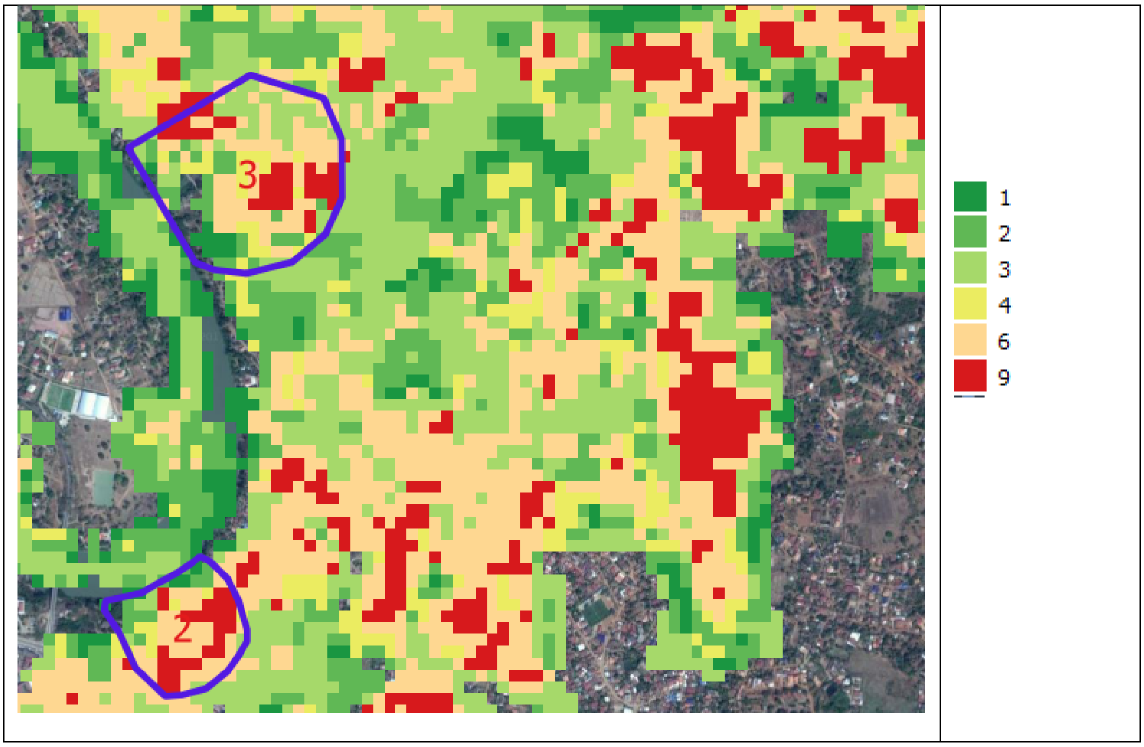


Figure 7-22 Pakse, Sites 2+3; Vulnerability map (1-3 low, 4+6 medium, 9 high)

7.5 Paksan (Bolikhamaxy)

The identified 2 sites in Paksan are shown in the figure below. Site 1 is urban – peri-urban with flood prone areas in the urban parts to the west of the project site. Project site 2 is rural but involves areas, which seems to be under build-up.

Figure 7-23 Paksan and the project sites.

7.5.1 Hazard mapping - Paksan

The flood hazard map for Paksan area including the two sites is shown in Figure 7-24. The two sites show clear differences with substantially higher flood hazards for site 1 than for site 2. From the map it seems as if even small rises in the water level in the Mekong or further increase in water flows routed from the city towards the site 1 will cause flood conditions in site 1. However, the most flood prone areas are low-lying and are also classified as open water, indicating that the deep-blue areas are in fact lakes/wetlands. The remaining blue areas in the western part of site 1 are classified as agriculture/rice fields, which are typically low-lying and therefore flood prone. The flooding at site 2 is caused by overflow of the small tributary which crosses the site.

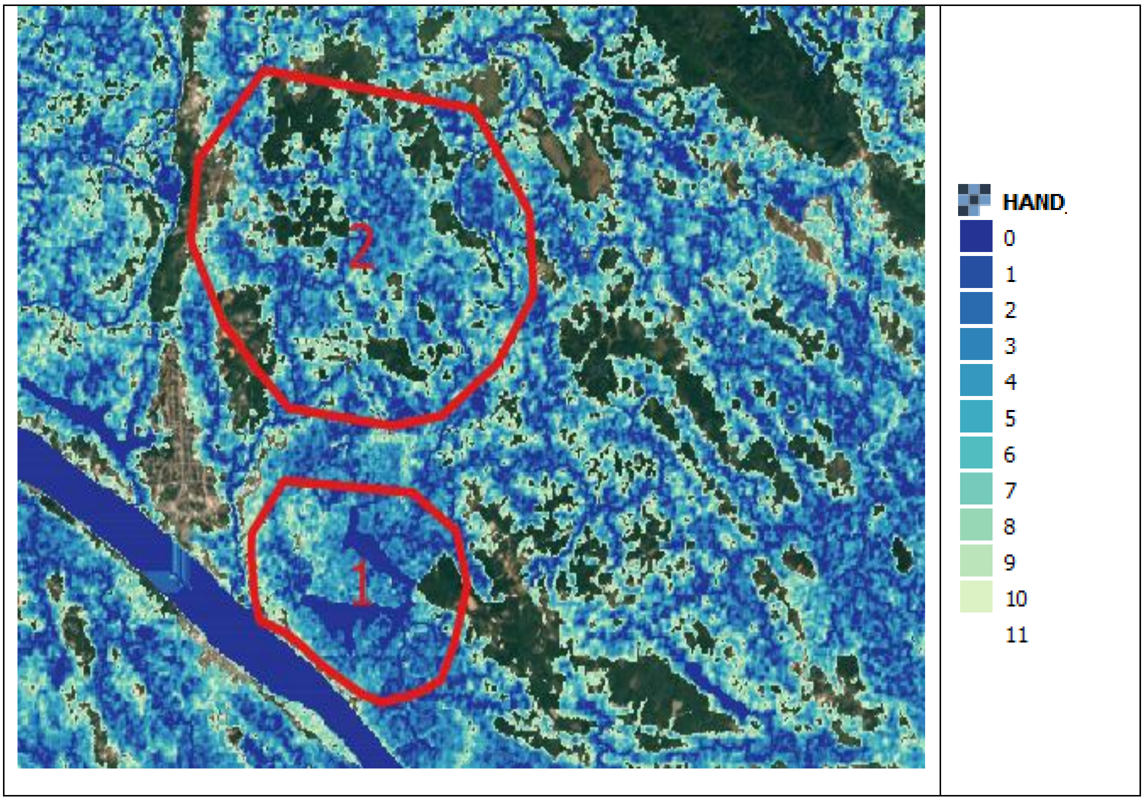


Figure 7-24 Paksan; Flooding hazard map (0 = open water, 1-11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded)

7.5.2 Sensitivity mapping - Paksan

Figure 7-25 shows the land cover classification in the Paksan area. The land cover classification indicates that site 1 contains substantial areas used for rice production (yellow). The class used for irrigated rice indicates that smaller areas are used for rice production, using irrigation (light green), thus producing more than one crop per year. Both rain-fed and irrigated rice crop-classes are considered highly sensible to flooding, if the flooding takes place during the production season.

Only a small fraction of the site to the east has an area of plantation (dark brown). The urban class is mainly restricted to the western fringe of the site (red).

The two rice crop classes are also found in site 2, but occupy proportionally a smaller area than in site 1. The urban class (red) is very limited on site 2, showing only a few scattered houses along the river and along the road in the western part of the site.

The land cover classification has been used to

7.5.3 Vulnerability mapping - Paksan

The vulnerability map, shown in Figure 7-26, indicate that for site 1 the rice areas come out as the most vulnerable areas. The urban areas in the western part of the site are not particularly vulnerable, mainly because they are rarely flooded. The existing lakes and wetlands are obviously not vulnerable, given the fact that all open water areas are classified as one type, without regards to potential use of the lakes/wetlands for aquaculture. The vulnerability analysis may be improved if information about aquaculture is included as a unique class with a high sensitivity, due to potential loss of the crop.

For site 2 it is also the rice areas, which are most vulnerable, whereas the forest and grassland areas only have a low vulnerability, because these land cover classes are deemed less sensitive to flooding.

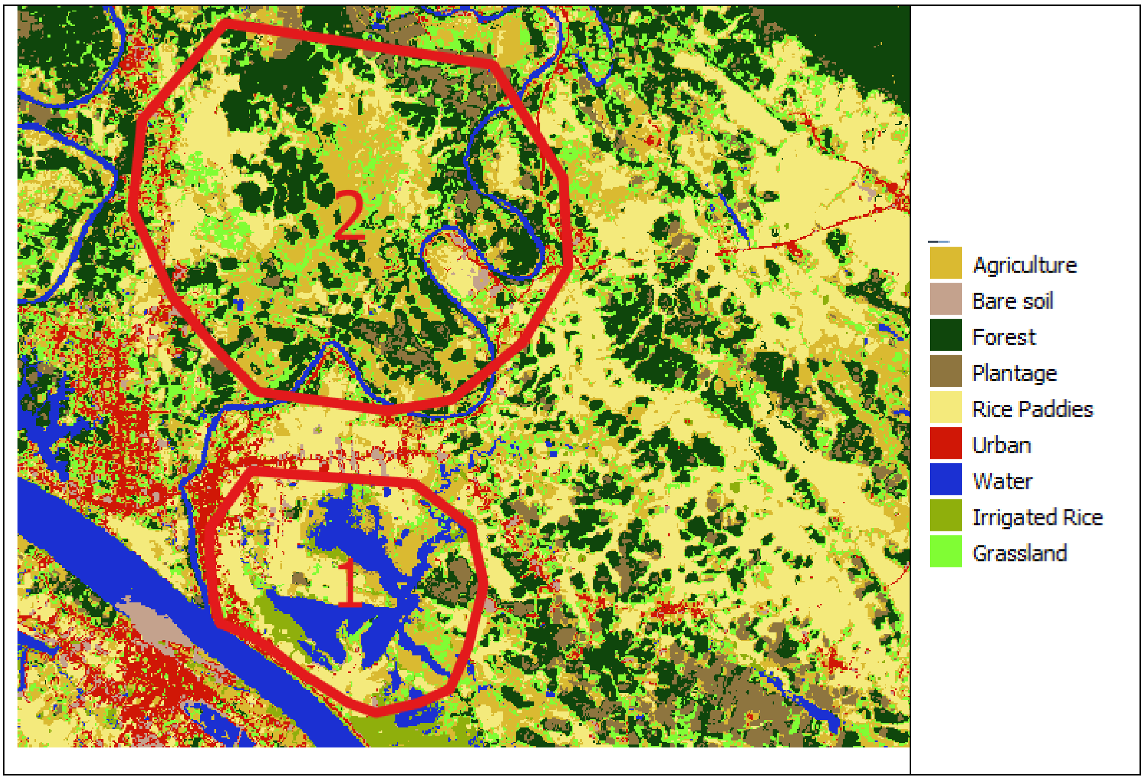


Figure 7-25 Paksan; Land cover classification

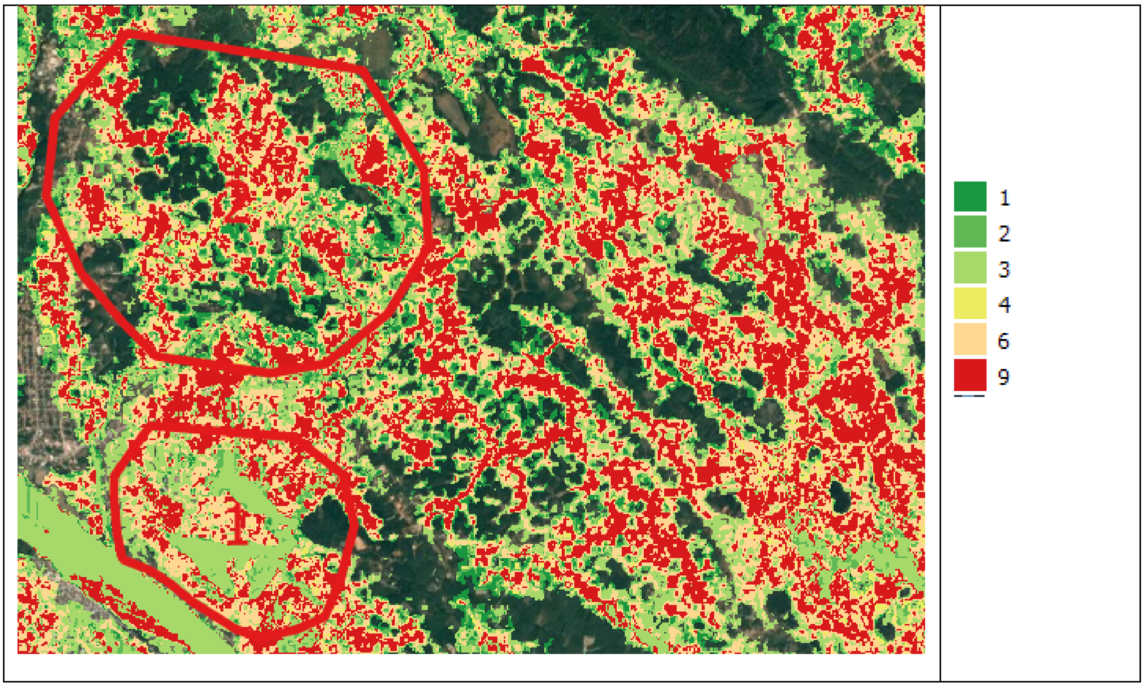


Figure 7-26 Paksan; Vulnerability map (1-3 low, 4+6 medium, 9 high)

7.6 Luang Prabang

The province and city of Luang Prabang differs significantly from the other cities, which are situated in the flood plains along the Mekong River. Luang Prabang is situated in a mountainous area, which means that floods are of a different nature and are mainly caused by flash-flood-like events, where run-off is routed fast down through the narrow valleys.

Figure 7-27 Luang Prabang; overview of the two project sites

The two sites, shown in Figure 7-27, are situated along narrow valleys and the impacts are different from those in the other cities.

7.6.1 Hazard mapping – Luang Prabang

Site 1, Kok Ngiew, is situated in a small village next to a small river, as shown in Figure 7-28. The impacts are caused by run-off from the catchment above the village. Since the valley is narrow, the hazards mainly occur very close to the river. The flooding is a combination of water and sediments, which are transported down through the village, causing physical damages and blocking effects from the sediments. Houses close to the river are damaged annually. The hazards are mainly caused by changes in the land cover upstream, where the precipitation is routed to the river faster than in the past.

Site 2, Huay Mow, is situated in the suburb of Luang Prabang and flash floods are the cause of hazards. The site is placed downstream of the confluence of two smaller rivers, as indicated in Figure 7-29. At the site, the river passes a narrow gorge and under a bridge. Blockage at the bridge can rise the water levels, causing flooding of the road, making it impassable. The lateral spread of the flooding is limited due to the local topography. The flooding impacts can be traced to changes in land cover in the whole catchment.

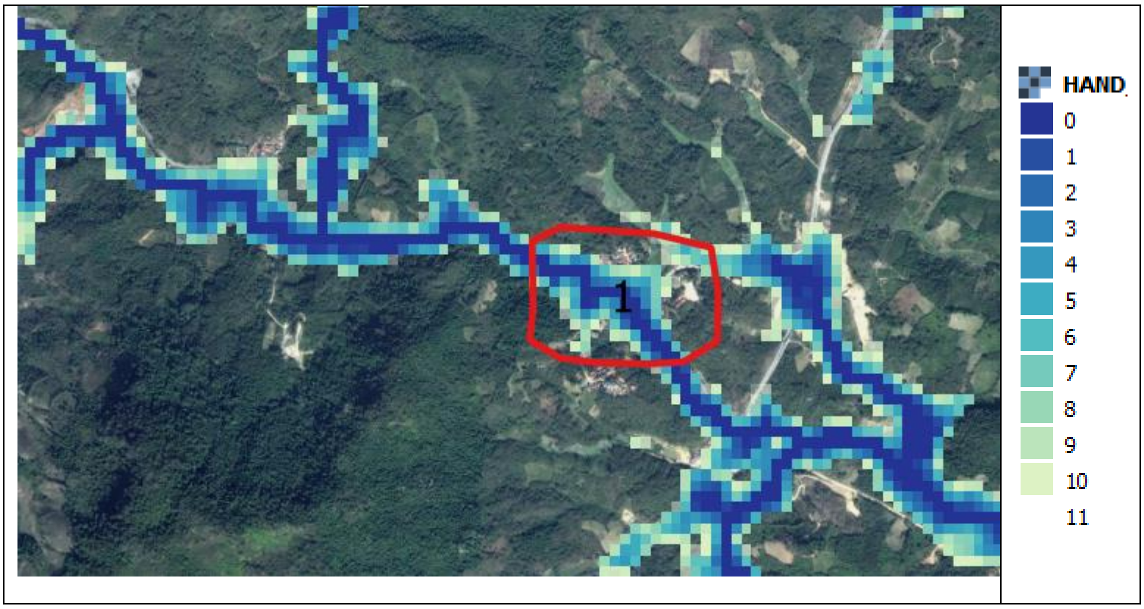


Figure 7-28 Luang Prabang, Site 1; Flooding hazard map (0 = open water, 1-11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded)

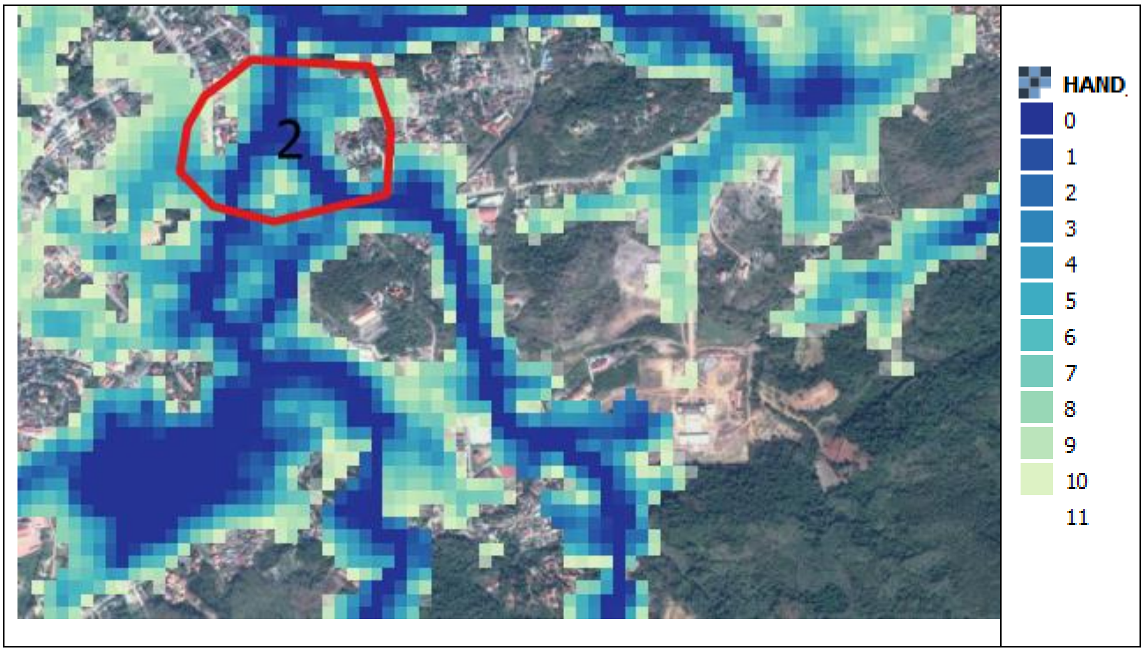


Figure 7-29 Luang Prabang, Site 2; Flooding hazard map (0 = open water, 1-11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded)

7.6.2 Sensitivity mapping – Luang Prabang

The land cover at Site 1 is mostly urban/village with grassland and forest in patches, as shown in Figure 7-30. Impacts from floods are restricted to the land close to the river, and houses, roads and bridges are damaged, which was also recorded by the local authorities. The land cover in the hills around the site is mainly forest with a low sensitivity

The sensitivity of Site 2 is shown in Figure 7-31. The main land cover in the area is urban with two larger patches of forest. The areas directly impacted by the floods are those in the immediate vicinity of the river and damages are thus mainly on the houses next to the river and damages to the road and the bridge.

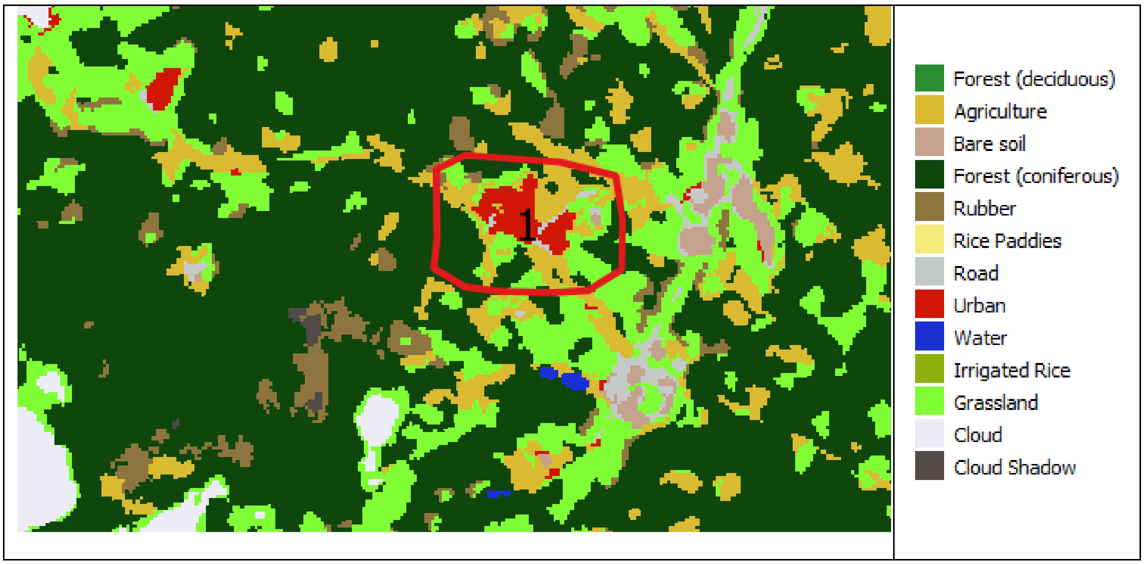


Figure 7-30 Luang Prabang, Site 1; Land cover classification

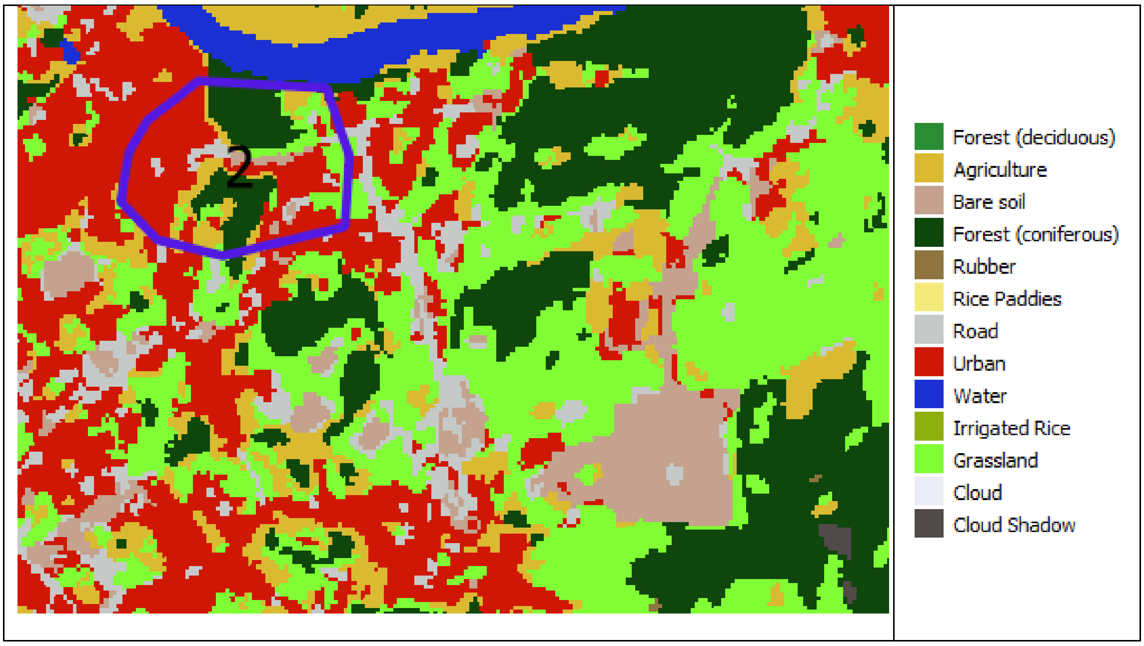


Figure 7-31 Luang Prabang, Site 2; Land cover classification

7.6.3 Vulnerability mapping – Luang Prabang

The map showing the area at Site 1 (Cf. Figure 7-32), indicate that flooding will mainly damage highly vulnerable infrastructure, but also to a lesser extent the agricultural land, which is restricted to narrow land plots along the river. Changes to the land cover and land-use in the catchment upstream of the village were visible during a visit to the site. A large quarry site upstream of the village has probably led to an increase in run-off during heavy rains, causing flood impacts in the village.

For Site 2 the vulnerability is also linked to the urban infrastructure elements adjacent to the river, as shown in Figure 7-33. As with Site 1, changes in the land cover and changes to the run-off in the catchment are the main reasons for the damages at the site.

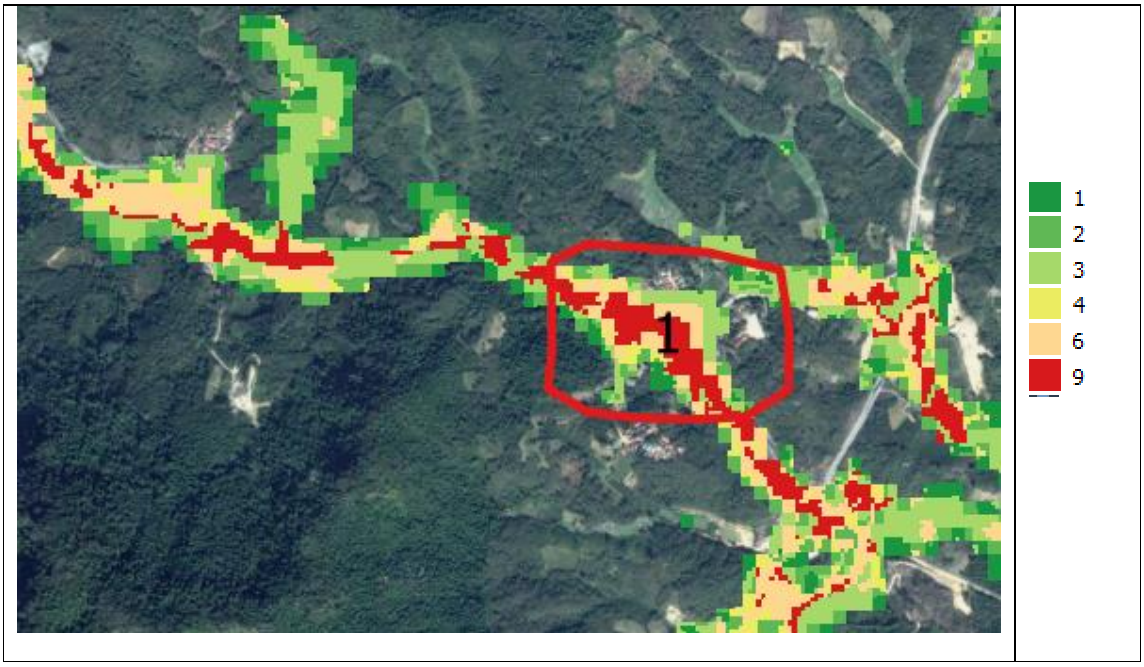


Figure 7-32 Luang Prabang, Site 1; Vulnerability map (1-3 low, 4+6 medium, 9 high)

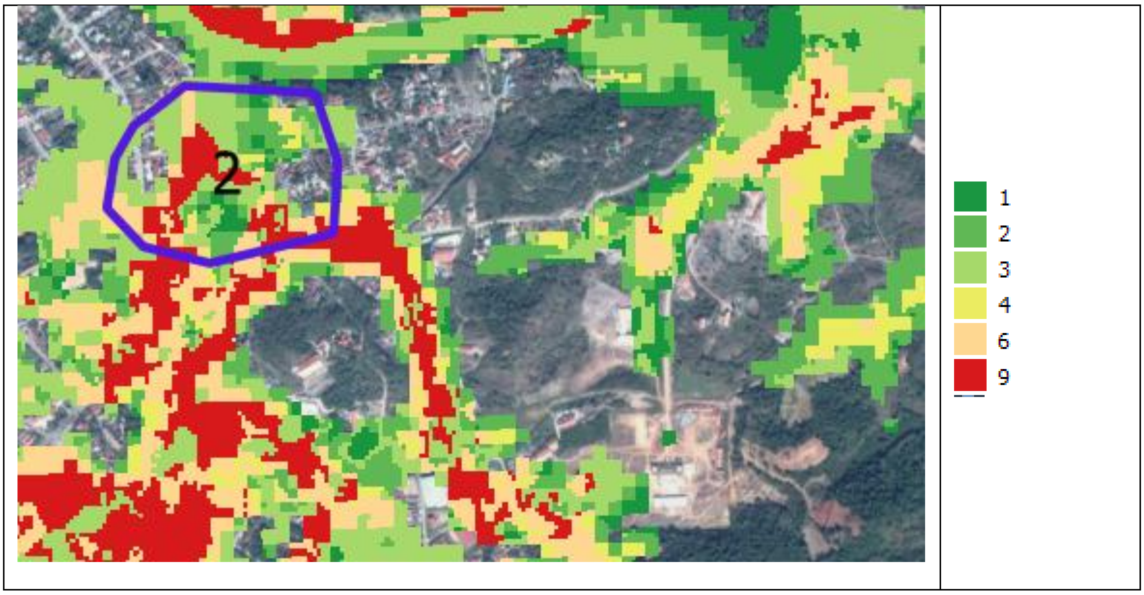


Figure 7-33 Luang Prabang, Site 2; Vulnerability map (1-3 low, 4+6 medium, 9 high)

8 Identification, prioritization and initial design of Ecosystem Based Adaptation options (Activity 4)

8.1 Identification of adaptation options in the six cities

The identification and prioritization of EBA adaptation options in the six cities focused on linking floods to the damages they create to people and ESS, but also the relationship between ESS damages and the benefits ESS provide to the local ecosystems and socioeconomic activities. The final selection and prioritization of EBA interventions therefore assessed not only the ways that EBA contributes to flood protection, but also the ways that EBA interventions can help strengthen vital ESS provisions[4].

The potential EBA interventions in each city and site were selected through mutual consultations between the consultants and city representatives, to ensure that the proposed options are rooted in reality and are thus feasible in implementation. The initial selection of potential EBA options was therefore based on a long-list provided by consultants, later on expanded by additions provided by workshop participants.

A long-list of EBA options considered for the 6 cities was as follows:

- Re/afforestation and forest conservation
- Riparian buffers
- Wetland restoration or conservation
- Constructing wetlands
- Reconnecting rivers to floodplains
- Establishing flood bypasses
- Water harvesting
- Green roofs
- Green spaces
- Permeable pavements
- Connecting existing green spaces
- Mixed solutions - combining green and built infrastructure to maximize flood protection (subject to the specific 'grey' infrastructure elements present in the specific site).

The proposed long-list formed a starting point for discussions and prioritization exercise. During group discussions, additional EBA options were added to the list by the participants, based on specific solutions suitable for the flooding sites.

8.1.1 Consultation and review of the findings

The long-list of EBA options was presented to the city representatives at the workshop on September 2017, along with presentation of potential additional benefits (supplementary ESS) that the various EBA interventions can provide in addition to flood protection. This presentation was also intended to strengthen the capacity of local stakeholders to evaluate ESS benefits of the various EBA options, and to increase understanding of EBA benefits for flood protection.

The consultations at this stage of the project were restricted to focus on EBA interventions suitable for the specific key sites (rather than entire city level). This enabled analysis to deliver highly detailed proposed EBA solutions for each site, including costing and tentative siting of key elements of the design. A thorough description is provided in the city site profiles in Appendix C).

[4] For more detailed description of the methodological approach see chapter 3.5.

Conducting analysis focusing on each specific flooding site, also allowed for a more precise evaluation of the feasibility of implementation and early consideration of potential barriers to overcome (e.g. parts of land under private property, needs for additional educational activities in case of wetland restoration in specific parts, etc.).

8.1.2 Prioritizing the adaptation options

After the initial discussions of possible EBA intervention options relevant for each site, each city selected 2-3 priority EBA interventions for each site. Detailed assessment of each option was further done based on the criteria of:

- ✓ Necessary scale of the intervention for best impact (local or basin)
- ✓ ESS that the selected EBA can provide (flood protection, but also environmental and socioeconomic ESS benefits)
- ✓ Expected complexity of implementation (feasible in reality? Known barriers to implementation?)
- ✓ Estimated cost of implementation
- ✓ Timeframe to achieve the desired ESS benefits (short-to long term).

The aim of this assessment was to enable further prioritization of 2-3 EBA interventions in each site. It is important to remark, that the analysis shows that in many of the flooding **sites a portfolio of EBA options may be most suitable to address flooding problems and ecosystem resilience.** This can help diversify the investment costs and associated risks, but also enable resilience of the EBA interventions if e.g. one of the interventions should deliver with sub-optimal efficiency. Ultimately, this also acknowledges that no single solution can help solve the causes of flooding and help manage and control impacts at the same time.

This also re-confirms the findings from site visits, where in many of the observed sites, flood problems are caused or exacerbated by poorly functional existing flood management infrastructure, or where improvement (or instalment) of simple conventional flood water management infrastructure may enable optimal utilization of the green spaces and associated EBA flood mitigation opportunities.

The table below summarizes the proposed selection of priority EBA adaptation interventions for the six cities. Each city has proposed a ‘key site’ – priority site for intervention, as well as ‘additional site(s)’, where immediate possibilities are seen for upscaling of same or similar EBA intervention within the same city.

City	Site name	Proposed EBA solution (or combination if more than 1)	Estimated cost
Vientiane	Ban Dontiou (key site)	Step 1: Maintenance and establishment of urban green areas at the individual households, providing green spaces and natural forest for the total areas of 455 ha. Step 2: Upgrading of the existing small stream through the construction of a mixture of concrete and compressed soil; provision of a drainage system from households into the stream; planting additional trees along the stream to prevent against the erosion and sedimentation.	USD 1 million (Step 1) + USD 3 million (Step 2)
	Ban Dong Xang Hin, Xaythany (additional site)	Step 1: Maintain and establish green areas at the individual households, providing green spaces and natural forest for the total areas of 863 ha. Step 2: Upgrading of the existing small stream through the construction of a mixture of concrete and compressed soil; provision of a drainage system from households into the stream; planting additional trees along the stream to prevent against the erosion and sedimentation.	USD 0.8 million (Step 1) + USD 2.8 million (Step 2)
Thakhek (Khammouan)	Nong Bua – Huay Simung (key site)	Combination of EBA and conventional elements: - Installation of 1 floodgate - Construction of a floating dam - Improvement of the drainage system - Construction of two ponds for water storage - Promoting local villagers to grow cash crops with short intervals - Planting trees along the river bank inside Huay Paksimung The proposed overflow structure is to be used to divert the water from the river to rice fields. The proposed ponds are to be used to store water for the dry season.	USD 4 million
	Huag Naly and Huay Nangsord (additional site)	Installation of water pumps for two spots inside the area with flood gate to help discharging water into Mekong River	USD 1 million
Kaysome Phomvihane	Huay LongKong, the Thahae village (key site)	The proposed solution in this project site involves installment of a green-grey solution to flooding problems. The specific interventions include a combination of: a) Bank stabilization along the stream and restoration activities in the wetlands (green) b) Installation of a flood gate for better management of water flows via improved release-close mechanisms.	USD 1.5 million

	Huoy Kylamung, HuaMuang village (additional site)	Proposed measures include a combination of both green and grey approaches, including following elements: - Restoration and protection of streams to prevent further erosion (EBA) - Establishment of a flood gate that allows for release-retention of water flows depending on the needs - Protect and restore ecosystems in the vicinity of the stream	USD 1.1. million
Pakse	Ban Tha Ha (key site)	- Widening part of the channel, which drains towards the Se Done river, for improved conveyance. The existing concrete channel will be removed and a natural channel consisting of natural material such as stones, grass, smaller plants will be established. The shape of the new channel will resemble a natural river profile. - Establishment of an electrical pump station located at the southern corner of the area. - Repair of the control structure facing the Se Done river, and the one facing the Mekong river.	USD 1.5. million
	Ban Ke (additional site)	- Upgrading the drainage system along the streams with grass; - Installation of water pumps and facilities for 2 completed sets of pumps and improvement of the flood gate (site observations show that flood gate is present however it does not appear to be fully functional); - Upgrading of the existing road and channel for higher 1.5-2 meters (the national route 13 south, next to Pa Bard temple in Ban Ke); The above measures are desired to be able to improve control over water flows particularly in improving the use of the natural depression in times of high rainfall, and protecting the actively used and inhabited areas, when the water levels in the river are high, and may push water in the channel.	USD 1.7 million
Paksan, Bolikhamaxy	Nong Peung (key site)	The proposed actions to mitigate floods and droughts on the site include a combination of green and grey measures. These cover: - Rehabilitation of the natural reservoir, including cleaning activities in the catchment area - Planting of grass and trees for ecosystem rehabilitation - Construction of a dyke to help prevent flooding damages - Installation of a flood gate to help management of water releases during floods and the dry season, allowing for controlled utilization of green spaces	USD 3.2 million

		- Establishment of a forested area to facilitate collection of water in the flood season and storage of water in the dry season	
	Ban Thabo village (additional site)	Proposed measures on site include a combination of the following green and grey adaptation elements: - Restoration of river banks in the length of 5 km - Installation of a flood gate at the location (width of the location 25m).	
Luang Prabang	Kok Ngiew (Key site)	A mix of conventional and ecosystem-based interventions for flood management and mitigation, including: - Restoration of the catchment area including planting of trees and forest conservation in the catchment area - Setting up the recovery plan with EBA approach in the city (re-plan) especially for the flooded area through the filling of surface soil, upgrade of the dyke, construction of immediate drainage, upgrading and expansion of the culverts, and construction of settling pond - Planting grass or vetiver (or other) plants along river banks to avert bank erosion Further, it is suggested to complement the physical interventions with development of the social and regulatory aspects for improved flood management. These include: - Development of regulations for forest conservation and wildlife hunting prohibition for catchment area conservation - Creating a provincial/district/village committee for flood management and/or for conservation - Training activities for all level committees on disaster management and response with EBA approach for the villagers of the 4 target villages.	USD 3.2. million
	Huay Mow (additional site)	- Restoration of the catchment area including planting of trees and forest conservation in the catchment area	USD 1.2 million

9 Input to GCF Project documents (Activity 5)

The outputs from this CTCN assistance project will provide necessary technical inputs to a GCF project funding proposal focusing on ecosystem-based adaptation in Laos, and specifically the data and information surrounding climate change vulnerability and ecosystem-based adaptation.

The list of necessary (and possible, based on data availability limitations) technical outputs from this project was discussed in detail with the consultant responsible for GCF funding project proposal, C4, during the project. This allowed for timely coordination on the content and shape of CTCN assistance outputs, to maximize their utility for the GCF proposal.

C4 representative was also present in the stakeholder workshop in Laos, dated September 2017, to further advance preparation of the GCF proposal, while coordinating with ongoing activities under CTCN technical work.

9.1 Identification and selection of CTCN assistance results that will support project proposal documents

The mutually agreed upon inputs to GCF proposal by DHI are summarized below. These are mapped against the agreed main inputs to GCF proposal (thematic only, not numbered) and contents of this technical report.

GCF proposal component	Corresponding section in this report	Comments on outputs that will support GCF proposal
Climate change in Laos	Section 4: Assessment of Climate Change Impacts (Activity 1), with further detailed analysis results for each city in Appendix A. Write up of methodological approach also provided in this report.	Includes assessment of impact of climate changes on meteorological variables including rainfall, evaporation, and temperature, developed for each of the six cities and also for upland catchment areas with potential to impact flooding and drainage in the cities. Because of the importance of Mekong River flows for flooding and urban drainage, estimates of changes to meteorological variables were also developed for headwater catchments in the upper part of the basin. Outputs include
Flood hazard mapping	Included in Section 7: Vulnerability Assessment (Activity 3). Write up of methodological approach also provided in this report	The Flood Hazard assessment was based on an assessment of the flood prone areas. A digital elevation model, based on the HAND system (Height above nearest drainage point), has been used for assessment of flood-prone areas. Hazard map produced for each city.
Sensitivity mapping	Included in the Section Identification, prioritization and initial design of Ecosystem Based Adaptation options (Activity 4)	The sensitivity assessment based on land cover, with sensitivity ranking (according to expected damages from flooding). Assessment based on combination of objective (land cover) and subjective (workshop discussions) criteria.
Climate change	Section 7: Vulnerability Assessment (Activity 3) and	Vulnerability assessment (with associated maps) for each city, based on combination of sensitivity ranking and flood exposure. Resulting in vulnerability

vulnerability mapping	city specific vulnerability maps in Appendix C. Write up of methodological approach also provided in this report.	maps for each city, with spatial vulnerability assessment in three categories: Low, Medium and High.
Climate impacts, risks and adaptation needs of the six cities: **Ecosystem services (ESS) assessment**	Write up of methodological approach also provided in this report. Supplementary Tables of outputs of ESS and Flood damages assessments for each city are available in Workshop reports.	Identification of ESS for each city focusing on ESS available and utilised by the population, and which were damaged as a result of climate change, and specifically flooding. Combining DHI assessment and participatory approach, in workshop setting with the representatives of all cities. Main flood damages, to ESS and other were also identified and ranked in importance. Further ESS assessment was undertaken for each proposed project site to prioritize necessary EBA.
Climate impacts, risks and adaptation needs of the six cities: **Ecosystem-based adaptation options**	Included in the section 8: Identification, prioritization and initial design of Ecosystem Based Adaptation options (Activity 4). Supplementary information in detail included n city site descriptions. Write up of methodological approach also provided in this report.	DHI together with stakeholders evaluated a range of possible EBA interventions each of the identified sites in each city. The selection and prioritization of the EBA interventions was linked to the previous assessments of the ESS, ensuring that the EBA interventions address the specific ESS damages in the site. Key outputs include a selection of potential project sites in each city, accompanied with potential priority EBA interventions, estimated costing and link to upscaling potential, as well as initial remarks on exiting or expected challenges for implementation.

The above agreed GCF proposal component section identification, can be documented with earlier communication documents exchanged between C4 and DHI, upon request.

9.2 Project document support

In addition to the technical inputs providing the scientific basis for GCF proposal, DHI will provide review comments and ad hoc inputs to preparation of GCF proposal in the months of December 2017 – January/February 2018. First draft of GCF proposal has been shared with DHI in view of DHI providing initial feedback to the proposal between December 15th 2017 and January 1st 2018.

10 Finalization and approval of results (Activity 6)

This report summarizes all activities and deliverables from the project. The project has been based on a participatory approach, where the national designated entity (NDE) together with the consultant have involved the regional authorities in all major activities of the project.

Due to the fact that the concepts Ecosystem services, hazard mapping, sensitivity/vulnerability assessments have not been used previously in Laos, the project has put emphasis on illustrating and visualizing these concepts, using the selected sites as examples. The results from the workshops have shown a growing understanding of working with the concepts and bringing the concepts into the planning vocabulary.

The analytical work in creating sensitivity maps has shown that although public data are available, there is a limit to how precise e.g. the digital elevation models are for the selected sites and cities. However, despite imprecise data, the development of the method to use public data, involving hazard mapping, land-cover classification and finally the vulnerability mapping, has shown that reasonable results can be obtained, but it has also shown that when it comes to the actual implementation of specific interventions, there may be a need for more precise assessment, involving development of e.g. local digital elevation models.

Overall, the project has delivered new information based on climate change models and assessments, hazard maps, showing most probable flood prone areas, land cover classification and sensitivity/vulnerability maps for large areas at and around each of the 6 cities, tools that will enable the national and regional authorities to take advantage of the results in the future planning.

The results from the project has been developed to add additional input to the GCF proposal.

