Building resilience of urban populations with ecosystem-based solutions in Lao PDR

Annex 2: Feasibility Study

Date: June 2019

List of acronyms

ADB	Asian Development Bank
CEEbA	Capacity enhancement to integrate ecosystem-based adaptation
DCC	Department of Climate Change
DoP	Department of Planning
EbA	Ecosystem-based Adaptation
GCF	Green Climate Fund
GDP	Gross domestic product
GEF	Global Environment Facility
GMS	Greater Mekong Subregion
GoL	Government of Laos
HAW	Hamburg University of Applied Sciences
ICEM	International Centre for Environmental Management
ICFMS	Integrated Climate-resilient Flood Management Strategies
IDCRM	Integrated Disaster and Climate Risk Management
INDC	Intended Nationally Determined Contributions
IRAS	Improving the resilience of the agriculture sector to climate change impacts
LBA	Lao Biodiversity Association
LLA	Law on Local Administration
LWU	Lao Women's Union
M-IWRMP	Mekong Integrated Water Resources Management
M&E	Monitoring and Evaluation
MAF	Ministry of Agriculture and Forestry
MONRE	Ministry of Natural Resources and Environment
MPI	Ministry of Planning and Investment
MPWT	Ministry of Public Works and Transport
MRC	Mekong River Commission
NAP	National Adaptation Plan
NAPA	National Adaptation Programme of Action to Climate Change
NDMO	National Disaster Management Office
NSCC	National Strategy on Climate Change
NSCCC	National Steering Committee on Climate Change
NTFP	Non-Timber Forest Product
PDR	People's Democratic Republic
PEI	Poverty Environment Initiative
SEADRM	Southeast Asia Disaster Risk Management
SEZ	Special Economic Zone
SFLM	Sustainable Forest and Land Management
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNDP	United Nations Development Programme
US	United States
UNFCCC	United Nations Framework Convention on Climate Change
VDMC	Village Disaster Management Committees
VDMP	Village Disaster Management Plans

Table of Contents

1 Introduction

1.1 Overview and summary of the feasibility study

The Feasibility Study for the project *Building resilience of urban populations with ecosystem-based solutions in Lao PDR* is structured thematically. The first half, Sections 1–5, describes the background, baseline conditions, past and ongoing initiatives in Laos, and remaining gaps and barriers to climate change adaptation. The second half, Sections 6–12, describes the climate impact modelling and vulnerability assessment conducted as part of the project preparation as well as identification of potential EbA interventions applicable in Laos, including how these assessments have led to the selection of sites and proposed interventions. Sections 11 and 12 present the design of proposed project activities and how they collectively contribute to achieving increased climate-resilient sustainable development in Laos.

It should be noted that the Feasibility Study and annexes contain some references to six cities, namely Luang Prabang, Thakek, Vientiane, Paksan, Savannakhet, and Pakse. The initial studies included analysis for these six cities. As hydrological conditions are more difficult to assess in Luang Prabang and Thakek, these cities presented more challenges in designing specific interventions. Consequently, Luang Prabang and Thakek have been excluded from the proposed project. The main factors informing project design are summarised below.

- Cities along the Mekong River in Laos are vulnerable to climate change, which is expected to result in an increase in the frequency and intensity of extreme events. Extreme rainfall events in particular are expected to be up to five times more severe under future climate change conditions. These cities are located in low-lying areas and have streams that drain into the Mekong River. They are therefore extremely vulnerable to backflow from the Mekong when water levels are high.

- Traditional engineering approaches to flood management are important, however, they do have limitations. For example, there is a risk of locking in infrastructure that does not account for climate change impacts, like fixed heights of flood gates and set drainage capacities. In addition, traditional engineering approaches are often expensive to operate and maintain. In the context of climate change, integrated, distributed solutions that focus on storing and retaining water upstream, attenuating downstream flows and increasing infiltration are needed.

- The implementation of urban EbA interventions in Laotian cities is a viable flood management option because these cities are not yet densely populated and heavily built up. There are also important opportunities to: i) improve land use planning and allocation; ii) preserve stream buffers and wetland ecosystems; iii) demonstrate permeable paving technologies; and iv) plan for the implementation of urban EbA interventions in the future.

- While the implementation of urban EbA interventions is recommended, there are barriers to their adoption in the Laotian context. These approaches are more common in developed countries with high technical capacity and policy frameworks that allow for such approaches. The “room for the rivers” approach in Dutch floodplain management is one example of this. In contrast, there are few examples of urban EbA approaches in Laos and other developing countries, as these approaches require testing and demonstration of interventions. As a result, traditional financing mechanisms from bilateral and multilateral partners have historically favoured hard infrastructure. Laos’ limited technical and financial resources also make undertaking the valuation of ecosystem services challenging.

- A range of projects and country initiatives have been examined to provide lessons and best practices on implementing urban EbA in Laos. These projects include: i) restoration approaches that have been adopted under a project led by the Food and Agriculture Organisation (FAO); ii) drone mapping and land use planning lessons derived from a project by GIZ; and iii) baseline information obtained from Asian Development Bank (ADB) projects. The proposed project was designed through a participatory process which included site visits, engagement with country stakeholders and community-level consultations.

- The methodology for the selection of interventions and sites included an iterative process of: i) identifying potential EbA measures for the Laotian context; ii) physical modelling of areas most vulnerable to flooding in each city; iii) consultations and prioritisation workshops with national and local officials on potential interventions; iv) on-site validation for technical feasibility and safeguard risk assessments; and v) village-level consultations to solicit community feedback.

- Project outcomes, outputs and activities are designed to: i) complement each other; ii) be technically robust; iii) create an enabling environment for monitoring and knowledge sharing; and iv) leverage on existing policy, regulatory, institutional and community frameworks in Laos. The sustainability of interventions is built into the project design, including the examination of opportunities for sustainable financing of EbA.

1.2 Concepts used in the proposal

Integrated flood management

An integrated flood management approach refers to the implementation of a set of complementary interventions that reduce flood impacts. In the context of the proposed project, this set of interventions includes: i) capacity-building activities that consider climate change adaptation as well as mainstreaming EbA into relevant policies in Laos (Component 1); and ii) the implementation of EbA interventions, such as the wetland and stream rehabilitation activities (Component 2), that will enhance the provision of ecosystem goods and services while also providing flood reduction benefits to surrounding communities.

Urban ecosystem-based adaptation

"Ecosystem-based Adaptation (EbA) is broadly defined as the sustainable use of biodiversity and ecosystem services to help people adapt and to strengthen societal resilience against the adverse effects of climate change"[1]*.* In the context of the proposed project, urban EbA refers to the use of ecosystems in urban areas in Laos to reduce flooding and to mitigate the impacts of climate change-induced flooding.

Green infrastructure

"Green infrastructure refers to the interconnected set of natural and man-made ecological systems, green spaces, and other landscape features. It includes planted and indigenous trees, wetlands, parks, green open spaces and original grassland and woodlands, as well as possible building and street-level design interventions that incorporate vegetation, such as green roofs. Together these assets form an infrastructure network providing a wide range of services and strategic functions in the same way as traditional hard infrastructure"[2]*.* In the context of the proposed project, the EbA interventions that will be implemented under

[1] CBD 2009, Doswald et al. 2014, Brink et al. 2016, Huq et al. 2017.
[2] State of Green Infrastructure in the Gauteng City-Region (GCRO 2013). Available at: http://www.gcro.ac.za/media/redactor_files/Green%20Infrastructure%20Citylab%20information.pdf. Accessed on 4 June 2019.

Component 2 — which include wetland and stream rehabilitation — are a form of green infrastructure that will be used to reduce flood impacts while providing a wide variety of economic, environmental and social benefits to targeted communities.

Sustainable urban drainage systems / Low Impact Development

Sustainable urban drainage systems (SUDS) are designed and used to manage rainfall events in a similar way to natural, undeveloped catchments. The primary function of SUDS is to manage stormwater by: i) reducing runoff; ii) filtering water to reduce pollution; and iii) protect water resources from point pollution (such as accidental spills) and diffused sources. Permeable pavements are an example of a SUDS intervention that will be implemented under the proposed project to improve the drainage of public areas in four major cities in Laos, namely Vientiane, Paksan, Savannakhet and Pakse. The drainage solutions will initially be implemented at a small scale to ensure that effective monitoring and evaluation is undertaken. In addition, lessons learned during implementation will be used in the scaling up and replication of permeable paving solutions across other urban areas in Laos. In this Feasibility Study and SAP Funding Proposal, the term SUDS will be used when referring collectively to urban drainage solutions.

1.2.1 Urban Ecosystem-based Adaptation and flood prevention

Urban areas internationally are characterised by large volumes of runoff attributable to impermeable surface areas. In Laos, urban runoff is a major contributor to seasonal flooding in cities. Traditional methods for managing urban runoff are focused on draining rainwater from urban areas by using hydraulically efficient stormwater drainage. While Laotian cities have been designed with stormwater drainage systems, these are frequently undersized and/or in a state of disrepair. While upgrading the stormwater networks in each of the cities with conventional technology would likely alleviate on-site flooding, it would also exacerbate existing surface water quality problems and downstream flooding, including through increased flow volumes and velocities.

In recent decades, international best practice on stormwater management has undergone a paradigm shift towards the use of nature-based solutions for runoff treatment and reduction. Whereas conventional stormwater management practices have focused on rapidly conveying stormwater to nearby rivers, streams and lakes, principles of Low Impact Development (LID) advocate processes of infiltration, retention and attenuation. The objective of LID is to mimic the pre-development hydrology of a catchment by using interventions such as permeable pavements, retention basins and infiltration trenches to reduce and detain runoff from impermeable surfaces. Examples include artificial wetlands, bioswales, bioretention basins and buffer strips. These interventions contribute to mimicking the hydrology of a natural catchment and use ecosystem services to reduce flooding. They are therefore categorised as a form of Ecosystem-based Adaptation (EbA).

Urban EbA reduces flood impacts by managing urban runoff, but also generates co-benefits through provision of other ecosystem services, including *inter alia*: i) improved water and air quality; ii) a reduction in the urban heat island effect; iii) recreational and aesthetic benefits; and iv) increased urban biodiversity. EbA interventions for flood management further provide significant co-benefits through promoting climate resilience (see Section 5 below for further detail on co-benefits).

Urban EbA has a distinct advantage over conventional flood management practices in that ecosystem interventions are inherently adaptable. Moreover, EbA interventions require less maintenance and are generally more cost-efficient than traditional 'hard' infrastructure[3].

1.3 Sustainable Urban Drainage Systems

Sustainable Urban Drainage Systems (SUDS) are the recommended flood management interventions for Laos' urban environment. In addition to the flood control benefits that they provide (see Section 7.3), these systems provide community amenities for recreation and various other ecosystem services.

Because an integrated approach to flood management, including the use of EbA measures for flood control, is an innovative approach within the Laotian context, local institutions would need to be engaged and coordination mechanisms supported in order to integrate flood risk management into: i) local socioeconomic and land-use plans; ii) regulations; iii) protection of stream buffers; iv) updates of local building codes; and v) other interventions to manage local flooding. The engagement of national level-institutions would support upscaling strategies and ensure consistency between national and local approaches to flood risk management. Additionally, opportunities for community involvement in the operations, maintenance and monitoring of interventions should be prioritised. For example, community monitoring committees should be established in each of the four cities, with the mandate of conducting regular monitoring of interventions and relaying collected data and information to the relevant local departments and the national knowledge hub. A local government representative should be part of each committee.

2 Impacts of Climate Change in Laos - Recent climate trends

Climate-induced events such as droughts, floods and storms are already negatively impacting Laos' economy. Losses from floods are particularly severe in Laos. The average annual economic cost of floods from 1981 to 2008 was US$11 million[4], equivalent to 0.18% of GDP in 2008. Another recent assessment found that damages caused by flooding amount to US$50 million every year[5] However, flood costs vary substantially across years and have been much higher than US$50 million in specific years. Modelling of flood costs based on historical data indicates significantly greater economic impacts. The annual estimated losses from flood events are modelled to be 2.8–3.6% of GDP and ~2.7% of the government's total annual spending[6,7]. Indeed, in 2018 floods caused damages of ~US$372 million[8] in Laos, amounting

[3] Doswald et al. (2014) Effectiveness of ecosystem-based approaches for adaptation: review of the evidence-base. Climate and Development 6(2): 185–201.
[4] Mekong River Commission. 2012. The Impact & Management of Floods & Droughts in the Lower Mekong Basin & the Implications of Possible Climate Change.
[5] Estimates of the economic costs of floods vary substantially depending on the methods used to quantify these costs and the scope of loss and damage that they include. For example, some calculations include only physical damage to infrastructure, while others consider agricultural and other livelihood losses as well. These estimates come from the Second National Communication and Post-Disaster Needs Assessment: 2018 Floods, Lao PDR. Available at: https://www.gfdrr.org/en/publication/post-disaster-needs-assessment-2018-floods-lao-pdr. Accessed on: 30 April 2019.
[6] Post-Disaster Needs Assessment: 2018 Floods, Lao PDR. Available at: https://www.gfdrr.org/en/publication/post-disaster-needs-assessment-2018-floods-lao-pdr. Accessed on: 30 April 2019.
[7] Estimates of flood damages can vary substantially, depending on the methods used to quantify damages and the scope of the damages included. For example, some studies include only estimates of the cost of physical damage to infrastructure, while other include agricultural losses and overall damage, or the cost of recovery.
[8] In 2018 alone, flood damages in Laos were estimated at ~US$371.5 million, equivalent to 2.1% of the country's projected 2018 GDP, and 10.2% of Lao PDR's 2018 annual budget in 2018. Recovery needs were estimated at US$520 million, with the highest impacts identified in the transport, agriculture, and waterways sectors. (Post-Disaster Needs Assessment: 2018 Floods, Lao PDR. Available at: https://www.gfdrr.org/en/publication/post-

to 2% of the estimated GDP for the year[9]. Floods of this magnitude are expected to become more frequent because of climate change. Expected economic losses from a high impact flood (occurring on average once every 100 years historically) are 11.7% of GDP. At the household-level, consultations with flood-affected people in Laotian cities have shown that the per-household costs are ~US$1,000, or ~40% of the annual GDP per capita.

The availability of historical temperature and rainfall data is limited for Laos. However, regional data show that throughout Southeast Asia, there have been: i) an average temperature increase of 0.1–0.3°C per decade from 1951 to 2000; ii) a decrease in total rainfall from 1961–1998; and iii) a decline in the number of rain days[10]. In addition, the IPCC Working Group on Asia notes that there is evidence, throughout the 20th century, of the increasing intensity and frequency of extreme weather events on a regional scale. In the Lower Mekong Basin[11] specifically, rainfall has increased in the wet season and decreased in the dry season and floods have become more intense over the past 30 to 50 years[12]. In Laos, historical records indicate increases in rainfall (analyses of observed changes are provided in Section 2.2 below) and increasing temperatures over the past four decades.

2.1 Temperature

Historical temperature data for Laos is limited, with data available from 1970 to 2009[13]. Records indicate a consistent increase in the annual mean temperature in South Asia over the past 40 years. Against this backdrop, the annual mean temperature in Laos has increased by ~0.05°C per year during the period 1970–2010, particularly in the southern parts of the country[14].

2.2 Rainfall

An analysis of rainfall data in Laos' Second National Communication to the UNFCCC indicates an increase in seasonal and annual rainfall in Laos. The rates of increase in seasonal and annual rainfall are 2.0 mm per year and 2.7 mm per year, respectively[15]. This increase in rainfall is linked to a higher frequency of extreme weather events in the region. For example, records show that the number of months with rainfall in excess of 600 mm have increased[16].

A new analysis of observed changes in precipitation in four major cities in Laos has also been conducted for this feasibility study. This analysis shows that the frequency and intensity of rainfall events in the cities of Vientiane, Paksan, Savannakhet and Pakse have increased. In summary, the analysis indicates that across the four cities: i) average annual precipitation increased by 70–216 mm (5–11%) in these cities in the last two decades compared to the

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disaster-needs-assessment-2018-floods-lao-pdr. Accessed on: 30 April 2019.) These costs are expected to be exacerbated by the projected increases in flood frequency, intensity and extent as a result of climate change.

[9] Damages during the 2018 flood events were great because of unusually intense rainfall. Furthermore, the collapse of a dam wall in Attapeu province, coupled with heavy rainfall, caused ~10% of the total damages countrywide.

[10] NAPA

[11] Which includes almost the entire country of Laos and large parts of Thailand, Cambodia and Vietnam

[12] Hijioka, Y., E. et al., 2014: Asia. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros, V.R., C.B. Field, D.J. Dokken, M.D. Mastrandrea, K.J. Mach, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L.White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp. 1327-1370. Available at: https://www.ipcc.ch/site/assets/uploads/2018/02/WGIIAR5-Chap24_FINAL.pdf. See page 1355.

[13] Lao PDR Second National Communication to the UNFCCC

[14] Lao PDR Second National Communication to the UNFCCC

[15] Lao PDR Second National Communication to the UNFCCC

[16] Lao PDR Second National Communication to the UNFCCC

1980s and 1990s; ii) the greatest increase in precipitation has occurred in the wettest months of the rainfall season, i.e. the time of year when floods are most likely – for example, rainfall in July was 60–81 mm (11–30%) higher in the four cities in the last decade compared to the historical average; iii) the number of days with extreme precipitation has increased; and iv) the probability of extreme rainfall events occurring more frequently has increased. The full results of this analysis are provided below.

<u>Observed precipitation changes in Vientiane, Paksan, Savannakhet and Pakse</u>

Climate changes have occurred over the observed record within Laos. There have been notable shifts in the precipitation profile that have occurred from 1980 to present day. These shifts may also be indicative of future trends. Observational assessment was done using CHIRPS data. This data is not constrained by the need for direct local measurement which is limited in Laos. Based on satellite imagery and *in situ* station data where available, the CHIRPS data set provides a continuous record from 1980 to near present day at high spatial resolution at a daily scale. As it is derived from remote sensed data, the on-the-ground magnitude of extreme precipitation events may be underestimated in areas of complex terrain and where station data are inadequate. The topographical factors that may lead to this underestimate, however, are mostly consistent over time and therefore trends over time in the data are considered to be reliable. The analysis below details the total annual precipitation changes, the monthly shifts, the changes in the magnitude of higher rainfall events and the number of days, and probability of exceedance above significant thresholds for the four cities. Analysis of the shifts in precipitation signal are summarised on a decadal basis to reduce the potential noise in the datasets.

Changes to average precipitation

Changes in precipitation for the four cities indicate ~3mm increase year on year over the 38 years of CHIRPS data. Each of the four cities show an increase in annual precipitation volumes. The largest noted anomaly is in Pakse which experienced +113mm (2000s) and +216mm (2010s) above the climatological means of the 1980s and 1990s. The city with the smallest increase is Savannakhet which rose by only ~70mm/year (Fig. 2.1). Mean annual precipitation for the period 1980–2000 in the four cities was as follows: Vientiane (1,790 mm), Paksan (3,068 mm), Pakse (1,927 mm), and Savannakhet (1,396 mm).

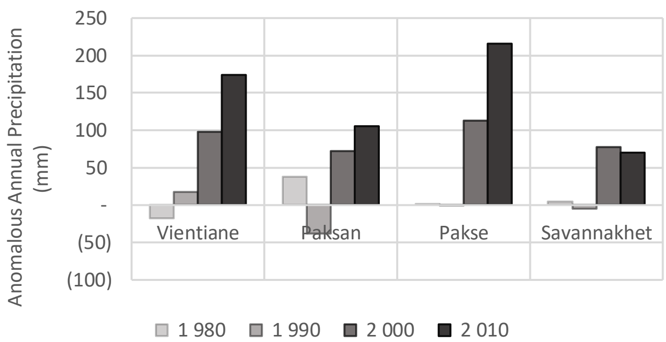
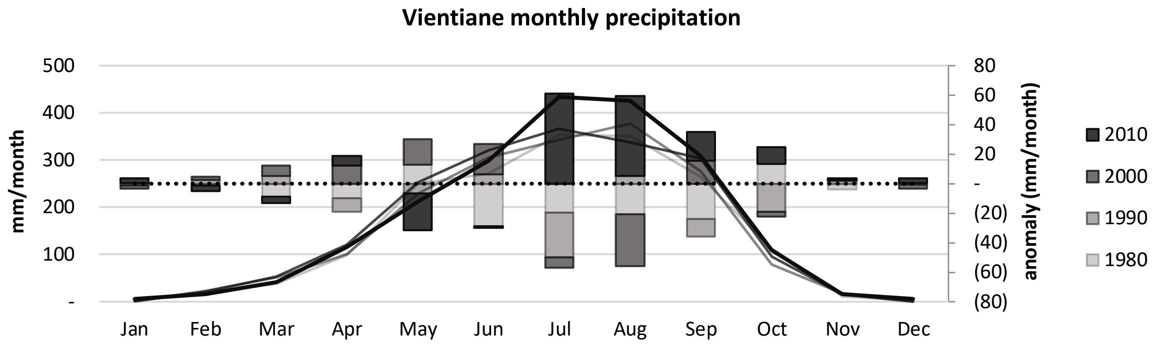
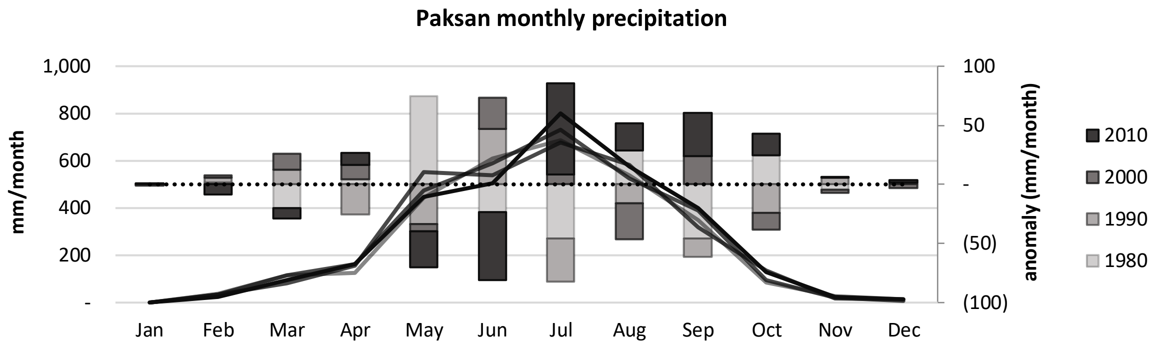


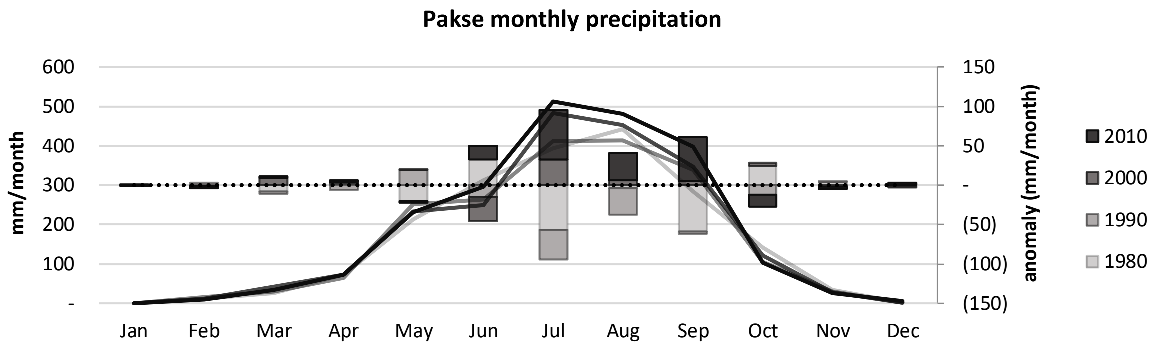
Figure 2.1: Anomalous annual precipitation averaged per decade

Increases in the precipitation profiles were not uniform over all months, rather there is a tendency for larger increases later in the precipitation season. Precipitation follows a similar seasonality as historically but appears to be shifting later into July and August. These months in general are showing large increases in all the cities over the climatological monthly mean.

Vientiane monthly precipitation shows an increased monthly volume for July (~+60mm), August (~+60mm), September (~+20mm), and October (~+5mm) in the 2010 decade (Fig. 2.2). Similar direction increases are present in the Paksan monthly precipitation for July to October (~+75mm, ~+20mm, ~+35mm, and ~+20mm) (Fig. 2.2). For Pakse the monthly precipitation profile trends earlier with an increase noted in June to September (Fig 2.2.). For Savannakhet the monthly precipitation profile is less clear, with July showing a large increased volume of ~80mm/month but other months having much reduced volume changes (Fig. 2.2).







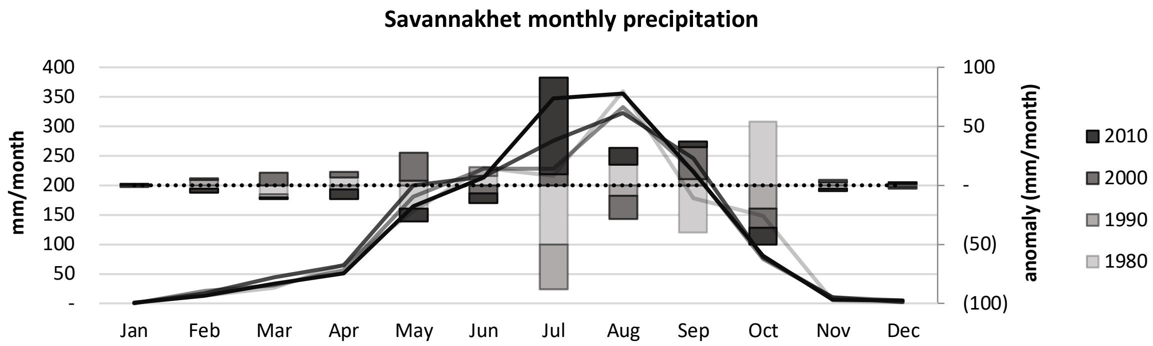
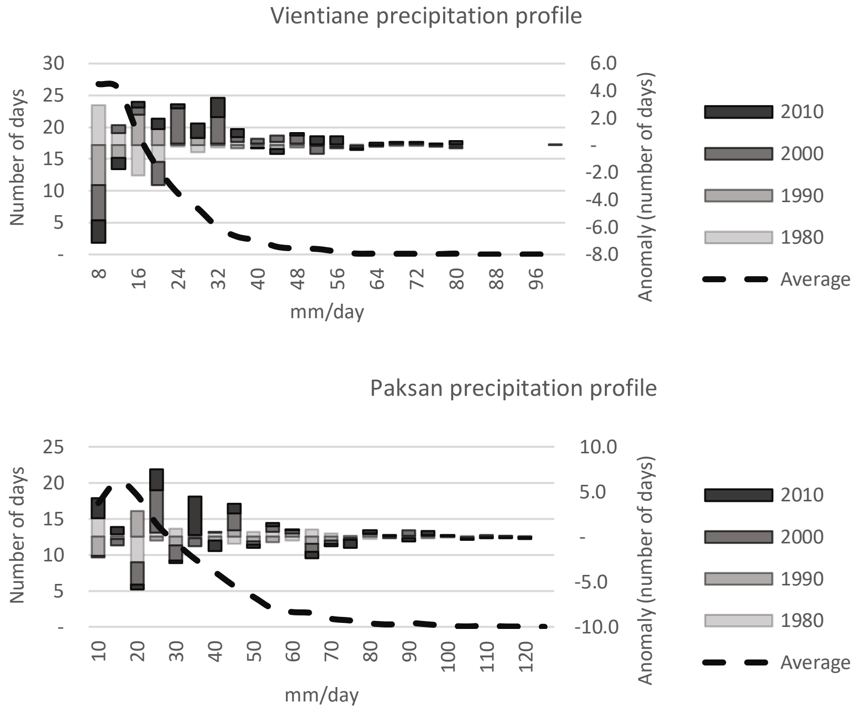


Figure 2.2: Monthly precipitation profiles for the four cities (lines) and monthly precipitation anomalies (bars)

Changes in monthly precipitation volume will be manifest in the frequency occurrence of daily rainfall magnitudes. The lower rainfall total days will contribute the majority of total rainfall days. Flood risk will alter in response to the change in occurrence of the higher magnitude days. Increase in the number of days at the upper end of the precipitation magnitude profile in recent decades are noted for the four cites (Fig. 2.3). This shift towards the larger event days is contrasted by the occurrence decreasing in some of the lower magnitude events, the exception being Paksan (10mm rainfall bin). These shifts will be further expressed in the precipitation intensity changes discussed below.



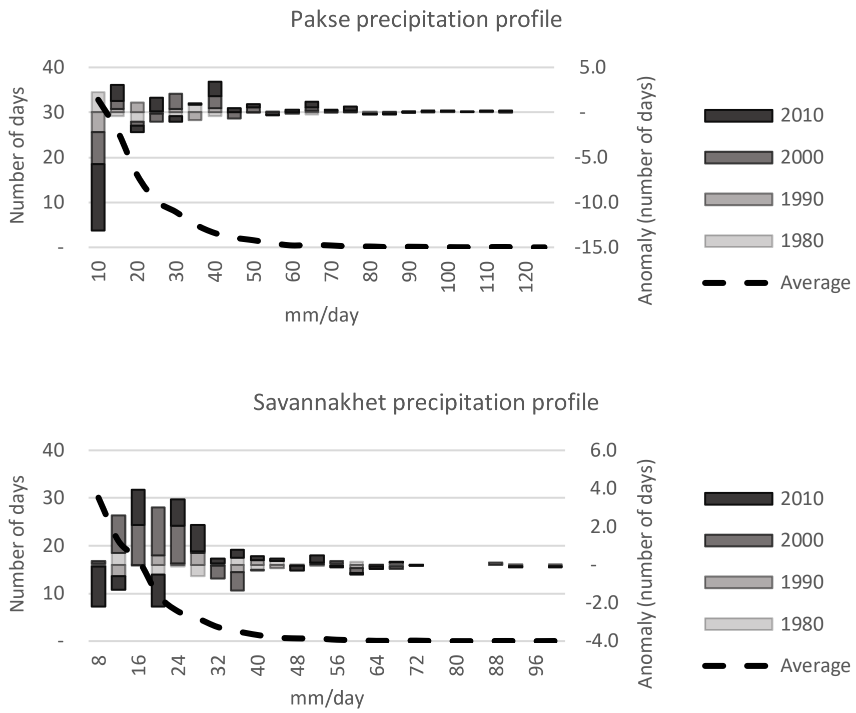


Figure 2.3: Precipitation event occurrence profile (average line), event magnitude shifts (bars)

Precipitation thresholds and intensity changes

Remote sensed precipitation may not always capture the magnitude of the more extreme precipitation events. Assessment of the changes in the 90th percentile precipitation events are therefore used as indicative of the potential shifts towards more extreme events in the precipitation profile. Figure 2.4 below shows the shift in 90th percentile precipitation events per city. The largest increase in recent decades is noted in Vientiane and Pakse with ~2mm/day in the 90th percentile event in 2010. This change is indicative of the shift in the most extreme precipitation events that are not adequately captured by remote sensed data.

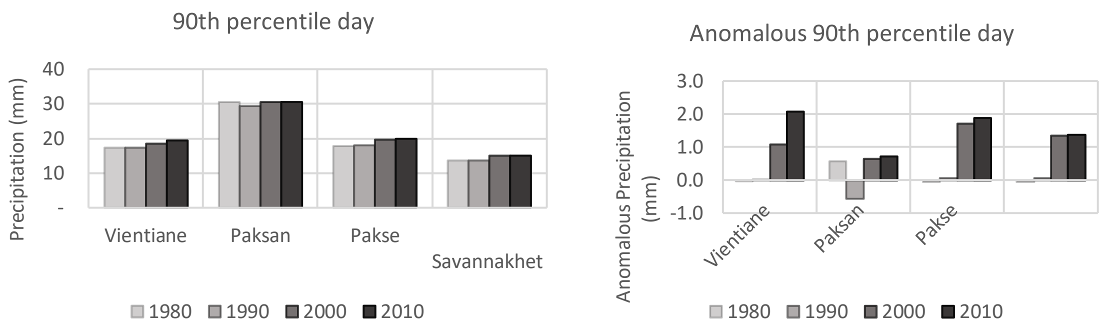


Figure 2.4: Percentile precipitation threshold per city (left) and occurrence anomaly (right)

These changes to the 90th percentile rainfall event volume over the recent decades have increased in magnitude for each city. While the noted increases may have only been in the order of 2mm per event, this incease from the total volume events of ~20mm to ~30mm represents substantial increases to the magnitude of these higher intensity events, i.e. over 10% in Vientiane, ~10% in Pakse and Savannakhet, but <5% in Paksan (Figure 2.5). Effectively, the already high volume precipitation events have increased, in some cases by as much as 10% from the volumes occuring in the 1980s and 1990s.

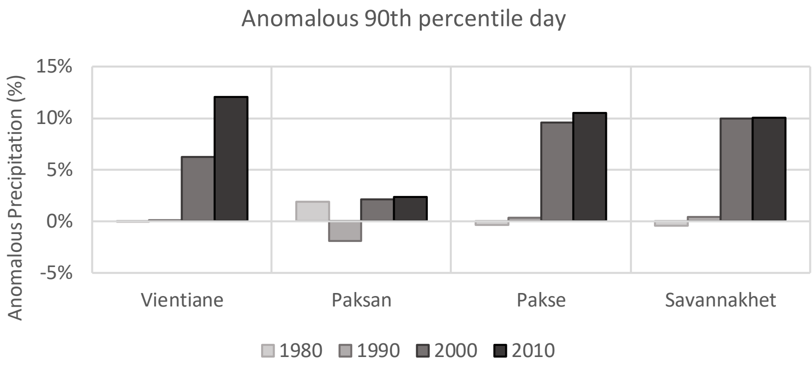


Figure 2.5 Change in precipitation for 90th percentile days

The probablity of the extreme rainfall events occuring with increased frequency was assessed for the four cities show shown below. In Paksan the probablility of experencing extreme precipitation events each year is ~55%. The other cities have smaller probabilities of ~30–40% of extreme events occurance. The anomaly from the 1980s to the 2010s, however, is most prominant in Vientiane, Pakse and Savannakhet with an increase in probability of large event return towards the later decades of ~2.5%. These changes are most prominent in the later precipitation months.

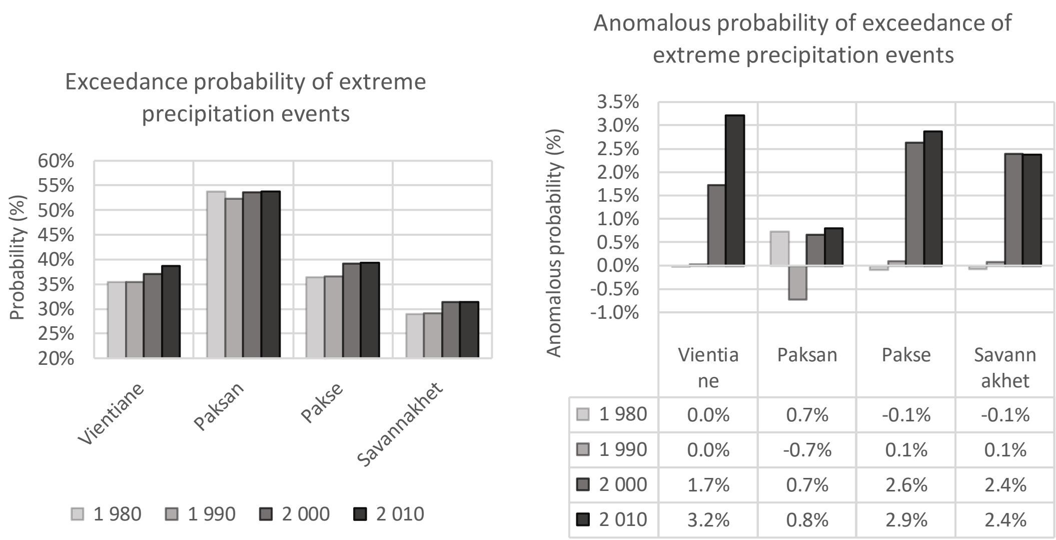
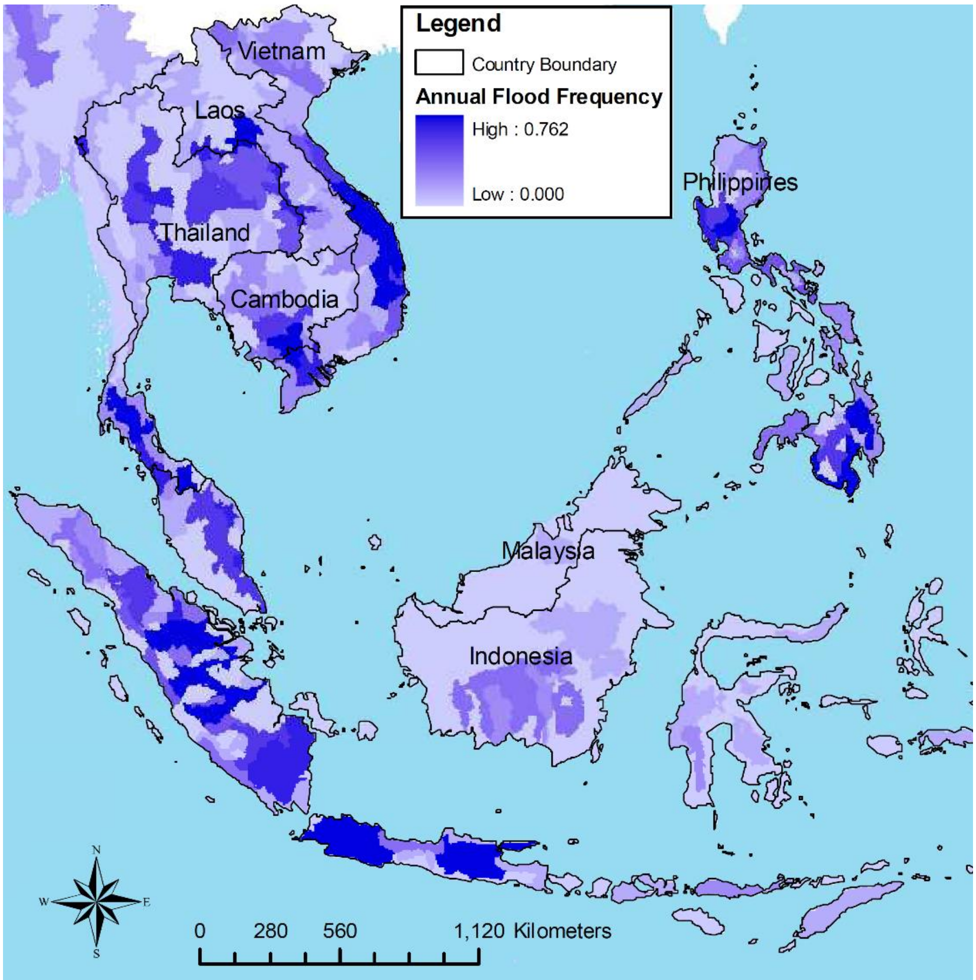


Figure 2.6: Exceedance probability of high precipitation events (left) and the shifted anomaly in probability (right)

Precipitation totals and intensity changes are most prominent in the later part of the precipitation season (July—September). In more recent decades there is more rainfall falling towards the mid and end season which will similarly alter the intensity profiles. Observed precipitation changes are indicative of larger scale climatological shifts that are projected to continue into the future (see Section 6: Climate Impact Modelling).

2.3 Floods

Laos is among the most vulnerable areas to flooding in South East Asia (Figure 2.6), and within Laos the areas along the Mekong River where the major cities are located have the highest flood frequency. Over the last three decades, national disaster statistics indicate an increase in the intensity and frequency of floods in Laos[17]. Thirty-six climate-related hazards of global significance occurred in Laos between 1966 and 2009. Flooding was the primary hazard (see Table 3), followed by health epidemics, storms[18] and droughts. Historical records show that Laos faces serious floods and droughts every one and a half years. Since the mid 1960's Lao has experience 25 floods ranging in magnitude, economic loss, and mortality rates[19]. In the upper Mekong River basin, flooding usually occurs from May to September, during the rain season. The areas located along the Mekong River and its main tributaries are most at risk of flooding. In addition, floods occur annually within much of the Lower Mekong Basin and biannually in the central and southern parts of the country[20].



[17] NAPA
[18] most storms resulted in floods
[19] Center for Excellence in Disaster Management and Humanitarian Assistance, 2017. Lao PDR Disaster Management Reference Handbook.
[20] NAPA

Figure 2.6. Flood frequency map (event per year for the period 1980–2001)[21] .

Table 3. Major floods in Laos from 1996 [22] to 2013[23] and 2017[24]

Year	Area	Description
1966	Vientiane	Flooding lasted several weeks; embankments along river destroyed
1995, 1996, 2000, 2001 and 2005	Laos	42,000–68,000 ha of rice fields destroyed by each flood
1996, 1998, 2003	Central and southern Laos	Extensive flooding
2008	Luang Prabang and Vientiane	Combination of tropical storm and monsoon caused highest water levels in Vientiane since 1913. 6 people killed, 204,190 people affected.
2009	Sebangfai, Nongbok, Mahax	General flood, 10 people killed
2011	Savannakhet, Kammouane	Flash flood, 34 people killed, 430,000 people affected.
2011	Xiengkhuang, Vientiane	General flood, 14 people killed, 37,000 people affected.
2013	12 out of 17 provinces of Laos	A series of five major storm events crossed the country resulting in severe flooding in 12 of the country's 17 provinces. According to a report to the National Assembly, approximately 350,000 people were affected, with 29 stormrelated deaths and 77 reported injuries. Loss and damages were estimated at LAK 2.2 trillion (USD$219 million).
2013	60% of Laos	Unusually heavy monsoon rains, exacerbated by tropical storms, caused widespread flooding in more than 60 percent of Lao from late June through August. Over 350,000 people were affected by floods throughout the country.
2015	Houphan, Bolikhamxay, Khammoune and Luangnamtha provinces	47,800 people affected.
2016	Xayabuly (Sainyabuli) and Louangphabang.	Heavy rain and flooding affected the northern provinces of Lao and Vietnam, where at least 6 people died as a result.

[21] Arief Anshory Yusuf and Herminia Francisco. 2009. Climate change vulnerability mapping for Southeast Asia. Available at: https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/46380/132875.pdf?sequence=1&isAllowed=y. Accessed on: 6 February 2019.
[22] NAPA
[23] Center for Excellence in Disaster Management and Humanitarian Assistance, 2014. Lao PDR Disaster Management Reference Handbook.
[24] Center for Excellence in Disaster Management and Humanitarian Assistance, 2017. Lao PDR Disaster Management Reference Handbook.

2017	Oudomxay, Bolikhamxay, Sekong, Attapeu, Saravane, Champasack, Xayyabuly, Vientiane and Khammoun provinces	Heavy rainfall in Lao between 25 July and 5 August resulted in flooding in several provinces, affecting human life, housing, agriculture and infrastructure. More than 100,000 people were affected and at least 4 people were reported dead

In addition to an increase in the intensity of floods, there has been a notable increase in the extent of areas affected by floods in Laos. For example, the areas affected by flooding increased from less than 1,200 km^2 pre-1992 to more than 2,500 km^2 in 2009. This aligns with the conclusion of the Mekong River Commission (MRC) that extreme flood years have been more common since 1986 and affect more extensive areas of the country[25]. This is corroborated by stakeholder consultations with government and communities which indicate that floods have become more frequent/intense (Annex 12).

Further climate downscaling, flood hazard mapping, and a vulnerability assessment conducted for this project are included in Section 7.

3 Context and Baseline

3.1 Physical and geographical situation

Laos, officially known as the Lao People's Democratic Republic, is a landlocked country located within the Mekong Region of Southeast Asia. It has a total land area of ~236,800 square kilometres (km^2), 20% of which comprises floodplains along the Mekong River[26]. The country is divided into three agro-climatic zones — one of which is the tropical lowland plain and floodplains, situated along the Mekong River and its main tributaries. Features in this zone include the: i) Vientiane plain in the West; ii) centrally located narrow plains in Bolikhamsay and Khammouan; and iii) larger plains of Savannakhet, Champasak, Saravane, and Attapeu in the southern provinces. Mountains in the southern parts of the country influence the climate, for example, through forming a barrier to storms.

Flooding is a major problem in Laos and every year the country experiences flooding in its cities. For example, in 2018 floods caused damages of ~US$372 million[27]. The frequency, intensity and extent of flooding in Laos is expected to increase because of climate change[28]. A vulnerability assessment of six major Laotian cities was conducted for the country, and the findings from this assessment identified the southern cities of Vientiane, Paksan, Savannakhet and Pakse as the primary cities for improved flood management measures.[29] The vulnerability assessment study was conducted through the CTCN and references to this work discusses six cities. However, to clarify, only the four priority cities are included in the current project.

3.2 Climate profile

[25] Lao PDR Second National Communication to the UNFCCC
[26] Lao People's Democratic Republic. 2009.National Adaptation Programme of Action to Climate Change.
[27] In 2018 alone, flood damages in Laos were estimated at ~US$371.5 million, equivalent to 2.1% of the country's projected 2018 GDP, and 10.2% of Lao PDR's 2018 annual budget in 2018. Recovery needs were estimated at US$520 million, with the highest impacts identified in the transport, agriculture, and waterways sectors. (Post-Disaster Needs Assessment: 2018 Floods, Lao PDR. Available at: https://www.gfdrr.org/en/publication/post-disaster-needs-assessment-2018-floods-lao-pdr. Accessed on: 30 April 2019.) These costs are expected to be exacerbated by the projected increases in flood frequency, intensity and extent as a result of climate change.
[28] Further details on the current and predicted climate trends for Laos, as well as the associated impacts, are presented in Section 2 of this Feasibility Study.
[29] Further details on site selection are presented in Section 1.9 of this Feasibility Study.

Laos has a tropical climate, which is influenced by typhoons from the southwest and monsoons from the northeast. The rain season occurs during the summer months from mid-April to October. This is followed by the dry season, which occurs from October to early April. Although 70% of rainfall occurs during the rain season, the climate is characterised by high inter-annual rainfall variability. Floods and droughts are the two major climatic hazards[30] across the country.

Laos' average annual rainfall ranges from 1,300 to 3,000 mm per year[31]. Average annual temperatures range from 20°C in the mountainous areas and highland plateaus to 25–27°C in the plains[32]. In the south of the country, the plains have a moist to dry tropical climate. The average rainfall of the tropical lowland plain and floodplains area is 1,500–2,000 mm per year[33].

3.3 Natural Hazards in Laos

The majority of the Laotian population is vulnerable to climate hazards, particularly floods and droughts. This vulnerability is exacerbated by the dependence of Laos' economy, as well as more than 70% of its population, on natural resources for their livelihoods. Fourteen out of seventeen provinces in the country, including the capital, Vientiane, have experienced floods since 1995. These flood events have adverse impacts on housing, health and education, industrial activities, and infrastructure — including transportation, water and sanitation[34]. One of the economic sectors most vulnerable to climate change impacts, such as increased frequency and intensity of flood events, is the agricultural sector. This sector contributes ~30% to the country's GDP and many Laotians depend on the sector for their livelihoods. Increasing the climate resilience of the agricultural sector should therefore be prioritised by the GoL to strengthen national food security and improve livelihoods.

3.4 Socio-economic context

Laos is a least developed country (LDC). It has one of the fastest-growing economies in the Asia and Pacific region and has been documented as having the 13th fastest-growing economy globally. Despite positive economic growth, poverty remains widespread, and the nation is still classified as an LDC. Extreme poverty — based on the international poverty line of US$1.90 per day[35] — declined from ~18% in 2014[36] to ~13% in 2017.

The total population of Laos is ~7 million people[37]. With a population density of ~31 people per square kilometre[38], it is one of the least densely populated countries in Southeast Asia — ranking 105th in the world. The population is spread unevenly across the country, with the majority of people residing in the valleys of the Mekong River and its tributaries, as well as

[30] Lao People's Democratic Republic. 2000. The First National Communication on Climate Change.
[31] Lao People's Democratic Republic. 2009.National Adaptation Programme of Action to Climate Change.
[32] Lao People's Democratic Republic. 2000. The First National Communication on Climate Change.
[33] Lao People's Democratic Republic. 2009.National Adaptation Programme of Action to Climate Change.
[34] NAPAREF
[35] This is the minimum level of income deemed adequate in a particular country. It represents the international equivalent of US$1.90 in the United States of America in 2011.
[36] World Bank. 2017. Lao PDR Economic Monitor: lowering risks and reviving growth. Available at: http:/ http://documents.worldbank.org/curated/en/677161512735183133/pdf/121960-PUBLIC-LEM-December-2017-final.pdf Accessed on 11 December 2017.
[37] United Nations Department of Economic and Social Affairs. Population Division. World Population Prospects 2017. Available at: https://population.un.org/wpp/Graphs/DemographicProfiles/. Accessed on 6 May 2019.
[38] *Ibid*

around the capital of Vientiane[39]. Approximately 40% of the population is located within urban areas and the annual urban growth rate is ~4%.

To meet the demands of this comparatively high urban growth rate, intensive urban development has taken place over the last decade across cities in Laos. This rapid development has often come at the expense of adequate coordination, strategic spatial planning or investment in infrastructure. The combination of unplanned development and rapid urban growth has resulted in poorly designed urban areas. Furthermore, there has been insufficient integration of the effects of climate change into urban planning in Laos, leading to high levels of exposure to climate risks. Flood impacts, in particular, are expected to become more severe if development continues at the present rate and in the current mode of planning. Importantly, current development does not adequately consider the upstream and downstream factors affecting flooding. Frequently, upstream areas are being covered with impermeable surfaces — such as roads and parking areas — that increase downstream flood impacts, while many buildings are constructed in flood plains. To increase the resilience of urban areas in Laos, integrated and sustainable city planning and development approaches that consider the future impacts of climate change should be adopted.

3.5 Legal and strategic framework

In recent years, Laos has made considerable progress in strengthening and reforming its national policies/strategies and institutional structures — providing the basis for the management and regulation of development. These also perform the necessary function of enhancing environmental sustainability. Recognising the potential impacts of climate change on its main economic sectors, the Government of Laos (GoL) has formulated and implemented several policies and strategies dealing directly with climate change. These policies and strategies are detailed below.

3.5.1 National Strategy on Climate Change (NSCC)

In March 2010, the NSCC was officially endorsed by the GoL. The purpose of the NSCC is "*to secure a future where Laos is capable of mitigating and adapting to changing climate conditions in a way that promotes sustainable economic development, reduces poverty, protects public health and safety, enhances the quality of Laos' natural environment, and advances the quality of life for all Lao people*"[40]. The GoL intends to implement the NSCC in a participatory manner, involving local people and the international community. In turn, the NSCC builds on several other development strategies such as the National Environment Strategy, Forest Strategy, Strategy for Water Resource Development and the National Disaster Prevention Strategy. It has also informed the National Socio-Economic Development Plan for 2016 to 2020. The primary goals of the NSCC are to:

- reinforce the Sustainable Development Goals of Laos, including measures to achieve low-carbon economic growth;
- increase the resilience of key economic sectors of the national economy and natural resources to climate change and its impacts;
- enhance cooperation, strong alliances and partnerships with national stakeholders and international partners to implement the national development goals; and
- improve public awareness and understanding among various stakeholders about climate change vulnerabilities and impacts, GHG emission sources and their relative contributions, and how climate change will impact the national economy.

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[39] The population density in Vientiane was 209 people per square kilometre – nearly eight times higher than the national figure.
[40] Government of Laos. 2010. Strategy on Climate Change of the Lao PDR.

The NSCC intends to achieve these goals by: i) mainstreaming climate change adaptation and mitigation into strategies, programmes and projects at all levels of government; ii) seeking support from international partners for capacity building and technology transfer to support the implementation of adaptation and mitigation strategies; iii) building capacities in government agencies, technical institutions, the private sector and local communities; iv) developing and implementing adaptation and mitigation solutions that are low-cost and have multiple social and environmental co-benefits; v) enhancing innovative financial instruments to ensure optimal implementation of adaptation and mitigation solutions; and vi) increasing public awareness and understanding of climate change impacts to encourage a shift in mindset towards climate-resilient development.

Within the NSCC, priority adaptation and mitigation options are identified for the sectors that are most vulnerable to climate change. These sectors include: i) agriculture and food security; ii) forestry and land use change; iii) water resources; iv) energy and transport; v) industry vi) urban development; and vii) public health. Within the water resources sector, two of the proposed adaptation options are to: firstly, develop reliable early warning systems to reduce disaster impacts through flood and drought risk management; and secondly, integrate climate change measures into current risk management strategies and planning processes.

3.5.2 Second National Communication

The GoL submitted the Second National Communication (SNC) to the United Nations Framework Convention on Climate Change (UNFCCC) on 24 June 2013. This document highlights the country's commitments to addressing climate change and contains following information: i) an outline of the country's national and regional development priorities, objectives and circumstances with regards to addressing the adverse impacts of climate change; ii) an inventory of greenhouse gas emissions as well as opportunities; iii) a description of steps taken or envisaged by the GoL to integrate climate change into development planning; iv) the major climate threats to the country; v) a description of Laos' vulnerability to the identified climate threats, including the most vulnerable economic sectors to these threats; and vi) the adaptation needs of the country, as well as barriers to achieving the adaptation and mitigation targets outlined in the country's NDC.

The adaptation needs of the country are extremely important for long-term development planning under future climate change conditions. Although the GoL's capacity to address climate change has improved since the submission of the First National Communication (FNC), several adaptation needs should be addressed to enable the country's long-term sustainable development, including the need for *inter alia:* i) increased knowledge of the impacts of climate change on the country's economic sectors, particularly the agricultural, water resources, forestry and public health sectors; and ii) enhanced technical and institutional capacity of national and local government to integrate climate change into relevant development policies, revise climate change policies and plans as required as well as access climate financing options. The need for improved urban planning and development is identified as a priority adaptation area for the country.

3.5.3 Land Law

The Land Law[41] was approved by a decree of the president of Laos on 21 October 2003.[42] The objectives of the Land Law are to: i) ensure the effective, legal and sustainable use of

[41] available at: http://www.vientianetimes.org.la/Laws%20in%20English/33.%20Law%20on%20Land_Decree%20(2003)%20Eng.pdf
[42] A revised Land Law is pending approval in 2019.

land in accordance with the country's land use objectives, laws and regulations; ii) contribute to national socio-economic development; and iii) ensure the protection of the environment as well as national borders. The law determines classifications of land use according to sector and assigns different ministries to manage allocated land use within those sectors.

