REPORT

Freshwater Nature-Based Solutions in the Mekong Sub-Region

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Royal HaskoningDHV
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1 Introduction

1.1 Home

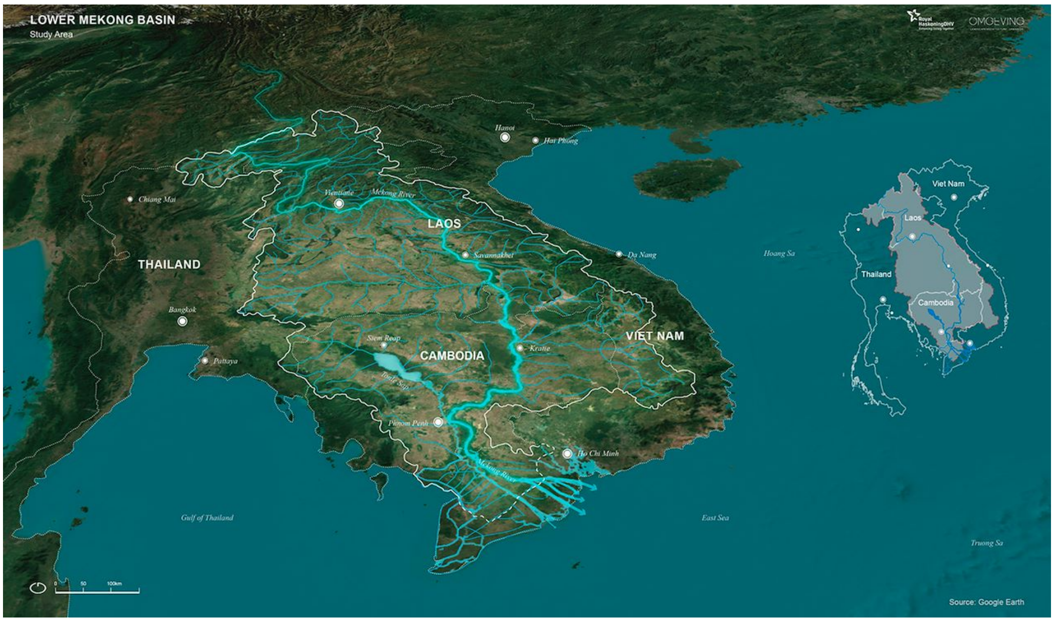
This assignment was commissioned under the Climate Resilient by Nature (CRxN) Mekong Expansion Project. The CRxN Mekong Project focuses on the protection and restoration of the Upper Mekong River and floodplain ecosystem through the implementation of nature-based solutions projects in Thailand, Laos, Cambodia and Vietnam.

The project also aims to showcase how local communities and economies across the Mekong subregion can leverage economic and social resilience – including gender, disability, and social inclusion - through the adaptation services provided by nature.

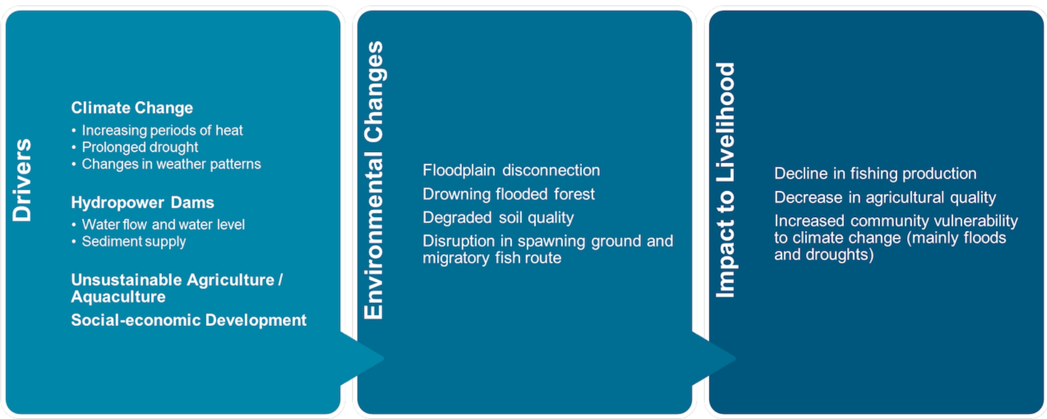
Mekong River Basin

The Mekong River Basin is one of the most productive and diverse global ecosystems. The river's floodplains provide essential ecosystem services. Key services are buffering of floods and food production, but other services include nutrient cycling, water purification, and habitat for countless species. Typical habitats and land uses occurring along the floodplain of the Mekong River are wetlands and flooded forests. Rivers, lakes, and wetland fisheries benefit from abundant freshwater and nutrients supplied by seasonal flood surges, while crops were grown on rich soils timed with plentiful seasonal rainfall. Together these ecosystem services supported millions of people to sustain their livelihoods in the region for generations.

Flood duration and extent is the principle process that supports the productivity and biodiversity of the Mekong River floodplains. Working with floods and its numerous associated benefits (e.g. nutrient cycling, cleansing) has the potential to bring direct cost effective benefits to in-situ communities, on top of reducing flood risks to other communities downstream.



Despite its importance, the Mekong River faces various threats from the increased construction of hydropower dams, land use changes, and unsustainable livelihood practices that disturb biodiversity and riverine ecosystem. Additionally, climate change has impacted the Asian monsoon, leading to more frequent and severe floods and droughts. These events devastate crops and aquatic ecosystems, causing significant disruptions to rural livelihoods.



Nature-based Solutions

To address these issues, there is a growing emphasis on nature-based solutions (NbS), which utilize natural or modified ecosystems to manage floodwaters and runoff. Implementing NbS in the region could serve as a risk management strategy while supporting the protection and restoration of riverine ecosystems and their social and environmental benefits.

'Nature-based solutions' (NBS) is an approach that uses the power of natural processes in innovative ways to tackle socio-ecological challenges such as climate change and flood risk.

Incorporating natural processes into design and construction leads to resilient and sustainable solutions that can adapt to environmental changes. This results in integrated solutions which benefit society, biodiversity and the economy

Study objectives

The objective of the assignment is to aid in moving forward in scaling up nature-based solutions for climate change approaches that focus on the protection, restoration and management of freshwater ecosystems in the Mekong subregion. This is done in the following manner:

1. Showing the potential improvements in climate resilience that could be gained from investment in nature-based solutions at scale and the cost-effectiveness of such an approach compared to taking no action or deploying non-nature-based solutions.

2. Quantifying the returns that could be realized from public and private sector investment in nature-based solutions and the modalities that would be needed to implement such investments.

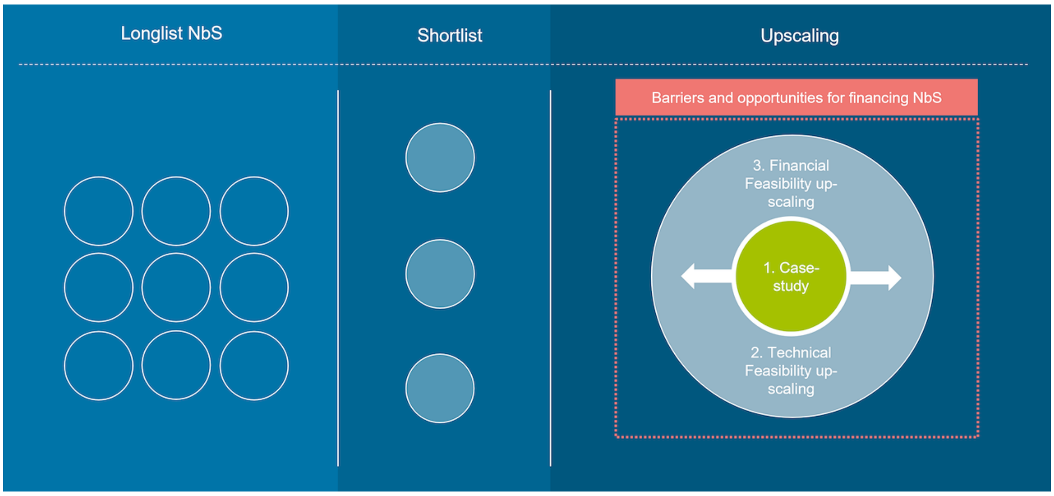
3. Describing the likely co-benefits of investment in nature-based solutions at scale

4. Investigating the barriers to the feasibility of scaling up nature-based solutions in the Mekong region, including their viability for public and private sector financial investment.