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APPENDICES

APPENDIX A –

Climate change impacts

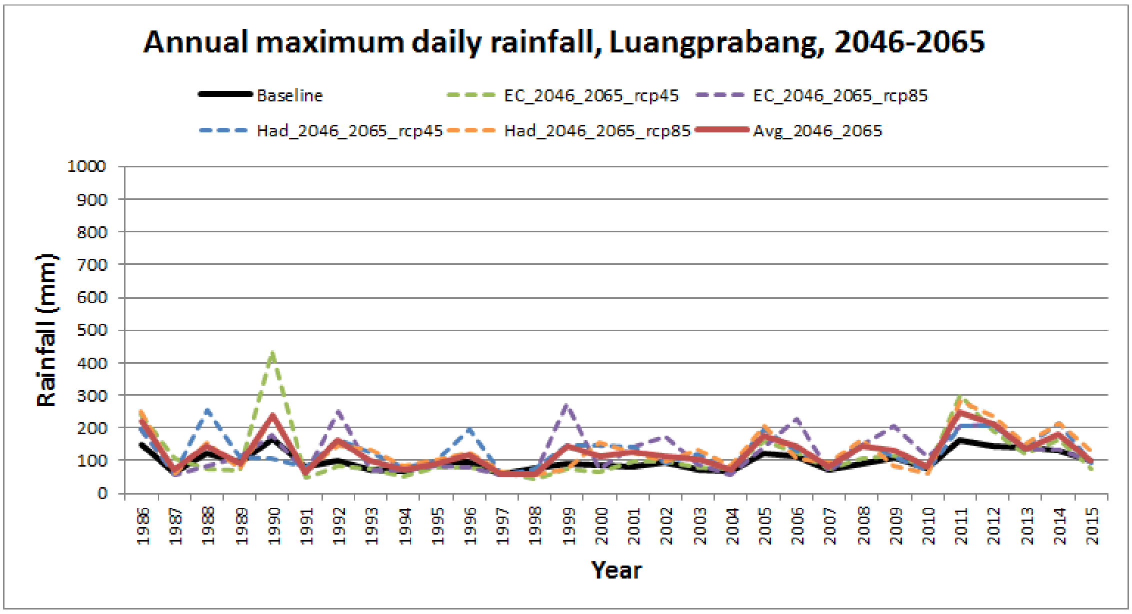
A Climate change projections

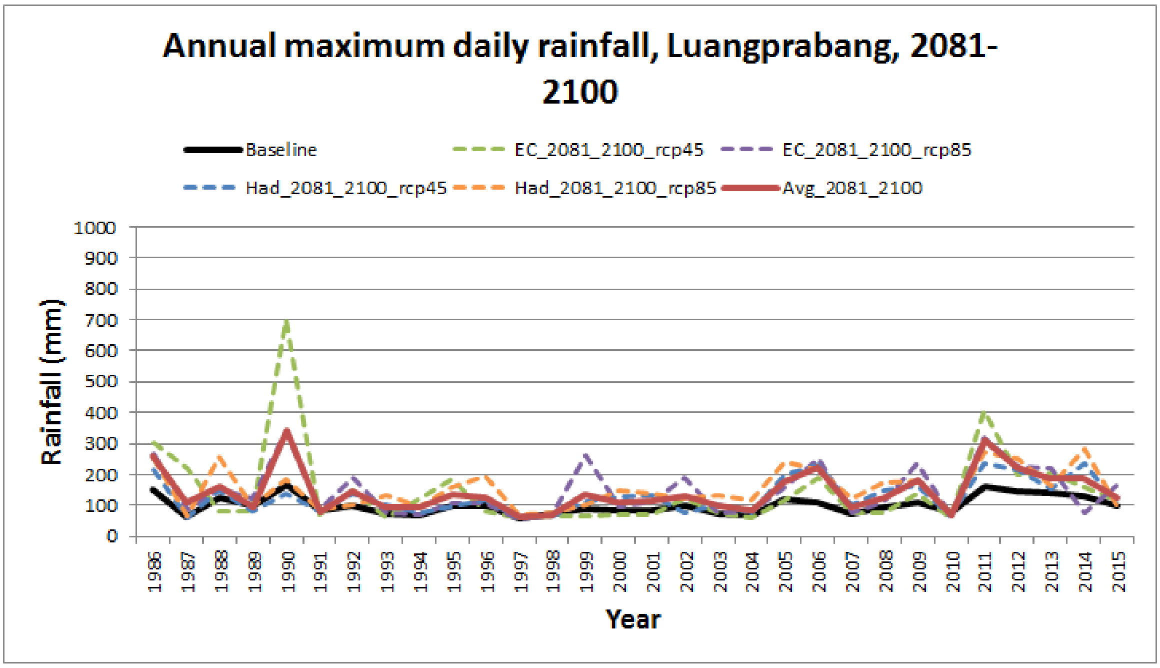
This section presents additional projections of climate change impacts on rainfall, temperature, and evaporation. Indicators are presented for cities and catchments in addition to the representative city and catchment presented in 4.3. All indicators that were presented in 4.3 are presented here, with the exception of the indicator, “Duration curve of monthly maximum timeseries”.

A.1 Rainfall

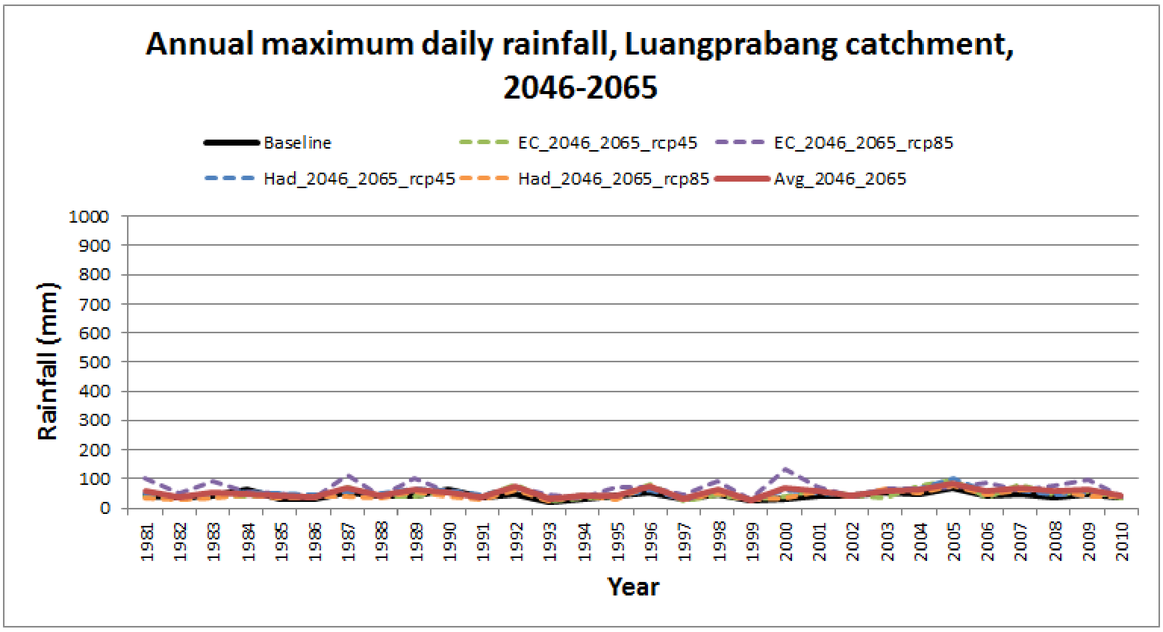
A.1.1 Annual maximum time series

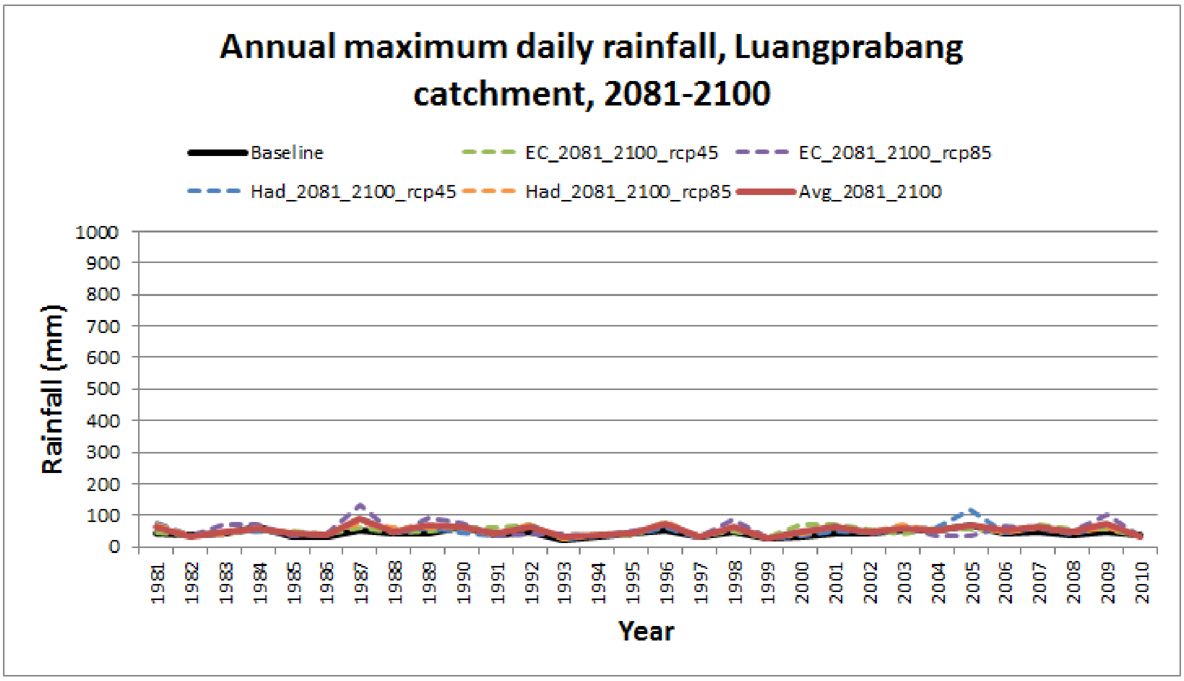
A.1.1.1 Luang Prabang city



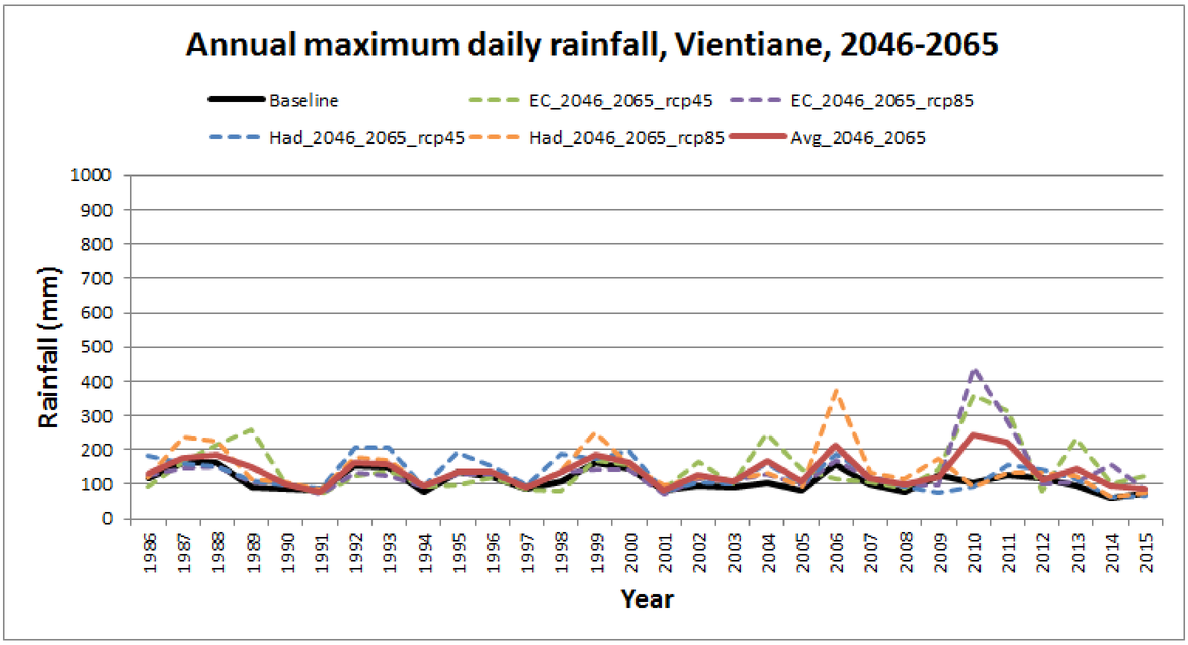


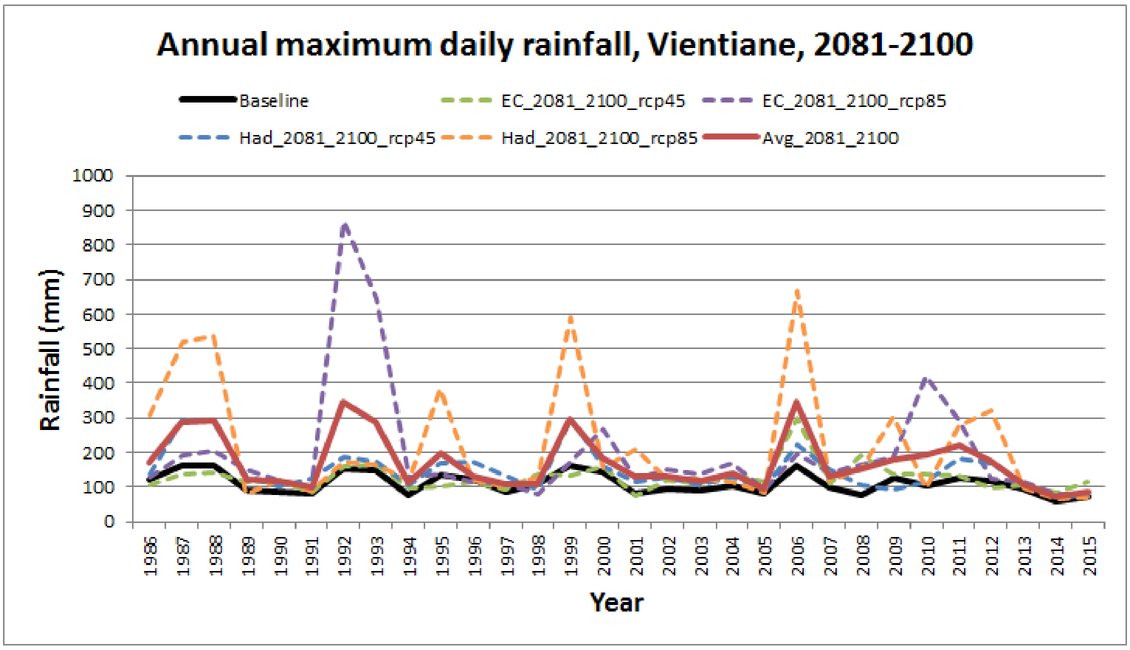
A.1.1.2 Luang Prabang catchment



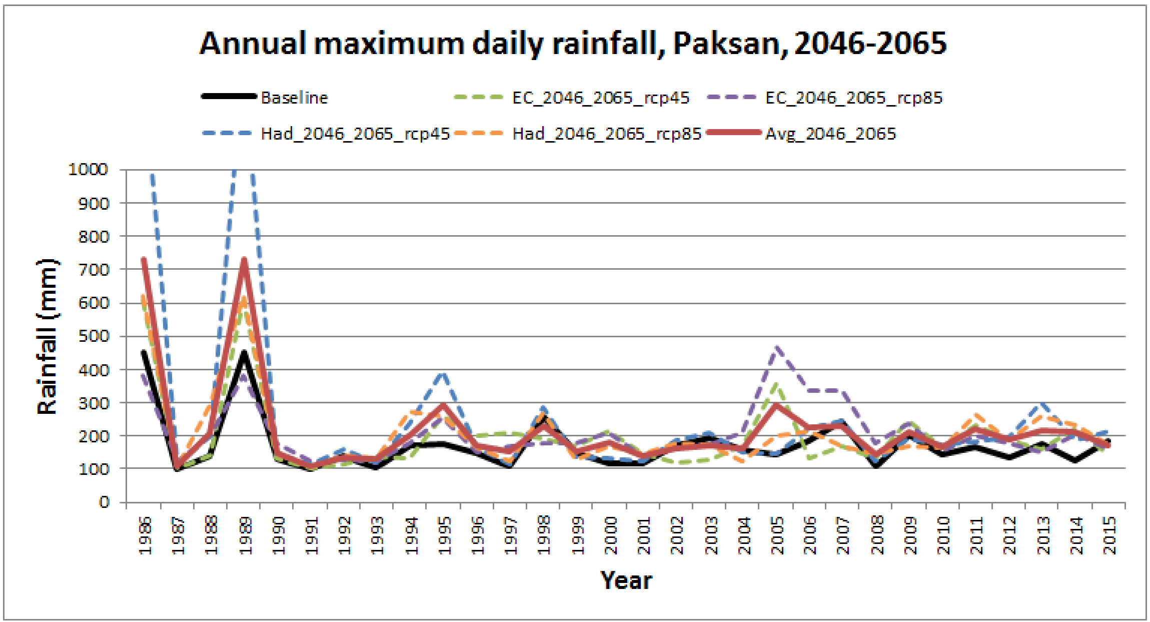


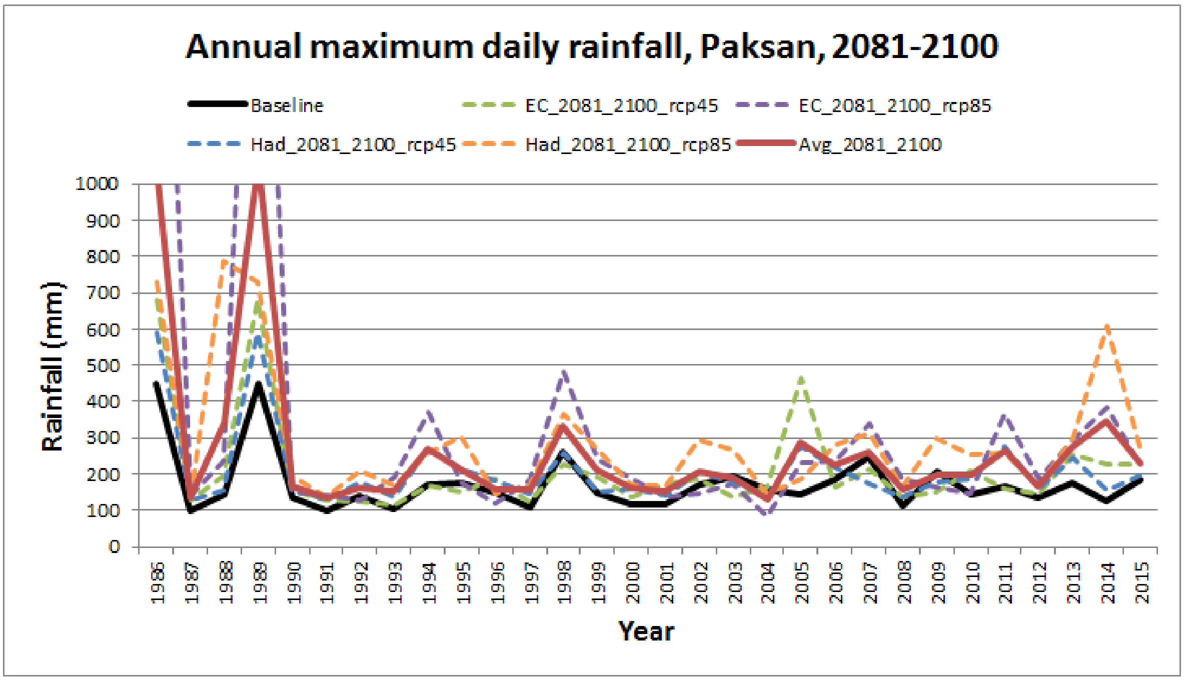
A.1.1.3 Vientiane city



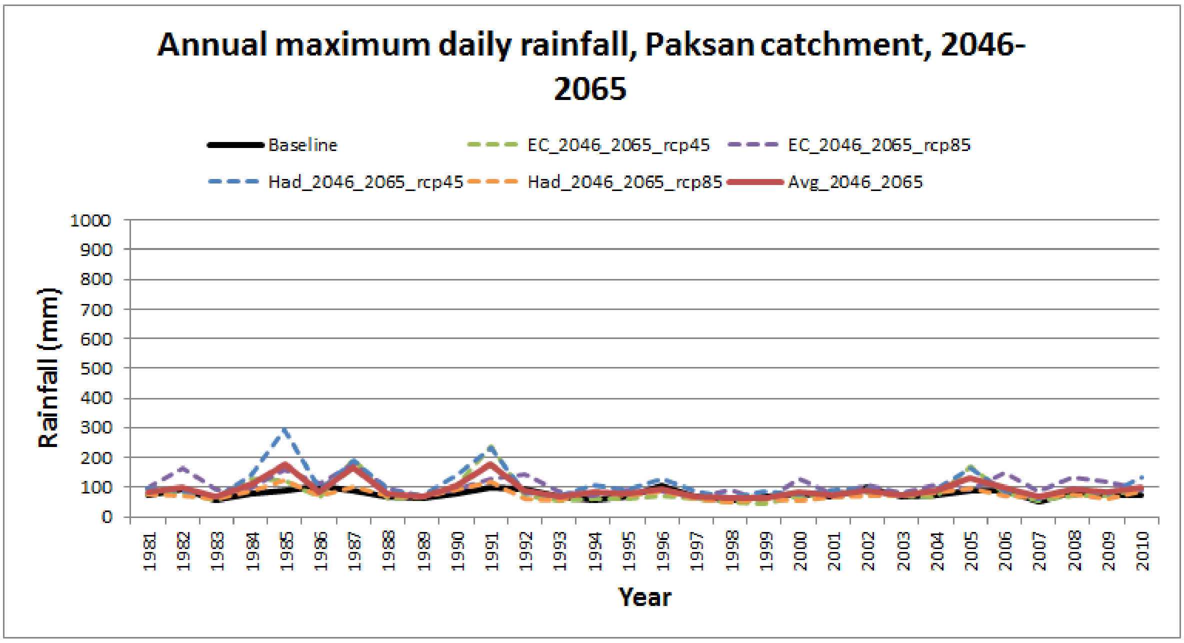


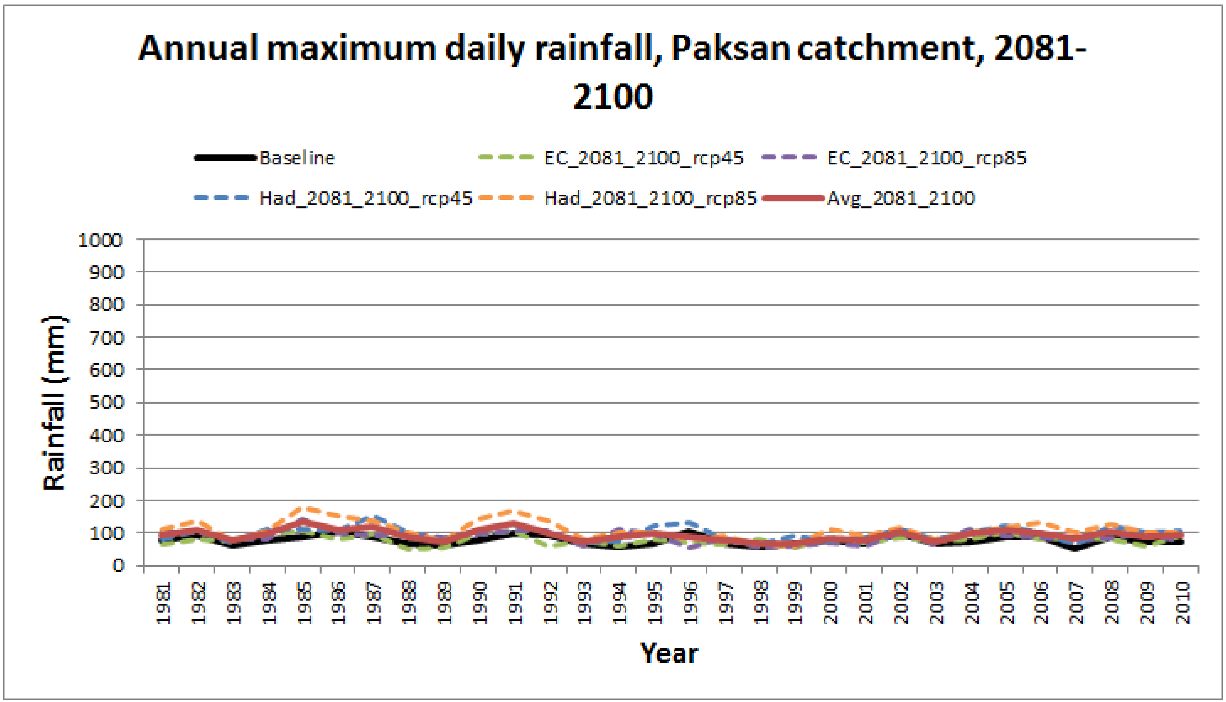
A.1.1.4 Paksan city



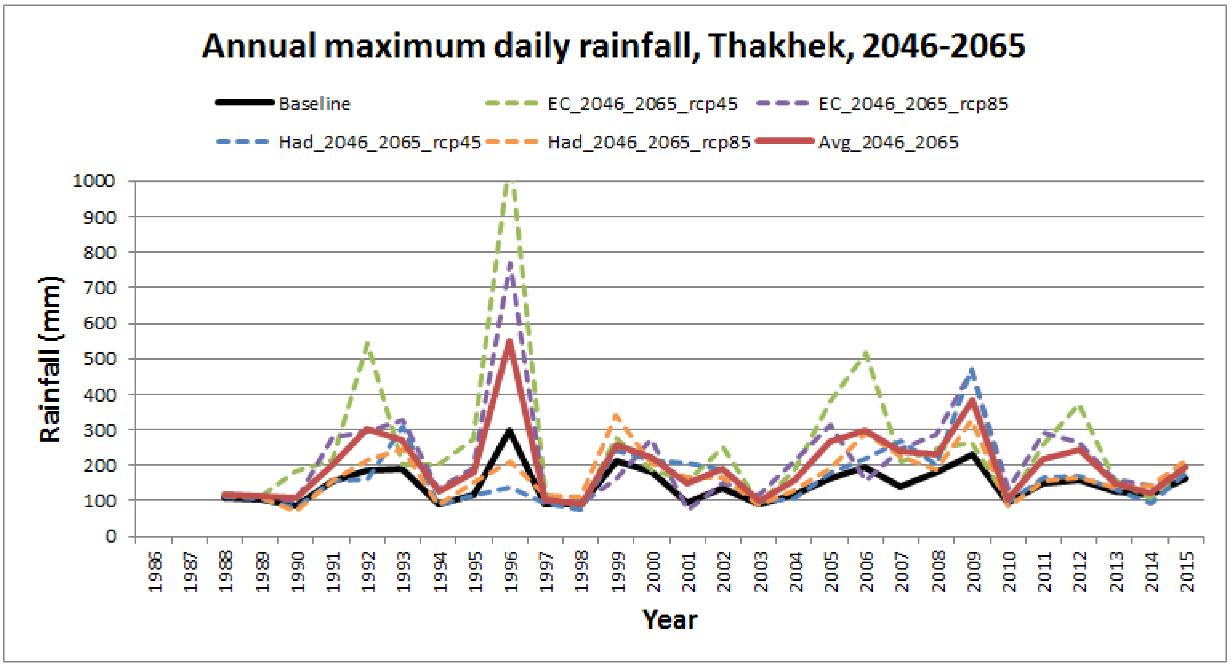


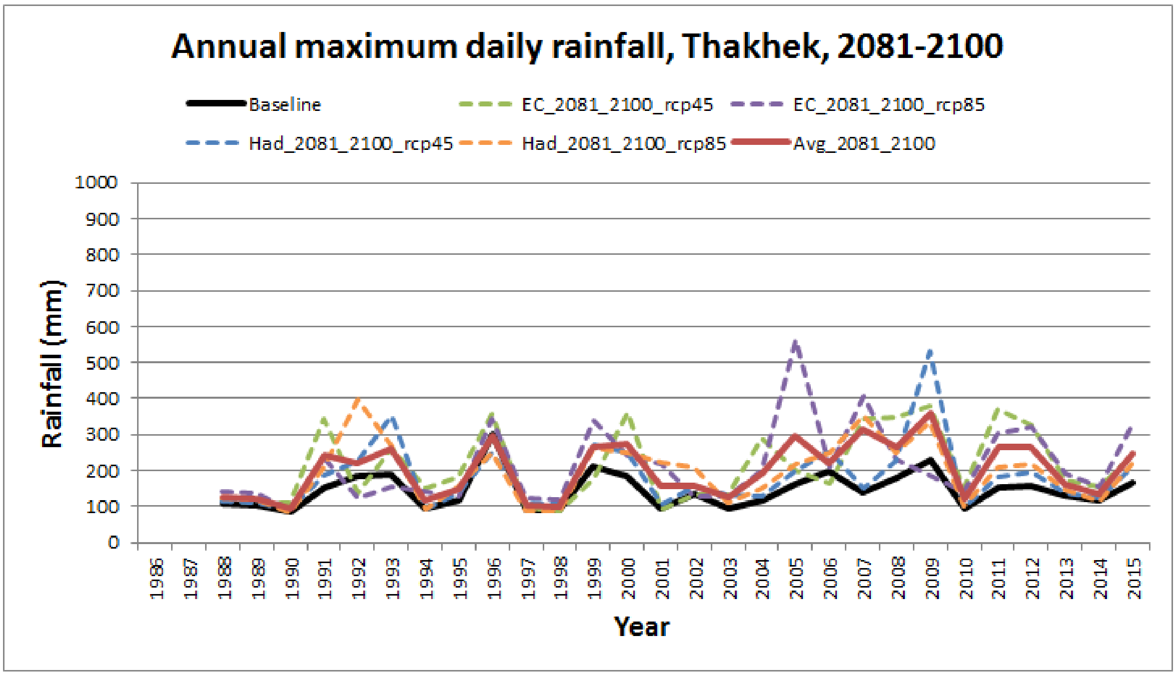
A.1.1.5 Paksan catchment



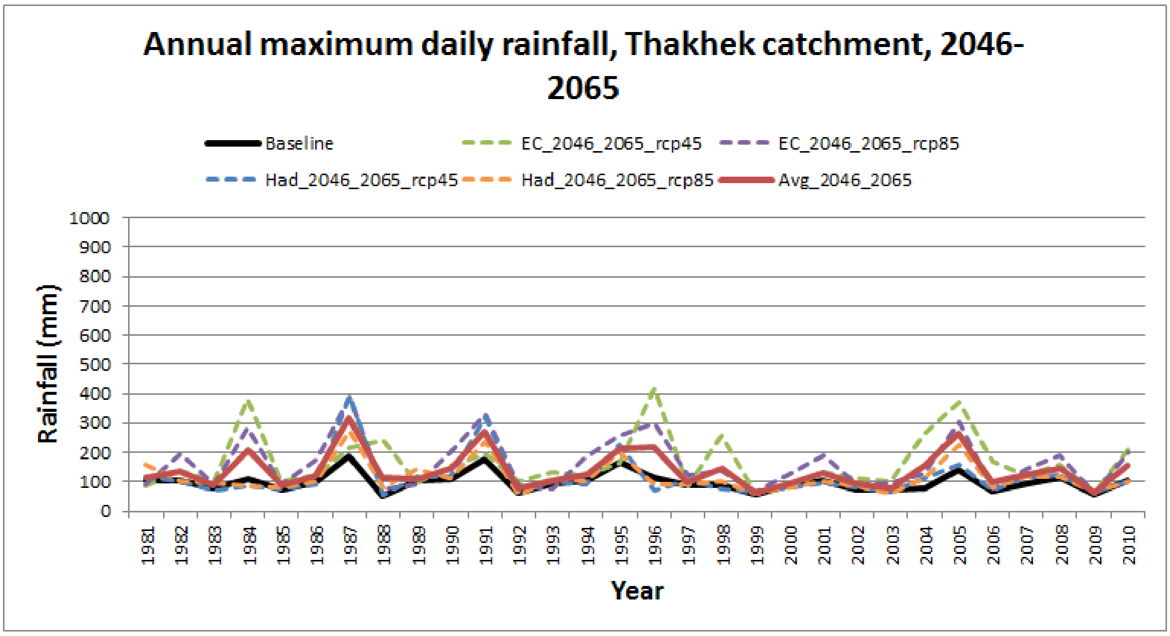


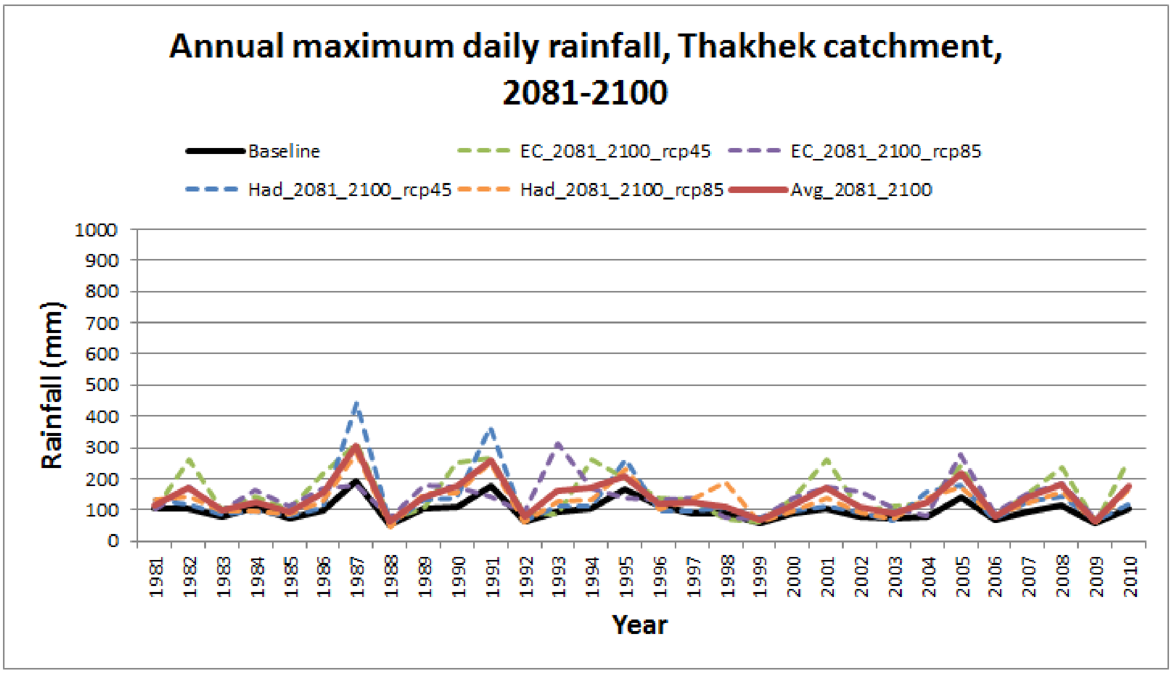
A.1.1.6 Thakhek city



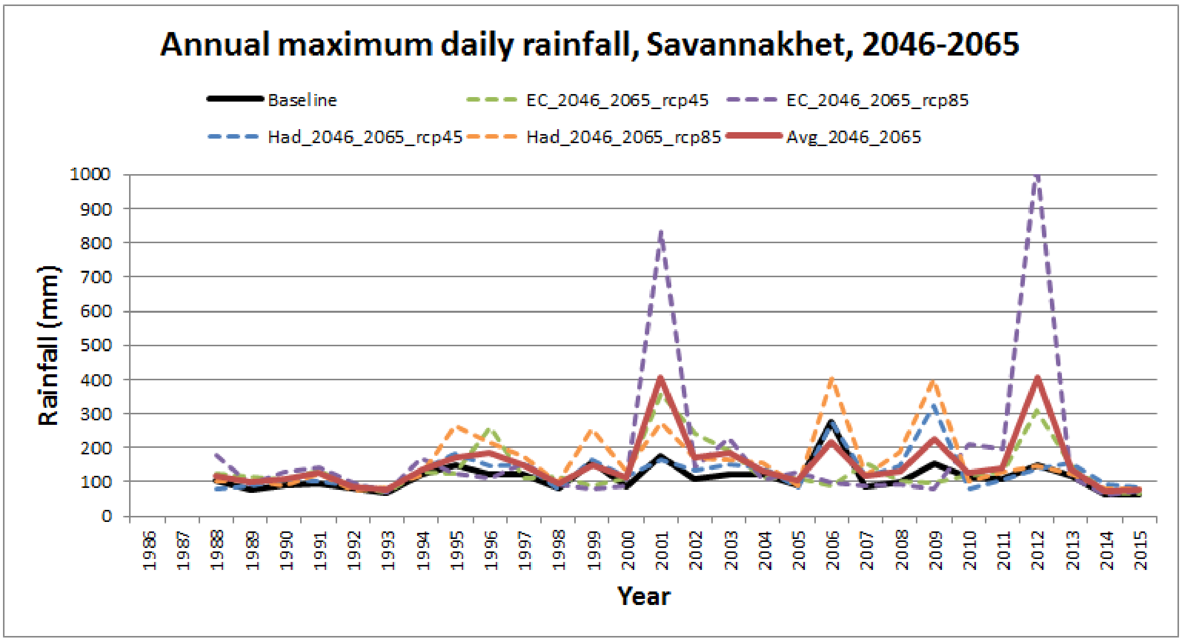


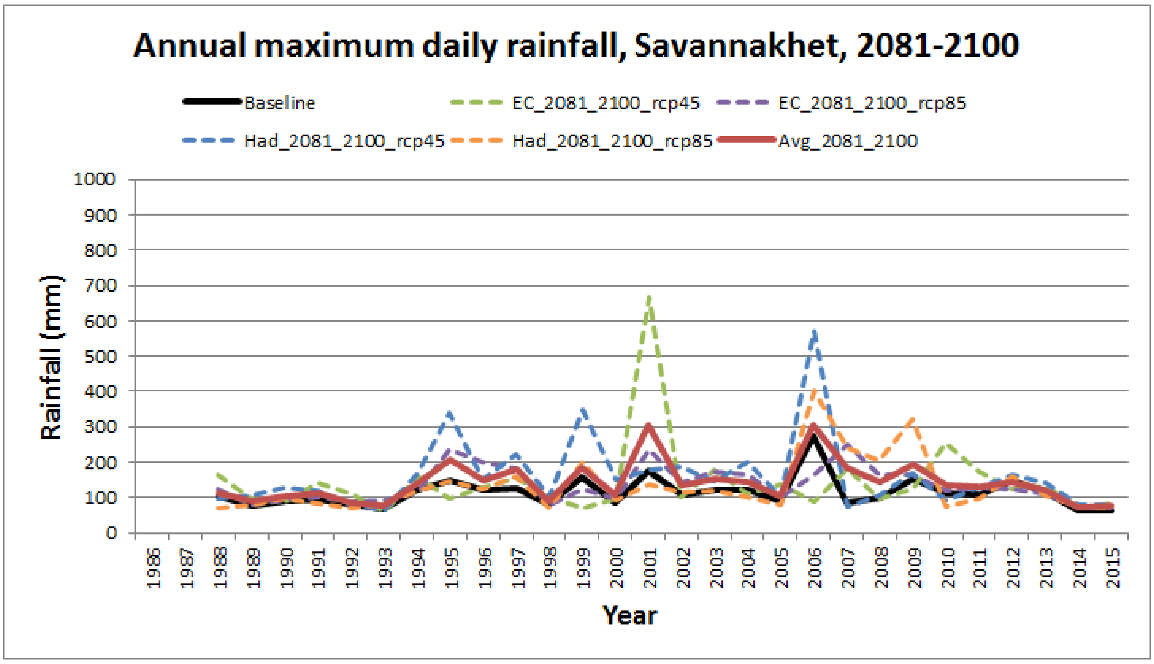
A.1.1.7 Thakhek catchment



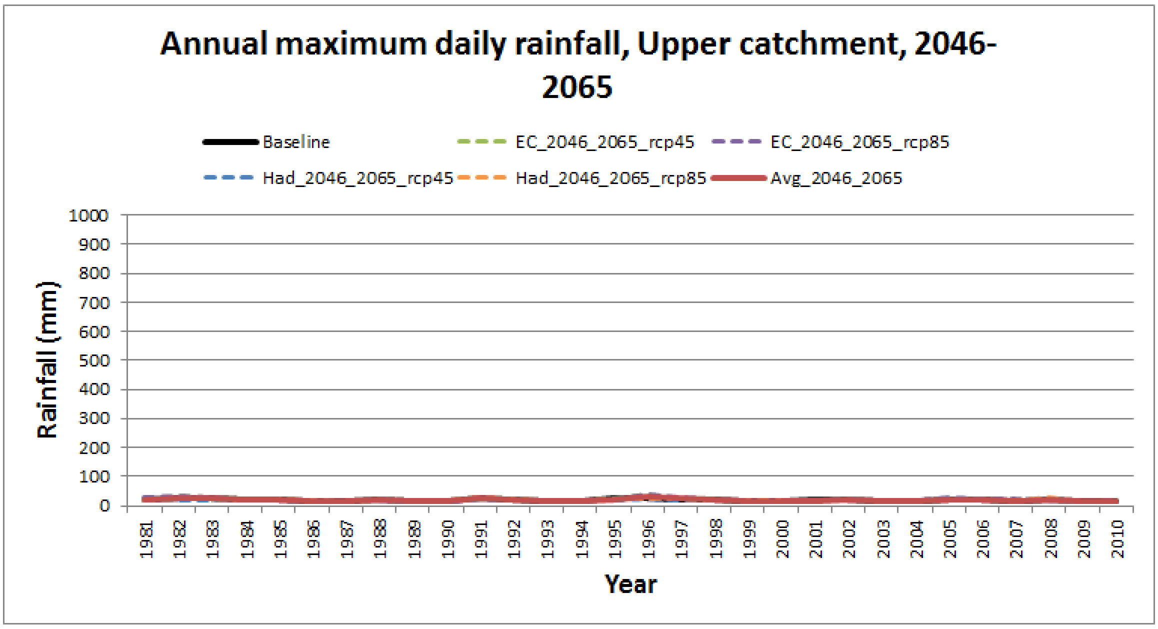


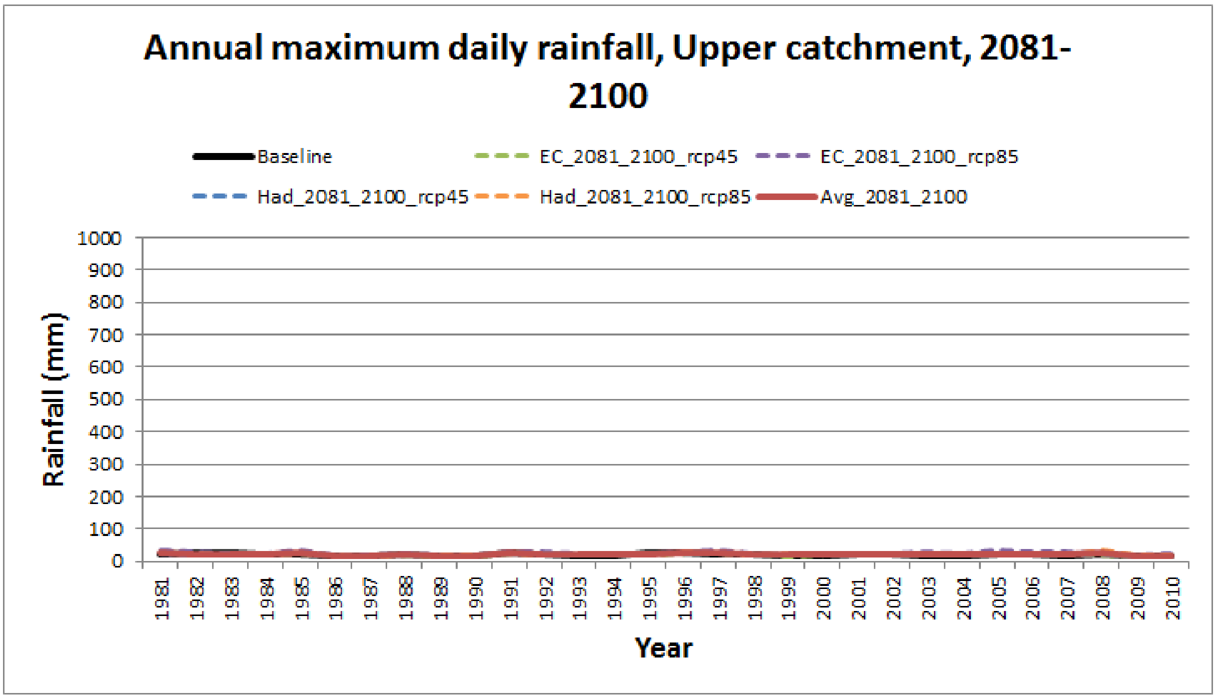
A.1.1.8 Savannakhet city



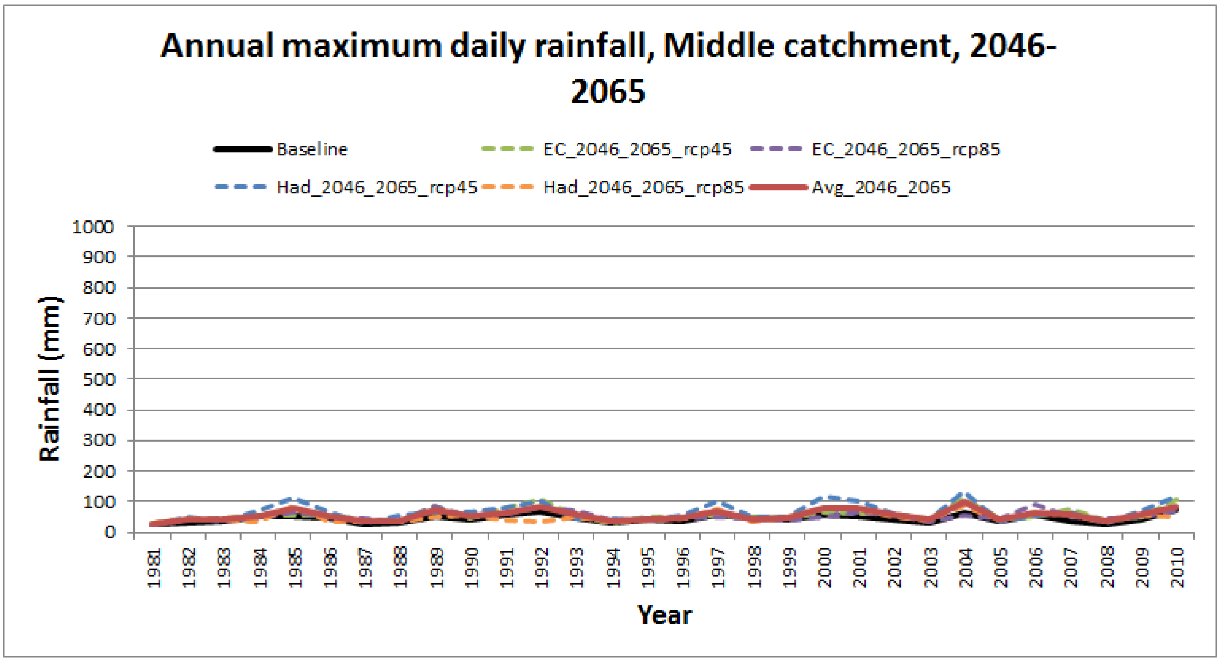


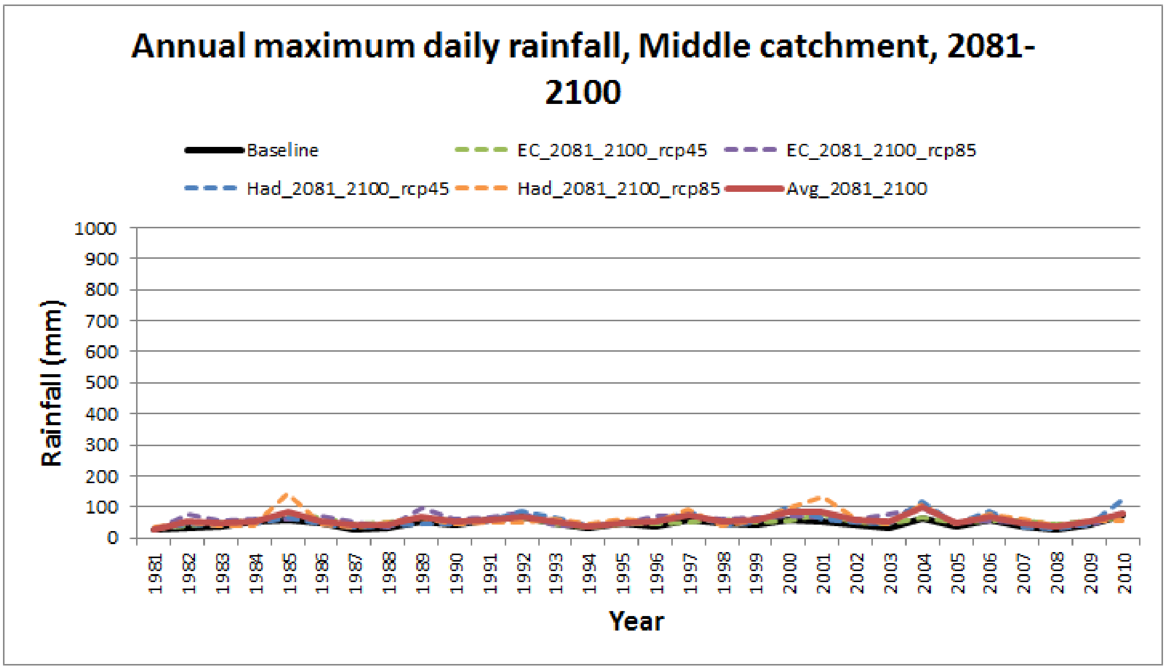
A.1.1.9 Upper Mekong headwater catchment