3.5.4 Law on Urban Plans

This law[43] was approved by a decree of the President of Laos on 26 April 1999. The law outlines principles, regulations and actions relating to land-use management and construction in the country. Its purpose is to ensure that relevant policies and laws pertaining to urban planning are adhered to during the urban planning process to develop safe, healthy and sustainable cities. Furthermore, the law highlights the importance of protecting national heritage, architecture, culture, environment and natural resources. The GoL recognises the importance of involving local communities in the planning process and, as a result, future development in Laos will apply a bottom-up approach. Under this approach, submissions from villagers will be integrated into District Development Plans, which in turn will be integrated into Provincial Development Plans. In addition, Decision 37/PM taken by the Prime Minister in September 1999 states that local communities should be involved in the development of water supply and wastewater management systems from inception through to operational stage.

3.5.5 Law on Investment Promotion

This law[44] was approved on 8 July 2009 and replaces the Law on the Promotion of Domestic Investment No. 10/NA (dated 22 October 2004) and the Law on the Promotion of Foreign Investment No. 11/NA (dated 22 October 2004). The Law on Investment Promotion outlines principles, regulations and measures to be followed to promote and manage domestic and foreign investments. In particular, the law has the objective of enhancing the benefits of investment in contributing to sustainable national socio-economic growth and development.

3.5.6 Law on Local Administration

This law[45] was approved in November 2003. The objective of the law is to outline basic principles for the organisation, functions and operational procedures for local administrations in Laos. It applies to administrations at provincial (including cities), district and village level and includes *inter alia* outlines of the: i) authority and duties; ii) roles and functions; and iii) organisational structure of local administrations.

3.5.7 Draft Law on Disaster Risk Management and Climate Change

A draft version of this law was developed in 2016. It will form the overarching legal framework for climate change and disaster management in Laos. The draft law is divided into several parts, *inter alia*: i) Disaster Risk Management and Climate Change; ii) Relief and Recovery; iii) Level of Disaster Risks and Damages and Notification; iv) Investment Promotion into Disaster Risk Management and Climate Change; and v) Encouragement and Public Participation. It defines the challenges of disaster risk management and climate change, followed by opportunities for managing these challenges. Crucially, this law recognises the need for public participation in dialogues and planning processes, as well as the need to

[43] available at: http://www.vientianetimes.org.la/Laws%20in%20English/41.%20Law%20on%20Urban%20Plans%20(1999)%20Eng.pdf
[44] available at: http://portal.mrcmekong.org/assets/documents/Lao-Law/Law-on-Investment-Promotion-(2009).pdf
[45] available at: http://www.vientianetimes.org.la/Laws%20in%20English/49.%20Law%20on%20Local%20Administration%20(2003)%20Eng.pdf

ensure that disaster risk reduction and climate change adaptation measures are gender, disability and culturally sensitive. It also highlights the need to address these challenges in an integrated manner, both across different sectors and at different levels of government i.e. working at the district, province and national level. Furthermore, the law proposes the establishment of a Disaster Management and Climate Change Fund to ensure sufficient and sustainable budgets for implementing the disaster risk reduction and climate change adaptation interventions.

3.5.8 National Strategic Plan for Disaster Risk Management

Disaster risk reduction (DRR) has been identified as a national priority in Laos and therefore the government developed a National Strategic Plan for Disaster Risk Management. The objectives of this plan are to: i) safeguard sustainable development and reduce the adverse impacts of natural disasters on the population; ii) initiate a shift from providing relief support to affected communities after the occurrence of a natural disaster to planning for these events, and implementing measures to reduce the impacts of natural disasters on communities, civil society and the economy; and iii) build the institutional capacity of the GoL to plan for disaster events and improve the coordination between local and national governments as well as community members to reduce the impacts of these events[46].

3.5.9 Lao PDR Nationally Determined Contribution (NDC)

The GoL submitted its INDC to the UNFCCC in September 2015. It outlines the country's climate change-related actions to date, including the development of the NSCC, and identifies the country's mitigation and adaptation contributions. These contributions are detailed in Table 1 below.

Table 1. Adaptation activities in critical sectors[47].

Sector	Focus of projects and programmes
Agriculture	• Promote climate resilience in farming systems and agriculture infrastructure. • Promote appropriate technologies for CCA.
Forestry and land use change	• Promote climate resilience in forestry production and forest ecosystems. • Promote technical capacity in the forestry sector for managing forests for CCA.
Water resources	• Strengthening water resource information systems for CCA. • Managing watersheds and wetlands for climate change resilience. • Increasing water resource infrastructure resilience to climate change. • Promoting climate change capacity in water resources sector.
Transport and urban development	• Increasing the resilience of urban development and infrastructure to climate change.
Public health	• Increasing the resilience of public health infrastructure and water supply systems to climate change. • Improving public health services for CCA and coping with climate change induced impacts.

3.5.10 Eighth Five-Year National Socio-Economic Development Plan (NSEDP 2016—2020)

[46] Disaster Prevention and Control Committees (DPCC) have been set up at the national and village levels to contribute to this process.
[47] Government of Laos. 2015. Lao PDR Intended Nationally Determined Contribution.

The 8th NSEDP defines the strategic guidelines for the country's development until 2020 and stresses the need for ensuring environmental sustainability, while promoting economic growth. It highlights the main achievements of the preceding development plan — the 7th NSEDP — before identifying its own objectives, outcomes and outputs. The overall objective of the NSEDP is "*to ensure political stability, peace and order in society".* This includes: i) reducing poverty levels in all areas; ii) graduating from LDC status by 2020; iii) effectively managing and efficiently using natural resources; and iv) enhancing favourable conditions for regional and international integration. The outcomes of the NSEDP are listed below.

- Sustained, inclusive economic growth and reduced economic vulnerability.
- Human resources are developed and the capacities of the public and private sectors are expanded; poverty in all ethnic groups is reduced; all ethnic groups and genders have access to quality education and health services; the unique culture of the nation is protected and consolidated; political stability, social peace and order, justice and transparency are maintained.
- Natural resources and the environment are effectively protected and utilized according to green-growth and sustainable principles; there is readiness to cope with natural disasters and the effects of climate change and for reconstruction following natural disasters.

Under Outcome 3, sustainable rural and urban development is prioritised alongside the integration of climate change risks into strategic and operational plans of critical economic sectors. To achieve such outcomes and their associated outputs, several measures for implementation have been identified, including the: i) development of a financing plan; ii) application of international technology; iii) the promotion of small and medium enterprises; and iv) the development of capacity-building initiatives. The progress of the NSEDP is being monitored and evaluated through the Department of Planning's (DoP)[48] sustainable Monitoring and Evaluation (M&E) Framework that reflects the outcome-based structure of the NSEDP. This M&E Framework will be a tool for identifying lessons learned and incorporating them into future iterations of the NSEDP process. It will also help to: i) formulate and justify future budget requests; ii) make resource allocation decisions; iii) motivate personnel to continue improving planning efforts; iv) support other long-term planning efforts; and v) build public trust.

3.5.11 Climate Change Action Plan (2013—2020)

The GoL has developed climate change action plans for the period 2013–2020 to define mitigation and adaptation actions in the sectors of: i) agriculture; ii) forestry and land-use change; iii) water resources; iv) energy; v) transportation; vi) industry; and vii) public health.

3.5.12 National Adaptation Programme of Action (NAPA) to Climate Change

The Laos NAPA report, released in May 2009, presents a comprehensive overview of existing environmental, economic and social conditions, current and predicted climate change impacts, as well as the overall framework for the NAPA process. This includes the identification of immediate and urgent needs for CCA and the barriers preventing implementation. The barriers identified include: i) limited coordination and cooperation among sectors; ii) weak institutional structure; iii) low levels of public awareness on climate change matters; and iv) limited budget available to implement the priority adaptation activities identified in the NAPA. In total, 45 priority interventions — totalling US$ 85 million — have been identified for the four priority sectors for CCA, namely agriculture, forestry, water resources and public health. The priority interventions for the water sector are outlined below.

[48] within the Ministry of Planning and Investment (MPI)

- raising awareness on water and water resource management;
- mapping of flood-prone areas;
- establishing an early warning system for flood-prone areas and improving and expanding meteorology and hydrology networks as well as weather monitoring systems;
- strengthening of institutional and human resource capacities related to water and water resource management;
- surveying of underground water sources in drought-prone areas;
- studying, designing and building of multi-use reservoirs in drought-prone areas;
- undertaking conservation and development of major watersheds;
- building and improving of flood protection barriers to protect existing irrigation systems;
- improving and protecting navigation channels and navigation signs; and
- repairing/rehabilitating infrastructure and utilities damaged by floods in agricultural areas.

These interventions are expanded upon in the NAPA report. For each intervention, the project rationale and implementation arrangements are identified alongside the objectives, activities, short-term outputs and potential long-term outcomes.

3.5.13 National Growth and Poverty Eradication Strategy (NGPES)

The long-term goal for Laos is to graduate from the status of LDC by 2020. To achieve this, the GoL adopted the NGPES in 2004. The NGPES is the strategic framework under which all future economic growth and poverty eradication programmes will be developed and implemented in the country. It presents a comprehensive, ecologically sound and strategic approach to national development and poverty reduction — involving all sectors and policy areas. This strategy — which is central to the national development agenda — was developed after an extensive consultative process, involving stakeholders at national, provincial and district levels. Both qualitative and quantitative national poverty assessments were undertaken to identify the most vulnerable groups and districts. In total, 47 districts were identified as being the ‘poorest’, and a further 25 were identified as ‘less-poor’. These findings were used to inform the national sectoral plans developed within the NGPES. The main sectors focused upon include agriculture/forestry, education, health and transport, while the supporting sectors include trade, tourism, manufacturing and energy. Environment, gender, population and capacity building are the cross-sectoral priorities focussed upon in the NGPES. The abovementioned sectors were chosen in consideration for Laos’ development obstacles, needs and opportunities as well as in response to the national poverty assessments. With investment and support in each of these sectors, the GoL expects the following results:

- improved food security, which is perceived as an essential accomplishment for poverty reduction;
- diversification and modernisation of the economy to be brought about by human resource development, together with effective participation by civil society;
- more equal sharing of resources and access to public goods, leading to reduced regional and rural/urban income gaps by facilitating a greater level of national integration; and
- social progress, leading to quality education and healthcare for all, improved status of children, women and ethnic minorities, and other social services.

3.5.14 National Environment Strategy

The National Environment Strategy was formulated to provide the general direction, targets and programmes for ensuring environmental protection up to the year 2020. This strategy aims to: i) implement policies that ensure valuable environmental resources are conserved; ii) manage water and water resources; iii) develop and promote the use of land to ensure rich bio-diversity; iv) develop and promote environmental and social assessment in rural and urban development projects; v) protect historical and cultural heritage; and vii) develop and promote environmental and education awareness.

3.5.15 Forestry Strategy (2005)

The Forestry Strategy provides guidance on the sustainable management and development of forest resources in Laos up to the year 2020. It provides a comprehensive review of the status of the forestry sector, including: i) use and management; ii) an overview of past and ongoing policies and programmes; iii) future challenges; and iv) objectives for sustainable development and management of the forestry sector. The strategy also identifies a range of actions (146 in total) to be undertaken to meet these objectives. These actions include *inter alia*: i) formulating a national land use policy; ii) providing training on sustainable land use and forest resource management to local villages; iii) publicising the location of approved logging sites and annual harvest volumes; iv) establishing sustainable Non-Timber Forest Product (NTFP) harvesting plans; v) promoting agroforestry at the household level; vi) identifying sites for the conservation of tree genetic resources; vii) establishing an inter-sectoral coordination mechanism for effective watershed management; viii) improving the collection, storage and retrieval of information and statistics at both departmental and ministerial levels; ix) promoting participatory, gender-sensitive approaches to improving forestry and the multipurpose management of woodlands; and x) establishing a fund to support forestry development.

Within the Forest Strategy, an indicative implementation framework for each of the proposed activities is outlined, including the responsible parties, main stakeholders, timeframe and potential resource availability. The Ministry of Agriculture and Forestry (MAF) will be responsible for overall coordination, implementation and M&E of the Forestry Strategy, while relevant ministries, local administrative authorities and other stakeholders will manage the implementation of their corresponding actions.

3.6 Institutional Framework

3.6.1 Roles across ministries and agencies related to flood risk management

Non-structural approaches

Land use planning, registration and administration in Laos falls within the mandate of MONRE. The Department of Land Administration within MONRE is responsible for supporting the classification of land according to regions and categories. Specifically, there are four types of regions — urban, rural, specific economic regions and special economic regions. There are also eight major categories — agricultural, forest, water, industrial, communication, cultural, land for national defence and security, and construction land. In addition to these, there are 50 sub-categories. Once land has been classified and allocated, the different ministries manage and administer land use. For example, the Ministry of Industry and Commerce manages industrial land, Ministry of Agriculture and Forestry (MAF) manages agricultural land, the Ministry of Planning and Investment (MPI) manages land allocated to special economic zones, and so forth. MONRE works with these ministries to monitor and report on land use. Land in Laos is leased for up to thirty years and land concessions for foreign investment are leased for up to fifty years.

There is a general understanding that land-use planning is important, considering climate change. However, climate vulnerability and impact assessments — and the integration of these into land use planning — are not done systematically. Landslide and floodplain areas, for example, are usually only considered with project support. In addition, industrial development, construction, and energy requirements are the primary drivers of land use planning processes[49].

One challenge in the country is the apparent disconnect between the socio-economic planning — traditionally led by the MPI — and spatial planning — led by the Ministry of Public Works and Transportation (MPWT) — particularly for urban environments[50]. Socio-economic development plans at the village, district, provincial and national levels are institutionalised to occur in five-year cycles. By contrast, there are no laws mandating spatial planning in the form of provincial, district and village land use plans. The project will address this by including MPI and MPWT, among other relevant agencies, in the Project Steering Committees, both at the national and city-level, as well as by establishing permanent Flood Risk Management Committees in each city. At the city-level, these Flood Risk Management Committees in conjunction with the project steering committees will serve as the coordination mechanisms for developing the Integrated Flood Management Strategies and mainstreaming across different policy areas.

GIZ, through the Land Management and Decentralised Planning project, has been working on introducing the Area Physical Framework (APF) using a landscape approach to planning. These plans are in addition to the current Socio-Economic Development Plans (SEDP) produced primarily through MPI. The APF aims to guide all sectors on the strategic use, allocation, and development of land, instead of having separate maps and frameworks for each sector. Guidelines for village, district and provincial land use planning were issued in 2017 by MPWT also with GIZ support.

Urban planning and development are within the mandate of MPWT. Specifically, the Department of Urban Planning under the Provincial Public Works and Transportation Office is responsible for master planning processes. Urban master plans are available for Vientiane and Pakse. For Savannakhet, a Japanese firm has been engaged to develop the urban master plan for the city. The project will coordinate with ongoing and new master planning processes, should these be initiated during the project implementation period, through the MPWT participation in the project steering committees and integrated flood management strategy formulation.

Other non-structural approaches to flood risk management include early warning and EbA investments. These investments include: i) watershed rehabilitation upstream; ii) catchment management; and iii) wetland, river and stream restoration programmes. Early warning is managed by the Department of Meteorology and Hydrology in MONRE. The World Bank supports investments into the upgrade of observation and monitoring systems and the improvement prediction capacity through projects such as the Lao PDR Southeast Asia Disaster Risk Management Project (2017-2021; US$31 million) and the Mekong Integrated Water Resources Management Phase 1 (2017-2021; US$ 25 million). The Mekong River Commission also supports early warning for floods at the regional level.

Ecosystem-based investments are largely absent in the four cities. Proposals for using natural catchments for flood control appear in master plans and sector analyses but are not financed. The Department of Water Resources (within MONRE) in coordination with the Department of Forests (within MAF) may have a role in leading such initiatives. Currently, the flood management discourse mostly focuses on structural measures or some grey-green measures[51]. In Savannakhet, for example, the ADB supported an area-wide approach in

[49] Discussions with Department of Land Administration, MONRE.
[50] ADB. 2012. Lao People's Democratic Republic: Urban Development Sector Assessment, Strategy and Road Map.
[51] Grey-green measures refer to a combination of hard infrastructure and nature-based solutions to flood management.

Houay Longkong, which involved rehabilitation of the floodgate, canal and bioengineering measures to stabilize stream banks.[52]

Structural approaches

The Ministry of Public Works and Transport is responsible for building flood control and management infrastructure such as drainage canals, floodgates, installation of pumps, dykes and for riverbank stabilisation. Villages are usually responsible for the daily operation and maintenance of the pumps, including the purchase of diesel. In the late 1990s, the Urban Development Administration Authority (UDAA) was created in part to execute ADB urban projects[53]. Changes in governance arrangements have since seen the limiting of UDAA's role to solid waste management and beautification programs. UDAA is also responsible for maintaining and cleaning drainage lines.

3.6.2 Decentralisation, local governance and participation

The national capital city of Laos is Vientiane, situated in the Vientiane prefecture. Laos is further divided into 17 provinces, each of which has its own provincial capital. Each province is subdivided into the administrative levels of districts and villages. Since 2000, the country has been undergoing a process of decentralization called Sam Sang, where strategic development functions are performed at the provincial government level, budgetary and planning functions are at the district government level, and implementation functions are at the village council level.[54] It is under this framework that planning and development takes place. The provincial level consists of provinces and cities, the district level consists of districts and municipalities, and the village level consists of villages.

Spatial planning most relevant to flood risk management is conducted at the city, district or village level. In terms of executive functions, each government ministry is represented at the district and provincial levels. For example, MONRE has the Provincial Office of Natural Resources and Environment (PONRE) within each province and the District Office of Natural Resources and Environment (DONRE) within each district. Coordination across departments and ministries at the provincial level is done through the Provincial Council which is chaired by the Provincial Governor.

Legislation at the provincial level consists of orders, decisions and guidelines from the provincial governor or mayor. Similarly, legislation at the district level consists of orders, decisions and instructions from the district governor or head of municipality. There are also village regulations. In the last two years, Provincial Assemblies were created to pass local legislation. In addition, local courts can adjudicate violations. However, poor enforcement of existing regulations — such as not building on river and stream buffers — by relevant institutions is a major challenge. The project addresses this by demarcating stream buffers with signage and supporting enforcement by MONRE through training.

The decentralization process in Laos has enhanced public participation, although challenges still remain in the public's understanding of institutions, processes and how to access information and engage[55]. Formally established organizations that offer opportunities for

[52] ADB. 2016. Nature-based Solutions for Building Resilience in Towns and Cities: Case Studies from the Greater Mekong Sub-region. Accessed from: https://www.greatermekong.org/sites/default/files/nature-based-solutions.pdf#overlay-context=nature-based-solutions-building-resilience-towns-and-cities-case-studies-greater-mekong-subregion. Accessed on 15 May 2019.
[53] Laine, Elsa. 2015. Urban Development and New Actors in Lao PDR in the Context of Regionalization: Case studies of two border towns. Social Science Research on Southeast Asia. 25: 99-122.
[54] ADB. 2012. Lao People's Democratic Republic: Urban Development Sector Assessment, Strategy and Road Map.
[55] SIDA. 2003. Governance and Participation in Laos.

engagement include the National Women's Union, Lao Youth Union, and the National Front. These are mass-based organisations associated with the Lao People's Revolutionary Party. Water-user associations and village-level groups consulted in the project preparation have nuanced understandings of flood-related issues in their communities and can be important channels for awareness campaigns and promoting behaviour change in resource use and maintenance of small-scale community infrastructure.

3.7 Mekong River cities

Flooding in urban areas generally occurs as a result of the accumulation of excess runoff from large rainfall events[56]. Urban areas near the Mekong River are particularly vulnerable to such flooding for the following reasons.

- Mekong River levels rise during the rain season. This causes river water to flow into urban canals and streams, preventing urban runoff from draining effectively. The interaction of stormwater with high levels of the Mekong River exacerbate flooding.
- Some urban areas are low-lying or on the floodplain alongside the Mekong and other rivers.
- Urban areas have high population densities and many people are therefore exposed to flood risks. Moreover, inadequate spatial planning and enforcement have resulted in urban development occurring in flood-prone areas.
- Urban areas consist mainly of impermeable surfaces which generate large volumes of runoff during rainfall events.

Six major Laotian cities are situated along the Mekong River. Four of these cities will be targeted by the proposed project and these cities are listed from north to south below.

3.7.1 Vientiane

Vientiane is the capital of Laos with a population of 639,601. This city is the major economic and administrative hub of the country. It is located in the floodplain of the Mekong River and is exposed to frequent localised flooding which causes business disruptions and damage to infrastructure. The flooding is exacerbated by poor drainage infrastructure and is expected to intensify with the effects of increasing urbanisation and climate change.

Better planning and implementation — particularly the consideration of wetland ecosystem services and values — are necessary for effective flood management. For example, That Luang Marsh is a 2000-hectare wetland that is a drainage area for Vientiane’s stormwater. However, it has been drained and converted into a special economic zone despite recognition that the wetland ecosystem provided critical flood protection functions. In addition to flood control, the marshes used to provide, among other services: i) fish; ii) water for irrigation; iii) fertile soils for farming; and iv) natural wastewater treatment and other services.[57]

An economic valuation of That Luang Marsh was carried out in 2004 with funding from the World Wildlife Fund. Goods and services provided by the marsh, including flood control, were valued at US$ 5 million per year. Flood control services alone were valued at US$ 2.8 million per year. While flood damages avoided were considered, replacement cost for infrastructure to provide the same services as the marsh were not considered in the valuation[58] which therefore under-estimated the economic value of the wetland.

The Japan International Cooperation Agency (JICA) has been supporting urban development master planning in Vientiane. In 1991, a master plan, feasibility studies and drainage guidelines were developed for the city. These plans were largely reliant on the flood retention capacity of the That Luang Marsh[59]. Other projects on urban development and drainage have

[56] ADB. 2012. Lao People’s Democratic Republic: Urban Development Sector Assessment, Strategy and Road Map.
[57] USAID. 2015. Valuing Ecosystem Services in the Lower Mekong Basin: Country Report for Lao PDR.
[58] Gerrard, Pauline. 2004. Integrating Wetland Ecosystem Values into Urban Planning: The case of the That Luang Marsh, Vientiane, Lao PDR.
[59] Gerrard, Pauline 2004.

been based on this master plan, including investments into the sustainability of the marsh. In 2011, the master plan was updated (see Figure 1), with the functions of the That Luang Marsh still featuring prominently in flood control[60]. It was also around 2011 that the That Luang Lake Specific Economic Zone was established, and the marsh has since been converted into an artificial lake and parts of the lower area have been ponded.

Planning for the drainage infrastructure in the That Luang Lake Specific Economic Zone was insufficient, and the area has experienced flooding. Drainage canals are now being upgraded up to 30 m width to accommodate floodwaters[61]. There are eleven other wetlands in the areas surrounding Vientiane that may offer flood control functions and maintain river flows during the dry season, including Na Khay marsh, Nong Ping and Nong Tha. To improve flood management in the city, the conservation of these wetlands and streams needs to be included in the integrated flood master planning.

[60] JICA. 2011. The Project for Urban Development Master Plan Study in Vientiane Capital. Available at: http://open_jicareport.jica.go.jp/pdf/12023693_01.pdf. Accessed 13 May 2019.
[61] Discussions with Ministry of Planning and Investment, Special Economic Zone Promotion and Management Office. April 9, 2019.

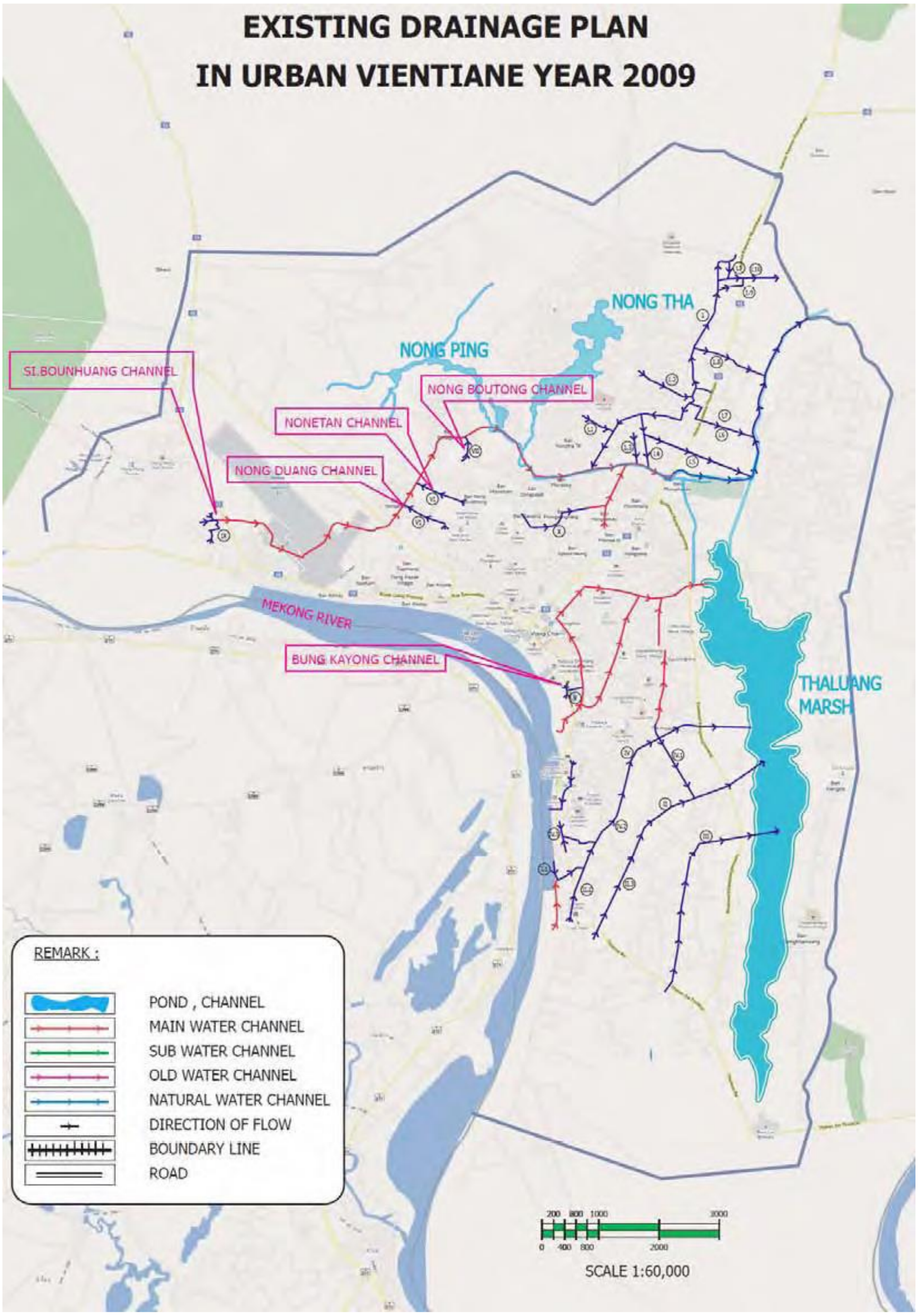

Figure 1: Existing Drainage System in Urban Vientiane Capital from the Vientiane Urban Administration Authority [62].

[62] JICA. 2011. The Project for Urban Development Master Plan Study in Vientiane Capital. Available at: http://open_jicareport.jica.go.jp/pdf/12023693_01.pdf. Accessed 13 May 2019.

3.7.2 Paksan

Paksan (also spelled Pakxan, Paksane, Pakxane) is the capital of Bolikamsay Province and the smallest of the four cities, with a population of 25,805. The city is nevertheless an important hub in the inter- and intra-country transportation network. Paksan is located at the confluence of the Mekong and the Nam San Rivers, which bisects the city. The Nam San River is the main cause of flooding in the city as it overtops its banks during heavy rainfall events. Water flows from the Nam San River in the north, inundating riparian villages. Communities report that sheet flooding occurs and flows southward when the riverbanks are flooded. The Stakeholder Engagement Report (see Annex 12) documents flood damages experienced by communities in Paksan.

A natural flood buffer that reduces rainfall and river flooding is a large wetland in the peri-urban area of Paksan called Nong Peung wetland[63]. However, this wetland is being adversely impacted by land use change. Land uses in and around the wetland include fishing, aquaculture, rice farming, and grazing. North of the wetland, soils are excavated for construction. In addition, the wetland water is used for irrigation for a second annual crop of rice.

While the Nong Peung wetland is not under a formal management regime, there are informal management practices in place such as no take zones for fish during spawning season and village patrols. The Water User Association manages water extraction and pumping from the wetland and user fees go towards the cost of energy. In addition, the Department of Irrigation in the Provincial Agriculture and Forestry Office supports infrastructure maintenance costs. There is no management structure in place to ensure the preservation of environmental flows or the availability of water required to sustain the ecosystem and species in it. This is a big gap in the existing management structure, as the wetland is a listed as a key biodiversity area, supporting migratory birds and endangered fish species.

3.7.3 Savannakhet

Also known as Kaysone Phomvihane, Savannakhet has a population of 91,684 and is the capital of Savannakhet Province. The Second Thai-Lao Friendship Bridge connects Savannakhet to Mukdahan, Thailand, making the area an important economic hub. The city is also part of the East-West Economic Corridor connecting Myanmar, Thailand, Laos, Cambodia and Vietnam. Savannakhet has a cultural heritage area along the river. The city has experienced rapid development beyond the capacity of existing planning processes, largely driven by foreign direct investment and regional integration[64]. As a result, the drainage network of the city is insufficient to prevent flooding of urban areas. In addition, water quality in local canals and streams has been negatively affected by pollutants from the urban environment. A map showing the predicted extent of flooding for the city as a result of climate change is presented below (Figure 2).

The main causes of flooding in Savannakhet are: i) flooding of the Mekong River; ii) periodic intense rainfall; and iii) tropical storms that inundate farmland, temples, houses, markets and other assets. New urban developments, hard paving, infrastructure and buildings that

[63] Locals refer to the wetland as Nong Peung while international sources such as Birdlife International refer to it as the Paksan wetland.
[64] Laine, Elsa. 2015. Urban Development and New Actors in Lao PDR in the Context of Regionalization: Case studies of two border towns. Social Science Research on Southeast Asia. 25: 99-122.

encroach on natural drainage lines and reduction of green spaces further exacerbate flooding [65].

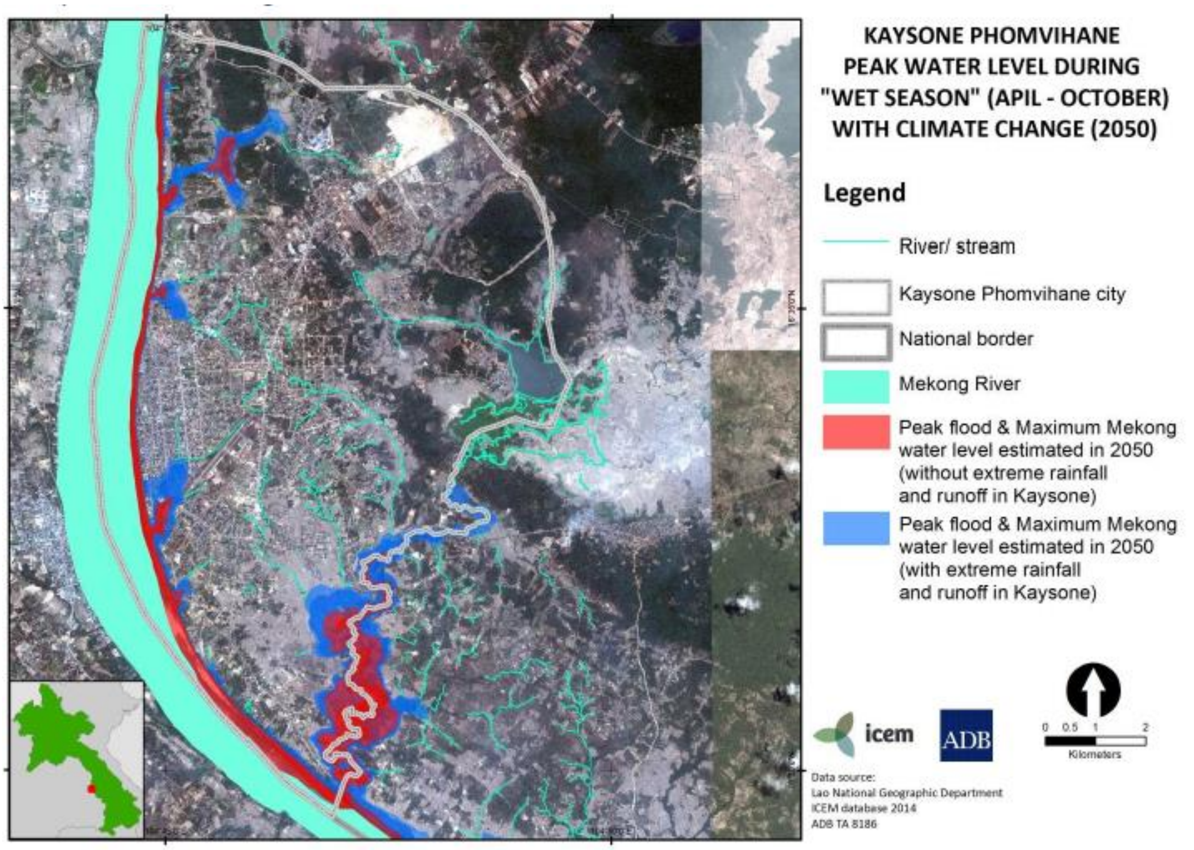

Figure 2. Kaysone Phomvihane (Savannakhet) town showing projected flooding extent (overtopping and catchment rainfall and runoff) with climate change to 2050[66]

One of the most rapidly urbanising areas in the city is the Savan-Seno Special Economic Zone (SSEZ). Established in 2003, it is among the first in the country. Although this has been established for a few years, many lots in the 954-hectare development are still unoccupied and the surface is mostly unpaved. Plans have been made for drainage and wastewater treatment in the area. However, paving of the economic zone may contribute to flooding of downstream areas from increased runoff, if unstudied and unabated. Figure 3 below shows the SSEZ development footprint north of the city.

[65] ADB. 2015. *Building Resilience in Kaysone Pomvihane, Lao PDR*, Volume 7 of the Resource Kit for Building Resilience and Sustainability in Mekong Towns, Prepared by ICEM – International Centre for Environmental Management for the Asian Development Bank and Nordic Development Fund. Manila (TA 8186)
[66] Ibid.

Figure 3. Savannakhet's northward development to the Second Friendship Bridge Area[67]

Urban planning and drainage in the city are supported by Japanese funding and ADB. The project steering committee in the city through PWT, will engage with these initiatives to ensure synergy and to involve stakeholders in the development of the Integrated Flood Management Strategies. The old city center is a heritage area, for which a heritage conservation and land use plan has been developed.

3.7.4 Pakse

Pakse, (also spelled Pakxe) capital of the Champasak Province, is the second largest city in Laos, with a population of 68,093. From 2021 to 2030 growth rates in this city are expected to be around 2.5% [68]. The city serves as an important commercial, services, tourism and transport hub in the south, because it is strategically located near the East-West and Southern Economic Corridors of the Greater Mekong Subregion. Despite a promising location, the city faces development constraints. Situated at the confluence of the Mekong and Xe Don (or

[67] Ibid.
[68] ADB.2011. Technical Note: Urban Development Strategy. Available at https://www.adb.org/sites/default/files/linked-documents/43316-012-lao-oth-03.pdf. Accessed on 13 May 1986.

Sedone) Rivers, much of the city is on low-lying land which is vulnerable to 1-10-year floods (Figure 4). In addition, the steep gradient to the surrounding mountains results in flash floods (Figure 5) and riverbank erosion — which results in the loss of land — is also a significant problem.

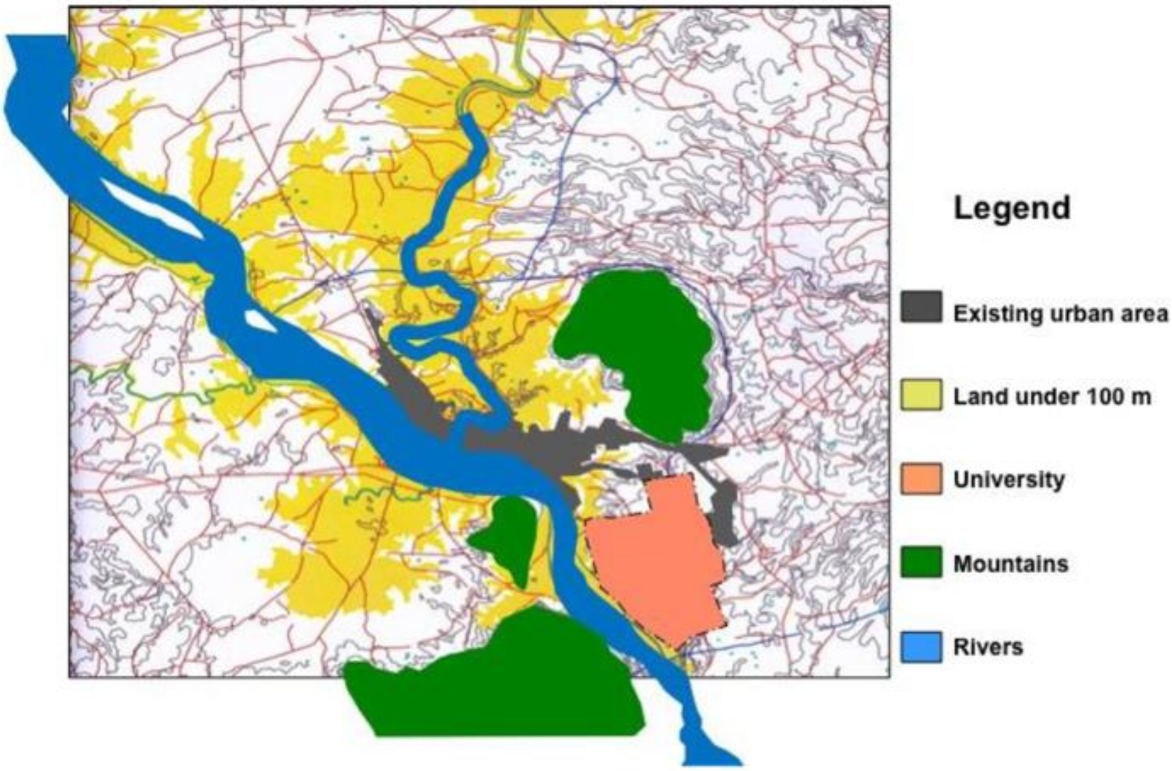

Figure 4. Flood risk zones in Pakse, constraining urban development[69].

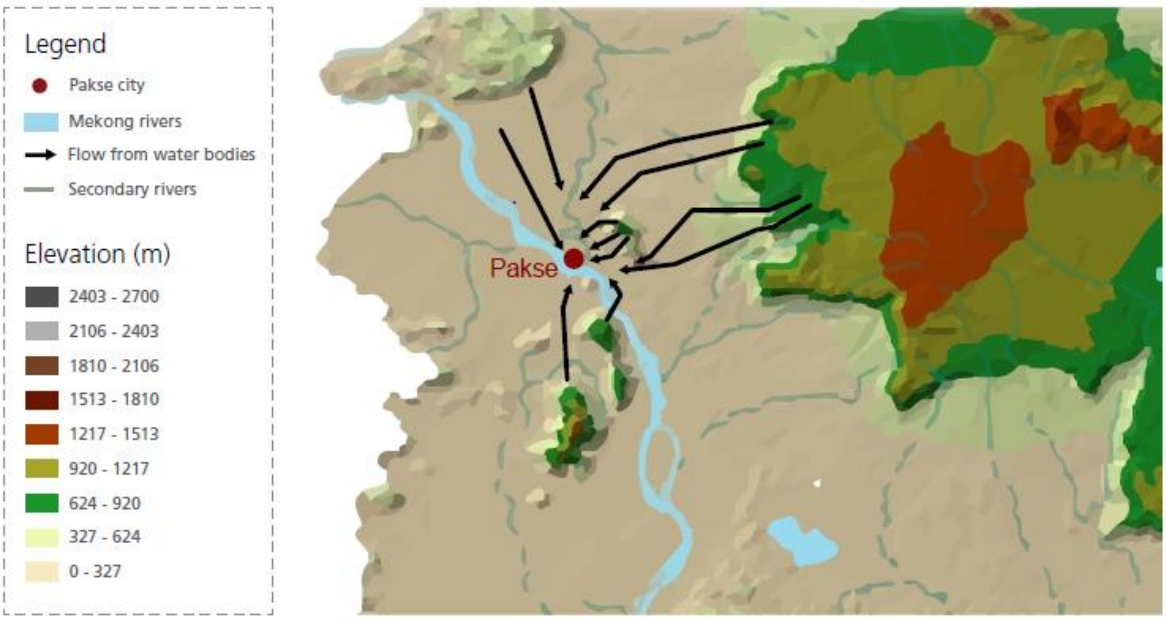

Figure 5. Direction of floodwaters into Pakse[70].

[69] ADB.2011. Technical Note: Urban Development Strategy. Available at https://www.adb.org/sites/default/files/linked-documents/43316-012-lao-oth-03.pdf. Accessed on 13 May 1986.
[70] UN Habitat. 2014. Pakse Lao People's Democratic Republic Climate Change Assessment. Available at: https://unhabitat.org/books/95406/. Accessed on 13 May 2019.

In 2011, ADB released an Urban Development Strategy[71] for Pakse, in connection with the Pakse Urban Environmental Project. Urban development is expected to focus on the northern side of the city, up to the tributary of the Xe Don River and then to the east and southeast (Figure 6). The flood protection strategies proposed include: i) raising riverbanks; ii) improving drainage in central urban area; and iii) identifying sites for easements of primary drains and retention ponds[72]. A climate change vulnerability assessment for the city from UN Habitat[73] proposed a mix of: i) hard engineering solutions; ii) relocating people from flood risk zones; iii) flood proofing houses and infrastructure; iv) improving early warning; v) supporting governance systems and clarifying agency roles; and vi) improving public health measures.

Many of the investments observed in a field mission[74] include installed flood gates and pumping stations. A big challenge in this is the maintenance of the floodgates and payment for diesel to operate the pumps. In some areas, pumps are not able to function fast enough to discharge water into the main rivers.

Figure 6: Urbanisation trends in Pakse[75]

These four cities are becoming increasingly vulnerable to flooding as the impacts of climate change increase the frequency and intensity of large rainfall events (see Section 2.2 for further detail). Local governments in each of the cities have not had the financial and technical capacity to implement flood reduction methods to alleviate recurrent flooding. This situation

[71] ADB.2011. Technical Note: Urban Development Strategy. Available at https://www.adb.org/sites/default/files/linked-documents/43316-012-lao-oth-03.pdf. Accessed on 13 May 1986.
[72] Ibid.
[73] UN Habitat. 2014. Pakse Lao People's Democratic Republic Climate Change Assessment. Available at: https://unhabitat.org/books/95406/. Accessed on 13 May 2019.
[74] Conducted in April 2019
[75] ADB.2011. Technical Note: Urban Development Strategy. Available at https://www.adb.org/sites/default/files/linked-documents/43316-012-lao-oth-03.pdf. Accessed on 13 May 1986.

has been exacerbated by inadequate maintenance of much of the existing flood management infrastructure such as floodgates, canals and drainage pipes because of limited financial capacity.

4 Past and ongoing projects, best practices, lessons learned, and project approaches

4.1 Past and ongoing projects

The GoL recognises that its people and resources are vulnerable to the impacts of climate change and that urgent action is needed to increase the country's climate resilience. This section provides details of relevant past and ongoing projects from the last two decades in Laos. The projects are focused on *inter alia* sustainable land management, urban and rural infrastructure, as well as disaster management. The projects discussed below cover non-climate change- and climate change-linked projects.

4.1.1 Projects without a focus on climate change adaptation

Lao PDR: Vientiane urban infrastructure and services project (2001—2007; US$37,000,000)

In 2001, the GoL requested assistance from the Asian Development Bank (ADB) to enhance urban productivity and economic growth. The project was aimed at improving the quality of life for urban residents in Vientiane, particularly the poor and disadvantaged. The objectives of the project were to: i) support decentralisation and urban governance reforms; and ii) invest in citywide and village-area infrastructure and services improvements. Infrastructure improvements focused on road upgrades, traffic management and road safety, as well as drainage and solid waste management. For the drainage subcomponent, ~16 km of new drains were built. Similarly, for the solid waste management subcomponent, the coverage of waste collection services was increased from 15,000 to 70,000 households. Over 50 villages were targeted for infrastructure and services improvements. Awareness campaigns — facilitated by the Lao Women's Union (LWU) — were particularly important for garnering support and enhancing understanding of service provision challenges such as sanitation. The urban governance project component successfully contributed to the passing of the Law on Local Administration (LLA). Overall, the project was viewed as effective and efficient in achieving its objectives and outcomes and in some instances exceeded its targets for urban infrastructure improvements[76]. For example, improvements in roads and drainage works exceeded their project target by 24% and 10% respectively.

Sustainable forest and land management in the dry dipterocarp forest ecosystems of southern Lao PDR (SFLM; 2016—2022; US$89,872,274)

The primary objective of this GEF-funded project is to demonstrate sustainable forest and land management in the forested landscape of Savannakhet Province. This is being undertaken to secure critical wildlife habitats, conserve biodiversity and maintain a continuous flow of ecosystem services, including quality water provision and flood prevention. To achieve this objective, the project is strengthening the land- and resource-use planning and management capacities of government agencies, local communities and private actors. It is simultaneously developing innovative financing mechanisms and initiatives (including on ecotourism and livelihoods) which ensure the sustainability of land use and resource management. The components of the project include: i) promoting an enabling policy environment and increasing compliance and enforcement capacities for SFLM across landscapes, including protected areas; ii) implementing sustainable forest management and protected area expansion in five

[76] Asian Development Bank. 2008. Lao PDR: Vientiane Urban Infrastructure and Services Project. Completion Report.

priority districts of Savannakhet Province; and iii) developing and promoting incentives and sustainable financing for biodiversity conservation and forest protection.
The dry dipterocarp forest ecosystems are recognised as being globally and nationally important for their provision of numerous ecosystem services such as water supply, sustainable timber and carbon sequestration. Their conservation has, therefore, been prioritised by the GoL. The parties responsible for this project include the Department of Forest Resources Management, MONRE and UNDP.

Poverty Environment Initiative: Phase 2 (PEI; 2012—2016; US$4,349,851)

The United Nations Environment Program (UNEP) and UNDP have provided the framework for investment in the Laotian economy through the Poverty Environment Initiative (PEI) since 2009. PEI's overarching objective is to contribute to poverty reduction through capacity building of the national and provincial authorities. To protect the country's interests while promoting quality investment, the PEI Phase 2 is structured around the following five core working areas. These are: i) building the capacity of the GoL to manage its investments and effectively implement the five-year National Socio-Economic Development Plan; ii) supporting the GoL in strengthening the national and provincial investment management systems; iii) ensuring effective review and approval processes of environmental and social impact assessments in coordination with the concerned line ministries and state enterprises; iv) building the capacity of the National Assembly to provide oversight and support for the selection of quality investments; and v) informing investment decisions through targeted economic and environmental research services and policy analyses.

The GoL has identified the careful management of investments as being particularly important because of the country's reliance on extractive industries for economic growth, such as mining, hydropower and agro-forestry.

Research on sustainable management of Pak Peung wetland and fisheries (2010–2018; budget not available)

Researchers at Charles Sturt University in Australia have conducted a programme of research on the Pak Peung wetland on the Mekong River, Bolikhamxay Province. These studies have been funded through the Australian Centre for International Agricultural Research (ACIAR) and Industry and Investment New South Wales, and conducted in collaboration with researchers from the National University of Laos and the Living Aquatic Resources Research Centre in Laos. The research has included: i) a proof-of-concept study of fish passage construction in the Lower Mekong Basin at the Pak Peung wetland; and ii) engaging with the Pak Peung community to research traditional wetland management and transitions to wetland co-management, with a focus on fishing and fish populations. Research outputs have included the construction of experimental fish passages, peer-reviewed publications and official reports.

Land management and decentralised planning I & II (LMDP; 2015–2019; budget not available)

The Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) has funded this project to improve land governance and land use planning at all levels of government in Laos. The Ministry of Planning and Investment (MPI) and MONRE have partnered with the German Federal Ministry for Economic Cooperation and Development to implement this project, with the aim of enhancing tenure security for rural communities through improving policies, practices and planning processes. The main components of the project are: i) the development of technical capacity for land management and planning with staff in several ministries; and ii) the implementation of participatory planning processes at community, district and provincial level.

In the first phase of the LMDP project, participatory land use planning was conducted in 67 villages in four provinces and 25,000 land titles were issued. In addition, remodelled area spatial plans were developed with community participation and a system for identifying and resolving land use conflicts was piloted.

Pakse Urban Environmental Improvement project (2012–2021; US$27.5 million)

This project is being funded by the Asian Development Bank and implemented by the Department of Public Works and Transport in Champasack Province. The aim of the project is to contribute to the development of Pakse as a regional economic and tourism centre in southern Laos. This will be done by: i) improving solid waste management and sanitation; ii) enhancing flood protection and drainage; iii) reinforcing the banks of the Xe Don River; and iv) strengthening capacity for urban planning at provincial level. Engineering and civil works to improve flood protection and drainage are major components of the project. While the goals of these components are similar to those of the proposed project, this project employs only hard engineering to improve urban flood protection. In contrast, the proposed GCF project will promote an integrated, climate-resilient approach that includes the use of green infrastructure.

The project includes a community environmental improvement component to address solid waste management and sanitation, as well as activities to build capacity for provincial urban planning. The civil works and capacity building components of the project are underway and designs for the community environmental improvement initiatives have been completed.

Mekong Integrated Water Resources Management — Lao PDR project (2012–2021; US$26.9 million)

This World Bank-funded project is being implemented by the Mekong River Commission in cooperation with the Lao Ministry of Agriculture and Forestry, and MONRE. The project is the national component of a larger programme which aims to improve cross-sectoral water resources management in the Lower Mekong Basin (Lao PDR, Cambodia and Viet Nam). The main components of the project are: i) facilitating transboundary dialogues focussing on water resources management; ii) building capacity for integrated water resources management (IWRM) within the GoL; iii) improving local management of floodplains and fisheries; and iv) improving the regional collection, analysis and dissemination of hydromet and water quality data. Components of the project are being implemented in Attapeu, Champasak, Xekong, Khammouane and Savannakhet Provinces.

By May 2018, the project had made significant progress including: i) installing or upgrading 25 hydromet stations; ii) providing improved drainage and irrigation services to 7,500 hectares; iii) developing a joint action plan for transboundary IWRM; iv) revising the Laos Water Law and submitting it to the National Assembly; and v) developing and disseminating water management information products.

Greater Mekong Subregion Flood and Drought Risk Management and Mitigation Project (2012–2019; US$89.19 million)

This project incorporates Viet Nam as well as Lao PDR and is funded by the Asian Development Bank and the Government of Australia. The Ministry of Agriculture and Forestry is implementing the project in Laos. The overall objective of this project is to improve the management and mitigate the impact of floods and droughts in the region. This will be achieved by: i) improving regional management of data regarding floods and droughts; ii) upgrading water management infrastructure; and iii) building capacity for community-based disaster risk management (CBDRM). To date, 18 CBDRM groups have been established and contracts for the civil works components of the project have been awarded.

4.1.2 Projects with a focus on climate change adaptation

Lao PDR Southeast Asia disaster risk management (SEADRM; 2017—2022; US$31,000,000)

The World Bank-funded SEADRM project is a regional project covering Laos, Cambodia and Myanmar. Although the projects are independent, they have a similar design to address challenges that are common to the participating countries. The objective of the Laos project is to reduce the impacts of flooding in the city of Muang Xay and enhance the government's capacity to provide hydro-meteorological services (hydromet) and respond to disasters.

Five components are collectively achieving the project objective. The first component — coordinated by the Department of Urban Planning and Housing — is implementing integrated urban flood risk management in Muang Xay to strengthen flood protection and develop resilient urban planning. The second component focuses on hydromet modernisation and early warning systems, thereby improving the delivery of weather, climate and hydrological services as well as end-to-end early warning systems throughout Laos. Physical investments under this component primarily target the provinces of Luang Prabang, Oudomxay and Phongsali. The third component focuses on improving financial planning for disaster risk management. This is being done by providing support for strengthening national financial resilience, including the payment of disaster risk insurance. The fourth component supports overall project coordination and management, including M&E and financial audits. It is also generating knowledge by conducting studies for integrating disaster risk management into planning and investment. The fifth component is the contingent emergency response component. This component allows for a reallocation of funds from other components to provide emergency recovery and reconstruction support following a crisis or emergency.

Integrated disaster and climate risk management in Lao PDR (IDCRM; 2012—2016; US$860,000)

UNDP funded the IDCRM project which was implemented by the National Disaster Management Office (NDMO). The overall objective of this project was to strengthen the disaster risk management system in Laos, thereby enabling government and vulnerable communities to effectively respond to emergencies, adapt to a changing climate and prepare for disasters. This objective was to be achieved by: i) developing provincial, district and community disaster management plans; ii) strengthening information management systems and community early warning systems; and iii) enhancing coordination and information exchange among selected communities, districts and provinces. The project also sought to operationalise the country's National Disaster Management Plan through planning, legal, educational and information sharing initiatives. The project's three components are: i) strengthening institutional capacity for disaster risk management at national and sub-national levels; ii) strengthening disaster preparedness and response systems to coordinate, manage information, identify and assess risks and warn at-risk communities; and iii) building gender and socially inclusive community-based disaster preparedness, CCA and early recovery.

The project worked with communities in Xieng Khouang and Sayabouly — two provinces that are at high risk of natural disasters[77]. As part of the project, several provincial government officials were trained in the process of carrying out disaster assessments and forming committees. Furthermore, their capacity for disaster and climate risk management was developed. As a result of this training, the organisation and performance of disaster management have improved at provincial and local levels.

At the local level, 14 Village Disaster Management Plans (VDMP) have been launched by Village Disaster Management Committees (VDMC) in the two provinces. These committees are run by community volunteers who have been trained in disaster risk management and response as part of this project. Approximately 30% of these community volunteers are women. Each VDMP plan identifies safe emergency shelters for people (providing particularly for vulnerable groups including children, the elderly and disabled) and animals, evacuation routes, and plans for stockpiling and storing emergency provisions. In early 2015, the project also initiated a national-to-village level study for assessing the status of early warning systems in Laos. This was done based on the need for clear and timely disaster warning systems to improve disaster preparedness. The study aims to provide a list of villages and districts that have functional early warning systems and those that do not. These findings will be used to inform the next stage of this project or future projects.