The CRxN-Mekong learning program will draw on a literature review, case studies, and a series of workshops to explore the question: *How can Nature-based Solutions be scaled up in the Greater Mekong to benefit freshwater habitats and rural communities that rely on them?*

The principle of NbS is that they follow from a co-creation process, accepted and validated at community level. Moreover, the solutions should be based on understanding of basin wide processes and should be scalable. This ensures that the NbS increase resilience of communities at scale, and contribute to address the root causes of systemic loss of resilience of the entire river basin.

Study Approach



We created a preliminary long list of freshwater NbS in rural contexts for the Mekong Sub-region based on our experience in the basin and the supportive information and literature collected. If available, we then shortlisted high-potential nature-based solutions based on the goals per country and high-priority areas (Rationale). Together with WWF we have selected a set of preferred NbS types that have a high potential to address the five societal challenges that can be addressed by nature-based solutions:

- Protecting human health
- Disaster risk reduction
- Safeguarding access to clean water
- Ensuring food security
- Climate change resilience

Selected Nature-based Solutions

The selected NbS are all based on improving natural floodplain dynamics. However, the way this is achieved and the requirements for implementation may vary across the Mekong region depending on the present-day land use and desired use after implementation of the NbS.

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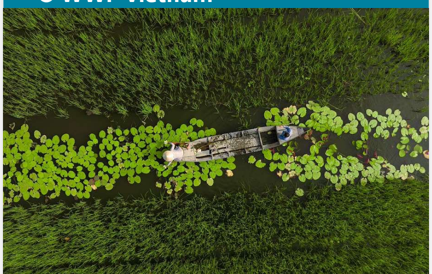

Improving floodplain dynamics

Read more

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Improving riverine wetland ecosystems

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Improving flooded forest ecosystem

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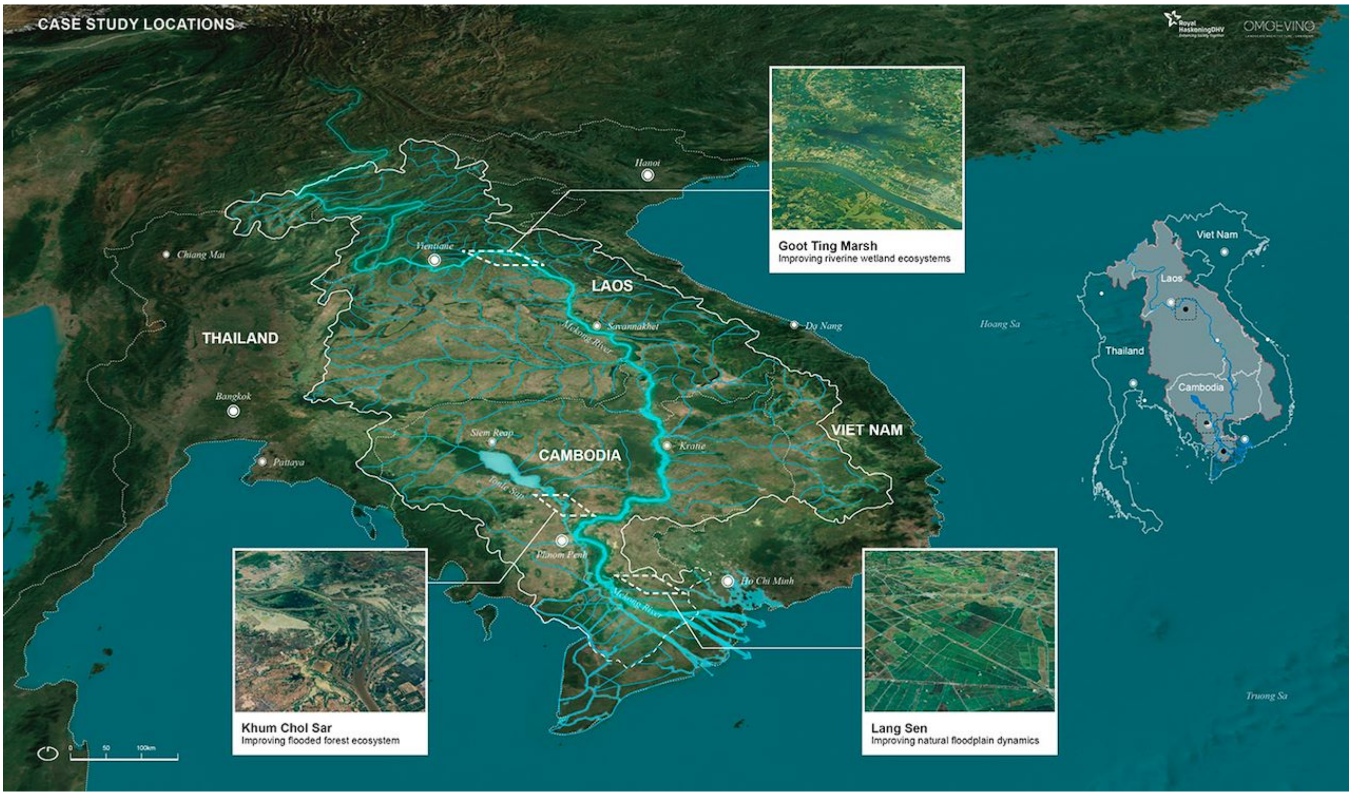
Case study locations

Please note that the three case studies differ in sub-floodplain conditions. Case 1(improving floodplain dynamics) involves a highly modified and high human population floodplain. Case 2 (improving riverine wetland ecosystems) involves wide functional floodplains. Case 3 (improving flooded forest ecosystem) involves the narrow mainstem and large tributaries floodplains of the Mekong middle reach.


CASE STUDY LOCATIONS
Hanoi
Chiang Mai
Vientiane
LAOS
THAILAND
Savannakhet
Mekong River
Da Nang
Hoang Sa
Bangkok
Siem Reap
CAMBODIA
Kratie
VIET NAM
Pattaya
Tonle Sap
Phnom Penh
Ho Chi Minh
Mekong River
Truong Sa
Goot Ting Marsh
Improving riverine wetland ecosystems
Khum Chol Sar
Improving flooded forest ecosystem
Lang Sen
Improving natural floodplain dynamics
Viet Nam
Laos
Thailand
Cambodia
0
50
100km
OMOEVINO