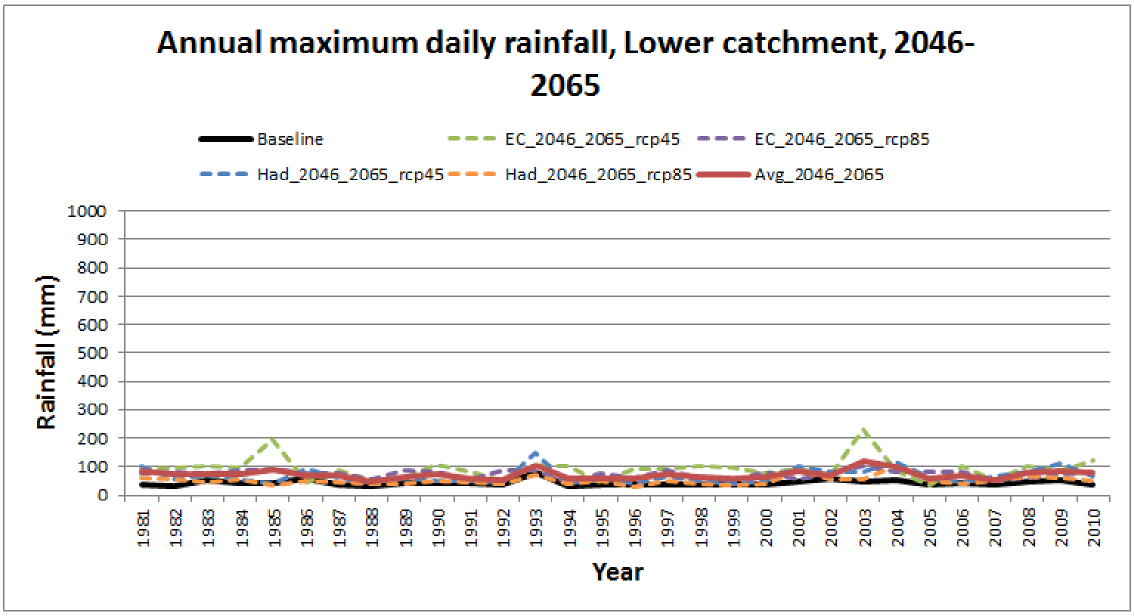


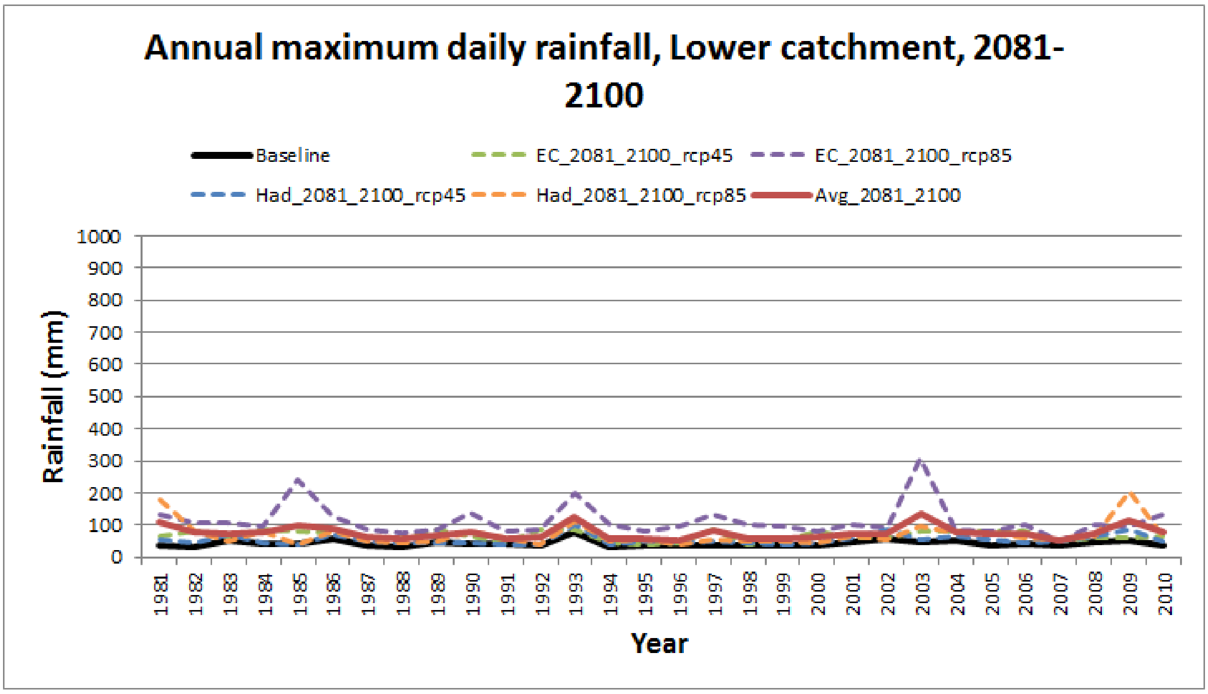
A.1.1.10 Middle Mekong headwater catchment





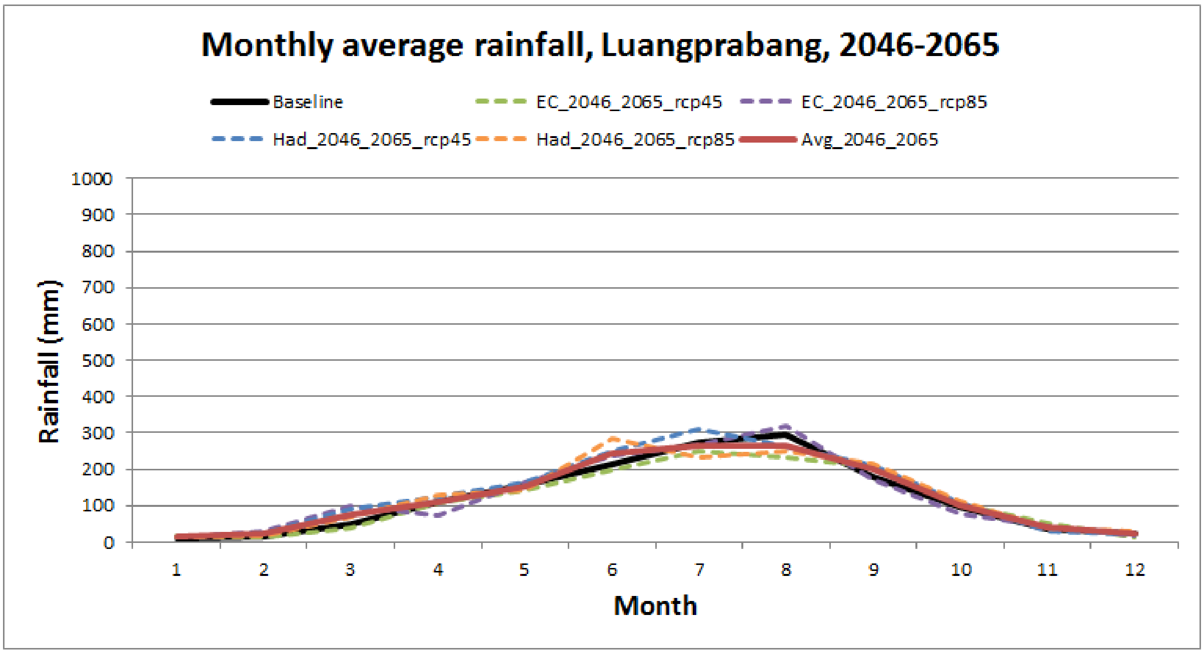
A.1.1.11 Lower Mekong headwater catchment





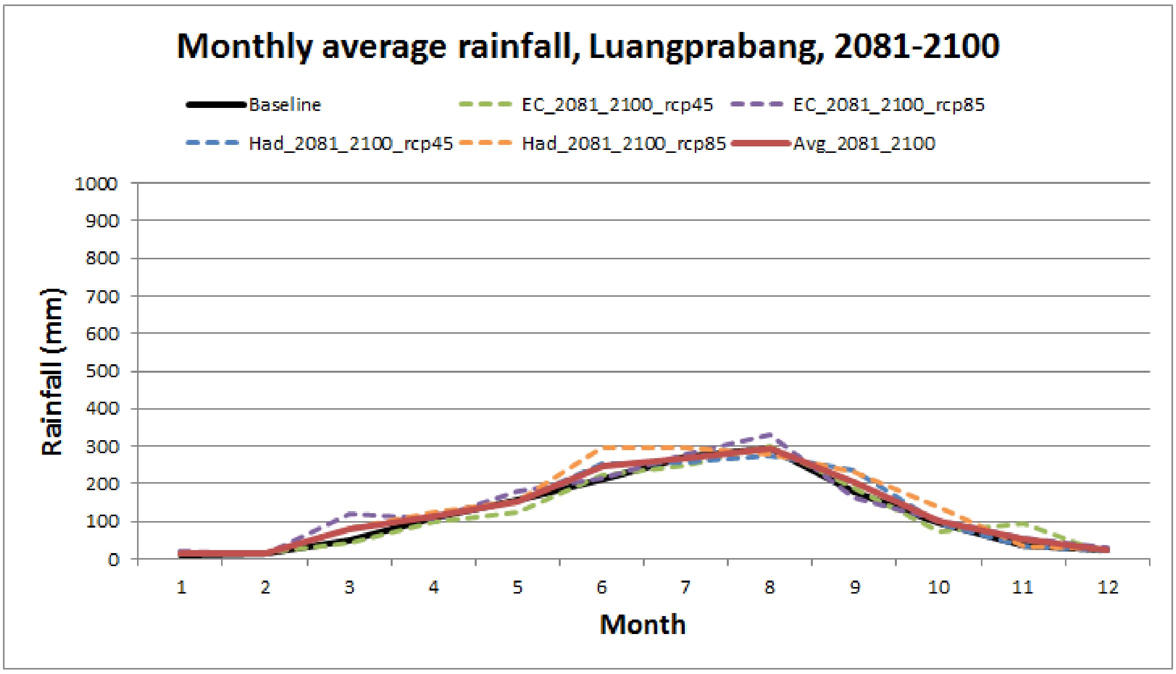
A.1.2 Average monthly rainfall

A.1.2.1 Luang Prabang city



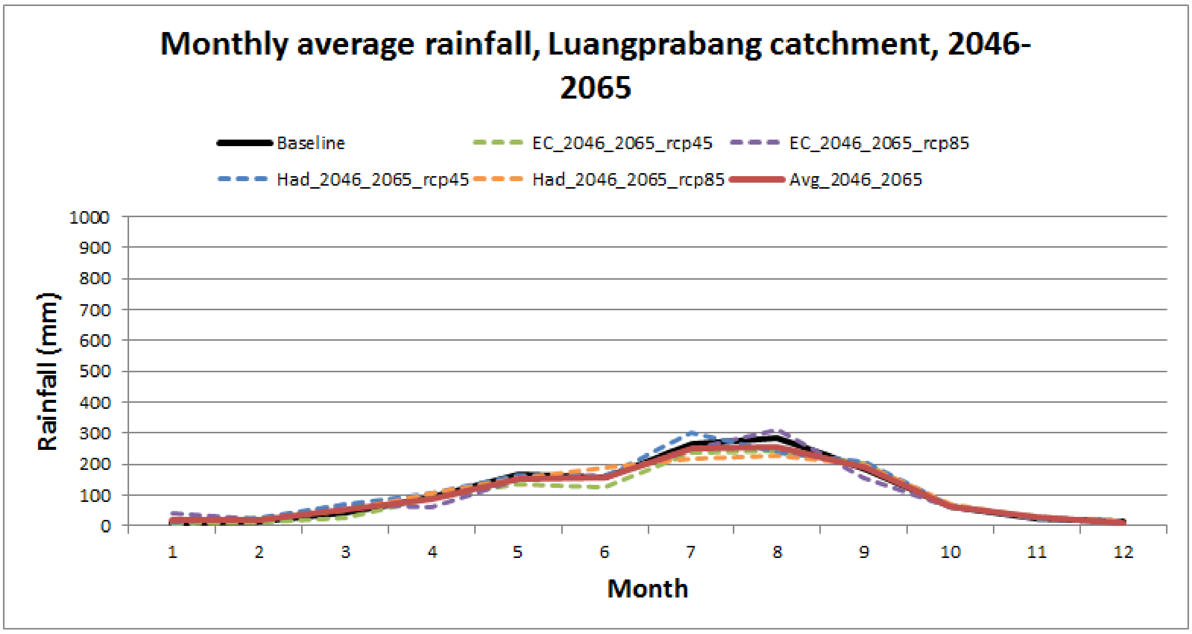
Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	12.3	13.3	50.7	111.1	158.0	211.4	272.7	295.7	177.4	95.0	36.2	22.9
Ensemble average	14.0	21.8	73.8	107.9	153.7	242.2	264.4	266.5	200.8	101.1	40.7	21.3

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Change factor	1.14	1.63	1.45	0.97	0.97	1.15	0.97	0.90	1.13	1.06	1.13	0.93

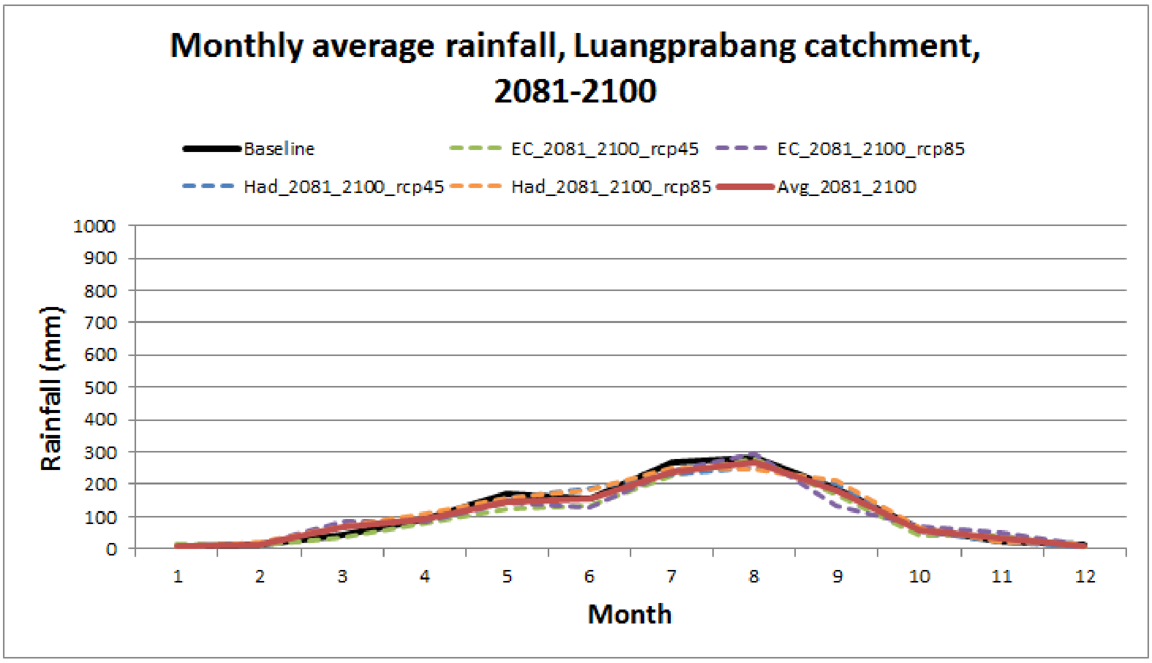


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	12.3	13.3	50.7	111.1	158.0	211.4	272.7	295.7	177.4	95.0	36.2	22.9
Ensemble average	15.2	15.0	81.1	111.9	154.3	247.1	270.3	296.0	204.8	102.4	53.7	21.3
Change factor	1.24	1.12	1.60	1.01	0.98	1.17	0.99	1.00	1.15	1.08	1.49	0.93

A.1.2.2 Luang Prabang catchment

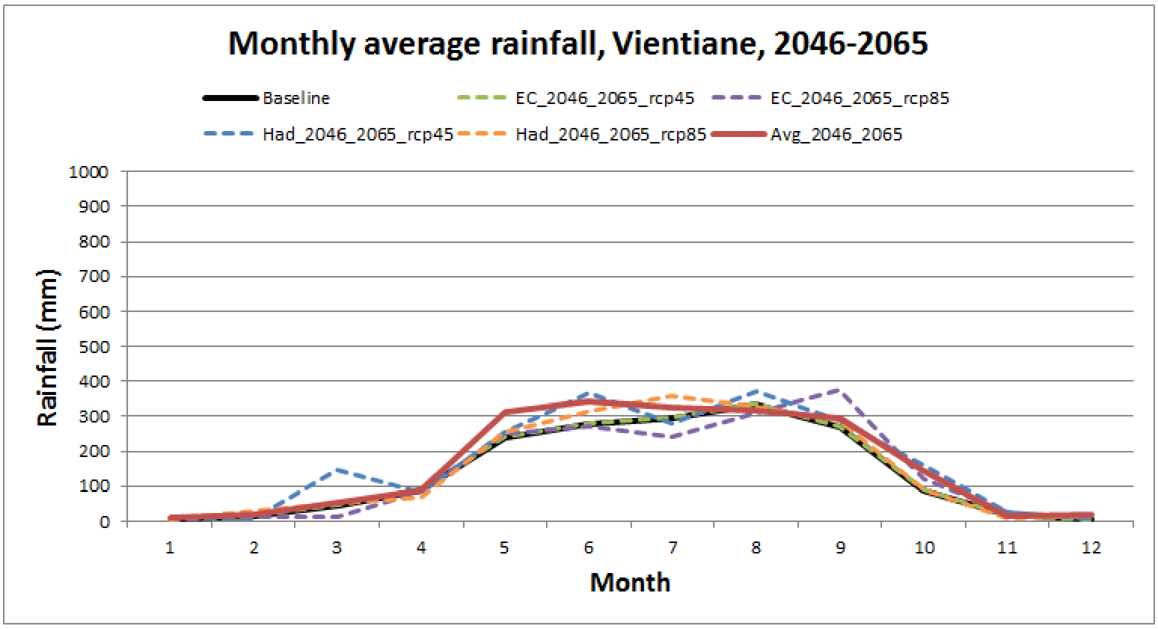


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	8.7	16.1	42.5	93.2	168.3	154.7	267.3	283.5	187.2	63.5	22.0	12.0
Ensemble average	19.0	20.9	54.3	89.7	150.6	158.5	251.5	255.5	191.4	63.6	27.3	11.1
Change factor	2.19	1.30	1.28	0.96	0.89	1.02	0.94	0.90	1.02	1.00	1.24	0.93

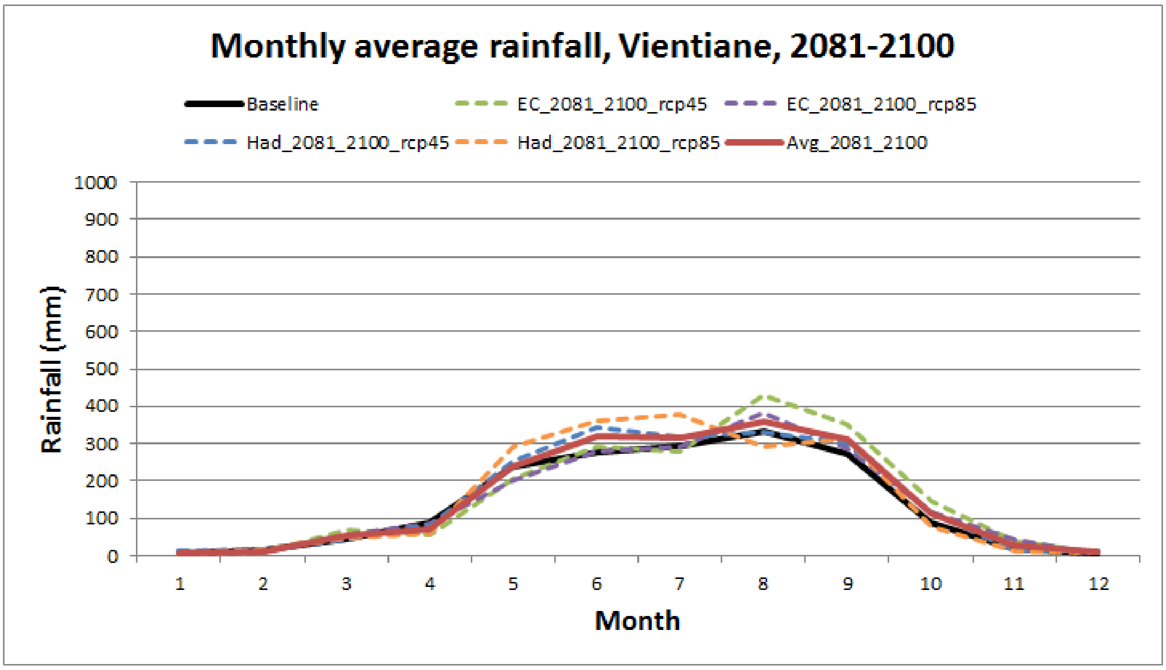


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	8.7	16.1	42.5	93.2	168.3	154.7	267.3	283.5	187.2	63.5	22.0	12.0
Ensemble average	9.1	15.9	65.8	90.4	145.9	158.0	237.0	268.7	178.6	57.7	33.8	9.9
Change factor	1.05	0.99	1.55	0.97	0.87	1.02	0.89	0.95	0.95	0.91	1.53	0.83

A.1.2.3 Vientiane city

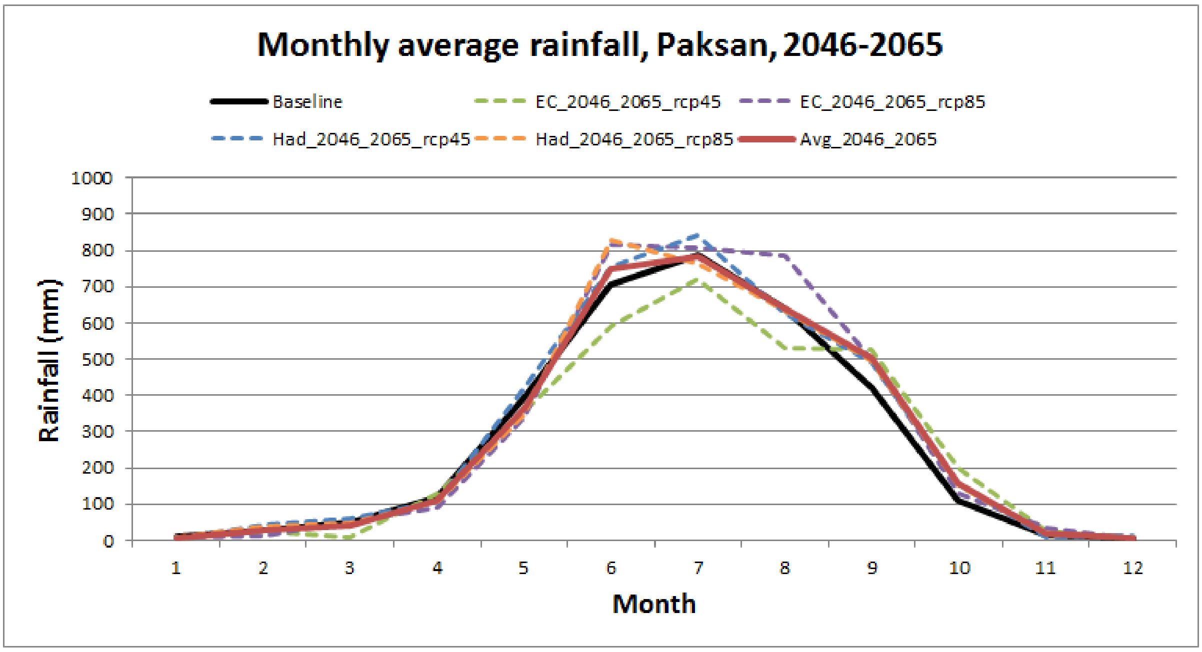


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	6.9	15.3	45.1	89.0	239.3	278.3	295.7	334.3	270.9	89.3	17.4	4.7
Ensemble average	9.3	19.9	51.8	86.9	312.5	344.4	325.3	319.0	297.4	144.3	15.4	18.2
Change factor	1.34	1.30	1.15	0.98	1.31	1.24	1.10	0.95	1.10	1.62	0.88	3.87

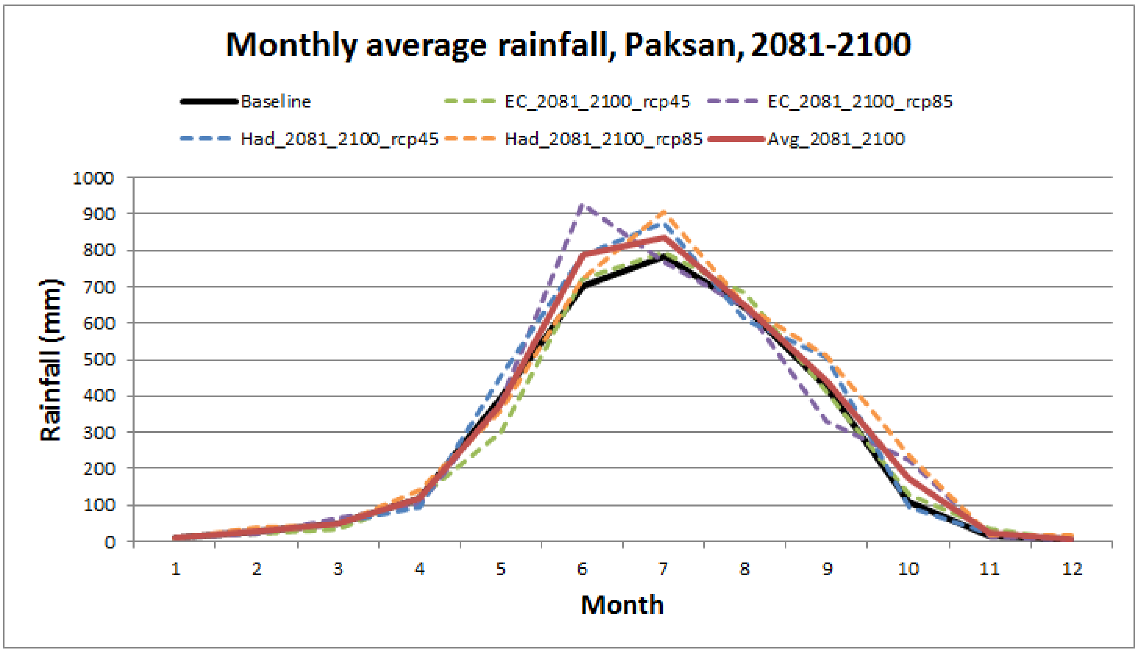


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	6.9	15.3	45.1	89.0	239.3	278.3	295.7	334.3	270.9	89.3	17.4	4.7
Ensemble average	7.5	11.8	53.9	70.4	239.7	319.2	316.7	358.1	313.3	112.4	27.8	9.1
Change factor	1.08	0.77	1.19	0.79	1.00	1.15	1.07	1.07	1.16	1.26	1.60	1.94

A.1.2.4 Paksan city

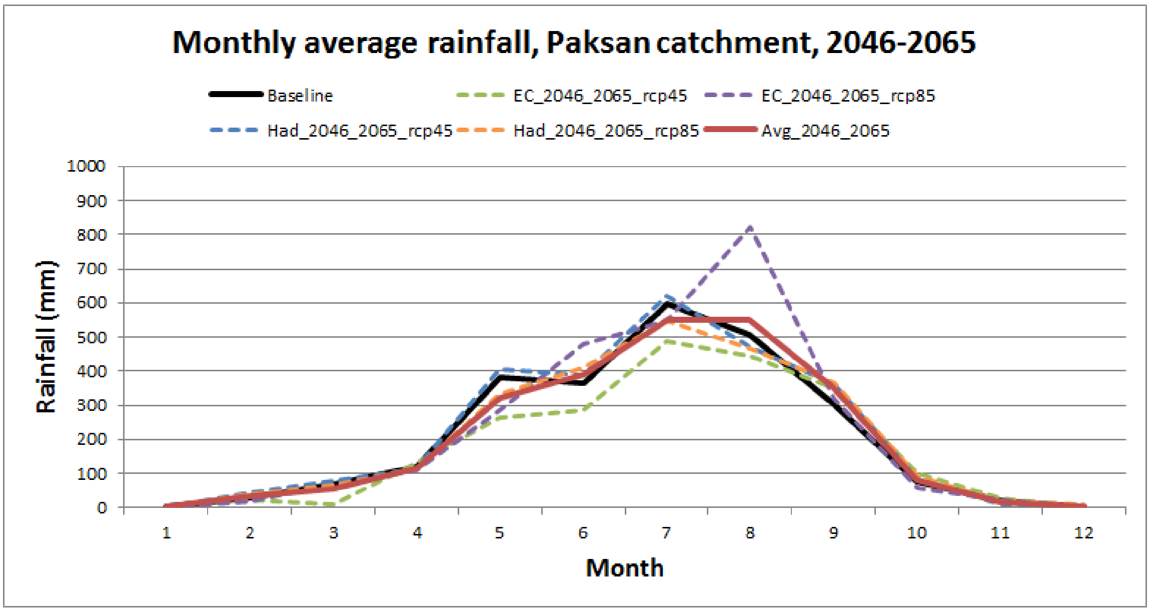


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	8.5	28.1	49.5	119.2	393.0	703.9	785.6	641.5	421.9	108.0	16.3	4.5
Ensemble average	6.0	29.5	41.7	108.2	363.9	747.9	783.0	642.1	503.3	157.9	20.9	7.8
Change factor	0.70	1.05	0.84	0.91	0.93	1.06	1.00	1.00	1.19	1.46	1.28	1.72

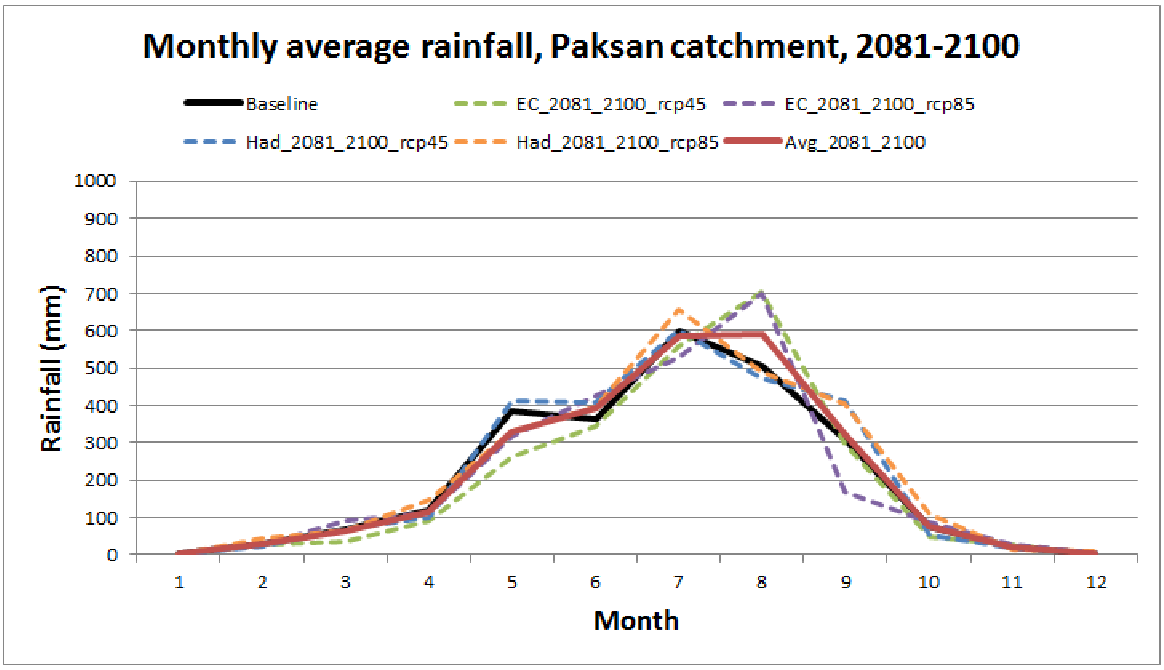


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	8.5	28.1	49.5	119.2	393.0	703.9	785.6	641.5	421.9	108.0	16.3	4.5
Ensemble average	8.4	27.1	49.3	115.7	375.3	789.4	836.1	646.9	440.3	171.7	21.7	6.8
Change factor	0.99	0.97	1.00	0.97	0.95	1.12	1.06	1.01	1.04	1.59	1.33	1.50

A.1.2.5 Paksan catchment

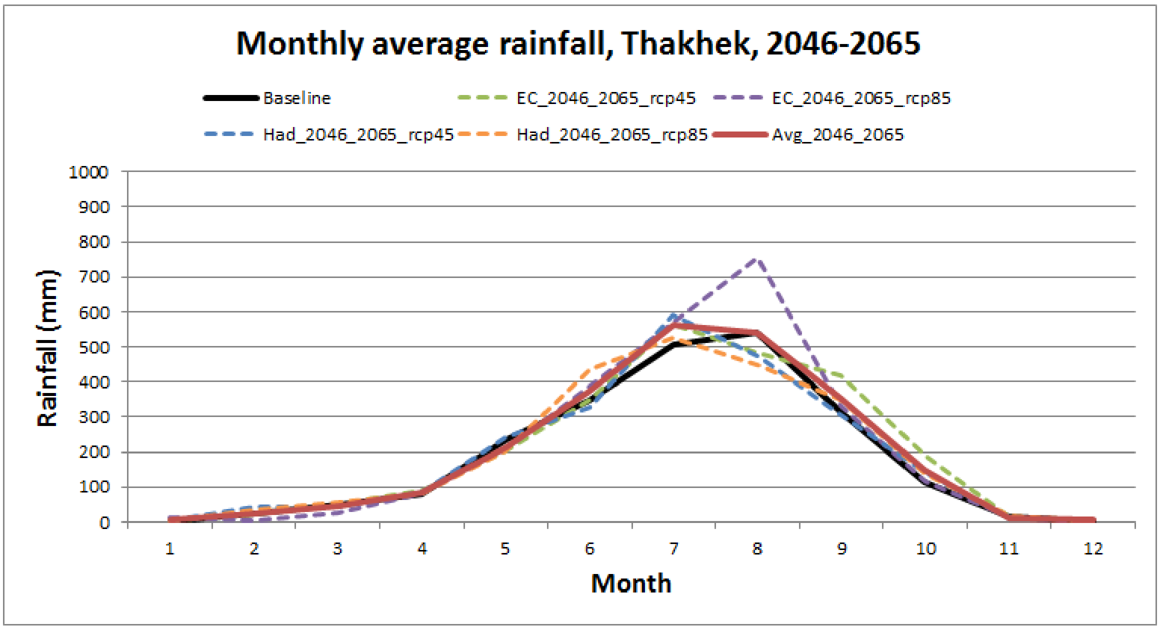


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1.4	28.0	69.2	118.5	383.2	364.2	596.7	504.7	305.7	74.6	20.0	3.8
Ensemble average	2.1	31.8	55.6	116.8	321.1	389.9	549.7	551.7	350.6	83.0	18.5	4.8
Change factor	1.46	1.14	0.80	0.99	0.84	1.07	0.92	1.09	1.15	1.11	0.93	1.26

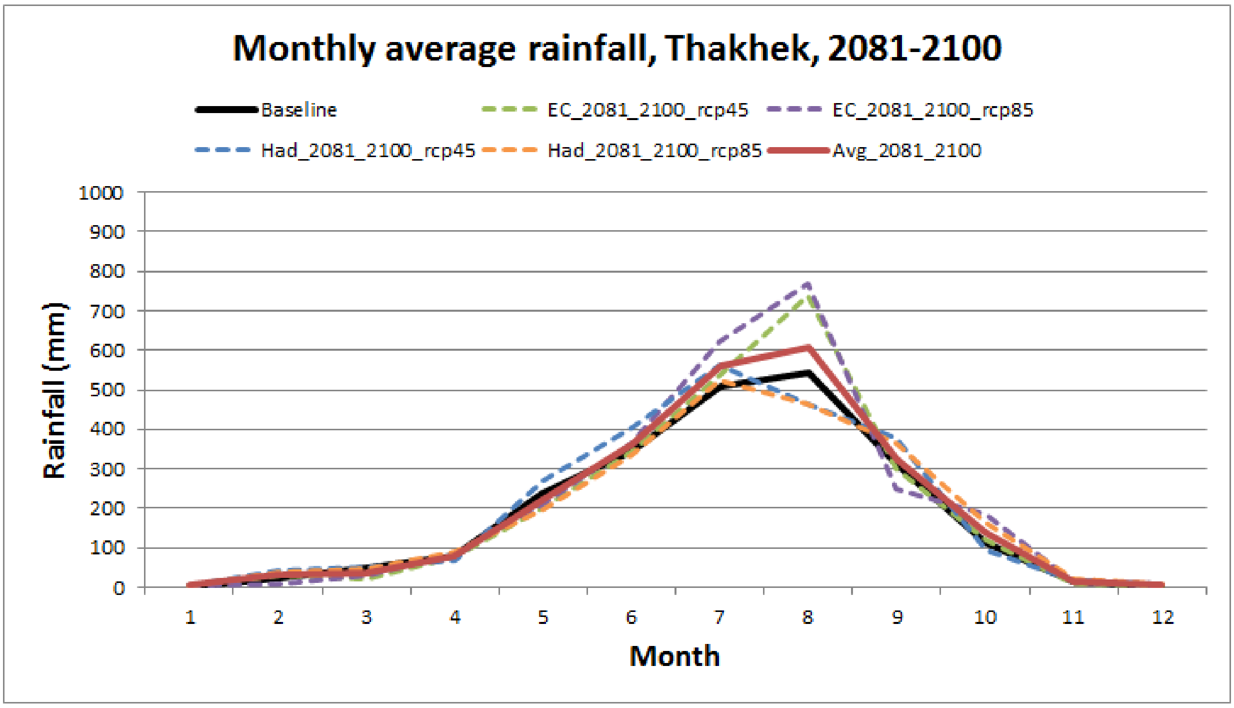


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1.4	28.0	69.2	118.5	383.2	364.2	596.7	504.7	305.7	74.6	20.0	3.8
Ensemble average	1.8	30.6	65.5	113.6	329.9	392.8	586.9	591.8	320.1	74.2	22.1	4.6
Change factor	1.31	1.09	0.95	0.96	0.86	1.08	0.98	1.17	1.05	1.00	1.11	1.22

A.1.2.6 Thakhek city

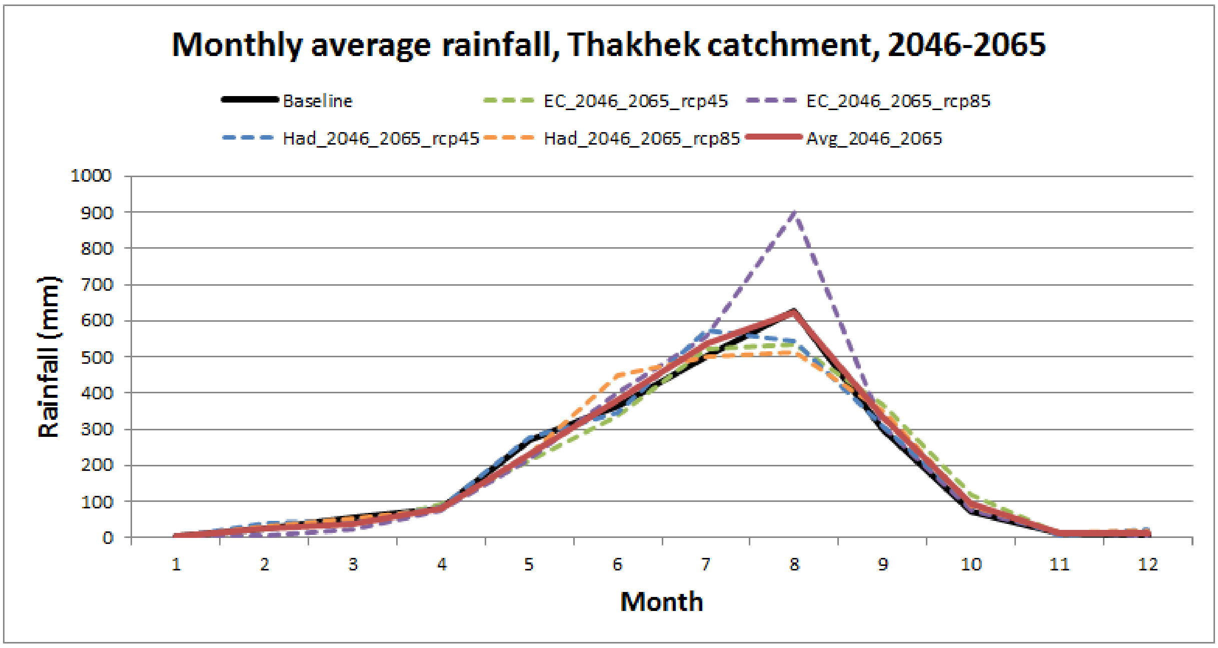


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	3.6	22.6	49.4	80.3	236.9	346.9	508.7	543.3	310.4	112.1	14.6	2.6
Ensemble average	4.7	24.7	43.8	84.0	213.2	374.9	564.2	540.2	350.8	146.6	12.0	4.4
Change factor	1.29	1.09	0.89	1.05	0.90	1.08	1.11	0.99	1.13	1.31	0.82	1.70

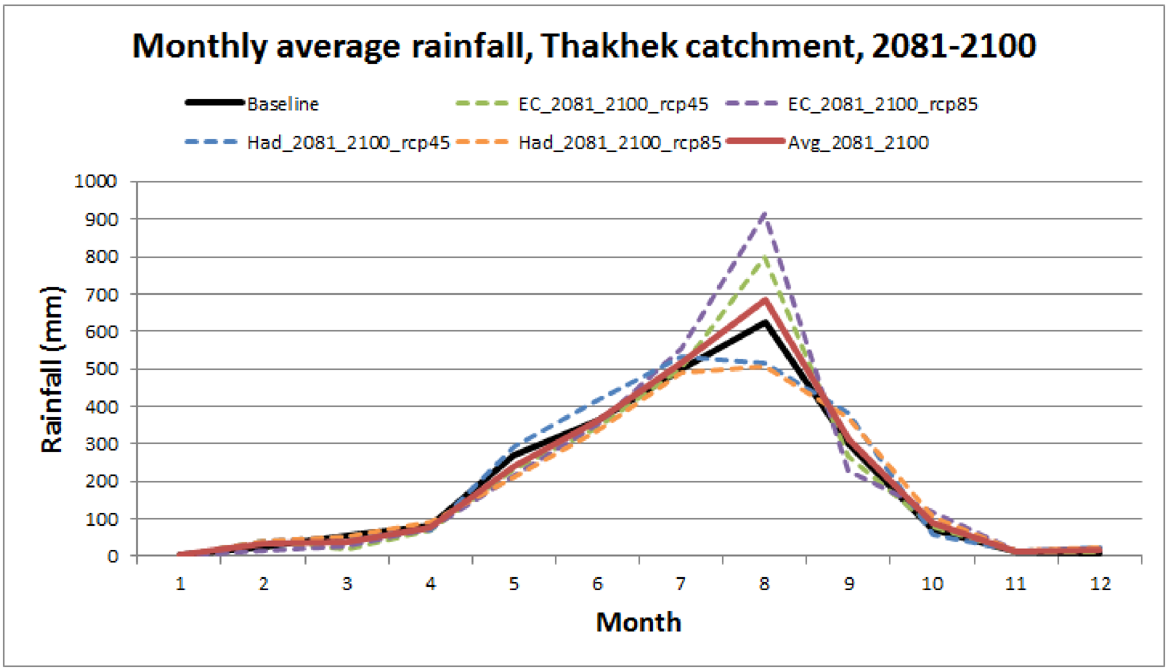


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	3.6	22.6	49.4	80.3	236.9	346.9	508.7	543.3	310.4	112.1	14.6	2.6
Ensemble average	4.7	30.1	36.8	79.6	221.0	361.1	560.7	609.4	322.8	140.6	14.1	5.2
Change factor	1.30	1.33	0.75	0.99	0.93	1.04	1.10	1.12	1.04	1.25	0.96	1.99