Lao PDR Nationally Determined Contributions (NDC; 2016—2017; US$234,199)

The Global Environment Facility (GEF) and GoL have allocated funding to support the implementation of Laos' mitigation and adaptation contributions listed in its NDC (see Section 1.3 for further detail). These contributions are being implemented by UNDP and the Department of Disaster Management and Climate Change within MONRE.

Effective governance for small-scale rural infrastructure and disaster preparedness in a changing climate (2013—2017; US$4,980,000)

The overall objective of this GEF-funded project was to improve local administrative systems affecting the provision and maintenance of small-scale rural infrastructure. This was achieved by facilitating participatory decision-making processes. These participatory processes will continue after project completion and will reflect the needs of communities and natural systems that are vulnerable to climate change, thereby enabling their development prospects. The components of the project complement each other in achieving the overall objective and overcoming the barriers to effective administration. Barriers identified include: i) weaknesses in climate change analysis and planning at sub-national levels; ii) financial constraints to building the climate resilience of rural infrastructure; iii) a 'silo' approach to local planning whereby ecosystem functions and services are not adequately taken into account; and iv) insufficient incentives for local officials and decision-makers to address climate-related risks. The three components of the project are: i) inclusive planning, budgeting and capacity development for reducing climate and disaster-related risks; ii) local investment for reducing climate risks and 'climate-proofing' communities; and iii) securing of ecosystem services and assets through enhancing critical ecosystem functions.

The parties responsible for this project were MONRE and UNDP. By December 2016, achievements included: i) capacity-building of local, district and government stakeholders through on-the-job training initiatives; and ii) a capacity development plan. This plan was informed by a capacity needs assessment and the integration of climate resilience planning into guidelines for the distribution of the District Development Fund.

[77] UNDP. December 2016. Integrated disaster and climate risk management project in Lao PDR. Project Brief.

Capacity enhancement to integrate ecosystem-based adaptation into sub-national development planning in Lao PDR (CEEbA; 2014—2018; budget not available)

IUCN Lao PDR developed this project in partnership with the Hamburg University of Applied Sciences and the Lao Biodiversity Association. The CEEbA project, primarily funded by the European Union, has aimed at strengthening the climate change-related institutional, policy and regulatory framework particularly in Laos' northern provinces of Luang Prabang, Phongsaly and Houaphanh. The project has focused on building the capacity of local administrative institutions to integrate climate change and climate risks into development planning. This has been achieved using an Ecosystem-based Adaptation (EbA) approach at both the national and sub-national levels. The project produced a capacity assessment review and baselines on institutional and regulatory frameworks for EbA.

Improving the resilience of the agriculture sector in Lao PDR to climate change impacts (IRAS; 2010—2015; US$4,445,450)

This GEF-funded project sought to improve the climate resilience of the agricultural sector in Laos by: i) strengthening climate change knowledge and agricultural/rural sector policies; ii) developing institutional capacity for systematic adaptation planning; iii) introducing adaptive agricultural practices and alternative livelihood options for poor rural communities in three provinces and five districts; and iv) initiating adaptation monitoring and learning as a long-term process to facilitate replication and ongoing development of adaptation planning and practices in Laos. The project sought to minimise food insecurity resulting from climate change and reduce the vulnerability of farmers to extreme flooding and drought events.

The IRAS project was implemented by the Ministry of Agriculture and Forestry through the National Agriculture and Forestry Research Institute, with technical support from UNDP. Vulnerability scenarios were constructed for four target districts and a variety of successful agricultural techniques — particularly those dealing with water management and harvesting — were implemented in the target areas and are expected to be continued beyond project closure. Other achievements include *inter alia* the development of disaster management plans for 22 villages and the training of government staff at national, provincial and district levels on climate change adaptation and the needs of rural communities.

Mainstreaming Disaster and Climate Risk Management into Investment Decisions (2011—2016; US$2,770,000)

This World Bank-funded project aimed to strengthen the institutional and implementation capacity of the GoL at national and sub-national levels. Its purpose was to mainstream disaster risk management and climate change adaptation into public infrastructure investments. In so doing, the project would decrease the vulnerability of the population and national economy to climate change and natural hazards. The project proposed to: i) integrate climate and disaster risk management into strategic national and sectoral planning and development policies; ii) improve the consideration of disaster and climate resilience in the planning and implementation of public infrastructure; iii) enhance personnel and institutional capacity for the design and implementation of resilient infrastructure through training at national, provincial, district, and community level; and iv) implement strategic structural and non-structural measures to enhance resilience in key growth sectors in two high-risk provinces (Vientiane and Phongsaly).

By June 2015, the project had made good progress including: i) the completion of sectoral risk assessments for three critical sectors, namely transport, irrigation and urban planning; and ii) the development of strategic as well as technical guidelines for mainstreaming disaster risk management into sectoral planning and budgeting processes[78]. Training initiatives had also been undertaken at national and local levels, while all outputs of the project were translated into English and Lao. These materials are planned to be shared on a web platform to ensure easy access for relevant stakeholders.

Climate resilience in cities in the Greater Mekong Subregion (2013—2014; US$650,000)

The International Centre for Environmental Management (ICEM) and the ADB with co-financing from the Nordic Development Fund designed this project to assist Greater Mekong Subregion (GMS) cities that are especially vulnerable to climate change. Three cities were assisted, namely Battambang (Cambodia), Dong Ha (Vietnam) and Kaysone Phomvihane/Savannakhet (Laos). The overarching project objectives were to: i) promote the climate-resilient development of critical infrastructure by using the participating cities as case studies; and ii) provide the tools and processes necessary to respond to their unique circumstances. The participating cities were chosen for their riverine and coastal flood vulnerability. Specifically, the city of Battambang is impacted by the large Tonle Sap basin, the seasonally changing and flood-prone Mekong river affects Kaysone Phomvihane (Savannakhet), and Dong Ha is situated on a typhoon-prone coastline affected by sea level rise.

Building climate resilience of urban systems through Ecosystem-based Adaptation (EbA) in the Asia-Pacific region (2017–2021; US$6,000,000)

This project is being implemented by UNEP and aims to leverage GEF-LDCF funding to enable the integration of EbA into urban planning in five pilot sites in Bhutan, Cambodia, Myanmar and Lao PDR. The sites include Phongsaly Province and Oudomxay Province in Lao. The purpose of the project is to catalyse sustainable development and build the climate resilience of poor urban communities. This will be done by: i) strengthening institutional and technical capacity of local authorities to plan and implement urban EbA; ii) implementing urban EbA interventions in the five pilot areas; and iii) promoting the generation, dissemination and management of knowledge on urban EbA in each pilot city and the region. Specifically, in Phongsaly, the project will undertake EbA interventions to increase the availability of groundwater and protect watershed ecosystems. Similarly, in Oudomxay an EbA approach will be used to restore watershed ecosystems and support alternative livelihoods, including tree nurseries and ecotourism initiatives.

Climate change adaptation in wetland areas in Lao PDR (CAWA; 2016–2020; US$4,717,579)

The CAWA project is being funded by the GEF-LDCF and executed through a partnership between MONRE and the IUCN. The FAO is the GEF Agency for the project and oversees its implementation. The project focuses on the restoration and improved management of the two Ramsar-designated wetlands in Laos — Xe Champhone and Beung Kiat Ngong. Specifically, EbA will be used in these wetland areas to increase the resilience of local communities and their livelihoods to climate change. This objective will be achieved by: i) building capacity and improving understanding of climate change risks, impacts, adaptation opportunities and disaster management in the two wetland areas; ii) implementing EbA measures to reduce the impacts of climate change on wetland ecosystems and local livelihoods; and iii) integrating climate change adaptation and disaster risk reduction into local and national planning processes.

[78] The World Bank. 2015. Lao PDR: Mainstreaming Disaster and Climate Risk Management into Investment Decisions. Implementation Status and Results Report.

To date, a participatory methodology for community vulnerability assessments has been piloted and vulnerability assessments have been completed for the two wetland sites. In addition, a report prioritising restoration actions for the Xe Champhone wetland has been produced.

Building the Capacity of the Lao PDR Government to Advance the National Adaptation Planning Process (proposal in development; US$3,552,969)

The proposal for this project is under development and will seek funding from the GEF-LDCF to develop capacity to undertake medium- to long-term planning for climate change adaptation in Lao PDR. The Department of Climate Change within MONRE will be responsible for implementing the project. The overall objective of the project is to improve national adaptation planning, financing, implementation and monitoring. This will be achieved through the coordination and integration of climate change considerations into development planning across sectors. The main components of the project include: i) developing capacity for the coordination of adaptation planning; ii) improving systems for knowledge and information management; iii) mainstreaming climate change into national development policies and plans; iv) improving access to domestic and international adaptation finance; and v) monitoring and reviewing the adaptation planning process to promote continuous learning.

Strengthening the Agro-climatic Monitoring and Information System in Lao PDR (SAMIS; approved in 2016; US$5,479,452)

This project was approved by the GEF-LDCF in 2016 to be implemented by the UN Food and Agriculture Organisation in collaboration with the Department of Meteorology and Hydrology within MONRE. The overall objective of the project is to increase capacity for collecting, analysing and disseminating climatic and geo-spatial information to support agricultural planning. The components of the project include: i) strengthening the analysis, communication and use of data for decision-making; ii) building institutional and technical capacity for the monitoring and analysis of agricultural production systems; and iii) enhancing knowledge management and the dissemination of information and lessons learned.

4.2 Best practices, lessons learned, and project approaches

This Feasibility Study draws upon best practices and lessons learned at the international, national and regional level during past and ongoing initiatives. It is also informed by insights gained from stakeholder consultations with national- and city-level government representatives from past and ongoing initiatives. The best practices and lessons learned are discussed briefly in the sections below. Best practices on the implementation and design of EbA interventions are well-documented in international literature[79] and will not be discussed in the Feasibility Study.

4.2.1 Integrated approach to development planning and inter-ministerial, inter-departmental coordination

The ADB-funded Vientiane Urban Infrastructure and Services project noted the importance of a participatory process across sectors and departments. During the implementation of this project, an attempt to create a decentralised urban management entity failed. This highlights the importance of central governance in project implementation in Laos. It is therefore recommended that future projects be implemented by existing government ministries and departments. Project Steering Committees (PSCs) should include all relevant government

[79] Examples of published literature illustrating the benefits of urban EbA include: Burns *et al*. 2012. Hydrologic shortcomings of conventional urban stormwater management and opportunities of reform and Armitage *et al*. 2013. The South African guidelines for sustainable urban drainage systems.

stakeholders. In addition, clear horizontal and vertical roles as well as responsibilities will have to be defined[80].

The importance of multiple cooperative stakeholders being involved in project implementation is illustrated further in the outcomes of the Integrated disaster and climate risk management project (IDCRM)[81] (see Section 4.1.2 for a description). In this project, the development of multi-sectoral provincial, district and community disaster management plans strengthened information management systems. This ultimately led to increased technical and institutional capacity to respond to climate change impacts. The project was co-implemented by Laos' Ministry of Natural Resources and Environment (MONRE) and the Department of Climate Change (DCC). A Secretariat Division under the DCC was established and has been effective in coordinating with other sectors. A similar approach was used in the Improving Land Governance through Spatial Framework Planning and Land Conflict Hotspots (LMDP) project[82] to generate land use plans through collaboration between local landholders, local government and national government. The cooperation of stakeholders at different levels was critical to developing integrated, high-resolution land use maps, identifying and resolving disputes and ensuring the success of the project. The project team has engaged with the project manager of this project in the preparation of this proposal and has adopted the approach of multi-sector, multi-level stakeholder engagement at the village, city and district, and national levels mainly through the steering committees and the role of the national project management unit in coordination.

Another example of the importance of multi-sectoral collaboration is the Mekong Integrated Water Resources Management Project (M-IWRMP), which is a transboundary cooperation for river basin management between Laos and Thailand[83]. This project has strengthened bilateral knowledge-sharing to improve wetland management and local livelihoods. It has facilitated this knowledge-sharing process by means of peer-to-peer learning, which has been promoted through meetings, joint actions and exchange visits. Bilateral organisations and entities involved include: i) relevant government ministries and departments in the two participating countries; ii) Thailand and Laos' respective National Mekong Committee Secretariats; and iii) Thailand's Nam Kam Working Group. Various other line agencies, national transboundary consultants and coordination groups also participate in cooperative knowledge-sharing. Each year, these entities meet for Regional Reflection Workshops to share lessons learned since the project's inception. Frequent meetings are held, and exchange trips conducted, which allow stakeholders across multiple sectors and two nations to improve their collaboration. This project illustrates the importance of an ongoing structured dialogue for multi-sectoral projects.

4.2.2 Benefits and cost-effectiveness of investments in green infrastructure

There are numerous international examples of projects that illustrate the advantages of using green (ecological) infrastructure, as opposed to solely relying on grey (conventional) infrastructure[84]. For example, in parts of the Asia-Pacific region — including the Ho Chi Minh

[80] ADB. 2010. Performance Evaluation Report. Lao People's Democratic Republic: Vientiane Urban Infrastructure and Services Project.
[81] UNDP. December 2016. Integrated disaster and climate risk management project in Lao PDR. Project Brief. Accessed at http://www.la.undp.org/content/dam/laopdr/docs/Project%20Briefs_Fact%20Sheets/Environment/FINAL%20DRM2%20Project-Brief_Dec2016.pdf
[82] GIZ. 2018. Presentation. Improving Land Governance through Spatial Framework Planning and Land Conflict Hotspots. Lao-German Land Program.
[83] http://www.mrcmekong.org/assets/Publications/project-docs/Xe-Bang-Hieng-and-Nam-Kam-River-Basins-Wetland-Management-Project.pdf
[84] USAID. 2017. The economics of ecosystem-based adaptation.

City in Vietnam[85], Pasig River in the Philippines and Putrajaya Constructed Wetland in Malaysia — green infrastructure has been recognised to be of critical importance for providing social and environmental benefits[86]. In Laos, green infrastructure interventions are being implemented in Phongsaly and Oudomxay Provinces under the project “Building climate resilience of urban systems through Ecosystem-based Adaptation in the Asia-Pacific region” (see Section 5.1.2). This project focuses on *inter alia* the restoration of riparian zones and watersheds to increase infiltration and improve water supply and reduce the impacts of flooding[87]. Similarly, the CAWA project (Section 4.1.2) uses bioengineering (revegetation and tree planting) to stabilise erosion-prone riverbanks, reduce sedimentation and improve infiltration rates[88].

Green infrastructure improves air and water quality, reduces flooding, decreases strain on local drainage infrastructure and filters pollutants. It also provides recreational services in the form of urban parks. Work in the southern parts of Laos has demonstrated that ecological infrastructure could be economically beneficial by promoting nature-based ecotourism that subsequently leverages investment from the private sector (see Section 4.1.2 for further details)[89].

4.2.3 Monitoring to evaluate the success of project interventions

A study on the establishment and management of rubber concessions was conducted as part of the Poverty Environment Initiative: Phase 2 (See Section 4.1.1 for further details). Findings of the study showed limited vertical information sharing within the ministries of the GoL, few monitoring reports, insufficient technical capacity and inadequate equipment for the collection or analysis of environmental or socio-economic data. Furthermore, there was insufficient budget for central, provincial or district level monitoring to be carried out. This study highlighted how monitoring protocols that lacked the required planning, detail and implementation resulted in the loss of government revenues and the depletion of environmental resources. The identification of these challenges to effective monitoring prompted a restructuring of the Ministry of Public Investment’s approval procedures, the development of new funding mechanisms and the revision and improved integration of GoL’s monitoring frameworks, databases and reporting templates.

The importance of incorporating monitoring, review and revision in project design was a major lesson learned from the ICEM project on climate resilience in cities in the Greater Mekong Subregion (Section 4.1.2). It was recommended that master planning of towns involved in the ICEM project be formally adopted as a cyclical process. This process would involve the provincial and national government re-approving town plans every three to five years. The outcome of institutionalising this cyclical process is that development interventions would be periodically re-focused on the vulnerable areas most urgently requiring intervention. To the best knowledge of the project preparation team based on extensive interviews with stakeholders, there are no existing systems that do this. This is an approach that can be promoted through ICFMS where localized, distributed interventions can be planned and executed at the district level based on the city-level hydrological assessments to be done under Activity 1.2.2 of the project.

[85] Duy, P.N., Chapman, L., Tight, M., Linh, P.N. and Thuong, L.V., 2018. Increasing vulnerability to floods in new development areas: evidence from Ho Chi Minh City. International Journal of Climate Change Strategies and Management, 10(1), pp.197-212.
[86] https://www.greatermekong.org/sites/default/files/nature-based-solutions.pdf#overlay-context=nature-based-solutions-building-resilience-towns-and-cities-case-studies-greater-mekong-subregion
[87] UNEP. 2014. Project Document. Building climate resilience of urban systems through Ecosystem-based Adaptation (EbA) in the Asia-Pacific region.
[88] FAO. 2014. Project Document. Climate change Adaptation in Wetland Areas (CAWA) in Lao PDR.
[89] https://www.thegef.org/project/sustainable-forest-and-land-management-dry-dipterocarp-forest-ecosystems-southern-lao-pdr

4.2.4 Community involvement

Past and ongoing projects in Laos have demonstrated the importance of community involvement in successful project design and implementation. For example, the ADB Vientiane urban infrastructure and services project (see Section 4.1.1 for further details) identified the importance of engagement with communities for achieving project effectiveness, efficiency and sustainability. Full engagement with communities and other stakeholders was highlighted as vital for addressing the complexities associated with urban institutional reform. The demand-driven approach undertaken in the project's village area improvement programme was also identified as a major contributor to the project's effectiveness and sustainability. Similarly, improvements in the performance of the Xieng Khouang provincial government reported in the UNDP integrated disaster and climate risk management project (see Section 4.1.2 for further details) have been attributed to the capacity building component of the project which established Village Management Committees that are run by community volunteers. In addition, the GEF project on effective governance for small-scale rural infrastructure and disaster preparedness in a changing climate (see Section 4.1.2 for further details) successfully implemented a local participatory decision-making process. This participatory process led to improved local administrative systems by incorporating the specific needs of communities most vulnerable to climate risks into local planning and budgeting processes.

Similarly, engagement with community leaders in Paksan on traditional approaches to wetland management (see Section 4.2.1 for further details) has helped to better understand the management needs of the Pak Peung wetland. The local knowledge shared by community leaders helped to identify threats to wetland resources and develop suggestions to reduce these threats. Engagement with local communities was an important component of the success of fish passage construction experiments conducted as part of this research programme in Pak Peung. This indicates that community involvement in both planning and implementation can contribute to the success of an intervention.

5 Gaps and Barriers

The implementation of an integrated climate-resilient approach to urban flood management in Laos faces several challenges and barriers.

5.1 Limited technical and institutional capacity of provincial and national government for climate-resilient flood management

The GoL recognises the need to mainstream climate change adaptation into sectoral and cross-sectoral policies at national and provincial level[90]. However, the relevant sectors and institutions responsible for coordinating climate change adaptation largely lack the necessary training and guidance needed to carry out adaptation interventions. There is, therefore, limited technical capacity within the GoL to coordinate and implement adaptation interventions. In particular, there is limited technical and institutional capacity for the integrated management of climate change-induced floods.

The GoL has traditionally focused on disaster response rather than a systematic and proactive approach to flood management. Flood management is the responsibility of the Department of Waterways (DoW)[91], which falls within the Ministry of Public Works and Transport (MPWT).

[90] E.g. climate change was first integrated into the 7th National Development Socioeconomic- Development Plan for 2011–2015 and has since been carried over into the 8th Five-year National -Socioeconomic- Development Plan for 2016–2020. See further: 8th Five-year National -Socioeconomic Development Plan (2016–2020). 2016. Ministry of Planning and Investment. Officially approved at the -VIIIth National Assembly's Inaugural Session, 20–23 April 2016, Vientiane.
[91] The DoW is also responsible for riverbank protection.

However, the DoW can fulfil this responsibility only partially, as it has limited capacity for proactive planning to avoid and minimise flood risks in the rapidly growing Laotian cities. Currently, flood management is primarily site-specific and focused on end-of-pipe solutions[92]. Consequently, insufficient strategic planning and limited consideration of existing and future land use exacerbates flooding in Laos' cities. The project addresses these gaps through provision of training on EbA interventions to project stakeholders including DOW in MPWT (Activity 1.1.1) as well as improving coordination mechanisms through the project steering committees and ICFMS process. A comprehensive strategic approach to flood management requires collaboration between different departments and ministries[93], but coordination among the ministries involved in urban planning, flood management and city development is often limited. In addition, there is limited capacity at the provincial and city-level for spatial planning that reduces flood risks and impacts. Besides lack of capacity for proactive flood management, the existing planning measures to reduce flood risk are not always implemented. For example, the existing building regulations and zoning — such as buffer zones around rivers and wetlands — are often inadequately enforced because of a lack of capacity.

Past projects have also identified limited institutional and technical capacity as a barrier to sustainable urban planning and climate change adaptation. For example, the ADB Vientiane urban infrastructure and services project (Section 4.1.1) found that inadequate institutional capacity and human resources have constrained sustainable urban development across the country. Similarly, the GEF project on effective governance for disaster preparedness and the provision and maintenance of small-scale rural infrastructure in a changing climate (Section 4.1.2) identified a lack of technical capacity for climate change analysis as a barrier. Technical capacity for hydrological modelling and assessments, flood risk and land-use mapping, and monitoring are also lacking, particularly at the provincial and district levels.

5.2 Lack of integrated, climate resilient flood management approaches and investments

Few, if any, integrated flood management interventions — i.e. interventions that consider climate change and include EbA — have been implemented in Laos. The government often depends on international donor projects for the funding of urban flood management infrastructure. These projects frequently focus on constructing traditional hard infrastructure to manage flooding. This strong reliance on hard infrastructure for flood management is evident in the four cities (Vientiane, Paksan, Savannakhet and Pakse) that will benefit from the proposed GCF project. In Savannakhet, for example, a previous assessment of Houay Long Kong — an urban catchment — recommended a mixture of hard and green infrastructure to reduce flood risks. However, very few of the recommended green infrastructure approaches have been implemented to date[94,95]. Similarly, the Pakse Urban Environment Improvement Project[96] has installed only hard infrastructure for stormwater and flood management in Pakse[97]. This lack of integrated flood management and EbA interventions on the ground mean that there is a limited local evidence base to convince decision-makers to adopt such approaches. In Vientiane, existing ecosystem services (the drainage function of the That Luang marsh) were actually replaced by inadequate hard

[92] 'End-of-pipe' suggests that you solve the problem downstream in the catchment, rather than preventing it from becoming a problem by using integrated, distributed solutions. Examples observed on field visits include the canalisation of water courses, installation of floodgates where streams drain out into the Mekong River to prevent Mekong backflow, and pumps to discharge water from the stream to the Mekong when the Mekong level is high.
[93] Roles of some of these agencies in flood management are discussed in 1.5.1.
[94] ADB. 2015. Building resilience and sustainability in Mekong Towns.
[95] Personal communication. 2018. ADB Project Manager and international consultants.
[96] See Section 5: Past and ongoing projects.
[97] Personal communication, April 2019. Project Manager, Pakse Urban Environmental Improvement Project

infrastructure (artificial lake and installation of drainage system). Some thinking on integrated approaches including EbA is present[98], but these are not matched by investments.

While some policies and plans related to urban flood management include climate change adaptation measures, few address this challenge comprehensively and in an integrated manner. For example, building regulations and zoning do not always make adequate provision for flooding, especially not for increasingly frequent and severe flooding predicted under climate change.

5.3 Limited knowledge about EbA and the valuation of ecosystems

To effectively use EbA for flood management, decision makers, planners and contractors require the technical capacity and knowledge to identify, design, implement and maintain urban EbA interventions. However, the GoL has had limited exposure to the adaptation benefits of urban EbA and therefore knowledge on urban EbA is limited. Although National Guidelines on EbA in Laos have been developed with the help of the WWF[99], there have been no known initiatives promoting urban EbA for flood management in the country. In addition, while the Department of Civil Engineering at the National University of Laos (NUoL) offers a course on the management of sustainable infrastructure, the course does not include specific content on EbA for flood management. Limited knowledge of EbA means that decision-makers still perceive hard infrastructure and end-of-pipe solutions[100] as the only way to effectively manage flooding.

In addition to having limited knowledge about the implementation of EbA, government decision-makers do not have sufficient access to information on the value of ecosystem services. There are a few examples of valuation of ecosystem services in Laos[101], but again, they have not led to investments in EbA. Consequently, the GoL is more likely to finance traditional hard engineering solutions, where costs and benefits are well understood. This issue is not particular to Laos. In the Philippines, for example, investment selection procedures by the economic planning agency favour structural flood control measures in the absence of methodologies for the economic valuation of ecological measures[102]. As a result, the paradigm of using only hard engineering approaches has largely remained in the Philippines, as is the case in Laos[103].

5.4 Lack of data for modelling climate impacts to inform climate change adaptation solutions for flood management

[98] Discussions with the Savannakhet Department of Urban Planning Department, the Pakse Department of Public Works and Transport, and the national-level Department of Housing and Urban Planning in MPWT have all demonstrated understanding of EbA solutions. Personal communications, April 2019. Public Works and Transport officials.

[99] MONRE, 2013. Available at: https://www.researchgate.net/publication/283898362_National_Guidelines_on_Ecosystem-based_Adaptation_Practices_in_Lao_PDR/download

[100] ‘End-of-pipe’ suggests that you solve the problem downstream in the catchment, rather than preventing it from becoming a problem by using integrated, distributed solutions.

[101] WWF. 2013. The Economic Value of Ecosystem Services in the Mekong Basin: What we know, and what we need to know. Gland, Switzerland. Accessed from https://d2ouvy59p0dg6k.cloudfront.net/downloads/report_economic_analysis_of_ecosystemservicesnov2013.pdf. Accessed on 17 May 2019.

[102] Personal communication. 2013. National Economic and Development Authority, Infrastructure Division.

[103] This approach is also described as pursuing the “hydraulic mission”. Molle, Mollinga, and Wester. 2009. Hydraulic bureaucracies and the hydraulic mission: Flows of Water, Flows of Power. Water Alternatives 2(3): 328-349.

While investments are being made to improve technology and performance in generating base climatological information from the monitoring of hydrological and meteorological trends in priority areas in the country, these are not adequate to support the development and implementation of activities to adapt to climate change. For the development of this proposal, independent work has been carried out to downscale climate change parameters in the target areas to assess flood risks. Even then, the scale of modelling is at a coarse scale. Further hydrological assessments based on quality spatial data and model calibration are needed in order to support the planning and design of coordinated distributed flood management solutions.

6 Climate Impact Modelling

To fill the knowledge gap in climate change forecasts in Laos, a study was comissioned by UNEP through the Climate Technology Centre and Network (CTCN) to predict the change in climate that can be expected in Laos[104]. This analysis predicts the following changes in climate for Laos:

- **Changes to mean annual and monthly rainfall are likely to be small.** Average monthly rainfall is compared in Figures 13, 14, 17 and 18 (Section 2.4.1).
- **Significant increases in the frequency and intensity of extreme events are likely to occur.** This is largely attributed to the projected increase in intensity of extreme rainfall events (Figures 11 and 12).
- **Larger increases in the intensity of extreme rainfall events are expected to occur within cities than within catchments.** The projected increases in intensity of extreme rainfall events for the periods 2046–2065 and 2081–2100 are presented in Figures 10 and 11 (Section 2.4.1).
- **Significant increases in average temperatures are expected.** Greater increases in temperature are projected for the end of the century than for mid-century (Section 2.4.2).

According to the analysis undertaken in preparation of the Second National Communication, there will be no significant change in rainfall patterns over the next decade in Laos. Rainfall patterns are, however, expected to change considerably by the middle of the century. Seasonal rainfall changes are also likely to occur, with a delay in the onset of the monsoons in the southern region. This variation in rainfall patterns indicates a possible shift in the rain season for Laos[105]. The intensity and frequency of extreme weather events are also predicted to increase — which will result in an increase in floods during the rain season.

Regional climate forecasts also predict an increase in temperature and rainfall variability throughout Southeast Asia, linked to climate change[106]. An average increase of 2.6°C in annual mean temperatures, as well as an increase in the number of wet days, are expected to occur for the period 2080–2099[107].

The methods and datasets used to determine the current and predicted climate trends in Laos are described in detail in Sections 2.2 and 2.3 below. In addition, the projected changes in temperature and rainfall for the periods 2046–2065 and 2081–2100, respectively, are discussed in Section 2.4 below.

6.1.1 Local downscaling of General Circulation Models (GCMs)

[104] Further details on the current and predicted climate trends for Laos are presented in Annex 13: Vulnerability Assessment.
[105] Second National Communication
[106] NAPA – cf. Asian Development Bank 2007
[107] NAPA

The UNEP-DHI study estimated the impact of climate change on meteorological variables including rainfall, evaporation and temperature. These estimates were based on the potential of the city catchment areas and upland catchment areas to impact flooding and drainage in the cities. As the Mekong River flows are important 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 predicted climate change impacts are based on local datasets, global datasets and climate model projections. Downscaling and statistical correction were used to estimate the effects of changes projected by climate models at local scales and to remove biases from climate model outputs. Because extreme rainfall events are an important cause of flooding, the projection of rainfall changes includes estimates of changes to rainfall extremes. The projection of changes to evaporation and temperature is limited to estimation of changes to average values.

6.1.2 Collection and harmonisation of key datasets

The dataset used to estimate climate change impacts was developed by DHI in collaboration with the NDE. This dataset was assembled from local sources and globally-available datasets. Local data were used for impact assessments at the city level, while global datasets 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.

6.1.3 Rainfall data

Rainfall data were obtained from local sources and the CHIRPS (Climate Hazards Group InfraRed Precipitation with Station data) global dataset. Local daily rainfall data were obtained for each of the six cities for the period 1 January 1986 to 31 December 2015. Data for Savannakhet and Thakek from 1986 and 1987 were not available, so these records started from 1 January 1988. The CHIRPS dataset[108], was used to develop rainfall estimates for upland catchment areas and headwater catchments in the Mekong River basin.

The CHIRPS dataset is a global rainfall dataset that incorporates satellite imagery and station data to create a gridded rainfall time series. 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 areas with the potential to contribute to urban flooding, either by overbank flooding or by constraining discharges from the urban drainage system during high-flow periods. In addition, 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: Paksan, Pakse, Luang Prabang and Thakek. No side catchment areas were identified for Vientiane or 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 7 below.

[108] Funk, C., Peterson, P., Landsfeld, M., Pedreros, D., Verdin, J., Shukla, S., . . . Michaelsen, J. (2015). The climate hazards infrared precipitation with stations—a new environmental record for monitoring extremes. Scientific Data, 2, 150066. doi:10.1038/sdata.2015.66

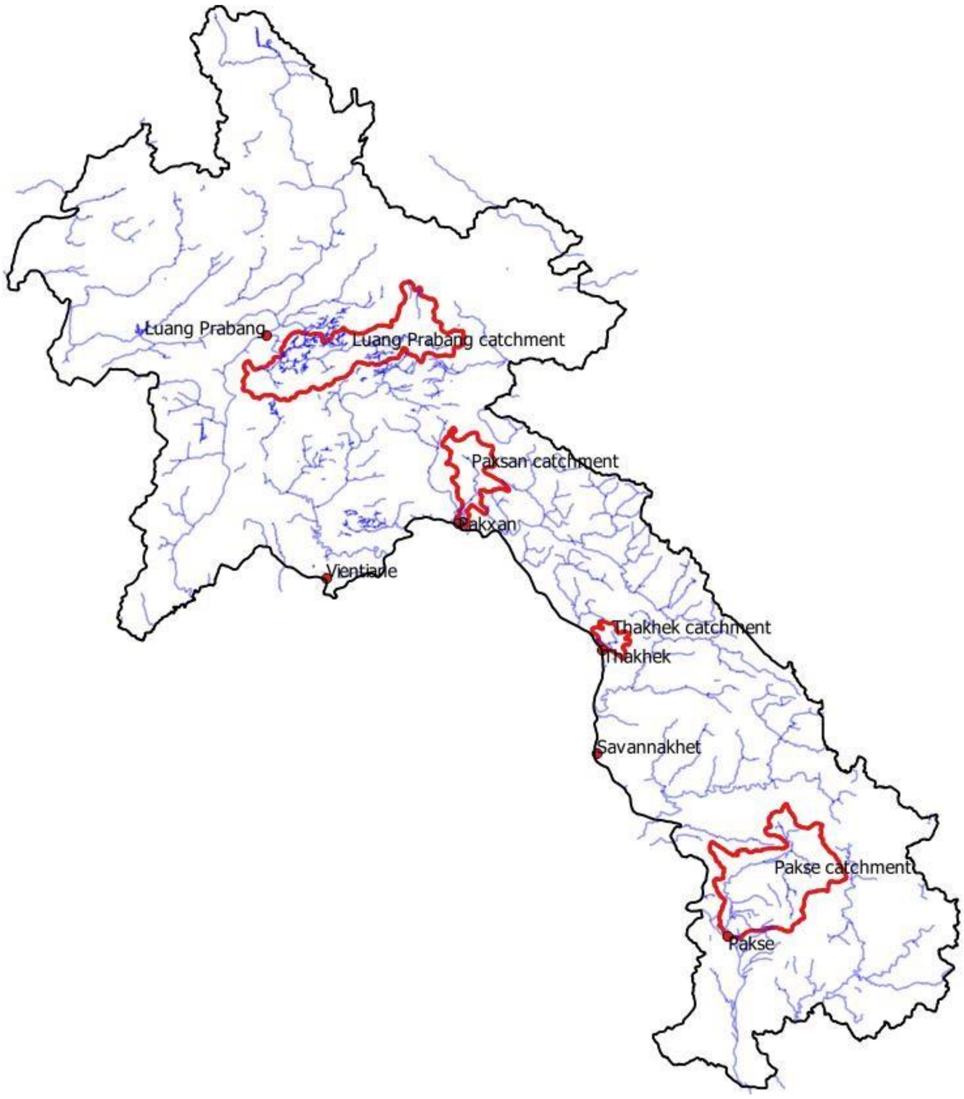

Figure 7. Paksan, Pakse, Luang Prabang and Thakekcatchments.

The headwaters of the Mekong River basin upstream of Luang Prabang were divided into three areas. The three headwater sub-catchments are displayed in Figure 8 below.

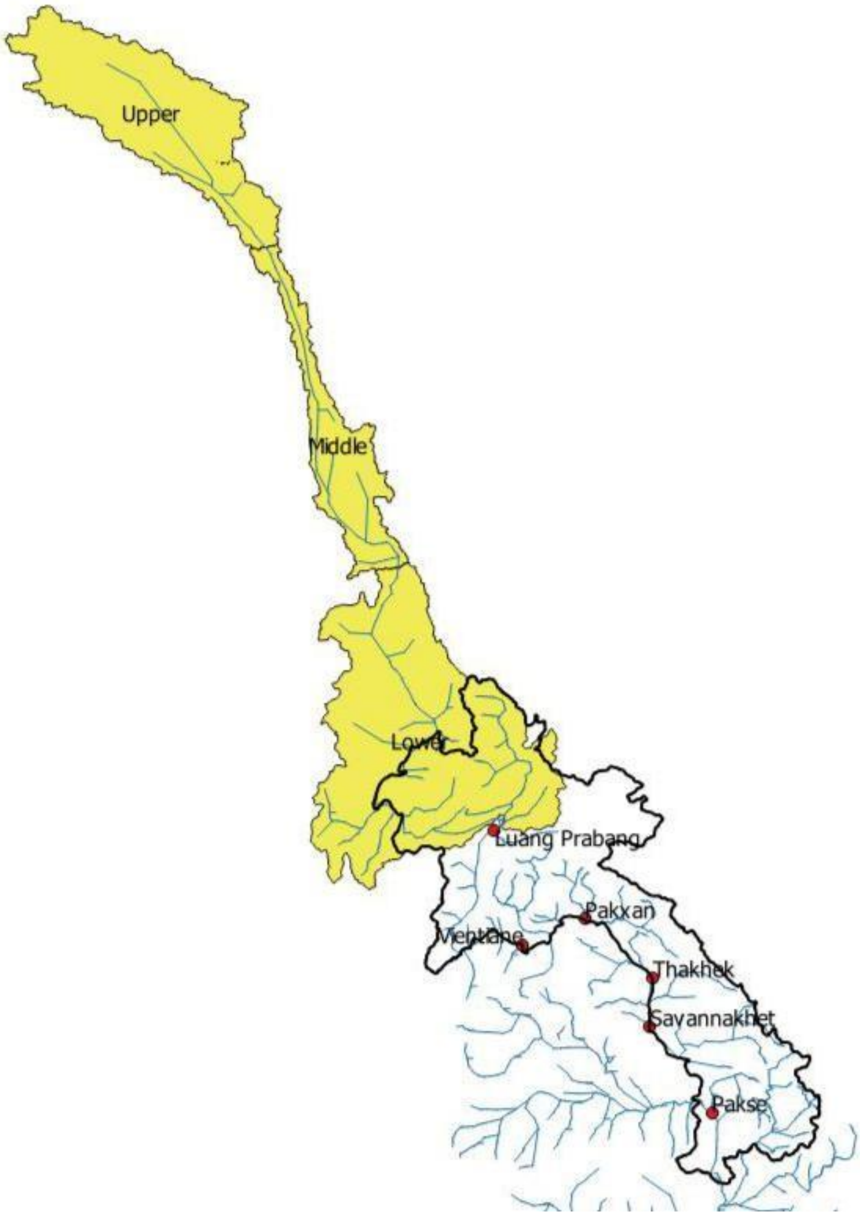

Figure 8. Upper Mekong headwater catchment areas.

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.

6.1.4 Temperature data

Temperature data were obtained from local sources and the CRU global dataset. Local daily temperature data were obtained for the period 1 January 1986 to 31 December 2015 for Vientiane, Pakse and Luang Prabang. Data for Thakek was only available from 1990 and local temperature data were not available for Paksan or Savannakhet. The CRU dataset[109] was used to develop temperature estimates for upland side catchment areas and headwater catchments in the Mekong basin.

The CRU dataset was used to develop time-series records of temperature for upland side catchment areas and headwater catchments in the Mekong basin. The upland side catchment and headwater catchment areas are the same as those described in Figure 8. Time series were estimated by taking a weighted average of CRU grid cells intersecting each of the catchment areas. The catchment temperature time series are monthly as the CRU dataset consists of monthly data.

6.1.5 Climate model projections

Climate models project how the climate will evolve in response to changes in greenhouse gas concentrations and other forcings. Projections for Laos were used to estimate how meteorological variables might change under future conditions. This section provides an overview of the climate model datasets used in this analysis. Methods used to project climate model output to city or catchment scales are described in Table 4.

The climate model projections use outputs from regional climate models (RCMs). RCMs simulate the atmosphere overlying a portion of the Earth's surface, in contrast to general circulation models (GCMs), which simulate the entire atmosphere. As a result 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 rainfall. Therefore, RCMs have been developed to provide a finer discretisation of the atmosphere and land surface than is possible with GCMs. RCMs use GCM outputs as boundary conditions.

RCM outputs used by the project were disseminated by CORDEX[110], which coordinates and evaluates regional climate modelling efforts by partner research organisations. Outputs from RCMs of the CORDEX East Asia region have been used. A map of the CORDEX East Asia region is displayed in Figure 9.

At the time of analysis, 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[111]. The other RCM model result available through CORDEX is from HIRHAM5[112], which uses boundary conditions from the GCM ECEARTH[113].

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,

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109 Harris, I., Jones, P., Osborn, T., & Lister, D. (2014). Updated high-resolution grids of monthly climatic observations–the CRU TS3. 10 Dataset. International Journal of Climatology, 34(3), 623-642.
110 Giorgi, F., Jones, C., & Asrar, G. R. (2009). Addressing climate information needs at the regional level: the CORDEX framework. *World Meteorological Organization (WMO) Bulletin, 58*(3), 175.
111 Martin, G. M., Bellouin, N., Collins, W. J., Culverwell, I. D., Halloran, P. R., Hardiman, S. C., . . . Wiltshire, A. (2011). The HadGEM2 family of Met Office Unified Model climate configurations. *Geosci. Model Dev., 4*(3), 723-757. doi:10.5194/gmd-4-723-2011
112 Bøssing Christensen, O., Drews, M., Hesselbjerg Christensen, J., Dethloff, K., Ketelsen, K., Hebestadt, I., & Rinke, A. (2007). *The HIRHAM Regional Climate Model. Version 5 (beta)*.
113 Hazeleger, W., Wang, X., Severijns, C., Ştefănescu, S., Bintanja, R., Sterl, A., . . . van der Wiel, K. (2012). EC-Earth V2.2: description and validation of a new seamless earth system prediction model. *Climate dynamics, 39*(11), 2611-2629. doi:10.1007/s00382-011-1228-5

only one of these — HadGEM3-RA[114] — was selected to conserve resources for other project activities. Results from ECEARTH-HIRHAM5 were also used. A comparison of results from the five RCMs associated with HadGEM2-AO has been done by Park and others[115].

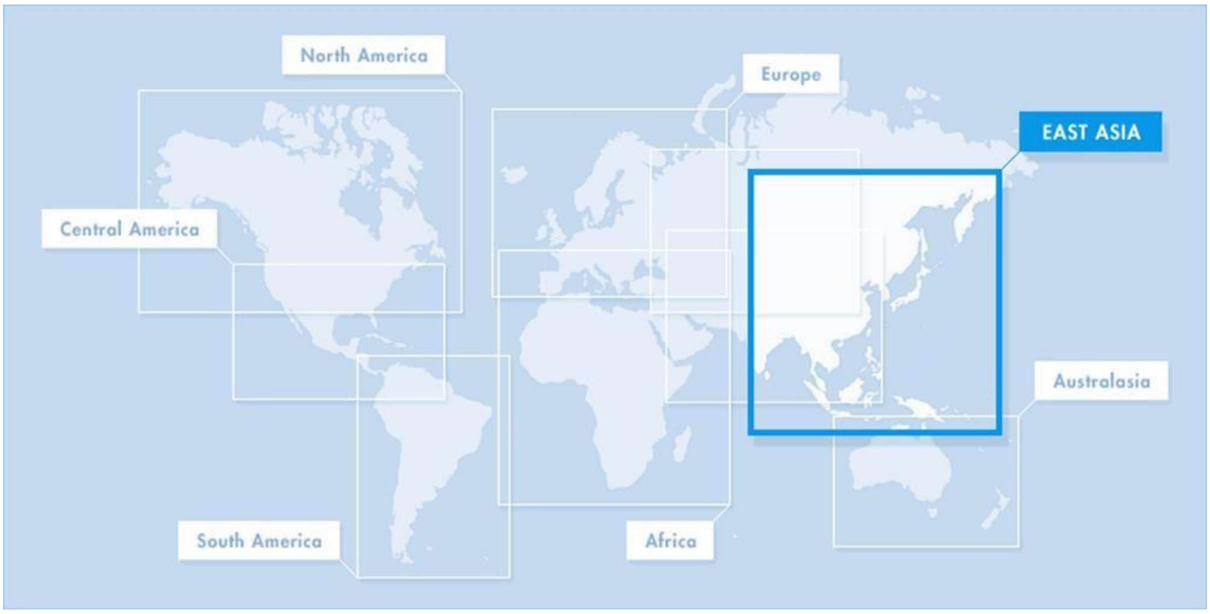


Figure 9. CORDEX East Asia model domain.

A total of five-time series 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 on different assumptions about how greenhouse gas concentrations will evolve in the future, as defined in the IPCC's Representative Concentration Pathways scenarios[116]. 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.

Table 4. 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

[114] Davies, T., Cullen, M. J., Malcolm, A. J., Mawson, M., Staniforth, A., White, A., & Wood, N. (2005). A new dynamical core for the Met Office's global and regional modelling of the atmosphere. *Quarterly Journal of the Royal Meteorological Society, 131*(608), 1759-1782.
[115] Park, C., Min, S.-K., Lee, D., Cha, D.-H., Suh, M.-S., Kang, H.-S., . . . Boo, K.-O. (2016). Evaluation of multiple regional climate models for summer climate extremes over East Asia. *Climate dynamics, 46*(7-8), 2469-2486.
[116] Pachauri, R. K., Allen, M. R., Barros, V. R., Broome, J., Cramer, W., Christ, R., . . . Dasgupta, P. (2014). Climate change 2014: synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the Intergovernmental Panel on Climate Change: IPCC.

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

6.2 Assessment of climate change at city and catchment level

Data and climate model results described in Table 4 were used to develop projections of meteorological variables at city and catchment level. These projections were developed through statistical post-processing that estimates changes to meteorological variables based on RCM projections.

6.2.1 Statistical post-processing

The RCM models described in Table 4 do not include all local-scale processes involved in rainfall generation[117]. In addition, the RCMs use a spatial grid size of ~50 km^2, which is too coarse for estimating local changes. An additional statistical post-processing step is therefore 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 temperature. Because this study focuses on flooding, the approach used for predicting changes in rainfall estimates how the frequency and magnitude of extreme rainfall events may change in the future. The approach used for predicting changes in temperature estimates changes to average values only.

6.2.2 Rainfall

Changes to rainfall are estimated using change factor quantile mapping118. The method is applied using the steps described below.

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

[117] Maraun, D., Wetterhall, F., Ireson, A., Chandler, R., Kendon, E., Widmann, M., . . . Themeßl, M. (2010). Precipitation downscaling under climate change: Recent developments to bridge the gap between dynamical models and the end user. Reviews of Geophysics, 48(3).
[118] Sunyer Pinya, M. A., Hundecha, Y., Lawrence, D., Madsen, H., Willems, P., Martinkova, M., . . . Kriaučiuniene, J. (2015). Inter-comparison of statistical downscaling methods for projection of extreme precipitation in Europe. *Hydrology and Earth System Sciences, 19*(4), 1827-1847.

- Each value of the observed time series is multiplied by the change factor associated with that value's month and cumulative distribution increment.

6.2.3 Temperature

Changes to temperature are estimated using the change factor of the mean method[119]. The method is applied using the steps listed below.

- Climate model outputs and observed time series are grouped by month. For the climate model outputs, average values are estimated for each month.
- The ratio of average temperature 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".
- Each value of the observed time series is multiplied by the change factor associated with that value's month.

6.3 Predicted changes in rainfall and temperature

Results of the model projections presented in this section are derived from the UNEP-DHI study (Annex 13). Six Laotian cities — Vientiane, Paksan, Savannakhet, Pakse, Luang Prabang and Thakek— were considered in this assessment. However, in this section four of these cities — Vientiane, Paksan, Savannakhet and Pakse — are discussed because they have been identified as the most appropriate sites for the proposed project interventions. Because similar changes were predicted for all four cities, detailed graphs of model outputs are only presented for one representative city — Pakse. Further detail for all six cities as well as for model projections regarding evaporation can be found in Annex 13.

Each presented plot compares four climate projections to an observed baseline. In addition, an average of the four projections is presented. Each plot shows projections of the four possible combinations of the two RCMs and two RCP scenarios. Projections for the two projection periods (2046–2065 and 2081–2100) are presented separately.

6.3.1 Rainfall

The model simulations predicted an increase in magnitude and frequency of extreme rainfall events and a small increase in the average monthly rainfall during the rain season. These trends are larger for cities than for catchments, which is likely to be due to the averaging out of extreme events over a larger area.

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

- **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 with 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 with projected maximum events.

[119] Sunyer Pinya, M. A., Hundecha, Y., Lawrence, D., Madsen, H., Willems, P., Martinkova, M., . . . Kriaučiuniene, J. (2015). Inter-comparison of statistical downscaling methods for projection of extreme precipitation in Europe. *Hydrology and Earth System Sciences, 19*(4), 1827-1847.

Changes to average values are estimated using average monthly rainfall — a series of 12 values, each providing the average rainfall for a month of the year.

The climate change models show that the frequency of extreme rainfall events will increase (Figure 10). Of even greater concern is that the intensity of the extreme rainfall events is also expected to increase several fold, with some events being five times greater than what has been experienced in the past[120,121]. Climate models also predict that the current 100-200 mm/day extreme rainfall events that cause flooding could become 400-600 mm/day rainfall events in the future, and that the current 200-400 mm/day rainfall events may become rainfall events of as high as 1000 mm in a single day (Figures 11 and 12).

The graphs presented in Figures 11 and 12 below highlight this impending problem of dramatically increasing intensity of extreme rainfall events that cause flooding in Laotian cities. The solid black lines in these graphs show the historical record of daily maximum rainfall in each year between 1986 to 2015 in three different cities, i.e. the events that would in all likelihood have caused the greatest amount of flooding in these cities. This historical data shows that the worst flooding over the period 1986 to 2015 in these cities would have occurred when rainfall of ~100 mm to ~400 mm occurred in one day. These were the extreme events over this period. The coloured lines in the graphs present the results of four different climate models. What these lines show is that it is highly plausible that the current 100-200 mm/day rainfall events become 400-600 mm/day rainfall events in the future, and that the current 200-400 mm/day rainfall events become rainfall events that exceed 1000 mm per day.

There are three main reasons for being cautious about expecting Laos to experience 600 to 1000 mm of rainfall per day in some of its cities in the future: firstly, it is not known which climate model presented in Figures 11 and 12 is most appropriate for modelling rainfall in Laos; secondly, the four climate models presented in these figures do show considerable variation; and thirdly, the figures of 600 to 1000 mm a day are the worst-case scenarios across all the models. It is, however, arguably prudent to follow the precautionary principle and for Laos to be prepared for worst-case scenarios produced by a range of credible climate models. The government should also take into account that the average of the four models, presented by the red line in the graphs in Figures 11 and 12, shows a consistently greater maximum daily rainfall figure compared with the historical data. It is therefore extremely likely, based on the best available science, that the severity of flooding across Laotian cities will increase dramatically. The scale of this increase is not known at present, but worst-case scenarios show that more than 1000 mm of rainfall can be expected to fall within 24 hours in many Laotian cities in the future (as shown in Figures 11 and 12 below). Under baseline conditions, the annual maximum daily rainfall in Laos ranges from 100 to 200 mm and flooding is already experienced at least once a year. It is, consequently, an extremely alarming prospect to consider that these same cities will, as a result of climate change, need to be managing rainfall events up to ten times greater than this in the future.

[120] The impacts of climate change in the target cities were determined by a UNEP-DHI study that was commissioned specifically for the proposed project and conducted through CTCN. This study is summarised in Annex 2: Feasibility Study and provided in full as Annex 13
[121] i.e. the events that currently cause flooding in urban and peri-urban areas.

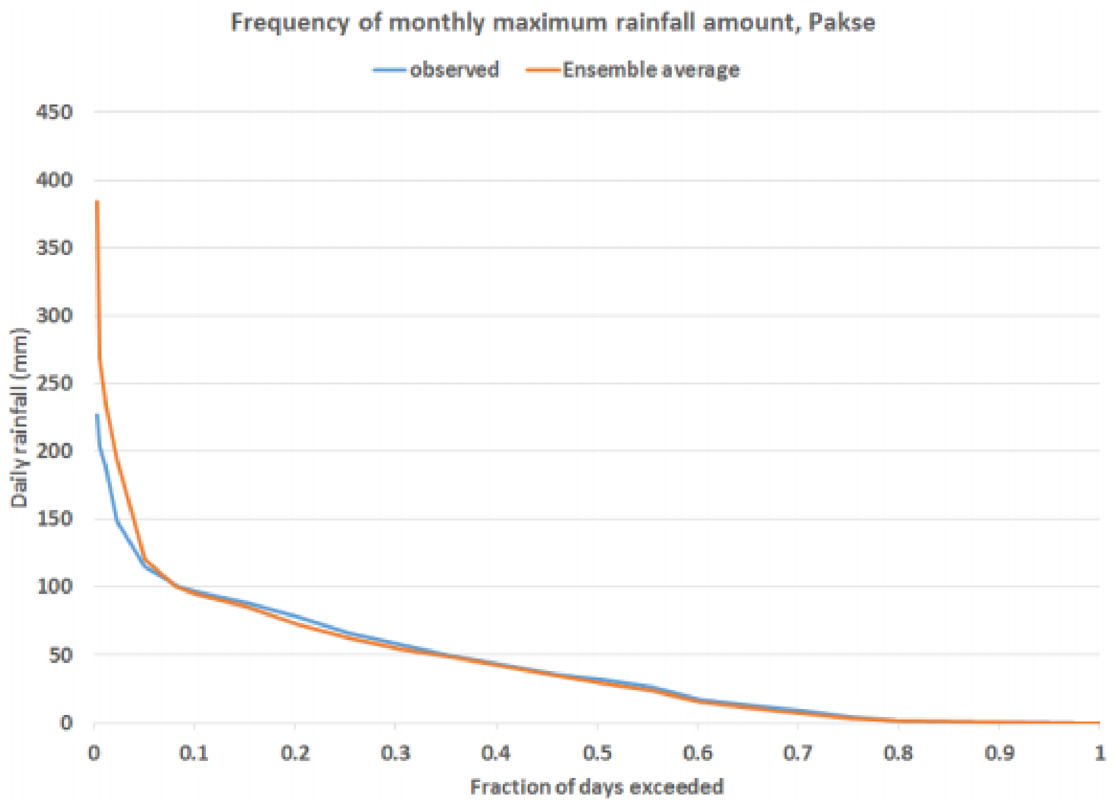


Figure 10. Sample of frequency for monthly maximum rainfall showing observed vs predicted frequencies

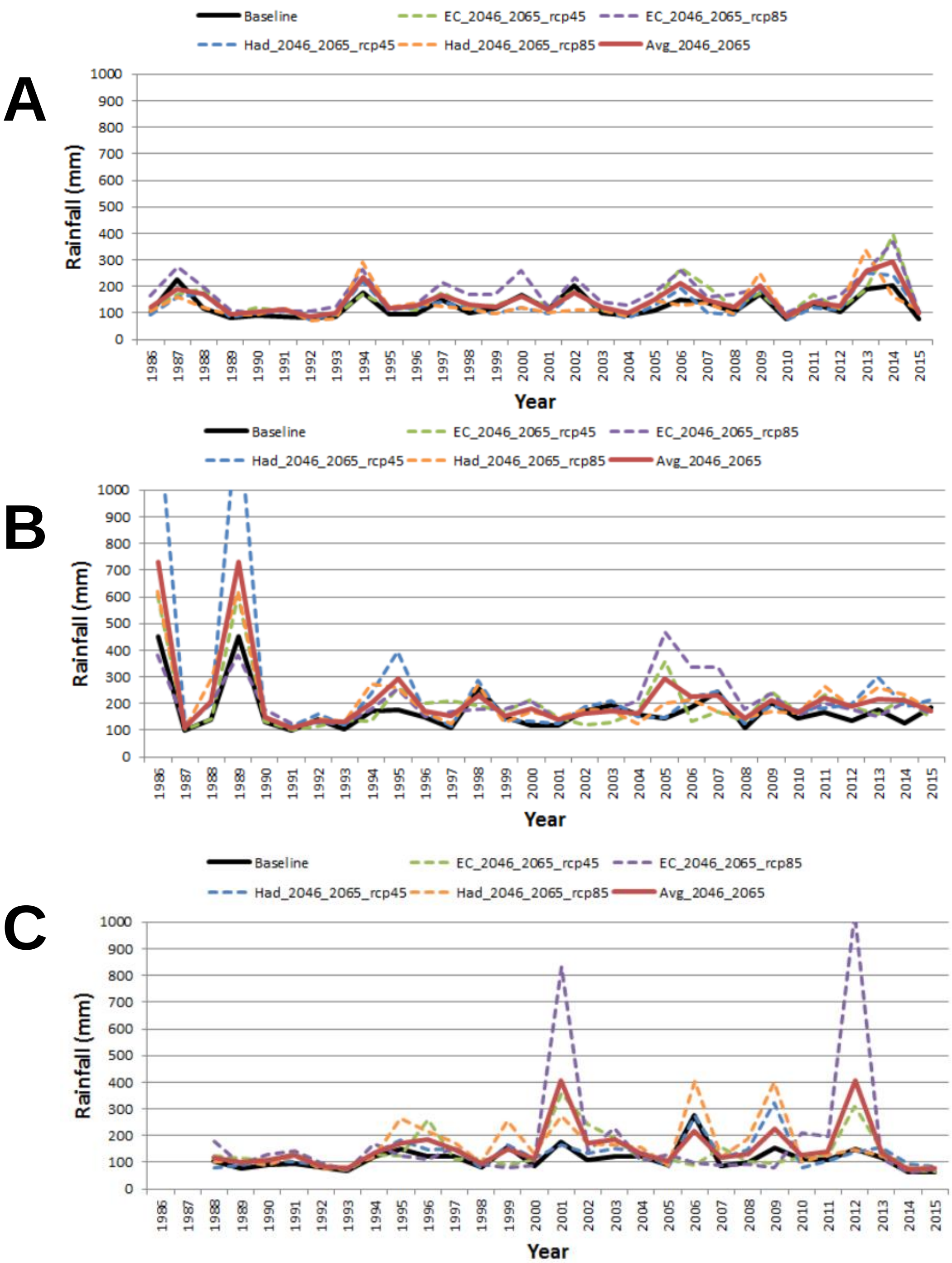


Figure 11. Annual maximum daily rainfall for the period 2046—2065. A = Pakse city; B = Paksan city; C = Savannakhet city. The graph depicts a time series of the maximum daily rainfall event for each year of the observed rainfall time series. Solid black lines represent the baseline climate conditions, solid red lines represent the average of all model projections, and dashed lines represent individual model projections under either RCP 4.5 (blue, green) or RCP 8.5 (orange, purple).