2 Project Rationale

2.1 Challenges in the Sub-Mekong region

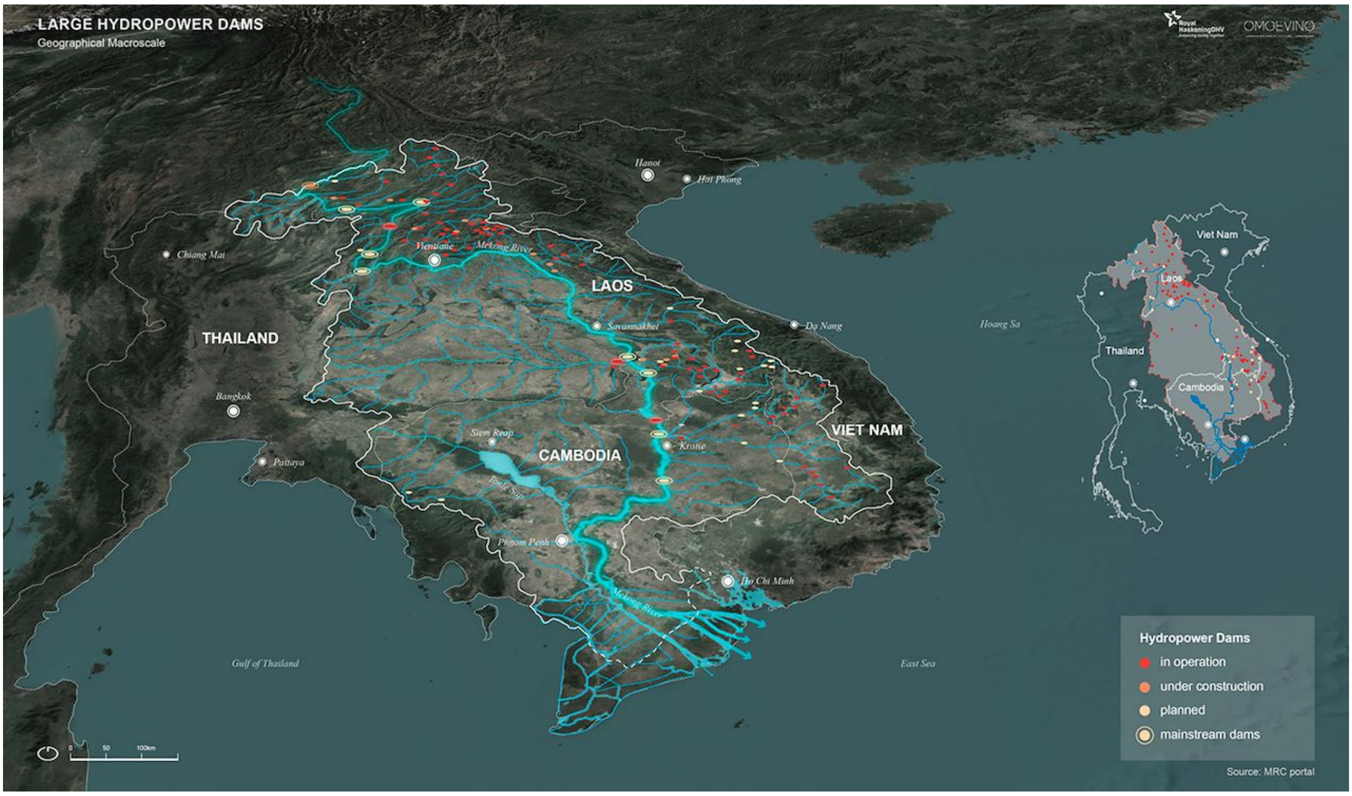
2.1.1 Challenges in the Mekong Sub-Region

The transboundary Mekong River is currently experiencing ongoing changes arising from climate change and human activities. These factors are anticipated to impact the flow patterns and floods substantially. Consequently, there is a notable decline in the productivity of aquatic ecosystems, disruptions in riverine transport, and a potential reduction in the availability of freshwater resources. These changes pose significant challenges to the communities that rely on the Mekong River for their livelihoods. To address these pressing issues, it is crucial to prioritize implementing Nature-based Solutions (NbS) in the Mekong Region, because they result from a systems approach applied to the physical-, ecological-, social- and financial system.

The CRxN Mekong Project has identified three sites in Vietnam, Cambodia, and Laos as part of its initiative. Thailand was added to the scope of the commissioned assignment. To this end, it is essential to also highlight the issues, challenges, and desired goals associated with implementing NbS at the country level.

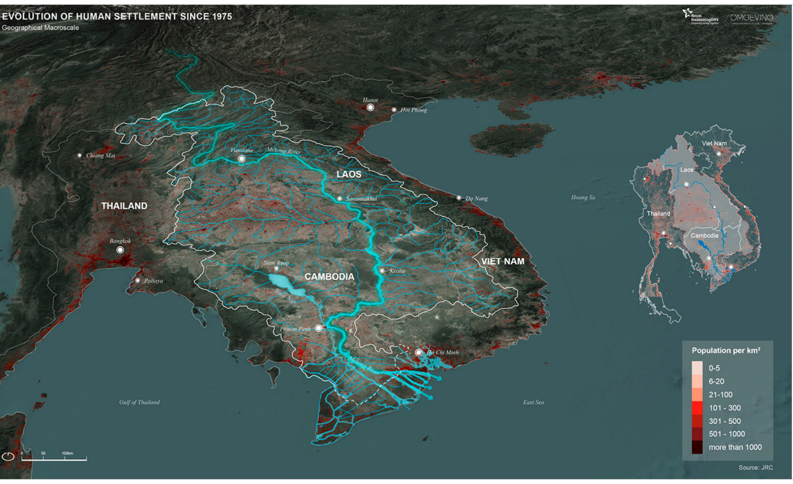
2.1.2 Hydropower dam development

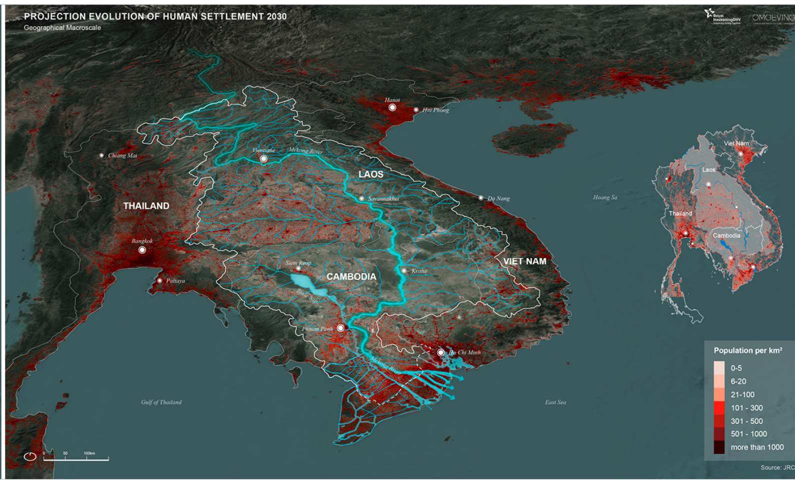
The construction of hydropower dams has increasingly regulated water levels and reduced natural sediment transport pathways. This has reduced water levels in the river during the wet season and elevated river levels when water is released for hydropower production in the dry season. The reduction in sediment transport has caused riverbed incision, resulting in less frequent flooding of the floodplains