A.1.2.7 Thakhek catchment

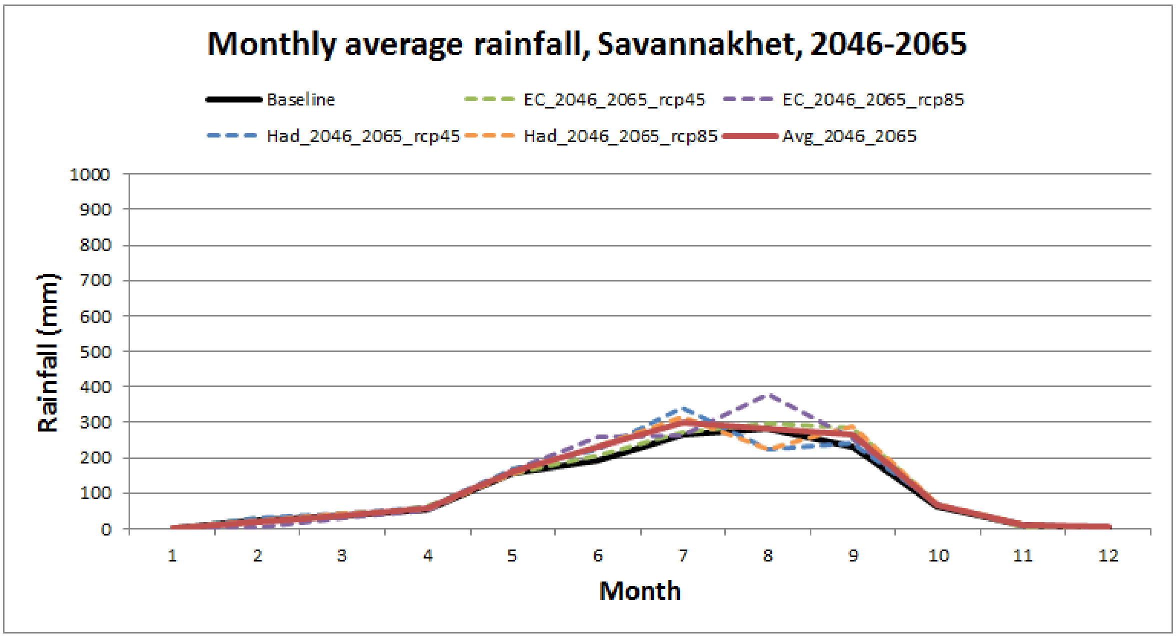


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1.9	23.5	53.5	81.3	270.3	363.5	502.1	626.4	298.2	73.8	14.0	8.0
Ensemble average	2.3	27.1	39.6	82.1	232.9	383.4	537.8	623.4	333.4	93.6	11.6	13.8
Change factor	1.19	1.15	0.74	1.01	0.86	1.05	1.07	1.00	1.12	1.27	0.83	1.72

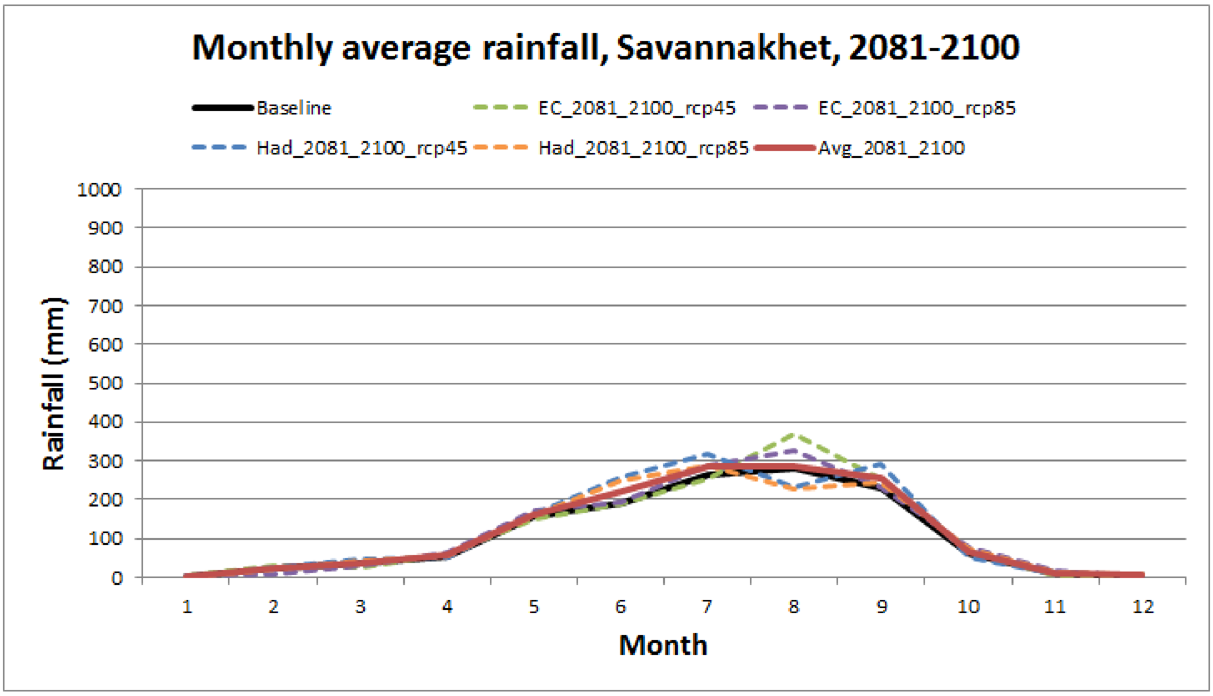


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1.9	23.5	53.5	81.3	270.3	363.5	502.1	626.4	298.2	73.8	14.0	8.0
Ensemble average	2.2	33.9	38.4	76.5	238.0	361.8	519.0	682.6	311.4	89.1	13.9	16.3
Change factor	1.17	1.44	0.72	0.94	0.88	1.00	1.03	1.09	1.04	1.21	0.99	2.03

A.1.2.8 Savannakhet city

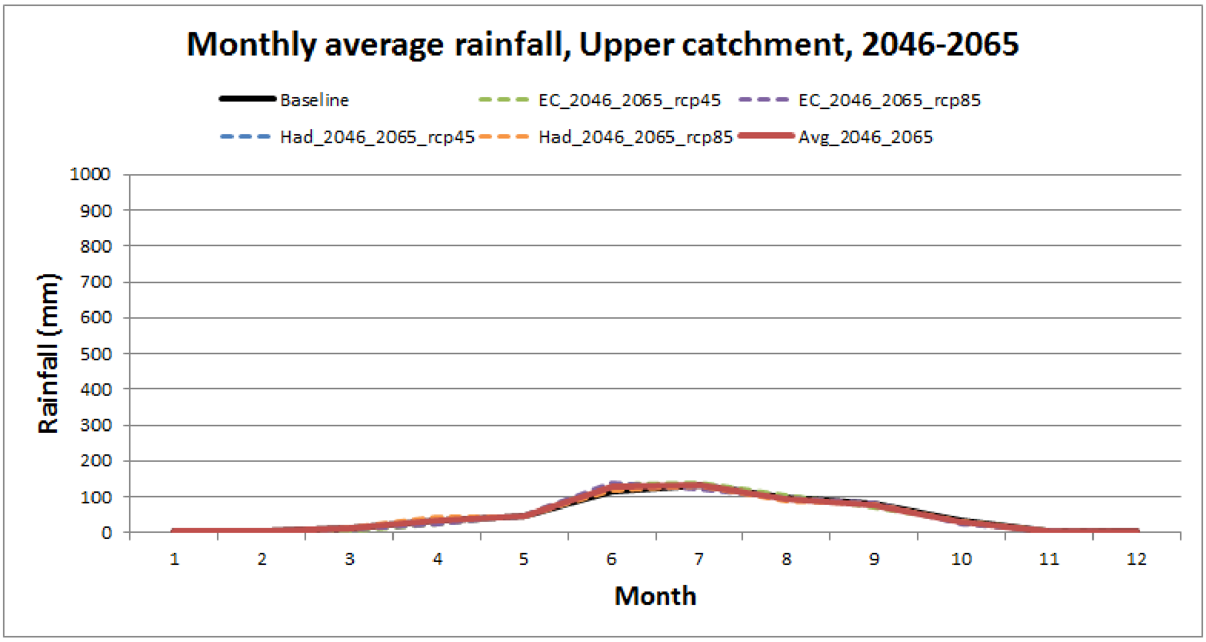


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	2.7	24.5	37.4	53.5	155.7	191.8	264.6	283.0	228.8	61.0	8.9	2.6
Ensemble average	2.4	20.5	36.7	57.1	161.2	229.8	297.5	281.4	266.2	66.6	8.4	4.1
Change factor	0.90	0.84	0.98	1.07	1.04	1.20	1.12	0.99	1.16	1.09	0.94	1.60

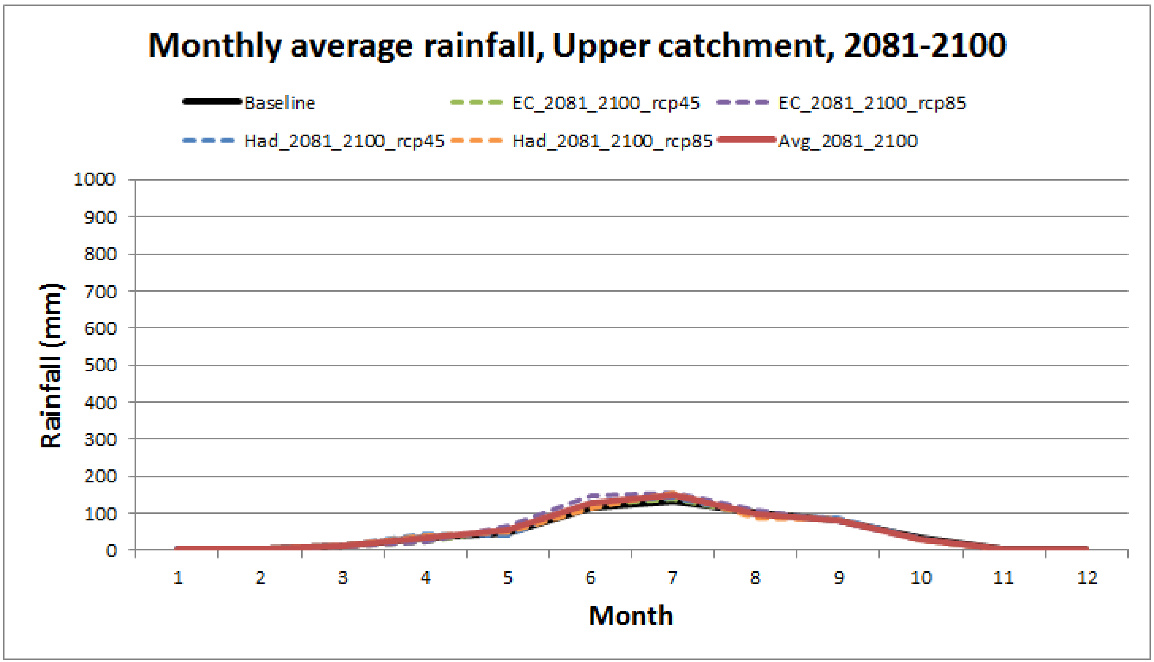


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	2.7	24.5	37.4	53.5	155.7	191.8	264.6	283.0	228.8	61.0	8.9	2.6
Ensemble average	2.4	21.6	36.3	57.2	161.0	221.9	285.9	286.7	255.7	67.4	10.3	6.1
Change factor	0.89	0.88	0.97	1.07	1.03	1.16	1.08	1.01	1.12	1.10	1.16	2.38

A.1.2.9 Upper Mekong headwater catchment

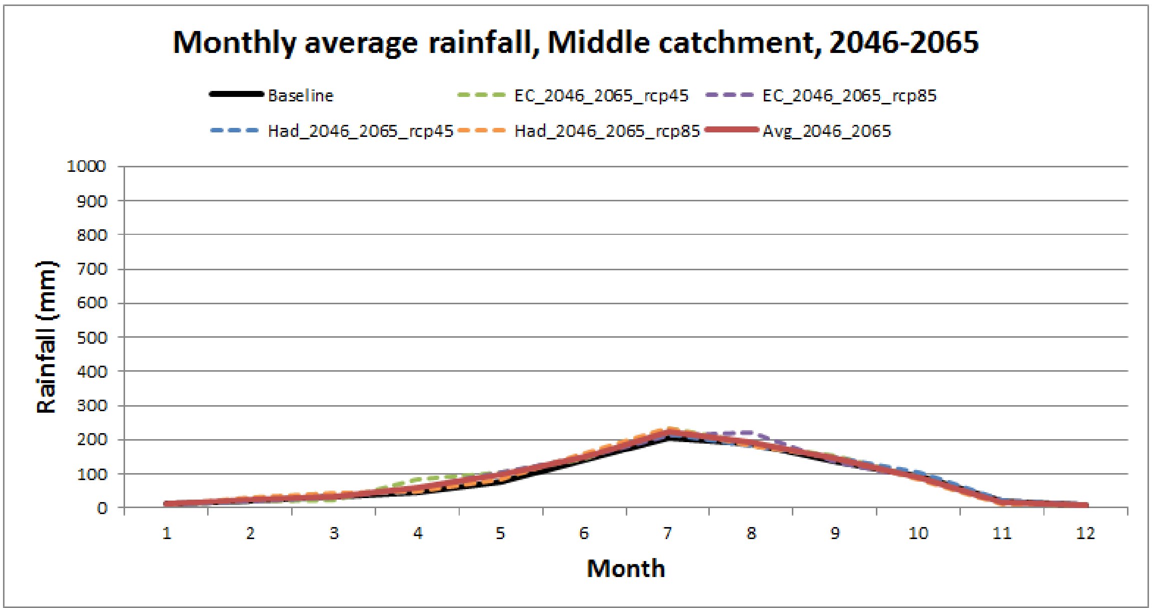


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1.9	2.7	12.2	32.1	46.8	113.5	132.5	100.1	80.8	31.9	2.6	1.4
Ensemble average	2.1	3.0	11.7	33.1	46.3	128.6	131.4	95.3	76.5	28.3	3.4	1.5
Change factor	1.08	1.11	0.95	1.03	0.99	1.13	0.99	0.95	0.95	0.89	1.29	1.07

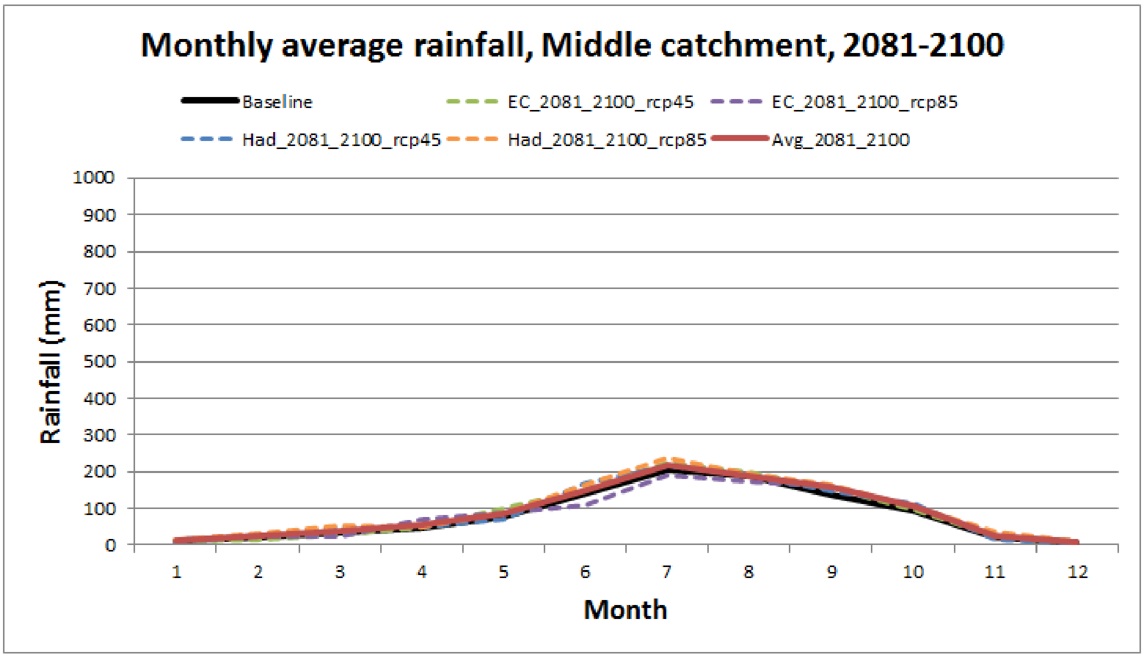


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1.9	2.7	12.2	32.1	46.8	113.5	132.5	100.1	80.8	31.9	2.6	1.4
Ensemble average	2.6	3.6	12.8	33.0	52.9	128.2	148.0	98.1	82.2	27.7	2.6	2.1
Change factor	1.32	1.31	1.05	1.03	1.13	1.13	1.12	0.98	1.02	0.87	1.00	1.45

A.1.2.10 Middle Mekong headwater catchment

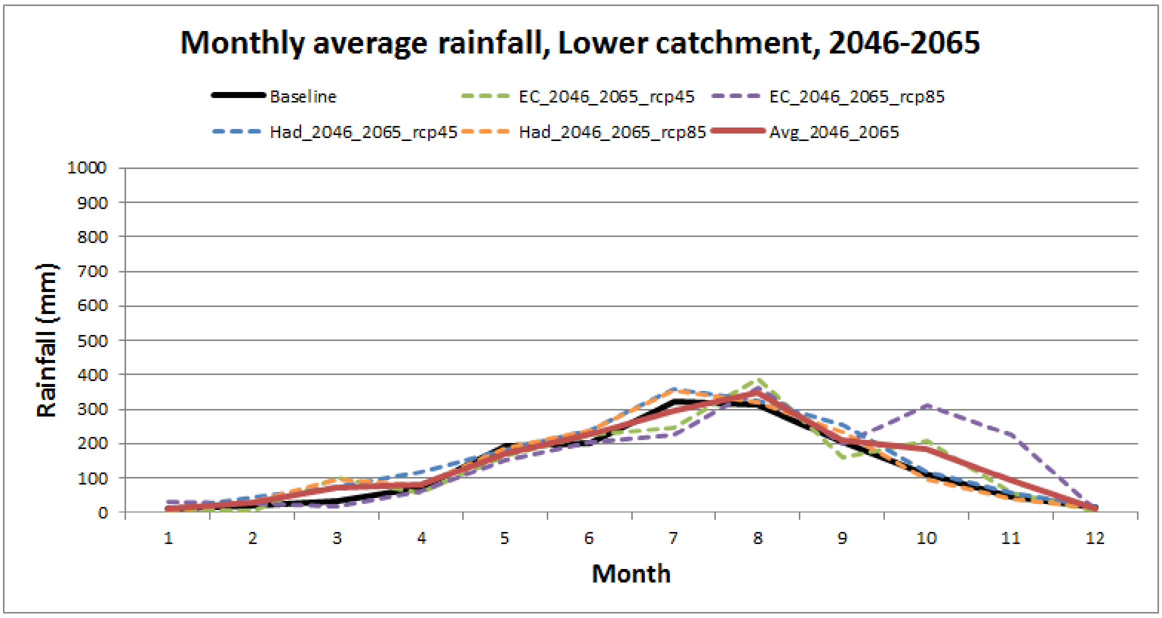


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	10.5	20.9	32.3	46.6	75.8	139.7	203.6	187.3	134.8	92.7	19.9	8.8
Ensemble average	10.3	23.6	35.4	58.7	98.5	149.7	224.2	193.4	144.3	91.3	17.9	6.6
Change factor	0.98	1.13	1.10	1.26	1.30	1.07	1.10	1.03	1.07	0.99	0.90	0.74

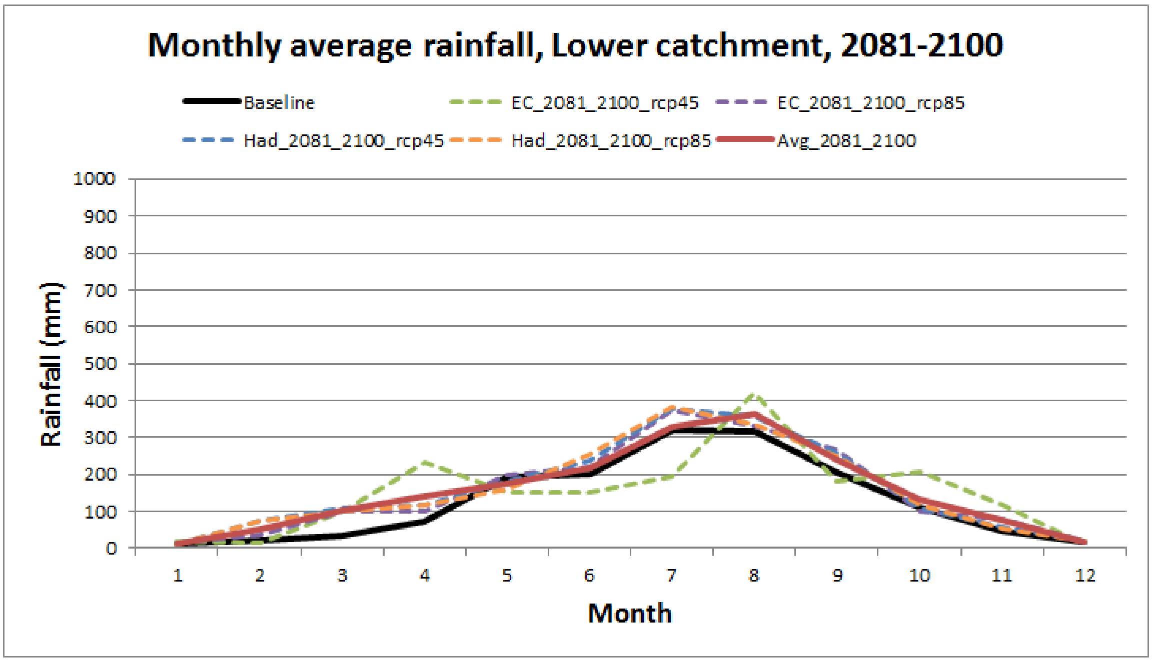


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	10.5	20.9	32.3	46.6	75.8	139.7	203.6	187.3	134.8	92.7	19.9	8.8
Ensemble average	10.0	23.9	37.7	53.0	85.2	148.2	216.6	187.4	157.1	105.6	24.4	7.9
Change factor	0.95	1.14	1.17	1.14	1.12	1.06	1.06	1.00	1.17	1.14	1.22	0.90

A.1.2.11 Lower Mekong headwater catchment



Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	11.1	20.3	31.6	71.5	191.8	200.4	320.3	315.3	205.5	112.4	47.4	16.3
Ensemble average	14.0	27.3	72.1	79.4	171.1	225.6	294.9	348.2	212.1	182.7	95.2	11.6
Change factor	1.26	1.34	2.28	1.11	0.89	1.13	0.92	1.10	1.03	1.63	2.01	0.71

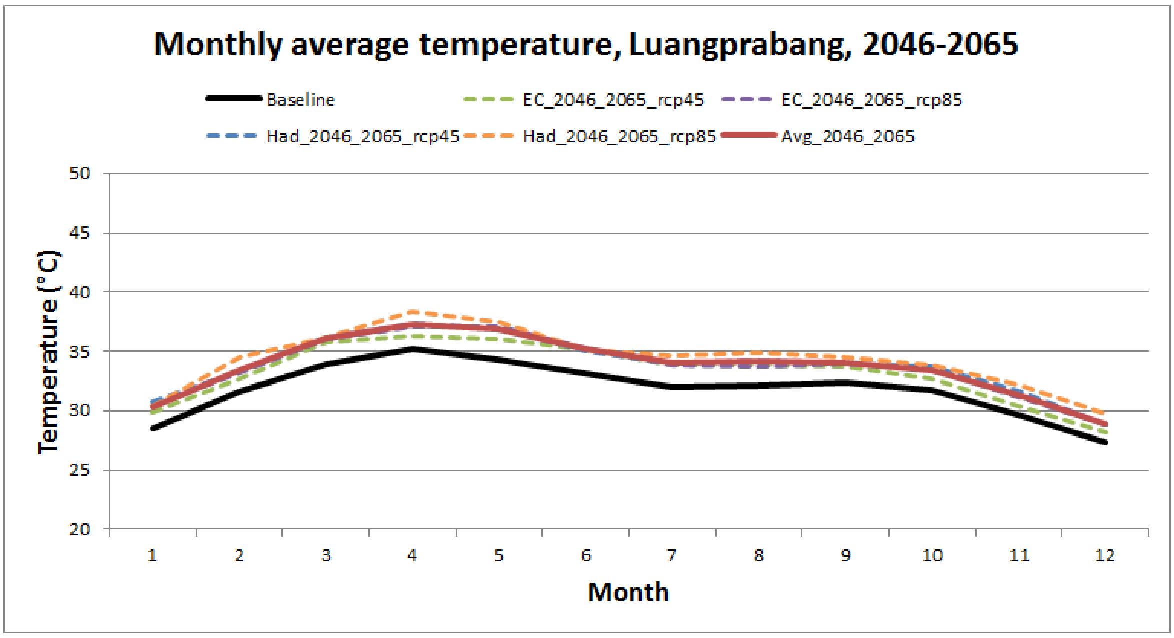


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	11.1	20.3	31.6	71.5	191.8	200.4	320.3	315.3	205.5	112.4	47.4	16.3
Ensemble average	12.5	50.5	102.3	141.5	173.1	216.6	331.0	362.0	240.5	133.2	76.7	16.4
Change factor	1.13	2.49	3.24	1.98	0.90	1.08	1.03	1.15	1.17	1.19	1.62	1.01

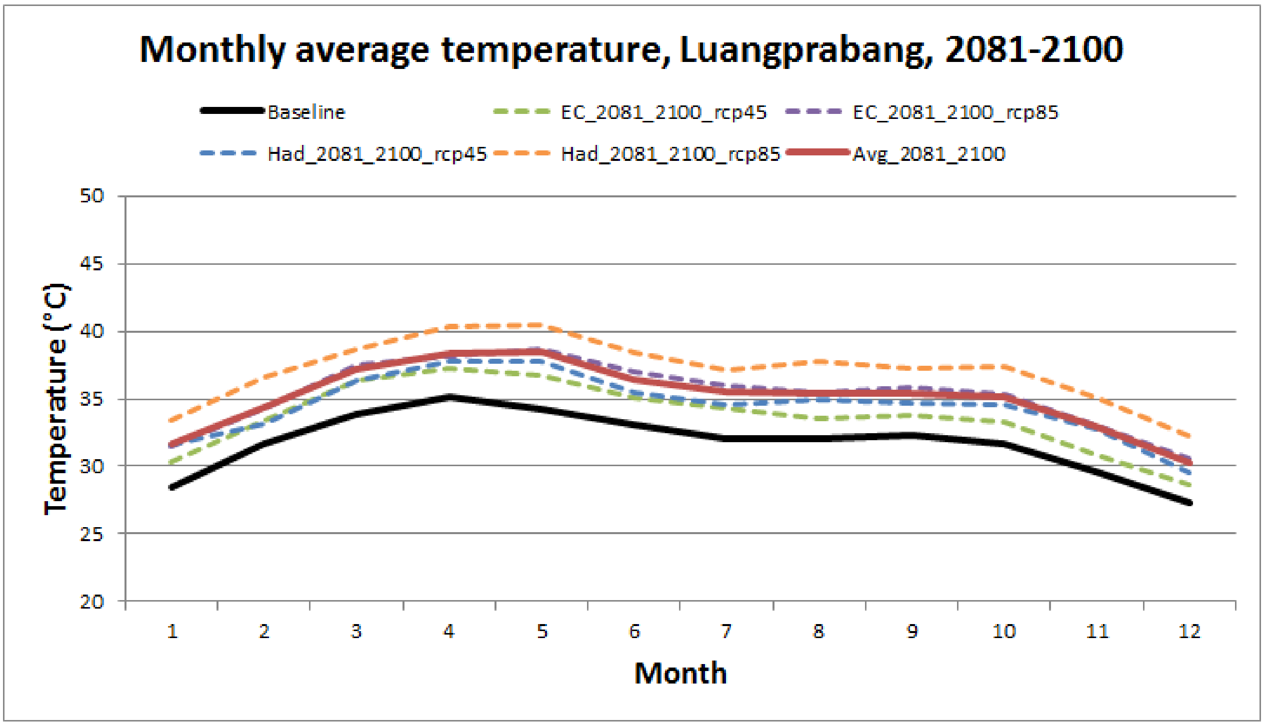
A.2 Temperature

A.2.1 Average monthly temperature

A.2.1.1 Luang Prabang city

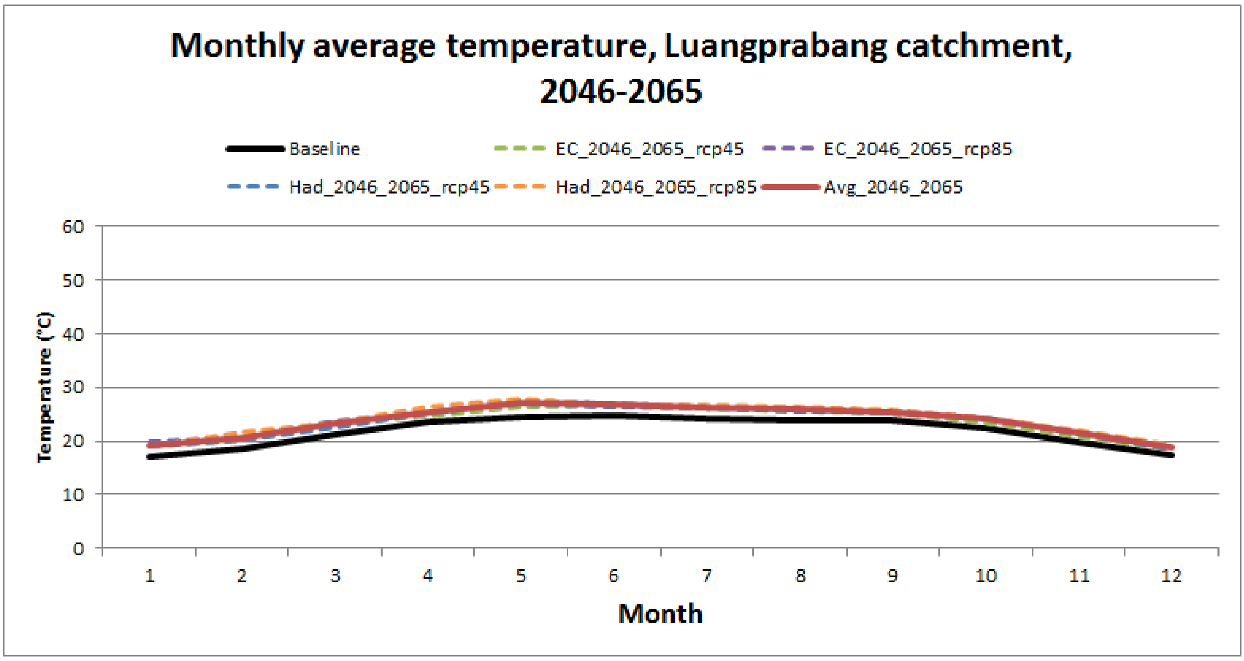


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	28.4	31.6	33.9	35.2	34.3	33.1	32.0	32.1	32.3	31.7	29.6	27.3
Ensemble average	30.3	33.4	36.1	37.3	36.9	35.1	34.1	34.2	34.0	33.4	31.3	28.9
Change factor	1.89	1.80	2.17	2.08	2.62	2.01	2.08	2.10	1.75	1.69	1.75	1.62

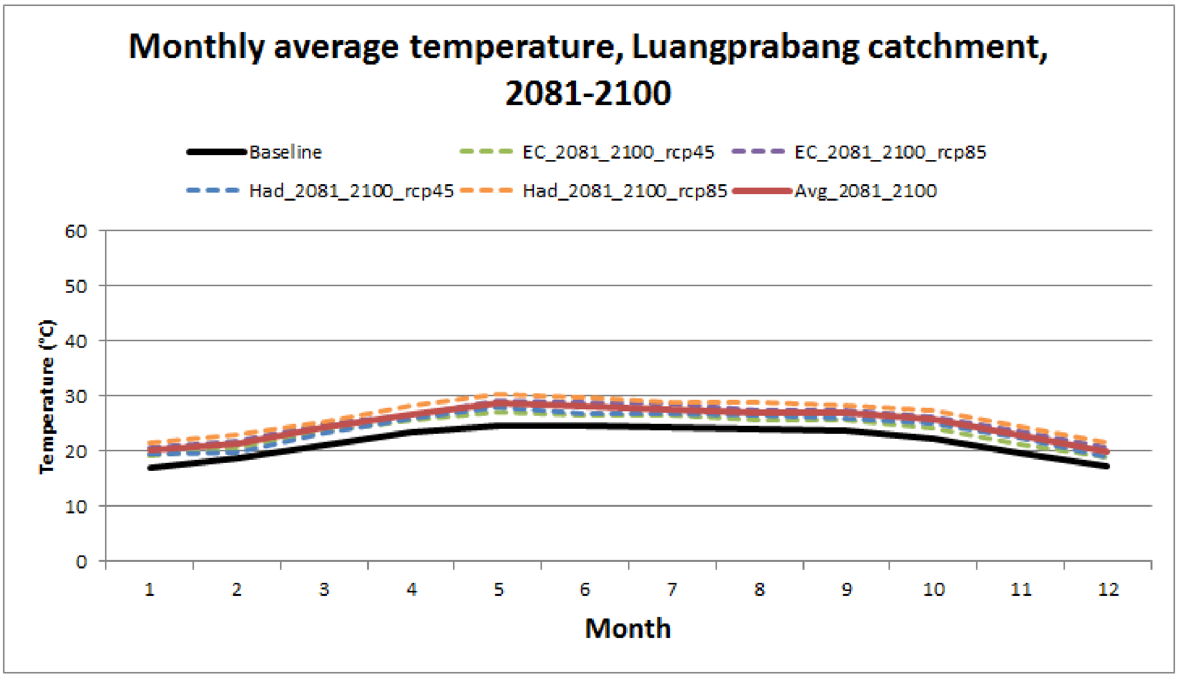


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	28.4	31.6	33.9	35.2	34.3	33.1	32.0	32.1	32.3	31.7	29.6	27.3
Ensemble average	31.7	34.4	37.2	38.4	38.4	36.5	35.5	35.4	35.4	35.1	32.9	30.2
Change factor	3.27	2.72	3.34	3.17	4.15	3.34	3.49	3.38	3.11	3.38	3.33	2.96

A.2.1.2 Luang Prabang catchment

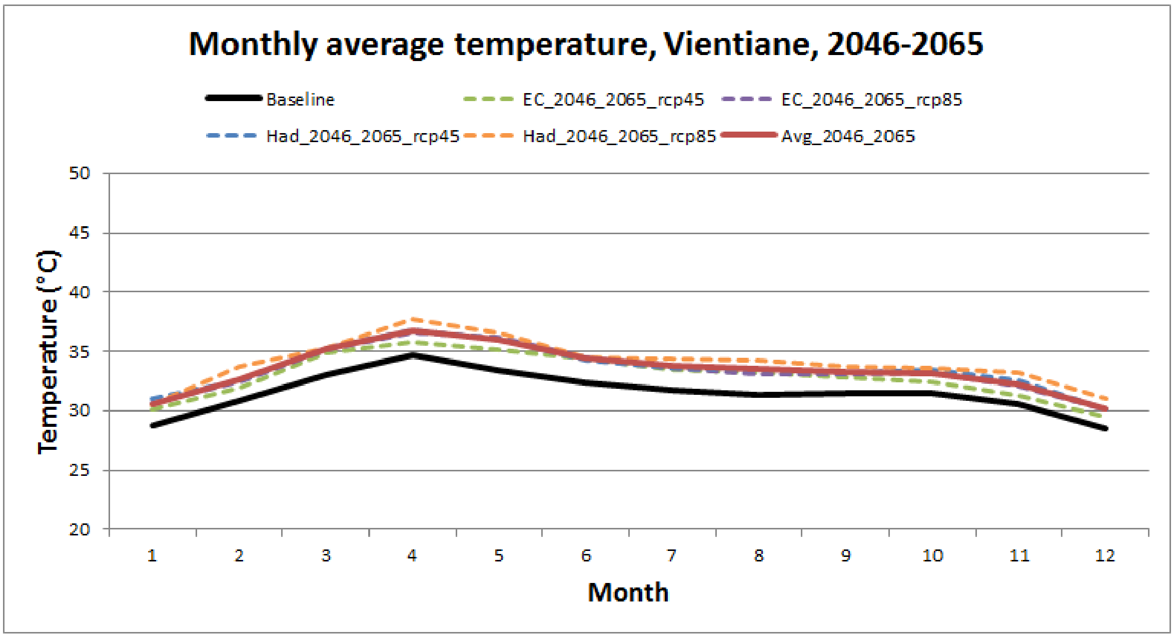


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	17.1	18.7	21.2	23.5	24.5	24.6	24.2	23.9	23.8	22.3	19.7	17.2
Ensemble average	19.2	20.6	23.2	25.4	27.2	26.7	26.3	25.8	25.5	24.1	21.4	18.8
Change factor	2.09	1.92	2.07	1.96	2.68	2.10	2.10	1.88	1.71	1.76	1.73	1.54

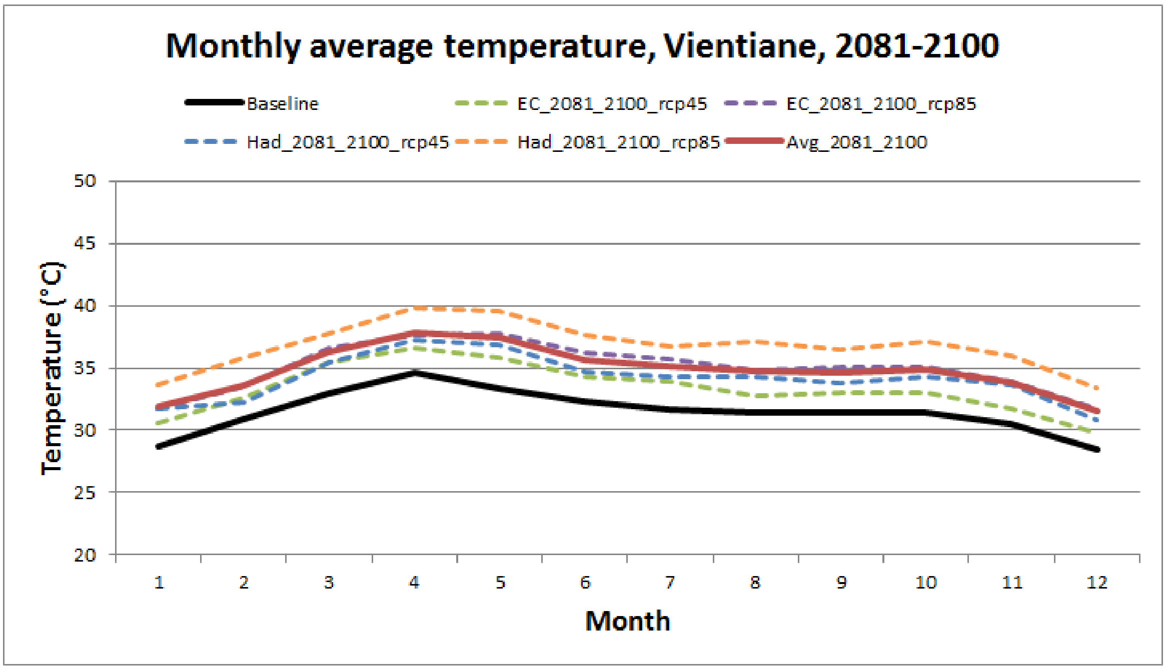


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	17.1	18.7	21.2	23.5	24.5	24.6	24.2	23.9	23.8	22.3	19.7	17.2
Ensemble average	20.2	21.3	24.3	26.6	28.6	28.0	27.7	27.1	26.9	25.7	22.9	20.0
Change factor	3.09	2.61	3.15	3.13	4.07	3.37	3.44	3.20	3.11	3.44	3.27	2.79

A.2.1.3 Vientiane city

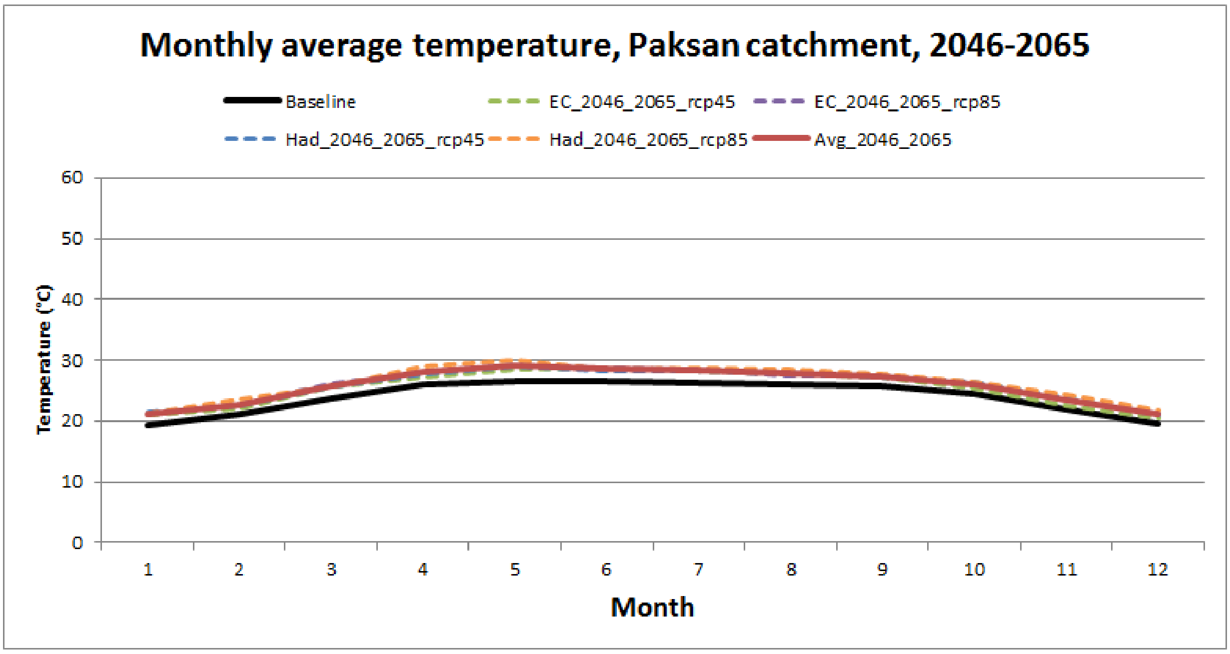


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	28.7	30.9	33.0	34.7	33.3	32.4	31.7	31.4	31.5	31.5	30.5	28.5
Ensemble average	30.6	32.7	35.2	36.7	35.9	34.4	33.8	33.5	33.2	33.2	32.3	30.1
Change factor	1.86	1.80	2.16	2.08	2.59	2.03	2.08	2.08	1.78	1.70	1.76	1.62

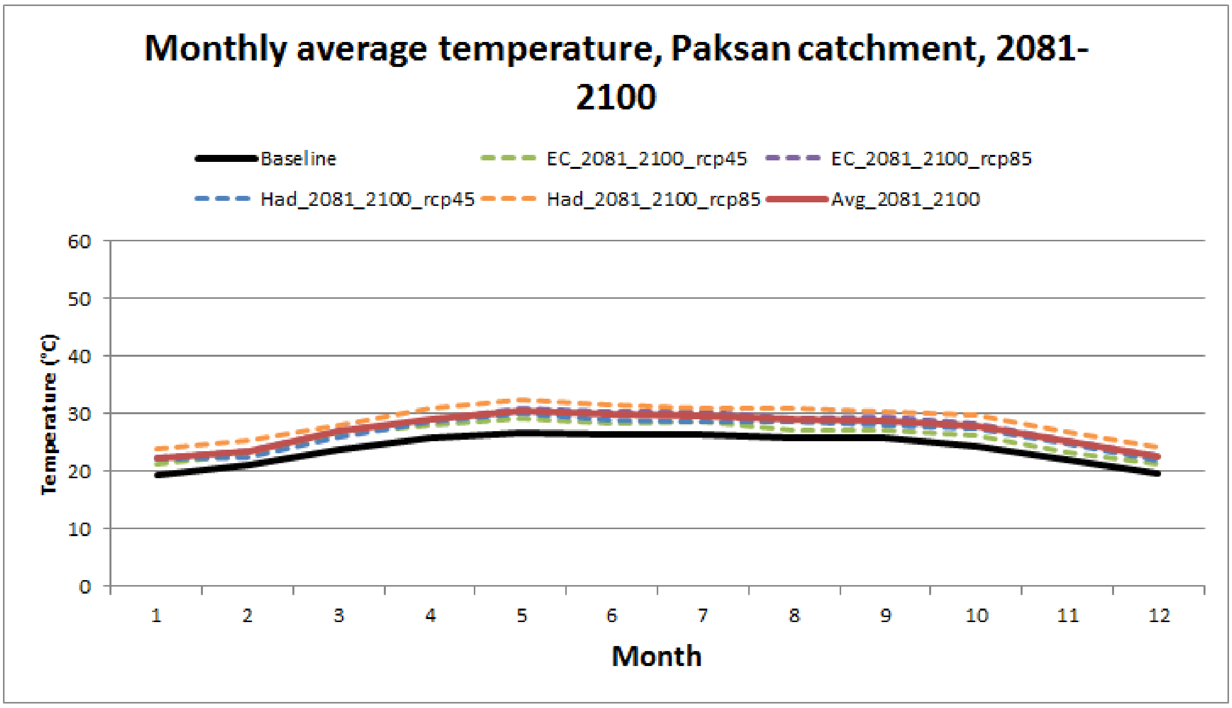


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	28.7	30.9	33.0	34.7	33.3	32.4	31.7	31.4	31.5	31.5	30.5	28.5
Ensemble average	31.9	33.6	36.3	37.8	37.5	35.7	35.2	34.8	34.6	34.9	33.9	31.5
Change factor	3.24	2.72	3.33	3.17	4.12	3.35	3.49	3.37	3.14	3.39	3.34	2.96