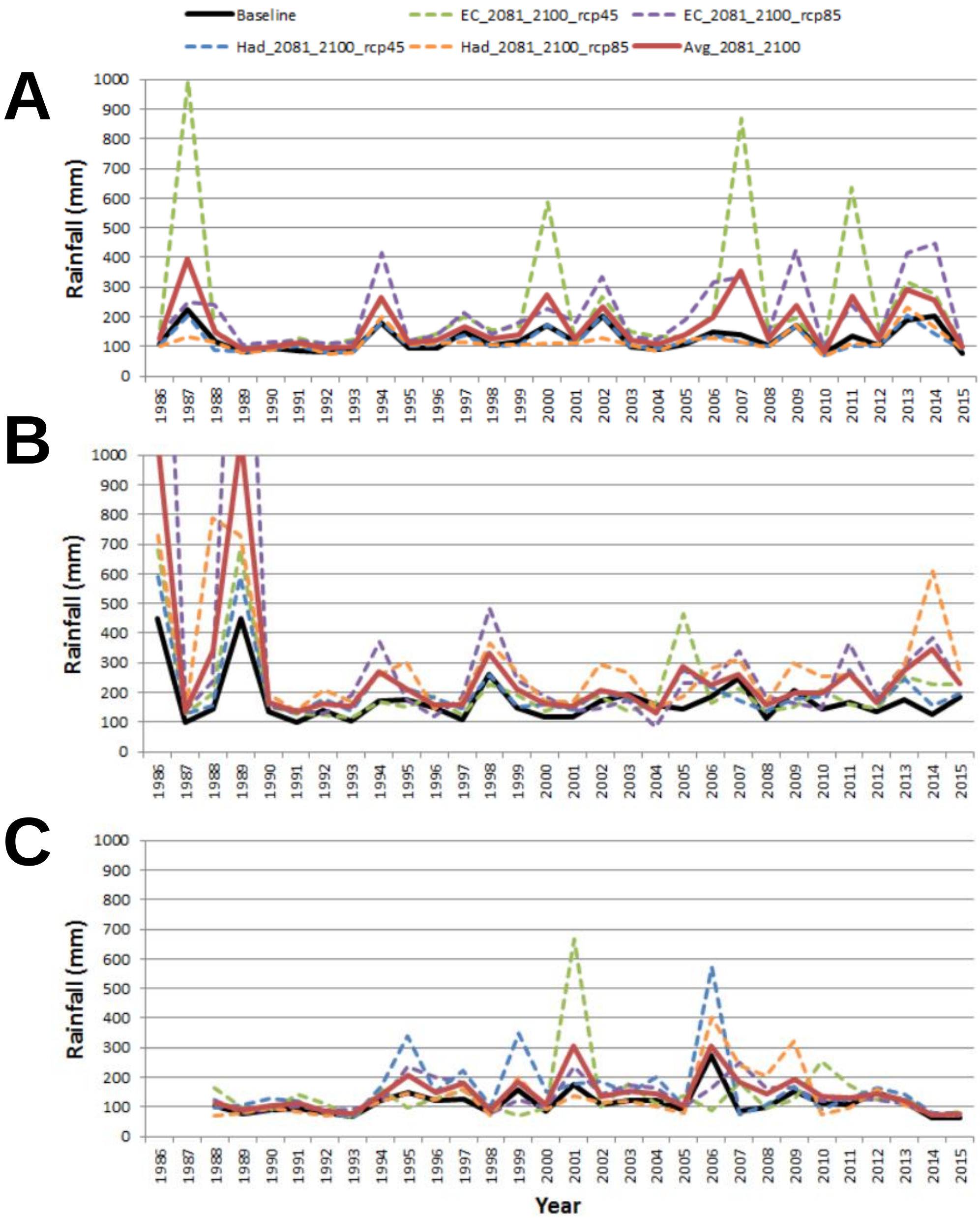


Figure 12. Annual maximum daily rainfall for the period 2081—2100. A = Pakse city; B = Paksan city; C = Savannakhet city. The graph depicts a time series of the maximum daily rainfall event for each year of the observed rainfall time series. Solid black lines represent the baseline climate conditions, solid red lines represent the average of all model projections, and dashed lines represent individual model projections under either RCP 4.5 (blue, green) or RCP 8.5 (orange, purple).

6.3.1.1 Pakse City

Average monthly rainfall

Relatively small increases in average rainfall are predicted for the rain season. The predicted average monthly rainfall values are compared for Pakse city in Figures 13 and 14 and for the catchment in Figures 17 and 18.

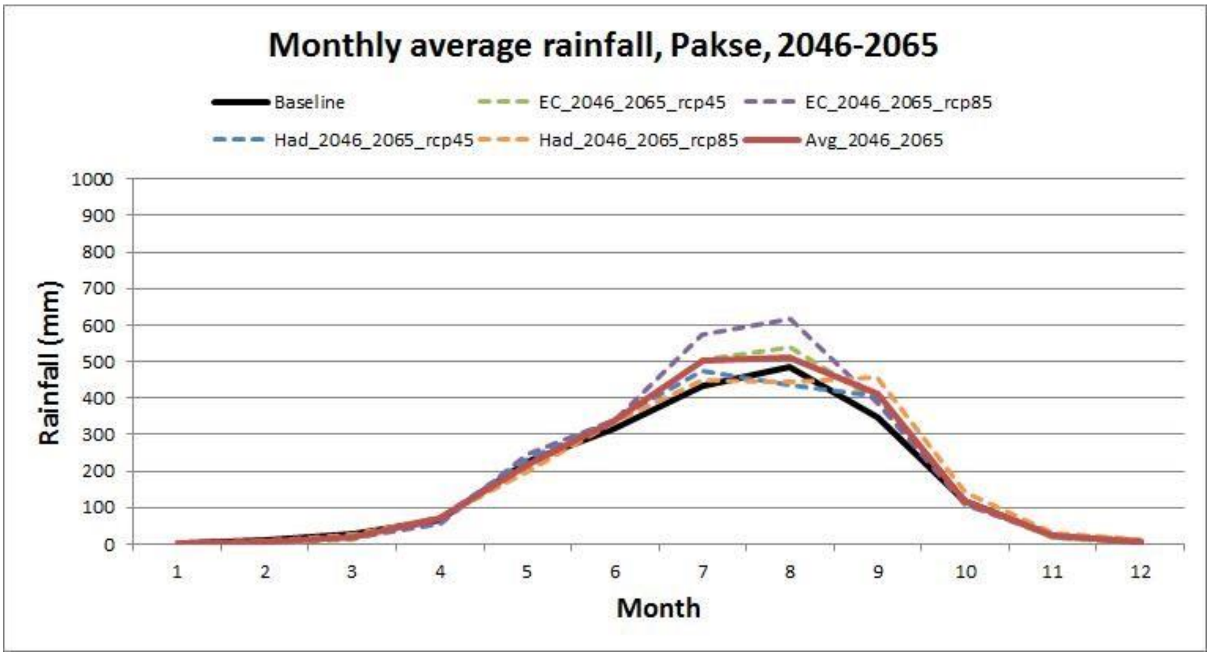


Figure 13. Average monthly rainfall, Pakse, 2046–2065. The graph depicts a time series of the monthly average rainfall. Solid black lines represent the baseline climate conditions, solid red lines represent the average of all model projections, and dashed lines represent individual model projections under either RCP 4.5 (blue, green) or RCP 8.5 (orange, purple).

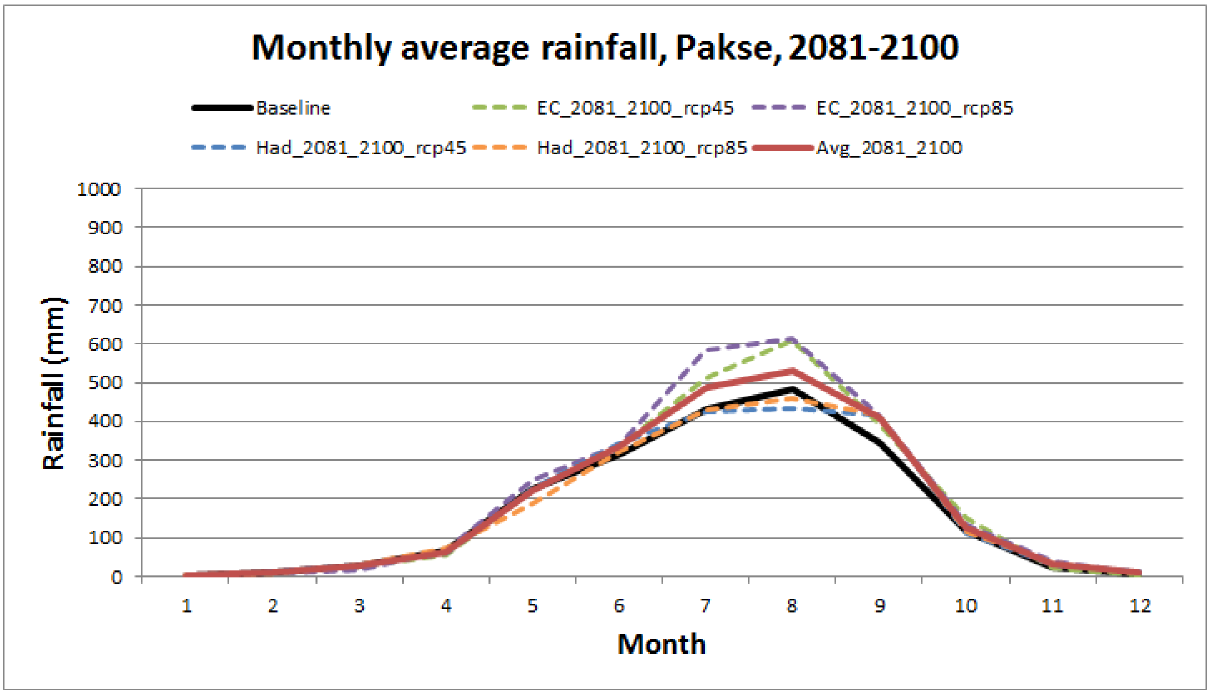


Figure 14. Average monthly rainfall, Pakse, 2081–2100. The graph depicts a time series of the monthly average rainfall. Solid black lines represent the baseline climate conditions, solid red lines represent the average of all model projections, and dashed lines represent individual model projections under either RCP 4.5 (blue, green) or RCP 8.5 (orange, purple).

The largest changes by proportion were predicted in the driest months (Dec–Feb). These changes ranged from a 45% decrease in February to a 54% increase in December for the 2046–2065 projections. Similarly, the 2081–2100 projections ranged from a 37% decrease in January to an 85% increase in December. The 2046–2065 and 2081–2100 projections predicted an overall increase in rainfall of 8% and 10% respectively (see Annex 13 for further detail).

6.3.1.2 Pakse catchment

Annual maximum time series

Changes in the magnitude of extreme rainfall events are likely to be less noticeable at larger catchment scales because the impacts of local extreme rainfall events are averaged out over a larger area. The annual maximum time series for Pakse catchment, which shows this result, is displayed in Figures 15 and 16.

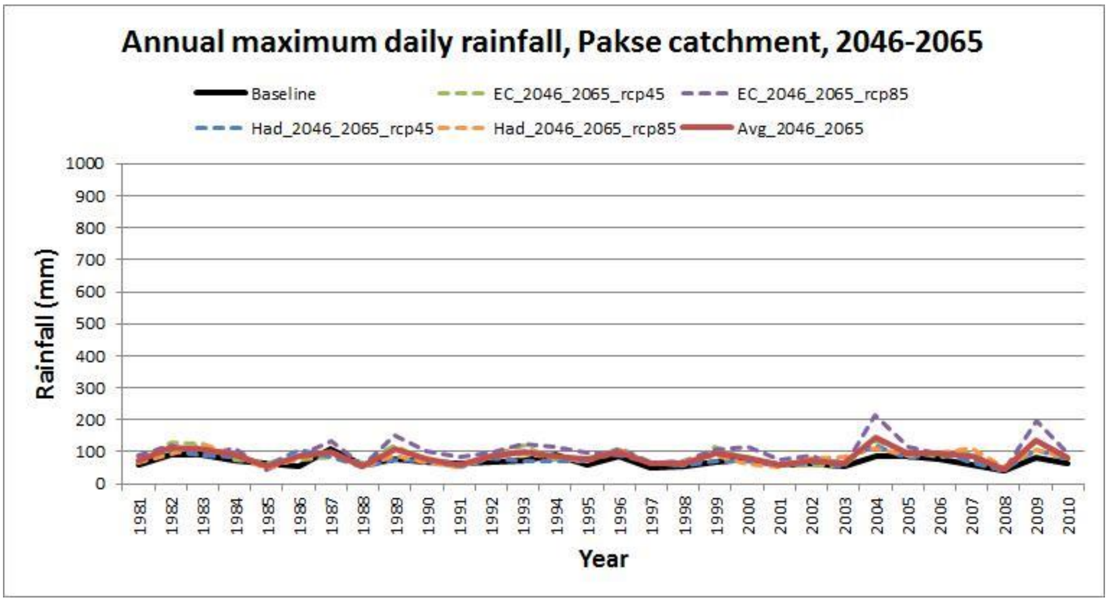


Figure 15. Annual maximum daily rainfall, Pakse catchment, 2046–2065. The graph depicts a time series of the annual maximum daily rainfall for the Pakse catchment. Solid black lines represent the baseline climate conditions, solid red lines represent the average of all model projections, and dashed lines represent individual model projections under either RCP 4.5 (blue, green) or RCP 8.5 (orange, purple).

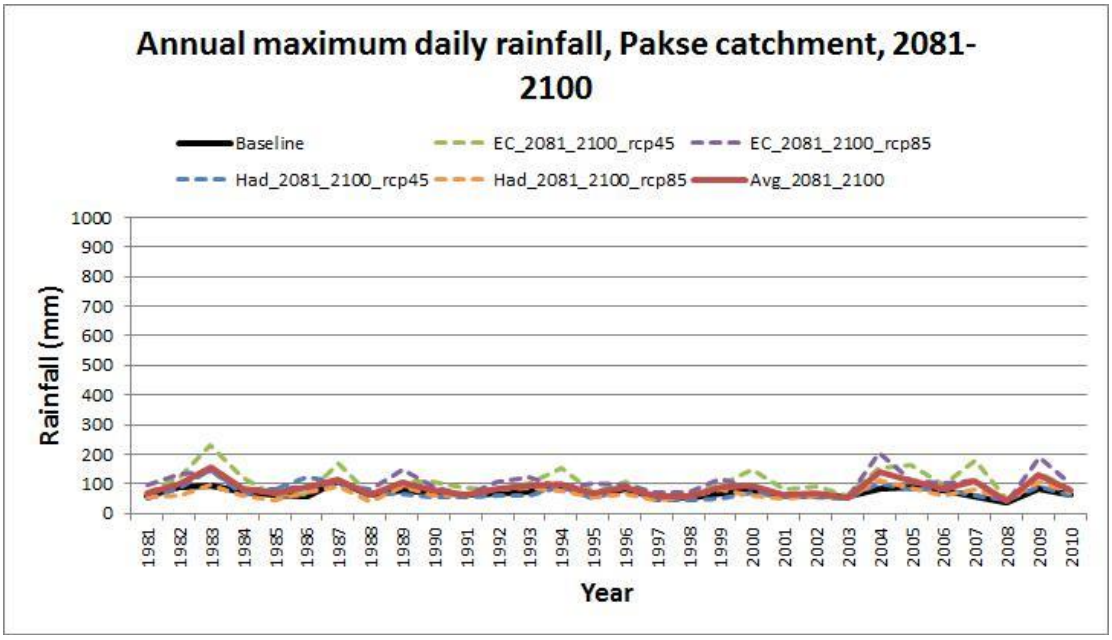


Figure 16. Annual maximum daily rainfall, Pakse catchment, 2081–2100. The graph depicts a time series of the annual maximum daily rainfall for the Pakse catchment. Solid black lines represent the baseline climate conditions, solid red lines represent the average of all model projections, and dashed lines represent individual model projections under either RCP 4.5 (blue, green) or RCP 8.5 (orange, purple).

Duration curve of monthly maximum rainfall time series

Extreme rainfall events in the Pakse catchment are projected to be more likely in future, although the projected change is not as significant for the catchment as for Pakse city. Further details on the predicted increase in extreme rainfall events are presented in Annex 13: Vulnerability Assessment.

Average monthly rainfall

Projections indicate that significant changes to average rainfall are unlikely at larger scales. This is shown in projections of monthly average rainfall for Pakse catchment (Figures 17 and 18).

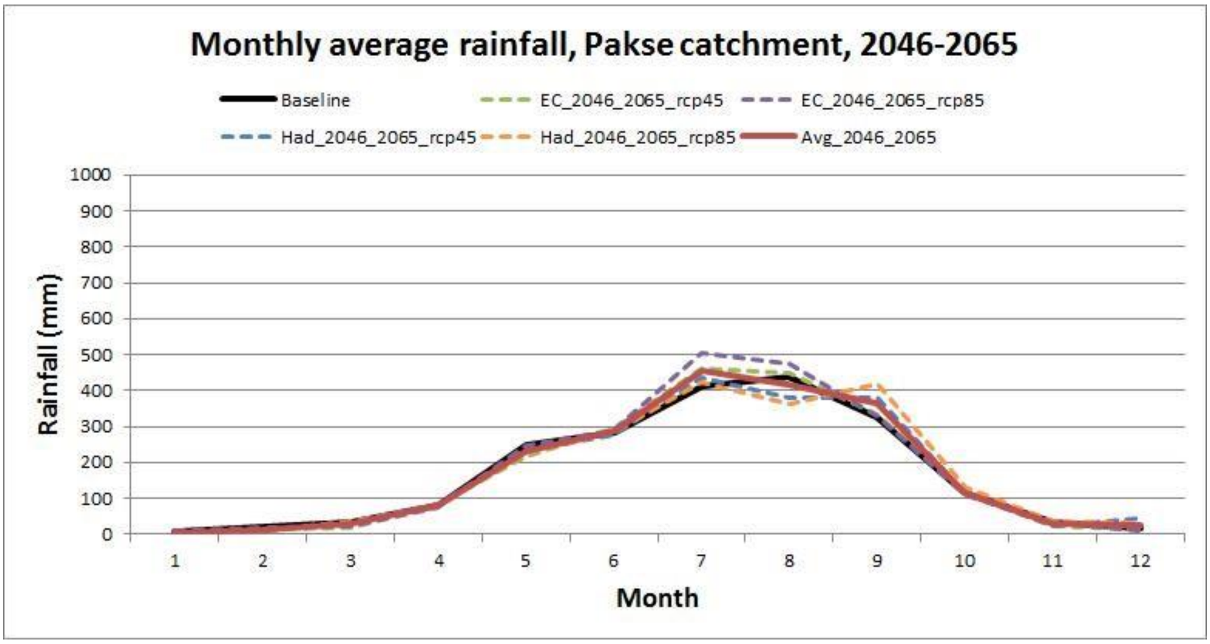


Figure 17. Average monthly rainfall, Pakse catchment, 2046–2065. The graph depicts a time series of the average monthly rainfall for the Pakse catchment. Solid black lines represent the baseline climate conditions, solid red lines represent the average of all model projections, and dashed lines represent individual model projections under either RCP 4.5 (blue, green) or RCP 8.5 (orange, purple).

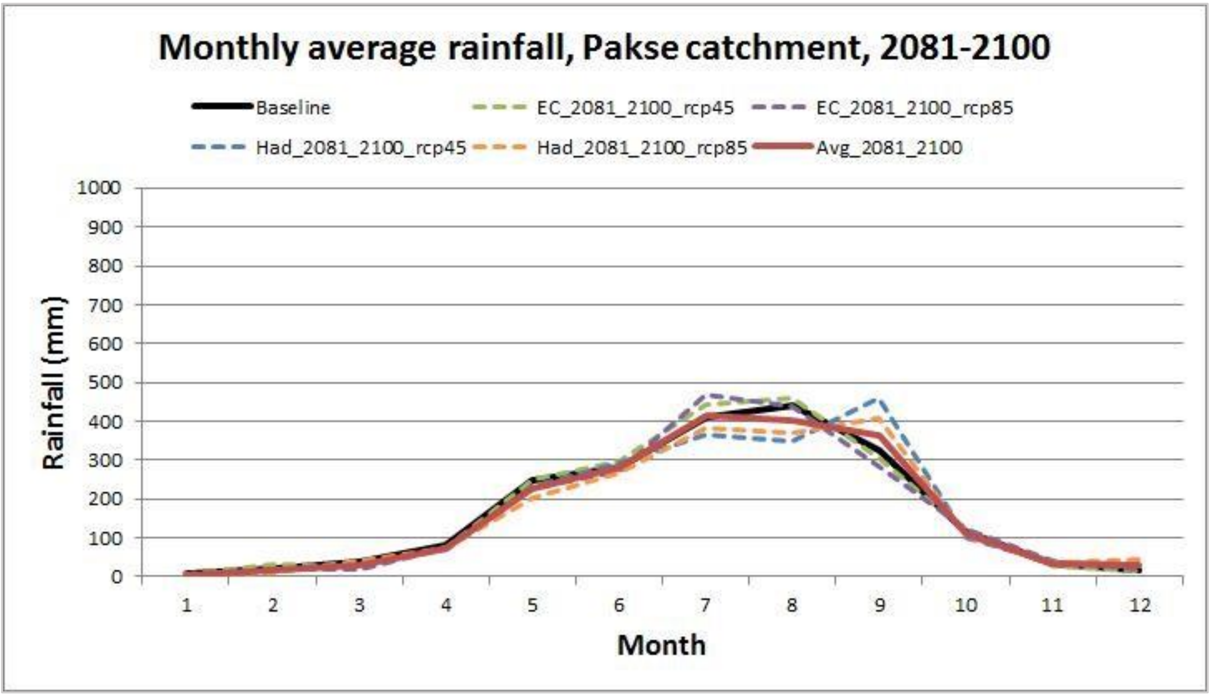


Figure 18. Average monthly rainfall, Pakse catchment, 2081–2100. The graph depicts a time series of the average monthly rainfall for the Pakse catchment. Solid black lines represent the baseline climate conditions, solid red lines represent the average of all model projections, and dashed lines represent individual model projections under either RCP 4.5 (blue, green) or RCP 8.5 (orange, purple).

The largest changes by proportion were predicted in the driest months (Dec–Feb). These changes ranged from a 36% decrease in February to a 32% increase in December for the 2046–2065 projections. Similarly, the 2081–2100 projections ranged from a 25% decrease in January to an 51% increase in December. The 2046–2065 and 2081–2100 projections predicted an overall increase in rainfall of 1.5% and decrease of 1.5% respectively (see Annex 13 for further detail).

6.3.2 Temperature

In the model projections, temperatures were projected to increase by 1.8°C for 2046–2065 and 3.1°C for 2081–2100. Trends for Pakse city and Pakse catchment were similar.

6.3.2.1 Pakse city

Average temperatures are projected to increase, with more significant increases and greater uncertainty in the end-of-century projection. In the 2046–2065 projections, temperatures were predicted to increase by 1.8°C. Monthly average temperature increases ranged from 1.45°C in December to 2.52°C in May. Similarly, the 2081–2100 predict an average increase of 3.1°C, with monthly temperature increases ranging from 2.5°C in February to 3.84°C in May (see Annex 13 for further detail).

6.3.2.2 Pakse catchment

As with extreme rainfall events, changes in average temperature are projected to be smaller at the catchment scale than at the city scale, because of averaging effects. In Pakse catchment, the 2046–2065 projections predicted an increase in temperature by 1.8°C. Monthly average temperature increases ranged from 1.39°C in December to 2.49°C in May.

Similarly, the 2081–2100 predict an average increase of 3.1°C, with monthly temperature increases ranging from 2.43°C in February to 3.82°C in May (see Annex 13 for further detail).

7 Vulnerability assessment

Vientiane, Paksan, Savannakhet, Pakse, Luang Prabang and Thakek have been identified as being vulnerable to seasonal flooding[122], which is predicted to be exacerbated by climate change. Increases in the number of extreme rainfall events will increase both the intensity and frequency of flooding in the six cities. A flood vulnerability assessment was conducted for each of the six cities, however only the results of the assessment for the four target cities (Vientiane, Paksan, Savannakhet and Pakse) are presented below. This assessment consisted of a remote sensing analysis of flood-prone areas and sensitive land-use types as well as engagement with local stakeholders.

7.1 Remote sensing analysis

The analysis consisted of three steps. Firstly, flood-prone areas were modelled and mapped using digital elevation data. Secondly, land-use in each of the cities was classified using remote sensing imagery. Lastly, a sensitivity map was generated by overlaying the land-use and flood maps. These steps are described in the following sections.

7.1.1 Hazard assessment and mapping

Hazard maps were produced for each city to show flood-prone areas. A digital elevation model (DEM), based on the height above nearest drainage point (HAND system), was used to assess flood-prone areas. The HAND model is a simple approach for rapid flood-risk assessment that classifies flood risk in an area by its elevation above the nearest inlet point. HAND models are preferable to simply classifying terrain by elevation because they take flow pathing into account. In addition, existing spatial datasets for the four cities are of insufficient resolution and quality to justify the use of dynamic hydrological models which would have enabled the assessment of parameters such as event duration and flow dynamics.

The HAND model used in this assessment is based on a DEM derived from Shuttle Radar Topography Mission (SRTM) remote sensing imagery. The DEM has a resolution of 30 metres, but its accuracy is limited in urban areas because the quality of spatial data is still limited. For verification, the HAND model was compared with local information received from Laos. Although there was not complete agreement between the datasets, it was decided that the data were sufficient for creating preliminary maps of flood extent. The information provided by the maps can be improved by using specific records of flood events and their extent. Examples of outputs from the HAND model are shown in **Error! Reference source not found.**20 for Pakse.

[122] A vulnerability assessment conducted by DHI (Annex 13) identified these cities as being vulnerable to seasonal flooding.

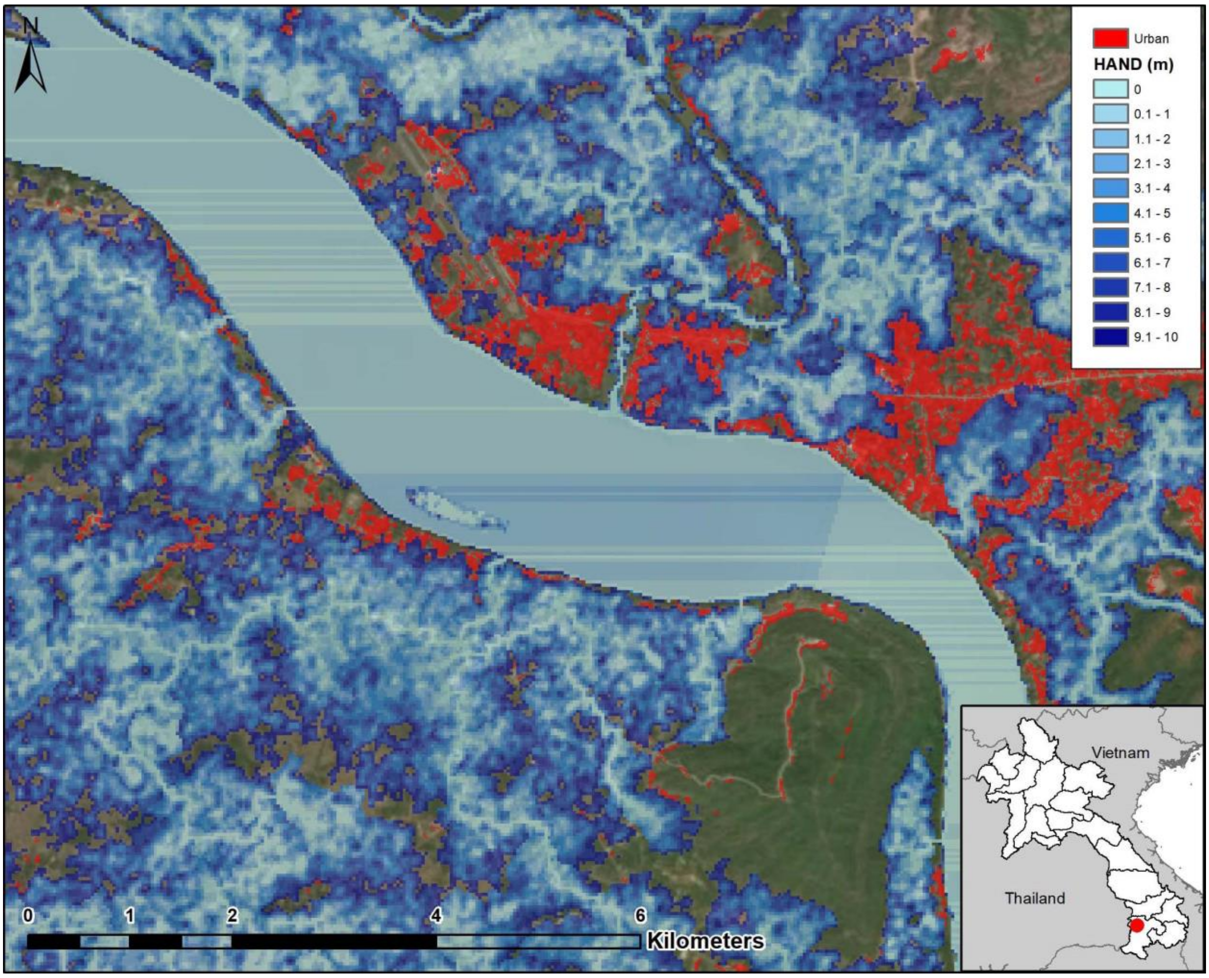


Figure 50. HAND-index map for Pakse with index values. Red lines indicate built-up areas. The dark blue "0 m" corresponds to the water levels in rivers and lakes. White areas are more than 10 m above potentially flooded terrain.

7.1.2 Land-use classification analysis

Existing land-use data could not be used for the analysis, as they were either of insufficient resolution, inaccurate or outdated. A land-use classification analysis was therefore performed on satellite images from Sentinel 2 (see Table 5). These images were taken over two seasons, with a resolution of 10 metres.

Table 5. Dates of the land-use classification analysis undertaken at each site.

City	**Image I, date**	**Image II, date**
Vientiane	28 November 2016	16 February 2017
Paksan	25 December 2016	24 January 2017
Kaysone Phomvihane/Savannakhet	25 December 2016	5 March 2017
Pakse	12 November 2016	2 March 2017

The classification was developed by identifying 11 different types of land uses typical to the Laotian context. The 11 classes identified were: i) forest (deciduous); ii) agriculture; iii) bare soil; iv) forest (coniferous); v) rubber plantation; vi) rice paddies; vii) irrigated rice; viii) roads; xi) urban (built-up); x) water; and xi) grassland.

The distinction between rice paddies and irrigated rice was created during an analysis of the images across seasons. This revealed that few rice paddies are irrigated during the dry season.

With a resolution of 10 metres, the method cannot identify small houses or sections of roads, but the results are suitable for further use in the overall vulnerability analysis. An example of a land cover analysis is shown in Figure 221 below.

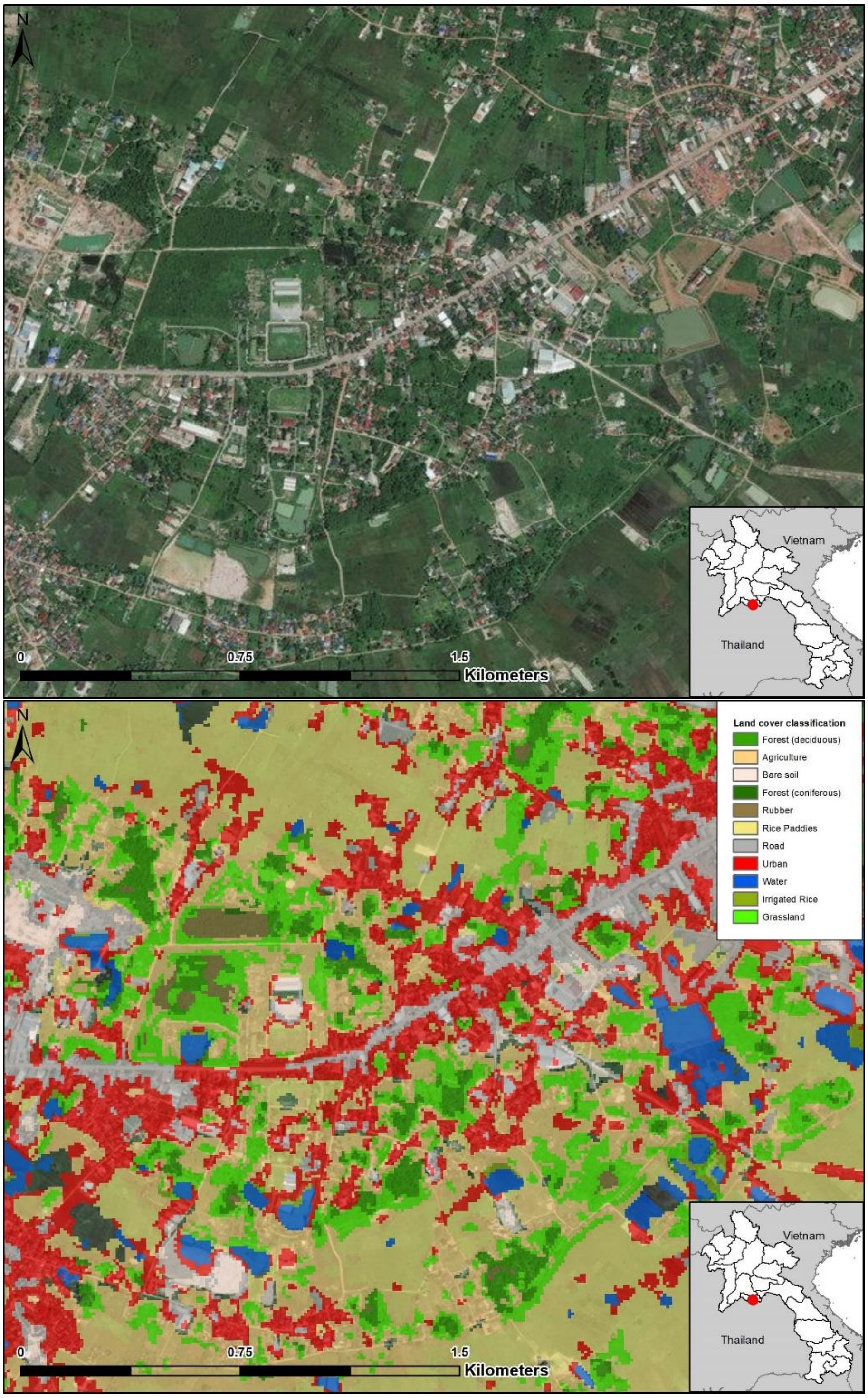


Figure 21. Example from the land cover classification in Vientiane.

7.1.3 Sensitivity analysis

The sensitivity analysis consists of an overlay of the land use spatial layer and the HAND model outputs. Land uses were ranked according to their sensitivity to flooding (see Table 6 below). The rankings were based on expert opinion and stakeholder input provided during a workshop in September 2017. Notably, stakeholders commented that rice farming should be ranked as highly sensitive.

Table 6. 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 — and areas with water levels above 10 m were disregarded. These four categories are shown in Table 7. The exposure codes are skewed towards high-frequency flood levels. For example, 3-metre bands were used for high and medium exposure (0–2.99 m and 3–5.99 m) and 4 meters for low exposure (6–9.99 m).

Table 7. Exposure code for flooding, based on the HAND-method.

HAND Index, m	Exposure code	Exposure text
0.0–2.99 m	3	High exposure and flooded often
3.0–5.99 m	2	Medium exposure and flooded less often
6.0–9.99 m	1	Low exposure and seldom flooded
Above 10 m	NULL	Very low exposure and disregarded

7.2 Site identification

Six major Laotian cities (Vientiane, Paksan, Savannakhet, Pakse, Luang Prabang and Thakek) were identified by the government based on their economic importance and flood vulnerability. A UNEP-DHI study, commissioned and conducted through CTCN, was undertaken to assess the vulnerability of six major Laotian cities (Vientiane, Paksan, Savannakhet, Pakse, Luang Prabang and Thakek) to the impacts of climate change and to identify potential sites for the implementation of EbA interventions. Results from this study identified the increased frequency, intensity and extent of flooding as the major climate threat to urban areas in Laos[123]. Concomitantly, stakeholders from the six cities, including city-level representatives from MONRE, MPI, MPWT, MAF and the National Women's Union, were engaged during initial site identification workshops conducted in September 2017. Following these initial engagements, participatory mapping exercises were conducted with relevant stakeholders in October 2017 to validate the potential sites for EbA (see Section 10). During the validation of potential sites, it was determined that hydrological conditions were difficult to assess in Luang Prabang and Thakek. This led to challenges in the design of appropriate EbA interventions for these cities. As a result of these factors, Vientiane, Paksan, Savannakhet and Pakse were identified as the primary cities to receive EbA interventions[124]. These cities were visited by international consultants and engagement with local community members took place to verify flood impacts in the area.

Where sites selected and validated by stakeholders did not appear as vulnerable areas on the vulnerability assessment, stakeholder input was prioritised. This is because the resolution and of the vulnerability assessments were not as high as local knowledge.

[123] Further details on current and predicted climate trends in Laos, as well as the associated impacts, are presented in Section 2 of this document (Annex 2. Feasibility Study) and in Annex 13. Vulnerability Assessment.
[124] Further details on site selection are presented in Section 1.9 of this Feasibility Study.

Final site selection was based on the above analyses, as well as extensive stakeholder consultations and site visits.

7.3 Vulnerability assessments of four major cities along the Mekong

The following sections show the results of vulnerability assessments for the four cities. Data used to produce the following maps and assessments is suitable for preliminary risk assessment. To identify the precise location of interventions within the identified sites, in-depth assessments will need to be undertaken during project implementation using technology such as LIDAR.

Sections for each city the identified sites, are presented below, showing the: i) location of the site; ii) flood hazard map; iii) land cover classification map; and iv) vulnerability map. A short description and specific observations are given for each site. The demarcation of the sites is indicative only.

7.3.1 Vientiane

The two sites identified in Vientiane are located to the north of the city centre and both sites can be classified as peri-urban. The sites are situated adjacent to each other, as illustrated in **Error! Reference source not found.**22. The description of these sites provided in Annex 13: Vulnerability Assessment indicates that flooding occurs annually in both areas, which are crossed by small streams.

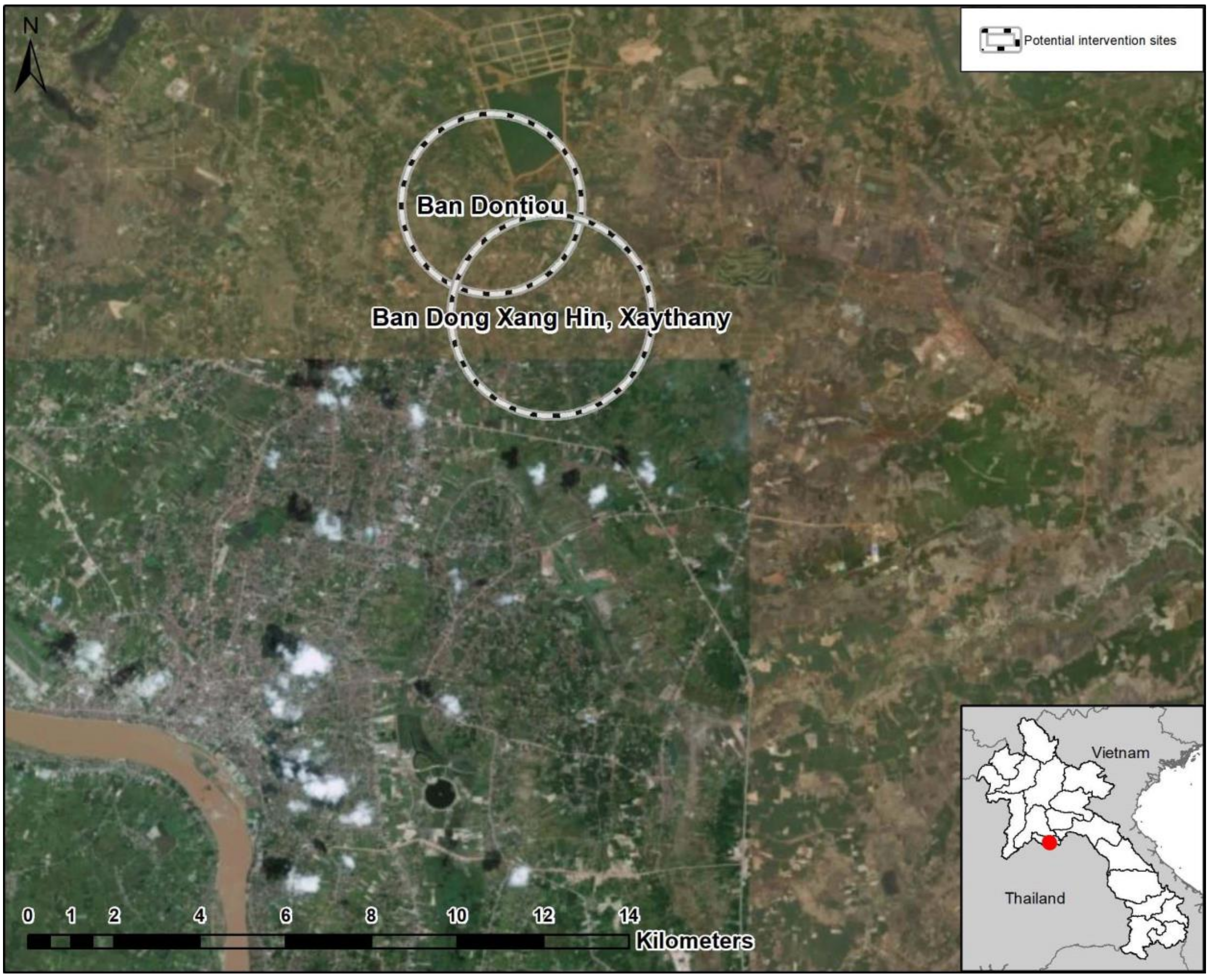


Figure 22. Potential intervention sites in Vientiane.

7.3.1.1 Hazard mapping

Figure 23 shows that both sites are in low-lying areas, where flooding happens when stream levels rise. The outlines of the small streams are shown on the map. Most of the built-up areas in the Ban Dontiou site are elevated and are thus not as flood-prone as other land uses. The Ban Dong Xan Hing site shows similar characteristics to Ban Dontiou.

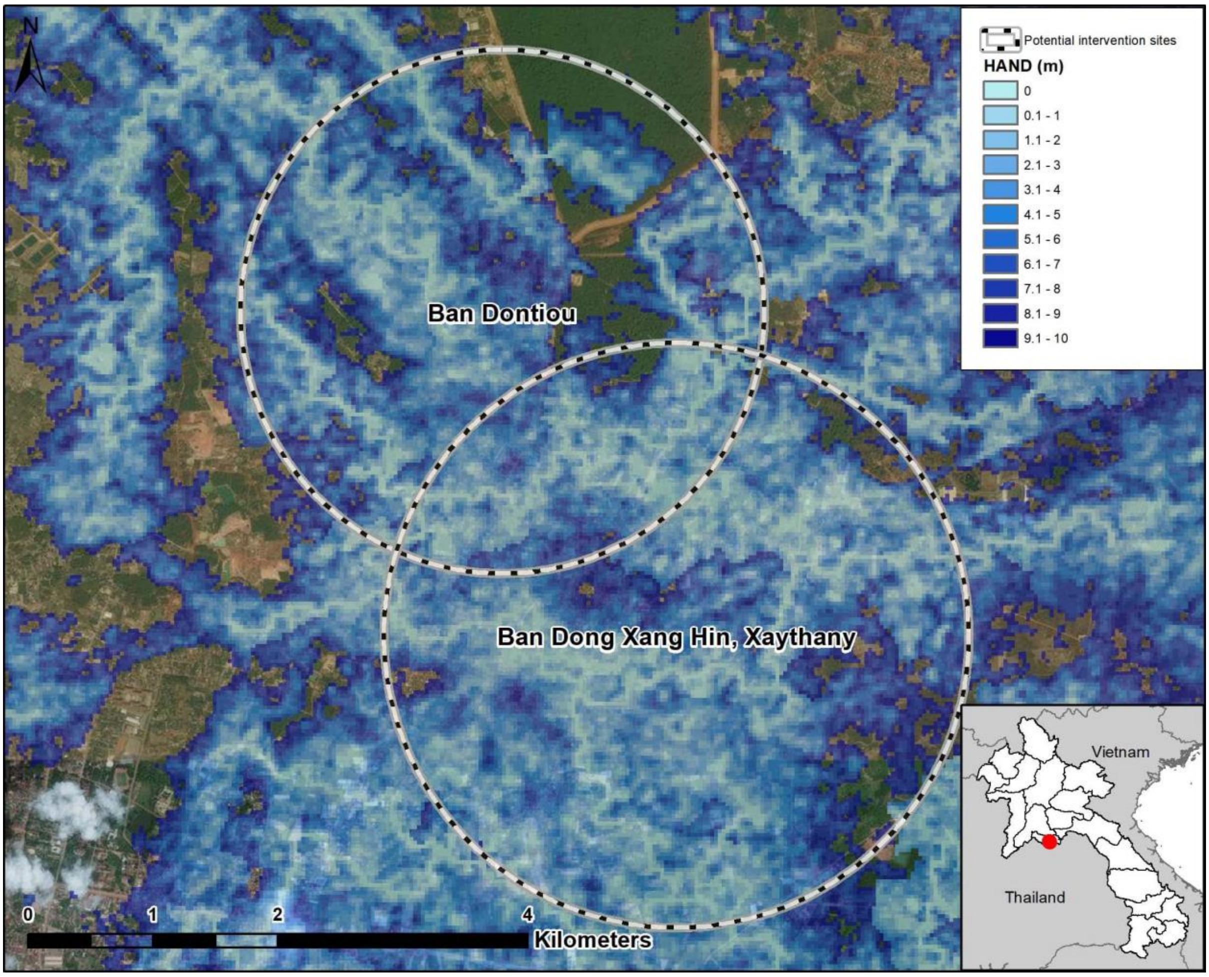


Figure 23. Vientiane flooding hazard map (0 = open water, 1–11 = 1 metre increase in elevation, areas above 10 m are not expected to be flooded).

7.3.1.2 Sensitivity mapping

The land cover classification (shown in **Error! Reference source not found.**24) shows that both sites contain concentrated urban areas as well as scattered houses along the main roads. Ban Dontiou mainly consists of forest and grassland, with some rice farming — which is one of the dominant land uses in the Ban Dong Xang Hin area.

7.3.1.3 Vulnerability mapping

The vulnerability assessment of the two sites shows that the differences in dominant land uses have a direct impact on vulnerability. **Error! Reference source not found.**25 shows the vulnerability map of Vientiane. Ban Dontiou has large areas of low vulnerability, whereas the Ban Dong Xang Hin site has substantial areas where the vulnerability is considered medium or high.

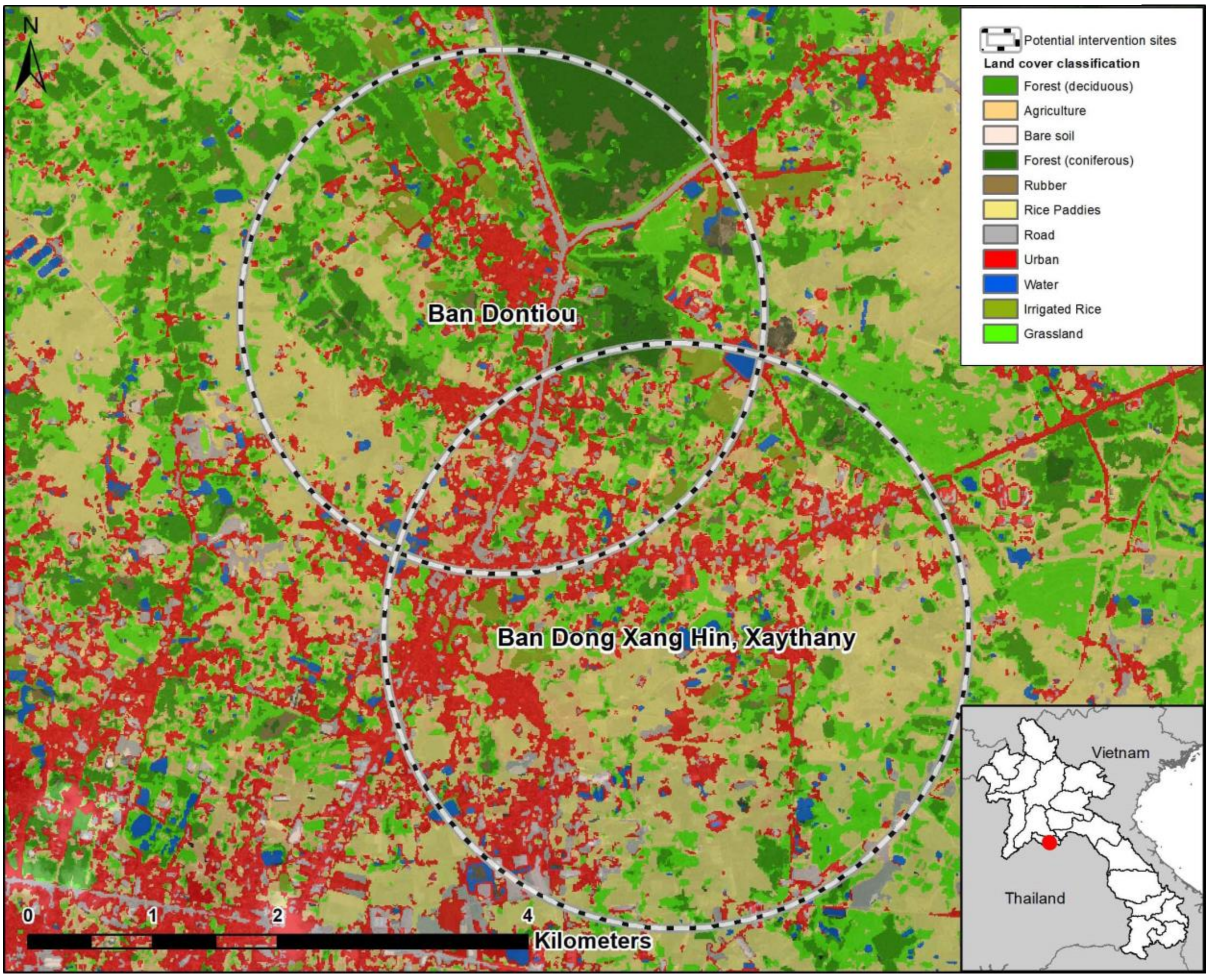


Figure 24. Vientiane land classification.