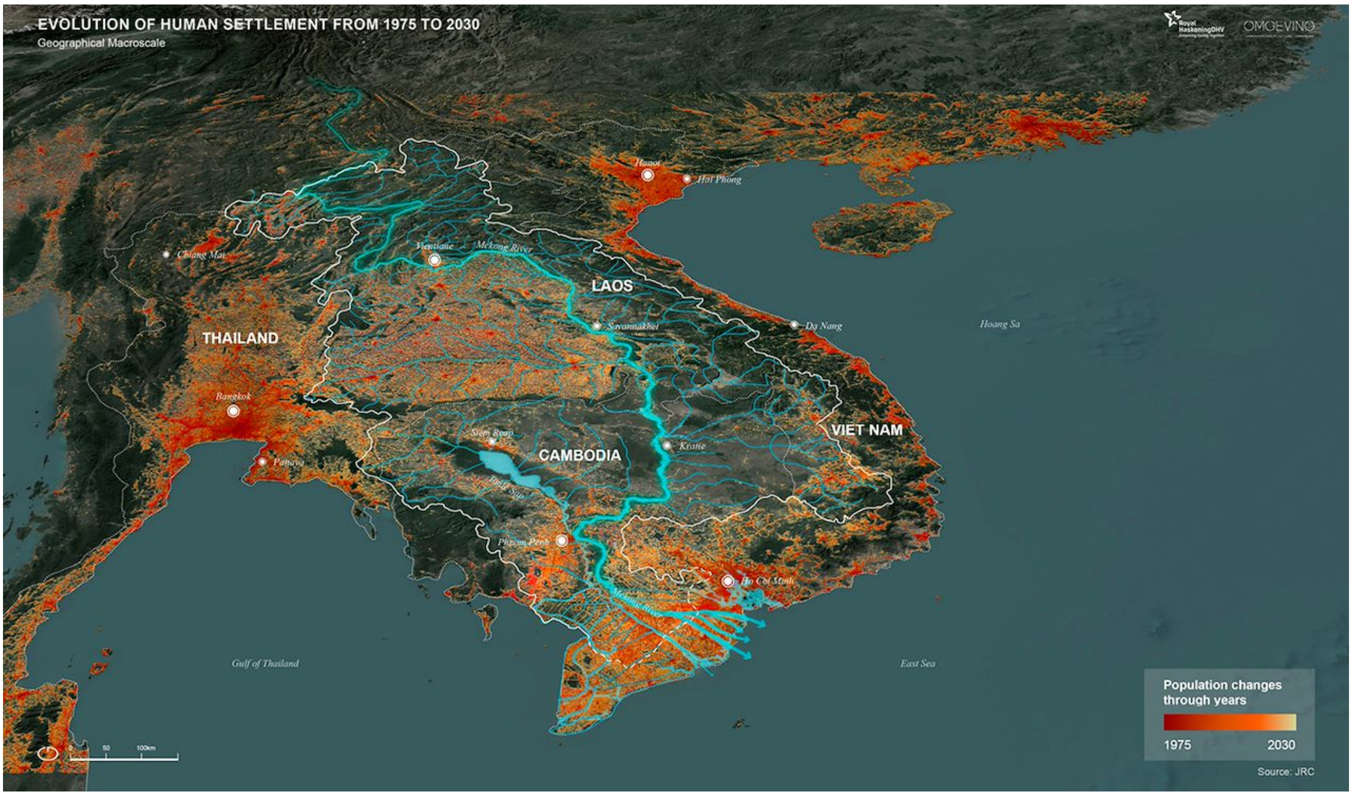


2.1.3 Social-economic development

Human settlements have rapidly expanded and are expected to grow further. This has encroached on the natural environment and changed land use across the region from primarily natural to built-up and agricultural areas.







Population changes from 1975 to 2030

2.1.4 Floodplain disconnection

Three primary factors are responsible for disconnecting floodplains: physical barriers, river bed incision and alterations in flow. When it comes to physical barriers, floodplains often become separated from rivers due to engineered river channels that introduce various structures, like levees, that obstruct the connection between the rivers and floodplains. On the other hand, hydrological disconnection occurs when river flow is modified to the extent that high flows no longer inundate the floodplain. This lack of periodic inundation significantly reduces the floodplain's ecological functions and benefits. This includes disrupting the exchange of surface water, nutrients, sediment, and organisms, which can adversely affect riparian habitats.

Moreover, it can worsen erosion and lead to incisions in the river channel. In turn, riverbed incision is an additional factor that affects inundation levels, extent, frequency and duration, and river bank erosion. The main channel becomes more focussed (with increased stream energy) and incised, and this process continues, increasing the physical barriers. The most direct and important impact of reduced frequency and extent of the inundation of floodplains is reduced expansion for floods that expose people and nature downstream to non-natural flood events.

To tackle this challenge, it is essential to restore the natural function of floodplains. This restoration will enable the system to facilitate the movement of aquatic organisms and materials like sediment, minerals and nutrients that are important for the soil quality of floodplains. Many fish species migrate to floodplains as a part of their life cycle, to feed and refuge during high flood episodes, notably for young fish, to not have to fight high energy flows in the mainstream. Moreover, the active floodplain plays a crucial role in maintaining water quality, mitigating flood stages, recharging ground water reserves, washing soil for excess salt, and it acts a natural pesticide. Re-establishing a connection with the floodplain is anticipated to enhance the resilience of the community against floods and improve livelihoods that depend on the quality of the floodplains. Additionally, active floodplains will also enhance resilience against droughts and extreme heat, because natural habitats and water mitigate heat.

2.1.5 Drowning flooded forest

Flooding plays a crucial role in shaping the flooded forest ecosystem, influencing the floodplain habitat's structure, quality, and function. However, upstream hydropower and water resource infrastructure in the Mekong River threaten the downstream sensitive ecosystem by altering the flood-pulse system, particularly in the flooded forest and its surrounding protected area. According to Kummu and Sarkkula's study (2008), an increase in water levels during the dry season could lead to a 17-40% expansion of open water, resulting in permanent forest inundation and reducing ecosystem productivity. Conversely, a decrease in water levels during the wet season may cause a 7-16% reduction in the seasonally inundated floodplain area, disturbing the migratory patterns and spawning grounds for fish (Pantulu, 1986).

A sufficiently large flooded forest ecosystem is essential feeding and spawning grounds for fish, contributing to the overall health of the ecosystem and supporting aquatic biodiversity. Taking a practical approach, implementing measures to prevent additional degradation, like revegetation and maintaining flood-pulse in key areas, is crucial to the restoration efforts in the flooded forest.

2.1.6 Degraded soil quality

Soil degradation in the Mekong Region results from multiple factors, including the cumulative impacts of hydropower dams that disrupt the flow of sediment carrying essential nutrients and intensive and unsustainable farming practices reliant on chemical fertilizers. Erosion, driven mainly by deforestation, inappropriate land use, and heavy rainfall, compounds this issue. These combined factors contribute to the loss of fertile topsoil and deteriorating texture, compromising the soil's ability to support crops effectively. The decrease in texture affects the ability of soils to drain water. Floods can wash the soil from excess salt and may, in some cases, also wash away pollutants.

Recognizing the Mekong Region's significant agricultural dependence, introducing sustainable farming methods is crucial for long-term viability. Incorporating sustainable farming into the **restoration of natural floodplain functions** helps preserve and enhance soil, preventing degradation in the area. This approach supports a healthy floodplain ecosystem and the livelihoods of the local community.

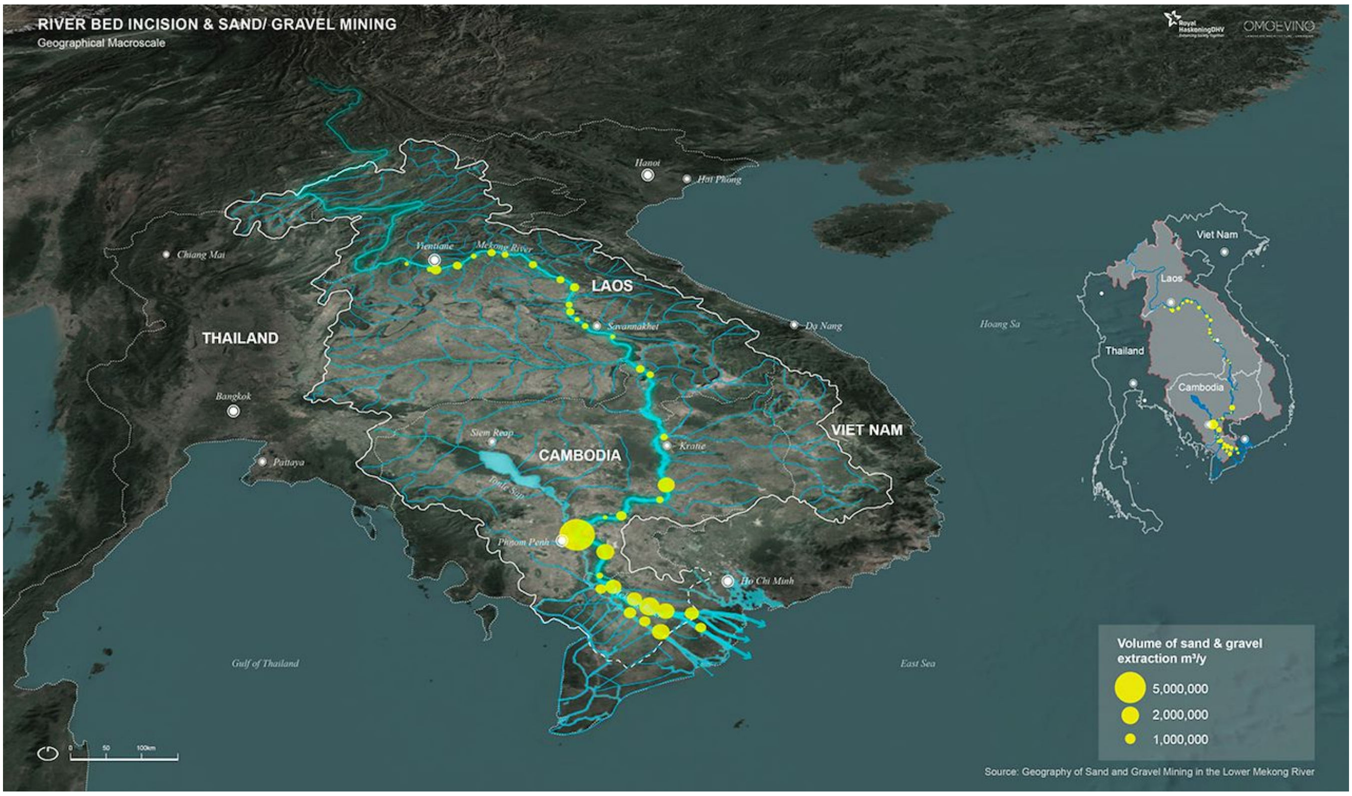
2.1.7 Disruption in spawning zone and migratory route due to insufficiently large wetlands and insufficient connectivity

Commercial groundfish species, like whitefish, migrate upstream to areas along the Mekong River in Cambodia, southern Laos, and central Laos as part of their yearly breeding cycle. During this migration, fish eggs and young fish are transported by floodwaters when the season begins, eventually reaching the Mekong Delta. There, they can find food and finish growing.