A.2.1.4 Paksan catchment

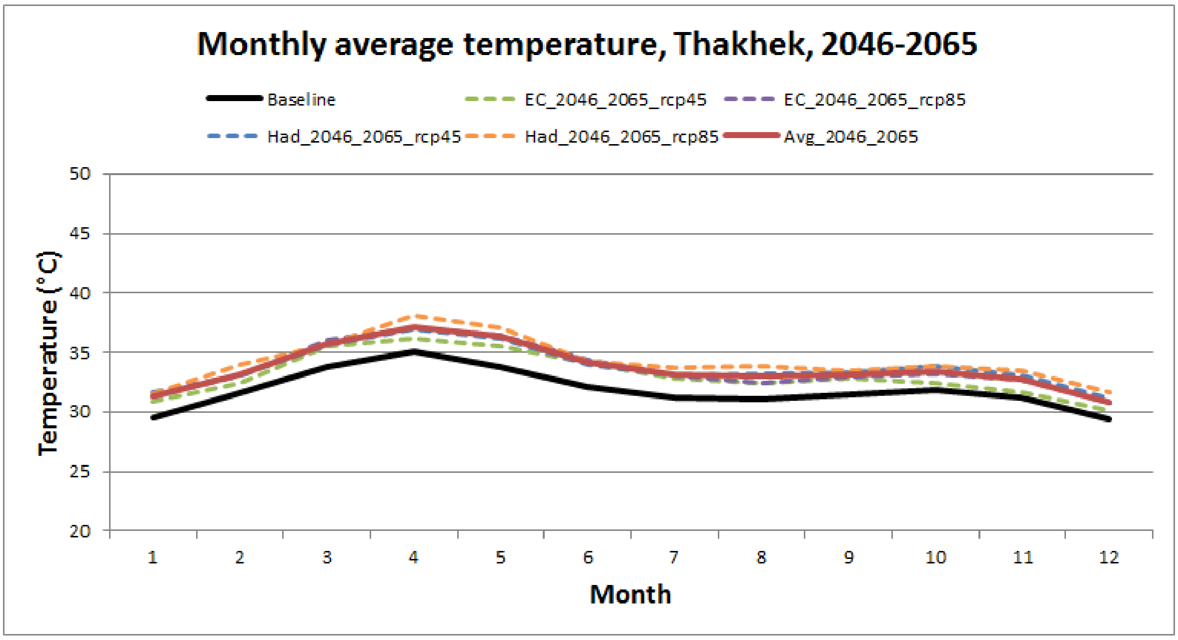


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	19.3	21.0	23.7	25.9	26.6	26.5	26.3	25.9	25.7	24.4	21.9	19.5
Ensemble average	21.2	22.7	25.8	28.0	29.2	28.6	28.3	27.8	27.3	26.1	23.6	21.2
Change factor	1.91	1.71	2.11	2.04	2.62	2.06	2.07	1.92	1.61	1.65	1.61	1.66

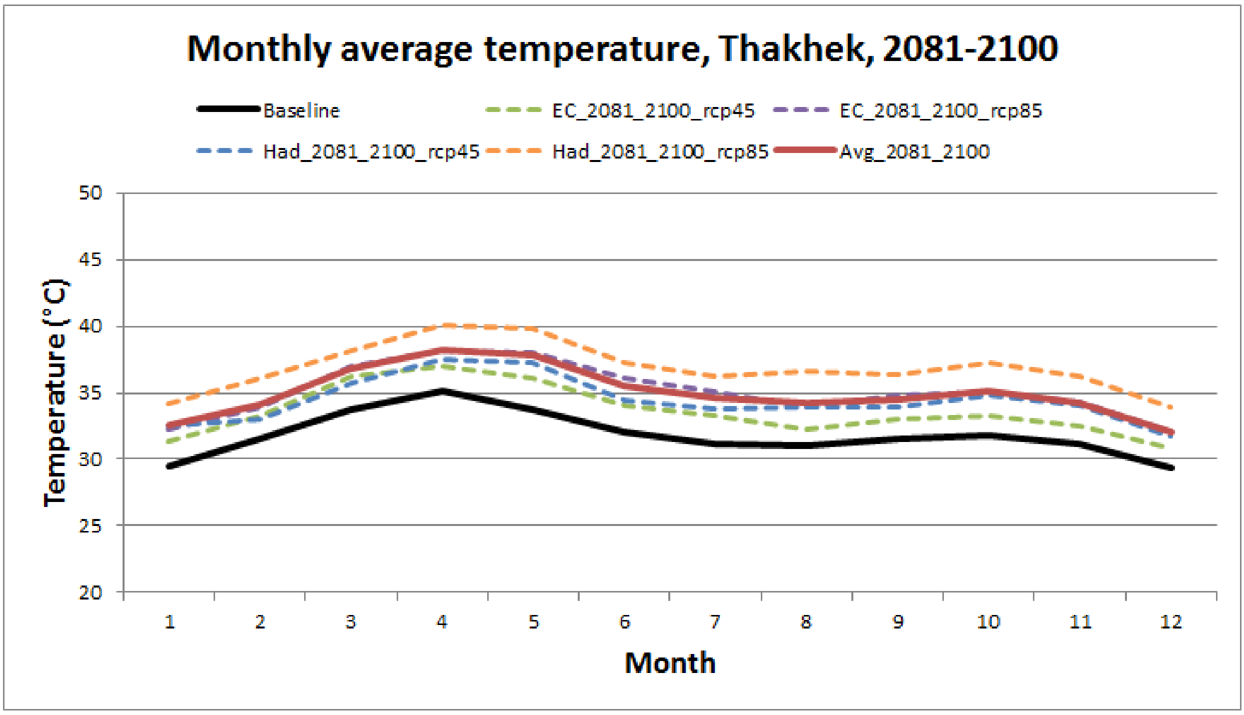


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	19.3	21.0	23.7	25.9	26.6	26.5	26.3	25.9	25.7	24.4	21.9	19.5
Ensemble average	22.4	23.6	26.9	29.1	30.6	29.8	29.6	29.0	28.7	27.9	25.2	22.5
Change factor	3.12	2.57	3.20	3.16	4.07	3.31	3.38	3.12	2.99	3.40	3.23	2.94

A.2.1.5 Thakhek city

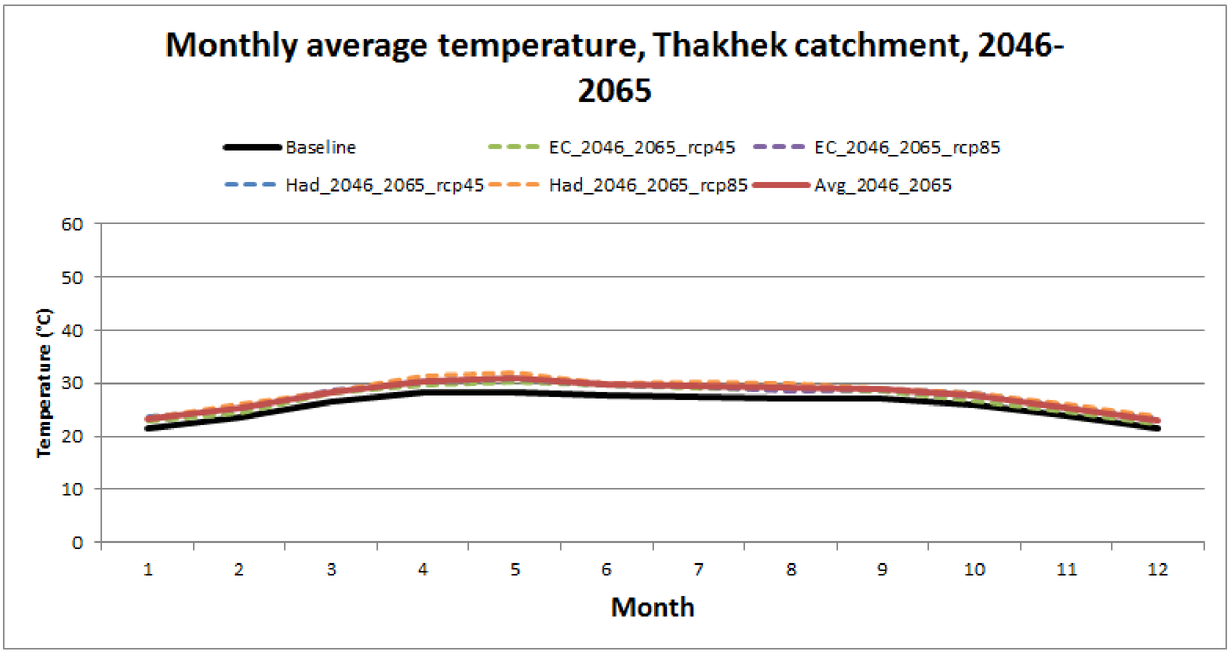


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	29.5	31.5	33.8	35.1	33.7	32.1	31.2	31.0	31.5	31.8	31.1	29.4
Ensemble average	31.3	33.1	35.7	37.1	36.3	34.2	33.2	33.0	33.2	33.3	32.7	30.9
Change factor	1.80	1.61	1.94	1.97	2.57	2.05	2.00	1.95	1.67	1.53	1.59	1.53

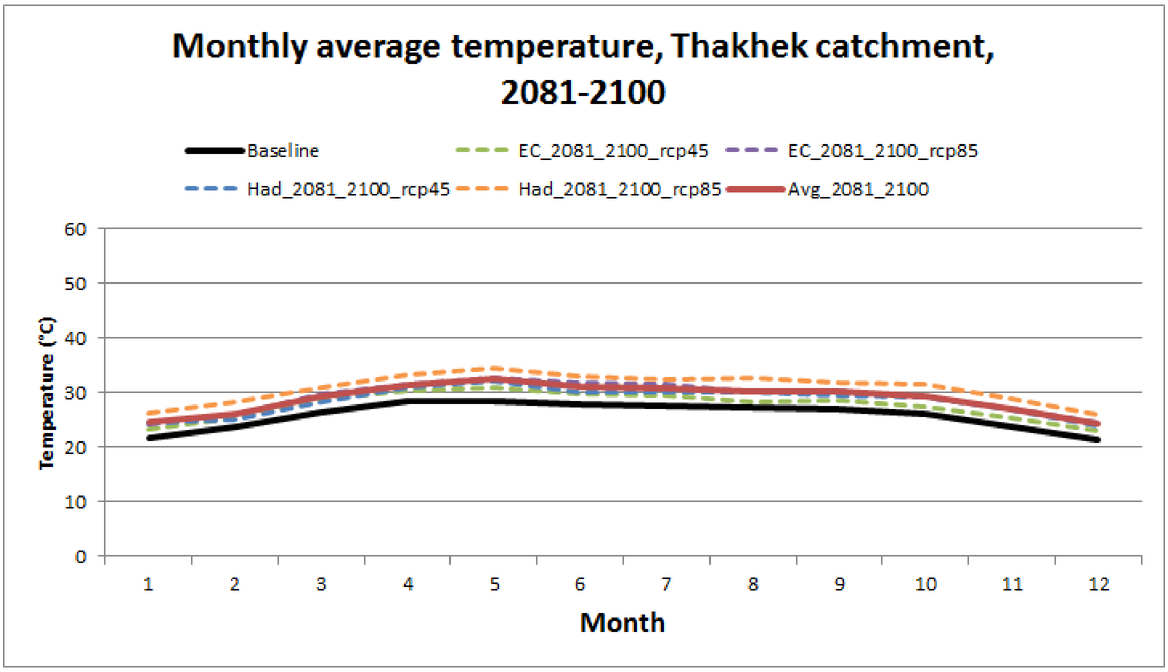


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	29.5	31.5	33.8	35.1	33.7	32.1	31.2	31.0	31.5	31.8	31.1	29.4
Ensemble average	32.6	34.1	36.8	38.2	37.8	35.5	34.6	34.2	34.5	35.1	34.2	32.1
Change factor	3.02	2.51	3.04	3.07	4.06	3.36	3.38	3.15	3.05	3.30	3.10	2.76

A.2.1.6 Thakhek catchment

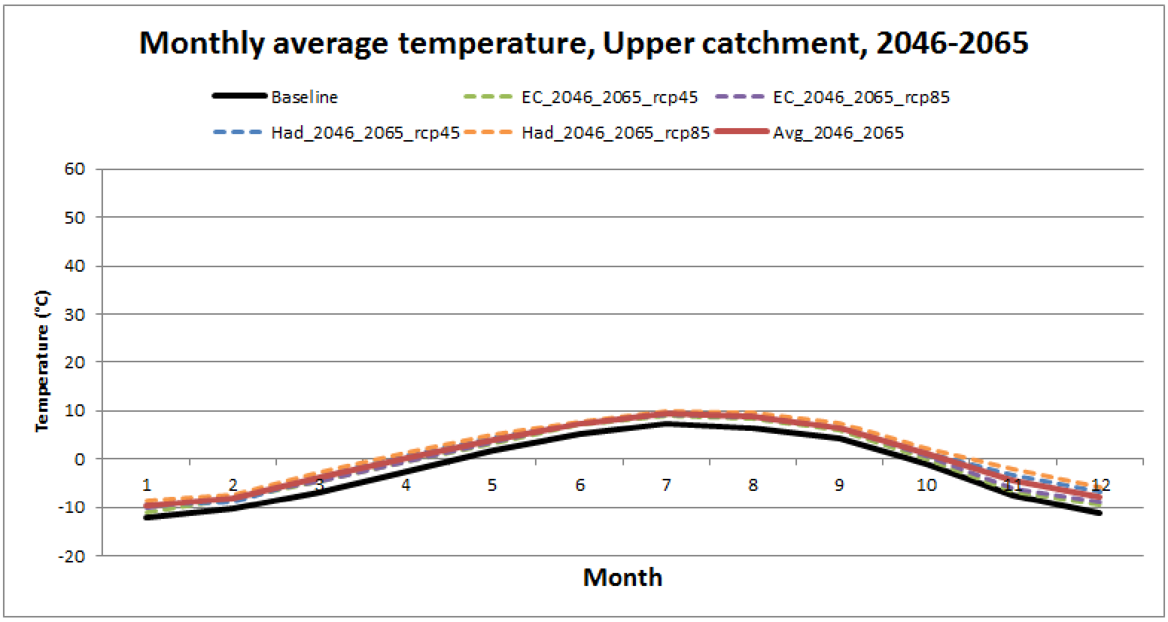


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	21.5	23.6	26.5	28.4	28.4	27.7	27.5	27.2	27.1	26.0	23.9	21.5
Ensemble average	23.3	25.2	28.4	30.4	31.0	29.8	29.5	29.1	28.8	27.6	25.5	23.1
Change factor	1.78	1.57	1.91	1.98	2.61	2.08	2.03	1.95	1.65	1.55	1.59	1.56

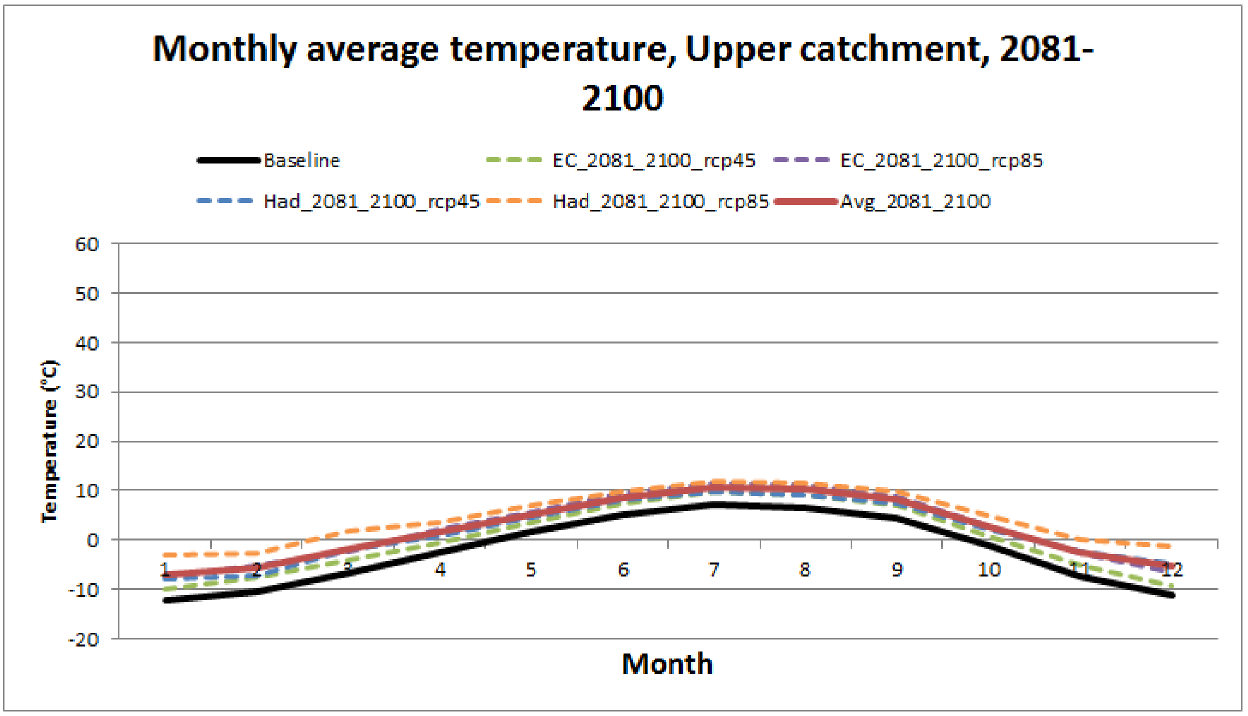


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	21.5	23.6	26.5	28.4	28.4	27.7	27.5	27.2	27.1	26.0	23.9	21.5
Ensemble average	24.6	26.1	29.5	31.5	32.5	31.1	30.9	30.3	30.1	29.3	27.0	24.3
Change factor	3.00	2.47	3.01	3.08	4.10	3.39	3.41	3.14	3.04	3.32	3.11	2.80

A.2.1.7 Upper Mekong headwater catchment

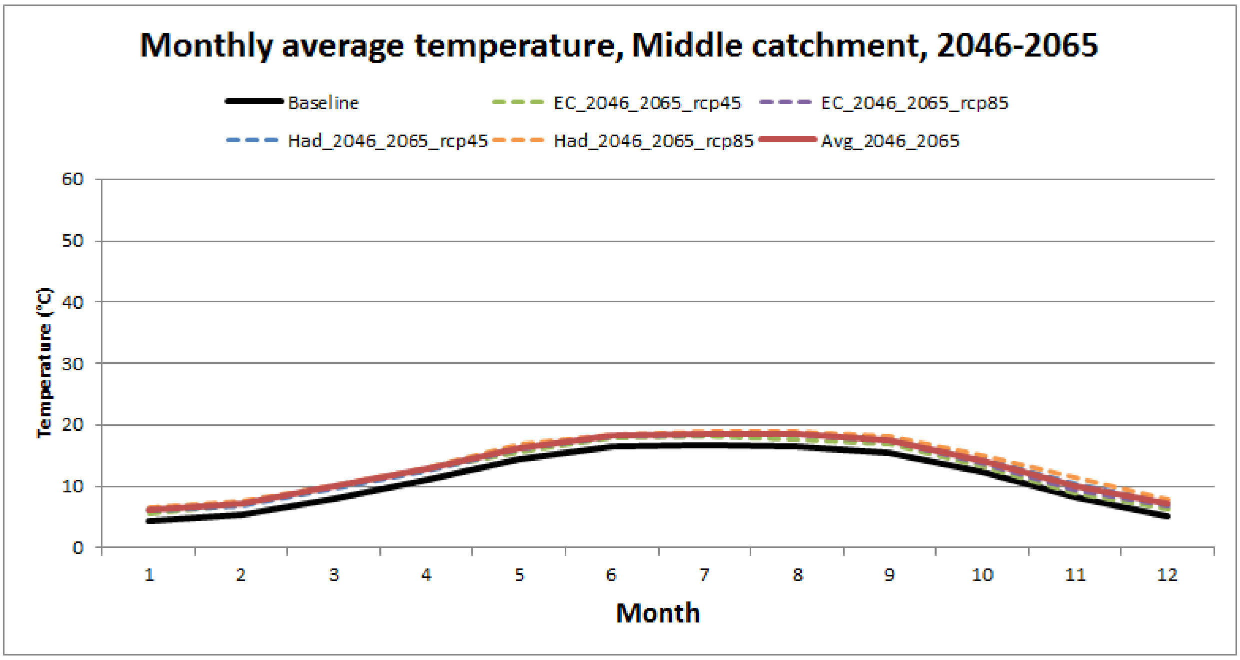


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	-12.2	-10.3	-6.7	-2.6	1.7	5.2	7.2	6.5	4.3	-1.1	-7.5	-11.2
Ensemble average	-9.8	-8.0	-3.8	0.2	4.0	7.5	9.4	9.0	6.5	1.1	-4.5	-7.8
Change factor	2.46	2.33	2.96	2.86	2.30	2.25	2.20	2.41	2.22	2.23	2.97	3.43

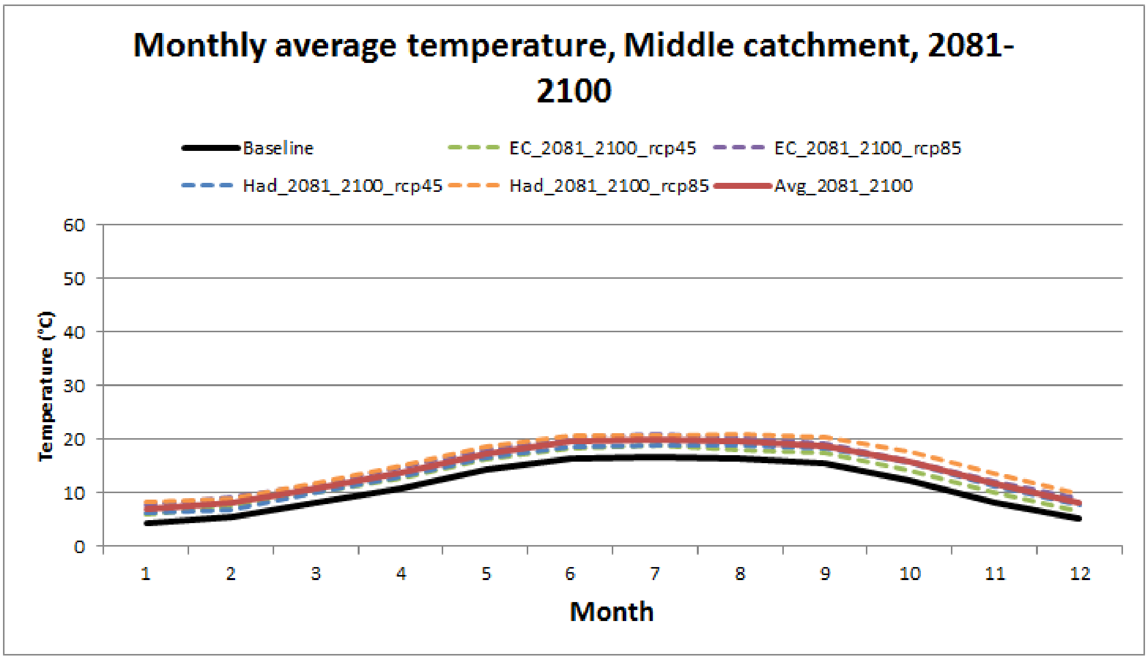


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	-12.2	-10.3	-6.7	-2.6	1.7	5.2	7.2	6.5	4.3	-1.1	-7.5	-11.2
Ensemble average	-7.1	-5.7	-1.7	1.6	5.2	8.6	10.7	10.2	8.2	2.7	-2.4	-5.4
Change factor	5.08	4.64	5.06	4.25	3.52	3.39	3.54	3.66	3.91	3.83	5.05	5.82

A.2.1.8 Middle Mekong headwater catchment

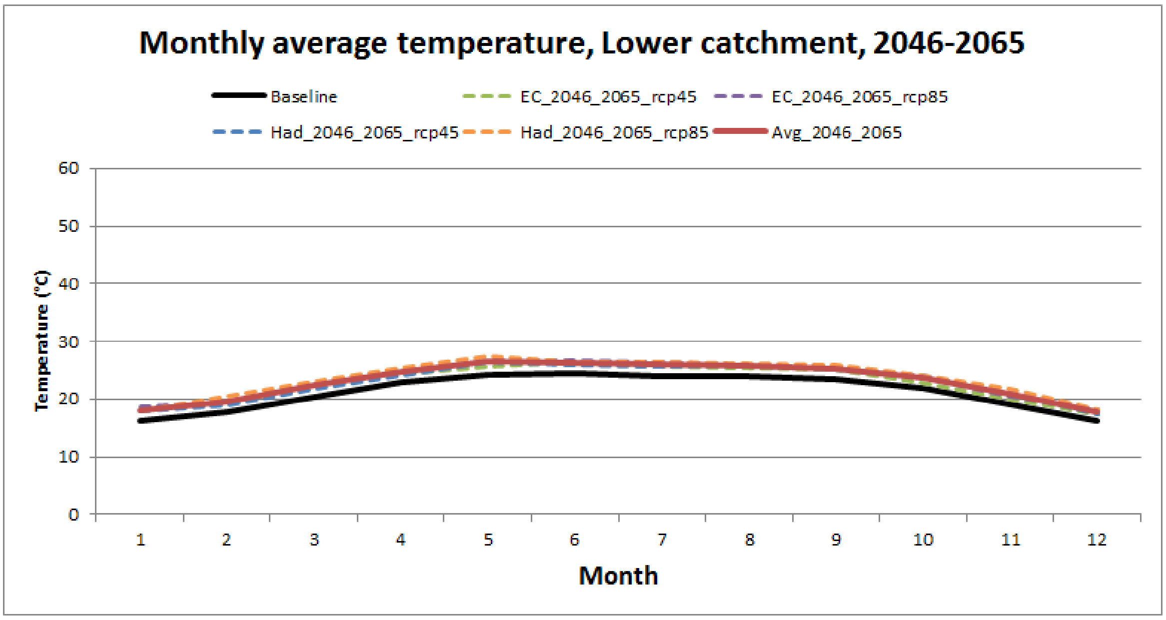


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	4.3	5.4	8.0	11.0	14.3	16.5	16.8	16.4	15.5	12.3	8.2	5.2
Ensemble average	6.0	7.2	9.9	12.8	16.1	18.2	18.5	18.4	17.4	14.2	10.0	7.1
Change factor	1.78	1.76	1.85	1.81	1.86	1.74	1.73	2.01	1.98	1.81	1.77	1.88

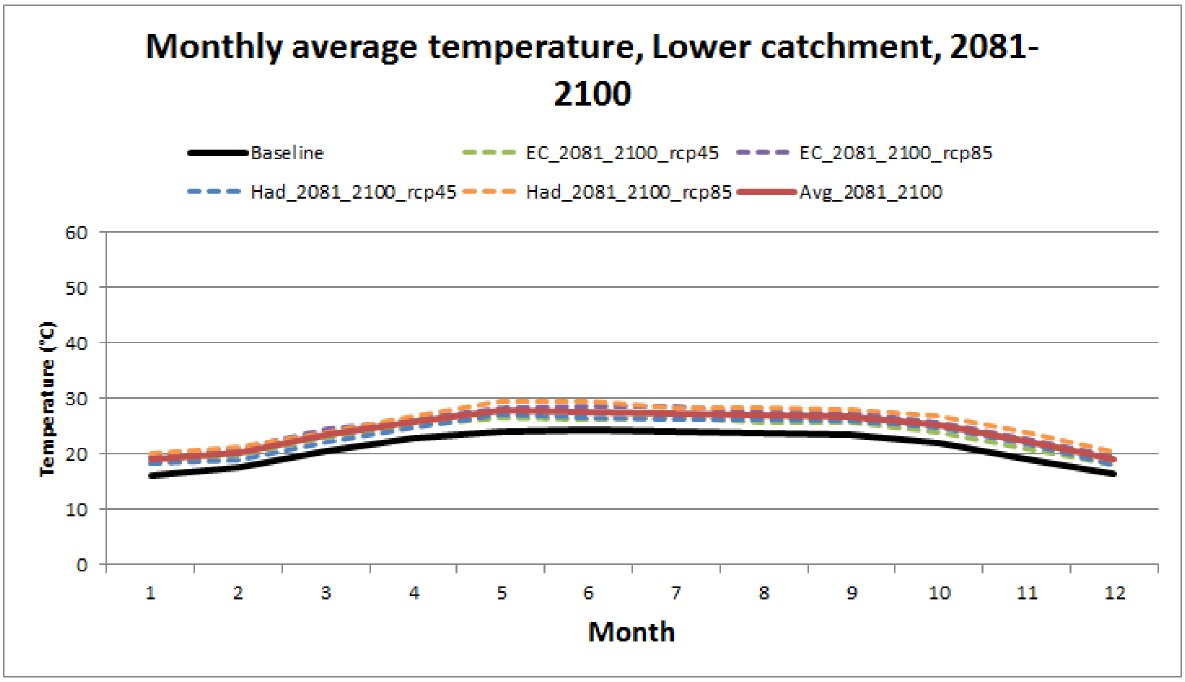


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	4.3	5.4	8.0	11.0	14.3	16.5	16.8	16.4	15.5	12.3	8.2	5.2
Ensemble average	7.1	8.1	10.9	13.9	17.3	19.6	19.9	19.7	18.8	15.8	11.8	8.2
Change factor	2.87	2.67	2.85	2.94	3.00	3.13	3.14	3.26	3.37	3.50	3.54	3.01

A.2.1.9 Lower Mekong headwater catchment



Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	16.1	17.7	20.4	22.9	24.1	24.4	24.0	23.9	23.6	21.9	19.1	16.3
Ensemble average	18.1	19.5	22.5	24.6	26.6	26.4	26.0	25.8	25.3	23.6	20.7	17.8
Change factor	2.00	1.85	2.07	1.68	2.44	2.00	2.07	1.91	1.78	1.73	1.65	1.49

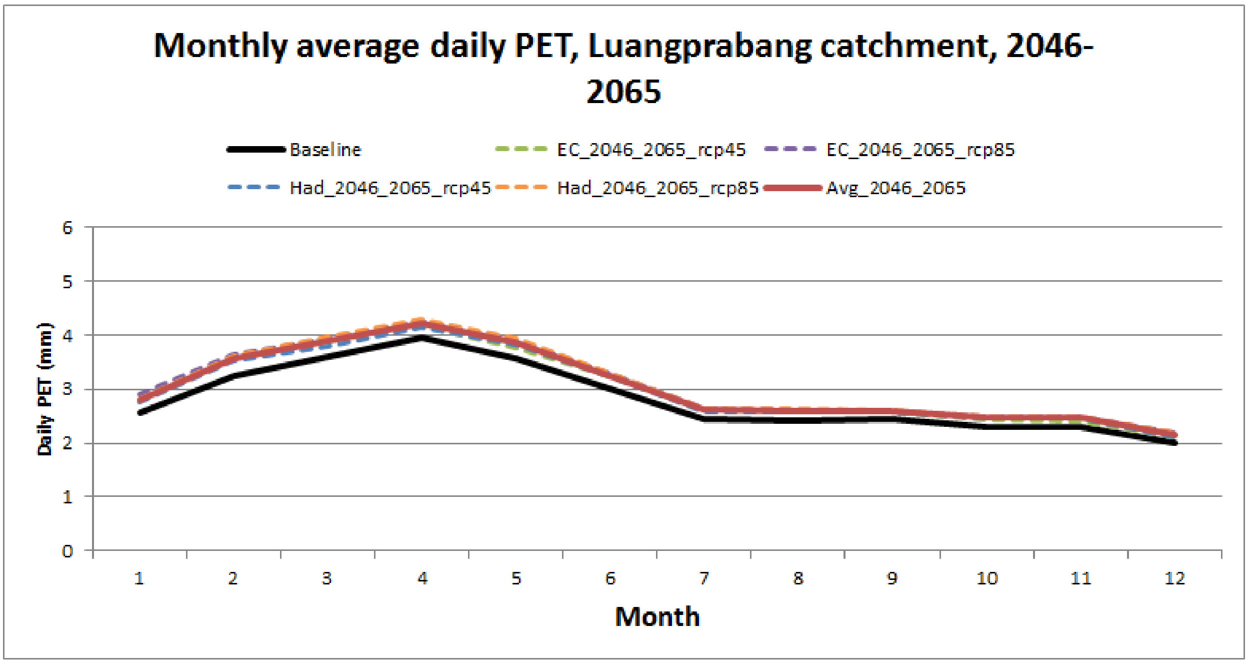


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	16.1	17.7	20.4	22.9	24.1	24.4	24.0	23.9	23.6	21.9	19.1	16.3
Ensemble average	19.1	20.3	23.4	25.7	27.9	27.7	27.3	26.9	26.7	25.3	22.3	18.9
Change factor	2.92	2.60	3.00	2.74	3.73	3.31	3.35	3.07	3.13	3.39	3.24	2.65

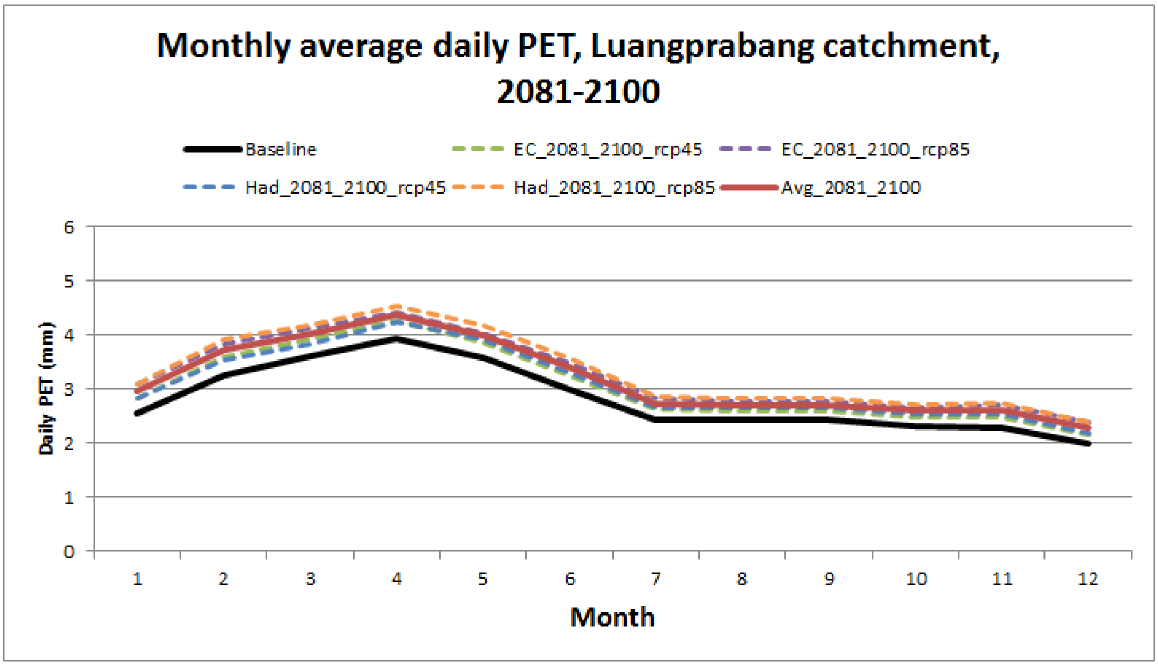
A.3 Evaporation

A.3.1 Average monthly evaporation

A.3.1.1 Luang Prabang catchment

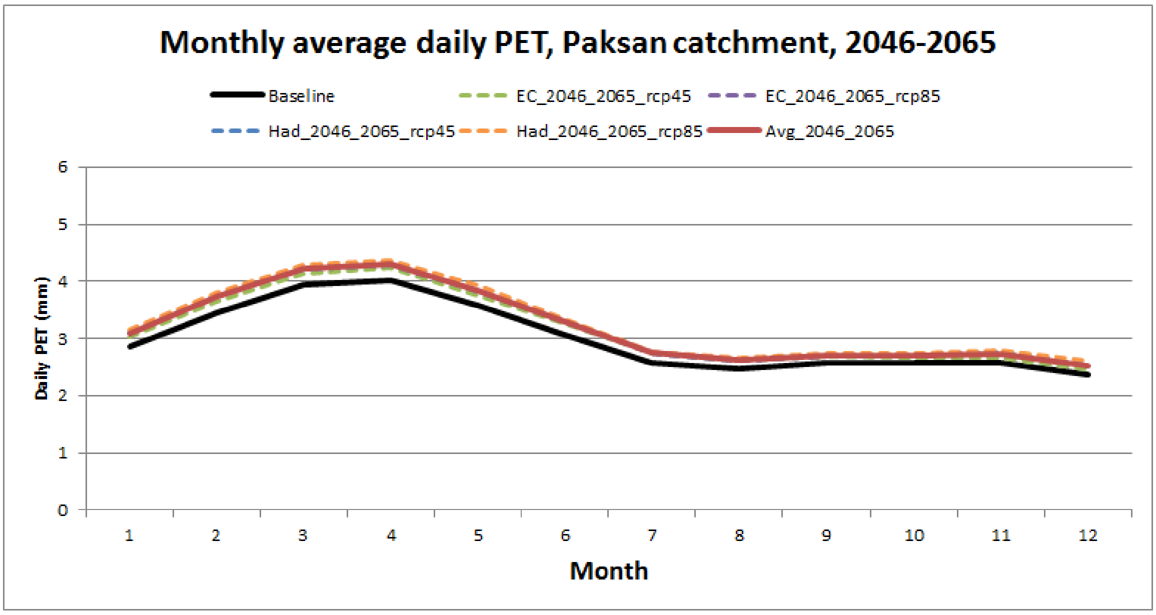


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	2.6	3.3	3.6	3.9	3.6	3.0	2.4	2.4	2.4	2.3	2.3	2.0
Ensemble average	2.8	3.6	3.9	4.2	3.8	3.3	2.6	2.6	2.6	2.5	2.5	2.2
Change factor	1.10	1.10	1.08	1.07	1.08	1.08	1.07	1.07	1.07	1.07	1.08	1.08

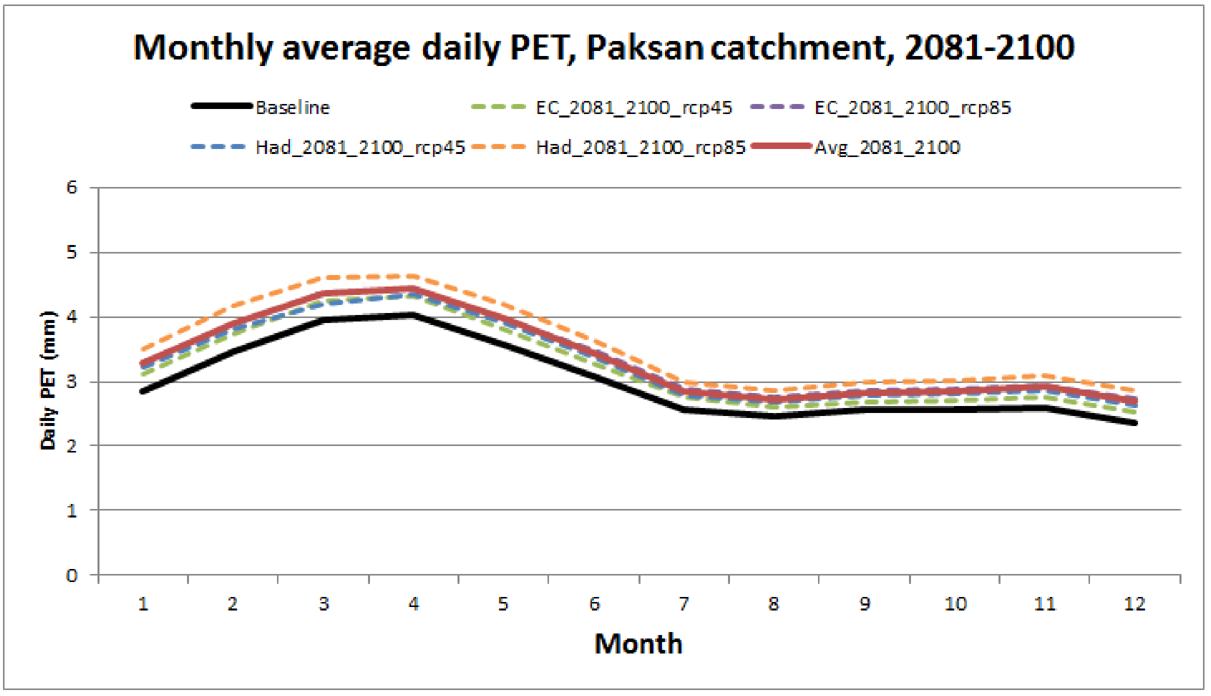


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	2.6	3.3	3.6	3.9	3.6	3.0	2.4	2.4	2.4	2.3	2.3	2.0
Ensemble average	3.0	3.7	4.0	4.4	4.0	3.4	2.7	2.7	2.7	2.6	2.6	2.3
Change factor	1.16	1.14	1.11	1.11	1.12	1.13	1.12	1.12	1.11	1.13	1.14	1.15

A.3.1.2 Paksan catchment

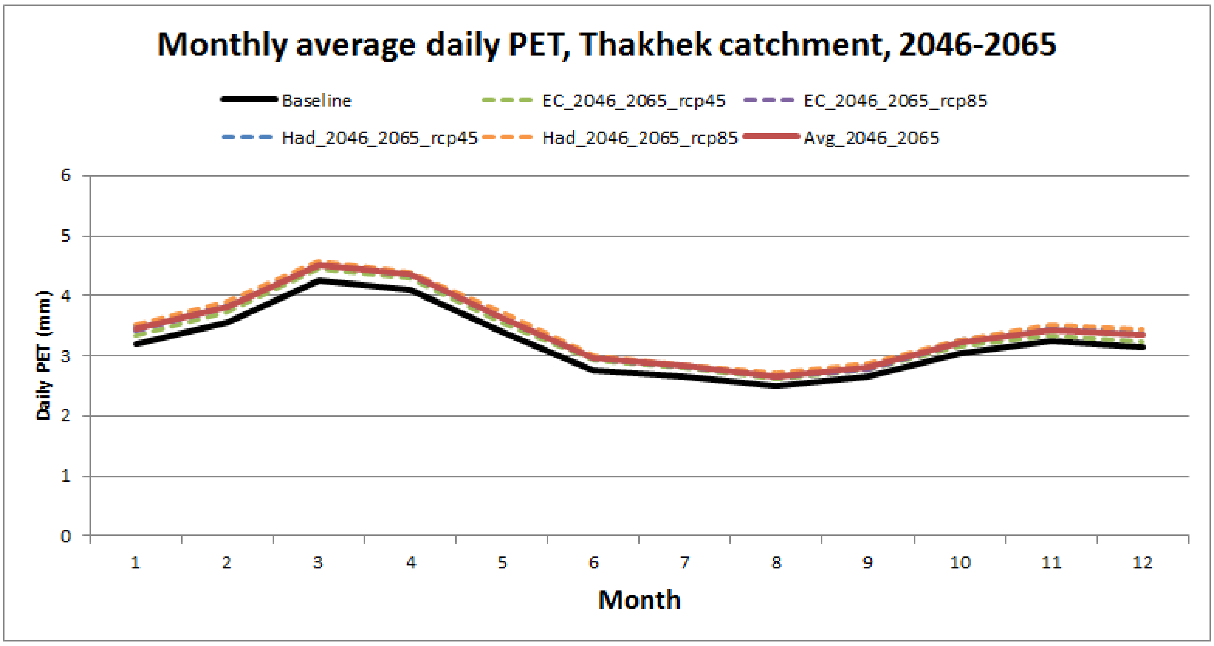


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	2.9	3.5	3.9	4.0	3.6	3.1	2.6	2.5	2.6	2.6	2.6	2.4
Ensemble average	3.1	3.7	4.2	4.3	3.8	3.3	2.7	2.6	2.7	2.7	2.7	2.5
Change factor	1.09	1.08	1.07	1.07	1.07	1.07	1.07	1.07	1.06	1.06	1.06	1.07

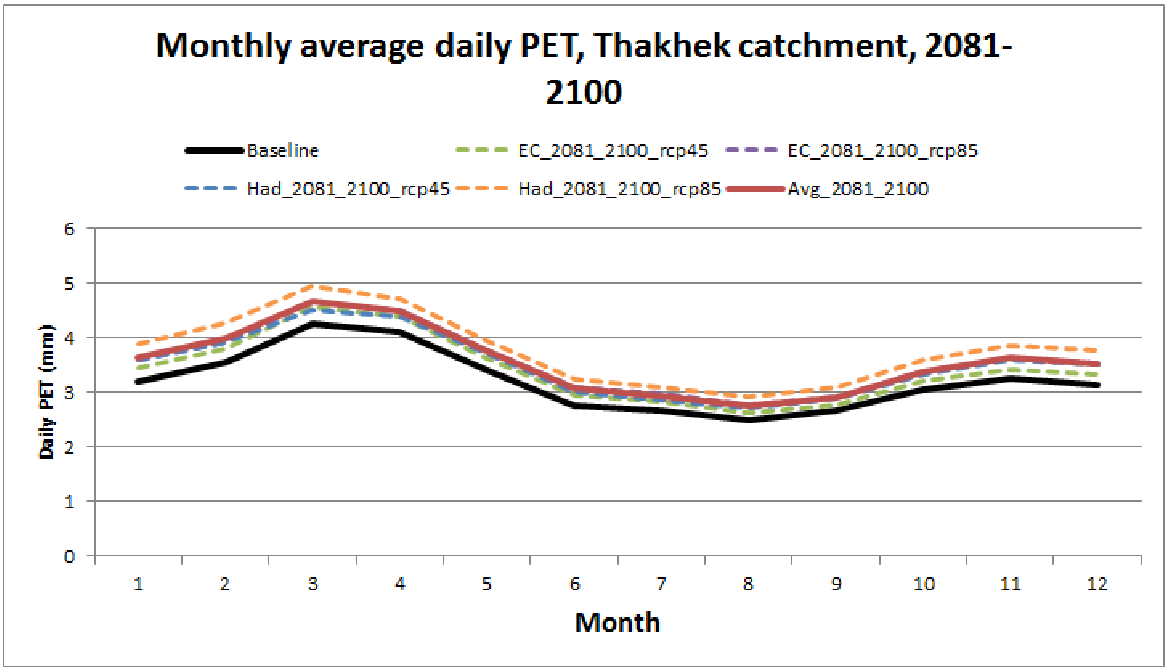


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	2.9	3.5	3.9	4.0	3.6	3.1	2.6	2.5	2.6	2.6	2.6	2.4
Ensemble average	3.3	3.9	4.4	4.4	4.0	3.4	2.9	2.7	2.8	2.9	2.9	2.7
Change factor	1.15	1.13	1.11	1.10	1.11	1.12	1.11	1.11	1.10	1.11	1.13	1.14