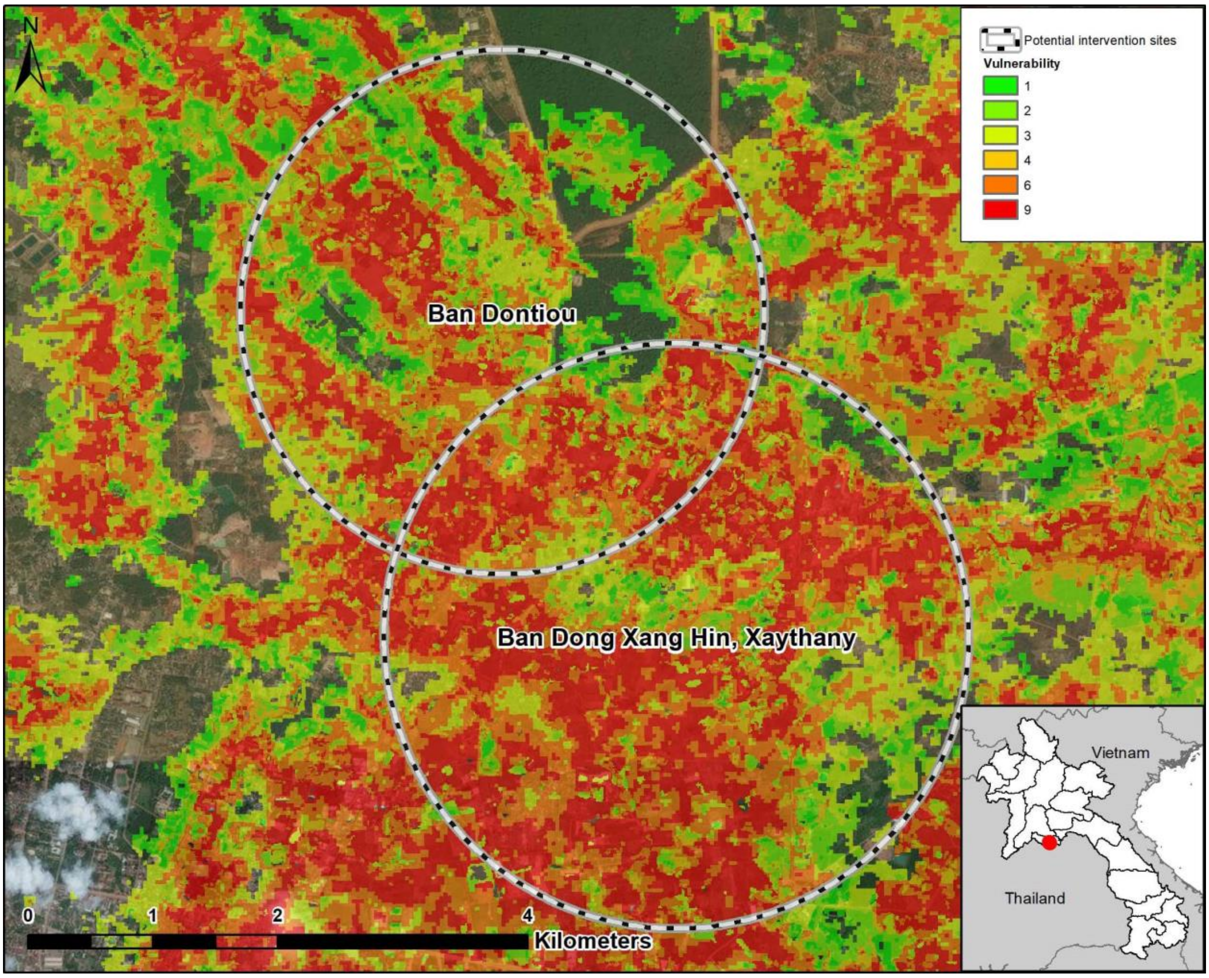


Figure 25. Vulnerability map of Vientiane.

7.3.2 Paksan

The two identified sites in Paksan are shown in Figure 26. Site 1 has peri-urban characteristics, with flood-prone areas in the urban parts to the west. Project Site 2 is rural but includes areas that are under development.

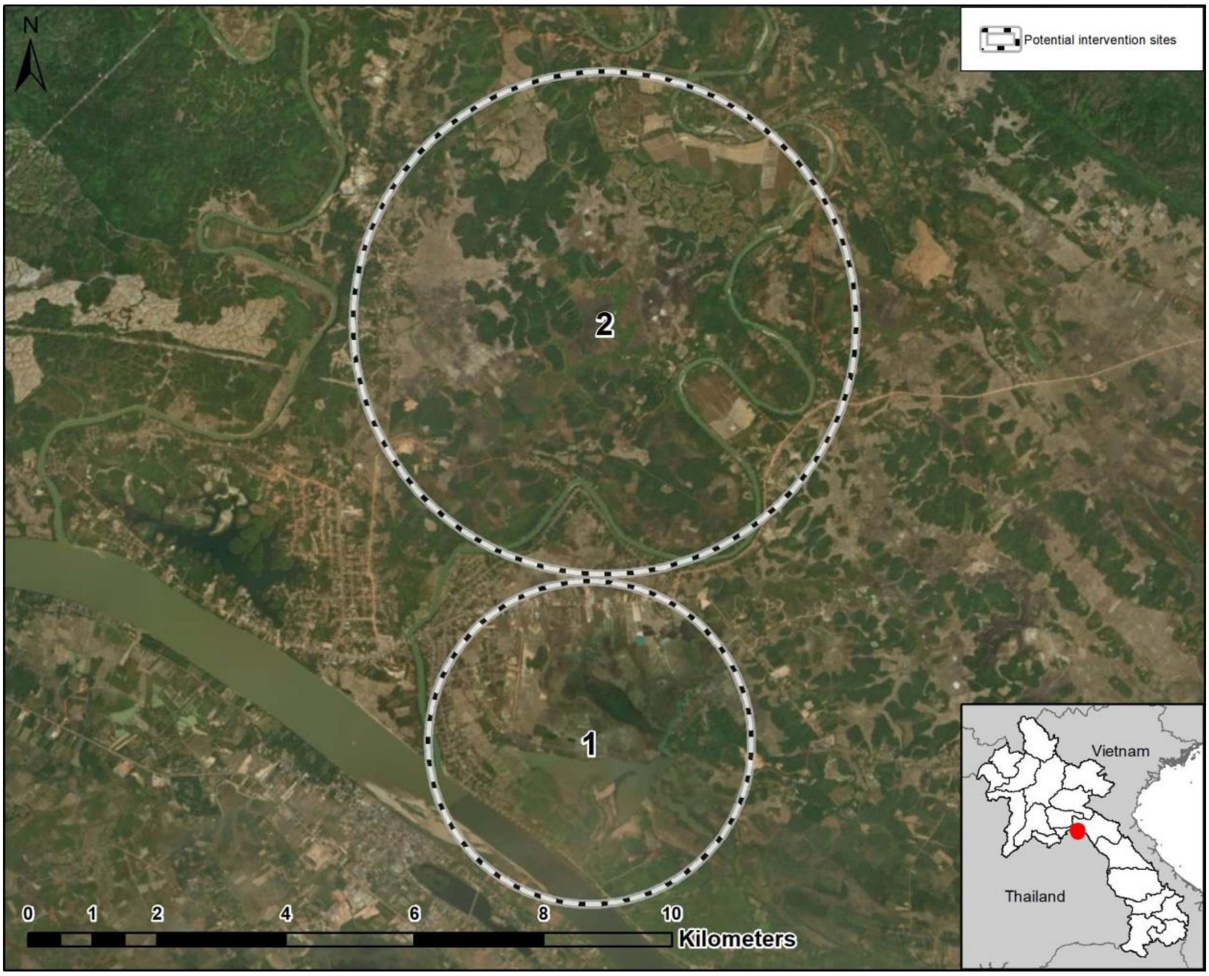


Figure 26. Potential intervention sites in Paksan.

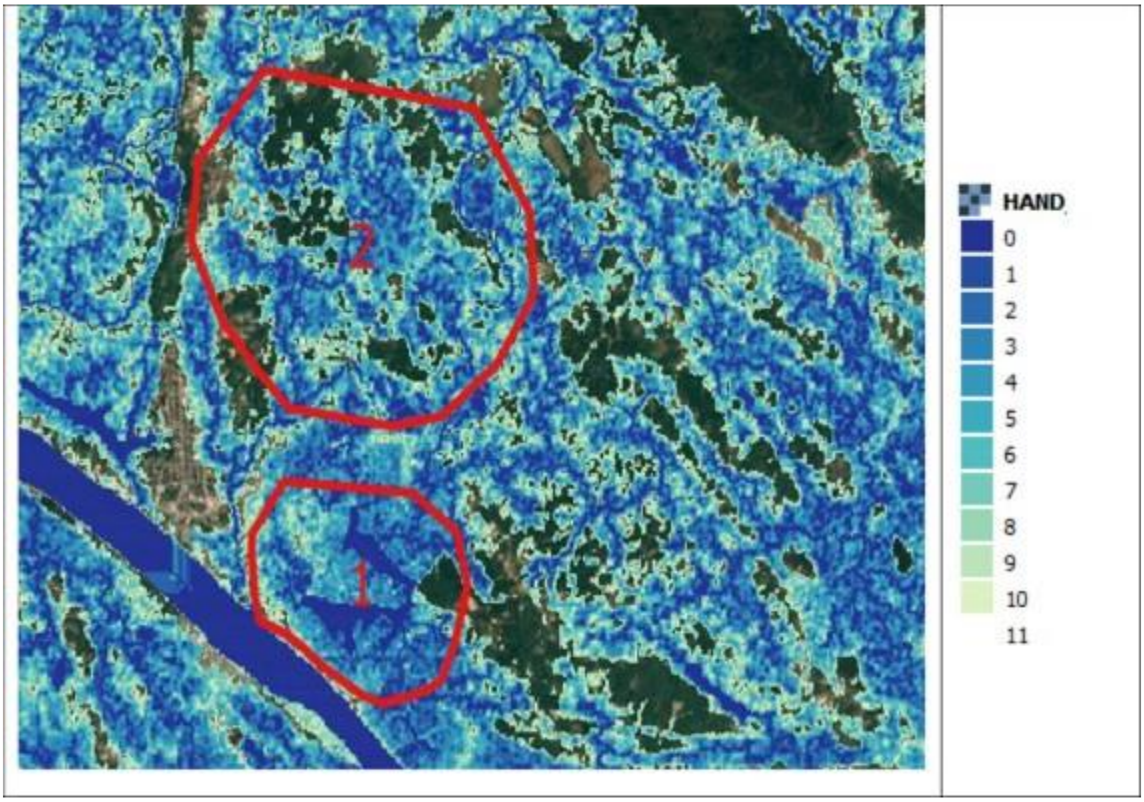
7.3.2.1 Hazard mapping

The flood hazard map for Paksan is shown in Figure 27. Site 1 is shown to be substantially more exposed to flood hazards than Site 2. The assessment shows that even small rises in the water level in the Mekong — or a further increase in water flows routed from the city — will cause flood conditions in Site 1. However, the most flood-prone areas have been identified as lakes and wetlands. The remaining sensitive areas in the western part of Site 1 are classified as agriculture/rice fields, which are typically low-lying and consequently flood prone. The flooding at Site 2 is caused by the overflow of the tributary river which crosses the site.

7.3.2.2 Sensitivity mapping

Figure 28 shows the land cover classification in the Paksan area. The land cover classification indicates that Site 1 consists mostly of rice paddies and irrigated rice. Both rain-fed and irrigated rice crop-classes are considered highly sensitive to flooding. The remaining land uses are plantation forest and urban areas, but these are not prevalent.

Site 2 consists mostly of rice agriculture (irrigated and non-irrigated), with large patches of forest. In addition, sparse houses are situated near roads and streams.



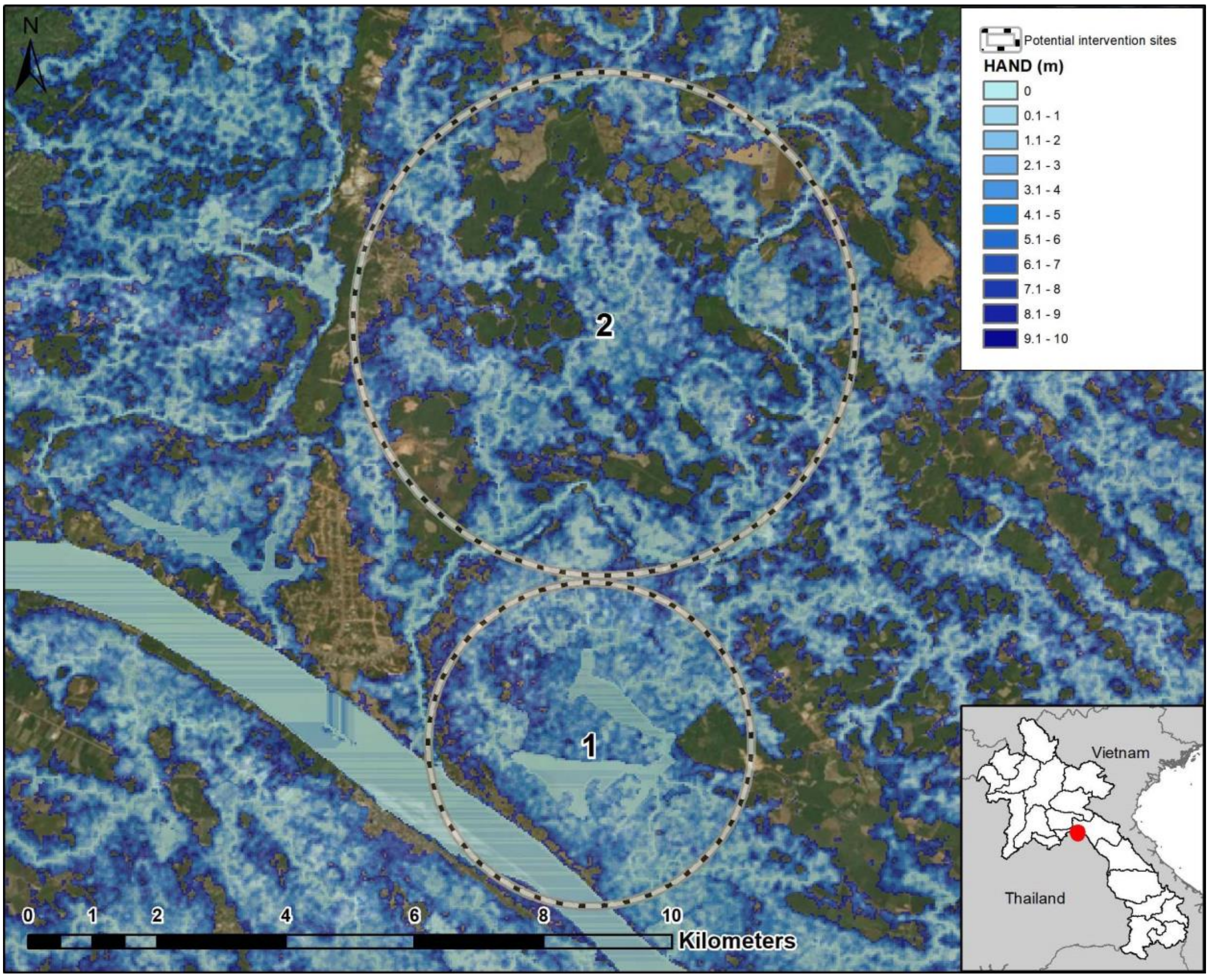


Figure 27. Paksan. Flooding hazard map (0 = open water, 1–11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded).

7.3.2.3 Vulnerability mapping

The vulnerability map, shown in **Error! Reference source not found.**29, shows that rice paddies are the most vulnerable areas to flooding. Urban areas in the western part of Site 1, however, are not particularly exposed.

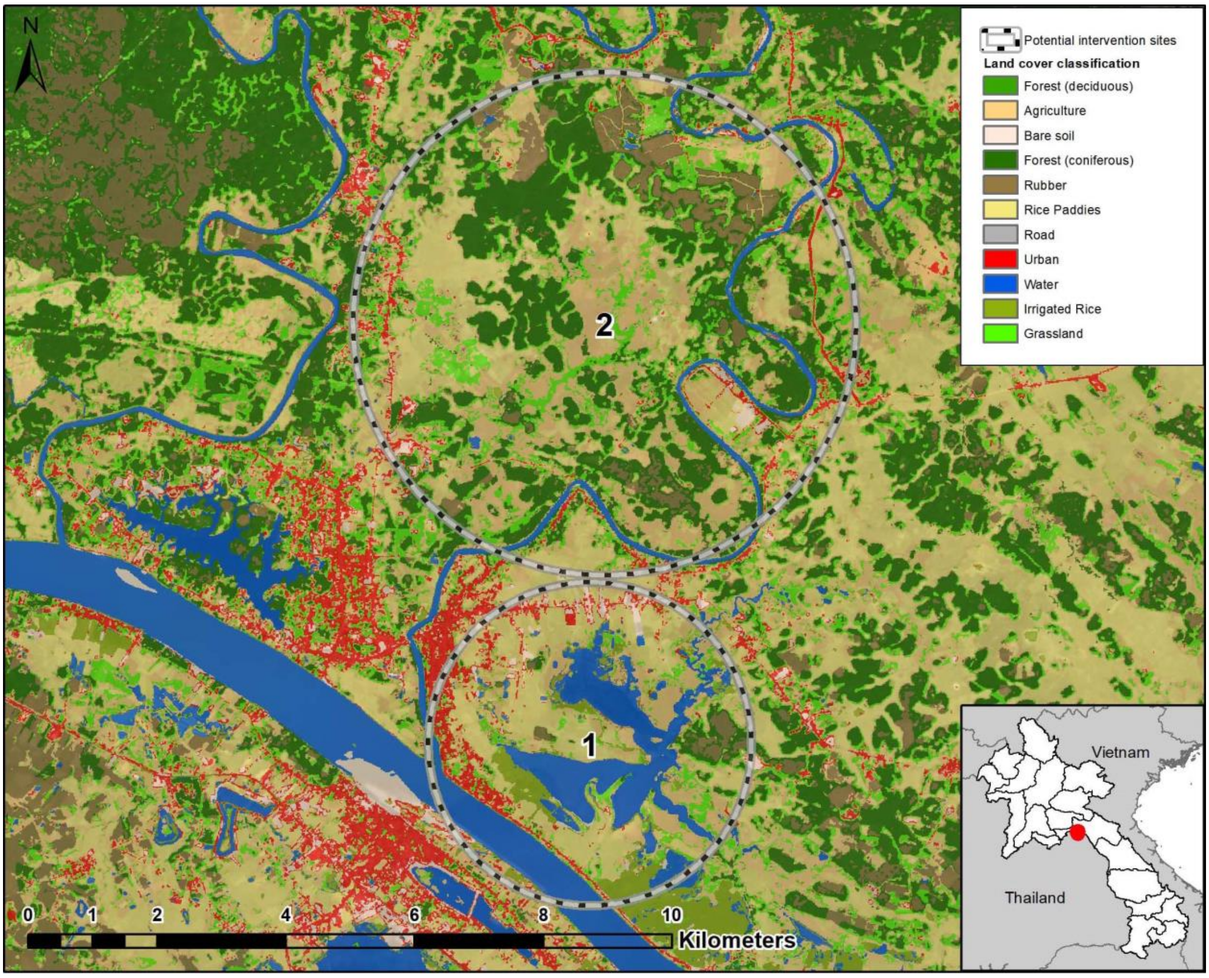


Figure 28. Paksan. Land cover classification.

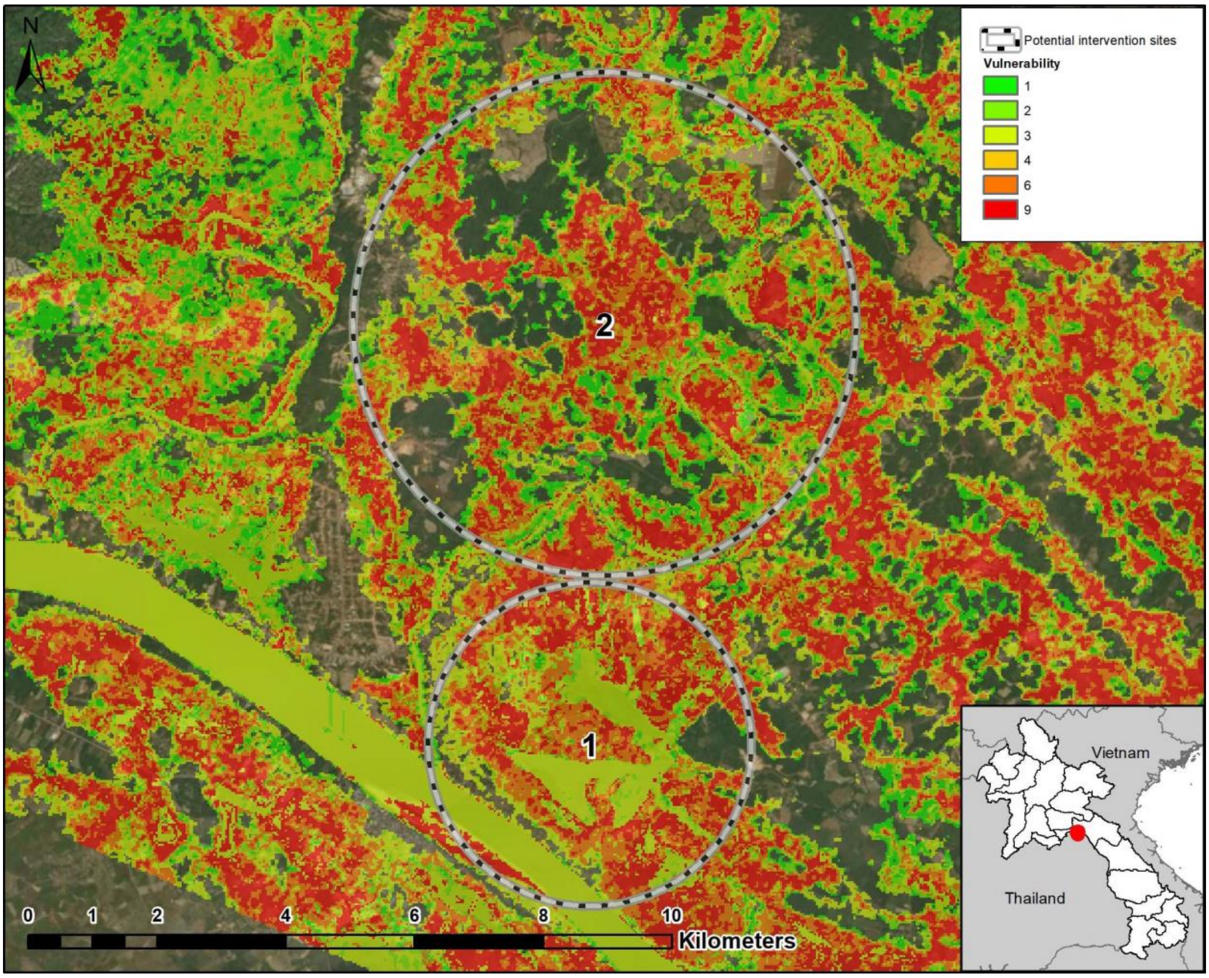


Figure 29. Paksan. Vulnerability map (1–3 low, 4–6 medium, 9 high).

7.3.3 Savannakhet

Two sites were identified in Savannakhet, namely Houay Long Kong (Site 1) and Houay Khi La Meng (Site 2; Figure 30). Houay Long Kong is an urban canal flowing into an urban stream which discharges into the Mekong River. During the rain season, Houay Long Kong receives water from an upstream urban area and overflows into adjacent areas.

Site 2 is along Houay Khi La Meng, a stream with similar conditions to Houay Long Kong.

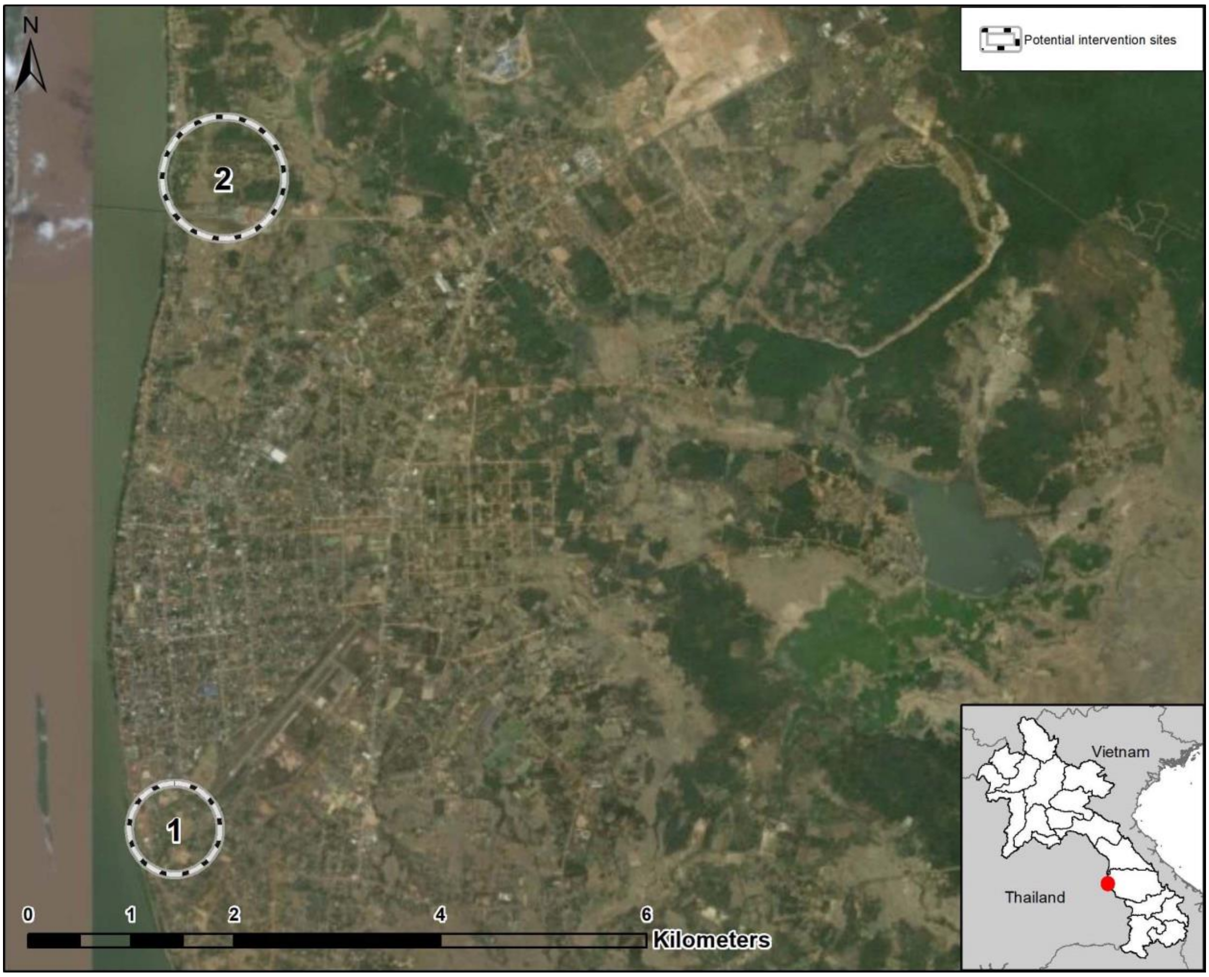


Figure 30. Potential intervention sites in Savannakhet.

7.3.3.1 Hazard mapping

At Site 1 the main flood-prone areas are along Houay Long Kong (see Figure 31). Flooding along the stream is caused primarily by runoff from the urban catchment directly upstream. The flooding comes from the upstream area, where dense urban build-up has increased the velocity of runoff into the stream. Project Site 1 is located in the lower part of the catchment, where the stream to the east is surrounded by rice and vegetable fields. Houses and dwellings along the road to the northeast are also situated in flood-prone areas.

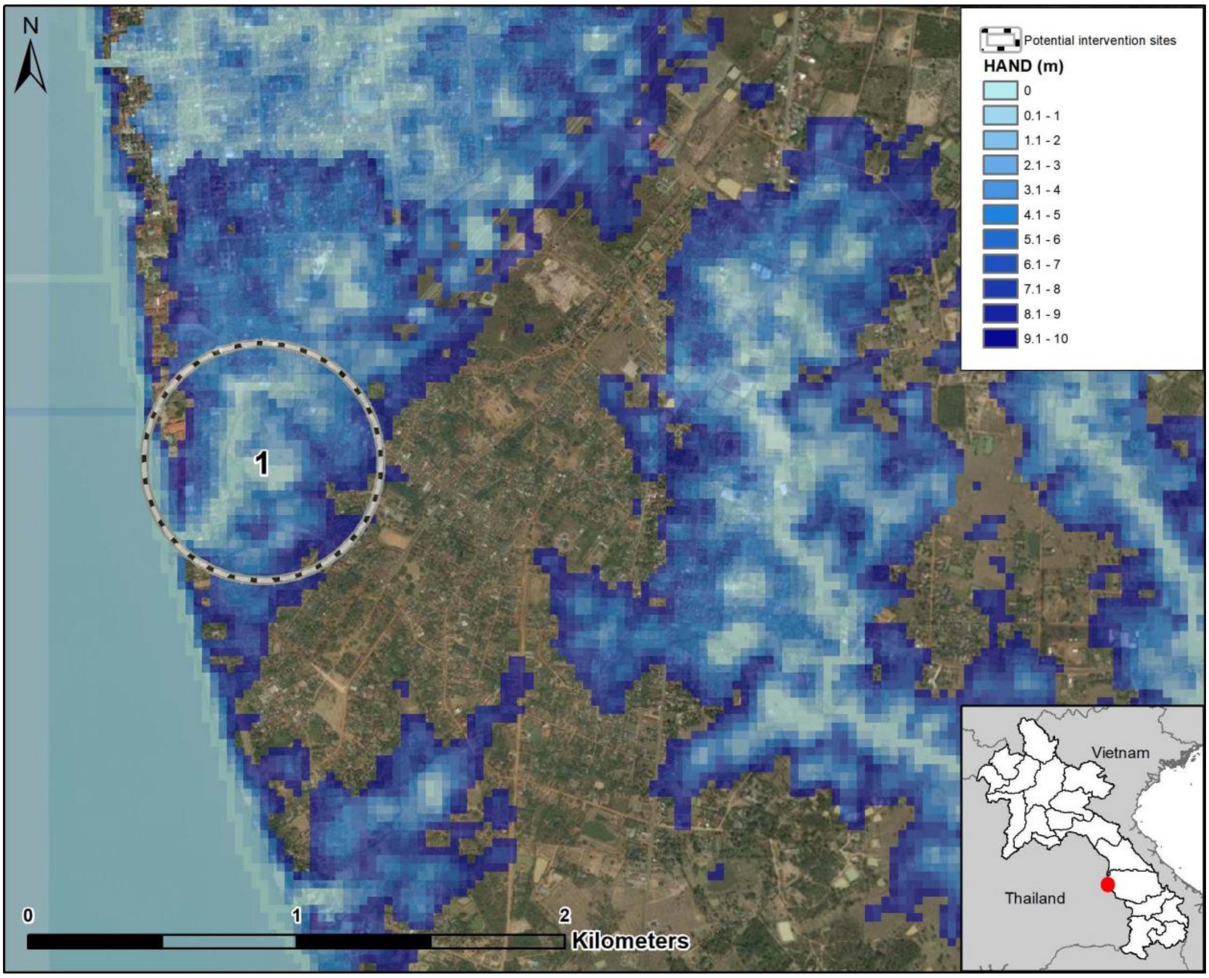


Figure 31. Site 1: Savannakhet. Flooding hazard map (0 = open water, 1–11 = 1 meter increase in elevation. Areas above 10 m are not expected to be flooded).

The land at Site 2 slopes down from the east towards the west along the Mekong River. This low-lying area along the Huay Nong Douan is highly flood-prone. Only a few meters' rise in the river level will eventually flood the area. A caveat to this statement is that the HAND model is not capable of identifying narrow dykes, which may protect houses along the river. In addition to the rising river levels, the development of villages and other activities in the area has increased pressure on the stream — resulting in an increased frequency of flooding. Figure 32 shows the project site in Savannakhet.

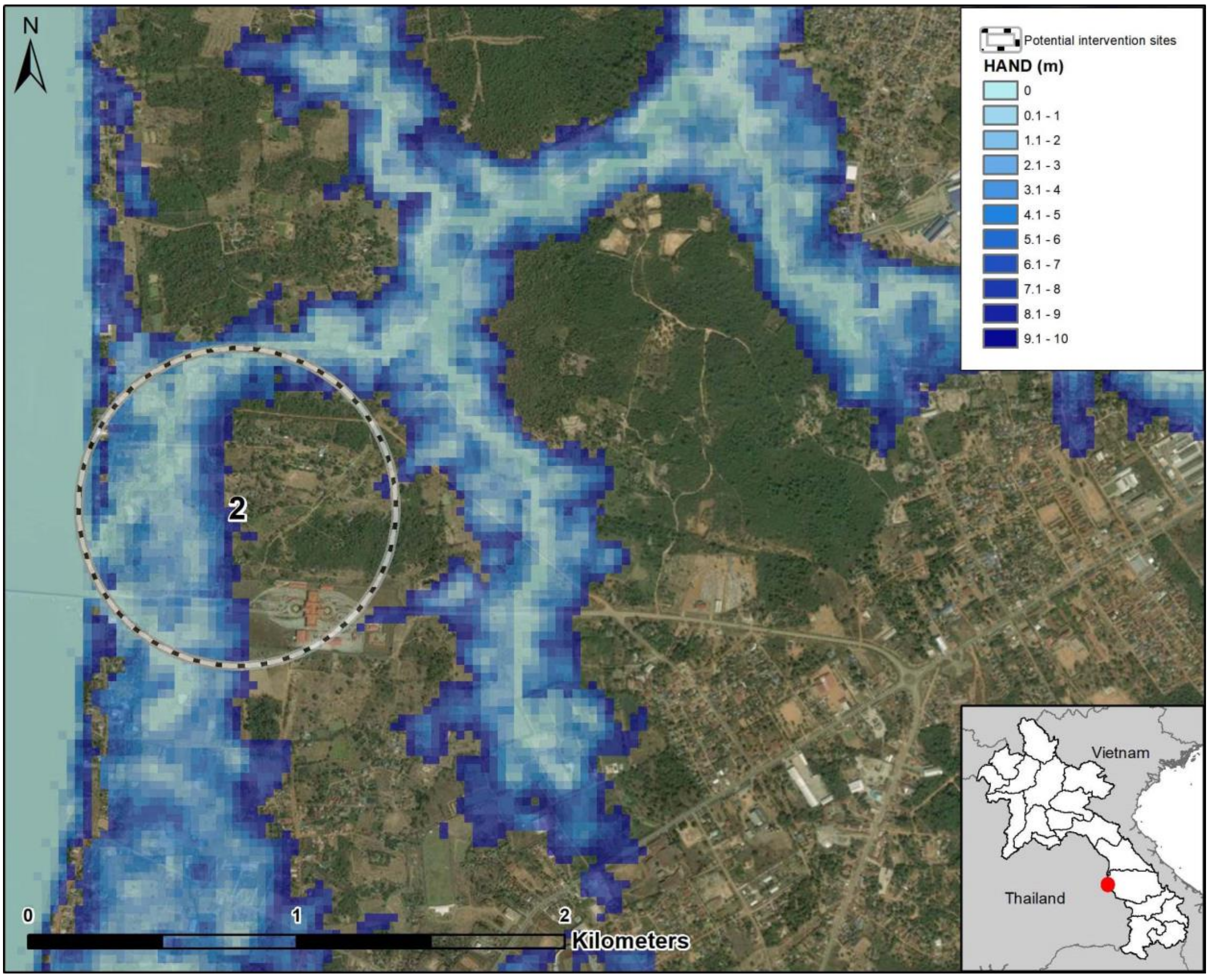


Figure 32. Site 2: Kaysone Phomvihane (Savannakhet). Flooding hazard map (0 = open water, 1–11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded).

7.3.3.2 Sensitivity mapping

Site 1 is mostly occupied by either urban structures or rice fields, encompassing ~70% of the area. Both of these land cover classes are in the highest sensitivity category (see Figure 33). The rest of the area is covered by patches of grassland and forests. A high percentage of land cover classified as highly sensitive indicates that floods at this site will cause damage 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 structures towards the Mekong River and then scattered urban/housing areas in the rest of the site (see Figure 34). South of the site, there are large areas occupied by urban and road development from the toll station. There are large areas with rice fields towards the west and scattered rice fields and grassland towards the east, intertwined with patches of forest. The rice production and urban areas are the most sensitive elements inside this project site.

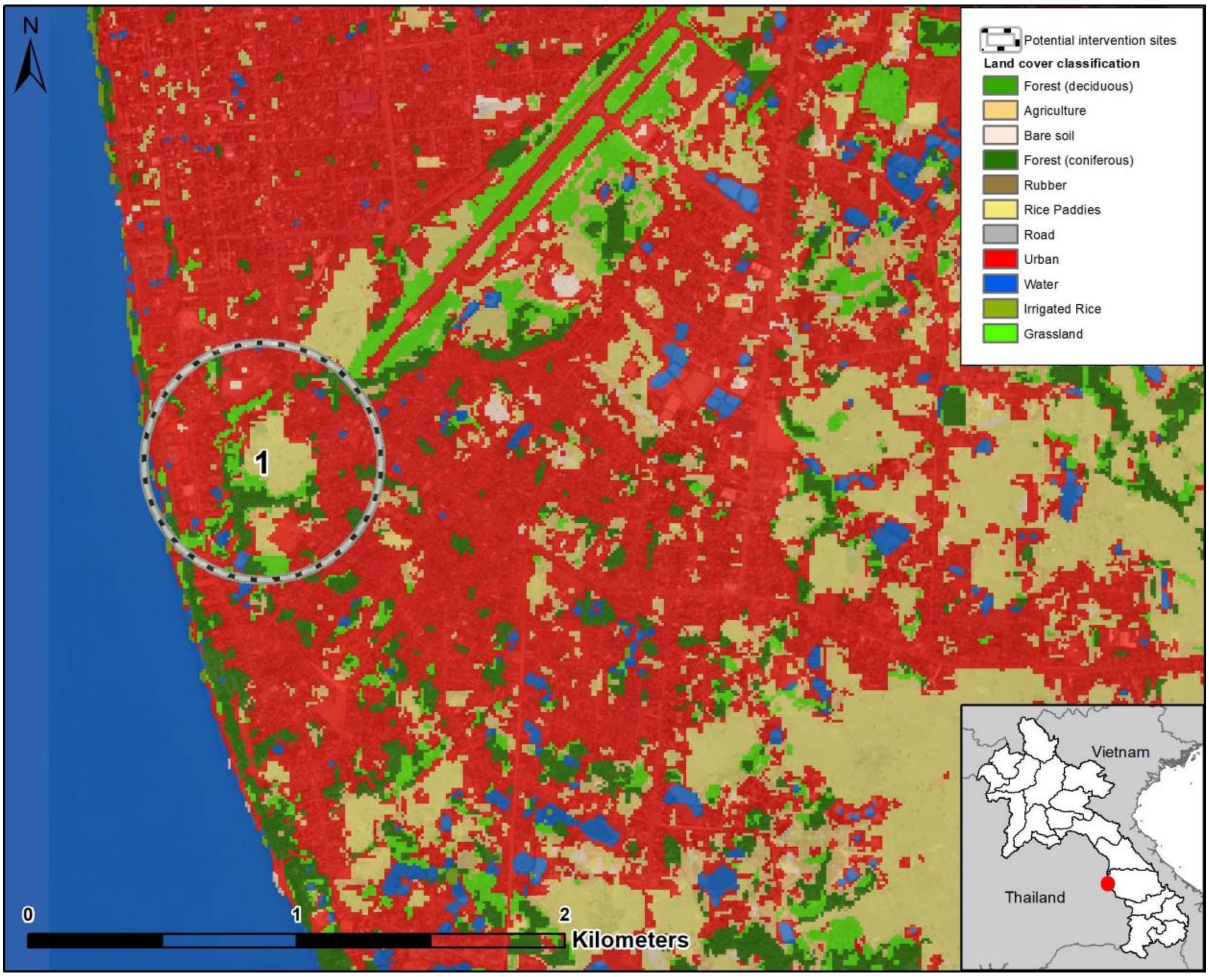


Figure 33. Site 1: Kaysone Phomvihane (Savannakhet). Land cover classification.

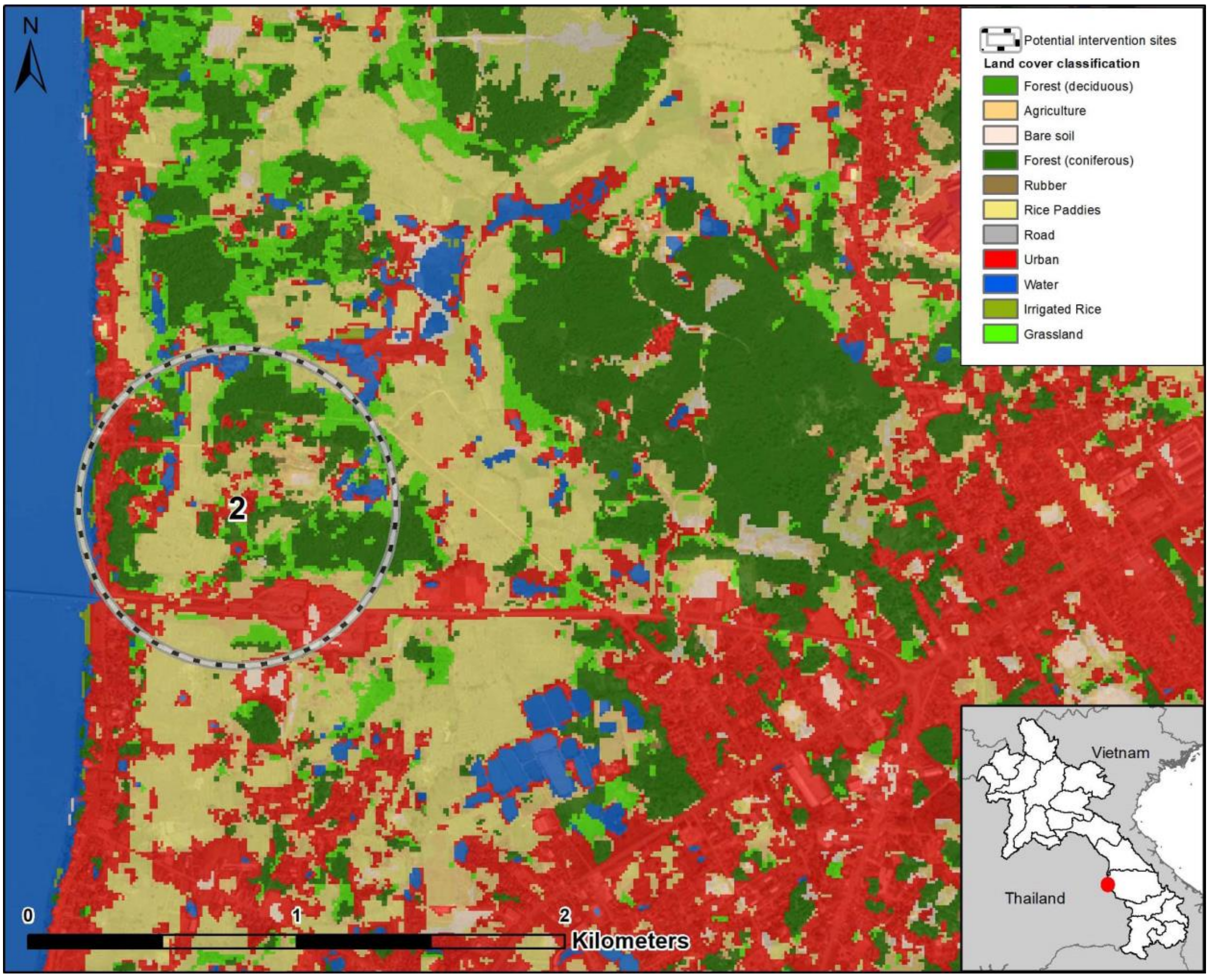


Figure 34. Site 2: Kaysone Phomvihane (Savannakhet). Land cover classification

7.3.3.3 Vulnerability mapping

As shown in the description of the sensitivity of the different land cover classes, Site 1 is extremely vulnerable to floods, mainly due to large areas with rice and urban sprawl. The hazard map shows that most of the site is low-lying and, as a result, extremely flood prone. In addition, urban sprawl along the edges and across the site also increases the vulnerability of the area. A rough estimate indicates that 80–90% of the area can be regarded as a medium and high vulnerability, as shown in Figure 35. The vulnerability assessment for Site 2, shown in Figure 36, indicates that the eastern part of the site is not impacted by floods at all. This is a result of a high elevation above the Mekong River. In contrast, the western part of the site, with the urban areas and rice fields, shows high vulnerability. To decrease the impact of flooding at this site, interventions will have to be implemented in the catchment to reduce the inflow of water in the Huay Nong Douan.

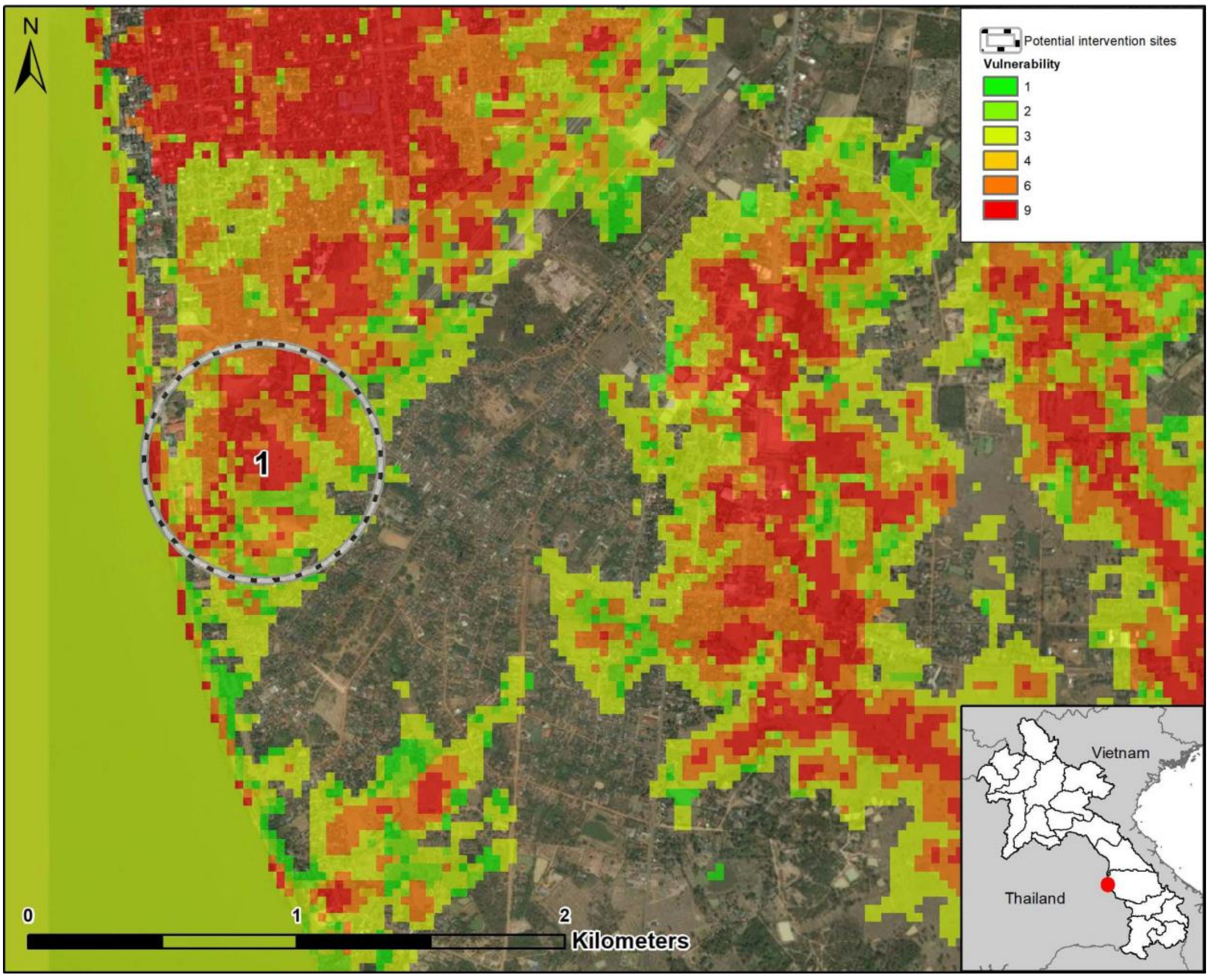


Figure 35. Site 1: Kaysone Phomvihane (Savannakhet). Vulnerability map (1–3 low, 4–6 medium, 9 high).

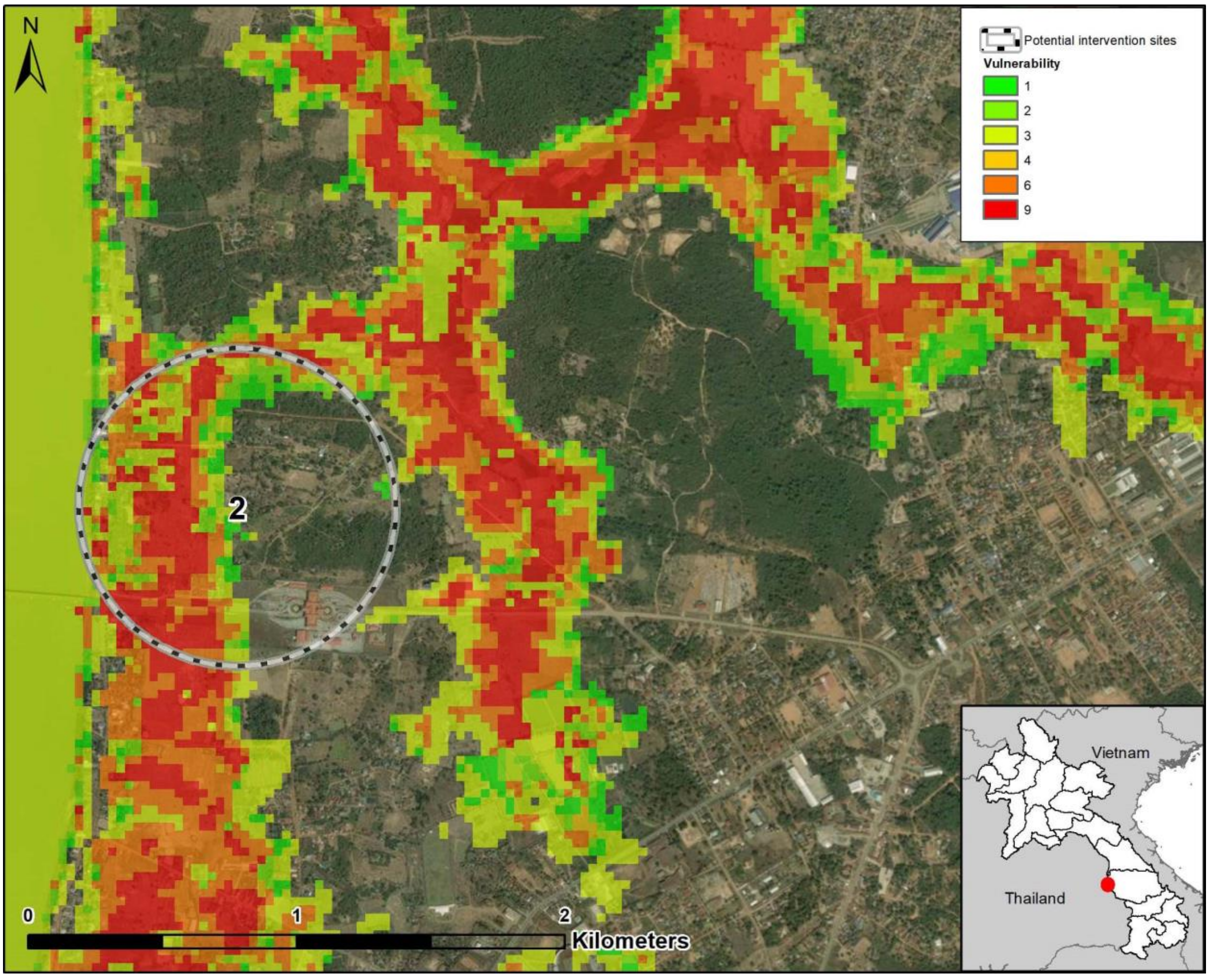


Figure 36. Site 2: Kaysone Phomvihane (Savannakhet). Vulnerability map (1–3 low, 4–6 medium, 9 high).

7.3.4 Pakse

The authorities of Pakse have identified three sites — one along the Mekong River (Site 1) and two along the Se Done River (Sites 2 and 3) as shown in Figure 37. All three sites are flood-prone but through different mechanisms (described in Section 3.3.6.1).

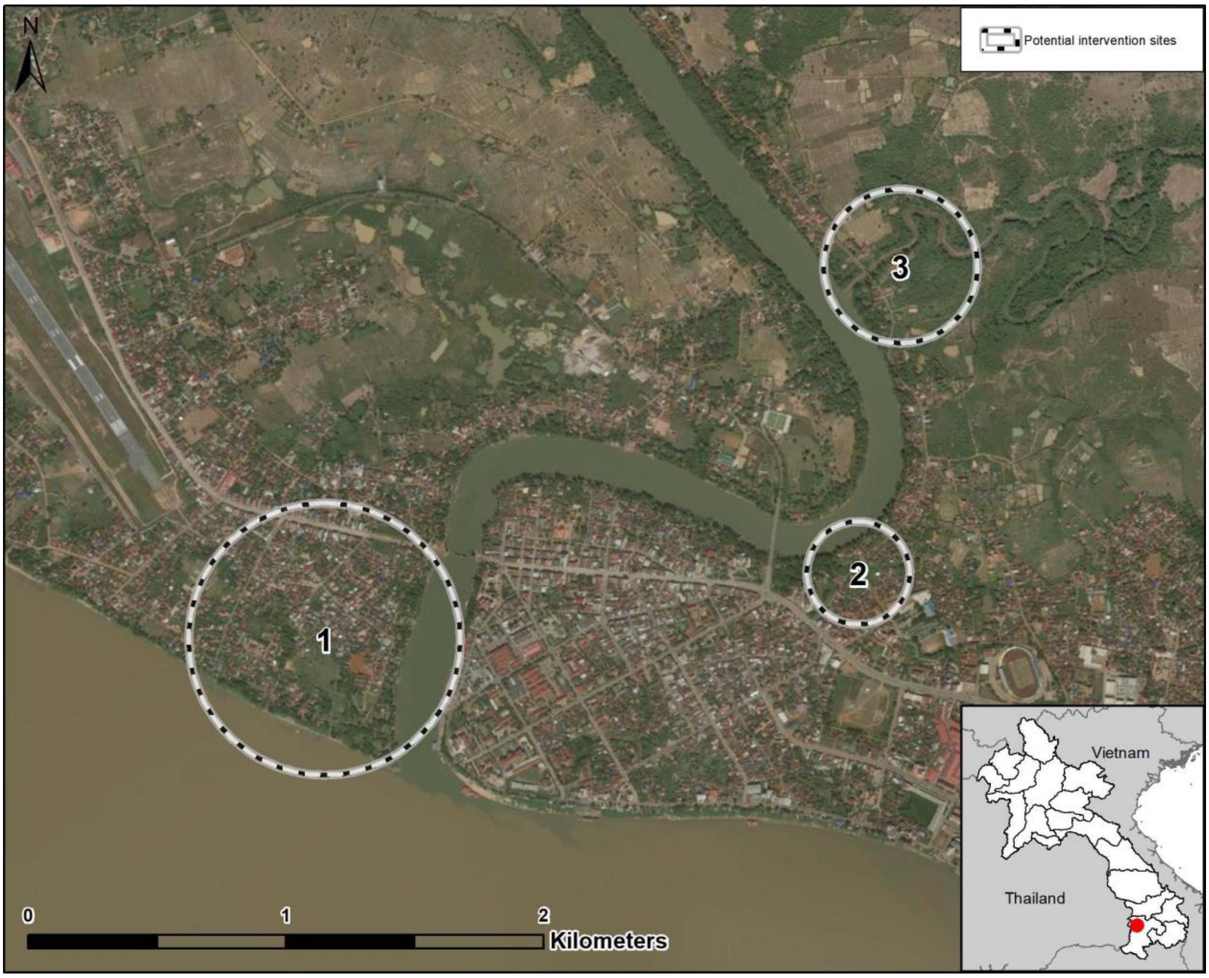


Figure 37. Potential intervention sites in Pakse.