The impact of climate change, coupled with the operation of hydropower dams upstream, has led to the drying up of water bodies in various wetland areas along the Mekong River. This has caused a significant depletion of fish stocks. In recent years, the water level in the Mekong River has consistently dropped well below the typical average during the peak of the monsoon season. As a result, the reduced wetlands area has restricted the breeding habitat for fish, leading to a decline in their breeding rates[1].

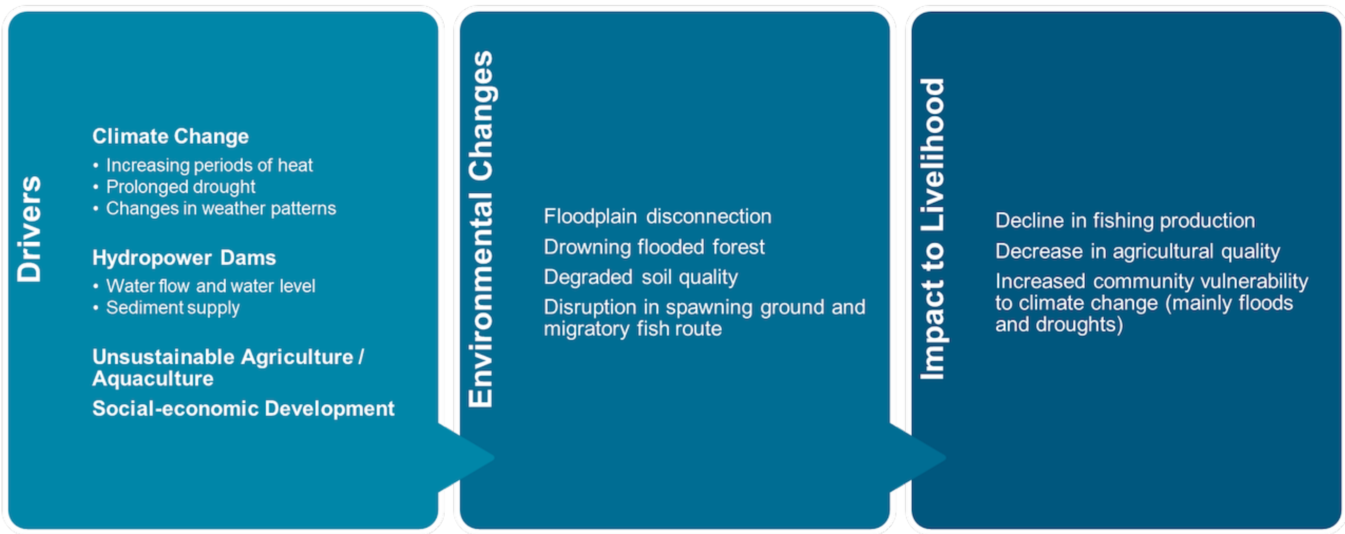
Preserving the natural river flow and **ensuring the health of the wetlands ecosystem** to provide a suitable spawning habitat for fish is essential. Restoring fish productivity often requires a multifaceted approach that combines habitat restoration, sustainable management practices, and community involvement. Additionally, mitigation efforts can be further enhanced by implementing measures focusing on **improving connectivity between the main river channel and the river floodplains.**

1 *https://earthjournalism.net/stories/mekong-fishermen-struggle-to-survive*



2.1.8 Summary of Rising Problems

This section provides a summary of the issues identified in the four countries across the Mekong Region. The drivers, which serve as root causes, are interconnected with environmental changes. The subsequent impact of disturbances in the natural environment is linked to underlying challenges in the lives and livelihoods of local communities. This broader perspective helps in understanding the complex interplay among these drivers, environmental shifts, and the well-being of affected populations.



2.2 Challenges per Country

2.2.1 Disconnection of the Floodplain in Vietnam

Main Problem

The disconnection of floodplains in an agricultural region due to the establishment of dike systems causes degradation of soil quality and texture and soil subsidence in the floodplains.

Challenges

- Extensive agricultural and aquaculture production triggers the dikes' development. The dikes prevent water, sediments, nutrients and wildlife from moving from channels to floodplains. It also leads to pollution of the water.
- The construction of large-scale hydropower dams in the Upper Mekong/Lancang and the Central Highlands has significantly altered hydrodynamics. The hydrodynamic regime has shifted from being more variable to more stable, resulting in low waters being less low and high waters being less high and delaying the onset of the flood season. The dams reduced sediment supply, which led to riverbed erosion and decreased bank stability.
- Sand mining activities have caused morphological changes in the river channels, including riverbed incision. These changes affect water levels and exchange with floodplains, exacerbating saltwater intrusion into the channel and altering tide dynamics. Riverbank and coastal erosion further degrade infrastructure, cause land loss, diminish mangrove habitats, and reduce climate resilience.
- Climate change is changing the patterns of the river's water flow, leading to increased variability in flow and water levels, as well as heightened salt intrusion in the delta. This is affecting the seasonal rhythms, making it challenging for communities that depend on the river for agriculture, transportation, and livelihoods.

Rationale to solve these challenges

Restoring the natural connection between floodplains and rivers would mitigate downstream flood risks while enhancing wild fisheries' productivity and biodiversity. This restoration would facilitate water flow and nutrients, improve soil fertility and height, mitigate land subsidence, wash away excess salt, and promote groundwater recharge. It would also facilitate the movement of native species between the river, floodplain, buffer zone, and protected areas. This approach increases system functioning and ecosystem services and improves the sustainability of livelihoods that depend on flood-based agri- and aquaculture.

Identifying livelihoods and business solutions, such as flood-based agri- and aquaculture, will allow local communities and businesses to be more resilient to the impacts of climate change.

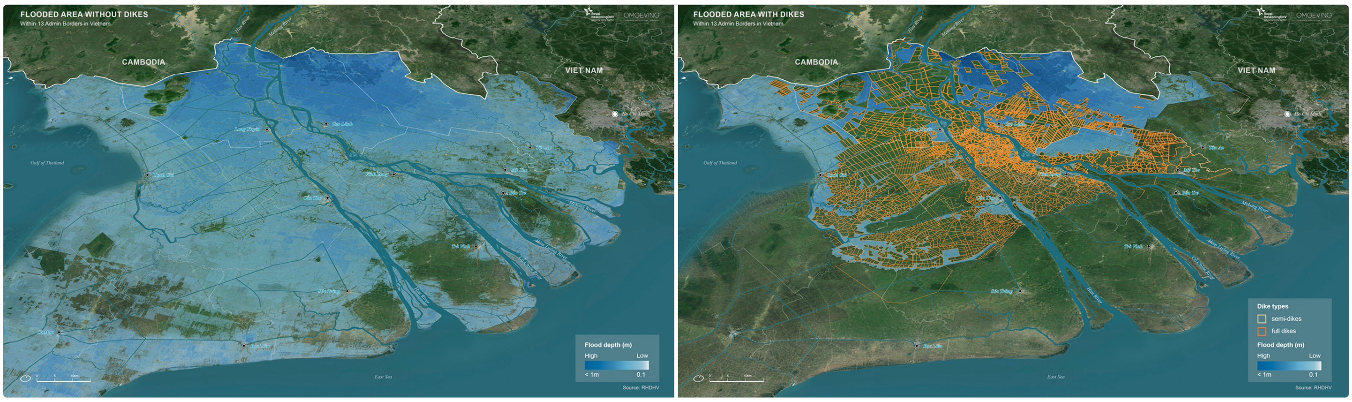
A more resilient delta will reduce the costs of constructing and maintaining flood, storm/typhoon, and drought-proofing infrastructure. It will also reduce exposure of public and private assets to water and climate disasters, thus avoiding future costs.