A.3.1.3 Thakhek catchment

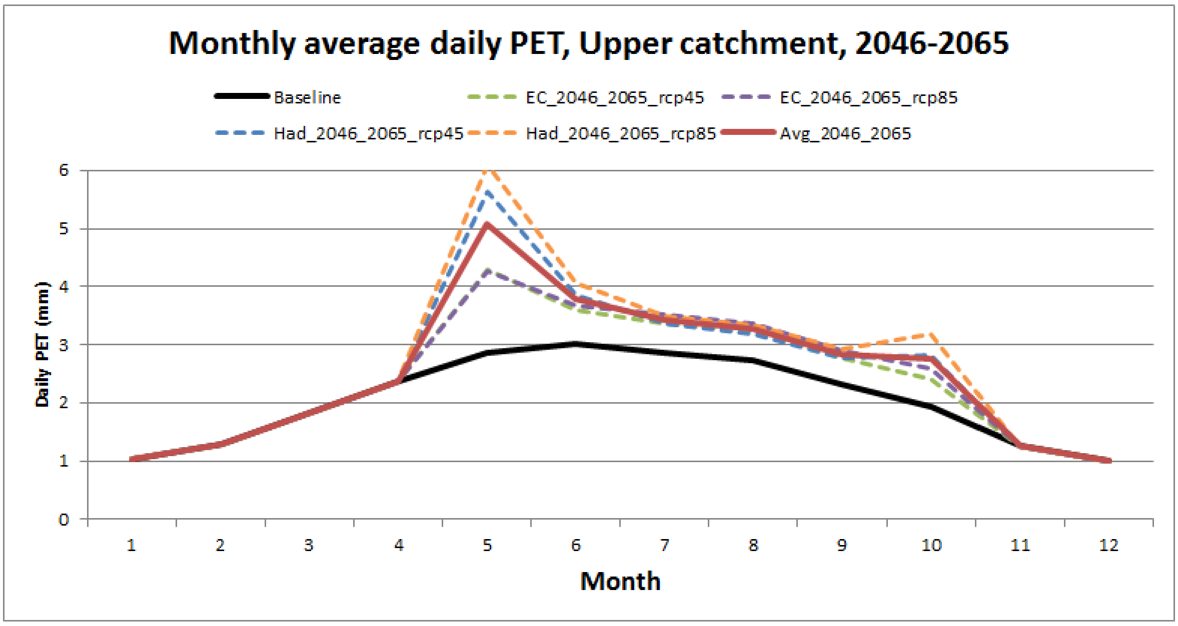


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	3.2	3.6	4.3	4.1	3.4	2.8	2.7	2.5	2.7	3.1	3.3	3.1
Ensemble average	3.4	3.8	4.5	4.4	3.6	3.0	2.8	2.7	2.8	3.2	3.4	3.4
Change factor	1.08	1.07	1.06	1.06	1.07	1.07	1.06	1.06	1.06	1.05	1.06	1.07

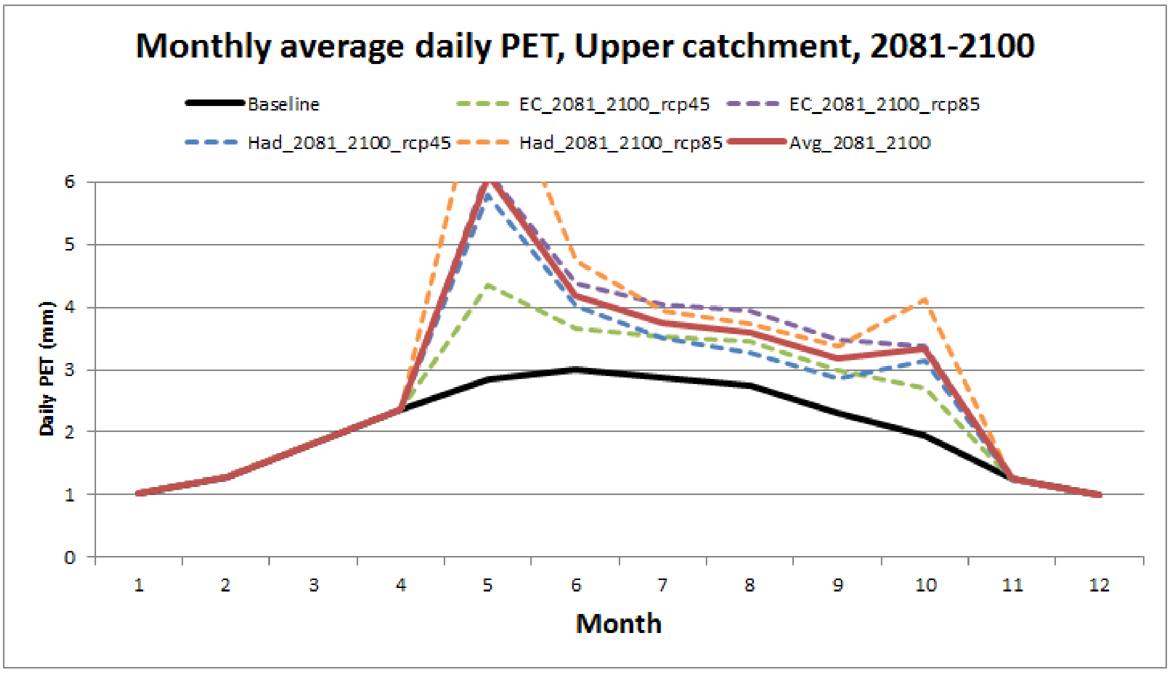


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	3.2	3.6	4.3	4.1	3.4	2.8	2.7	2.5	2.7	3.1	3.3	3.1
Ensemble average	3.6	4.0	4.7	4.5	3.8	3.1	2.9	2.8	2.9	3.4	3.6	3.5
Change factor	1.13	1.12	1.10	1.09	1.11	1.11	1.11	1.10	1.10	1.11	1.12	1.12

A.3.1.4 Upper Mekong headwater catchment

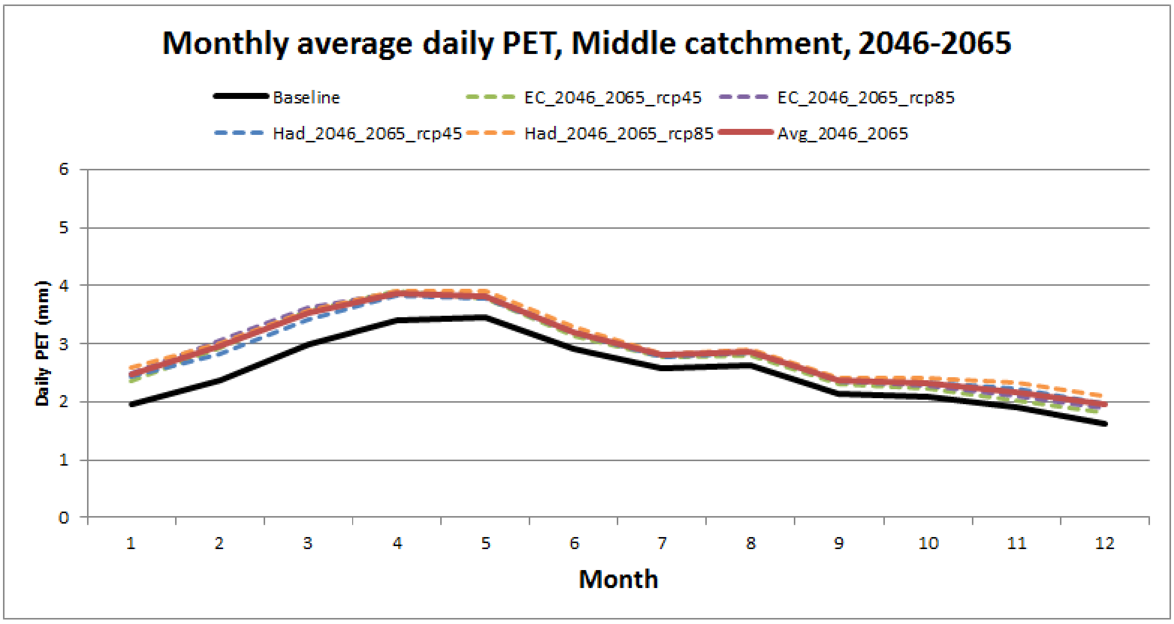


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1.0	1.3	1.8	2.4	2.9	3.0	2.9	2.7	2.3	1.9	1.3	1.0
Ensemble average	1.0	1.3	1.8	2.4	5.1	3.8	3.4	3.3	2.8	2.7	1.3	1.0
Change factor	1.00	1.00	1.00	1.00	1.78	1.26	1.20	1.20	1.23	1.41	1.00	1.00

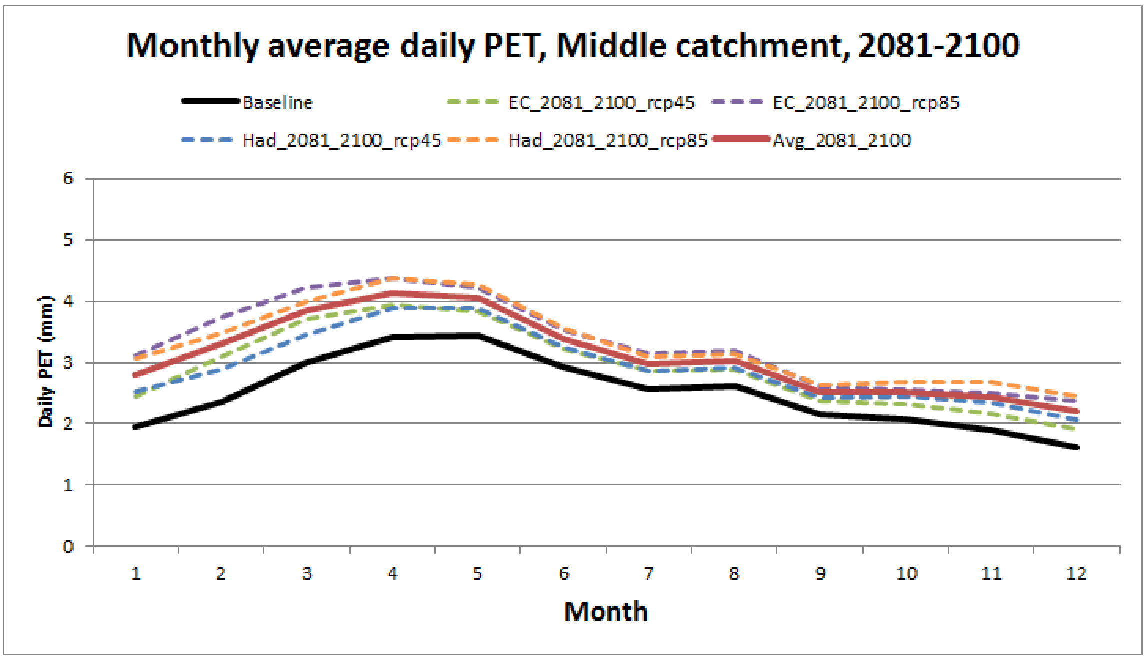


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1.0	1.3	1.8	2.4	2.9	3.0	2.9	2.7	2.3	1.9	1.3	1.0
Ensemble average	1.0	1.3	1.8	2.4	6.1	4.2	3.7	3.6	3.2	3.3	1.3	1.0
Change factor	1.00	1.00	1.00	1.00	2.14	1.39	1.31	1.32	1.37	1.71	1.00	1.00

A.3.1.5 Middle Mekong headwater catchment

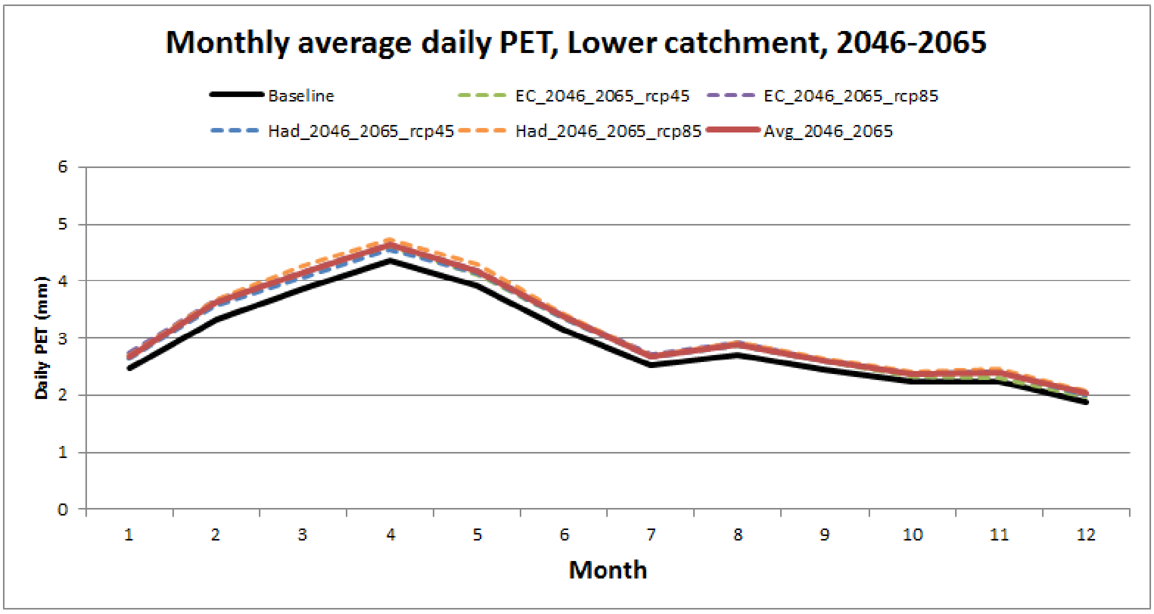


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1.9	2.4	3.0	3.4	3.4	2.9	2.6	2.6	2.1	2.1	1.9	1.6
Ensemble average	2.5	3.0	3.5	3.9	3.8	3.2	2.8	2.9	2.4	2.3	2.2	1.9
Change factor	1.27	1.25	1.18	1.14	1.11	1.09	1.09	1.09	1.10	1.11	1.14	1.21

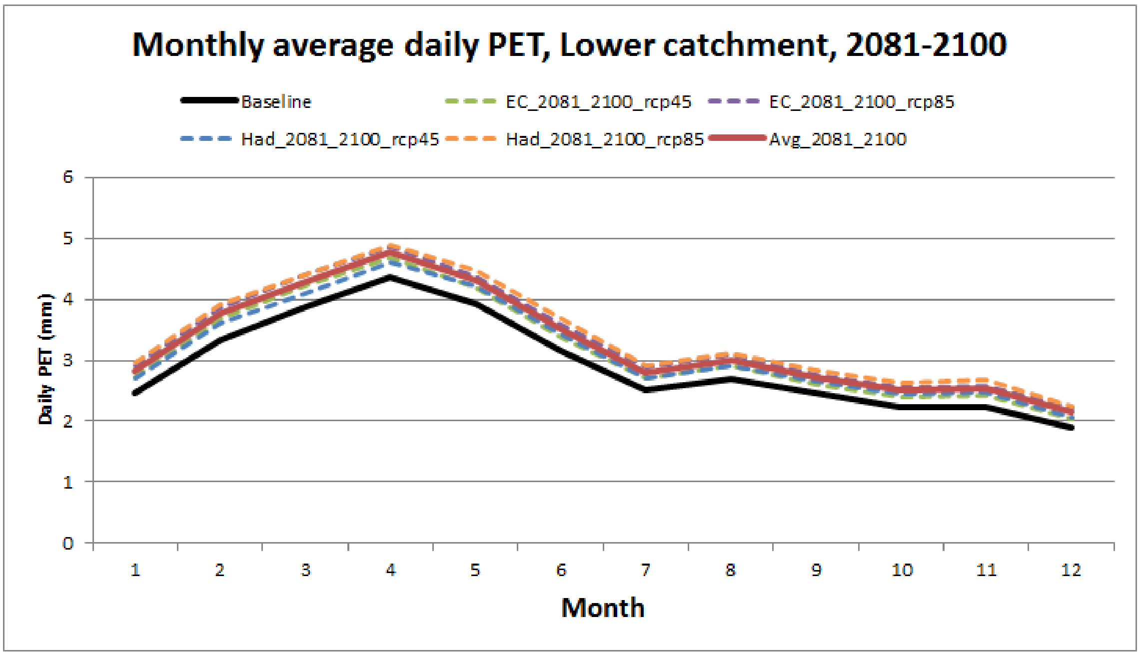


Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	1.9	2.4	3.0	3.4	3.4	2.9	2.6	2.6	2.1	2.1	1.9	1.6
Ensemble average	2.8	3.3	3.8	4.1	4.0	3.4	3.0	3.0	2.5	2.5	2.4	2.2
Change factor	1.43	1.40	1.28	1.21	1.17	1.16	1.16	1.16	1.17	1.20	1.27	1.37

A.3.1.6 Lower Mekong headwater catchment



Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	2.5	3.3	3.9	4.4	3.9	3.1	2.5	2.7	2.5	2.2	2.2	1.9
Ensemble average	2.7	3.6	4.2	4.6	4.2	3.4	2.7	2.9	2.6	2.4	2.4	2.0
Change factor	1.09	1.09	1.07	1.06	1.06	1.07	1.07	1.07	1.06	1.06	1.07	1.07



Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baseline	2.5	3.3	3.9	4.4	3.9	3.1	2.5	2.7	2.5	2.2	2.2	1.9
Ensemble average	2.8	3.8	4.3	4.8	4.3	3.5	2.8	3.0	2.7	2.5	2.5	2.1
Change factor	1.14	1.13	1.11	1.09	1.10	1.11	1.11	1.11	1.11	1.12	1.13	1.14

APPENDIX B –

ESS and EBA Assessments

B ESS and EBA Assessments

B.1 Flood damages to ecosystems and infrastructure identified by cities

Tables summarizing findings from workshops in August 2016, included below (Cross-cutting results from the flood damage discussion: Highest priority on top to the extent possible):

Flooding damages	VTE	PKS	LPB	SVK	PAK	THK
Inconvenience in public and private transportation	x				x	
Electricity polls falling over, cutting the supply	x		x	x		x
Dirty residential areas (smell, dirt)	x			x	x	x
Damaged sanitation /toilets	x					
Rice production inhibited periodically	x	x				
Damage to houses and public property			x	x	x	x
Poor water quality in wells	x					
Water supply problems (sedimentation)			x	x		
Water supply system cannot operate during flooding						x
Landslides	x	x				
Soil erosion			x			
Bank erosion				x		
Loss of school time (no access to school during flooding)	x	x	x			x
Teaching material damaged			x			x
Affecting drainage systems	x			x		x
Damaged irrigation systems	x	x				
Damaged roads	x			x	x	x
Damage to bridges			x			
Difficult livelihood	x	x			x	x
Water-borne diseases (dengue fever)	x	x	x	x	x	x
Poor quality of food	x	x				
Loss of crop yield		x	x	x	x	x
Loss of poultry and pigs					x	x
Affect house hold income	x	x	x			
Inconveniences for residents			x			
Affecting state budget for repairing damages	x	x			x	
Poor quality of water	x	x				
Affect mental health	x	x				
General health problems			xD			
Traffic congestion	x	x	x			
Shortage of state budget to rehabilitate ecosystems	x	x	x			
Impacts on tourism and temples			x			x
Impacts to livestock activities	x	x	x			x
Impacts on aquaculture				x		
Damaged forest	x	x				
Affect habitats	x	x				
Affect culture	x	x				
Salt from salt factory impacts drinking water during flooding				x		

B.2 Damages to ecosystems

Cross-cutting results from damage to ecosystem services discussion: Highest priority on top to the extent possible

Eco system damages	VTE	PKS	LPB	SVK	PAK	THK
Impacts on rubber tree plantations	x	x				
Loss of trees for landslide protection			x			
Food supply chain affected	x	x				
Changes in water flow	x	x				
Changes in water quality			x			x
Reduced biodiversity	x	x				
Less firewood				x		
Change of water channel corridor (change in the physical place of the river channel)	x	x			x	
Damage to non-timber forest products	x	x		x		
Erosion	x	x			x	
Affecting the agriculture: Impacts on seeds, livestock, Products, Crops, vegetables	x	x		x		
Decrease in wild plants and wildlife			xD[5]	x		
Affect insect habitats	x	x		x		
Lack of budget to prevent bank erosion	x	x				
Ruining habitats (??)	x	x				
Fewer food sources for livestock			xD			
Damage to vegetables and herbs	x	x				
Damage to aquatic animals	x	x				
Damage to aquatic plants			x			
Damaged fish cages	x	x				
Flooded fish farms	x	x				
Damage to natural mushroom	x	x				
River bank erosion	x	x				
Soil fertility goes down				x	x	
Affected water plants (Green plants or water facilities??)	x	x				
Affected green areas	x	x				
Damaged wells and drinking water facilities	x	x		x		
Forest fires			xD			
Trees die due to higher temperatures			xD			
Shallow fish-filled pools disappear during flooding			x			

[5] D = drought

B.3 Flood induced damages, prioritized by cities

Grouped in 5 sections, and ranked on no. cities with the same problems.

Priority	Flooding damages	VTE	PKS	LPB	SVK	PAK	THK
	Agriculture, forest and aqaculture						
21	Loss of crop yield		x	x	x	x	x
32	Impacts to livestock activities	x	x	x			x
5	Rice production inhibited periodically	x	x				
20	Poor quality of food	x	x				
22	Loss of poultry and pigs					x	x
34	Damaged forest	x	X				
35	Affect habitats	x	x				
33	Impacts on aquaculture				x		
	Economy and tourism						
25	Affecting state budget for repairing damages	x	x			x	
30	Shortage of state budget to rehabilitate ecosystems	x	x	x			
31	Impacts on tourism and temples			x			x
	Geology						
9	Landslides	x	x				
10	Soil erosion			x			
11	Bank erosion				x		
	Infrastructure damages						
16	Damaged roads ands bridges	x		x	x	x	x
2	Electricity polls falling over, cutting the supply	x		x	x		x
3	Dirty residential areas (smell, dirt)	x			x	x	x
29	Traffic congestion	x	x	x		x	
14	Affecting drainage systems	x			x		x
15	Damaged irrigation systems	x	x				
4	Damaged sanitation /toilets	x					
37	Salt from salt factory impacts drinking water during flooding				x		
	People, property and health						
19	Water-borne diseases (dengue fever)	x	x	x	x	x	x
6	Damage to houses and public property			x	x	x	x
12	Loss of school time (no access to school during flooding)	x	x	x			x
18	Difficult livelihood	x	x			x	x
8	Water supply problems (sedimentation)			x	x		x
23	Affect house hold income	x	x	x			
27	General health problems	x	x	xD			
7	Poor water quality in supply and shallow wells	x	x				
13	Teaching material damaged			x			x
36	Affect culture	x	x				

B.4 Damages to Ecosystem Services, prioritized

Priority	Eco system damages	VTE	PKS	LPB	SVK	PAK	THK
	Biology/Habitats						
13	Affect insect habitats	x	x		x		
6	Reduced biodiversity	x	x				
15	Ruining habitats (??)	x	x				
18	Damage to aquatic animals	x	x				
19	Damage to aquatic plants			x			
29	Trees die due to higher temperatures			xD			
	Crops, wild and cultivated						
9	Damage to non-timber forest products	x	x		x		
11	Affecting the agriculture: Impacts on seeds, livestock, Products, Crops, vegetables	x	x		x		
1	Impacts on rubber tree plantations	x	x				
3	Food supply chain affected	x	x				
12	Decrease in wild plants and wildlife				x		
14	Lack of budget to prevent bank erosion	x	x				
17	Damage to vegetables and herbs	x	x				
20	Damaged fish cages	x	x				
21	Flooded fish farms	x	x				
22	Damage to natural mushroom	x	x				
25	Affected water plants (Green plants or water facilities ??)	x	x				
7	Less firewood				x		
16	Fewer food sources for livestock			xD			
30	Shallow fish-filled pools disappear during flooding			x			
	Geology, soil						
10	Erosion	x	x			x	
23	River bank erosion	x	x				
24	Soil fertility goes down				X	x	
	Protection, impacts,						
26	Affected green areas	x	x				
2	Los of trees for landslide protection			x			
28	Forest fires			xD			
	Water related damages						
8	Change of water channel corridor (change in the physical place of the river channel)	x	x			x	
27	Damaged wells and drinking water facilities	x	x		x		
4	Changes in water flow	x	x				
5	Changes in water quality			x			x

B.5 Systematized Ecosystem Services for stakeholder exercises

Food provision TRANSLATION	Provisioning TRANSLATION
Water provision TRANSLATION	
Fuels and fibers TRANSLATION	
Genetic resources TRANSLATION	
Medicinal and other biochemical resources TRANSLATION	
Ornamental resources TRANSLATION	
Air quality regulation and other urban environmental regulation TRANSLATION	Regulation and Maintenance TRANSLATION
Climate regulation TRANSLATION	
Moderation of extreme events TRANSLATION	
Water flow regulation TRANSLATION	
Water purification TRANSLATION	
Erosion prevention TRANSLATION	
Maintenance of soil quality TRANSLATION	
Pollination services TRANSLATION	
Biological control TRANSLATION	
Maintenance of life cycles of migratory species TRANSLATION	Habitat/Support TRANSLATION/TR ANSLATION
Maintenance of genetic diversity TRANSLATION	
Spiritual, religious, aesthetic, inspirational and sense of place TRANSLATION	Cultural TRANSLATION
Recreation, ecotourism, cultural heritage and education TRANSLATION	

APPENDIX C

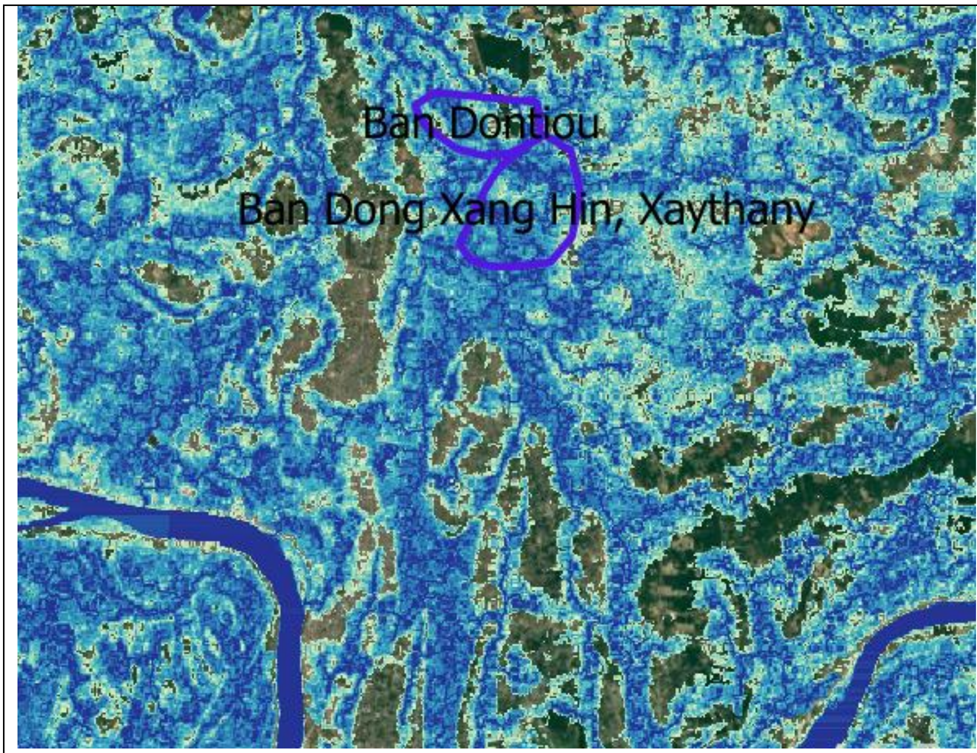
Site selection for the six cities

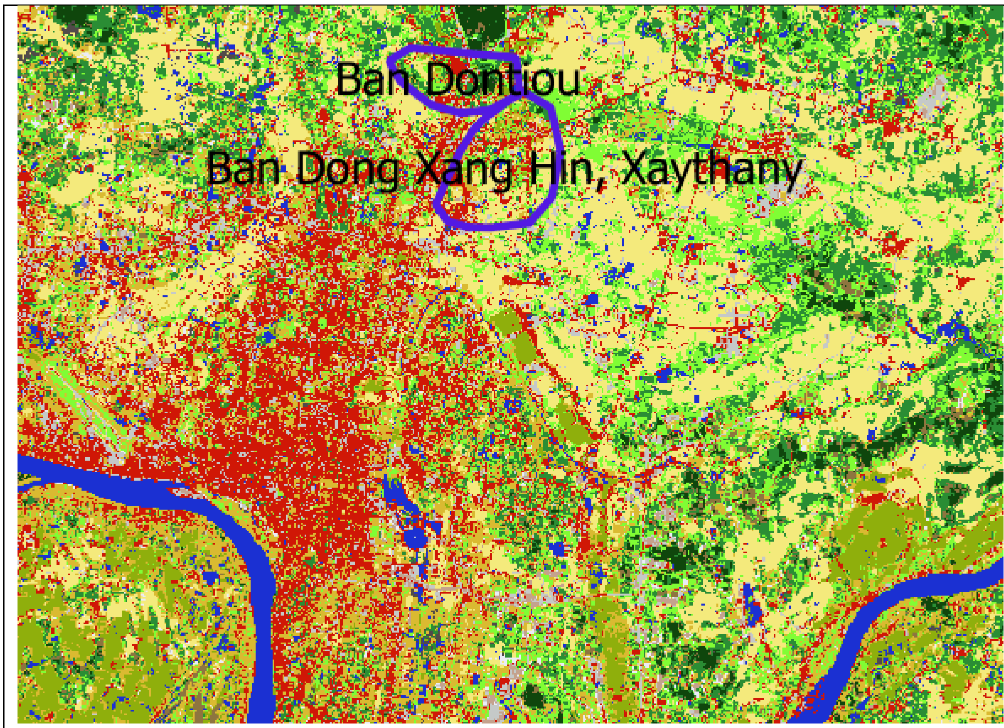
C Site selection for the six cities

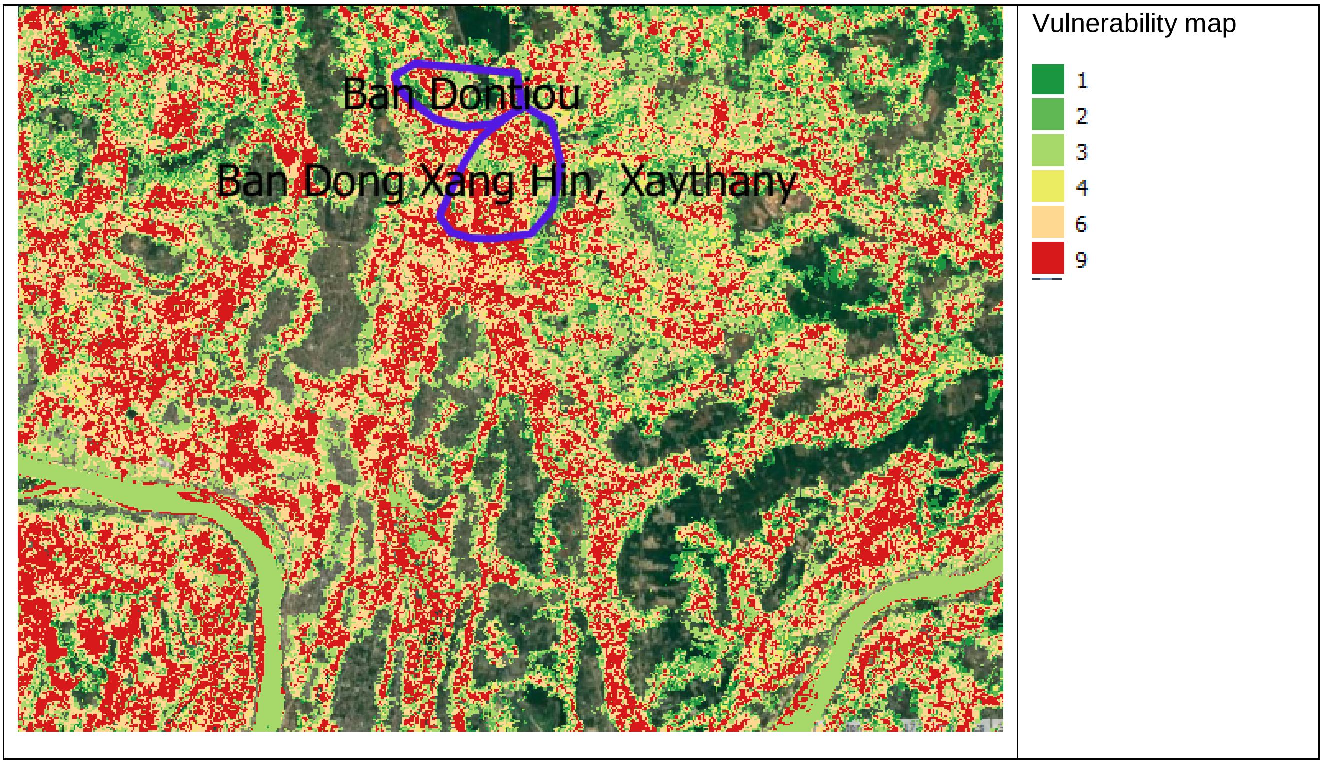
C.1 Vientiane

4 overview maps are provided for each city: **Google map** with sites, **Hazard map** (flooding), **Land cover classification** and **Vulnerability map**

	Vientiane with sites

	Hazard map HAND 0 1 2 3 4 5 6 7 8 9 10 11

	Land cover classification Forest (deciduous) Agriculture Bare soil Forest (coniferous) Rubber Rice Paddies Road Urban Water Irrigated Rice Grassland Cloud Cloud Shadow



C.1.1 Key site – Ban Dontiou

1. **Site name and location**
   The area is called Ban Dontiou and has a size of approximately 455 ha. The area is peri-urban, and there is a mixture of gardens and rice paddies. The stream Huay Yang runs through the area. The length of the stream is 10.5 km.

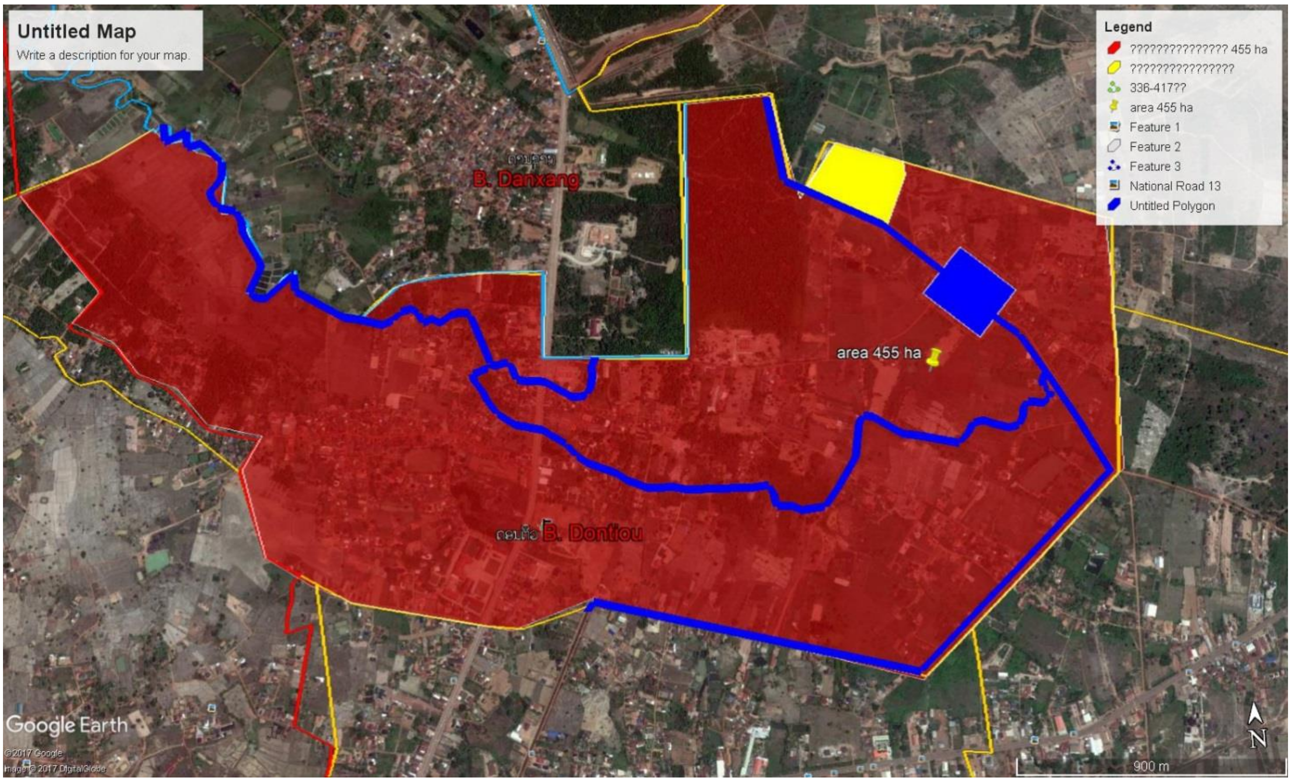


Figure 11-1 Layout of key site

2. Background information of the site

tbd

3. Description of the flood problem in the area

Changes to ecosystems (e.g. damages) in the catchment has decreased the runoff time with increased flood as a result.

4. Proposed solution

- Step 1: Maintain and establish green areas at the individual households, providing green spaces and natural forest for the total areas of 455 ha.

- Step 2: Upgrading of the existing small stream through the construction of a mixture of concrete and compressed soil; provision of a drainage system from households into the stream; planting additional trees along the stream to prevent against the erosion and sedimentation.

Timeline:

  - 18 months for construction
  - 38 months for monitoring and evaluation

5. Estimated project costs

Cost: Step 1: USD 1 million, Step 2: USD 3 million

Total costs of two steps: 4 million

6. Upscaling potential

tbd.

7. Unsolved issues

C.1.2 Additional site 1: Ban Dong Xang Hin, Xaythany

1. **Site name and location**
   The area is called Ban Dong Xang Hin at Xaythany and has a size of approximately 863 ha. The area is peri-urban, and there is a mixture of gardens and rice paddies. Smaller streams runs through the area.

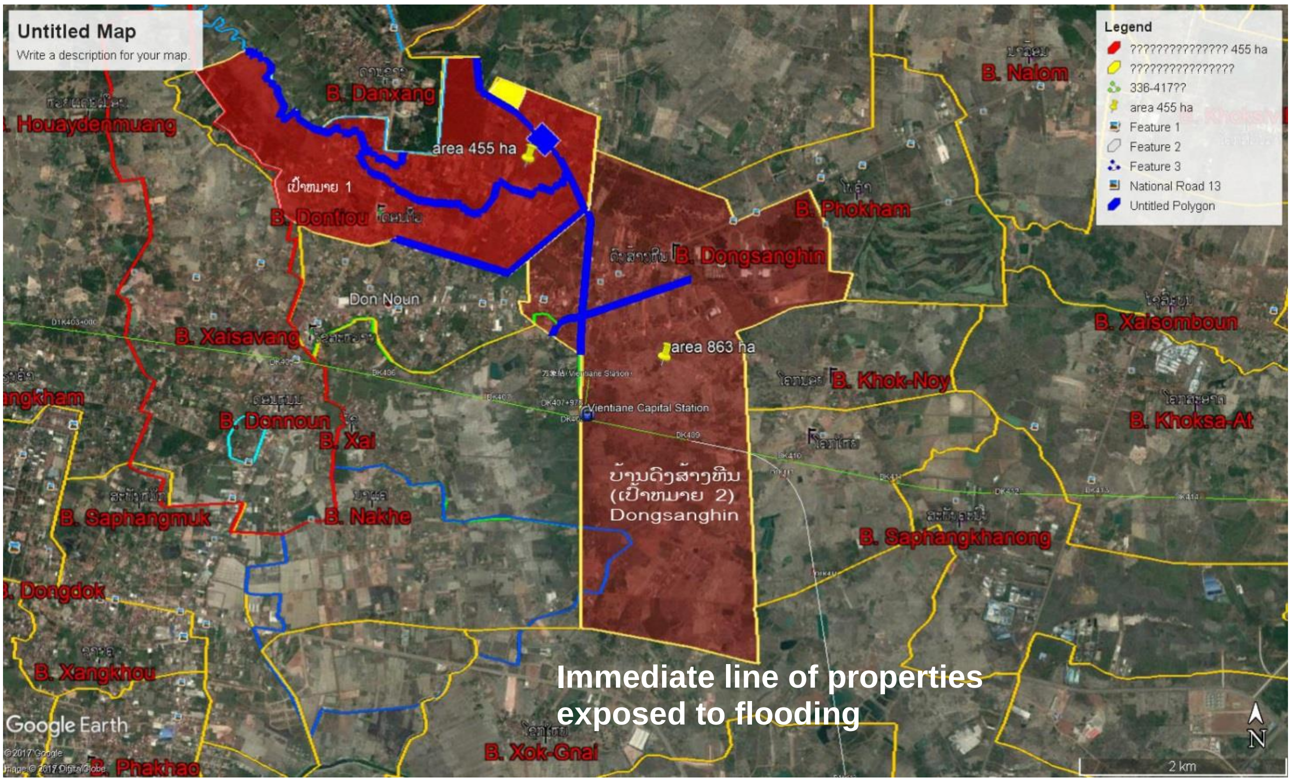


Figure 11-2 Layout of additional site (Dong Xang Hin)

2. **Background information on the site**
   tbd

3. **Description of the flood problem in the area**
   Changes to ecosystems (e.g. damages) in the catchment has decreased the runoff time with increased flood as a result.

4. **Proposed solution**
   Step 1: Maintain and establish green areas at the individual households, providing green spaces and natural forest for the total areas of 863 ha.

   Step 2: Upgrading of the existing small stream through the construction of a mixture of concrete and compressed soil; provision of a drainage system from households into the stream; planting additional trees along the stream to prevent against the erosion and sedimentation.

Timeline:

a. 18 months for construction
b. 38 months for monitoring and evaluation

5. Estimated project costs

Cost: Step 1: USD 0.8 million, Step 2: USD 2.8 million

Total costs of two steps: 3.6 million

6. Upscaling potential

Tbd.