7.3.4.1 Hazard mapping

Site 1 is a relatively large area south of the main road, as shown in Figure 38. It is an urban area with some open grasslands and scattered rice fields. A small stream runs through the site and drains out to the Mekong River through a flap gate. The gate, however, is broken and rising water in the Mekong River is forced back into the canal, which subsequently causing flooding. The hazard map does not reflect this particular risk — it incorrectly indicates that the area is not at risk because it is 10 metres or more above the Mekong River. The identified hazards are 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 Xe Done / Se Done River, where the drainage from the area goes through a broken flap gate (see Figure 39). When the water levels in the Mekong River are high, the discharge from the Se Done River is reduced and water is forced upstream into the smaller sub-catchments. The dyke along the river will protect the hinterland until a certain water level is reached. Flooding of the hinterland — because of the non-functional flap gate that is exacerbated by the run-off from the sub-catchment — generally takes place every year.

Site 3 shows the same trends as Site 2, but there are no protective structures preventing water from the Se Done from being 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.

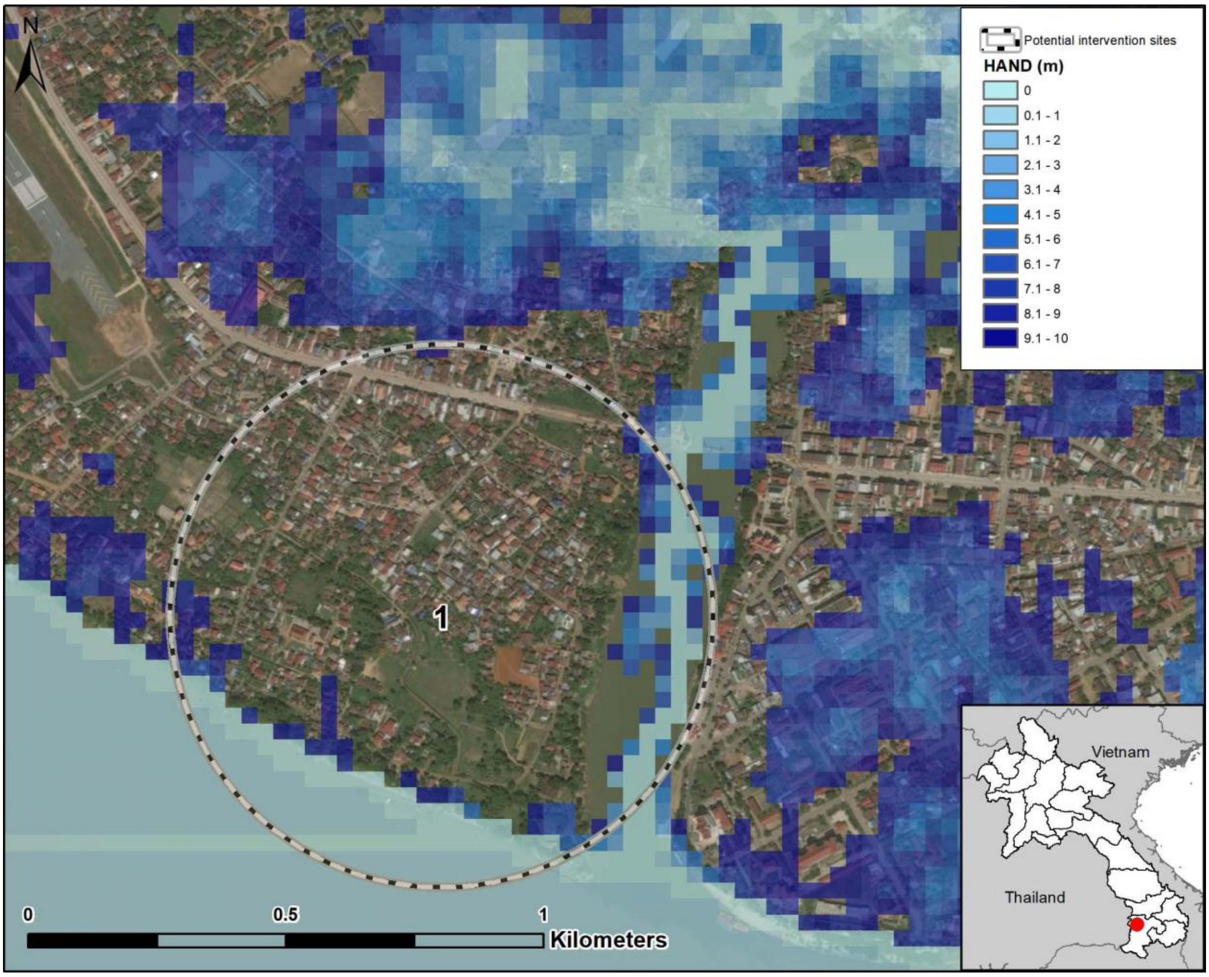

N
Potential intervention sites
HAND (m)
0
0.1 - 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 5
5.1 - 6
6.1 - 7
7.1 - 8
8.1 - 9
9.1 - 10
1
0
0.5
1
Kilometers
Vietnam
Thailand

Figure 38. Site 1: Pakse. Flooding hazard map (0 = open water, 1–11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded).

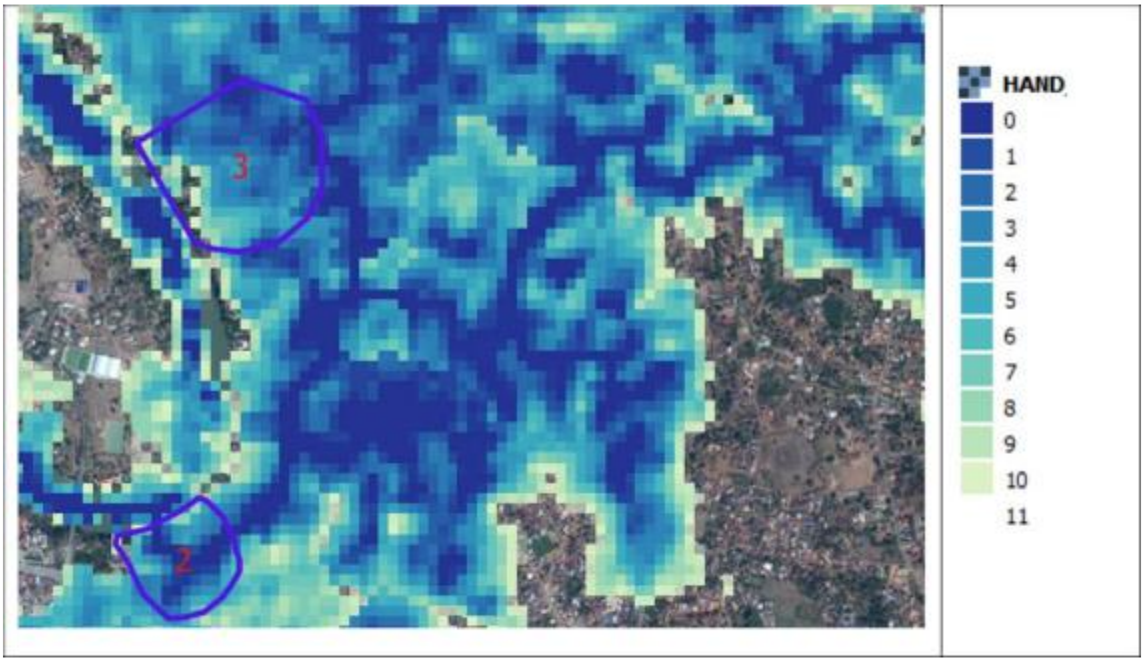


Figure 39. Sites 2 and 3: Pakse. Flooding hazard map (0 = open water, 1–11 = 1-meter increase in elevation. Areas above 10 m are not expected to be flooded).

7.3.4.2 Sensitivity mapping

The land in Site 1 is mostly urban, with the rest of the area comprising grasslands (Figure 40). Urban areas are extremely sensitive to flooding and, according to the authorities, the area receives runoff from the areas north of the main road. This runoff increases the flood impacts in Site 1. Similarly, Site 2 is mostly urban, with some forests and grassland (Figure 41). The catchment area in Site 2 is larger and flood impacts are therefore likely to be more pronounced in this area. Land-use for Site 3 mostly consists of grassland and peri-urban areas (Figure 41).

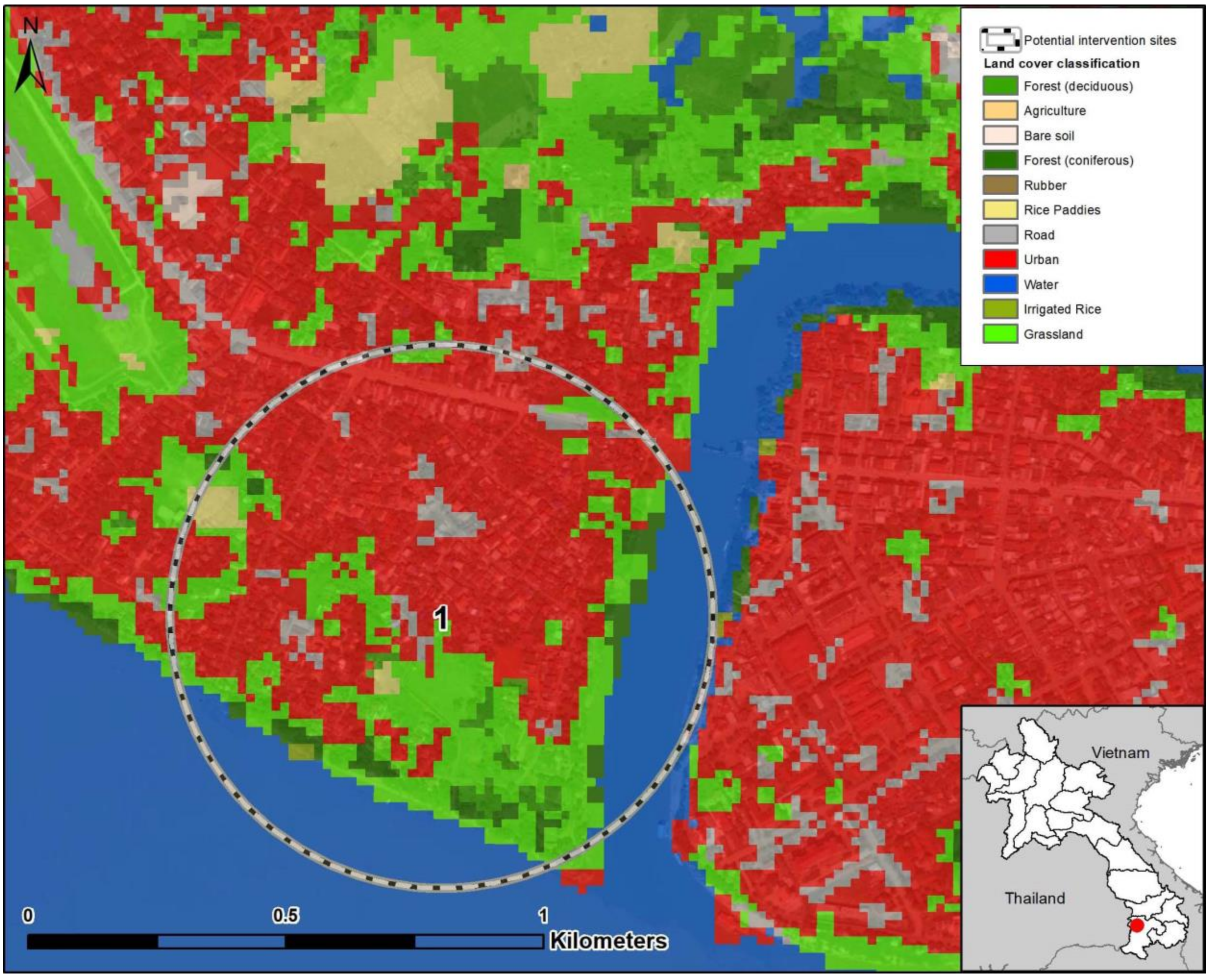


Figure 40. Site 1: Pakse. Land cover classification.

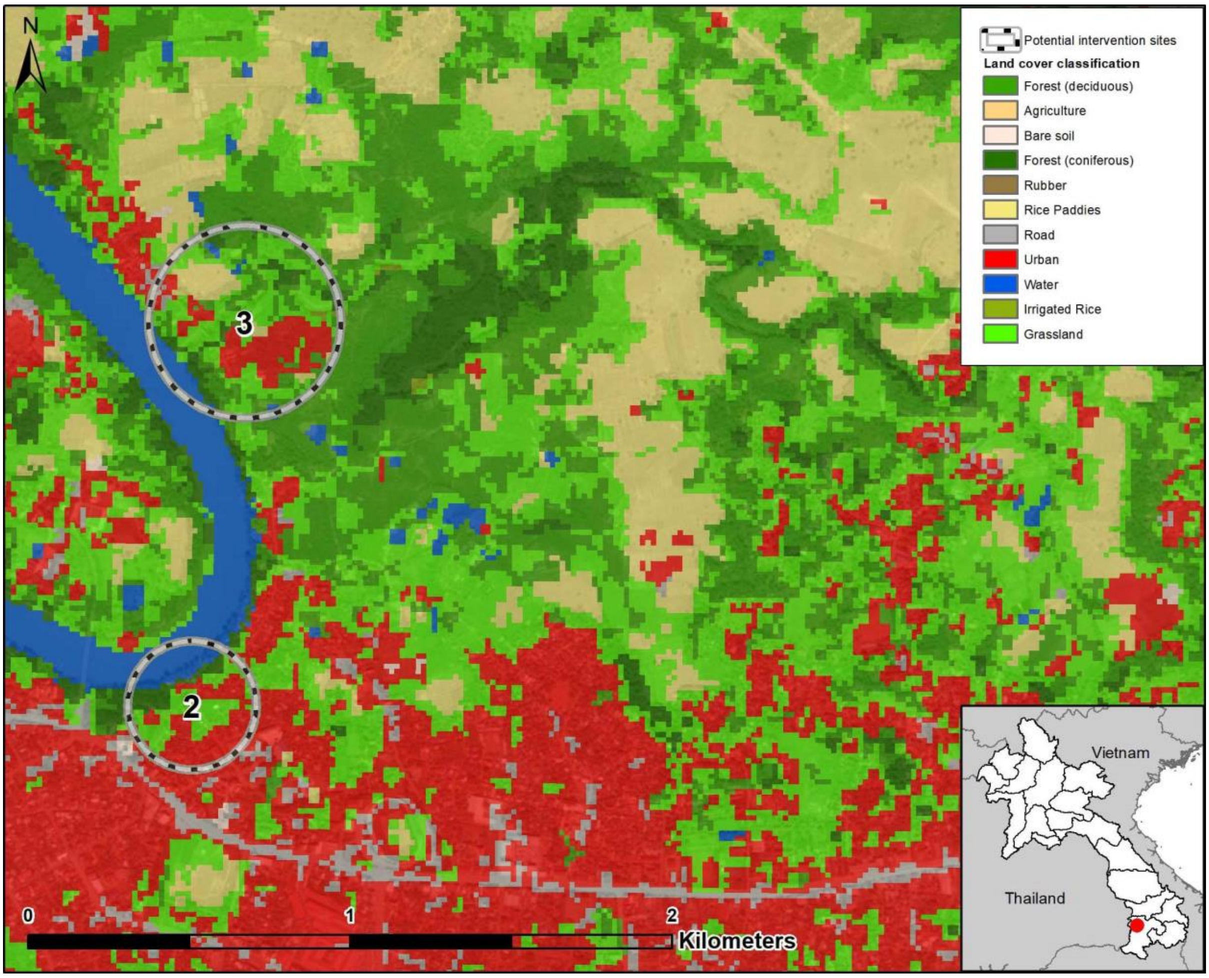


Figure 41. Sites 2 and 3: Pakse. Land cover classification.

7.3.4.3 Vulnerability mapping

Flood impacts in Site 1 cannot be captured by the existing HAND model. However, this area is flooded regularly because of runoff from the upstream catchment as verified through field missions and stakeholder consultations (Figure 42).

Approximately 80% of Site 2 is classified as having medium or high vulnerability (see Figure 43), while most of Site 3 is classified as having low to medium vulnerability, with high vulnerability only in the urban areas.

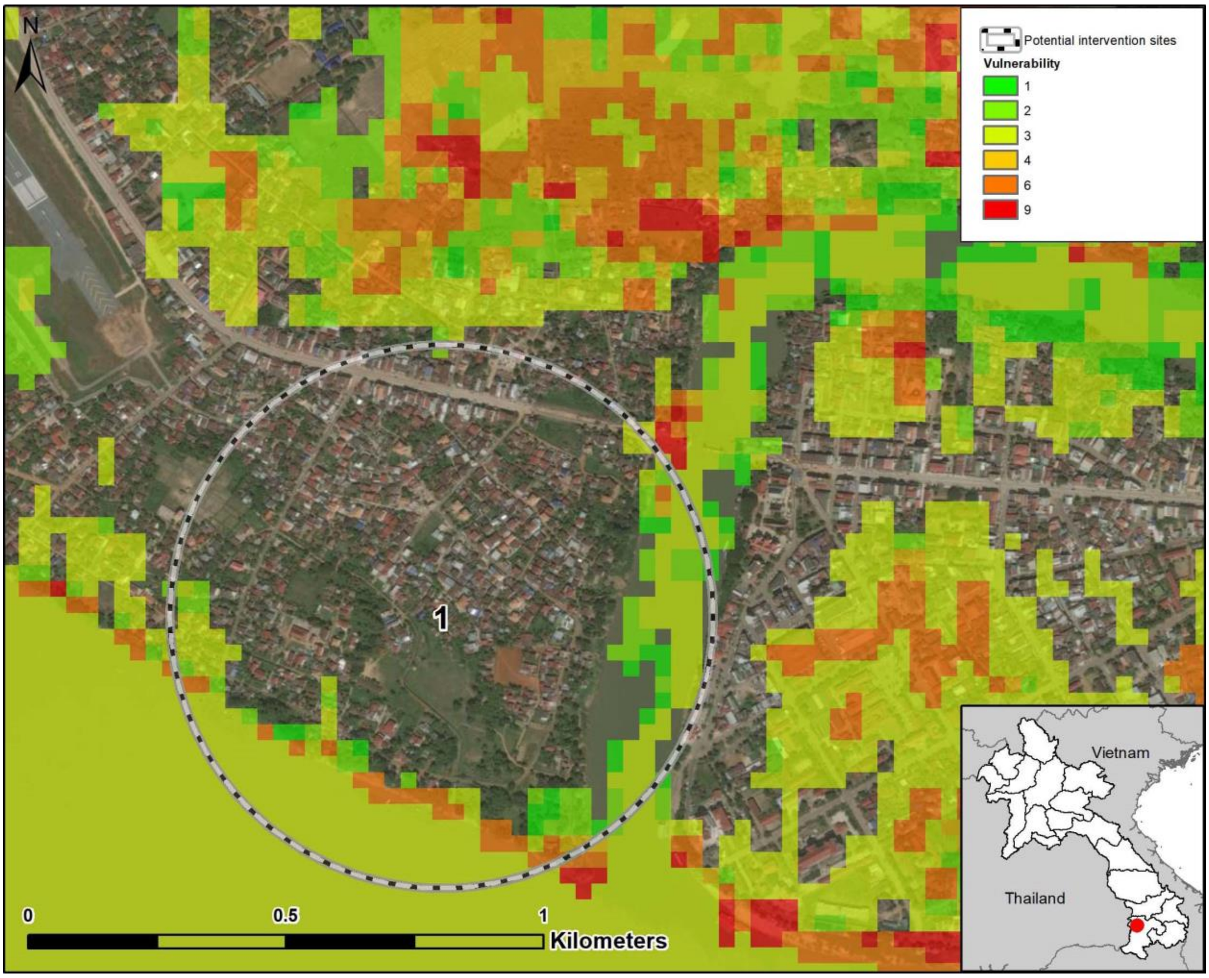


Figure 42. Site 1: Pakse. Vulnerability map (1–3 low, 4–6 medium, 9 high).

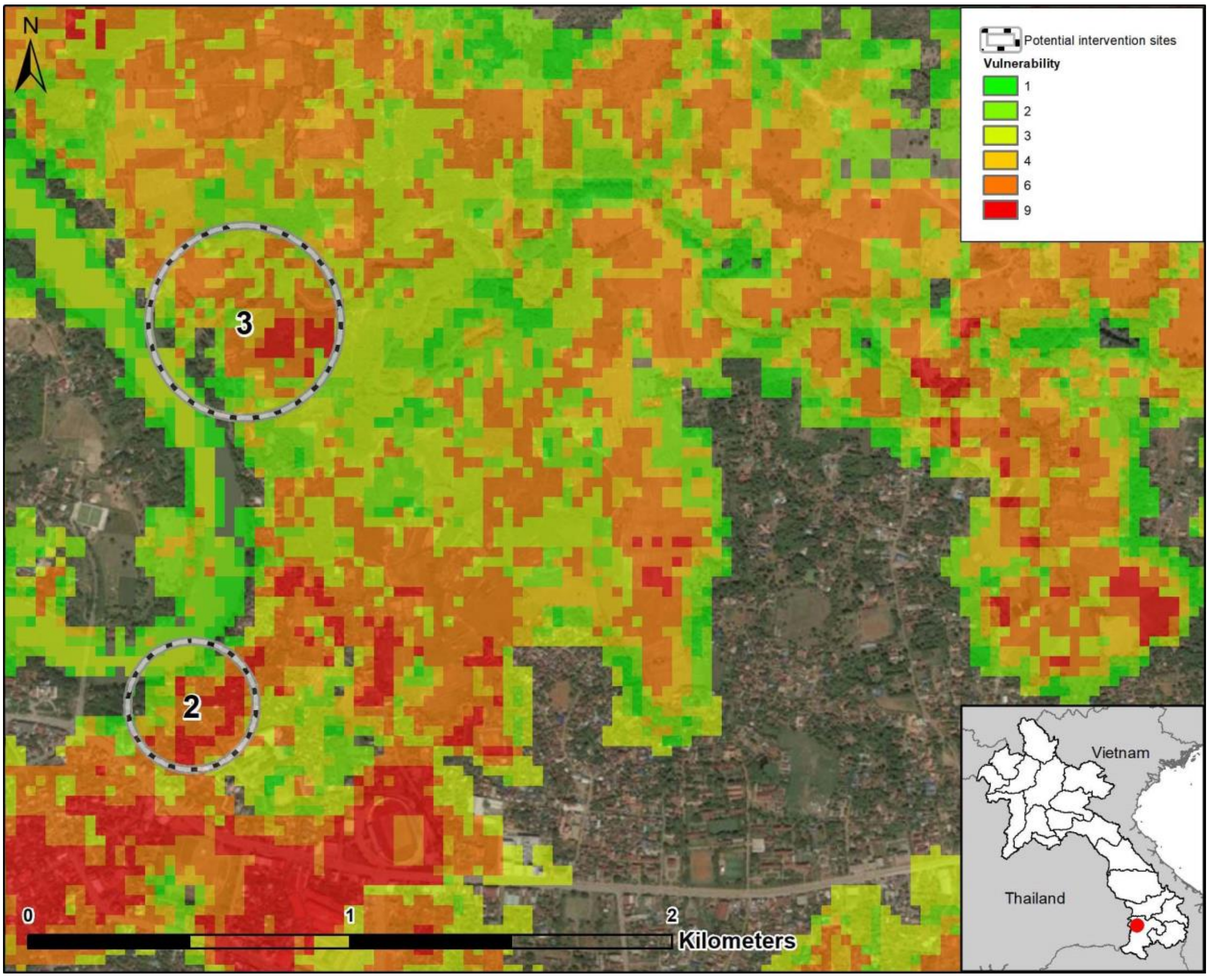


Figure 43. Sites 2 and 3: Pakse. Vulnerability map (1–3 low, 4–6 medium, 9 high).

8 Potential Urban EbA Interventions for Laotian cities

8.1 Integrated Flood Management

The aim of Integrated Flood Management (IFM) is to reduce the risks associated with development in areas prone to flooding. In Laos, implementing IFM is likely to reduce vulnerability to flooding if a participatory, multi-disciplinary approach with a focus on ecosystem conservation is undertaken[125]. Such an approach will ensure that flood management is co-ordinated, community-centred and environmentally sustainable.

Laotian cities along the Mekong River would benefit from the implementation of IFM — particularly as climate change will cause more frequent and severe floods (see Section **Error! Reference source not found.**). These increased floods are likely to be compounded by the rapid growth of urban areas and the associated increase in impervious surfaces. Implementing climate-sensitive IFM in Laotian cities would reduce the flood risk in urban areas, as development practices begin to take into account upstream and downstream factors that affect flooding. Upstream factors include land-use changes in the catchment that affect the amount of surface runoff and therefore the amount of water flowing to downstream areas. Deforestation, reduced surface permeability and construction of concrete canals are all upstream factors that increase runoff and, consequently, downstream flooding. Downstream factors are related to land-use planning in flood areas. In Laos, for example, houses are frequently built either directly adjacent to waterways or in flood-prone areas, without consideration for flood impacts. IFM approaches address both factors by improving land-use planning to avoid placing flood sensitive land-uses in flood plains and changing development practices to reduce surface runoff.

8.2 Ecosystem-based Adaptation

Ecosystem-based Adaptation (EbA) in urban areas is one of the approaches that can be used to achieve IFM. Urban ecosystems reduce the impact of downstream floods by promoting natural hydrological processes of infiltration, storage and attenuation. Specifically designed urban EbA interventions can complement or even replace hard infrastructure flood controls such as concrete canals. These interventions either allow rainwater to infiltrate into the ground[126] or act as storage areas[127] to reduce the amount of water flowing downstream. EbA measures are widely recognised as an economically sound approach to adapting to climate change[128] and these measures provide a wide variety of economic and social benefits[129,130]. For example, artificial wetlands increase biodiversity, have aesthetic and amenity value and improve downstream water quality. Initiatives using EbA interventions therefore usually have

[125] Grabs *et al*. 2007. Integrated Flood Management

[128] UN-Water, 2018. The United Nations World Water Development Report 2018: Nature-Based Solutions for Water. Paris, UNESCO.
[129] Colls et al. (2009)
[130] Doswald et al. (2014) Effectiveness of ecosystem-based approaches for adaptation: review of the evidence-base. Climate and Development 6(2): 185–201.

a greater cost-benefit ratio than those using only traditional infrastructure[131,132,133]. For example, an economic analysis undertaken in Lami, Fiji showed EbA interventions for watershed management to have more than double the benefit-cost ratio as traditional 'hard' infrastructure[134]. Moreover, the co-benefits of EbA interventions often result in them being classified as 'no-regrets' or 'low-regrets' interventions.

Additional Ecosystem-based Adaptations that could address urban flooding in Laotian cities include:

- re/afforestation and forest conservation;
- permeable pavements;
- riparian buffers;
- reconnecting rivers to floodplains;
- establishing flood bypasses;
- water harvesting/green roofs;
- green spaces;
- connecting existing green spaces; and
- mixed grey/green solutions.

8.2.1 Challenges of implementing urban EbA

Implementing EbA in the urban context requires close consideration of social, physical and political processes. These are often complex in urban areas that are characterised by multiple competing land-uses, multi-stakeholder interests and various levels of governance. Effective implementation of EbA interventions requires cross-sectoral co-ordination at local and national government levels, private sector engagement and community participation.

Urban EbA interventions are new to the country of Laos. As a result, specific additional challenges that will need to be overcome include: i) limited knowledge on the benefits of ecosystem services; ii) limited technical capacity for climate change planning and EbA implementation; and iii) discrepancies between political and administrative boundaries.

8.2.2 Adaptation benefits of urban EbA interventions

Each urban EbA intervention listed above will have a variety of adaptation benefits that will determine its suitability to a specific context. Various EbA interventions suitable for an urban context and their adaptation benefits are listed in Table 8 below.

Table 8. Potential interventions and expected adaptation benefits.

Ecosystem-based physical solutions/Direct adaptation benefits	**Water supply regulation**	**Water quality regulation**	**Food and raw material provision**	**Riverine flood prevention and control**	**Storm water runoff and flood prevention and control**	**Urban temperature regulation and cooling**	**Soil erosion and subsidence prevention and control**	**Biodiversity protection and supporting services**	**Social, cultural, aesthetic aspects**

[131] Balderas Guzman C, et al. 2018. Design Guidelines for Urban Stormwater Wetlands. Available at: https://www.researchgate.net/publication/326356857_Design_Guidelines_for_Urban_Stormwater_Wetlands. Accessed on: 14 May 2019.
[132] De Groot et al. 2013. Benefits of investing in ecosystem restoration. *Conservation Biology* 27: 1286-1293.
[133] Doswald et al. (2014) Effectiveness of ecosystem-based approaches for adaptation: review of the evidence-base. Climate and Development 6(2): 185–201.
[134] Rao et al. 2013. An economic analysis of ecosystem-based adaptation and engineering options for climate change adaptation in Lami Town, Republic of the Fiji Islands.

Wetland restoration / rehabilitation	X	X		X	X				
Stream restoration / rehabilitation	X	X		X	X		X		
Permeable pavements	X	X			X	X			
Peri-urban and urban trees and forests	X	X	X	X	X	X	X	X	X
Bioswales	X	X			X	X	X	X	
Bioretention ponds and rain gardens	X	X			X	X	X	X	X
Green roofs and walls					X	X			
Flood bypasses				X					
Riparian buffers		X		X			X		
Slope stabilisation							X	X	
Rainwater harvesting and storage	X				X				
Peri-urban and urban agriculture and agroforestry			X					X	X

Table 9 below indicates applicable considerations that should be consideration during the implementation of EbA interventions. These are shown alongside the impact each intervention is expected to have within the Laotian social and environmental context.

Table 9. Environmental and technical considerations for the feasibility of EbA interventions.

Potential Urban EbA interventions (selection of examples)	**Environmental and technical considerations (context-specific)**	**Positive or negative impact in the Laotian context?**
Wetland restoration / rehabilitation	• Feasibility of conservation or restoration will depend on the current state of degradation. • Managing the transition period is crucial in successful restoration efforts. • Careful monitoring and management will be required to prevent potential adverse effects such as the spread of invasive species and increases in disease-carrying insects.	Positive — wetlands are already providing ecosystem services to urban residents in Laos. Wetland restoration would ensure that the ecosystem continues to benefit all users. Additionally, wetlands have numerous biodiversity benefits and restoration activities will contribute to protecting plant and animal species that inhabit the wetland.
Stream restoration / rehabilitation	• Feasibility of restoration activities will depend on the current state of degradation.	Positive – Streams provide numerous ecosystem goods

Potential Urban EbA interventions (selection of examples)	Environmental and technical considerations (context-specific)	Positive or negative impact in the Laotian context?
	• Monitoring and evaluation of the stream after restoration activities have been undertaken is critical in ensuring that the correct processes are followed.	and services. Stream restoration will contribute to: increased biodiversity; and improved water quality by reducing erosion.
Permeable pavements	• Increased risk of groundwater contamination if water infiltrates the substrate. • Usually advised for public areas such as universities, schools, government offices, residential roads, parking lots, walkways, driveways and patios. • Allows for hybrid solutions combined with other systems such as suspended slabs, geothermal pumps and tree pits. • Can be used to pre-treat stormwater for potential re-use on-site. • Cost-benefit ratio is uncertain in the Laotian context. • The efficiency of permeable pavements as an urban EbA solution is strongly dependent on the physical conditions of the proposed site for implementation.	Uncertain — permeable pavements may have a use in the expanding urban environment. However, limited local technical capacity and a lack of local case studies raise uncertainties about the construction and maintenance costs of permeable pavements in the Laotian context. The benefits associated with permeable pavements include *inter alia*: i) reduced stormwater volume; ii) reduced flows to storm sewer systems and streams; and iii) increased groundwater recharge.
Riparian buffers	• Several factors should be included in the identification and selection of buffer zone areas, including the soil type, potential impacts on water quality and wildlife, as well as potential impacts on groundwater resources. • Appropriate management measures should also be implemented to ensure long-term functionality of the buffer zones. These measures include: i) demarcating buffer zones; ii) identifying and implementing suitable management measures to maintain buffer functions; iii) reviewing the need to integrate protection requirements with social and development considerations; and iv) establishing monitoring processes to ensure that buffer zones are implemented and maintained effectively.	Positive — These buffers are particularly beneficial for the agricultural sector and for securing and improving the provision of ecosystem goods and services. Riparian buffers reduce erosion, improve water quality, contribute to stream bank stabilisation, increase biodiversity, and expand wildlife habitats. They also remove sediment from surface runoff and reduce concentrations of nutrients and pesticides.
Peri-urban and urban trees, forests, parks	• Runoff mitigation potential depends on the soil's porosity, permeability and infiltration rate. Intensive forest activities may reduce the local total annual runoff and groundwater recharge due to increased water loss through evapotranspiration. • Increased risk of groundwater contamination when high concentrations of contaminants are present in runoff. • Harvesting of timber needs to be managed sustainably to preserve water resources.	Positive — aligns with the strategic objective of having 70% of the land surface covered with vegetation by 2021, including urban surfaces.

Potential Urban EbA interventions (selection of examples)	**Environmental and technical considerations (context-specific)**	**Positive or negative impact in the Laotian context?**
Bioswales, bioretention ponds and rain gardens	• Increased water infiltration may result in negative downstream impacts, depending on local hydrology features. For example, increased water infiltration could elevate groundwater levels to such an extent that basements become flooded[135]. • When high concentrations of contaminants and/or pollutants are present in storm water, infiltration may not increase the risk of groundwater contamination. • Water should only pool for a maximum of a few hours. • Bioswales can be installed next to paved areas — such as parking lots, pavements and roads. Their linear nature makes them well-suited for residential roads and highways. • Bioretention ponds can be included in the designs for gardens, commercial developments, parking lot islands and roadways. • Bioretention areas should be used on small sites (i.e. two hectares or less). Larger ponds are associated with an increased risk of clogging. • Vegetation must be chosen with high tolerance to wet conditions. • Regular inspections are needed to ensure that vegetation cover is adequate and that soil infiltrability is maintained.	Positive — cities are still small. Natural areas and waterbodies are distributed across urban surfaces. This results in an opportunity to prevent excessive build-up of impermeable surface areas that are not present in larger cities globally.
Flood bypasses, Reconnecting rivers to floodplains	• Feasibility will be impacted by the possibility of ensuring space for periodic flooding, taking into account the frequency of floods and the overlap between flood season and the growing season (the vegetation within a bypass can influence its hydraulic roughness and affect the ability to convey floodwaters).	Uncertain — bypasses require large amounts of land that may not be readily available in an urban context.
Slope stabilisation	• Material choice will depend on site characteristics. • May be used alongside traditional flood control practices.	Positive — slope stabilisation is a 'no regrets' option and in areas with hilly terrain.
Water harvesting and storage	• Large-scale rainwater harvesting can significantly affect the natural hydrological regime of a river by reducing surface runoff and increasing groundwater recharge and evaporation losses. • Harvested water may require further treatment to ensure that it is fit for use.	Uncertain — rainwater harvesting is generally considered a 'no regrets' adaptation option. No domestic supply shortages have been uncovered in Laos. Rainwater harvesting is as a result more likely to be useful in the agricultural sector.

[135] Initial consultations with local stakeholders indicate that urban groundwater levels are deep (>40 m). However, no comprehensive groundwater dataset is available for Laotian cities.

Urban EbA solutions are highly consistent to the "six Souls" vision for future cities (Green, Clean, Peaceful, Bright, Charming, Civilised), which was consistently commented on during stakeholder meetings held in 2015.

8.2.3 Social considerations of urban EbA

EbA interventions would increase the provision of ecosystem services and as 70% of Laos' population rely on natural ecosystems to supplement their income, these interventions are likely to be accepted by local communities. However, EbA for flood management is not standard practice for Laos and local communities would require awareness-raising efforts on the benefits of EbA interventions to increase community buy-in. Awareness-raising and private sector engagement would also be required to design and implement sustainable financing strategies for the construction and maintenance of sustainable financing strategies for EbA interventions. Payment for Ecosystem Services (PES) is one of the options for providing sustainable financing to implement and maintain EbA interventions. There have been very few examples of PES in Laos so this option for the project setting will have to be investigated. Some studies have indicated though that the Laotian institutional context has been demonstrated to be favourable for PES[136][137]. Further social considerations for urban EbA include land tenure and incorporating livelihoods aspects in management plans (see stakeholder consultation report annex).

Table 10 below shows some of the socio-economic considerations that would have to be taken into account for each of the EbA interventions.

Table 10. Socio-economic considerations for physical interventions.

Potential EbA physical interventions (examples)	**Socio-economic considerations (context specific)**	**Positive or negative impacts in the context of Laos**
Wetlands construction, Conservation and restoration	• Investment costs can vary from just a few dollars to tens of thousands per hectare. • Some pre-treatment might be necessary to avoid build-up of solids in the inflow area. • Restoration costs can be high, requiring investment not only in the physical restoration works but also in long-term management, to ensure recovery. Socio-economic and environmental returns from wetlands are generally high.	Positive — wetlands frequently form part of the urban landscape and provide a wide variety of benefits to surrounding communities. These benefits include improved social cohesion and increased aesthetic value. Wetlands also provide green areas for recreational use by communities.
Stream restoration	• Investment costs can vary according to the scale of restoration required • An understanding of who uses the identified streams is required to ensure that restoration activities do not have negative impacts on those people using the streams to support their livelihoods.	Positive — Streams provide a wide variety of ecosystem goods and services to surrounding communities; for example, many community members use streams for fishing

[136] Scheufele, G. & Bennett J. & Kyophilavong P. (2018). Pricing biodiversity protection: Payments for Environmental Services schemes in Lao PDR. Land Use Policy, Vol. 75, 284-291.
[137] USAID / CIFOR. 2014. Motivation for payments for ecosystem services in Laos - The essential alignment.

Potential EbA physical interventions (examples)	**Socio-economic considerations (context specific)**	**Positive or negative impacts in the context of Laos**
		to support their livelihoods. In addition, streams provide numerous social benefits including *inter alia* improved social cohesion and increased aesthetic value. Restoration of streams will ensure that streams continue to benefit the surrounding communities, which will contribute to improved livelihoods.
Permeable pavements	• Costs of installing a permeable pavement (US): US$ 30 to 150 per square metre[138]; lifetime between seven and 35 years, depending on the type of pavement and required maintenance.	Uncertain — local case studies are recommended before large-scale adoption.
Riparian buffer zones	• Buffer zones should be designed to ensure that access to ecosystem goods and services provided by streams is not restricted. • The identification and selection of sites for the implementation of buffer zones should be undertaken in a participatory way with surrounding communities. This will ensure community ownership and long-term sustainability of the zones.	Positive — riparian buffer zones contribute to improved livelihoods of surrounding communities through the protection of ecosystems that provide goods and services.
Peri-urban and urban trees, forests, parks	• The time lag may increase the overall project costs (vegetation, particularly trees, may take time to mature and be able to deliver the full range of services). • Maintenance cost will depend heavily on local conditions.	Positive — aligned with the "six Souls" vision for future cities (Green, Clean, Peaceful, Bright, Charming, Civilised)
Bioswales, Bioretention ponds and rain gardens	• Relatively low construction costs. Cost estimates (US): US$ 4.5 per square metre, with costs ranging from US$ 3 to 9 per square metre[139]. • Low maintenance costs once vegetation has been established. • Additional costs may occur as some plants may need to be replaced when they reach the limit of pollutant uptake.	Positive — high cost-effectiveness compared to 'hard' solutions (hybrid solutions may be considered)

[138] Foster et al. 2011. The value of green infrastructure for urban climate adaptation.
[139] CNT & American Rivers. 2010. The Value of Green Infrastructure.

Potential EbA physical interventions (examples)	Socio-economic considerations (context specific)	Positive or negative impacts in the context of Laos
Flood bypasses, Reconnecting rivers to floodplains	• Need to secure the access to land (easements or title for land to ensure access to the floodplains). • Feasibility will be impacted by the possibility of ensuring space for periodic flooding, of organising multi-uses during the different periods (inundated and non-inundated). • Potentially very high investment (including weir or gate to direct water into bypass, removal and construction of levees to delineate the floodway) though the costs can often be counterbalanced by avoided grey infrastructure investments[41] and reduced flood damage.	Uncertain — highly dependent on local characteristics.
Slope stabilisation	• Highly suitable for mixed grey/green solutions that improve the cost-effectiveness of both aspects.	Positive — particularly useful in hilly terrain.

9 Cost effectiveness of integrated flood management and urban EbA

9.1 Introduction

The overall approach of the project in describing the cost-effectiveness of urban EbA in Laos cites quantitative values and considers the following:

- Ecosystem services values calculated in various ecosystem types and contexts in Laos
- Cost benefit analyses of urban EbA interventions in different country contexts
- Reference to modelled flood damages potentially avoided through flood mitigation in the project sites

A stand-alone economic analysis for the project calculating economic internal rates of return, considering project interventions and the resultant rate of flood abatement and production of ecosystem services would be beyond the scope and availability of project preparation resources. Site-specific studies are required, based on reliably collected primary data through site-specific ground surveys and spatial analysis. The flood abatement potential of restoration is particularly challenging to calculate in the case of this project. Comparable projects on ecosystem valuation conducted by UN Environment in Morocco, Senegal, Kazakhstan, India, and South Africa typically cost US $ 1.5 million.

The economic valuation of ecosystem services, including flood abatement, is challenging to cost compared with hard engineering approaches where standardized methodologies are available. Economic valuation is nonetheless, important in making investment decisions, and this is one of the gaps identified in the case of Laos. Development partners recognize the importance of ecological functions in flood abatement. For example, the JICA flood master plan for Vientiane is dependent on the water storage capacity of That Luang Marsh[140], while ADB analysed nature-based solutions in different cities along the Mekong, including in Savannakhet[141].

[140] JICA. 2011. The Project for Urban Development Master Plan Study in Vientiane Capital. Available at: http://open_jicareport.jica.go.jp/pdf/12023693_01.pdf. Accessed 13 May 2019.
[141] ADB. 2016. Nature-based Solutions for Building Resilience in Towns and Cities: Case Studies from the Greater Mekong Sub-region. Accessed from: https://www.greatermekong.org/sites/default/files/nature-based-

Despite this recognition, there have not been any significant investments in urban EbA in Laos. This underinvestment can be due to many reasons — competing development priorities, normative preference for hard infrastructure solutions, lack of demonstrated successful examples in developing countries, and others. Countries' investment priorities are greatly influenced by economic decision tools, such as calculation of returns on investment. For urban EbA methods to be considered in lieu of or together with infrastructure measures, comparable economic analyses should be available. Unfortunately, the complexity of conducting ecosystem services valuation and associated costs, present a barrier. In the case of the Metro Manila in the Philippines, for example, an interviewed planning ministry official, when asked why EbA for flood control is not financed, pointed to the absence of methodologies to value soft or non-structural methods and that planning and priority of government projects relies heavily on rates of return on investments[142].

EbA investments may be viewed by other financiers such as JICA and ADB, as well as the country, as risky due to the absence of economic return values. This proposed GCF project has an important role to play in overcoming barriers to investments in urban EbA. By providing robust economic valuation of ecosystem services for flood management in particular, it has the potential to contribute to consideration of EbA investments in the future.

9.2 Overview

Hydrological disasters, such as floods, are the most regularly occurring natural disaster in Laos[143]. The impacts of these events are expected to worsen with the increased frequency and severity of floods due to climate change (see Section **Error! Reference source not found.**) and compounded by rapid urbanisation[144]. The effect of floods on the economy in Laos, including losses and damages, between July and September 2018 has been estimated to total over US$ 370 million, or almost a tenth of the country's annual budget[145]. Interventions are needed to limit the additional negative impacts on property, livelihoods and quality of life.

Integrated Flood Management (IFM), including Ecosystem-based Adaptation (EbA), has been shown to be the most cost-effective intervention, in the long-term, for reducing the impacts of flood events in the region. The cost-effectiveness of EbA solutions were compared with that of traditional 'hard' engineering solutions in Lami Town, Fiji[146]; it was concluded that EbA solutions are more than twice as cost-effective at the same scale of damage avoidance than the alternative. Similar results were found when assessing coastal flooding interventions in Philippines[147], as well as for coastal flooding measures in Vietnam[148] (see Annex K for further details).

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solutions.pdf#overlay-context=nature-based-solutions-building-resilience-towns-and-cities-case-studies-greater-mekong-subregion. Accessed on 15 May 2019.

[142] Baviera, M. 2013. Flood Policy Discourses in Metro Manila (Unpublished master's dissertation).

[143] Guha-Sapir, D., Hoyois, P.H. & Below, R. 2016. Annual Disaster Statistical Review 2016: The Numbers and Trends. Brussels: CRED.

[144] Laos Population and Housing Census (PHC) 2015. The 4th Population and Housing Census, Results of population and housing census.

[145] Post-Disaster Needs Assessment: 2018 Floods, Lao PDR. Available at: https://www.gfdrr.org/en/publication/post-disaster-needs-assessment-2018-floods-lao-pdr. Accessed on: 30 April 2019.

[146] Rao, N.S., Carruthers, T., Anderson, P., Sivo, L., Saxby, T., Durbin, T., Jungblut, V., Hills, T. & Chape, S. 2013. An Economic Analysis of Ecosystem-based Adaptation and Engineering Options for Climate Change Adaptation in Lami Town, Republic of the Fiji Islands. Technical report by the Secretariat of the Pacific Regional Environment Programme. Apia, Samoa.

[147] Baig, S.P., Rizvi, A., Josella, M., Palanca-Tan, R. 2016. Cost and Benefits of Ecosystem Based Adaptation: The Case of the Philippines. Gland, Switzerland: IUCN.

[148] International Federation of Red Cross and Red Crescent Societies (IFRC) 2012. Mangrove plantation in Vietnam: measuring impact and cost benefit. Geneva, Switzerland.

Outside South-East Asia, several case studies have demonstrated the cost-effectiveness of integrated flood management and urban EbA for flood management. Firstly, in Durban, South Africa, the impacts of an improved planning scheme were, for example, shown to be more cost-effective than all alternative stormwater management systems, including infiltration trenches, subsurface soakaways, green roofs and detention basins[149]. The planning scheme included the promotion of conservation activities and retention of natural, green, open spaces in the city. This reduced the total area of hardened surfaces in the city, increasing soil infiltration and reducing flood impacts. Secondly, in Beijing, China, the economic benefits of rainwater-runoff reduction by urban green spaces was analysed[150]. For each additional hectare of urban green space, potential runoff was reduced by 2,494 m^3 as a result of increased soil infiltration rates of between 8 and 10 mm/min. The 2012 value of this runoff reduction was estimated to be equivalent to US$ 3,150 per hectare, but this is expected to increase with the increased frequency and intensity of floods due to climate change. Lastly, in Portland, Oregon, USA, it has been estimated that US$ 250 million was saved by the city due to the planting of urban green spaces rather than constructing hard infrastructure for the same stormwater management outcomes[151]. The cost-effectiveness of street trees for reducing rainwater runoff was calculated to be 3 to 6 times greater than traditional drainage systems.

Besides avoided flood damages, EbA solutions provide additional co-benefits compared with traditional hard engineering solutions. These benefits include the provision of natural resources, carbon storage, biodiversity, erosion control, water quality improvement, and recreation.

9.3 Valuation of ecosystem services in Laos

Various studies in Laos have been examined to investigate values of ecosystem services calculated in Laos. These are indicated in Table 9.1 below.

In addition, Kyophilavong[152] has also developed a manual for wetland valuation in Lao PDR using benefit transfer, market price, and contingent valuation or willingness to pay methods. A USAID study in 2015 for economic valuation in Lao PDR explore the methods of avoided cost, replacement cost, market prices, and market substitutes. There are also a few examples of using economic valuation to develop sustainable financing solutions, such as the initiative from the Australian National University and National University of Laos to develop two payments for ecosystem services project with funding from the Environment Protection Fund[153].

Table 9.1. Examples Studies Valuing Ecosystem Services in Laos[154]

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149 Turpie, J., Gwyneth, L., Chrystal, R., Corbella, S. and Stretch, D. 2017. Evaluating the potential returns to investing in green urban development in Durban, Part II. World Bank Report

150 Zhang, B., Xie, G., Zhang, C. and Zhang, J., 2012. The economic benefits of rainwater-runoff reduction by urban green spaces: A case study in Beijing, China. Journal of environmental management, 100, pp.65-71.

151 Foster J, Lowe A, Winkelman S (2011) The value of green infrastructures for urban climate adaptation. The Center for Clean Air Policy. Washington, DC

152 Kyophilavong, P. 2011. Simple manual for estimating economic value of wetland for Lao policymakers.

153 https://ipesl.crawford.anu.edu.au/.

154 WWF. 2013. The Economic Value of Ecosystem Services in the Mekong Basin: What we know, and what we need to know. Gland, Switzerland. Accessed from https://d2ouvy59p0dg6k.cloudfront.net/downloads/report_economic_analysis_of_ecosystemservicesnov2013.pdf. Accessed on 17 May 2019.

Year	Author	Ecosystem services valued	Values	Methods employed
2005	Rosales et al.	Watershed protection benefits Downstream fisheries, irrigation and micro-hydropower, and flood control benefits	US$0.85 million a year or US$ 3 /ha US$26.60 million or US$92.3 per hectare	Market prices, participatory environmental valuation, willingness to pay, production, and other approaches
2004	Gerrard	Flood protection and wastewater treatment services	US$2.87 million a year or US$1,436/ha	Market prices, examining damages avoided during floods, and replacement costs of wastewater purification services, and production
2009	Ayumi and Chanhda	Forest conservation	US$2,008 per hectare over 10 years, or an average of US$200/ha/year	
2010	ADB	Carbon storage values Watershed protection Water quality regulation Soil erosion control	US$1,846/ha/year US$681/ha/year US$718ha/year US$380ha/year	
2015	USAID	Wastewater treatment Species consumed	$1.7 million $2.5 million / year	Replacement cost, market prices, market substitutes

The figures generated by these studies are site-specific, mostly covering forest ecosystems and large watersheds. In the context of That Luang marsh, an urban wetland in Vientiane, the costs of ecosystem services per hectare are not directly translatable to Paksan, where the wetland considered in the project is located. Relative to Vientiane, Paksan has a much smaller population density, different socio-economic profile, and different livelihood opportunities, and likely different level of dependence on natural resources for food, medicine, and other services.

9.4 Urban wetlands and streams

Urban wetlands act as flood buffers for the surrounding areas[155], which is of increasing value in the context of increasing flood risk in Laos due to climate change. The economic value of wetlands, however, extend beyond the mitigation of flood damage. Wetlands provide various other economic benefits. In Laos, wetland benefits include paddy rice production, vegetable

[155] Gerrard, P. 2014. Integrating Wetland Ecosystem Values into Urban Planning: The Case of That Luang Marsh, Vientiane, Lao PDR.

production, traditional fishing as well as aquaculture operations, wastewater treatment, water storage through groundwater recharge, leisure and tourism[156]. The value of many of these benefits, for example, were quantified in 2004 for That Luang Marsh in Vientiane (Table 9.2).

Table 9.2. Annual value of That Luang Marsh wetland, Vientiane co-benefits in 2004[157].

Co-benefit	Area (ha)	Value (US$/year)
Rice production	774	349,681
Vegetable production	47	55,017
Traditional capture fishing	200	1,336,000
Aquaculture	38	179,671
Non-fishery wetland products	200	354,106
Total		**2,274,475**

The case of That Luang Marsh illustrates the value of intact urban wetlands. When the functioning of such wetlands is lost because of urban development, there are substantial negative impacts. For example, the recent development of a special economic zone on the That Luang Marsh has led to major drainage and flooding problems on the site and in the surrounding area[158]. However, where wetlands are degraded, the cost of rehabilitation is highly site-specific, as are the potential benefits that can subsequently be derived. The composition, structure and function of a wetland is dependent on its position in the landscape and the catchment. The most efficient wetland rehabilitation projects are usually those that require the least modification to existing conditions. The conditions required for a wetland to exist include: i) a suitable geomorphological setting; ii) favourable hydrology; and iii) a substrate able to support wetland vegetation. Sites that have the above-mentioned conditions in place and require only minor modifications offer cost-effective opportunities for wetland rehabilitation and are the most likely to be successful[159]. Considering the costs of rehabilitating severely degraded wetland sites and the benefits provided by intact wetlands, there is a strong economic case for protection measures to avoid the degradation of wetland functioning in the first place, and for investing in appropriate ecological restoration of wetlands to enhance their functioning.