NbS Measures

- Developing and implementing livelihood and business strategies for dealing with floods and droughts, focusing on both agriculture and aquaculture. The strategies should consider the benefits of floods and sediment, and should be included in cost/benefit analysis and business plans. Consider factors such as not having to invest in flood and climate-proofing measures (opportunity costs).
- Adopting production models that best fit agricultural, ecological, and socioeconomic conditions.mic conditions.
- Rehabilitating, restoring and enhancing the ability of nature to provide ecosystem service in the floodplain area and improve the connectivity between the floodplain and the Mekong River.

How the NbS solve the issue

- River mainstreams can re-establish connections with the floodplain, revitalizing its role. This helps improve soil quality by depositing essential fertile sediments, increases/maintains the elevation of the floodplain, and reduces the risk of floods in the agricultural area.
- The implementation of flood-based agriculture can offer a sustainable alternative to conventional farming methods.
- Priority Area: *Plain of Reeds & Long Xuyen Quadrangle*



Slide the visual above to visualize the extent of flooding during a 1/10-year flood event, with (right) and without (left) the current dyke system in Vietnam.

2.2.2 Decrease of flooded forest cover in Cambodia

Main Problem

The Mekong Flooded Forest in Cambodia is under threat from the dual impact of climate change and dam development. Reports indicate up to a 40-50% loss of tall trees. These changes have resulted in reduced ecosystem productivity and have disrupted the migratory patterns and spawning areas of fish.

Challenges

- High-volume dams store water during the monsoon season and release it in the dry season, causing higher water levels during the dry season, which disrupts the natural floodplain's seasonal dry cycle.
- Unsustainable practices in the community include illegal logging, land encroachment through appropriation of traditional lands, illegal wildlife trade, and unsustainable fishing practices, driven by poverty and weak enforcement.
- Due to climate change, weather patterns, such as precipitation and monsoon rain intensity, are shifting, potentially altering the timing and volume of floodwaters entering the flooded forest.

Rationale to solve these challenges

- Adopting effective measures to protect and manage natural resources and ecosystems will enhance the Mekong Flooded Forest's resilience to the impacts of climate change. This measure is expected to provide opportunities for sustainable use.
- Creating alternative livelihood options to reduce human pressure on using vulnerable (and non-vulnerable) natural resources and ecosystems and to ensure that communities can withstand residual climate change impacts better.

NbS Measures

- Assessing areas threatened by habitat loss and identifying suitable new areas to compensate for flooded forest losses.
- Assessing how the local population is now using the flooded forest and whether that contributes to its degradation. If that is the case, alternative livelihoods can/should be found.

How do NbS solve these issues

- Maintain a specific key area of the flooded forest ecosystem so that it can continue providing essential services for the local community. For instance, many communities nearby rely on natural resources as their main livelihood, which makes them even more susceptible to the impacts of climate change. Supporting a healthy flooded forest ecosystem will ensure a community protein source from capture fisheries, clean water for drinking, protection from floods, and safeguarding lives and property.
- By adopting a balanced approach to conservation and sustainable resource utilization within the flooded forest, the intervention aims to ensure long-term community benefits, such as food security, water supply and purification, and climate adaptation. Additionally, the forest can serve as a carbon sink, contributing to climate mitigation.

Decrease of forest between 2000 and 2022

2.2.3 Disconnected wetland in Laos and Thailand

Main Problem

Wetland conversion for agriculture and urbanization often disconnects them from rivers and reduces wetland area. Moreover, the construction of hydropower dams has made river flow more constant, reducing sediment and nutrient supply. These changes disrupt aquatic habitats, reducing fish populations and posing a significant risk to Irrawaddy Dolphin habitats.

Challenges

- Controversial government's plan of developing nine mainstream dams to boost the country's economy.
- Dam development significantly alters the sedimentation and hydrodynamic conditions of the connected rivers.
- Dams in large rivers disrupt fish migration, life cycles, and access to vital habitats, reducing species diversity due to sediment accumulation and nutrient depletion.
- Villagers from Laos and Thailand, who depend on the Mekong River for their livelihoods, have reported a declining trend in fishing catches following the construction of a hydro dam.
- Climate change intensifies rainfall variability, leading to floods and droughts, impacting habitats, species, and agriculture.

Rationale to solve these challenges

- Healthy wetlands and riparian habitats function as storage areas for water, reducing the impacts of floods and droughts on people and nature. Additionally, the area contributes to improved soil health and fertility.
- Restored forests absorb heat, which helps to cool the landscape and address increased temperatures.
- The fisheries in the Mekong River are incredibly diverse, exhibiting seasonal and geographical variations. The general fish migration patterns in the Mekong River form interconnected systems between the lower, middle, and upper regions. Ensuring the proper environmental flow will help protect wetlands and riparian habitats, sustaining aquatic biodiversity and fisheries productivity.
- If biodiversity rebounds in productive areas outside natural habitats, the overall ecosystem functioning of the riverscape will be improved, and nature-positive, species-rich farmed landscapes are more resilient to climate stress than degraded ones.

NbS Measures

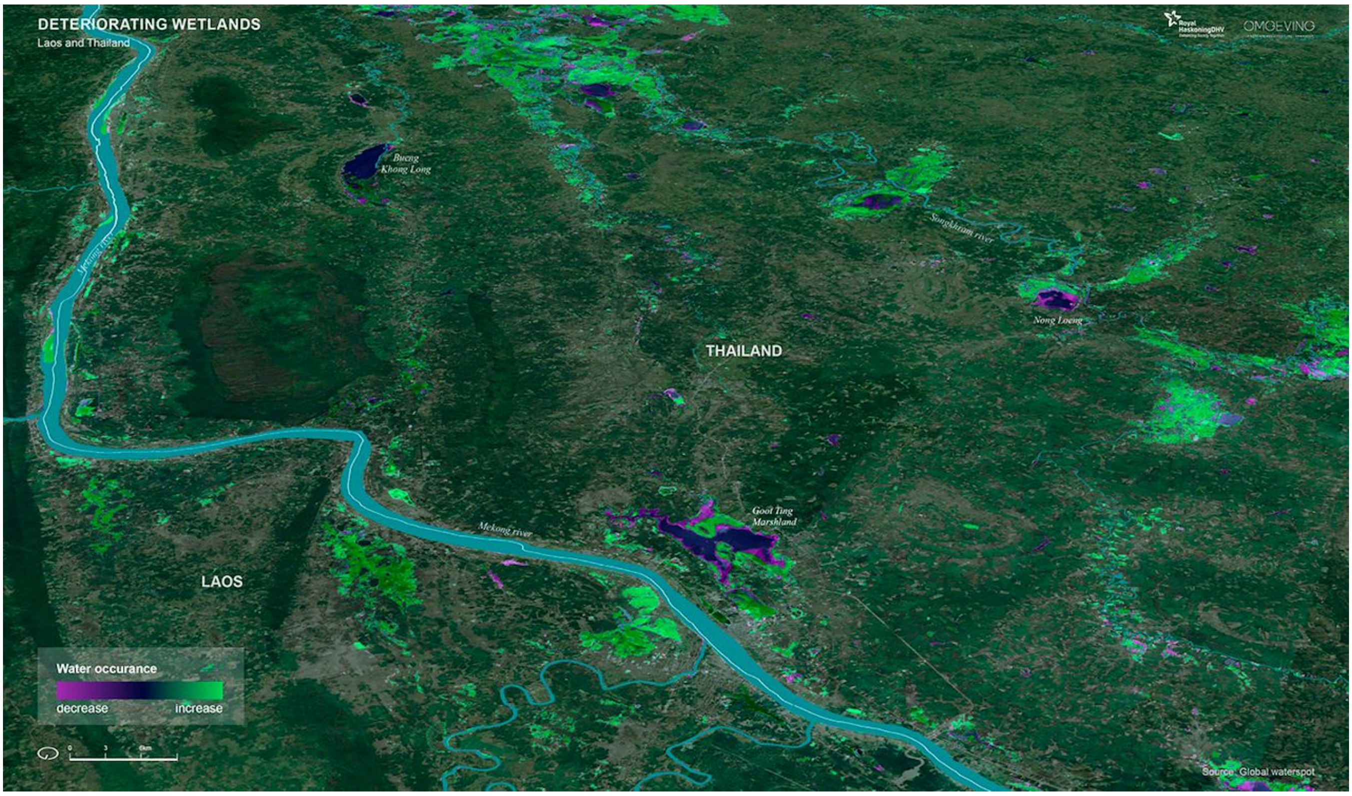
- Restore flooded forests and riverbanks by re-establishing wetlands, flooded forests, and riparian habitats.
- Restoration/rehabilitation of riverine wetland ecosystems and increasing the connectivity between the wetlands and the main river (thus allowing water, sediments, nutrients, and fauna/fish to transfer from the river to the wetlands and vice versa). Possibly, this requires an engineering measure. Alternatively, new suitable areas for those wetlands may be found. Protect existing wetlands.
- Introducing aquafarming to the community as an alternative livelihood offers a solution that is less dependent on river flow variations.