Vientiane Capital City
District: Xaythany
Village: Ban Dontiew

1. Background: the village is known as the home for many generations with Huay Yang flowing through. There is production area (paddies and garden).
2. Problem: Due to the ecosystem damage, there is the flood.
3. EBA intervention:

- Activity 1: Promoting green areas with individual households, green spaces and natural forest for the total areas of 455 ha (green spaces for the empty areas)
- Cost: USD 1 million
- Activity 2: upgrade the degradable areas of the small stream (through the construction with concrete and compressed soil); install the drainage system from households into the stream; planting more tree along the stream to prevent against the erosion and sedimentation. The length of the stream is 10.5 km
- Cost: USD 3 million
- Total costs of two activities: 4 million

4. Timeline:

- 18 months for construction
- 38 months for monitoring and evaluation

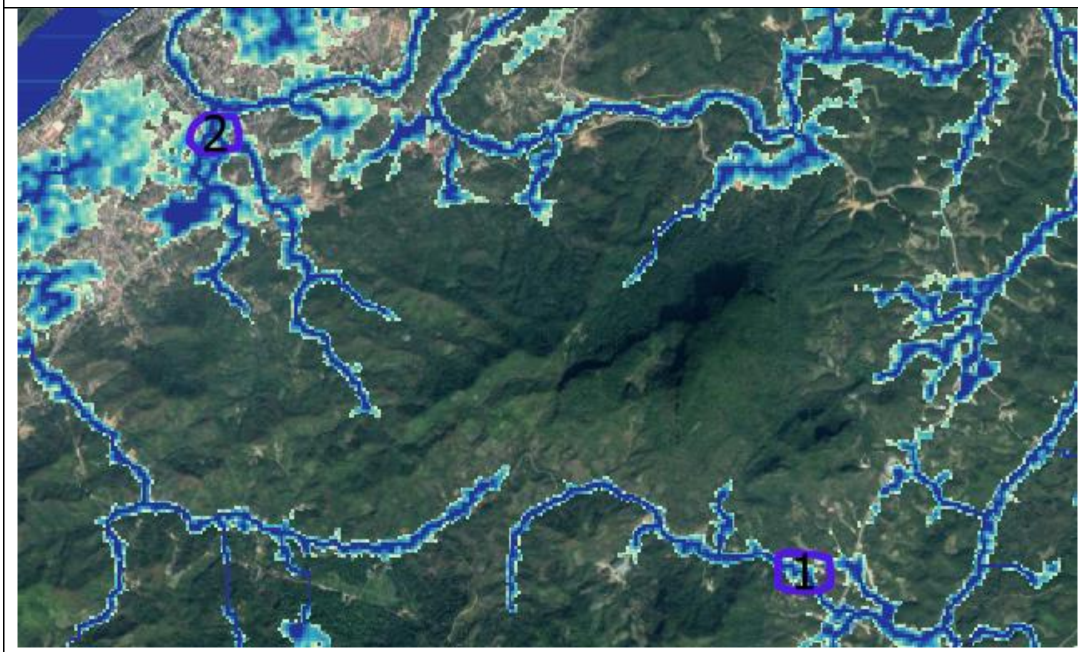
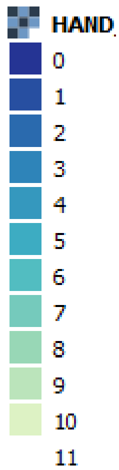
Additional Site:
District: Xaythany
Village: Ban Dong Xang Hin

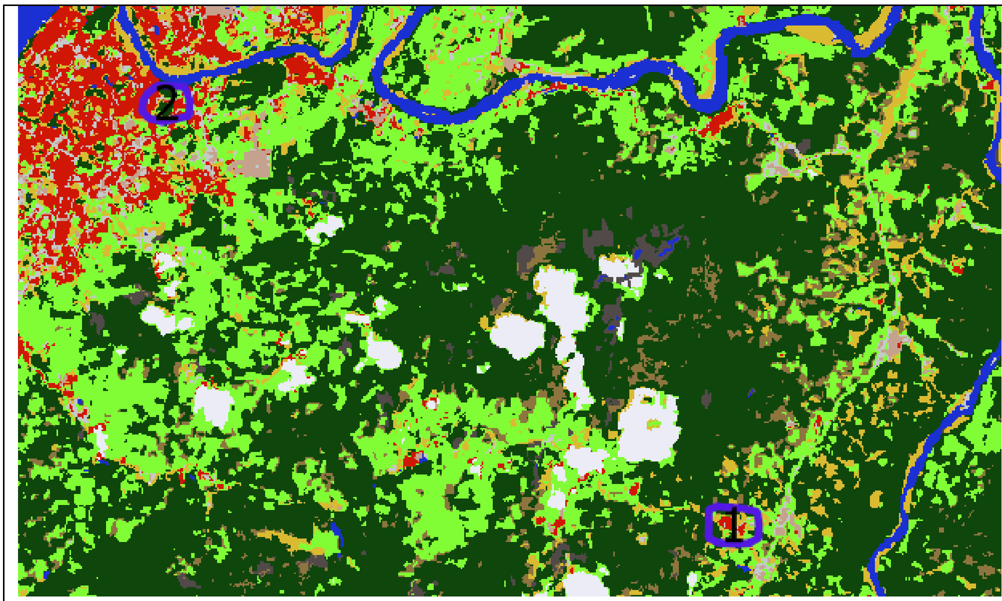
1. Background: there are communities living in this area for many generations with the flow of small streams (paddies and garden).
2. Problem: there is flood due to the ecosystem damage

3. EBA intervention:
- Activity 1: Promoting green areas with individual households, green spaces and natural forest for the total areas of 863 ha (green spaces for the empty areas)
- Cost: USD 800,000
- Activity 2: upgrade the degradable areas of the small stream (through the construction with concrete and compressed soil); install the drainage system from households into the stream; planting more tree along the stream to prevent against the erosion and sedimentation.
- Cost: USD 2 million
- Total costs of two activities: 2.8 million

4. Timeline:
- 18 months for construction
- 38 months for monitoring and evaluation

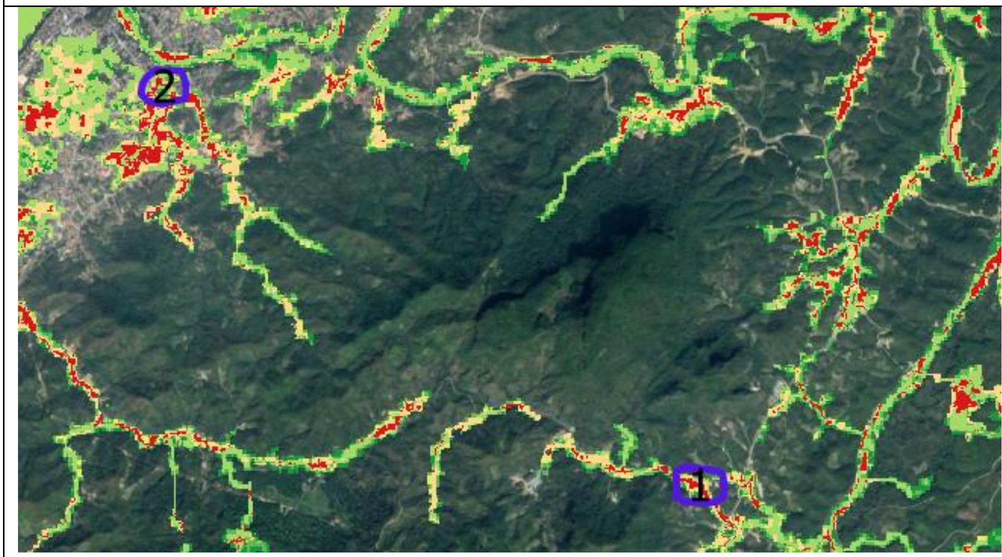
C.2 Luang Prabang

	Luang Prabang with sites
	Hazard map 



Land cover classification

- Forest (deciduous)
- Agriculture
- Bare soil
- Forest (coniferous)
- Rubber
- Rice Paddies
- Road
- Urban
- Water
- Irrigated Rice
- Grassland
- Cloud
- Cloud Shadow



Vulnerability map

- 1
- 2
- 3
- 4
- 6
- 9

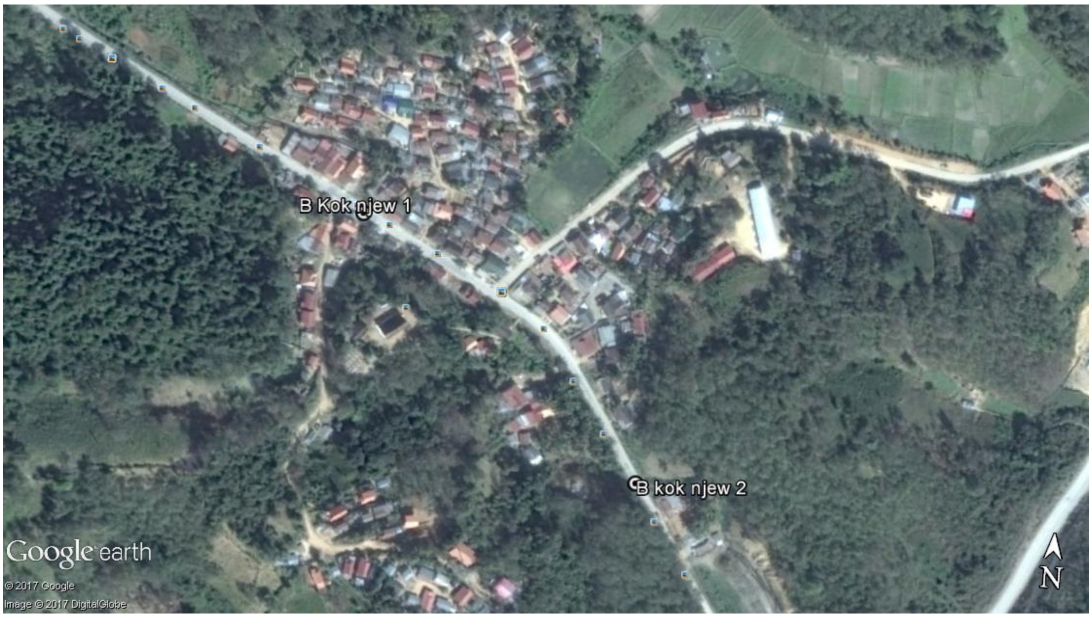
C.2.1 *Key site: Kok Ngiew*

1. Site name and location:

Province: Luangprabang
District: Luangprabang
Site: Kok Ngiew

Kok Ngiew village is the proposed main site for the project. The approximate coordinates of the project are: 19°50'33.92"North, 102°12'0.27"East.

The below figure shows flood site location and location of the affected village:



2. Background information of the site

The site is located approximately 8 km from LPB. The small village is situated along a stream, which 3-4 times per year floods parts of the village. The flood events are short, but intense and usually bring large amounts of soil and mud, filling up the stream along the road and affects the houses adjacent to the stream.

The key damages are to property along the river, whereas houses away from the stream are not damaged. There are also damages to cropland up- and downstream of the village. The stream passes a quarry upstream and a visit to the quarry showed that there is no protective walls or dikes to prevent soil and mud from the quarry to run into the river. The two culverts seen in the village were both more or less blocked with debris and sediments and were by far too small to take the flow from the stream. Therefore, the culverts serve as true bottlenecks and the water is forced into the street, causing the problems.

3. Description of the flood problem in the area

Ban Kok Ngiew is a site with long history of flooding. The Kok Ngiew village is flooded every year as a result of heavy rain and flash floods into the Huay Nam Ann. Floods create damages to local villagers' houses and the National Route 13 North.

The main causes of flooding at the site is a combination of de-forestation in the catchment area, in combination with poor maintenance (or lack of) flood management structures such as culverts under roads and bridges.

The increased amounts of sediments from mining activities upstream (see map) and small rocks and sediments from the mountain areas pose a special challenge and create blockages in the culverts, thus creating flooding on the road and adjacent to the houses.

Flash floods usually last for about 1-2 hours, but also create a lot of damage to the properties of local villagers. The main impacts are on households (including houses), agriculture, livestock, and infrastructure.

Experienced damages include:

- Damages to national road and temporary shutdown of roads
- Damages to properties and assets
- Damages to wells
- Landslides along the river banks
- Changes and damage to agricultural land
- Damages to plantations
- Damages to eco-system and necessary resettlement of local villagers.

Photos of the stream along the road, a partly blocked culvert and the quarry:

4. Proposed solution

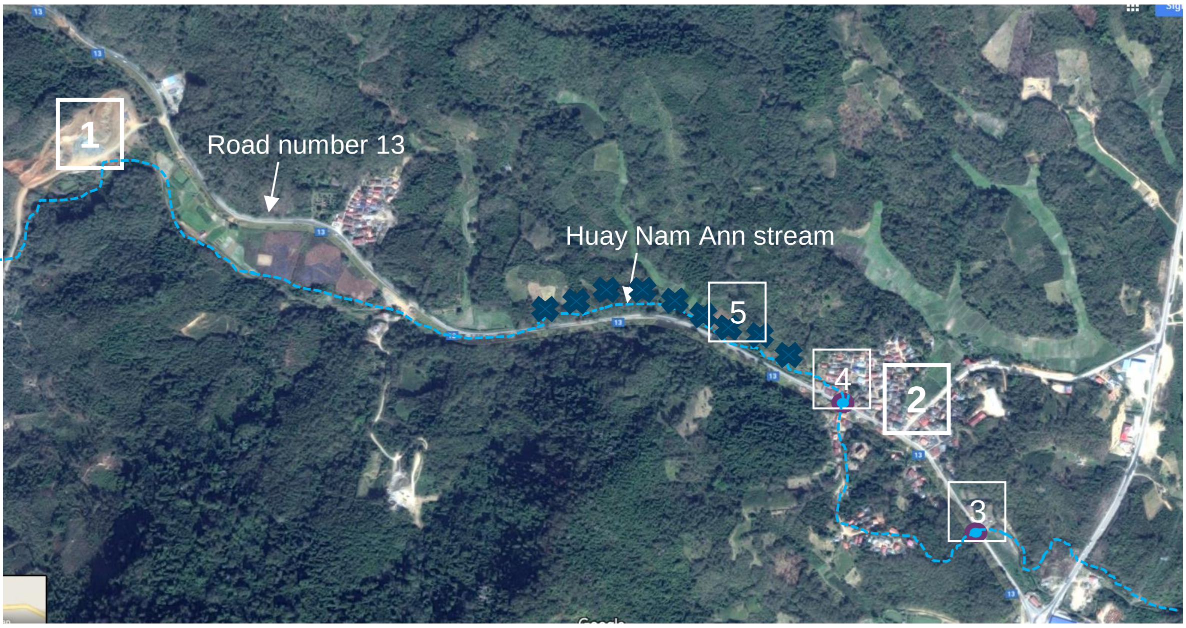
The damages, besides the physical load of soil and mud were mainly on cropland, and on the water supply system in the village. The main operational possibilities is to have better control over the land use and watershed management upstream and potentially. In addition, the run-off conditions in the quarry must be assessed to ensure that the village does not suffer from un-intended soil and mud transport from the quarry. Protective dikes and ponds may be used to reduce the soil transportation into the stream.

The proposed actions following the September 2017 workshop in Pakxe include a mix of conventional and ecosystem-based interventions for flood management and mitigation, and they include:

- Restoration of the catchment area including planting of trees and forest conservation in the catchment area
- Setting up the recovery plan with EBA approach in the city (re-plan) especially the flooded area through the filling of surface soil, upgrade of the dyke, construction of immediate drainage, upgrading and expansion of the culverts, and construction of settling pond
- Planting grass or vetiver (or other) plants along river banks to avert bank erosion

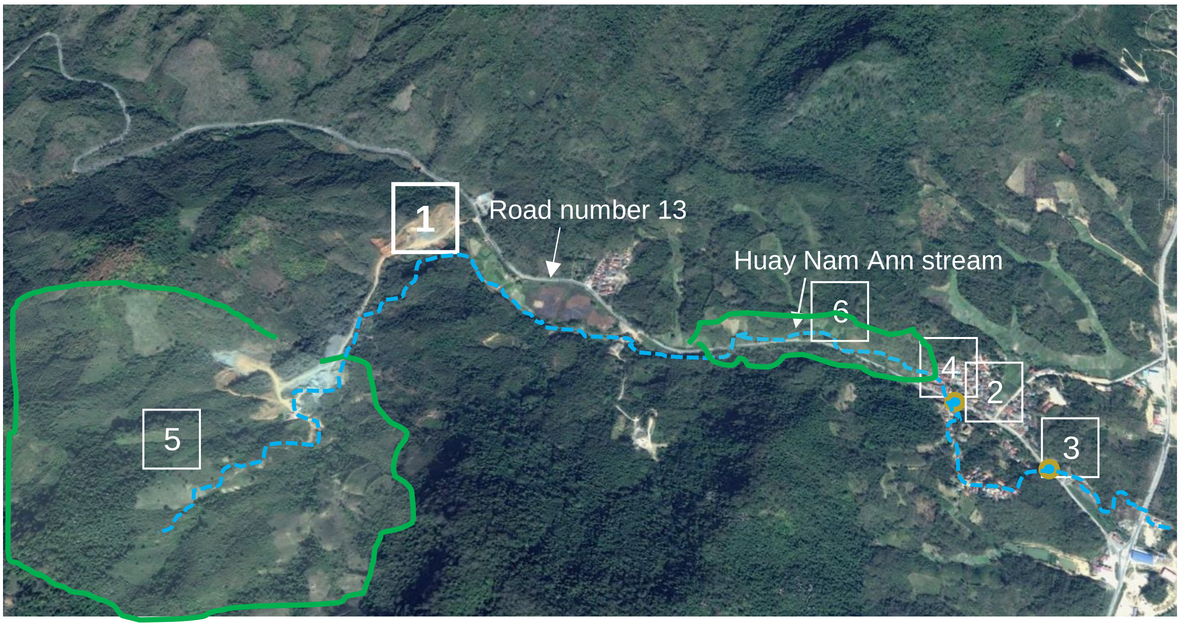
Further, it is suggested to complement the physical interventions with development of the social and regulatory aspects for improved flood management. These include:

- Development of regulations for forest conservation and wildlife hunting prohibition for catchment area conservation
- Creating a provincial/district/village committee *for flood management and/or for conservation*
- Training activities for all level committees on disaster management and response with EBA approach for the villagers of the 4 target villages.



Layout of site showing (1) The Sandstone mine, the main source of the sediments; (2) Kok Ngiew villages experiencing flood problems; and (3) Downstream culvert, size 6x1.5m (experiencing sedimentation problems); (4) Upstream culvert, size 3x1.5m; (5) suggested location for planting trees along the stream for riverbank protection;

Suggested area for forest restoration in the catchment is shown below (zoomout of the location).



Zoomout of the project site showing (1) The Sandstone mine, the main source of the sediments; (2) Kok Ngiew villages experiencing flood problems; and (3) Downstream culvert, size 6x1.5m (experiencing sedimentation problems); (4) Upstream culvert, size 3x1.5m; (5) Approximate location of the catchment area proposed for forest conservation and restoration (approximately 60ha); (6) suggested location for planting trees along the stream for riverbank protection

5. Estimated project costs

The estimated project costs are USD 3.2 million.

6. Upscaling potential

tbc

7. Unsolved issues

tbc

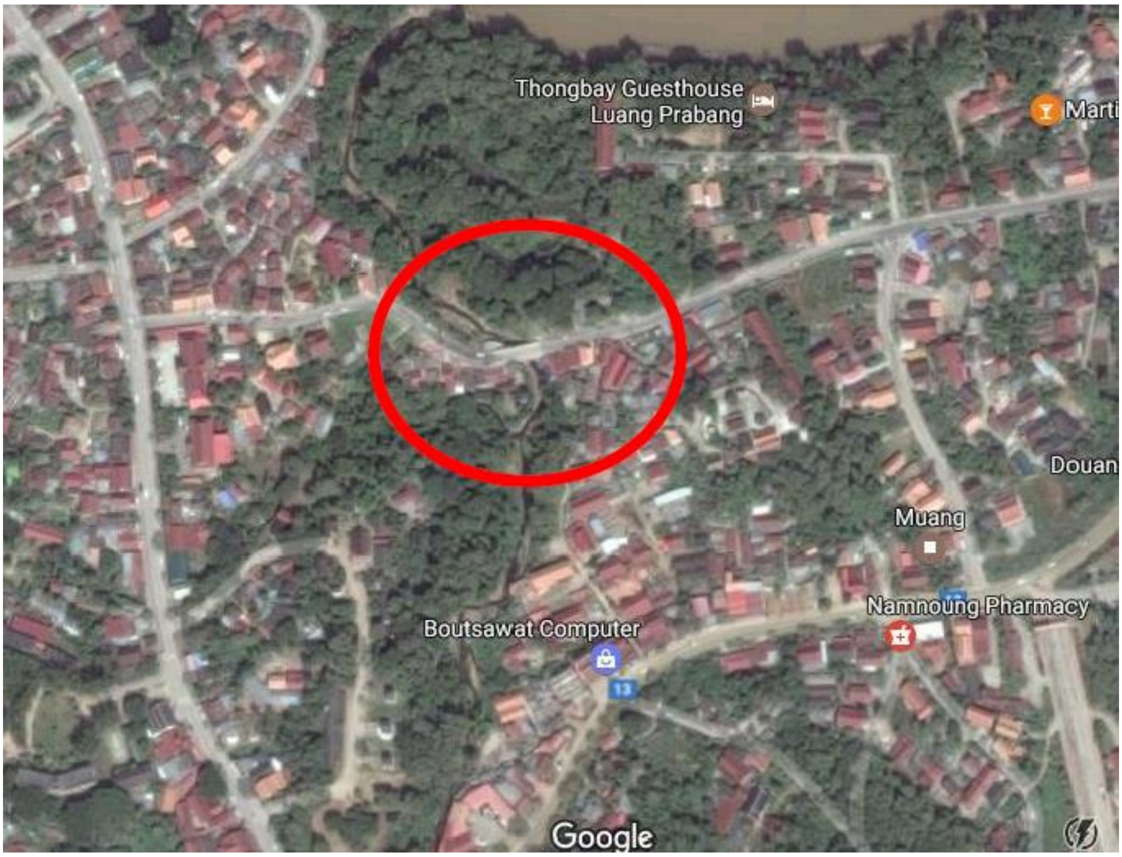
C.2.2 *Additional site 1 in Luang Prabang: Huay Mow*

1. Site name and location

Province: Luangprabang
District: Luangprabang
Site: Huay Mow

2. Background information on the site

The stream passing the bridge over the main road towards the airport was flooded in 2015 due to severe rain in the catchment and to high level of water in both Mekong and the local river, Nam Khan. It was estimated at the site that the water level in the river under the bridge must have been 6-8 meters above present level and this must have caused severe flooding both of the road and the houses close to the stream (LPB Ponre will check whether the event was unusual, making use of rainfall data).



3. Description of the flood problem in the area in the site[6]

A flash flood condition is created which lasted for about 1-2 hours. The flash flood occurred at the same time as the river water levels in the Mekong and Nam Khan were high, thus the water could not drain away sufficiently fast, and overtopping of the channel occurred. This created damages on the road and bridge structure as well as on the nearby properties and houses. Further upstream from the bridge site, flood water is believed to have made damages to properties and land adjacent to the stream.

[6] Almost all information in the main site also applies to the additional site below.

Photo of the stream downstream of the bridge. Severe bank erosion / land slides have occurred.

4. **Proposed solution**

   During the inception workshop it was also discussed that events like the one at the bridge can only be reduced if the whole catchment is analysed for changes like de-forestation or other substantial land-use changes, which have led to a situation, where the rainwater cannot be retained as long as previously in the catchment.

The areal view below shows approximate location of the catchment.

Features: (1) Project site experiencing flooding; (2) the approximate catchment area of the stream

The proposed interventions in the site include restoration of the catchment area including planting of trees and forest conservation in the catchment area.

5. Estimated project costs

PONRE estimates project costs at USD 1.12 million.

6. Upscaling potential

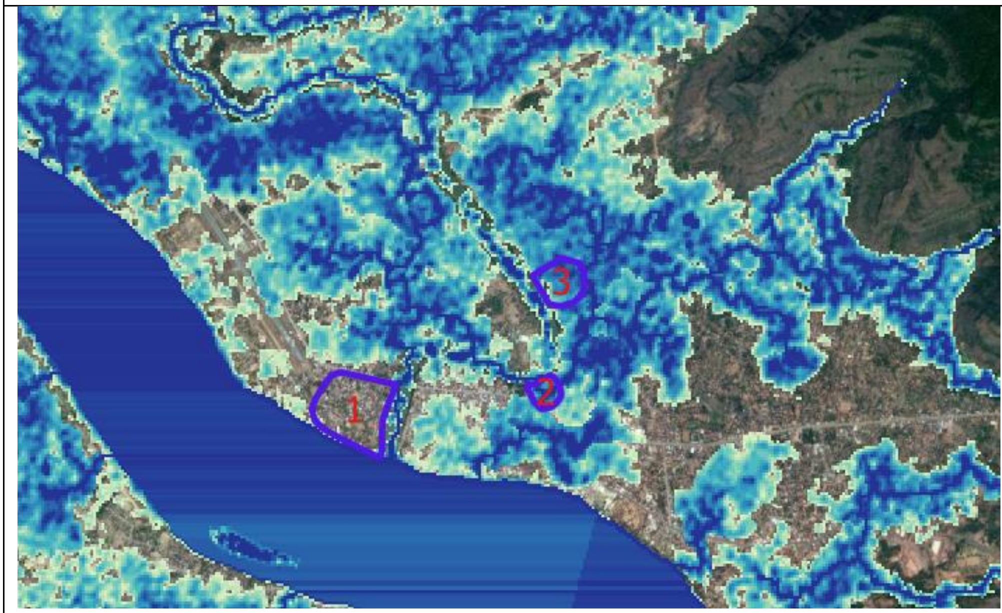
tbc

7. Unsolved issues

Tbc

C.3 Pakse

Pakse with sites



Hazard map

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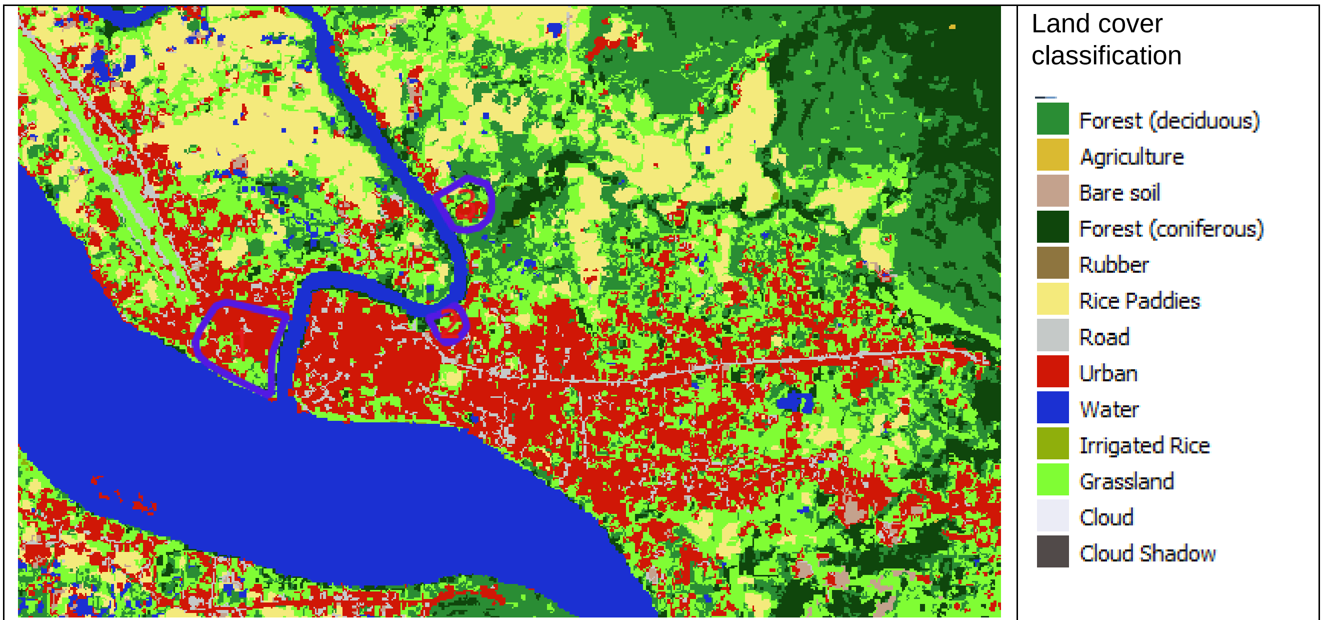
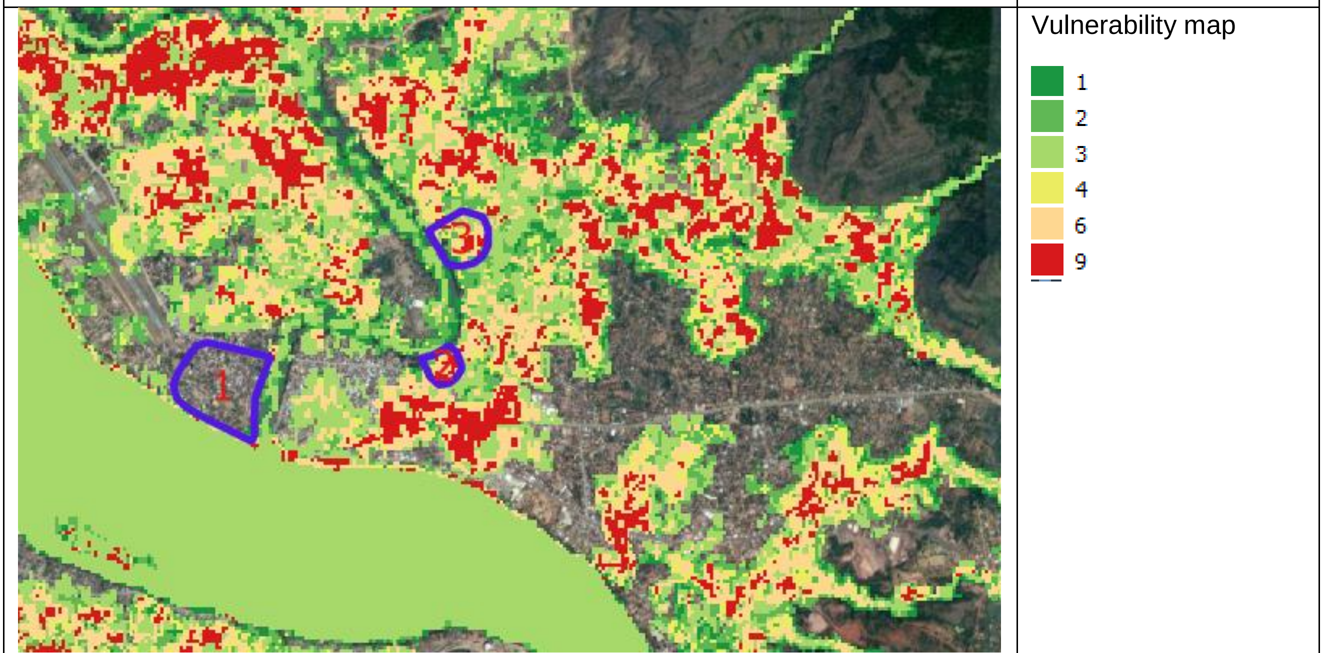




C.3.1 Key site – Ban Tha Ha

1. Site name and location

The Ban Tha Ha area is located between the outlet of Se Done river and the Mekong river on the right bank of Se Done river. Coordinates: 105.8E, 15.1N.

Figure 11-3 Layout of site showing (1) area to be used for flood storage and (2) approximate location of pumping facilities

2. Background information of the site

The Ban Tha Ha area is located on the inner side of the road embankment along the Se Done and Mekong rivers. The area contains a mixture of houses and open green spaces, of which a larger low lying grassland area with scrubs and smaller trees is located towards the Mekong outlet (Figure 11-1, 1). This area is currently being used temporarily for cattle grazing, and is also being used as a natural habitat for birds and likely smaller mammals as well as insects.

Two concrete drainage channels within the area convey water from the catchment to the Mekong and Se Done rivers via two control structures equipped with flap gates. The purpose of the flap gates is to prevent water from the Mekong and Se Done rivers to enter the area.

The flap gates require in general maintenance, and the control structure towards the Se Done river needs to be repaired (Figure 11-4, Flood gate 2).

Figure 11-4 Photos of site showing drainage channel 1 (upper left, lower left, and lower right) and flood gate 1 (upper left)

3. Description of the flood problem in the area

Flooding in the area is caused by two mechanisms. The first is when the water level in the Mekong and Se Done rivers rises above 11 metres, and water enters the area from the river side through the malfunctioning flap gate on the Se Done outlet (Figure 11-1Figure 11-4, Flood gate 2). The other cause for flooding is rainwater from the catchment which causes water ponding in the area at times when the flap gates are closed.

4. Proposed solution

There is a wish to be able to fully control the water and the flood condition in the area. If the open grass land can stay free of water, the area can be used for a variety of purposes such as cattle grazing, growth of cash crops, nursery of flowers and plants, and provide habitats for smaller mammals and insects. On the other hand, a full control of the water level in the area, also allows for controlled flooding in parts of the area, thus providing a mixture of aquatic life (insects, smaller fish) and terrestrial life.

The project envisages widening part of the channel, which drains towards the Se Done river, for improved conveyance (Figure 1, Drainage channel 2). The existing concrete channel will be removed and a natural channel consisting of natural material such as stones, grass, smaller plants will be established. The shape of the new channel will resemble a natural river profile. The natural river channel will increase the abundance of aquatic animals and insects, and as such provide improved habitat conditions and increase the genetic variation among species of plants and animals.

The project likewise includes the establishment of an electrical pump station located at the southern corner of the area (Figure 11-1, 2). The dimensions of the pumps will have to be determined on basis of a drainage basin analysis.

Finally, the project includes repair of the control structure facing the Se Done river (Figure 11-1Figure 11-4, Flood gate 2).

5. Estimated project costs

A rough estimation by the PONRE in Pakse indicates a total budget of USD 1.500.000 .

6. Upscaling potential

There are a number of locations in the Pakse area, and likely along the Mekong river in general, in which the hinterland is protected from flooding by the river embankments. However, the areas are getting flooded due to a combination of malfunctioning control structures and insufficient drainage of catchment runoff.

The project will therefore serve as a model for developing the necessary practical principles and implementation guides for areas with similar problems.

7. Unsolved issues

The land-ownership shall be clarified

Possible conflicts between interests to keep the area dry or wet shall be resolved

C.3.2 Additional site 1: Ban Ke

1. Site name and location

Ban Ke drainage system site is located in the vicinity of the national route 13 south, next to Pa Bard temple to Ban Ke. Project site location, as indicated by PONRE during workshop, is shown below. Coordinates: 15° 7'19.41"N X 105°48'37.85"Ø

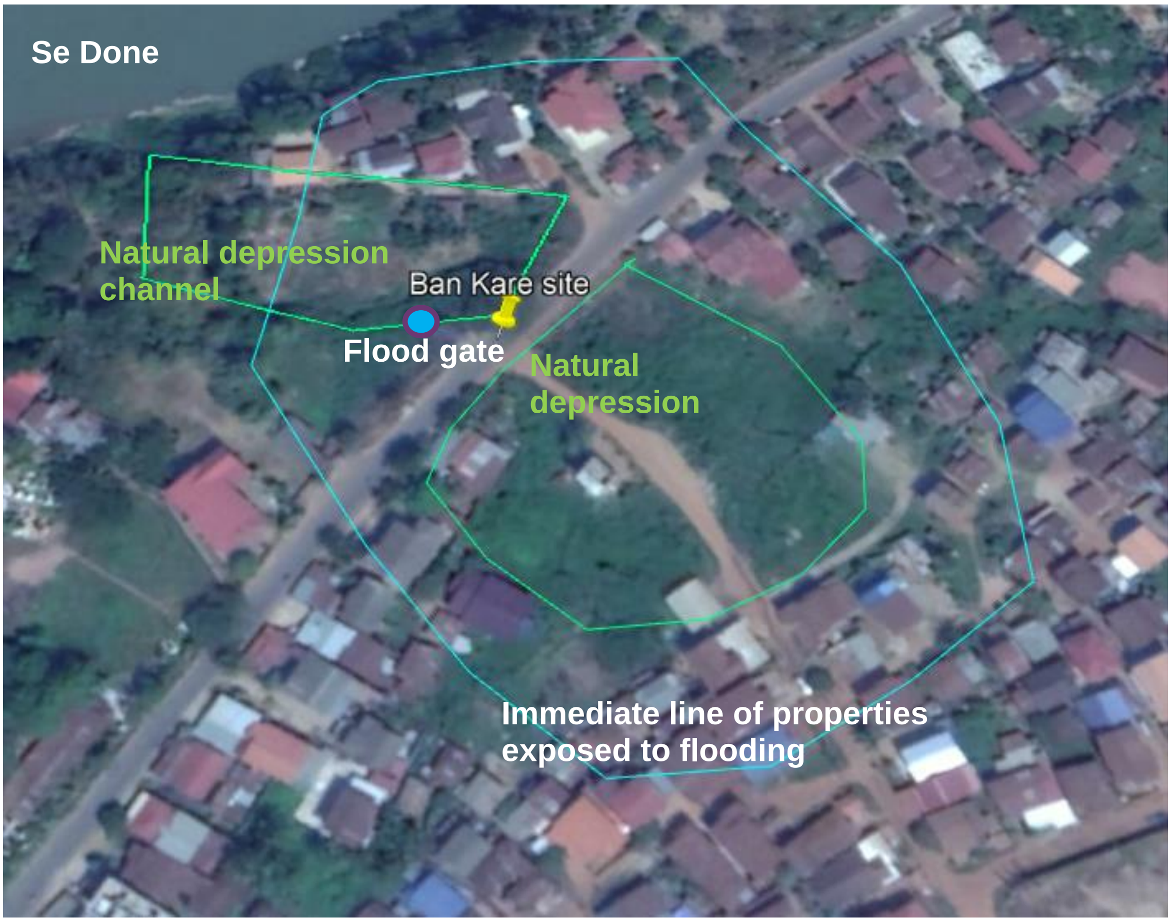
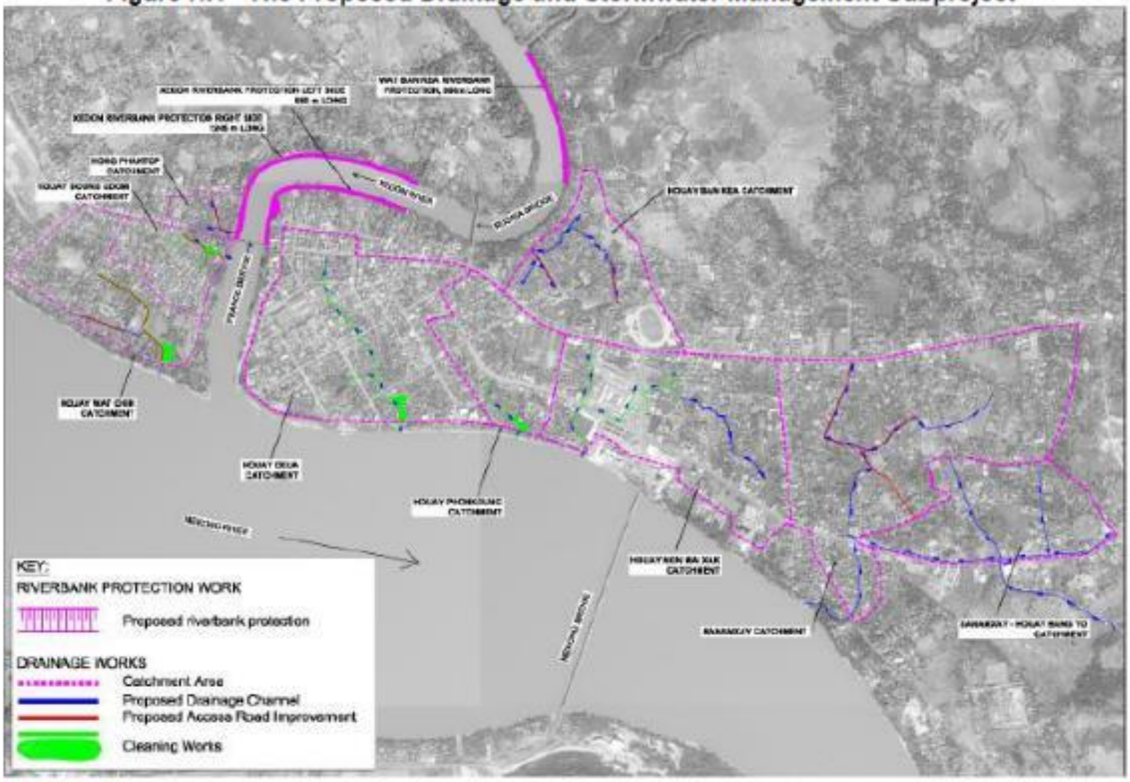


Figure H.1 The Proposed Drainage and Stormwater Management Subproject



2. Background information on the site

The project site spreads across both sides of road embankment – a road adjacent to the national route 13 South stretch. The road separates natural depression on the right side and a natural conveyance channel/depression on the left. Existing flood gate is currently only partially functional, limiting the capacity to proactively regulate the amount of water entering the existing natural depression adjacent to the dwellings and road.

Current use of are is mainly residential, with some plots of small scale agriculture.

3. Description of the flood problem in the area

Flood causes are similar to those experienced elsewhere in sites in Pakse – main causes being rainfall and the limited control over discharging water and controlling water flows, combined with high levels of water in Mekong. The flooding problem in this site os more severe than at Ban Tha Ha. Here a tributary of the Mekong River (the Sedong River) rises by several metres causing extreme flooding over large vast areas.

In the given site, it was observed that the existing flood gate was only partially functional.

Flooding events, with damage to nearby dwellings, are occurring every year, as illustrated by pictures below.


ຫ້ວຍ ບ້ານ ແກ
H. Ban Ke

Flood impacts can be accounted for as follows (as experiences in most times of flooding):

- Family and home appliances impacted - 5% of the total number of families.
- Trees yields impacted - 5 - 10% of the total number of families
- Animals impacted - 10% of the total number of families.
- Crops impacted and damaged - for 15% of households
- The productive area - 20% of the land area.

4. Proposed solution

Proposed solution for the Ban Ke site includes following elements:

- Installation of water pumps and facilities for 2 completed sets of pumps;
- Improvement of the flood gate: site observations shot that flood gate is present however it does not appear to be fully functional;
- Upgrading of the existing road and channel for higher 1.5-2 meters (the national route 13 south, next to Pa Bard temple in Ban Ke), in order to create a barrier. The pumps will serve the purpose to pump the water over the road.

The above measures are desired to be able to improve control over water flows particularly in improving the use of the natural depression in times of high rainfall, and protecting the actively used and inhabited areas, when the water levels in the river are high, and may push water in the channel.

5. Estimated project costs

Rough estimation by PONRE at the workshop indicates estimated costs at USD 1.7 million.

6. Upscaling potential

See description of main site in Pakse.

C.3.3 Additional site 2: Ban Pho Tark

1. Site name and location

The additional site is located in Ban Pho Tark, Pakse District.

Location: 15° 7'59.27"N X 105°48'49.83"Ø

2. Background information on the site

The proposed interventions in the site focus on discharging water from Huay Yang Kham stream from Huang Jiang into the Se Done river as a response measure to the flooding situations. The EBA response is also expected to contribute to drought mitigation and improvement of people's livelihoods.

The project site surround the Huay Yang Kham river/stream and the surrounding 7 villages.

3. Description of the flood problem in the area

The floods occur on annual basis during July - October. The causes for flooding are multiple and include following:

- The flood water is collected from the upper watershed and forests and accumulates in the low land of Huay Yang Kham.
- The water levels in Mekong River in turn push the water back into Pak Huay due to absence of flood gate, and it is above the warning level.
- Water gathers from Huay Jiang, Huay Yang Kham and forest as a consequence of extended rainfall
- Overflow above the Xedon river banks especially in Ban Kare, Hare and Pho Tark in case of Mekong and Xedon high water level

The main causes of flooding include build-up of sedimentation along the mouth of the river. The continued rainfall and water accumulation from the (Huang Jiang and Huay Yangham) streams creates river runoff to create flooding situations in several villages along the river when the water levels+sediment buildup exceed 11.5 – 12 m.

The floods affect 7 villages in the area:

- 413 families in Sichuan, 2,289 people
- 90 families in Nanjing, 517 people
- There were 232 families in Ban Gaya, with 1,382 people
- 233 families in the village, 1,776 people
- There are 79 families in Phat Tak, 632 people
- There were 272 families in Ban Kaeo Village, 1, 751 people
- There are 395 families living in Ban Na Oz, with 2,016 people
- Total 1,714 families and 10,363 people.

As a result of floods, damages to the production, livestock and fellow forest include damages to 15% of all villagers' crop production and 20-30% of production areas.

4. Proposed solution

In order to support the local villagers and the pursuance of the provincial socio-economic development plan through EBA, it is proposed that following activities are undertaken in the site:

- Develop the drainage system to support the natural discharge during the raining season
- Develop a floating dam so the local villagers can produce during the dry season for the provincial SEDP and sustainability of eco-system
- Improve the existing road and the dyke along the stream to prevent against the overflow

5. Estimated project costs

Estimated costs of the project are at USD 800,000.

6. Upscaling potential

tbc

C.3.4 Additional site 2: Phon Xi Khay/Tao Din Jy

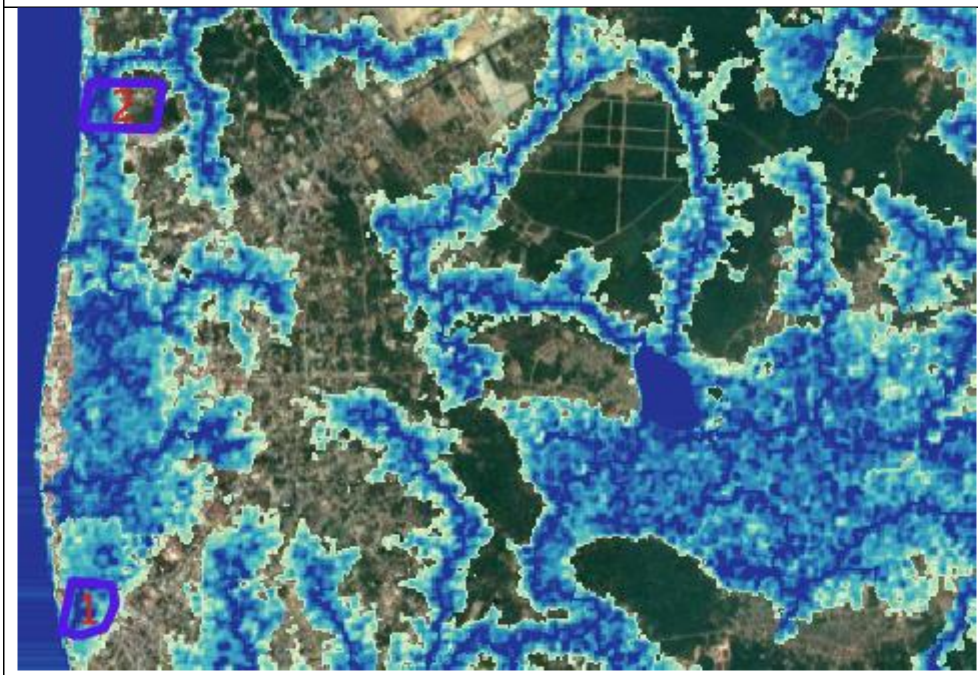
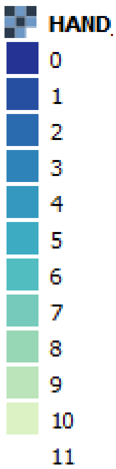
This site was identified during the C4 validation workshop in Pakse Unfortunately no time was available for a comprehensive site visit.

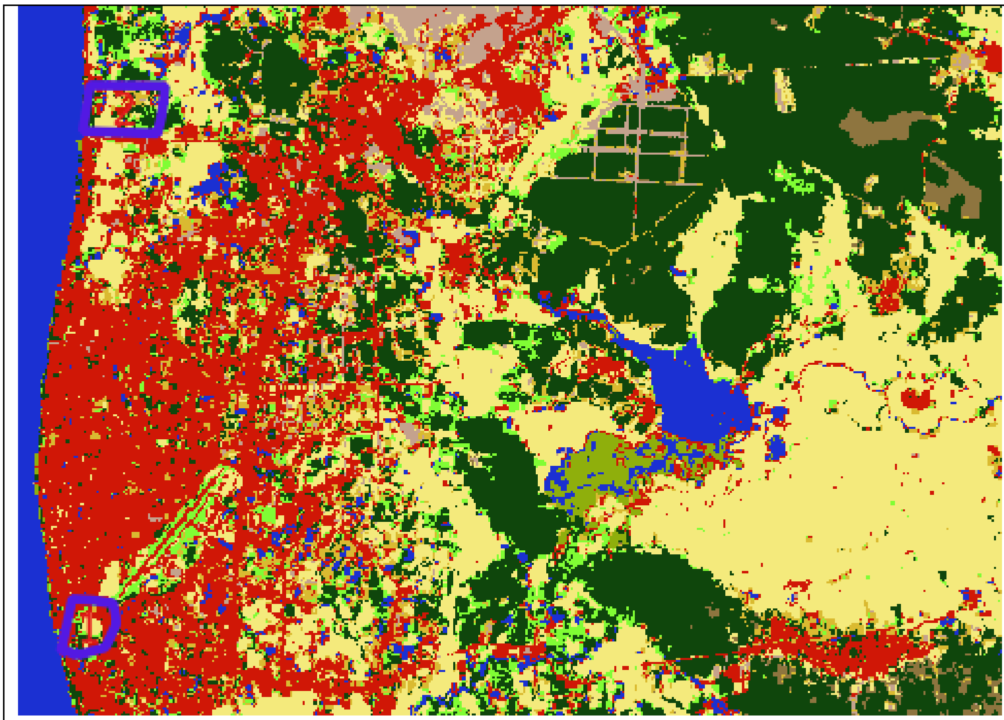
This site was identified during the C4 validation workshop

The flood is severe at this site during the rainy season. The site is located in the peri-urban area of the city in an area that is earmarked for urban development.