In the same way that the wetlands in Laos provide valuable ecosystem services, livelihoods are also supported by well-functioning and intact streams and rivers. The fisheries supported by the Mekong River are among the most productive inland fisheries in the world[160]. This productivity is supported by the seasonal migration of many fish species between different habitats through networks of wetlands and streams. The extent to which livelihoods and food security are dependent on fisheries increases the risk and potential cost of hard infrastructure development in streams, which is one of the greatest threats to fish populations[161]. Urban stream rehabilitation using EbA solutions, therefore, offers the benefits of flood regulation without the negative externalities on livelihoods that often accompany hard infrastructure

[156] Mitsch WJ, Bernal B and Hernandez ME. 2015. Ecosystem services of wetlands.
[157] Gerrard, P. 2014. Integrating Wetland Ecosystem Values into Urban Planning: The Case of That Luang Marsh, Vientiane, Lao PDR.
[158] Stakeholder consultation in Laos, April 2019; http://www.la.one.un.org/media-center/news-and-features/368-wetlands-and-the-paradox-of-urban-development; https://wle.cgiar.org/thrive/2016/02/01/luang-wetland-development-and-livelihoods
[159] Russel, W. et al. 2010. WET-Rehab Methods national guidelines and methods for wetland rehabilitation. *WRC Report* 341/09.
[160] Baumgartner et al. 2019. Achieving fish passage outcomes at irrigation infrastructure; a case study from the Lower Mekong Basin. Aquaculture and Fisheries
[161] Baumgartner et al. 2019. Achieving fish passage outcomes at irrigation infrastructure; a case study from the Lower Mekong Basin. Aquaculture and Fisheries

construction in streams. Establishing appropriate vegetation in streams, as opposed to concrete canals, can stabilise banks, filter water and slow down flash floods[162, 163].

To determine the cost-effectiveness of flood mitigation measures in rivers and streams, multiple EbA and hard infrastructure solutions were compared in two river catchments in Fiji[164]. The benefit to cost ratio for planting and preserving vegetation along riverbanks (riparian buffers) ranged from 2.8 to 21.6, depending on the catchment and the climate change scenario. For both catchments, the cost-effectiveness of riparian buffers compared to the alternatives increased under increasing climate change severity. Under the current climate conditions, the benefit to cost ratio was at least double the alternative EbA and hard infrastructure solutions, but this increased to at least four-fold the alternatives under sever climate change conditions. Non-monetised benefits that are not associated with hard infrastructure projects further increase the economic attractiveness of planting and preserving riparian buffers. These benefits include soil erosion control, maintenance of soil fertility, improved biodiversity and habitat, recreation and cultural value.

9.5 Permeable paving

The impacts of the increased frequency and intensity of rainfall events in urban areas due to climate change are exacerbated by the extent of hard surfaces that prevent the infiltration of stormwater runoff into the soil[165]. Without infiltration, the volume of runoff results in flash floods, threatening water quality and creating drainage problems, which leads to additional costs. Managing urban stormwater often, therefore, includes the use of permeable or semi-permeable paving on parking lots, low traffic streets, driveways and walkways.

In urban, built-up contexts, permeable paving is often the only feasible, cost-effective intervention that can be implemented as limited space precludes most nature-based solutions[166]. Greater permeability in built-up areas decreases the volume and intensity of stormwater runoff and alleviates the need for detention ponds or hard infrastructure that may be prohibitively expensive[167]. The cost of permeable paving in a Laotian context is uncertain as there are few comparable case studies in the region and because the available material, design and maintenance of the paving influences its effectiveness, efficiency and longevity[168]

9.6 Estimated avoided flood losses in target areas.

The avoided flood losses due to the implementation of a range of flood mitigation measures was estimated over a 20-year period in Vientiane, Paksan, Savannakhet and Pakse through a CTCN study. The losses included in the analysis were limited to direct loss of income from business closure, agriculture, household possessions and infrastructure. The methodology applied in the analysis is adopted from a World Bank report on the Lao PDR Southeast Asia Disaster Risk Management

[162] Bae, H. 2011. Urban stream restoration in Korea: Design considerations and residents' willingness to pay. *Urban Forestry & Urban Greening*, *10*(2).
[163] Lo, V. 2016. Synthesis Report on Experiences with Ecosystem-Based Approaches to Climate Change Adaptation and Disaster Risk Reduction. Technical Series No. 85 Secretariat of the Convention on Biological Diversity, Montreal.
[164] Daigneault, A., Brown, P. and Gawith, D. 2016. Dredging versus hedging: Comparing hard infrastructure toecosystem-based adaptation to flooding. *Ecological Economics,* 122, pp. 25-35
[165] Zhang, B., Xie, G., Zhang, C. and Zhang, J., 2012. The economic benefits of rainwater-runoff reduction by urban green spaces: A case study in Beijing, China. *Journal of Environmental Management*, 100, pp. 65-71
[166] Drake, J., Bradford, A. and Marsalek, J., 2013. Review of environmental performance of permeable pavement systems: state of the knowledge. *Water Quality Research Journal*, 48 (3), pp. 203-222
[167] Drake, J., Bradford, A. and Marsalek, J., 2013. Review of environmental performance of permeable pavement systems: state of the knowledge. *Water Quality Research Journal*, 48 (3), pp. 203-222
[168] Scholz, M. and Grabowiecki, P., 2007. Review of permeable pavement systems. *Building and Environment*, 42, pp. 3820-3836

Project[169]. Over 20 years, the avoided flood losses have been estimated to be US$24.45 million in Vientiane, US$27.89 million in Paksan, US$46.24 million in Savannakhet and US$12.26 million in Pakse.

These estimates are conservative as they make no assumption of the increased frequency and severity of flood impacts due to climate change, which would result in greater flood losses in the absence of mitigation measures. The additional benefits provided by EbA interventions and the indirect avoided costs due to flood losses are also not included in the estimates.

10 Selection of EbA Interventions and Sites

Based on the findings of the vulnerability assessment conducted by DHI and through a participatory process, a suite of EbA interventions for flood management were identified as suitable within the Laotian context. Potential sites for the implementation of these EbA interventions were identified through extensive consultations held with city-level government stakeholders across multiple sectors. Participants were introduced to, and asked to evaluate, a range of possible EbA interventions for selected sites in their city — which were prioritised based on the state of the ecosystem goods and services — ensuring that the interventions address the specific flood impacts on the site. Three rounds of group discussions (see details below) took place to select and prioritise EbA interventions.

Exercise 1: Identification of the damage experienced to ecosystems at the site, the causes of that damage (flooding and land conversion) and the resulting damage to ecosystem services. **Error! Reference source not found.**55 provides a schematic example of the analysis.

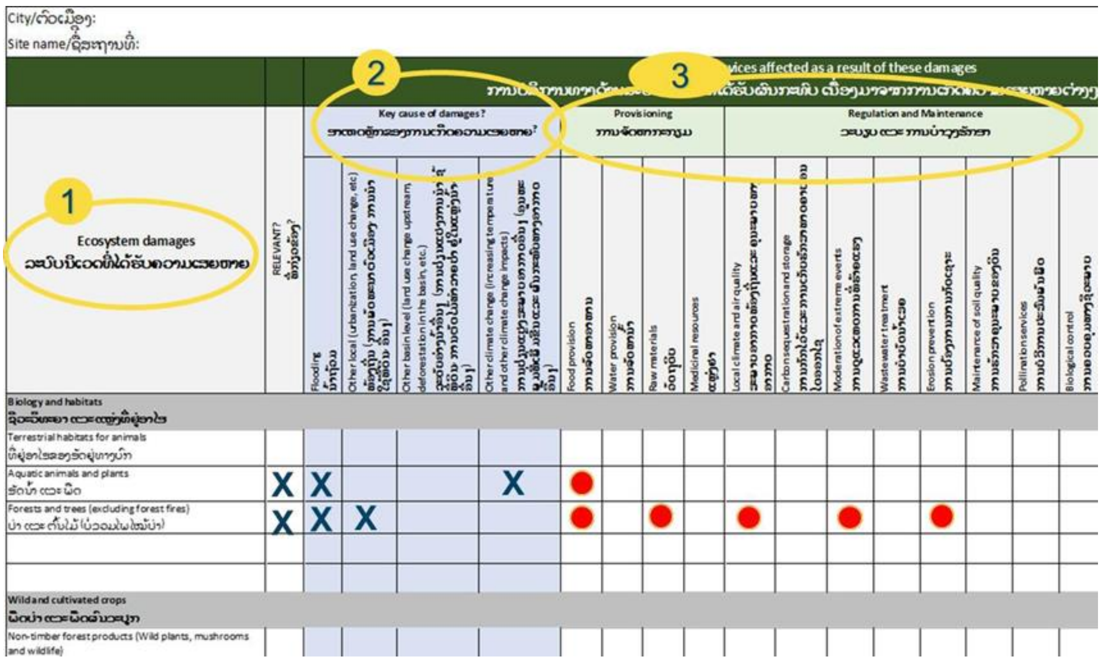


Figure 55. Example of the EbA intervention selection criteria.

Exercise 2: Group discussions and presentations of outcomes. Two to three EbA interventions were selected for further analysis. The considerations were that the selected EbA options are relevant for flood protection but that they also provide the ecosystem goods and services identified in Exercise 1.

[169] World Bank. (2017). Lao PDR South East Asia Disaster Risk Management Project: Project Appraisal Document. Washington D.C.: World Bank.

Exercise 3. Detailed assessment and prioritisation of the selected EbA interventions based on the following criteria:

- necessary scale of the intervention for best impact (local or basin);
- ecosystem goods and services that the selected EbA interventions can provide (flood protection, but also environmental and socioeconomic co-benefits);
- expected complexity of implementation;
- the estimated cost of implementation; and
- timeframe to achieve the desired ESS benefits (short- to long-term).

A schematic presentation of the analysis outcome can be seen in **Error! Reference source not found.** below.

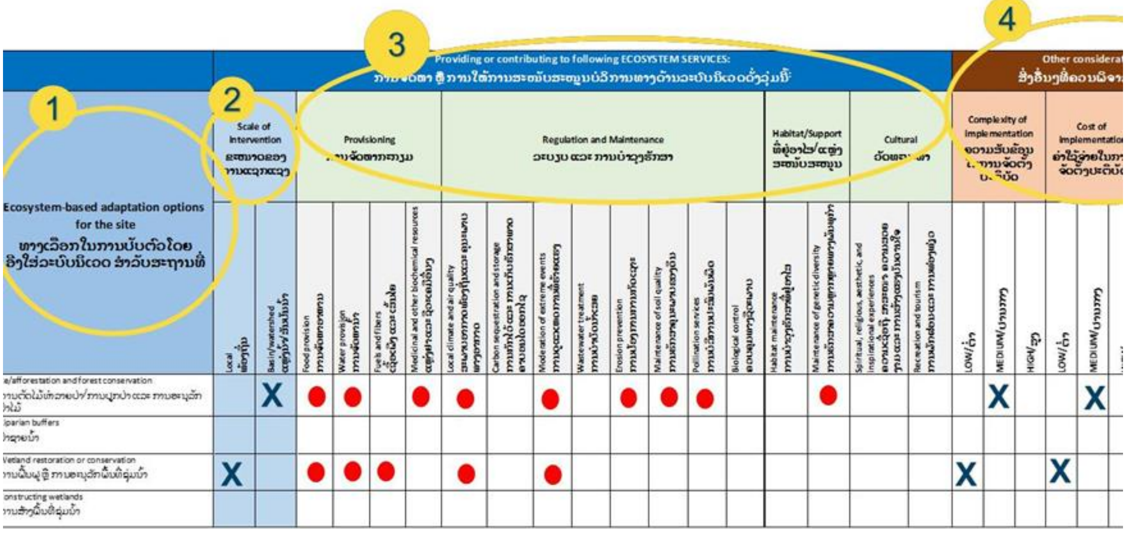


Figure 56. Schematic presentation of the analysis.

The aim of the assessment was to identify several EbA options for managing flooding at identified sites. It indicated that a portfolio of multiple EbA interventions may be most suitable to build climate resilience at many of the flooding sites. As a result, it is recommended that a suite of EbA options are selected and included in the recommended ICFMS[170], which should be used to inform future urban development. Using a portfolio of EbA interventions will diversify the investment costs and reduce the associated risks, as a single intervention type may underperform as a result of unforeseen circumstance. Additionally, having multiple EbA interventions will reduce the risk of overall system failure. Ultimately, this approach also acknowledges that no single intervention is likely to effectively manage flood impacts.

10.1.1 Validation of findings

After suitable EbA interventions were identified by stakeholders through the participatory process mentioned above, international consultants evaluated the identified interventions for technical feasibility and against safeguards standards. Based on this evaluation, wetland and stream restoration/rehabilitation as well as distributed interventions, such as permeable paving solutions as demonstration activities, were identified as the most feasible options for flood management of prioritised cities (Vientiane, Paksan, Savannakhet and Pakse). Distributed interventions, in particular, will require inputs from additional catchment hydrological analyses. Recommendations for EbA interventions for identified sites are shown in Section 7 of this Feasibility Study. The findings and consequent recommendations were based on limited spatial and hydrological data and did not include detailed intervention design.

[170] Section 7.2 of this Feasibility Study presents further details on the recommendation for ICFMS to be established for Laos to inform development planning.

Potential sites and interventions were validated through site visits and consultation with communities and local government officials conducted by international consultants documented in Annex 12: ESAP.

10.2 Detailed site selection in the target cities

Table 10.1 sets out the final selected sites; which included the evaluation of the potential for ecosystem services to increase resilience to climate change and consideration of safeguard risks. This final selection built on the other assessments described above and was refined further and finalised through extensive stakeholder consultations and site visits[171]. The identification of ecosystem services that are being negatively impacted by flooding and thus requiring appropriate protection has also formed part of this process.

Table 10.1. Selected intervention sites in the four target cities.

City	Village names
Vientiane, Vientiane Prefecture	Ban Dontiou
	Ban Dong Xang Hin
Paksan, Bolikhamxay Province	Nong Peung wetland area. Pakpung Paksuntay Pakxan-Nua Phonsa-At Phonxai Phosi Simoungkhoun Sisa-At Sivilai Pathsoum
Kaysone Phomvihane (Savannakhet), Savannakhet Province	Houamuang-Nua Nalao Phoxai-Noy Sibounhuang Lattanalangsi-Nua Nake Phonsavang-Nua Phoxai-Nua Phoxai-Tai Sounantha Thamuang

[171] by a UNEP and international consultants in April 2019.

Pakse, Champasak Province	Ban Photak Ban Kae Ban Nathaek Ban Sokamnouay Ban Huoainhangkam Ban Phaksae Ban Phonesaath Ban Thahai Ban Thahinnuea Ban Houachae Ban Xaysavang

Maps of the sites in each city are presented below.

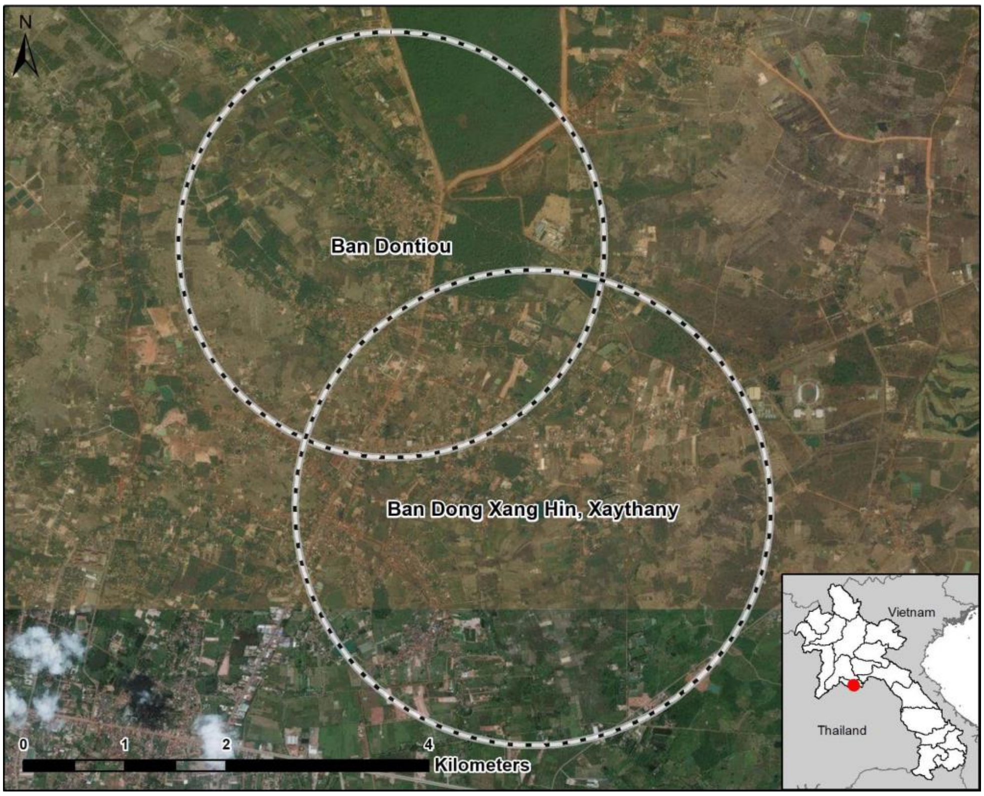


Figure 10.1. Target areas in Vientiane.

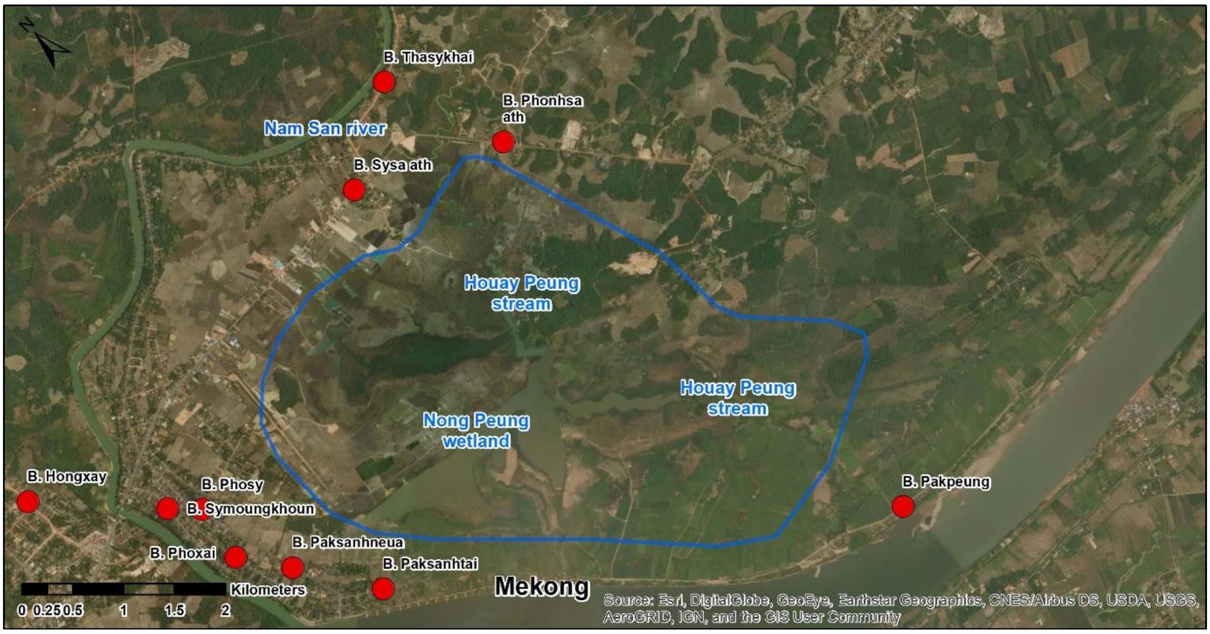


Figure 10.2. Target area in Paksan. The wetland area that will be restored is indicated.

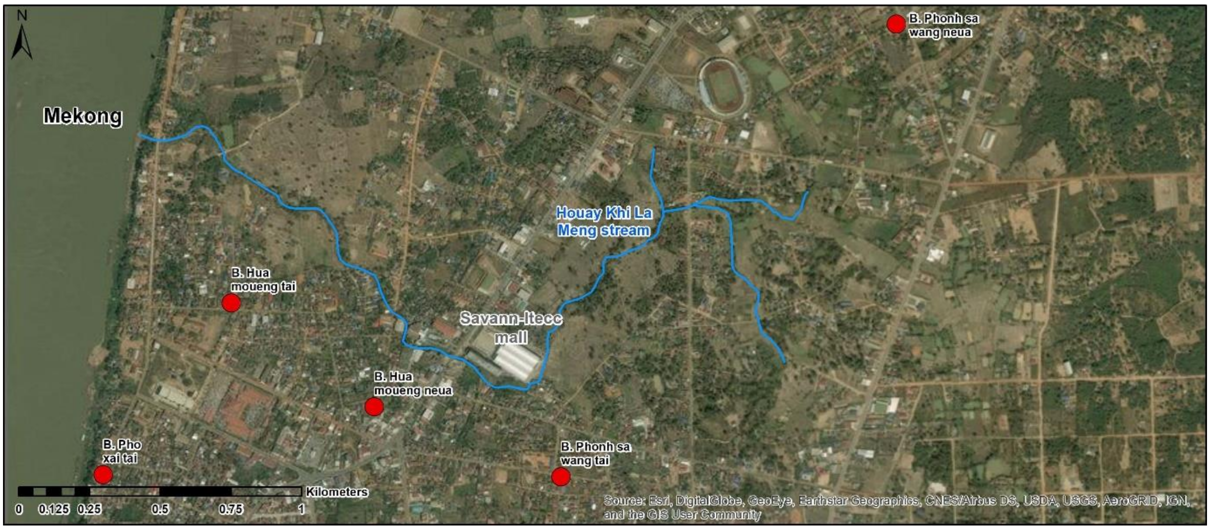


Figure 10.3. Target area in Savannakhet. The stream that will be restored is indicated.

Figure 10.4. Target area in Pakse. The stream that will be restored is indicated.

11 Designing Project Interventions

This Feasibility Study indicates that the cities located along the Mekong River in Laos are vulnerable to climate change-induced flooding (see Section 3). It is likely that these cities will remain vulnerable to both the current and future effects of climate change unless effective adaptation is undertaken. Best practices and lessons learned have emerged from past and ongoing projects in Laos (see Section 5). A number of barriers are also evident (see Section 6), which need to be addressed if Laotian cities are to adapt to climate change. Specific needs for building climate resilience were identified during stakeholder consultations conducted during the development of this Feasibility Study (see Annex 12: ESAP). Given the above scenario, it is recommended that urban EbA interventions should be implemented in Laotian cities in an integrated manner as an effective way of reducing the vulnerability of the country's cities, particularly along the Mekong River.

The sections below describe the project's approach to climate change adaptation for the four target cities along the Mekong River. This approach focuses on integrated flood management and investment in ecological infrastructure to reduce the impacts of floods. Cross-sectoral planning and management should form an integral part of this approach. It is also recommended that urban EbA for flood management should be integrated into planning and decision-making in local and national government structures.

11.1 Capacity building

Implementing integrated flood management (IFM) and EbA interventions effectively requires multi-sectoral coordination and technical capacity that is not currently available within the GoL. Contemporary water and flood management in Laos remains focused on traditional flood control methods, which are generally not implemented in ways that allow for involvement of sectors and stakeholders beyond those associated with hard infrastructure approaches. For EbA interventions to be effective, they will need to be implemented in an integrated manner along with grey infrastructure. This will require increased: i) awareness of, and capacity for, IFM in the context of climate change amongst Laotian stakeholders; ii) technical capacity of government for the implementation of EbA interventions, particularly for optimising co-benefits; and iii) multi-sectoral collaboration to manage floods, including with the private sector.

The relevant stakeholders[172] in the GoL should attend workshops and undergo training to ensure that they have the capacity to plan and implement urban EbA interventions to manage climate change-induced flooding. The method by which the capacity building will be achieved is described further under Section 12 below. Long-term capacity building of government and urban development professionals for EbA and flood management should also be undertaken. It is recommended that the National University of Laos (NUoL) integrate EbA content into their existing curricula for civil engineers and environmental scientists.

It is also recommended that a national knowledge hub on EbA for urban flood management is established in the National University of Laos. The staff of the hub would conduct action research about urban EbA for flood management, conduct joint research and facilitate linkages with international universities, monitor the performance of EbA interventions and provide information to government stakeholders. This process would facilitate adaptive management of EbA interventions, while also ensuring that the EbA curricula at NUoL benefit from current best practices and local practical examples. The civil engineering department at NUoL could potentially host the knowledge hub, considering its existing approach of lecturers and researchers providing advice on public and private sector projects and sharing their experience with students.

The final capacity-building recommendation is that GoL managers and decision-makers undertake knowledge exchange trips to countries where urban EbA has been successfully used to manage the impact of flooding. Bangkok in Thailand is the recommended location since it is geographically and culturally close to Laos and has successfully implemented urban EbA interventions. Another option for a knowledge exchange trip is Singapore, as it is internationally recognised as a leader in sustainable water management using EbA principles. Knowledge exchange trips are expected to provide stakeholders with practical examples of the use of urban EbA and to demonstrate its co-benefits.

11.2 Integrated flood management

Because urban EbA interventions will work best when applied within an integrated strategy, it is recommended that integrated flood management strategies are developed for Vientiane, Paksan, Savannakhet and Pakse. These strategies will form the basis of future IFM in Laotian cities, specifically focusing on the use of EbA to manage flood impacts. Strategies should be forward-looking and evidence-based. More data will need to be gathered to inform the strategies. While this Feasibility Study has conducted initial flood hazard mapping exercises, designing specific flood management interventions will require detailed hydrological models that: i) identify areas that contribute to flooding; ii) evaluate the flood reduction benefit of various interventions; and iii) take boundary conditions into account. Such models should be developed at the city level to inform flood management strategies and should incorporate the predicted changes in climate to ensure that the strategies developed account for the impacts of increasing extreme rainfall events.

Such Integrated Climate Resilient Flood Management Strategies (ICFMS) should qualify the role of private sector stakeholders and prioritise community engagement. in each city should be consulted during all stages of ICFMS development. Organisations representing local

[172] including, but not limited to, representatives of MONRE, MPI, MPWT and MAF

communities — such as the National Women's Union and National Front — should be invited to actively participate in the development of these strategies. Local academics from the NUoL and other institutions should also be invited to participate in and comment on the design and implementation of these strategies.

EbA should form an integral aspect of the ICFMS, as it is a flexible, climate-resilient approach to flood management that also provides numerous co-benefits. Urban EbA handbooks need to be developed — in close cooperation with local government stakeholders and communities — as annexes to each of the four ICFMS. These handbooks should include detailed instructions on how to plan, implement, maintain and monitor urban EbA interventions in each city specifically. Different types of EbA interventions should be prioritised, given the cities' specific requirements and local conditions. Overall, EbA recommendations should be based on national urban EbA guidelines. Such national guidelines need to be developed to provide general recommendations on urban EbA interventions for flood management in all the different urban contexts of Laos. These EbA guidelines should also provide detailed information on how to optimise co-benefits derived from different EbA interventions.

11.3 Permeable paving

Uncontrolled stormwater runoff creates drainage problems, flash floods and threatens water quality in Laotian cities. Sustainable urban drainage systems (SUDS) are a range of drainage techniques and devices primarily aimed at optimal stormwater management. These systems are used for runoff attenuation and mitigation, pollutant reduction and amenity construction. The most commonly used SUDS techniques include: i) permeable surfaces; ii) filter and infiltration trenches; iii) water storage; iv) swales; v) water harvesting; vi) detention basins; and vii) wetlands and ponds. Permeable surfaces, in the form of paving, are recommended for built-up areas as part of a suite of interventions for stormwater management.

Permeable paving is an efficient technology for managing urban stormwater to reduce flooding. This paving system incorporates permeable or semi-permeable materials overlaying a gravel storage layer (Figure 57). Several types of permeable pavement exist with differences in their materials, total pore space, spatial arrangement of the underlying pervious layers and structural strength. The most common types include: i) porous asphalt; ii) porous concrete; and iii) permeable interlocking concrete pavers (Figure 58, Table 11). Permeable paving is often used on parking lots, low traffic streets, driveways and walkways. As precipitation falls on these surfaces, water infiltrates down through layers of different aggregate sizes and is then released into the surrounding soil or stored in basins.

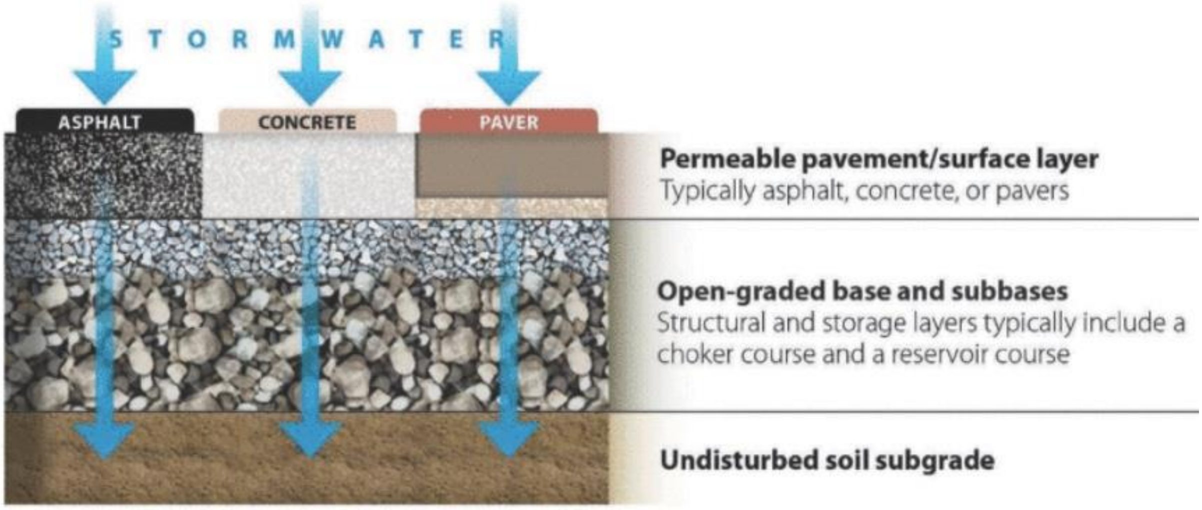


Figure 57: Permeable pavement structure[173]

Figure 58. Porous concrete, porous asphalt and interlocking pavers

Table 11: Characteristics of main types of permeable paving[174]

	Porous concrete	Porous asphalt	Interlocking pavers
Pavement Thickness	~12–20 cm	~7–10cm	~7cm
Construction Properties	Cast in place, 7-days cure, must be covered	Cast in place, 24-hour cure	No cure period; manual or mechanical installation of pre-manufactured units, over 460m^2/day/ machine
Permeability capacity	~3 m of water/day	~2 m of water/day	~0.5 m of water/day
Construction Cost	~US$20–65/m^2	~US$5–10/m^2	~US$50–100/m^2
Longevity	20 to 30 years	15 to 20 years	20 to 30 years
Temperature Reduction	Cooling in the reservoir layer	Cooling in the reservoir layer	Cooling at the pavement surface & reservoir layer
Colours/Texture	Limited range of colours and textures	Black or dark grey colour	Wide range of colours, textures, and patterns

	Porous concrete	Porous asphalt	Interlocking pavers
Traffic Bearing Capacity	Can support all traffic loads, with appropriate bedding layer design	Can support limited traffic loads	Can support limited traffic loads
Surface Clogging	Replace paved areas or install drop inlet	Replace paved areas or install drop inlet	Vacuum pavers when clogged joints are observed (up to twice a year). Replace permeable stone jointing materials when missing (e.g. granite chips)

Environmental benefits of permeable paving include: i) reduced stormwater runoff volume; ii) reduced flows to storm sewer systems and streams; iii) increased groundwater recharge; iv) decreased and delayed peak discharge; v) reduced water pollutant concentrations and improved water quality; and vi) reduced urban heat island effect. Several studies show successful applications of permeable paving to mitigate stormwater runoff[175,176]. However, the efficiency of these techniques is highly dependent on the physical conditions of the site selected. Therefore, site assessments including data collection on groundwater depth and technical designs are necessary to determine the type of permeable paving needed for specific sites. Paving infiltration rates can decline because of clogging of pores either by dry deposition of particles and/or shear stress of vehicles driving and degrading the permeable surfaces[177]. To maintain permeability, periodic vacuuming of the surface is required to remove material clogging pores. The average annual maintenance cost of permeable paving solutions is US$0.45 per m^2.[178] Initial construction and maintenance costs for permeable pavements are considered to be higher than for conventional pavements. However, these costs are often offset by a reduction in the use of other traditional stormwater structures. Permeable paving also improves water quality, thus reducing the need for additional water treatment measures.

11.4 Rehabilitation and sustainable management of urban wetlands

Urban wetlands provide a range of valuable ecosystem services, including but not limited to: i) controlling floods; ii) moderating local microclimate; iii) improving water quality; iv) recharging groundwater; and v) providing recreational spaces for nearby residents[179]. Considering the increasing flood risk because of climate change, wetlands are important for flood management. Wetlands can act as flood retention basins upstream or within a city when managed appropriately. In Laotian cities, this capacity of wetlands to store water will be particularly necessary as the magnitude and frequency of floods increase with climate change and threaten Laos' fast-growing urban population. However, rapidly expanding urban areas in the country are encroaching on wetlands and limiting their capacity to provide ecosystem

[178] Low Impact Development Stormwater Management Practice Inspection and Maintenance Guide. Toronto and Region Conservation Authority, 2016. Available at: https://sustainabletechnologies.ca/app/uploads/2016/08/LID-IM-Guide-7.4-Permeable-Pavements.pdf. Accessed on: 3 June 2019.
[179] Mitsch WJ, Bernal B and Hernandez ME. 2015. Ecosystem services of wetlands.

services such as flood control. For example, That Luang Marsh was identified as an important wetland for flood management in the city of Vientiane but continues to be drained for urban development as part of a special economic zone[180]. Urban encroachment restricts the space available to convey and store an increasing volume of flood water, therefore the protection and rehabilitation of urban and peri-urban wetlands is recommended as an EbA intervention to mitigate floods in Laotian cities.

As a wetland's composition, structure and function are dependent on its position in the landscape and its catchment, rehabilitation actions are site-specific and their costs vary greatly. When compared to stormwater treatment plants and hard infrastructure interventions for flood management, wetland rehabilitation is a cost-effective option. In addition, when the other ecosystem services provided by wetlands in addition to flood management are considered, rehabilitating and protecting wetlands make economic sense. The most efficient wetland rehabilitation projects are usually those that require the least modification to existing conditions. The conditions required for a wetland to exist include: i) a suitable geomorphological setting; ii) favourable hydrology; and iii) a substrate able to support wetland vegetation. Sites that have the above-mentioned conditions in place and require only minor modifications offer cost-effective opportunities for wetland rehabilitation and are the most likely to be successful[181]. Rehabilitation actions can include: i) alien vegetation clearing; ii) revegetation; and iii) the installation of gabion, concrete or earth structures. Table 12 below provides a list of guiding principles for wetland rehabilitation projects and Table 13 gives examples of methods used in these projects.

Table 12: Principles of wetland rehabilitation[182].

General Principles relating to wetland functioning and management	**Associated principles for implementing wetland rehabilitation**
Wetlands result from several driving forces, including geomorphological setting, hydrology, physical processes (e.g. fire, sediment movement), biochemical processes (e.g. nutrient cycling) and biological processes (e.g. colonisation). These driving forces interact to provide ecosystem services, e.g. water quality enhancement.	Rehabilitation is the reinstatement of these driving forces to a level close to the original system to improve the wetland's capacity to provide ecosystem services.
Wetlands are dynamic, changing across time scales of days, seasons, years, decades, millennia and longer. Given sufficient time (i.e. geological time spans) all wetlands will ultimately decline as wetlands develop elsewhere in the landscape.	The goal of wetland rehabilitation should not be to return and maintain a wetland in a static state but rather to achieve a persistent resilient system that is largely self-maintaining and can respond to change with little human intervention.
Wetland are an integral part of catchments and broader landscapes. The nature and rates of processes affecting wetlands can be influenced by human interventions within catchments and landscapes.	Wetland rehabilitation must be integrated with the surrounding landscape if it is to address the causes of wetland degradation and not just the symptoms.
All wetlands occur within a socio-economic context that may have a profound effect on	If wetland rehabilitation projects are to be sustainable, they must have meaningful ownership by local people and give adequate

[180] Gerrard, P. 2004. Integrating Wetland Ecosystem Values into Urban Planning: The Case of That Luang Marsh, Vientiane, Lao PDR.
181 Russel, W. et al. 2010. WET-RehabMethods national guidelines and methods for wetland rehabilitation. *WRC Report* 341/09.
[182] Russel, W. et al. 2010. WET-RehabMethods national guidelines and methods for wetland rehabilitation. *WRC Report* 341/09.

General Principles relating to wetland functioning and management	**Associated principles for implementing wetland rehabilitation**
management and land-use decisions, in turn affecting the functioning of the wetland.	consideration to socio-economic factors, particularly those relating to the direct users of the wetland.

Table 13. Common methods used for wetland rehabilitation[183].

Hard engineering interventions	**Soft engineering interventions**
• Earth berms in conjunction with gabion systems to block artificial channels that drain water from or divert polluted water to the wetland • Concrete and gabion weirs to act as settling ponds, to reduce flow velocity or to re-disperse water across former wetland areas thereby re-establishing natural flow paths • Earth or gabion structure plugs to raise channel floors and reduce water velocity • Concrete or gabion structures to stabilise head-cut or other erosion and prevent gullies • Gabion structures (mattresses, blankets or baskets) to provide a platform for the growth of desired wetland vegetation	• Invasive alien plant clearing • The re-vegetation of stabilised areas with appropriate wetland and riparian plant species • Fencing off sensitive areas within the wetland to keep grazers out and to allow for the re-establishment of vegetation • The use of biodegradable or natural soil retention systems such as eco-logs, plant plugs, grass or hay bales, and brush-packing techniques

Hard engineering interventions measures at a large scale will not be implemented under the proposed project. The permeable paving solutions will be implemented at small-scale in the four target cities and monitored regularly to track their success as an option for improving drainage across Laos' urban areas.

11.5 Rehabilitation and sustainable management of urban streams

Ecosystem services provided by streams — such as microclimate and flood regulation — are often degraded in urban locations as a result of: i) channelization through artificial banks; ii) /bed dredging; iii) water quality degradation; iv) loss of riparian vegetation; v) solid waste dumped in streams; and vi) invasive species. Establishing the appropriate vegetation is one of the most important components of urban stream rehabilitation. Plant species used in stream channels should not be easily washed away during flooding and be able to tolerate extended submergence. The vegetation established should be appropriate for the flood management goal of the particular section of a stream. In the upper and middle sections of streams both trees and shrubs that stabilise banks, as well as aquatic vegetation in stream channels that filter water and slow down flash floods are appropriate. In the lower reaches of urban streams where discharge capacity of channels is critical to prevent localised flooding, planting should be done in a manner that does not impede stream flow.
In general, plant species that have strong root systems, grow well in wet areas, and can tolerate submergence are useful for stream restoration. Examples of such plant species used in Korea are provided in Table 14 below. Locally indigenous species need to be used for the restoration of urban stream banks, based on surveys of riparian vegetation[184]. Further research on the appropriate vegetation needed for Laotian urban streams is needed.

[183] South African National Biodiversity Institute. 2014. Rehabilitation plan for Hogsback wetland project, Easter Cape.
[184] For example, an ecological survey done by the IUCN of the Mekong River in northern Laos has identified locally indigenous riparian vegetation in that region. Available at: https://www.iucn.org/sites/dev/files/import/downloads/ecologicalsurveymekong__iucn_cepf.pdf

Table 14. Common types of vegetation used in urban stream restoration in Korea[185].

Tree	Shrub	Grass
• *Salix* spp. L. • *Salix pseudolasiogyne* H.Lév. • *Salix babylonica* L. • *Iris ensata var. spontanea* Nakai • *Fraxinus rhynchophylla* Hance	• *Phragmites* Trin. • *Salix gracilistyla* Miq. • *Miscanthus sacchariflorus* Hack	• *Aster yomena* Honda • *Imperata cylindrica* P.Beauv. • *Zoysia matrella* Merr. • *Pennisetum alopecuroides* Spreng. • *Phragmites communis* Trin.

12 Description of project activities

Based on these project approaches and the particular findings of this Feasibility Study, the following section describes specific activities that the proposed GCF project will undertake in each of the four cities.

12.1 Project activities

Component 1. Technical and institutional capacity building to plan, design, implement and maintain integrated urban Ecosystems-based Adaptation (EbA) interventions for the reduction of climate change-induced flooding

Urban development in Laos is taking place without sufficient consideration of the increasing risks of climate change-induced floods. To enhance the flood resilience of cities in Laos requires a comprehensive, integrated approach to flood management that includes good planning and the use of EbA. Cities are not currently adopting such an approach because of the barriers described in Section B.1 above. The project interventions under this project component will work at multiple levels and through different entry points to overcome these barriers. This will be achieved through two project outputs. The first output will focus on increasing awareness and knowledge of urban EbA, as well as building technical and institutional capacity for the implementation of urban EbA interventions. The second output will focus on developing city-level strategies for integrated, climate-resilient flood management, which will be informed by hydrological and ecosystem assessments, and supported by creating an enabling policy environment.

<u>Output 1.1 Strengthening of institutional capacity for integrated flood risk management and implementation of urban ecosystems-based adaptation and males and females with increased awareness of climate threats</u>

The uptake of urban EbA for flood management in Laos is constrained by the limited knowledge and awareness of urban EbA among government, the private sector and communities. The activities under this output will address this barrier by building the capacity of the relevant government departments, by creating and sharing knowledge of urban EbA in

[185] Bae, H. 2011. Urban stream restoration in Korea: Design considerations and residents' willingness to pay. *Urban Forestry & Urban Greening*, *10*(2).

Laos, and by engaging with communities and the private sector. Improving knowledge of the benefits and successful examples of urban EbA in the public and private sectors and at the community level strengthens adoption and sustainability of incorporating urban EbA in planning frameworks as well as supports the sustainability of the investments themselves.

Activity 1.1.1 Build the capacity of national and local representatives for using urban EbA to manage climate change-induced flooding.

Successfully implementing urban EbA requires effective coordination across institutions and sectors, as well as effective urban planning that maintains the necessary space for urban EbA interventions. This activity will train decision-makers from MONRE, Ministry of Planning and Investment (MPI), Ministry of Public Works and Transport (MPWT), Ministry of Agriculture and Forestry, provincial governments and other relevant agencies on how to incorporate integrated climate-resilient flood management into urban planning for the cities of Vientiane, Paksan, Savannakhet and Pakse. This training will include training sessions and learning-by-doing and will cover *inter alia* the following topics: i) EbA concepts and roles of different institutions and sectors; ii) how to link spatial planning[186] with the planning of investments in socio-economic development[187]; iii) master planning processes, iterative planning and their applications at local level; iv) how to strengthen district-level planning systems and their links to provincial planning systems; v) how to use City-level Project Steering Committees as the multi-sectoral coordination mechanism for the Integrated Climate-resilient Flood Management Strategies (see Activity 1.2.3.) and linking this mechanism to the provincial administration; vi) existing legal frameworks and their enforcement. Furthermore, implementing urban EbA interventions such as wetland rehabilitation and detention ponds demands technical skills. Technical staff from the relevant national and city-level departments will receive training on how to use urban EbA to reduce climate-induced flooding. This training will include: i) hands-on spatial planning exercises using GIS; ii) drone mapping; iii) best practices on the design, implementation and maintenance of urban EbA; iv) enforcement of land use regulations and buffer zones around wetlands, rivers and streams; and v) submitting applications for the financing of urban EbA interventions, including to the Environmental Protection Fund (EPF). Lastly, the proposed project will arrange a knowledge-exchange trip for senior government representatives, technical experts and academics to a city with considerable experience with urban EbA for flood management[188] and is geographically and culturally close to Laos which will promote long-term knowledge exchange[189].

Activity 1.1.2 Establish a national knowledge hub that produces and disseminates information on urban EbA interventions locally, regionally and internationally.

A national knowledge hub will be established to produce, collate, analyse and disseminate information on local, regional and international urban EbA interventions, including local and indigenous knowledge on EbA. This knowledge hub will be hosted by the National University of Laos (NUoL) in Vientiane. Since urban EbA incorporates different disciplines, the knowledge hub will be multi-disciplinary, covering the fields of civil engineering, urban planning, water resource management, economics, agriculture, ecology and governance. The knowledge hub will contribute to economic valuation of ecosystem services (Activity 1.2.1), hydrological

[186] including land use planning and flood risk planning
[187] Through the Socio-Economic Development Plans of the Ministry of Planning and Investment, and building on lessons learned from the GIZ-funded project "Land management and decentralised planning I & II"
[188] Options for the knowledge exchange trip include Bangkok, Manila, and Singapore. In selecting the city, the considerations include similarity of institutional contexts, relevance of the urban EbA interventions to the Laotian setting, and potential for sustaining linkages across institutions.
[189] The project design adopts similar approaches with the Mekong Integrated Water Resources Management Project (M-IWRMP), which is a transboundary cooperation for river basin management between Laos and Thailand. The project has had successful outcomes in peer to peer learning.

modelling and wetland assessments (Activity 1.2.2), guidelines development (Activity 1.2.4) and other relevant activities. Funding will be made available to the NUoL and relevant institutions to conduct joint assessments and monitoring as well as increase knowledge of topics related to urban EbA. An MoU will be signed between the university and MONRE which will require the knowledge hub to deliver annual presentations and reports to the relevant line ministries and the research institutes affiliated with them and/or the Project Steering Committee. The knowledge hub will also create linkages between NUoL and international institutions specialising in urban EbA. The Knowledge Hub will support the hosting and attendance of conferences and regional forums[190] on EbA for relevant staff and students, as well as for knowledge exchange and joint research with other EbA initiatives in the region. By linking NUoL and international institutions, the national knowledge hub will ensure that international best practices are applied in Laos.

The knowledge hub will play an important role in providing technical support to government departments for the implementation of EbA interventions, as well as to the community management committees that will be established by the project under Component 2.

Urban EbA content will also be integrated into existing civil engineering curricula at the university. By expanding existing curricula to include modules on EbA, the project will ensure that the long-term capacity to design, implement and maintain urban EbA interventions in Laos remains after project completion. An international urban EbA expert will be contracted to assist with the integration of new content into the existing curricula.

Activity 1.1.3 Conduct awareness-raising campaigns in each of the four target cities for communities and the private sector on urban EbA and flood management.

The active support of various stakeholders is needed for urban EbA interventions to work well and for planning future urban EbA interventions. To achieve this the proposed project will raise awareness among the public about: i) the value of wetlands and urban streams; ii) the importance of proper solid waste disposal; iii) the need to protect natural streams and rivers; and v) regulations on waterway buffer zones; and v) household-level adaptation measures such as keeping drainage lines on private property open. The awareness-raising campaign will not only communicate the impacts of climate-induced floods and the benefits of urban EbA, but also recommend household-level adaptation measures. These awareness raising campaigns will be conducted via community management committees, village governance structures, water-user associations, and the National Women's Union. Water-user associations and village-level groups consulted during the project preparation have nuanced understandings of flood-related issues in their communities and can be important channels for awareness campaigns and promoting behaviour change in resource use and maintenance of small-scale community infrastructure. Awareness-raising campaigns will be focused on, but not limited to, villages around the wetland and stream rehabilitation sites (see Component 2). This will include information on the appropriate management of these ecosystems and sustainable natural resource use. In Paksan, it will be linked to the sustainable management plan that will be developed under the project for the Nong Peung wetland (see Component 2).

In addition to interactions with communities, the project will also engage selected private sector stakeholders to identify how they can contribute to and benefit from project activities. This will include especially stakeholders that manage large areas of urban land and can therefore contribute to effective management of stormwater runoff, for example special economic zones and shopping malls such as the Savann-Itecc mall in Savannakhet.

[190] Such as the Asia Pacific Climate Change Adaptation Forum, ASEAN working group sessions, and other appropriate venues.

Output 1.2 Integrated Climate-resilient Flood Management Strategies and urban EbA guidelines developed for Vientiane, Paksan, Savannakhet and Pakse, and effective Flood Risk Management Committees as coordination mechanisms

Responding adequately to increasing flood risk in Laotian cities because of climate change requires an integrated approach to flood management. Such an approach must include the use of ecosystems (green infrastructure) for flood reduction along with traditional grey infrastructure. To develop this approach in a given city demands cross-sectoral cooperation and comprehensive planning informed by hydrological assessments and understanding of the value of ecosystem services. The activities under this output will address these needs by determining the economic value of ecosystem services provided by urban wetlands and streams, conducting hydrological assessments and mainstreaming urban EbA into relevant policies and plans for each of the four target cities.

Activity 1.2.1 Conduct economic valuation of urban ecosystem services.

In order to prioritise urban EbA, decision-makers need to understand the value of the services, including flood reduction, provided by urban ecosystems. MPI, PWT and the National University of Laos and other key stakeholders will be engaged throughout the activity from inception, to refining methodologies, and presentation of results through meetings and workshops. Briefing notes will be developed and working sessions will be held with key decision makers (i.e. provincial governors, members of working committees for developing certain policies, investment committees under the MPI, staff of planning departments in key ministries) with the objective of communicating evidence of benefits of urban EbA, providing specific policy recommendations, and looking at opportunities for further engagement and investment. Under this activity the ecosystem services provided by the Nong Peung wetland in Paksan and urban streams in the four target cities will be measured and valued. Physical maps developed under Activity 1.2.2 will form the basis of a GIS analysis of the ecosystems. Subsequently, ecosystem services provided by the urban wetlands and streams under different climate change projections will be identified and valued, and a sensitivity analysis will be carried out. The valuation will be undertaken through a variety of market and non-market methods, such as direct damage assessment, spatial analyses of changes in the landscape and studies on people's willingness to accept compensation for losses. The valuation process will entail survey designs, training of enumerators, collection of socio-economic data, model calibration, and computation. Furthermore, based on the valuation, policy recommendations will be developed such as assessing how the valuation of climate change impacts on ecosystem services and EbA measures can contribute to natural capital accounting processes in the country[191], incorporation of operations and maintenance costs of EbA in the government's asset management system, and assessment of options for payments for ecosystem services and water allocation schemes. The policy recommendations will be integrated into the adaptation assessments in Activity 1.2.4 to help mainstream EbA into the planning, policy and legal frameworks.

[191] Approaches in Mekong countries, including Lao PDR, are outlined in ADB. 2015. Investing in Natural Capital for a Sustainable Future in the Greater Mekong Subregion. Manila, Philippines.

Activity 1.2.2 Conduct hydrological assessments and climate risk assessments to inform climate change adaptation solutions for flood management in Vientiane, Paksan, Savannakhet and Pakse.

Effective urban flood management strategies cannot be developed without detailed hydrological models at a city-scale. Presently, such models are either not available for Laotian cities, or if they do exist, they are at coarse spatial resolutions that do not assist with planning interventions. To address this gap, detailed spatial and hydrological assessments will be conducted for the four target cities. Data on elevation, land use and existing infrastructure will be collected for the assessments. Drone mapping will be used to obtain high-resolution spatial information.

Using these data, one hydrological model for each of the four cities will be developed to inform the integrated climate-resilient flood management strategies (ICFMS) that will be developed under Activity 1.2.4. The software that will be used to develop these hydrological models will be selected in consultation with local stakeholders to prevent vendor lock-in of costly and inappropriate software. There are also currently no demarcated floodplains[192] in Laotian cities. The hydrological models will be used to establish 20-, 50- and 100-year floodlines[193] in the four target cities, taking climate change scenarios into account. These floodlines will further inform the ICFMS and future development planning of the cities. To ensure sustainability and effective technology transfer, the modelling and mapping infrastructure and trained staff will be hosted within an appropriate institution to be selected at the start of the project[194].

In Paksan, the hydrological assessment will specifically include the Nong Peung wetland. In addition, other aspects of the wetland will be assessed, including the different functional zones, water quality, biodiversity, invasive alien species and community use of the wetland. This general wetland assessment will inform the management plan for the wetland that will be developed under Activity 2.1.1.

Activity 1.2.3 Develop the ICFMS and mainstream climate change and urban EbA into relevant policies, guidelines and plans.

Without a shift in the way cities in Laos are planned and developed, future urban development is likely to further contribute to flooding – particularly as rainfall intensity and frequency increases. Existing spatial development plans in Laos do not take into account the interaction between increasing rainfall and increases in catchment imperviousness. Moreover, many of the existing drainage systems in the four cities have been not been adequately designed to effectively drain runoff from large rainfall events. These poorly performing drainage systems increase the frequency and severity of floods and result in more frequent on-site flooding. To address these challenges, this project activity will develop one ICFMS for each of the four target cities. The development of the ICFMS will take place through broad consultation with stakeholders and continual engagement with existing policy-making processes and planning processes, as well as by holding various workshops focused on the ICFMS. This development will be driven by a dedicated full-time ICFMS Officer that will be established in the provincial office of MPWT, in coordination with the city-level project focal point sitting in PONRE in each city. These strategies will draw on the findings of the assessments done under Activities 1.2.1

[192] Floodplains are the areas adjacent to a river that are flooded.
[193] Floodlines are geographical demarcations of the floodplain for a flood with a particular return interval. For example, a 1-in-100-year floodline demarcates the floodplain of the 1-in-100-year flood.
[194] Options include the Civil Engineering Department of the NUoL or the Public Works and Transport Institute within MPWT.

and 1.2.2. The cross-sectoral ICFMS will be owned by the Provincial Office of Public Works and Transport. A coordination mechanism for the ICFMS with representation from the relevant government departments will be set up, the Flood Risk Management Committee (FRMC), to ensure effective cross-sectoral collaboration. Adopting a cross-sectoral approach will ensure that flood management is considered in all sectoral planning processes. Stakeholder consultations with affected communities, the private sector and civil society will also be conducted during the ICFMS development and implementation. The ICFMS will contain proposed EbA interventions, management recommendations and enforcement arrangements appropriate to each city, as well as options for specific improvements to city regulations and provincial policies.

Specific steps in the process include:

1. Sign MOU with PWT to carry out Activities 1.2.3 and 1.2.4 as an implementing partner and embed implementation within its urban planning unit, including looking at options for updating the ICFMS at regular intervals
2. Organise Flood Risk Management Committees at the city level, including representatives from MONRE, MPWT and MPI as well as representatives from relevant provincial departments, to be convened by the provincial governor[195]. The committee would agree on the terms of reference, as well as decide on indicators and targets for Activity 1.2.3.