How the NbS solve the issue

- The wetlands will again become large enough and well connected with the main river. Therefore, they can support a healthy ecosystem and fish population.
- The connectivity between the river and the wetlands will enhance the natural functions of wetlands, such as sediment trapping through slow water flow and vegetation, promoting sediment deposition, and creating a healthy environment as a spawning ground for aquatic organisms.
- The wetlands help store surface water and replenish groundwater through infiltration.
- Increased fish populations will enhance the livelihoods of those dependent on fishing. Rehabilitated wetlands could be utilized for other purposes, such as parks and water storage.

Priority Area

- Laos: Siphandone Wetlands
- Laos: Wetlands bordering Mekong river
- Thailand: Wetlands bordering Mekong River in the eight North-eastern provinces



Deteriorating wetlands in Laos & Thailand

2.3 Conclusion

From this overview, it is clear that the most effective solution to pursue is reconnecting river channels with floodplains. However, it is crucial to understand what caused their disconnection, such as embankments, reduced sediment supply, increased incision of the main river bed, and the impact of hydropower dams, which reduce peak flows and increase base flows. This disconnection has led to the loss of floodplains, wetlands, and flooded forests. These areas are disappearing, and their quality is deteriorating due to a lack of proper hydrological and biological conditions. Understanding this system highlights why we need to appreciate floods and sediments instead of considering them problems that need fixing.

The implementation of reconnecting solutions varies significantly between regions with low human population and limited environmental changes, such as the vast plains of Cambodia, and areas with high human population and intense land use, like the Vietnam Mekong delta where natural processes have been completely disrupted. In the latter, business plans should include the benefits of floods and sediment. In traditional Khmer culture, average floods were viewed positively, while both low and high floods were seen negatively. Farming practices could be adapted to work with floods and sediment, using the floods as a natural irrigation method. By creating human-made openings in natural levees, farmers can control the flow of sediment into the fields, enhancing soil texture and nutrient content suited to specific crops. This could result in high yields with minimal use of fertilizers and pesticides, thus reducing labor and input costs. Reviving and modernizing these lost practices could have significant positive impacts on production resilience and overall system resilience.

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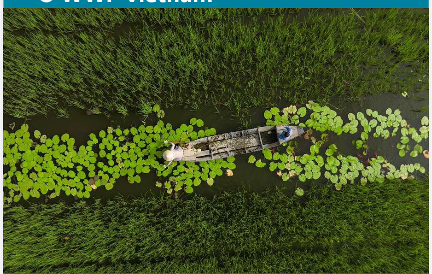

Improving floodplain dynamics

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Improving riverine wetland ecosystems

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Improving flooded forest ecosystem

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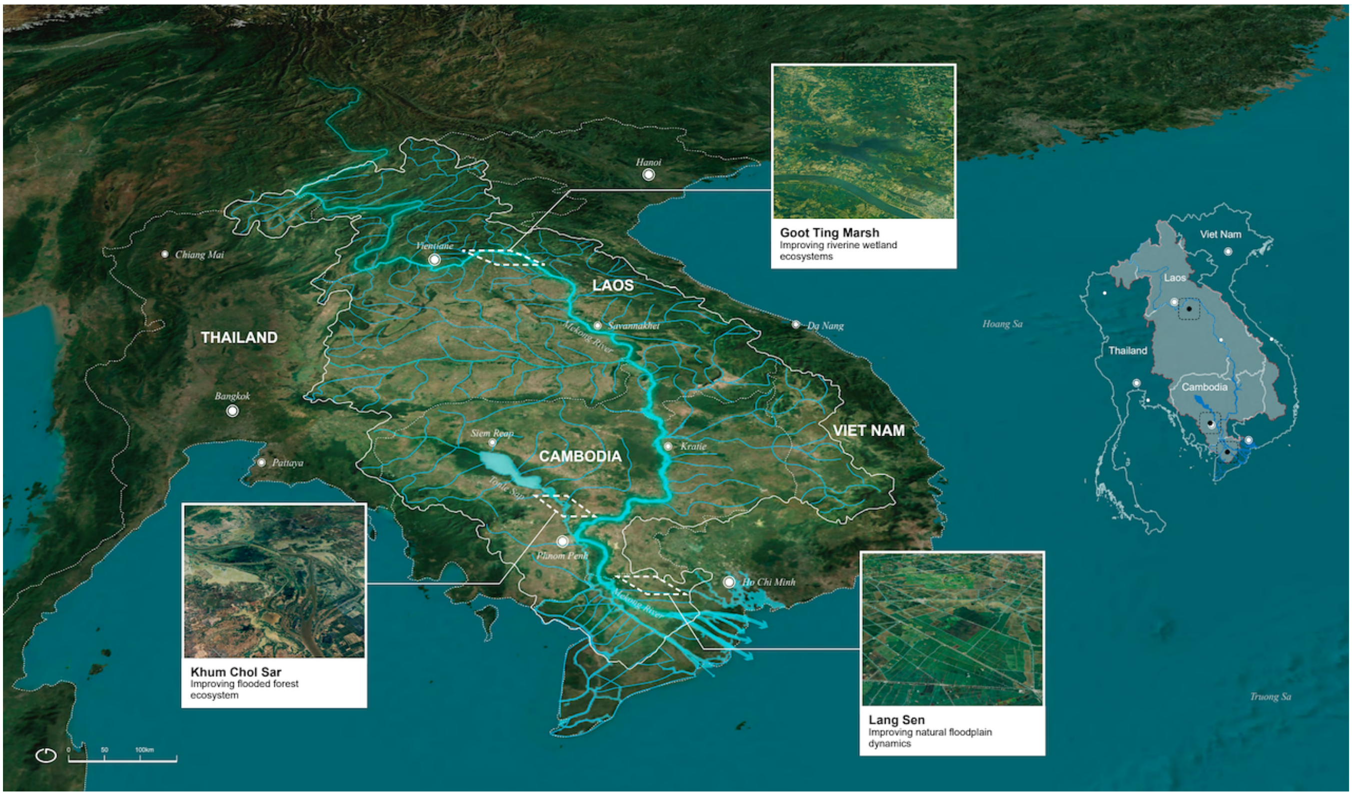