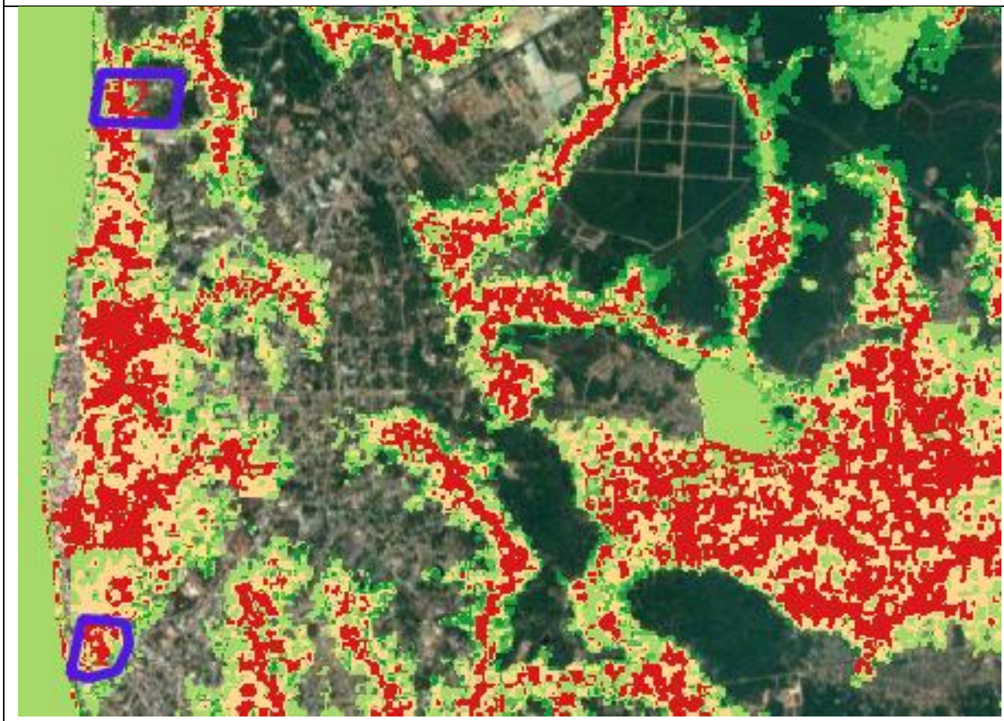
The area already has many natural ponds and earth channels. This a natural pond and an earth canal. These channels drains into a river/creek and then into the Se Done river.

C.4 Kaysome Phomvihane

	Kaysome Phomvihane with sites
	Hazard map 



Land cover classification



Vulnerability map

1. Site name and location:

Huay LongKong, the Thahae village is the proposed main site for the project. The coordinates of the project are: 16°32'36.77"N / 104°44'51.73"E.

Layout of site showing (1), (2) and (3) Housing in the project area, the H. Longkong stream, Mekong, (4) the approximate outline of the adjacent wetland area, (5) approximate location of the flood gate

2. Background information of the site

A large part of the central city drains to the HLK, which starts in a densely populated area. On its way towards Mekong it is met with several tributaries, all transporting sewage in the dry season. The HLK passes large agricultural areas close to the airport and during flooding, the paddy areas are flooded, as are parts of the dwellings along the river.

The project site is a lowland that gathers water from the catchment areas upstream. Project site image from lower resolution:

Photos of the site are presented below:

Figure 11-5: Canal north of Road 9W intersection

Figure 11-6: Where Houay Long Kong discharges into an urban stream, south of road 9W intersection

Figure 11-7: The natural stream mentioned in, as seen from the road

3. Description of the flood problem in the area

Flooding in site occurs as a result of two main influences:

- Rising water levels in Mekong
- Heavy rain during the rainy season.

As with so many of the other cities the main cause for flooding is high water level in Mekong, which forces water into the river and prevents a proper draining of the area. There are no immediate plans for establishing water locks close to the river, but it may be considered to install locks further up in the system. The site will provide possibilities for using open areas in the city to provide flood protection and other benefits.

The flooding affects the productive land and agricultural activities in the area.

4. Proposed solution

The proposed solution in this project site involves installment of a green-grey solution to flooding problems. The specific interventions include a combination of:

- Bank stabilization along the stream and restoration activities in the wetlands (green)
- Installation of a flood gate for better management of water flows via improved release-close mechanisms.

5. Estimated project costs

A rough estimation by the PONRE in Kaysome Phomvihane indicates a total budget of USD 1.500.000 for the wetland restoration activities and for the flood gate on the site.

6. Upscaling potential

tbc

7. Unsolved issues

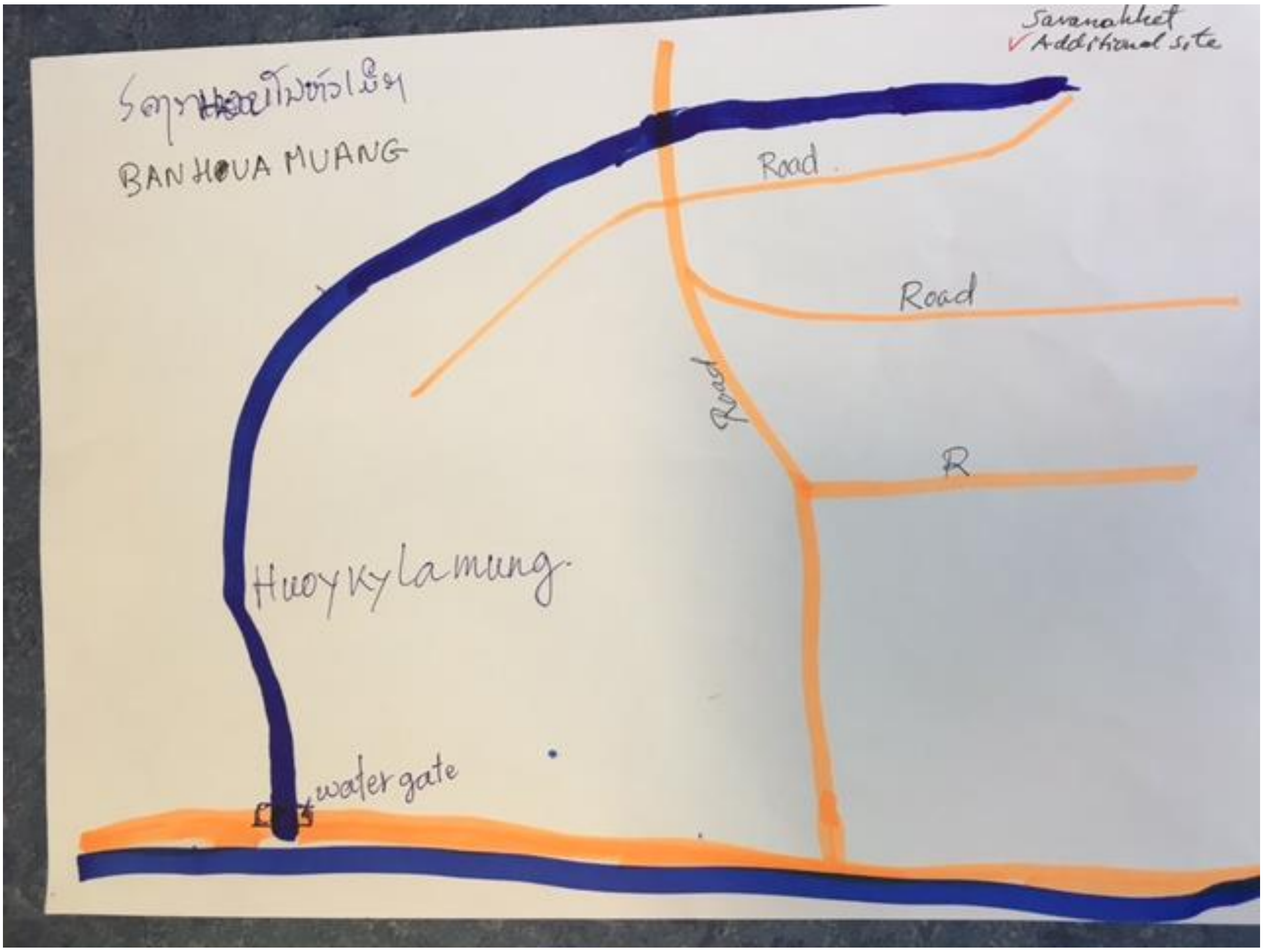
Estimated medium complexity of project implementation as some efforts will be needed for raising public awareness in relation to wetland restoration and protection.

C.4.1 Additional site 1: Huoy Kylamung, HuaMuang village

1. Site name and location

District: Kaisone Phomvihan
Village: Ban Hua Muang Neu

The name of the second site as identified I September workshop is Huoy Kylamung, in Ban Hua Muang. Only schematic drawing available.



2. Background information on the site

(The stream?) is about 4 km long and covers 6 villages. The stream is used as a natural dischanrge course to discharge water from the city to the Mekong river.

3. Description of the flood problem in the area in the site

Floods occur in the rainy season due to high water levels in the river, where the water is pushed back into the stream. In additional to flood problem itself, the floods also cause bank erosion and landslides, both causing damage to the nearby villages.

4. Proposed solution

Proposed measure include a combination of both green and grey approaches, including following elements:

- Restoration and protection of streams to prevent further erosion (EBA)
- Establishment of a flood gate that allows for release-retention of water flows depending on the needs
- Protect and restore ecosystems in the vicinity of the stream

5. Estimated project costs

PONRE estimates project costs at USD 1.1 million.

6. Upscaling potential

tbc

7. Unsolved issues

Tbc

C.4.2 Additional site 2: Huoy Nongdouan, Ban Nakare (Ban NaKea) village project

1. Site name and location

District: Kaisone Phomvihan
Village: Ban Nakare
The name of the second site as identified in September workshop is Huoy Nongdouan in Nakea village (Ban Nakare). The project site is located in the North-West of the municipality.

Location on the map. Only schematic drawing available. The below is possible guess based on schematic but requires verification and specifically identification of the different elements on the map.

2. Background information on the site

The stream is about 6 km long and covers 5 villages. Used as a natural channel for discharging water from the city into the Mekong river.

3. Description of the flood problem in the area in the site

The expansion of the city has resulted in the urbanization and encroachment in the downstream areas, limiting the drainage area which no longer can facilitate the water flows. Floods occur in the rainy season due to high water levels in Mekong which push back into the stream, causing flood damage including landslides/bank erosion along the banks near the mouth of the river. This causes damage to people living in the vicinity of the river.

4. Proposed solution – all these need to be pointed out on project site

Proposed measure include a combination of both green and grey approaches, including following elements, similar to that of the additional site 1. Elements include:

- Restoration and protection of streams to prevent further erosion (EBA)
- Establishment of a flood gate that allows for release-retention of water flows depending on the needs
- Protect and restore ecosystems in the vicinity of the stream

5. Estimated project costs

PONRE estimates project costs at USD 1.2 million.

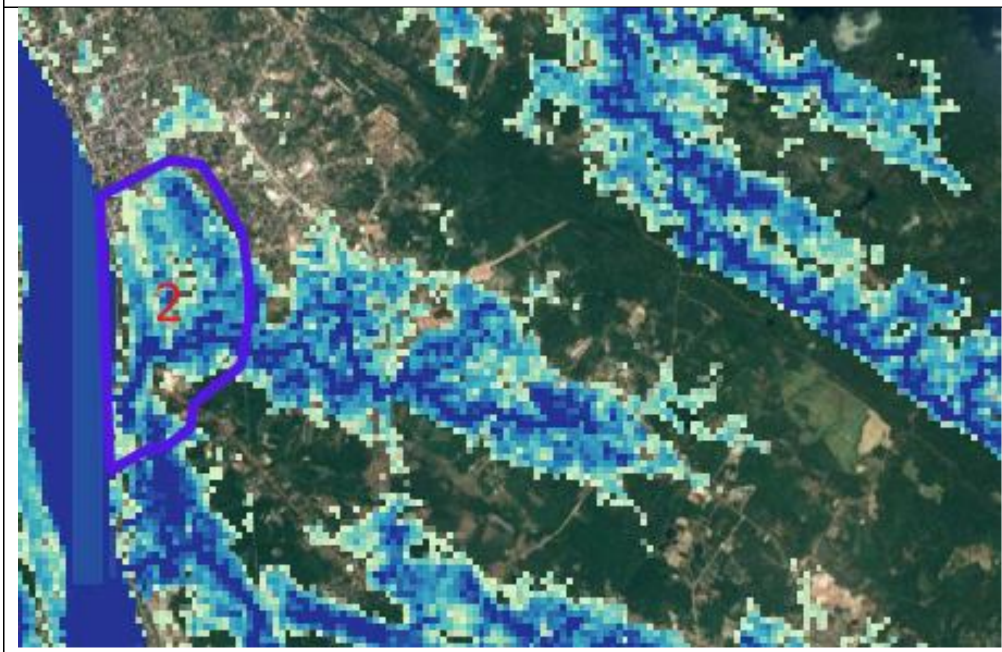
6. Upscaling potential

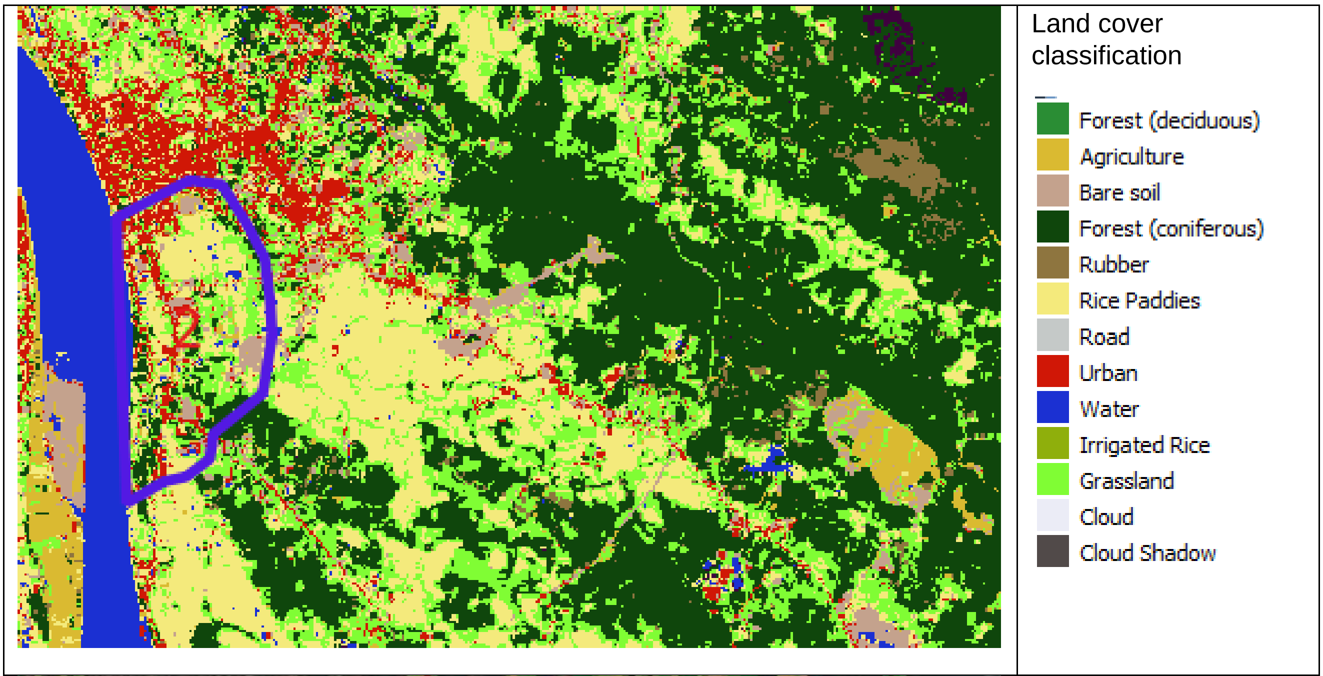
tbc

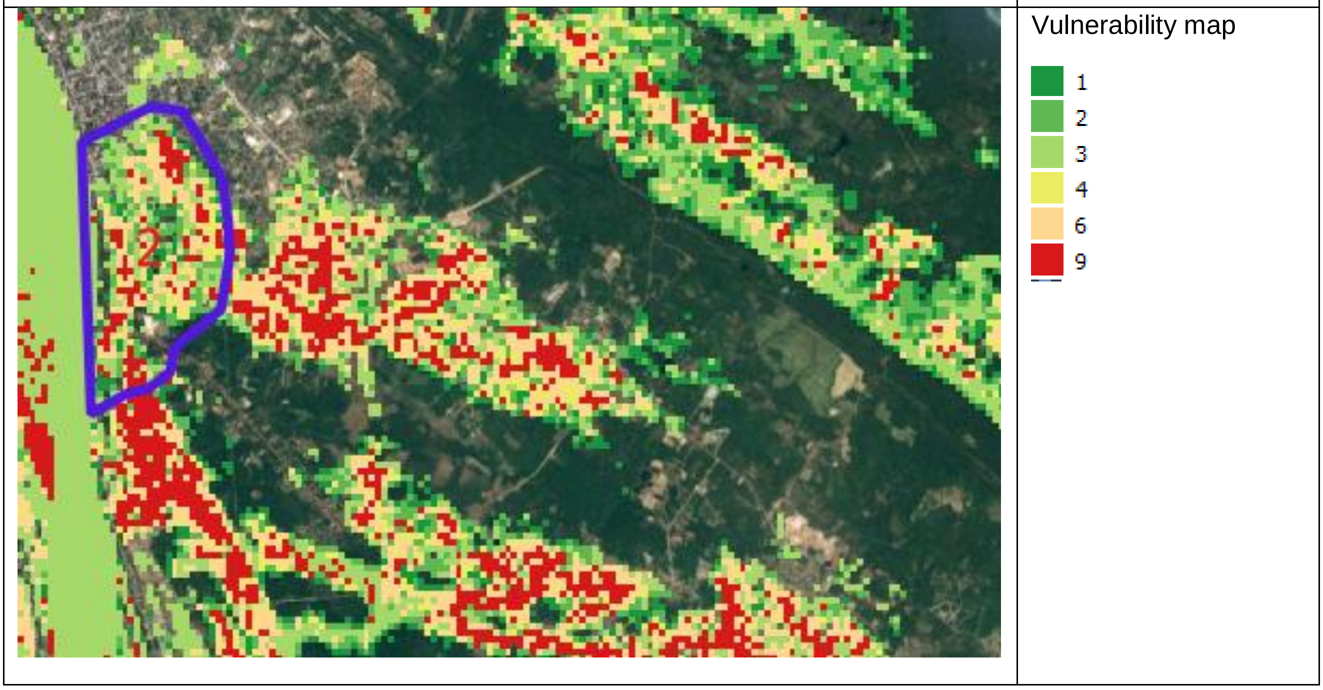
7. Unsolved issues

Tbc

C.5 Thakhek (Khammouan)

	Thakek with sites
	Hazard map





C.5.1 Key site: Nong Bua – Huay Simung

1. Site name and location:

Nong Bua – Huay Simung is the proposed main site for the project in Thakek district, Khammouan province).

The coordinates of the project are: 17º21’5.671”; 104º48’40.87499”

2. Background information of the site

Thakek district is one of 10 districts in Khammouane Province and it is the main city acting as the hub of economic and socio-cultural activities. The total area is 91,800 ha, 91 villages with 4 development clustered villages, 18,448 households, 97,108 people in which 48,743 are female. The density is 105 persons per square kilometer.

The proposed project location (Huay Paksimung) consists of 7 villages including Nong Viengkham, Donkhuan Xang, Lowpo Ngarm, Pakdong, Thakek Tai, Paksimung and Chomchange as the flat areas taking water from Pak Dong village. The proposed site consists of a catchment area in periurban area. It represents a mix of dwellings, roads as well as mixed green areas used for agriculture/grazing and recreation.

Previously Nong Bua area has not been developed, but now there is a project to build a park; Ban Nong Bua Kea has been transforming the original area into a multi-storey golf course and a place for accumulation of minerals and stones for sale. That also has created a drainage barrier for the water flows.

Photos of the site can be seen below:

Figure 11-8: Stream mouth, Houy Simeng

Figure 11-9: Houy Simeng tributary further up in the catchment. This stream floods the temple on the left and a school on the right. Additionally, there are houses directly behind the point where the picture was taken that are flooded twice annually

3. Description of the flood/drought problems in the area

Flooding occurs during the rainy season when the level of Mekong River reaches 13.5 meters above the warning benchmark, in combination with the accumulation of the storm runoff.

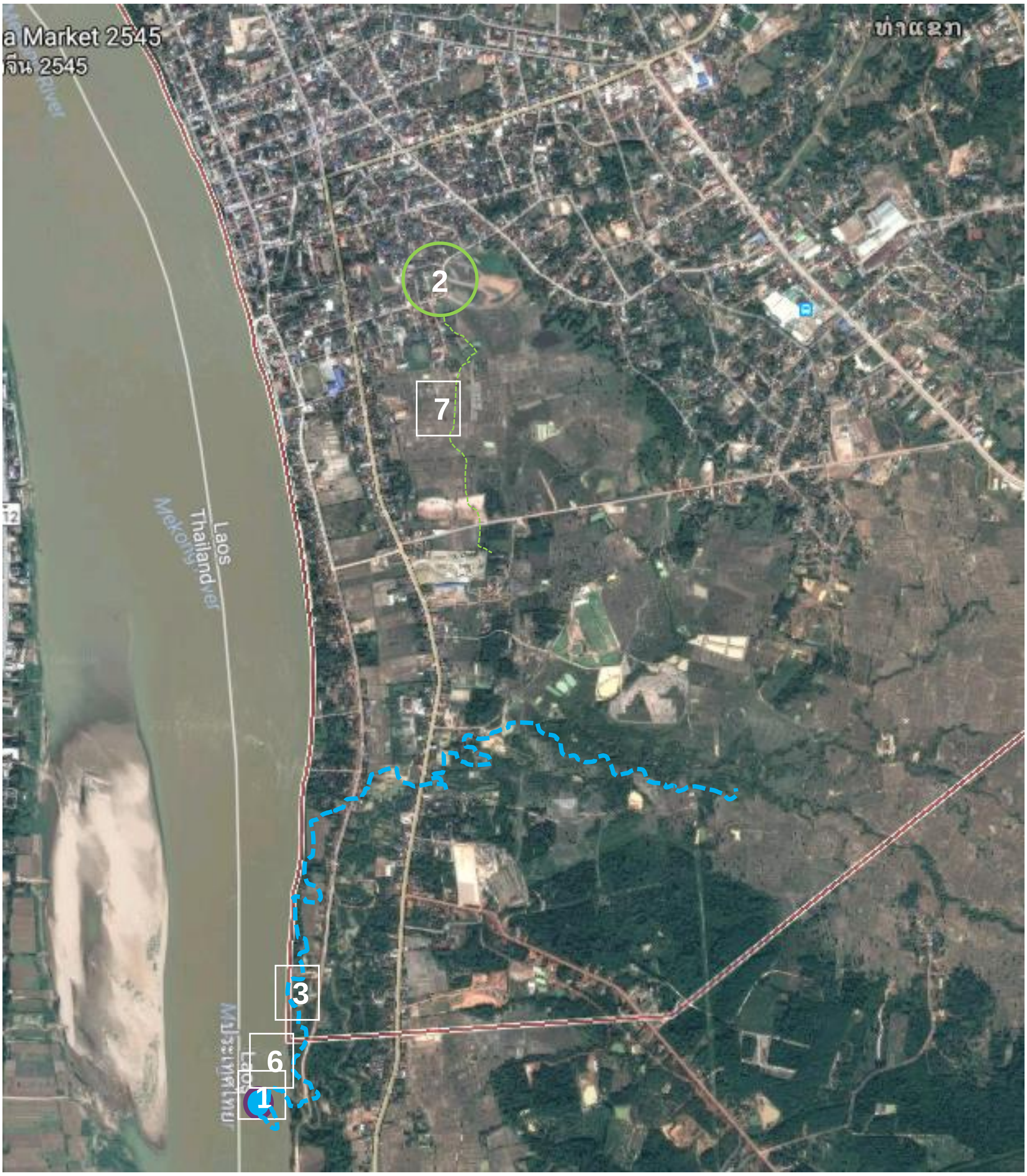
At the same time, there is not water storage during the dried season.

4. Proposed solution

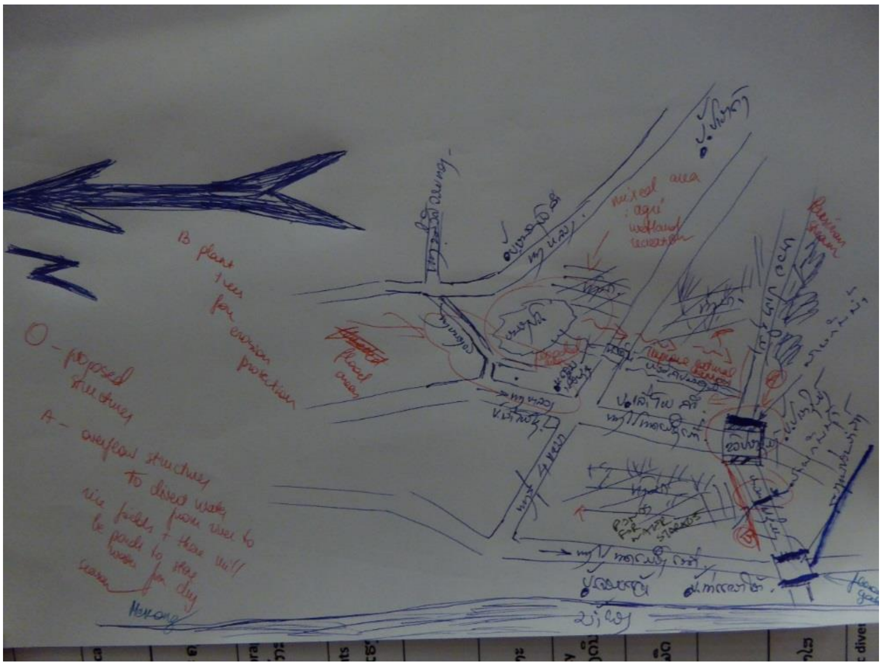
The proposed solution in this project site involves installment of a green-grey solution to flooding problems. The specific interventions include a combination of following elements:

- Installation of 1 floodgate
- Construction of a floating dam
- Improvement of the drainage system
- Construction of two ponds for water storage
- Promoting local villagers to grow cash crops with short intervals
- Planting trees along the river bank inside Huay Paksimung

The proposed overflow structure are to be used to divert the water from the river to rice fields. The proposed ponds are to be used to store water for the dry season.



Proposed flood gate location, (2) wetland and recreational area NongBua, (3) the Huay Simung stream, (5) Diversion structures? (6)Ponds for water storage (7) the natural channel



Unreferenced sketches of the site.

5. Estimated project costs

A rough estimation by the PONRE indicates a total budget of USD 4 million.

6. Upscaling potential

tbc

7. Unsolved issues

Tbc

C.5.2 Additional site - Huag Naly and Huay Nangsord

1. Site name and location

Huag Naly and Huay Nangsord consists of 4 villages including Chomkeo, Chompet, Huay Naly and Na Muang.

2. Background information on the site

None available.

3. Description of the flood problem in the area in the site

Floods occur in the rainy season due to high water levels in the river, where the water is pushed back into the stream. In additional to flood problem itself, the floods also cause bank erosion and landslides, both causing damage to the nearby villages.

4. Proposed solution – all these need to be pointed out on project site

Installation of water pumps for two spots inside the area with flood gate to help discharging water into Mekong River.

5. Estimated project costs

PONRE estimates project costs at USD 1 million.

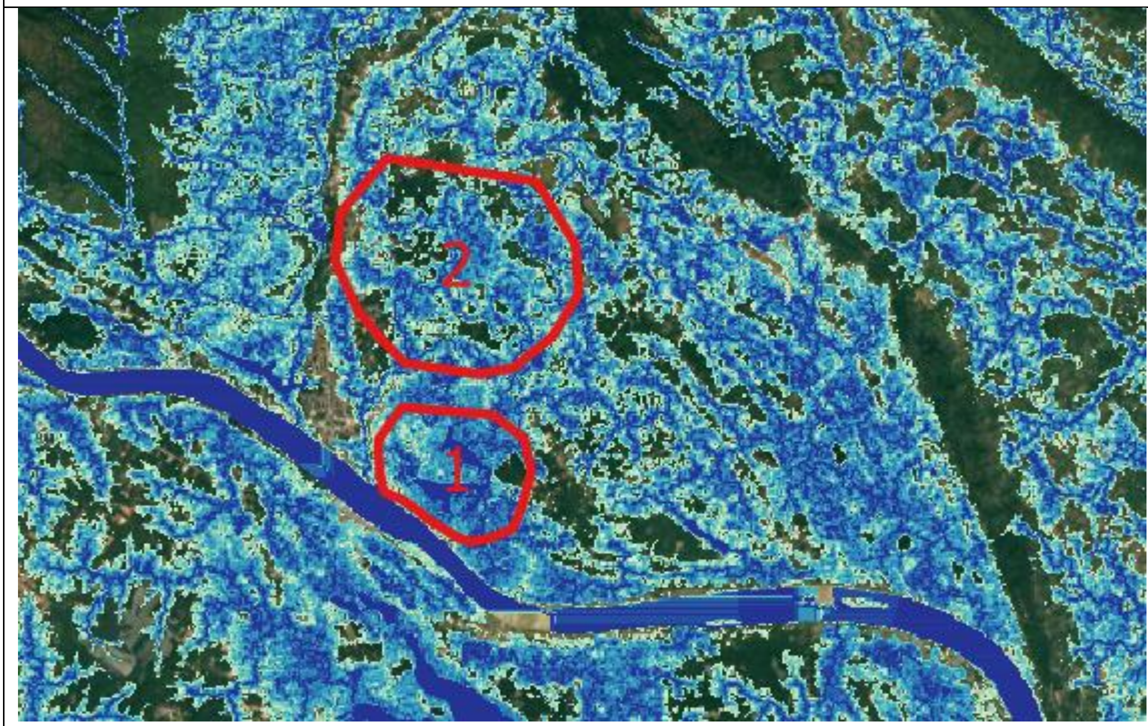
6. Upscaling potential

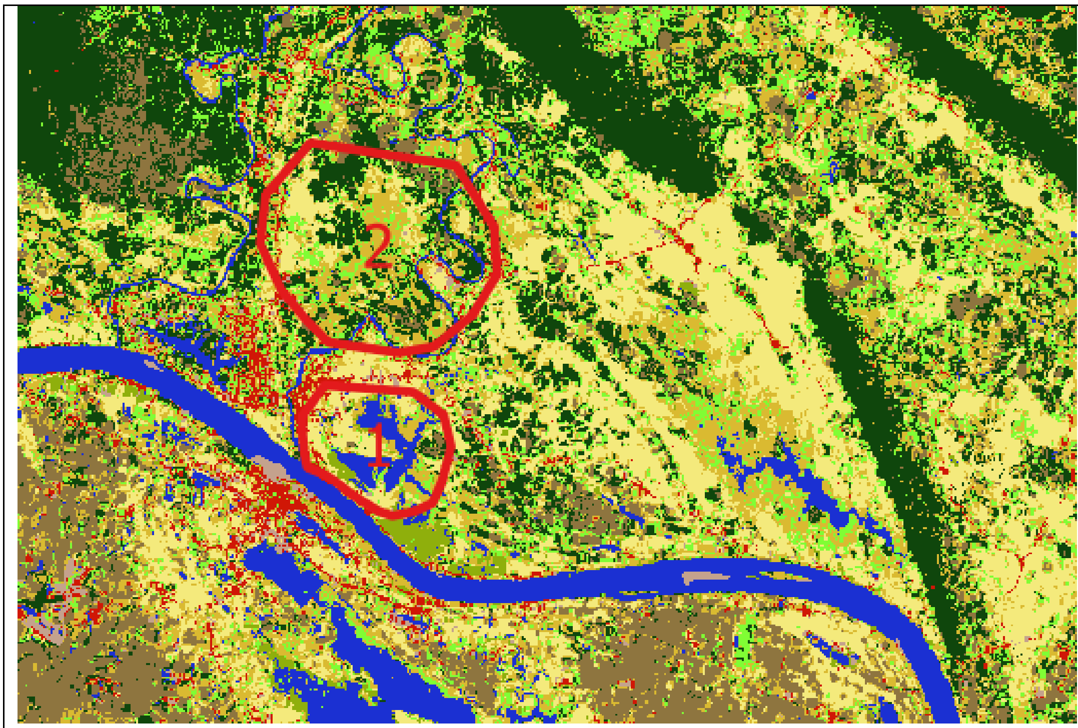
tbc

7. Unsolved issues

Tbc

C.6 Paksan, Bolikhamaxy

	Paksan with sites
	Hazard map HAND 0 1 2 3 4 5 6 7 8 9 10 11

	Land cover classification Forest (deciduous) Agriculture Bare soil Forest (coniferous) Rubber Rice Paddies Road Urban Water Irrigated Rice Grassland Cloud Cloud Shadow
	Vulnerability map 1 2 3 4 6 9

C.6.1 Key site Nong Peung

1. Site name and location:

Province: Bolikhamxay
District: Paksan
Site: Nong Peung

Nong Peung in Paksan district is the proposed main site for the project. The coordinates of the project are: North 18°22'51.60"N, East 103°41'13.93".

The below figure shows flood site location and location of the affected villages:

Layout of site showing (1) the wetland/natural reservoir – suggested location for construction of the pond and planting of the trees – total project area of 2351; (2) approximate location of construction of the dikes and flood gate for flood protection and water harvesting; and (3) Housing in the project area; (4) areas also used for farming (floodplain areas), (5) suggested location for planting trees along the stream for riverbank protection; (6) suggested location for construction of dikes for flood protection.

2. Background information of the site

Nong Peung is located in Paksan District within the area of villages: Paksan, Pak Peung, Sisaard, Mixay, Phoxi, Phonsaard and Nasombo. This covers a total population of 77,770 villagers across 14,137 households. The total area is 2,351 ha.

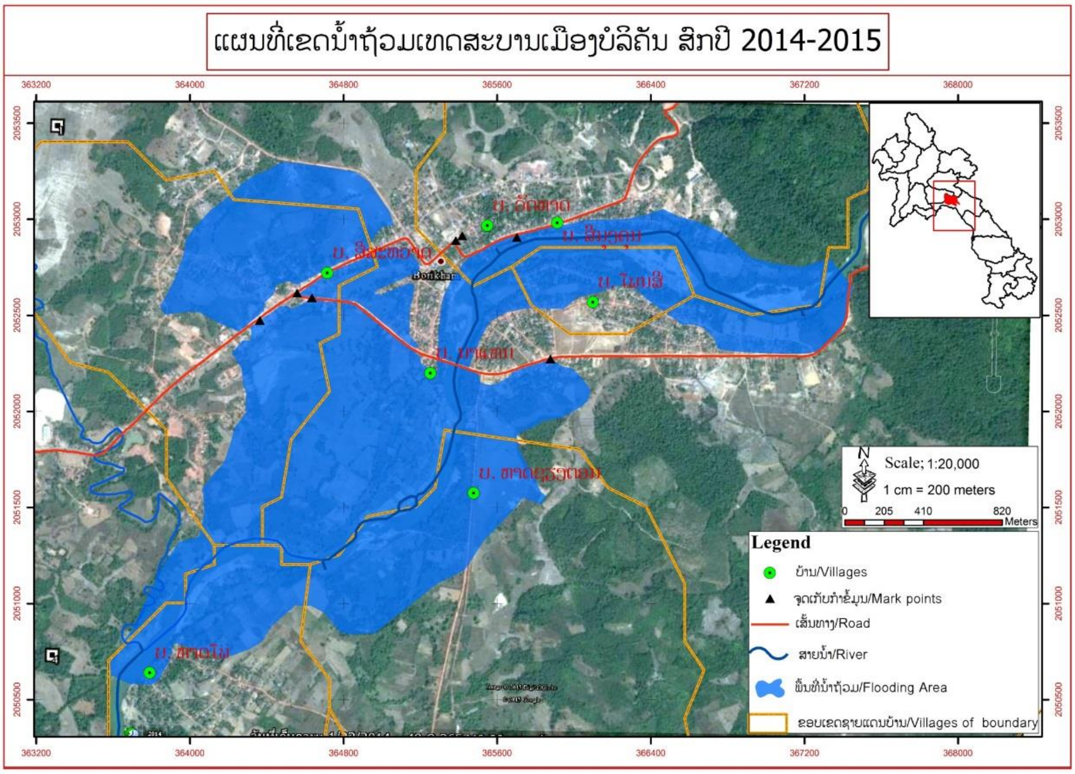
The area includes a natural stream, forming a wetland/ a natural reservoir in the central parts of Paksan, wherefrom stream joins the Mekong River. The reservoir provides water for agricultural production and people.

3. Description of the flood problem in the area

The natural wetland/reservoir provides water for agriculture and specifically for dry season irrigation, but it stakeholders indicate that it is challenging to manage water for the different uses.

Water shortages occur during the dry season, while the area experience floods during rainy season. The main causes of flooding are the rising water levels in the Mekong and NamXan rivers, combined with heavy rainfall. The management of flood waters is further complicated by a poorly functioning flood gate. Previously water could be maintained behind the closed flood gate, but now the malfunctioning flood gate has affected the ability to store water during the dry season. Other management measures to adapt to the dry season have included utilization of cash crops that require little water, along with protection of the trees and plants in the area.

Floods affect local residential dwellings, and other damages include damage to infrastructure (roads, schools) and wells. The below images show flood extent of the area:



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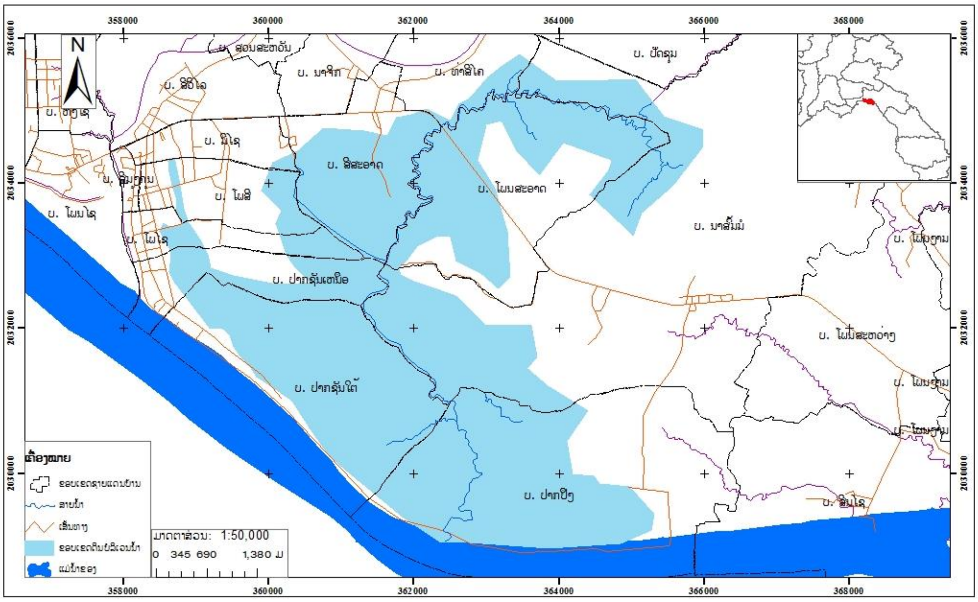


4. Proposed solution

The proposed actions to mitigate floods and droughts on the site include a combination of green and grey measures. These cover:

- Rehabilitation of the natural reservoir, including cleaning activities in the catchment area
- Planting of grass and trees to rehabilitate and help improve the local ecosystem
- Construction of a dyke to help prevent flooding
- Installation of a flood gate to help management of water releases during floods and the dry season

5. Estimated project costs

The estimated project costs are USD 3.2 million.

6. Upscaling potential

tbc

7. Unsolved issues

tbc

C.6.2 Additional site 1: Ban Thabo village

1. Site name and location

Province: Bolikhamxay
District: Paksan
Site: Ban thabo

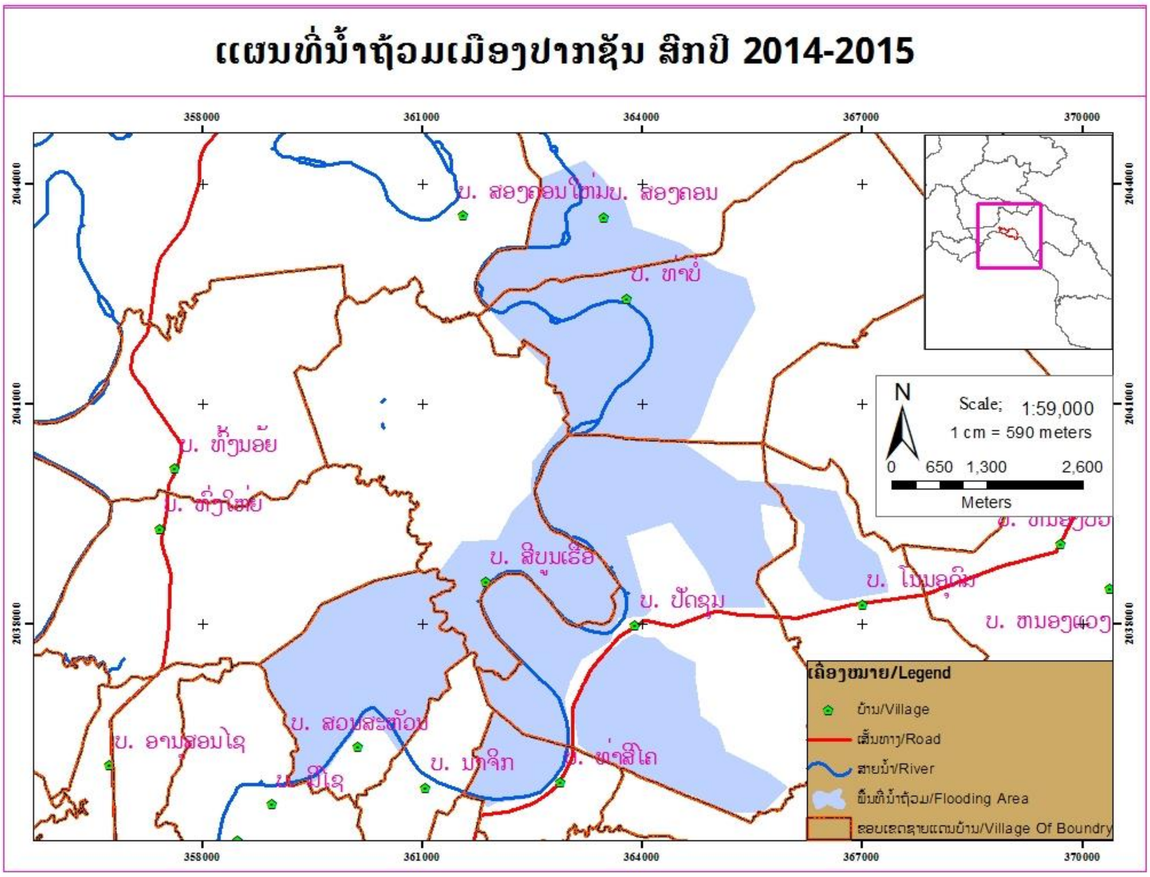
2. Background information on the site

Ban Thabo is one of the villages located along the Nam San River, Paksan in Bolikhamxay province. The area is a low lying area and is home to 132 households with total of 685 people. The majority of people are farmers growing rice and other crops such as cassava, maize, vegetable, rubber, also holding livestock.

3. Description of the flood problem in the area in the site

During the rainy season, Nam San river floods affects people and activities in Ban Thabo. Floods impact agriculture and livestock, as well as damage residential areas (damage to some households).

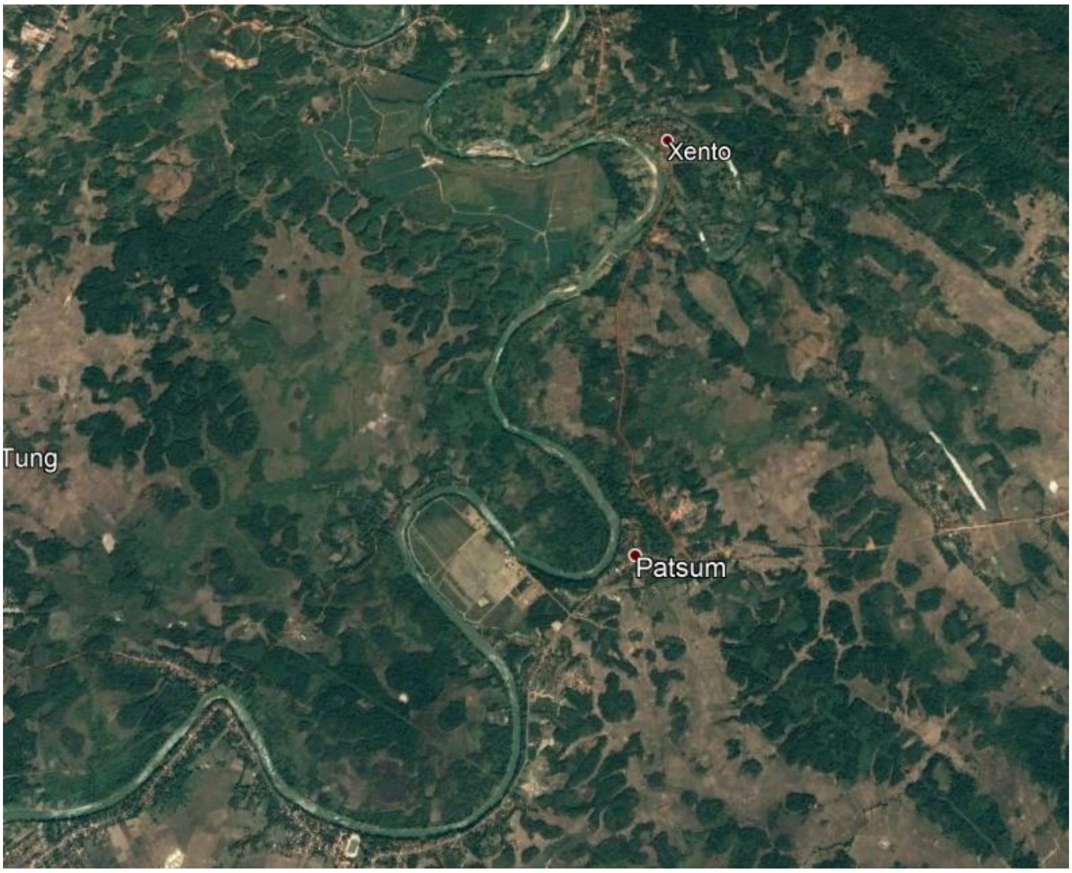
Flood extent in area is presented in image below:



4. Proposed solution

Previous government measures have included surveillance of site, social welfare programs and recovery measures post-flooding such as security measures, health care provision, immediate relief and provision of seeds to farmers. Proposed measures on site include a combination of the following elements:

- Restoration of river banks in the length of 5 km (verify)
- Installation of a flood gate at the location (width of the location 25m).



5. Estimated project costs

PONRE estimates project costs at USD 2.5 million.

6. Upscaling potential

tbc

7. Unsolved issues

Tbc