   The ICFMS includes:

   a. Based on hydrological assessments, develop flood risk maps including 50 and 100-year flood lines and how flood lines would shift under climate change scenarios
   b. Analysis of mix of investment options: infrastructure, urban EbA, early warning, land use and urban planning
   c. Priority urban EbA investments for each city
   d. Operationalization of priority investments
      i. Identification of financing sources
      ii. Scoping availability of potential service providers
      iii. Assessment of technical and operational capacity to execute
      iv. Operations and maintenance requirements
   e. Proposed zonation in the context of flood risk
   f. Institutional mapping and analysis of mandates on flood risk management
   g. Policy gap analysis and recommendations on urban planning, building codes, permitting processes, investment requirements for concessions including Special Economic Zones, environmental impact assessments, and other relevant areas
   h. Procedures for regular updating of ICFMS

   Options for the mainstreaming work plan are:

   a. Linking ICFMS into district and provincial Socio-Economic Development Plan for the next 5-year cycle
   b. Examine policies considered in the Provincial Assembly for points of entry
   c. Link with existing processes for updating building codes and construction approval processes

[195] This structure is adapted from the Land Allocation Committees in the GIZ project Land Management and Decentralized Planning.

   d. Propose revisions to the EIA guidelines in MONRE as appropriate to account for stream and wetland buffers and consistency with developed management plans
   e. Work with MPI in looking at investment requirements and any opportunities to promote permeable paving and sustainable urban drainage solutions
   f. Work with partners on the ground at the city-level to link with urban planning, master planning and other projects as appropriate (ADB, JICA, etc.)

3. Along with the mainstreaming work in Activity 1.2.1, policy briefs on the ICFMS will be developed and working sessions will take place with key decision makers and stakeholders to bring forward specific policy recommendations and evidence to be considered in policy working groups.
4. During project implementation, conduct an annual participatory review of the ICFMS developed, as well as the performance of stakeholders, against the indicators and targets agreed on in the first step.

In addition to the national urban EbA guidelines, national and provincial policies on flood management and urban planning will be reviewed and recommendations for appropriate policy reforms will be developed[196]. These will include incorporating climate change, integrated flood management and urban EbA into policies. This review will be conducted by an international expert working with a national policy expert embedded in the MPWT Department of Urban Planning. Similar to Activities 1.2.1 and 1.2.3, policy briefs will be developed and working sessions with key decision makers will be organized to highlight benefits of integrated flood management and urban EbA into various policies. A national workshop will also be organized.

Activity 1.2.4 Develop national urban EbA guidelines for Laos and recommendations for policies on urban flood management

National EbA guidelines will be developed to assist the achievement of ICFMS-set flood reduction targets and to promote the uptake of such approaches in other cities not targeted by the project. These guidelines will be designed to inform decision-makers, planners and contractors on how to plan, design, implement and maintain EbA investments. International civil engineering experts with urban EbA expertise will be contracted to assist in the development of the guidelines. These experts will have in-depth experience in developing urban EbA guidelines in a flood management context to ensure that international best practices are transferred to Laos. The national urban EbA guidelines will include: i) options for urban EbA and Sustainable Urban Drainage Systems in different contexts; ii) institutional responsibilities for enforcement, monitoring and implementation; iii) options for incentives and instruments to promote EbA in the private sector; and iv) options for regulatory reforms. In addition, the guidelines will offer detailed guidance on the processes of:

1. defining the flooding problem, including impacts on women, men and vulnerable social groups;
2. selecting EbA intervention sites;
3. assessing flooding scenarios without EbA interventions;
4. identifying how the flood reduction target can be met using EbA interventions;
5. assessing flooding scenarios with EbA interventions;
6. estimating costs and benefits of EbA interventions;
7. identifying and communicating the desired EbA interventions;

[196] for further information about the relevant policies, see Annex 2: Feasibility Study.

8. following due diligence procedures for procurement, environmental and social safeguards and risk assessment;
9. implementing and maintaining the desired EbA interventions;
10. monitoring and evaluating the EbA interventions; and
11. identifying appropriate sustainable financing strategies to fund the implementation and maintenance of EbA

In addition to the national urban EbA guidelines, national and provincial policies on flood management and urban planning will be reviewed and recommendations for appropriate policy reforms will be developed[197]. These will include incorporating climate change, integrated flood management and urban EbA into policies. This review will be conducted by an international expert working with a national policy expert embedded in the MPWT Department of Urban Planning. Similar to Activities 1.2.1 and 1.2.3, policy briefs will be developed and working sessions with key decision makers will be organized to highlight benefits of integrated flood management and urban EbA into various policies. A national workshop will also be organized.

Component 2. Rehabilitation and protection of ecosystem in response to climate variability and change

Wetlands and natural streams in Laotian cities play a vital role in flood reduction and provide various other ecosystem services. However, these ecosystems are frequently lost to urban development or degraded. The project interventions under this component will therefore rehabilitate an important urban wetland and urban streams in the target cities. The specific wetland and urban streams were chosen based on their importance to local communities and their role in flood management[198]. The areas to be rehabilitated are: i) the Nong Peung Wetland in Paksan; ii) the Houay Khi La Meng stream in Savannakhet; and iii) the Houay Nhang stream in Pakse[199]. At the same time, frameworks for the sustainable management of these urban ecosystems will be established. The restoration and establishment of management frameworks for these sites will comprise the first and second outputs under this component. The third output will focus on the problem of the increasing impervious surface area in the built-up parts of cities which contributes to stormwater flooding during extreme rainfall events. To address this problem, the project will introduce and demonstrate the technology of permeable paving in each of the four target cities.

<u>Output 2.1 Area of wetland restored contributing to flood reduction and sustainable management of the Nong Peung wetland in Paksan</u>

The Nong Peung Wetland in Paksan plays an important role in reducing flood impacts in the city by absorbing stormwater from intense rainfall events and by buffering river flooding from the Nam San River. This wetland provides a range of ecosystem services to the city and the surrounding farming communities as well as being an important habitat for many fish and bird species. Despite its importance, there is currently no management plan for the wetland and it has been negatively impacted by human activities. The activities under this output will therefore develop a full management plan for the wetland to ensure that it provides climate change adaptation benefits to the citizens of Paksan, as well as rehabilitating 800 ha of the wetland area to enhance its functioning.

[197] for further information about the relevant policies, see Annex 2: Feasibility Study.
[198] Further details on site selection are provided in Annex 2: Feasibility Study, Section 10.
[199] Maps of the wetland and streams are provided in Annex 2: Feasibility Study, Section 10.

Activity 2.1.1 Develop a wetland management plan for Nong Peung Wetland in Paksan.

The Nong Peung Wetland provides many ecosystem goods and services to the surrounding communities including fishing, irrigation water and flood reduction. However, the wetland is threatened by *inter alia*: i) encroaching rice farming; ii) excessive withdrawal of water to irrigate rice; and iii) invasive alien species. In addition, the wetland has no legal protection and lacks a management plan. To address these threats and gaps, a comprehensive, sustainable management plan for the wetland will be developed under this activity. This will be done through participatory land-use planning with local communities and other stakeholders. The management plan will also be informed by the findings of the wetland assessment that will be conducted under Activity 1.2.2. Community involvement in the management of the wetland will be facilitated by establishing a Community Wetland Management Committee, drawing on representatives from the Pak Peung water user association, local fishing organization, village-level National Women's Union, and other groups in the surrounding villages. A local government representative should be part of each committee[200]. The committee will work closely with the CPSC and city-level focal points in the ICFMS process, in developing the management plan and monitoring its implementation. This committee, consistent with citizen science approaches, will assist the government with water quality monitoring, fishery management and the monitoring and management of invasive species. The government and the Community Wetland Management Committee will receive technical support from experts from the knowledge hub established under Activity 1.1.2.

Activity 2.1.2 Rehabilitate the Nong Peung Wetland
Since the Nong Peung Wetland is used extensively by the surrounding communities and people from further afield it has been degraded in certain respects. Specifically, natural vegetation has been lost in parts of the wetland, invasive alien plants are encroaching, and the natural water flow has been disrupted in places. This activity will improve the ecological functioning of the wetland by: i) removing invasive alien plants, especially *Mimosa pigra* and *Eichhornia crassipes* (water hyacinth); ii) removing small human-made barriers that impede natural flow and wetland functioning; and iii) restoring natural vegetation by planting appropriate indigenous plant species including terrestrial and aquatic plants across 800 ha. The project will train and employ community members to do the restoration work under the technical supervision of the recruited firm and the CTA and following restoration protocols developed in the project. PONRE staff will be engaged in the execution of restoration work in a "learning by doing" approach to build capacity. Subsequent restoration work can be financed through local government, EPF, and other sources.

<u>Output 2.2 Area of urban streams restored contributing to flood reduction and sustainable management of urban streams in Savannakhet and Pakse</u>

Natural urban streams provide ecosystem goods and services in otherwise built-up areas, including helping to reduce flooding. Intact natural vegetation reduces the velocity of flash floods, protects riverbanks from erosion and reduces sedimentation. Urban development frequently leads to streams being degraded, through loss of vegetation, building within stream buffer zones and deposition of solid waste in streams. The activities under this output will

[200] Similar arrangements are expected for the Community Stream Management Committees under Activity 2.2.2.

rehabilitate 700 ha along two important urban streams in the cities of Savannakhet and Pakse which provide the above-mentioned services but are subject to degradation.

Activity 2.2.1 Restore natural urban streams in Savannakhet and Pakse.
Under this activity, the Houay Khi La Meng stream in Savannakhet and the Houay Nhang stream in Pakse will be rehabilitated. Firstly, social and environmental surveys of the streams will be undertaken to: i) gain a detailed understanding of how communities use the streams; ii) prioritise specific areas for rehabilitation; and iii) select appropriate indigenous plant species[201] to be used for restoration. Secondly, solid waste in and around the streams will be removed to increase the drainage capacity of the stream channels, in collaboration with UDAA through Activity 2.2.2. and combined with enhanced community awareness of good solid waste management practices through Activity 1.1.3. Thirdly, invasive alien plants such as *Mimosa pigra* that impede stream flow will be removed. Fourthly, locally indigenous, climate-resilient plant species will be planted along degraded stream banks to stabilise the banks and improve water quality. Where necessary, plantings will be combined with small-scale installation of geotextile sandbags to combat erosion. Lastly, the legislated buffer zones along the streams will be delineated, with signage installed to indicate the extent of the buffer zones and provide information about the need to protect the streams. These rehabilitation interventions will be implemented across 700 hectares along the two target streams. The project will train and employ community members to do the restoration work under the technical supervision of the recruited firm and the CTA and following restoration protocols developed in the project. PONRE staff will be engaged in the execution of restoration work in a “learning by doing” approach to build capacity. Subsequent restoration work can be financed through local government, EPF, and other sources.

Activity 2.2.2 Develop management plans for restored urban streams in Savannakhet and Pakse.
To ensure that the streams restored under Activity 2.2.1 are maintained and used sustainably, management plans will be developed in collaboration with communities along the streams. These management plans will include engagement with the Urban Development Administration Authorities (UDAA) on improving the effectiveness of existing regular solid waste collection and drainage maintenance regulations and operations. This engagement will include workshops with UDAA to co-develop the urban stream management plans, which will form part of the ICFMS process. Overall comprehensively addressing solid waste management challenges is beyond the scope of this project and is dealt with by other ongoing projects focused on improving solid waste management[202]. To assist with the implementation of the stream management plans, Community Stream and Drainage Management Committees will be established within the existing village governance structures. One such committee will be established in Savannakhet and one in Pakse. These committees will work with the relevant government authorities (PONRE and UDAA) to monitor and maintain the rehabilitated steams, with technical support provided by experts from the knowledge hub established under Activity 1.1.2, and in coordination with the city-level project steering committees (CPSCs). The stream management plans will include measures to: i) curb the introduction and spread of invasive plants; ii) raise awareness among streamside communities about improving household-level solid waste management and maintaining small drainage

[201] Indigenous plant species that occur naturally along streambanks in and around each city will be identified in consultation with local ecologists. A wide range of these species will be used, since diversity increases ecosystem resilience, as well as focusing on species that are climate-resilient e.g. heat tolerant and well-suited to withstand flooding and reduce erosion.
[202] such as the ADB-funded Pakse Urban Environment Improvement Project.

lines; and iii) promote the sustainable use of natural resources such as fish and wood from streambank ecosystems.

<u>Output 2.3 Area of permeable paving solutions installed in public areas contributing to flood reduction in Vientiane, Paksan, Savannakhet and Pakse</u>

As cities in Laos are expanding and densifying, the total impervious surface area in urban catchments is expanding. Green areas that are vital for rainwater infiltration are being converted into hard surfaces. For example, as new buildings are constructed impervious paving is installed around existing buildings and the remaining dirt streets are converted to asphalt roads. This exacerbates flooding caused by stormwater, especially following extreme rainfall events. To address this problem, the activities under this component will introduce permeable paving technology at demonstration sites at public institutions in the target cities. The design, implementation and monitoring of the permeable paving will be conducted in collaboration with the knowledge hub to ensure effective technology transfer.

Activity 2.3.1 Design permeable paving solutions for public areas in Vientiane, Paksan, Savannakhet and Pakse
Permeable paving technology is not well known in Laos. Public institutions such as hospitals, educational institutions and government offices will therefore be used to demonstrate the benefits of permeable paving. The specific sites in each target city where permeable paving will be installed will be selected at the project outset in consultation with local government and the host institutions. Site selection criteria will include: i) located on public land at public institution; ii) in an area already earmarked for development of conventional paving; iii) suited for comparison with nearby area of conventional paving and unpaved area; iv) suitable soil and groundwater level for permeable paving; v) local drainage problems; vi) visibility of areas and extent of use by the public[203]. Thereafter, specific permeable paving solutions will be designed for each site, considering *inter alia*: i) pedestrian and vehicle traffic volumes; ii) groundwater level; iii) potential surface pollutants; and iv) the risk of permeable paving pores becoming clogged through sediment deposition. The selection of specific permeable paving options and the design of the paving that will be installed will be based on international best practice. The design process will include consultation with staff at the knowledge hub to facilitate the transfer of knowledge about permeable paving from the knowledge hub to NUoL in general, civil engineering firms and the relevant government departments such as MPWT.

Activity 2.3.2 Install permeable paving in public areas in Vientiane, Paksan, Savannakhet and Pakse.
Based on the site assessments and paving designs completed under Activity 2.3.1, permeable paving will be installed at the selected public institutions such as hospitals, educational institutions and government offices. Signs will be installed at the sites to provide information about the advantages of permeable paving to the public. The permeable paving demonstration sites will be monitored by the knowledge hub and government staff to build the local evidence base for this technology. In addition, operations and maintenance arrangements will be set up with the host institutions. The knowledge hub will assess the reduction in stormwater run-off achieved through the permeable paving.

[203] The consultancy recruited for the design will propose sites for selection based on these criteria and in close consultation with the Chief Technical Advisor. The final sites will be approved by the Project Steering Committee.

12.2 Methods for evaluating flood reduction by EbA interventions and permeable paving

Quantifying flood reduction achieved through urban EbA interventions requires high-resolution spatial data such as local topography, vegetation, soil characteristics, land use and surface character, site-specific physical measurement of parameters such as infiltration, river discharge, high event lag time and baseline streamflow, and advanced modelling using design rainfall scenarios. While more common in developed countries (especially those with long histories of flood management), the data and skills needed for such quantification is typically limited in developing countries such as Laos. At the same time, it is exactly contexts such as Laos' cities – which have relatively low-densities but are rapidly expanding – where the potential for the use of urban EbA for flood reduction may be the greatest. Similarly, there is very limited experience of permeable paving in Laos and, as permeable paving solutions are site-specific, evaluation of their efficacy at the site-level can only be done once installed. Overall, this GCF project will contribute to addressing these data, knowledge and capacity gaps in Laos, so that EbA for flood reduction can be upscaled across the country's urban areas. The proposed methods for the quantification of flood reduction through the project interventions are described below.

Evaluation of flood reduction potential as a result of the proposed urban EbA solutions is critical: both as a measure of the project's impact, as well as to build the local evidence base for urban EbA to promote upscaling across all of Laos' cities. Such an evaluation of flood reduction potential will require a robust method that can be practically applied within the Laotian context. Overall, this will require the collection of existing baseline data, further data collection during and after the project period. These data will need to be used by a suitable qualified professional with the appropriate hydrological modelling software (such as HEC-RAS). There are various technical methods for quantifying flood reduction[204]. The specific method that will be used for this project will be chosen by the specialists who will undertake the assessment. For wetland and stream restoration, the following general steps will need to be taken:

1) Baseline assessment of the nature, frequency and magnitude of flooding in the target areas.
2) Baseline spatial assessment at fine scale of the target catchments and sub-catchments where appropriate, including land cover and specifically the extent and condition, and the ability of the wetland systems and riparian vegetation to increase flood discharge lag time.
3) Modelling of potential flood reduction that can be achieved through wetland and stream restoration.
4) Collection of data on flood dynamics and flood reduction achieved by wetland and stream restoration over time. This data will be compared to model predictions and could be used to further improve modelling.

In the case of permeable paving, the installation sites will be chosen to include areas covered in conventional paving/hard surfaces as well as unpaved areas, as well as those that are estimated, through modelling, to provide significant flood mitigation potential. This will enable further comparison of different types of surfaces to assess the efficacy of permeable paving in improving local drainage and reducing run-off to neighbouring areas that contribute to flooding. Physical measurements will be taken of the infiltration rates of the different surfaces and used to model the change in run-off, in local flooding and the contribution to flood reduction at the sub-catchment level if permeable paving were to be implemented at scale.

In terms of the monitoring and evaluation of this GCF project, baseline assessments will be required to determine appropriate baseline values, and the appropriate mid-term and terminal targets will then be determined based on the assessments and modelling described above. This will require collection of a range of fine-scale data, that is currently not available in the target areas and in fact rarely collected in all of Laos. In this regard, the project's data collection and modelling will make an important contribution to knowledge in Laos and could indeed serve as a valuable case study internationally. Considering that certain benefits of ecological restoration for flood reduction require more than three to five years to

[204] For example, Hammond, M.J., Chen, A.S., Djordjević, S., Butler, D. and Mark, O., 2015. Urban flood impact assessment: A state-of-the-art review. Urban Water Journal, 12(1), pp.14-29; Iacob, O., Rowan, J.S., Brown, I. and Ellis, C., 2014. Evaluating wider benefits of natural flood management strategies: an ecosystem-based adaptation perspective. Hydrology Research, 45(6), pp.774-787; Potter, K.W., 1994. Estimating potential reduction flood benefits of restored wetlands. Journal of Contemporary Water Research and Education, 97(1), p.8.

manifest, ongoing monitoring and evaluation by the government and the knowledge hub will also be important.

13 Annexes to the Feasibility Study

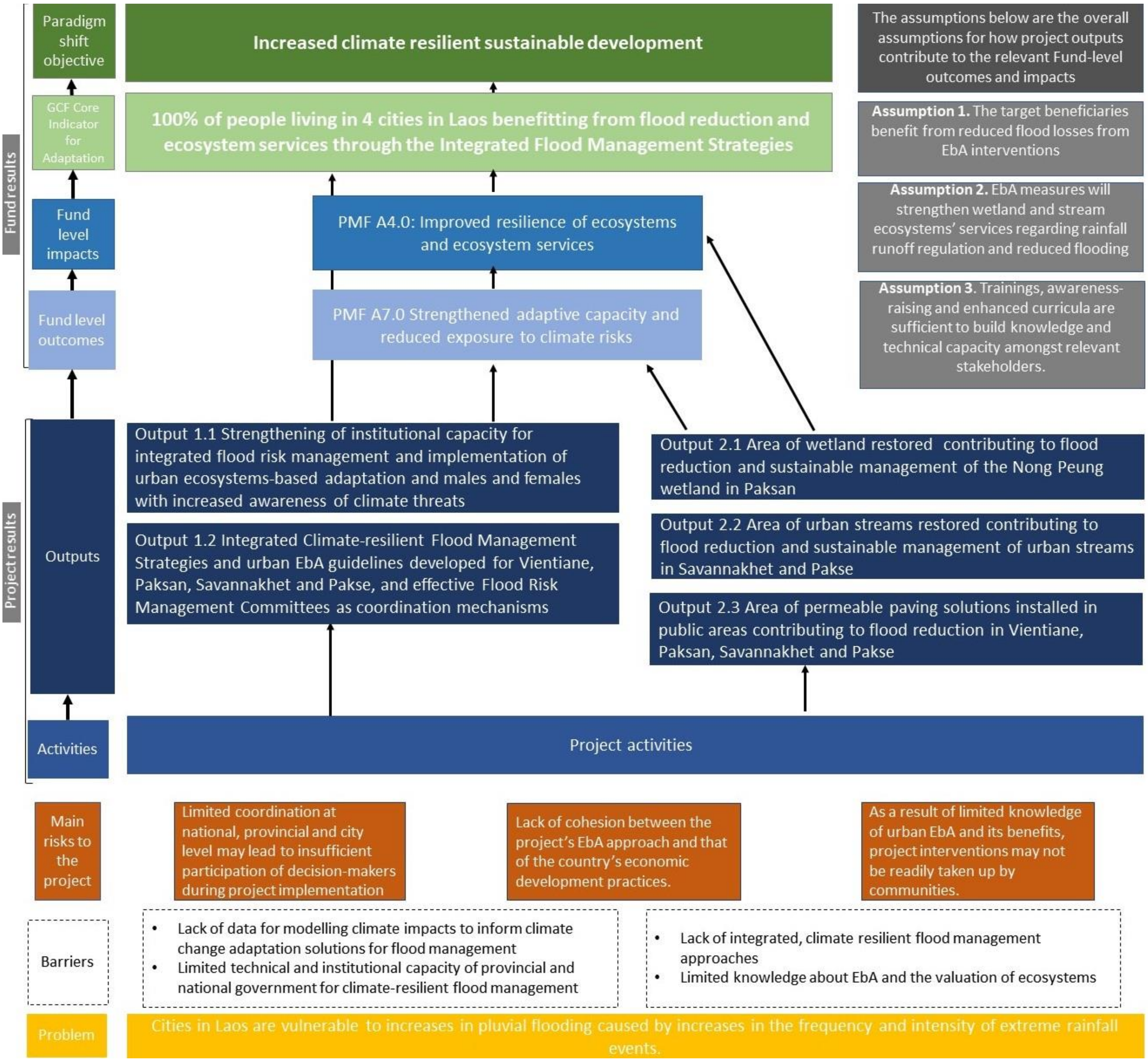
Annex 2a. Project Logic Framework

The project-level logic framework is provided as a separate standalone annex.

Annex 2b. Timetable

The timetable for the project is provided as a separate standalone annex.

Annex 2c. Theory of Change



Annex 2d. Map of Laos

Annex 2e: Technical note on restoration and flood reduction

Introduction

This annex provides further information about how the restoration of wetlands and streams can reduce flood impacts and enhance the climate resilience of vulnerable communities and ecosystems. The following topics are covered: i) mechanisms by which wetland and stream restoration reduce flood impacts; ii) approaches for the ecological restoration of wetlands and streams for flood reduction; and iii) methods for monitoring and evaluating the success of wetland and stream restoration. For further context, please read this annex in conjunction with Sections 9 and 11 and 12.2.

How wetland and stream restoration reduce flood impacts and enhance climate resilience

Wetlands and streams support rich biodiversity and provide numerous valuable ecosystem services. For wetlands, these services include but are not limited to water quality improvement, flood abatement, and carbon sequestration[205]. Likewise, natural rivers and streams[206] also provide various services including flood abatement and water quality improvement. In addition, both wetlands and rivers/streams support the livelihoods of people who depend on natural resources such as fishing, irrigated agricultural products and non-timber forest products (NTFPs). Considering all these important functions, protecting and restoring wetlands, rivers and streams is a central aspect of ecosystem-based adaptation (EbA) to climate change. This section focuses on the specific biophysical mechanisms in which wetland and stream restoration contribute to flood reduction.

Wetlands

The general role of wetland ecosystems in reducing floods is well-established[207]. Since intact wetland ecosystems function better than degraded ones, the conservation and restoration of wetlands contribute to improved wetland functioning, including flood attenuation. Wetlands alter flood regimes in several ways, for example, by influencing the peak flows, volume, timing and/or duration of floods[208]. One of the main ways wetlands reduce flood impacts is by storing water. In the case of short-term storage wetlands delay and attenuate flood peaks. When water is stored by wetlands for longer periods, flood volumes are also decreased[209].

Different kinds of wetlands interact in different ways with floods. The target wetland for the proposed GCF project, namely the Nong Peung wetland in Paksan, is a floodplain wetland. Consequently, the discussion here focuses on this type of wetland. Floodplain wetlands reduce the flood wave speed[210] and store large amounts of water, mainly on the surface, this water flows back into the river later, evaporates or recharges groundwater[211]. When flood water flows into wetlands that are flat and cover a large area, the discharge wave is flattened during a flood[212]. The speed with which water flows across a floodplain depends in part on the hydraulic roughness of the surface, including the vegetation. Floodplains with rough vegetation (e.g. trees and shrubs) have high friction and therefore slow flood wave speed[213]. Therefore, restoration of appropriate shrubs and trees in wetland areas where these elements have been lost can reduce the speed of a flood. For example, flow velocities were 29% greater

[205] Zedler, J.B. and Kercher, S., 2005. Wetland resources: status, trends, ecosystem services, and restorability. Annu. Rev. Environ. Resour., 30, pp.39-74.
[206] broadly used here to mean rivers/streams that have retained most or some ecological functioning, as opposed to concrete canals on the other end of the spectrum.
[207] For example, Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z., & Cerdà, A. (2018). The superior effect of nature based solutions in land management for enhancing ecosystem services. Science of the Total Environment, 610–611, 997–1009. https://doi.org/10.1016/j.scitotenv.2017.08.077; Acreman, M. and Holden, J., 2013. How wetlands affect floods. Wetlands, 33(5), pp.773-786.
[208] Acreman, M. and Holden, J., 2013. How wetlands affect floods. Wetlands, 33(5), pp.773-786.
[209] Acreman, M. and Holden, J., 2013. How wetlands affect floods. Wetlands, 33(5), pp.773-786.
[210] Flood wave speed is an important parameter in runoff and flood routing
[211] Acreman, M. and Holden, J., 2013. How wetlands affect floods. Wetlands, 33(5), pp.773-786.
[212] Watson et al., 2016 as cited in Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z., & Cerdà, A. (2018). The superior effect of nature based solutions in land management for enhancing ecosystem services.
[213] Acreman, M. and Holden, J., 2013. How wetlands affect floods. Wetlands, 33(5), pp.773-786.

in sloughs[214] compared to more densely vegetated ridges in the Everglade wetlands of Florida[215]. Similarly, modeling of a river in England indicated that wooded wetlands in particular reduce flood peaks, increase peak travel time and increase flood storage[216]. The latter study concluded that strategically placed floodplain woodland can play a valuable role in attenuating downstream flooding[217]. However, depending on the local context, an increase in shrubs and trees may also reduce the storage capacity of a wetland[218] and thereby increase the size of a flood[219]. For example, a vegetation shift from wet meadows (grass) to shrubs and trees in a wetland was found to double the size and depth of the inundated area for the same size flood event in Poland[220]. In the Nong Peung wetland, infestations of the invasive alien shrub *Mimosa pigra* have negative impacts on flood storage capacity, stream channel capacity and biodiversity. This is because *Mimosa pigra* forms dense infestations and invades areas of the wetland that would naturally be covered in grass, reeds or small shrubs.

The relative importance of floodplain roughness versus wetland storage capacity depends on the way water flows through a wetland. On floodplains with large depressions, or where the floodplain is only connected to the river at specific points (such as where there are gaps in levees), water can be stored rather than flowing along the floodplain parallel with the river flow direction. In such cases, the storage capacity is the main factor determining attenuation, rather than floodplain roughness[221]. This is true in part for the Nong Peung wetland, which is separated on one side from the Nam San river by a raised road and separated from the Mekong in parts by levees, with outflow from the floodplain wetland into the Mekong blocked in one location and regulated in another. However, water flows into the Nong Peung wetland from various directions, not only from the Houay Peung stream (see Paksan site map in Section 10 and Figure 1). Therefore, overland flow and thus the roughness (vegetation cover) of the Nong Peung floodplain, as well as roughness of stream channels will play a role in flood attenuation, in addition to water storage capacity.

[214] In this case sloughs have less vegetation than wooded ridge. A slough is a wetland, usually a swamp or shallow lake, often a backwater to a larger body of water. Water tends to be stagnant or may flow slowly on a seasonal basis. In North America, "slough" may refer to a side-channel from or feeding a river, or an inlet or natural channel only sporadically filled with water.
[215] Harvey et al. (2009) as cited in Acreman 2016.
[216] Thomas, H. & Nisbet, TR (2007) An assessment of the impact of floodplain woodland on flood flows. Water and Environment Journal, 21, 2, 114–126
[217] Examples of wetland ecosystems in tropical environments similar to Laos were sought but literature is scarce.
[218] Trees take up more space than grass, for example.
[219] When wetland storage capacity is lower a wetland stores less water during flood events, so floods are greater.
[220] Swiatek D, Szporak S, Chormański J, Okruszko T (2008) Hydrodynamic model of the lower Biebrza river flow - a tool for assessing the hydrologic vulnerability of a floodplain to management practices. Ecohydrology & Hydrobiology, 8:24-32.
[221] Acreman, M. and Holden, J., 2013. How wetlands affect floods. Wetlands, 33(5), pp.773-786.

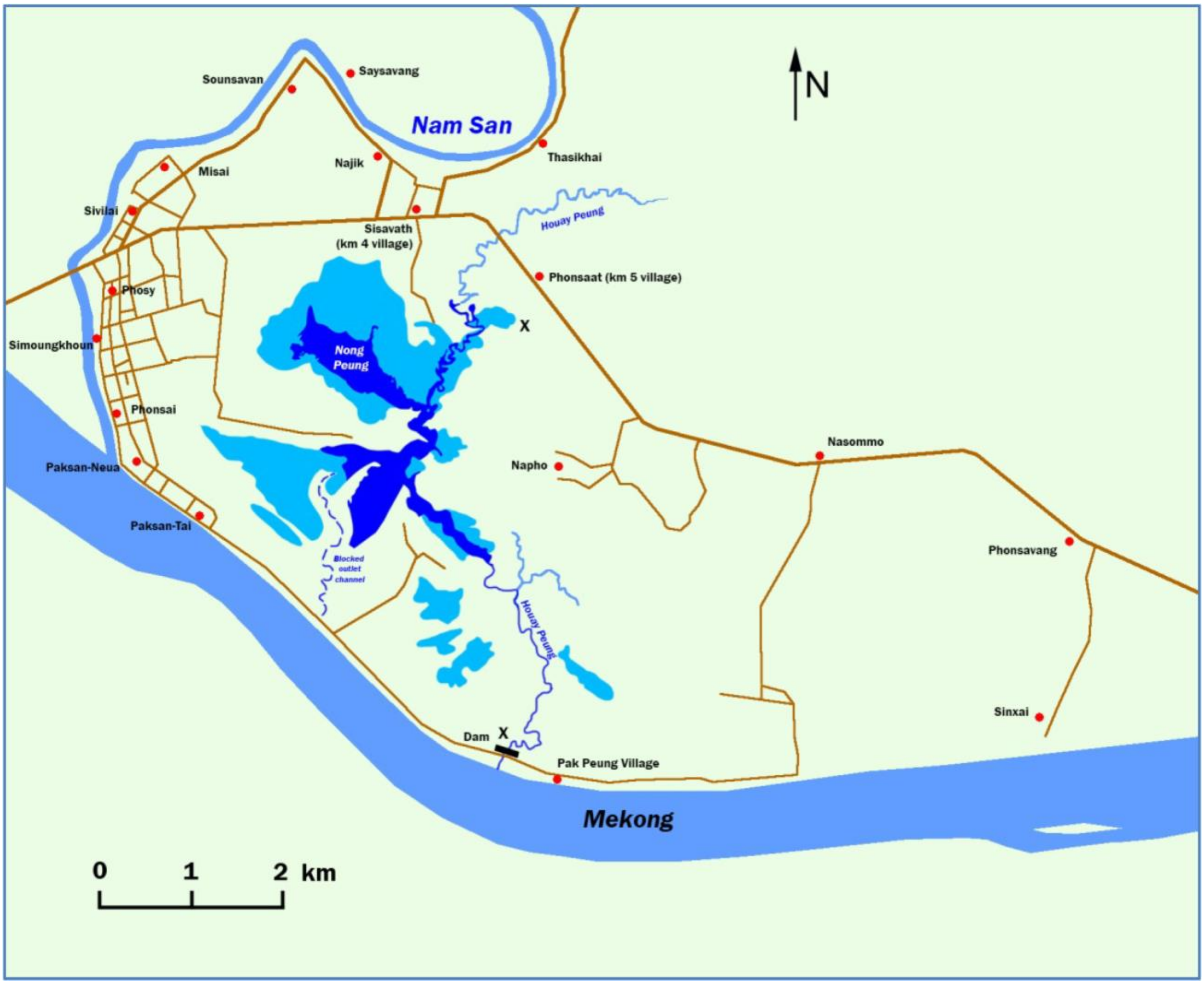


Figure 1. Map of Nong Peung wetland[222]

Besides shifts in vegetation, the capacity of wetlands to hold flood water – and therefore their capacity to attenuate floods – can also be influenced by the amount of water present in a wetland prior to flooding. The amount of water in a wetland is determined both by the surface water storage and by soil water storage. In terms of soil water storage, human interventions (such as impounding[223] for irrigation) that raise water levels in a floodplain reduce the potential for additional soil water storage, in areas where the soil would not be saturated otherwise, when floods occur. When wetland restoration increases soil organic matter, soil water-holding capacity is also increased. Similarly as for soil water, increased surface water that is present in a wetland system before the onset of a flood increases the magnitude of the flood[224]. There may thus be a trade-off between maintaining higher water levels for irrigation purposes during the dry season and the flood attenuation capacity of a wetland during the wet season; unless wetland water levels can be regulated seasonally through the use of for example wetland regulators (floodgates). In the case of Nong Peung wetland – where there is a wetland regulator installed at Pak Peung and a second wetland outlet permanently closed – an appropriate management strategy could be to decrease water levels in the wetland prior to the flood season, while maintaining the water level required for ecological functioning.

[222] Hortle and Khonglaliane, 2014. Aquaculture Survey of Six Reservoirs in Lao PDR. Report to the CGIAR Challenge Program on Water and Food, Vientiane, Lao PDR. Available at: https://www.researchgate.net/profile/Kent_Hortle/publication/301341982_Hortle_KG_T_Khonglaliane_2014_Aquaculture_Survey_of_Six_Reservoirs_in_Lao_PDR_Report_to_CGIAR_Challenge_Program_on_Water_and_Food_Vientiane_66_pages/links/571347b708ae39beb87a55aa.pdf
[223] Impounding means to hold back or confine water.
[224] because there is reduced space for additional water in the wetland.

It is not only water flow and water levels that influence the capacity of wetlands to attenuate floods. Sediment that enters the wetland system also plays a role. While sediment flow into wetlands is a natural process, excessive sediment flow because of human impacts into wetlands[225] or trapping of sediment in wetlands by bunds and regulators, increase sedimentation of wetlands and has negative impacts. One of these is that the flood storage capacity of a wetland may be reduced by sedimentation. Another negative impact of excessive sediment flow is to reduce water quality. As sediment flows from various sources into a wetland system and may originate in distant areas of the wetland catchment, it is important to identify the major sources and to implement appropriate land management across catchment areas. In the case of the Nong Peung wetland – where stakeholders have identified sedimentation as a problem – the wetland assessment to be conducted under the project will assess sedimentation. Following this, the wetland management plan developed through the project will provide for the necessary interventions. At a larger scale, the integrated climate-resilient flood management strategies (ICFMS) that will be developed by the project will also address land use and its effects on sediment flows into the wetland.

Rivers and streams

Along with wetlands, riparian corridors are vital for mitigating floods and for storing water. For this reason, measures should be taken to ensure that these ecosystems are in the best possible condition, especially in urban settings. Such measures include removal of invasive alien plants, re-grading riverbanks to reconnect floodplains to the active channel and a range of other measures[226]. Where the discharge of a stream has increased significantly compared to its natural, historic discharge (for example because of increased runoff from built-up areas), river restoration to stabilise eroding banks or to repair in-stream habitat may be required[227]. This should be coupled with improved stormwater management, because stormwater flows into streams at excessive volume and velocity if stormwater systems are not well-designed and without measures to attenuate runoff from built-up catchments. Other measures include creating storage basins away from the channel and creating or maintaining wetlands to absorb increased flow energy that result from urbanization and climate change[228].

Restoring urban rivers and streams provide numerous benefits against the backdrop of increasing climate-induced floods and urban development patterns that compound flooding[229]. These benefits include decreased flooding as well as reduced erosion and sedimentation from extreme flow events. Reducing erosion is important both to protect sensitive riparian ecosystems and to limit sediment loads. Increased sediment loads affect not only water quality[230] and stream ecology[231], but may also increase floods by: i) partially filling up downstream channels and thereby reducing their discharge capacity; and ii) potentially filling up detention/retention ponds and thereby reducing their floodwater holding capacity.

Along with its benefits in terms of reducing erosion and sedimentation, the restored and protected riparian vegetation attenuates floods by slowing down flow. As vegetation succession[232] progresses, forest growth increases the roughness and resistance of the stream bed, thereby decreasing the velocity of the discharged river water[233]. This contributes to mitigating flash flood impacts. However, excessive vegetation within a stream channel (for example infestation of invasive plants such as

[225] Such as soil erosion in catchment areas because of vegetation degradation
[226] Palmer, M.A., Lettenmaier, D.P., Poff, N.L., Postel, S.L., Richter, B. and Warner, R., 2009. Climate change and river ecosystems: protection and adaptation options. Environmental management, 44(6), pp.1053-1068.
[227] because stronger flow in a stream channel increases erosion and often damage the in-stream habitat. Palmer, M.A., Lettenmaier, D.P., Poff, N.L., Postel, S.L., Richter, B. and Warner, R., 2009. Climate change and river ecosystems: protection and adaptation options. Environmental management, 44(6), pp.1053-1068.
[228] Urbanization through increased catchment imperviousness which reduces infiltration and increase run-off; climate change through increases in the frequency and intensity of extreme rainfall events, which cause pluvial flooding.
[229] *inter alia* through the effect of urban development on stormwater
[230] because of increased suspended sediment loads
[231] Sedimentation affects many aquatic organisms negatively. Good ecological functioning of a stream is central to its capacity to supply ecosystem services. Nelson et al. 2009, as cited by Palmer, M.A., Lettenmaier, D.P., Poff, N.L., Postel, S.L., Richter, B. and Warner, R., 2009. Climate change and river ecosystems: protection and adaptation options. Environmental management, 44(6), pp.1053-1068.
[232] The process of vegetation going through stages of development following a disturbance, e.g. shifting from grass to shrubs to trees.
[233] Silva & Kok, 1996 cited in Nienhuis, P.H. and Leuven, R.S.E.W., 2001. River restoration and flood protection: controversy or synergism?. Hydrobiologia, 444(1), pp.85-99.

Mimosa pigra) can also reduce the channel capacity below the desired level[234] and thus increase the risk of local flooding. This is because *Mimosa pigra* forms more dense stands than native shrubs and invade areas where native shrubs do not occur.

Besides the role of riparian vegetation in slowing down floods, natural streams have another advantage over built concrete canals in terms of flood reduction. Natural streams typically meander more than built canals and therefore slow down floods: a sinuous stream has a longer flow path length than a straight channel, hence the length in contact with the bed and banks is greater and attenuation is thus greater[235]. Such meanders in a stream, vegetation and woody debris within the stream channel impact flood waves by reducing flow velocity and providing temporary storage of flood waters[236, 237].

In addition to flood reduction, the restoration of riparian vegetation also: i) enhances stream ecosystem functioning *inter alia* by increasing habitat heterogeneity[238]; ii) creates vegetation buffers that reduce runoff velocity[239]; iii) traps sediment and associated pollutants originating from surrounding hillslopes as it passes through the riparian zone before it enters the stream itself[240]; and iii) buffers changes in temperature and flow caused by climate change compared to clear-cut or entirely developed urban watersheds[241].

Approaches for ecological restoration of wetlands and streams to reduce flood impacts

International experts in wetland and stream restoration recommend taking a proactive approach to protecting and restoring wetlands and streams, in anticipation of future climate change. This is in order to minimise expensive, reactive restoration to repair damage as a result of climate change impacts[242, 243] that could otherwise have been limited by early action[244]. Such proactive measures should restore the natural capacity of wetlands and rivers to reduce climate change impacts. In addition to flood attenuation, these restoration efforts will provide other environmental benefits such as increased fish populations, non-timber forest product supply and improved water quality. In urban settings, restoration of wetlands and streams should be coupled with improved storm water management and urban planning (as discussed in Sections 1, 8, 9 and 11)[245], as was the case in the integration of That Luang marsh in the flood master plan of Vientiane prior to the marsh's conversion to a Special Economic Zone[246, 247].

[234] and as channel capacity decreases the Standard High Water Level in the river/stream typically increases.
[235] Acreman, M. and Holden, J., 2013. How wetlands affect floods. Wetlands, 33(5), pp.773-786.
[236] In technical terms, a flood wave traveling through a channel with these features will have its instantaneous peak discharge (Qpk) and celerity (wave speed, c), among other hydraulic parameters, reduced as it moves downstream, assuming no inputs from tributaries.
[237] Sholtes, J. S., & Doyle, M. W. (2010). Effect of Channel Restoration on Flood Wave Attenuation. Journal of Hydraulic Engineering, 137(2), 196–208. https://doi.org/10.1061/(asce)hy.1943-7900.0000294
[238] Palmer, M.A., Lettenmaier, D.P., Poff, N.L., Postel, S.L., Richter, B. and Warner, R., 2009. Climate change and river ecosystems: protection and adaptation options. Environmental management, 44(6), pp.1053-1068.
[239] Janes, V. J., Grabowski, R. C., Mant, J., Allen, D., Morse, J. L., & Haynes, H. (2017). The Impacts of Natural Flood Management Approaches on In-Channel Sediment Quality. River Research and Applications, 33(1), 89–101. https://doi.org/10.1002/rra.3068
[240] Keesstra, S., Nunes, J., Novara, A., Finger, D., Avelar, D., Kalantari, Z., & Cerdà, A. (2018). The superior effect of nature based solutions in land management for enhancing ecosystem services. Science of the Total Environment, 610–611, 997–1009. https://doi.org/10.1016/j.scitotenv.2017.08.077
[241] As the reference case, for a given change in temperature, free-flowing rivers in protected watersheds are expected to be the most resilient to climate change. (Nelson and others 2009) as cited in Palmer 2009
[242] Palmer, M.A., Lettenmaier, D.P., Poff, N.L., Postel, S.L., Richter, B. and Warner, R., 2009. Climate change and river ecosystems: protection and adaptation options. Environmental management, 44(6), pp.1053-1068.
[243] Taking the case of Pasig river in Manila, Philippines, clean up and restoration has taken two decades thus far and the expectation is that it would take another decade and a half for the river to sustain life. The costs are upwards of $100 million in grants form DANIDA and loans from ADB and included the resettlement more than 18,000 families living along the its banks and dismantling of nearly 400 private structures.
[244] Palmer, M.A., Lettenmaier, D.P., Poff, N.L., Postel, S.L., Richter, B. and Warner, R., 2009. Climate change and river ecosystems: protection and adaptation options. Environmental management, 44(6), pp.1053-1068.
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[246] Gerrard, P., 2004. Integrating wetland ecosystem values into urban planning: the case of that Luang Marsh, Vientiane, Lao PDR. IUCN− The World Conservation Union Asia Regional Environmental Economics Programme and WWF Lao Country Office, Vientiane.
[247] JICA. 2011. The Project for Urban Development Master Plan Study in Vientiane Capital. Available at: http://open_jicareport.jica.go.jp/pdf/12023693_01.pdf. Accessed 13 May 2019.

In addition to a proactive approach, the restoration activities in the project also take a process-based approach whereby the interventions aim to address the drivers of degradation instead of the resultant symptoms[248] The discussion below integrates site-specific restoration with catchment-scale activities that address such drivers.

The nature of streams and wetlands varies greatly across and within regions. Wetlands and streams should therefore be managed considering the local context and at the scale of local watersheds. Such a site-specific approach must take into account specific climate change projections for a region and what impacts the predicted physical changes in the climate will likely have in the local context.[249]

Development of restoration protocols

The development of restoration protocols in the proposed project is planned to account for the following elements:

Species selection for planting

It is important to develop and follow locally appropriate protocols for ecosystem-based adaptation in wetlands and streams. Since the ecology of wetlands and streams is fundamentally influenced by hydrology, any ecological restoration effort requires detailed spatial assessments and a clear understanding of the hydrology of the target systems. Thereafter, restoration protocols should be developed that detail locally appropriate plant species, density of planting, follow-up care of plants as required, as well as monitoring and evaluation protocols.

When selecting plant species to use for restoration, it is critical to identify species that are locally indigenous[250] and to include species with specific desirable traits that provide adaptation benefits. These traits include plant species that have root systems which bind soil in a manner that prevents stream bank erosion as well as species that are flood-tolerant[251]. As wide a variety of species as possible should be used (bearing in mind local species diversity), since diverse ecosystems are generally more resilient to climate change[252]. Therefore, the aim should not be only to restore ecosystems that enhance the climate resilience of vulnerable people through the provision of ecosystem services like flood reduction, but also to restore ecosystems in a manner that increase the resilience of the ecosystems themselves. Genetic diversity within species is an important component of biodiversity that enhances resilience[253], therefore seeds and seedlings for a given plant species should be obtained from many different local areas, rather than collected from only a few individuals in one area. At a larger scale, the variety of different habitats within the target ecosystems should also be considered, particularly in terms of gradients of wetness and seasonality.

Removal of invasive species

Invasive species in the target wetland and streams reduce the water storage capacity and overall harm ecosystem health, requiring their removal. The guidelines outlined below adopts methods proposed by the Climate Adaptation in Wetland Areas project[254].

Water hyacinth removal will be done in February and March during the dry season and prior to the start of rice planting. Regular monitoring and clearing will need to be done to ensure maintenance. To

[248] Beechie et al. 2010 as cited in Anim, D.O, Fletcher, T.D., Vietz, G.J., Pasternack, G.B., Burns, M.J. 2010. Restoring in-stream habitat in urban catchments: Modify flow or the channel?. Ecohydrology, 12(1).
[249] Palmer, M.A., Lettenmaier, D.P., Poff, N.L., Postel, S.L., Richter, B. and Warner, R., 2009. Climate change and river ecosystems: protection and adaptation options. Environmental management, 44(6), pp.1053-1068.
[250] i.e. indigenous to the province; species that naturally occur in the vicinity of the target city
[251] being tolerant of floods entails tolerance of inundation and/or of strong water flow.
[252] Oliver, T.H., Heard, M.S., Isaac, N.J., Roy, D.B., Procter, D., Eigenbrod, F., Freckleton, R., Hector, A., Orme, C.D.L., Petchey, O.L. and Proença, V., 2015. Biodiversity and resilience of ecosystem functions. Trends in ecology & evolution, 30(11), pp.673-684.
[253] For example, a more genetically diverse stand of trees of a given species is more resistant to climate change-related disease than a stand of clones.
[254] FAO and IUCN. 2017. Identification of spatial priorities for the re-opening of wetland to maintain the water flow required for ecological functioning, biological connectivity and habitat maintenance: Xe Champone Ramsar Site, Lao PDR. Climate Adaptation of Wetland Areas Project.

promote community incentives for maintenance, composting of water hyacinth will be promoted to be used as organic fertilizer for rice fields and vegetable gardens.

Mimosa pigra will be gradually removed over time. Blocks of limited area will be treated at a time in order to leave cover for wildlife and to avoid sudden changes to the habitat. *Mimosa pigra* shrubs will be cut down just before the start of the wet season in May – June. This will ensure that water levels are low and fish are not breeding or migrating. The timing allows for the flooding of the cut shrubs. This cut and flood method has been found to be effective after two years. The spread of *Mimosa* is difficult to control as the seeds are transported by the wind and water buffalos. Burning will not be used as a control method because fire promotes seed germination, unless coupled with good follow-up treatment with the aim of depleting the soil seed bank. Monitoring will be done in November just after the wet season to determine changes in the density after flooding.

In restoration activities, access, priority locations that would benefit women and men's livelihoods, and the occupational health and safety of people engaging in this work will be considered together with participating communities. The timing of activities will be validated with the communities.

Linking site-specific restoration to catchment-scale activities

The effectiveness of wetlands and streams in flood reduction is impacted by hydrology and human activities at the catchment scale. In the case of the Nong Peung wetland in Paksan, the catchment-scale factors that impact the wetland, include: i) land-use and the associated land cover; ii) small-scale soil mining; iii) agricultural practices in the catchment area that influence water quantity and quality; and iv) water use and water pollution from urban areas. In the case of the target urban stream in Pakse, factors that impact on the stream include: i) urban expansion; ii) degradation of vegetation on mountain slopes above the stream iii) agricultural land use; and iv) water pollution and solid waste from upstream human settlements. The target urban stream in Savannakhet is impacted by similar factors as the stream in Pakse, but is not situated adjacent to mountain slopes and is in a more heavily urbanized area. For this reason, the target stream in Savannakhet is impacted more by inadequate solid waste management and water pollution. Across all three these project sites, these factors that operate at the catchment scale will be addressed through the wetland and stream management plans at a more local scale, and especially through the ICFMS at a larger scale. Both the management plans and ICFMS will include measures to address these negative impacts on the wetland and streams comprehensively for long-term sustainability.

Methods for monitoring EbA for flood reduction

The general approach to monitoring and evaluation of flood reduction achieved by EbA in the proposed project is discussed in Section 12.2 of Annex 2: Feasibility Study. The following section considers further details of how flood reduction may be measured. Firstly, it should be noted that wetlands and streams are dynamic systems: hydrologically, with variations in water levels and sediment flows across seasons and years; as well as ecologically, with stochastic populations and variance in ecological succession. Successful EbA needs to work with these dynamics, as well as a range of expected climate change trajectories. Consequently, it is important to monitor EbA interventions rigorously and to feed back the lessons learned into management. While some benefits of the proposed EbA interventions will manifest quickly during the project, others will only be fully recognised beyond the project period. In this regard, it is important to ensure that some of the benefits of EbA interventions are visible to stakeholders during the project period: Trees take time to grow, therefore some fast-growing species should be included in restoration efforts. Since some benefits take time to manifest, long-term monitoring of EbA interventions is needed. This should include monitoring changes in wetland and stream responses, coupled with the development of local scenario-building exercises that take land use and water use into account[255].

[255] Palmer, M.A., Lettenmaier, D.P., Poff, N.L., Postel, S.L., Richter, B. and Warner, R., 2009. Climate change and river ecosystems: protection and adaptation options. Environmental management, 44(6), pp.1053-1068.

The success of ecological restoration of rivers and streams can be measured in terms of stakeholder success, learning success and ecological success (Figure 2). While developed for rivers, the general model applies equally well to wetlands.

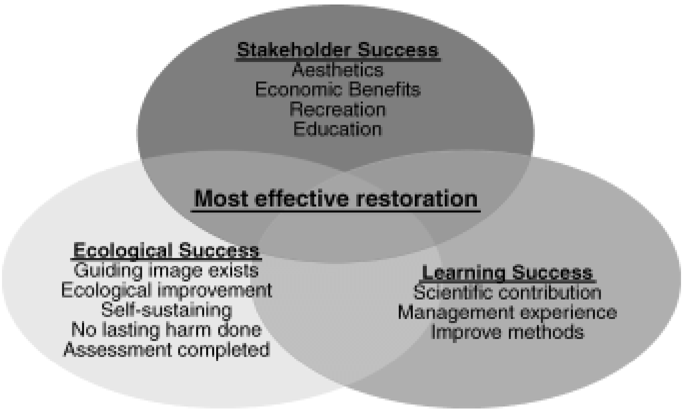

Figure 2. The different dimensions of successful river restoration[256].

In terms of the ecological success of restoration, five criteria have been proposed. These criteria and their respective indicators are widely cited internationally. The criteria are as follows:

1) the design of an ecological river restoration project should be based on a specified guiding image of a more dynamic, healthy river that could exist at the site.
2) the river's ecological condition must be measurably improved.
3) the river system must be more self-sustaining and resilient to external perturbations so that only minimal follow-up maintenance is needed.
4) during the construction phase, no lasting harm should be inflicted on the ecosystem.
5) both pre- and post-assessment must be completed and data made publicly available.

Each of these criteria are described further in the table below, along with the respective indicators.

Table 1. Criteria for measuring the ecological success of river/stream restoration, and associated indicators[257].

Criteria	Description	Indicators
Guiding image of dynamic state	The guiding image should take into account not only the average condition or some fixed value of key system variables (hydrology, chemistry, geomorphology, physical habitat and biology) but also the range of these variables and the likelihood they will not be static. It should explicitly recognise human-induced changes to the system.	Presence of a design plan or description of desired goals that are not orientated around a single, fixed and invariable endpoint (e.g. static channel, temporally invariant water quality)
Ecosystems are improved	Appropriate indicators of ecological integrity or ecosystem health should be selected based on relevant system attributes and the types of stressors causing impaired ecological conditions.	Water quality improved; natural flow regime implemented; increase in population viability of target species; percentage of native vs. non-native species increased; extent of riparian

[256] Palmer, M.A., Bernhardt, E.S., Allan, J.D., Lake, P.S., Alexander, G., Brooks, S., Carr, J., Clayton, S., Dahm, C.N., Follstad Shah, J. and Galat, D.L., 2005. Standards for ecologically successful river restoration. Journal of applied ecology, 42(2), pp.208-217.
[257] Palmer, M.A., Bernhardt, E.S., Allan, J.D., Lake, P.S., Alexander, G., Brooks, S., Carr, J., Clayton, S., Dahm, C.N., Follstad Shah, J. and Galat, D.L., 2005. Standards for ecologically successful river restoration. Journal of applied ecology, 42(2), pp.208-217.

Criteria	Description	Indicators
		vegetation increased; increased rates of ecosystem functions; bioassessment index improved; improvements in limiting factors for a given species or life stage (e.g. decrease in percentage fines in spawning beds or decrease in stream temperature)
Resilience is increased	River system should require minimal on-going intervention and have the capacity to recover from natural disturbances such as floods and fires, and to recover from further human encroachment.	Few interventions needed to maintain site; scale of repair work required is small; documentation that ecological indicators (see 2 above) stay within a range consistent with reference conditions over time.
No lasting harm	Pre- and post-project monitoring of selected ecosystem indicators (see point two in the criteria list above) should demonstrate that impacts of the restoration intervention did not cause irreversible damage to ecological properties of the system.	Limited native vegetation removed or damaged during implementation; vegetation that was removed has been replaced and shows signs of viability (e.g. seedling growth); limited deposition of fine sediments because of implementation process.
Ecological assessment is completed	Ecological goals for project should be clearly specified, with evidence available that post-restoration information or data were collected on the ecosystem variables of interest.	Available documentation of preconditions and post-assessment.

These criteria and indicators will be incorporated into the national EbA guidelines that will be developed by the project.

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