Overview map of the selected case studies

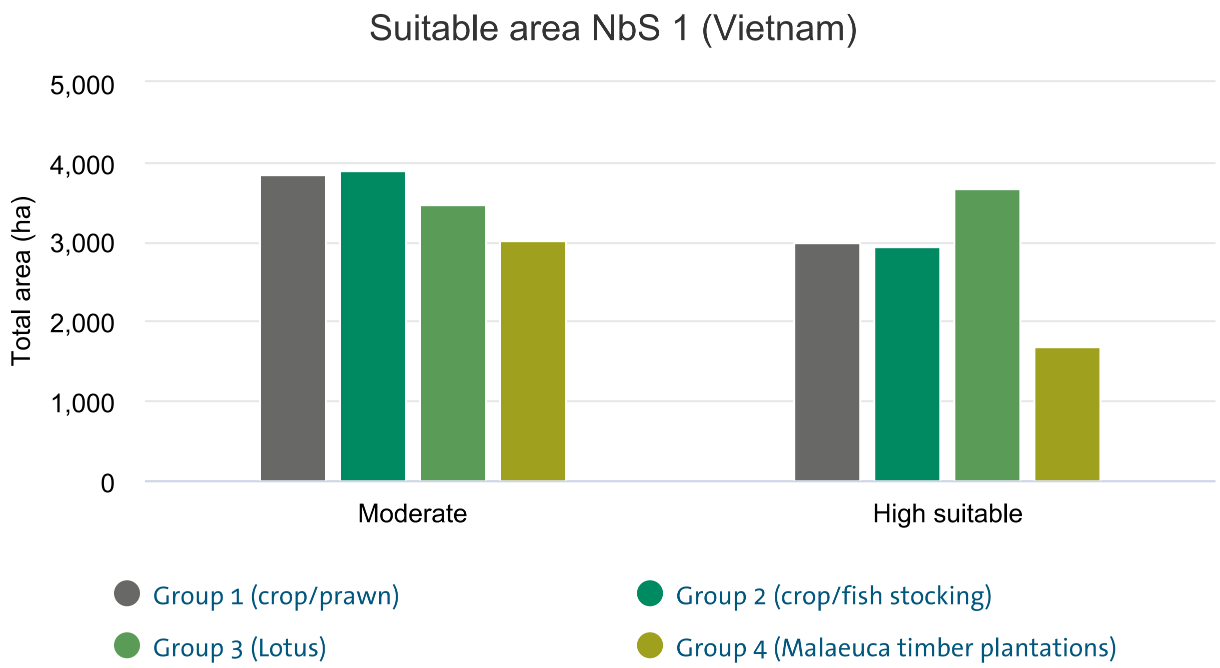
3 Improving natural floodplain dynamics

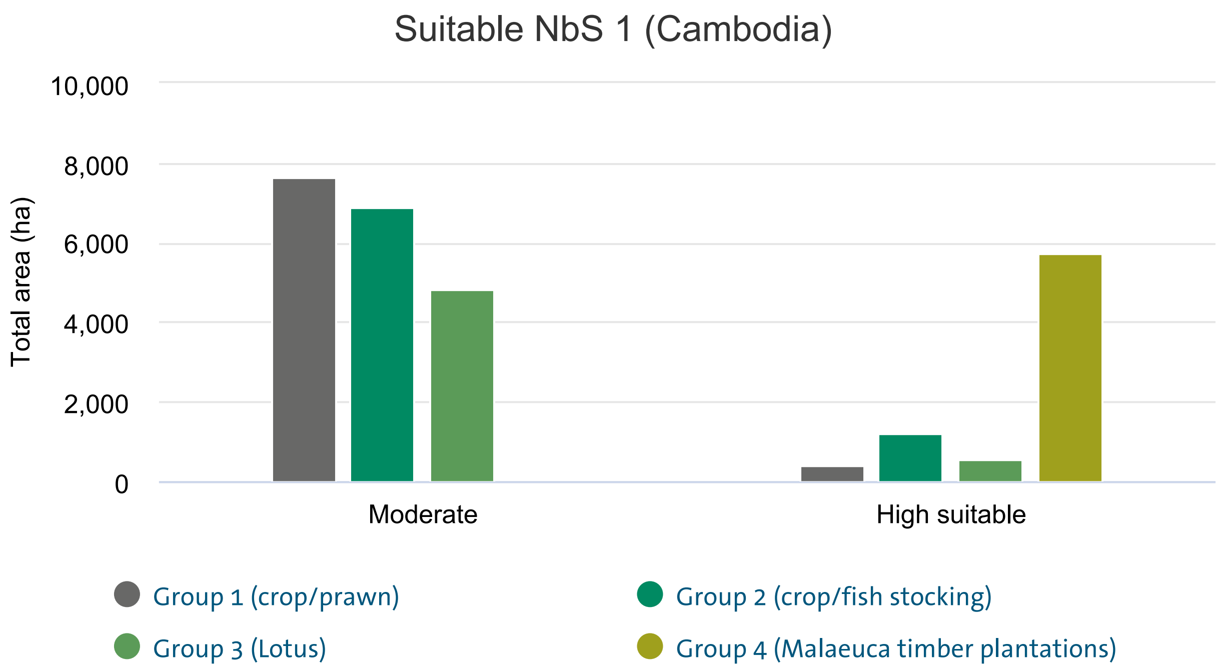
3.1 Introduction

3.1.1 Improving natural floodplain dynamics

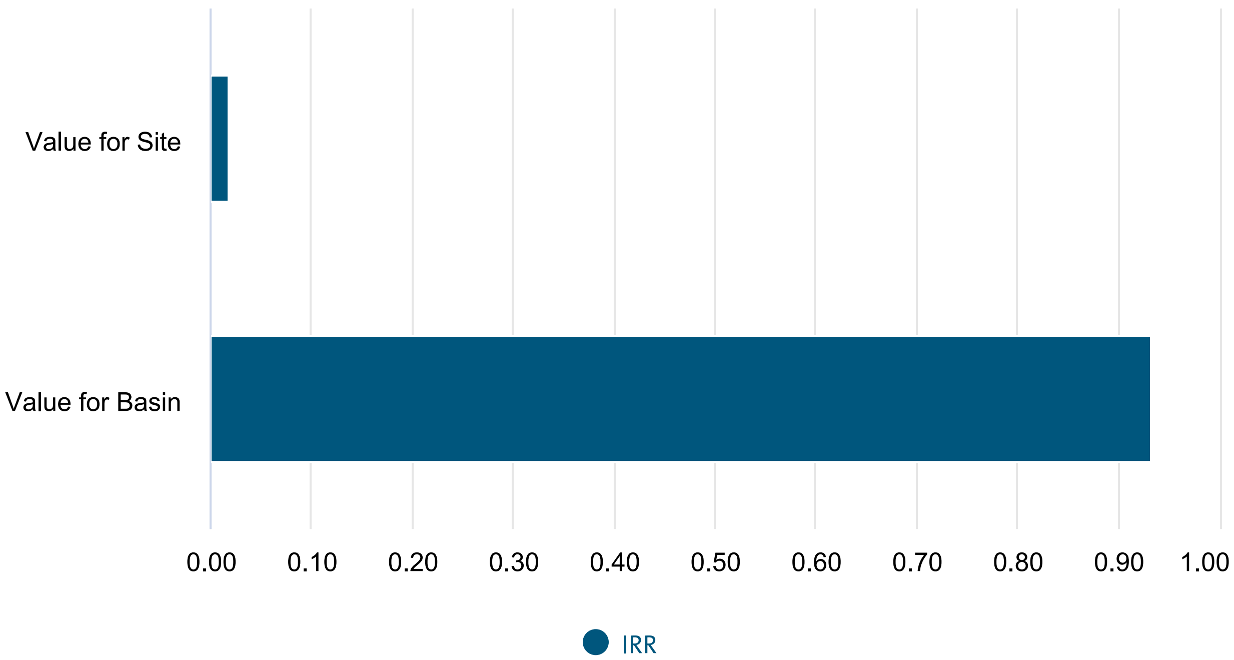
When a floodplain does not experience flooding or if its natural cover is damaged, it loses its ability to provide ecological services. Floodplain restoration is a method used to regain the benefits for both rivers and communities. This involves reinstating the natural processes responsible for creating and sustaining the ecosystem, enabling a return to its natural state over time.

Suitable area





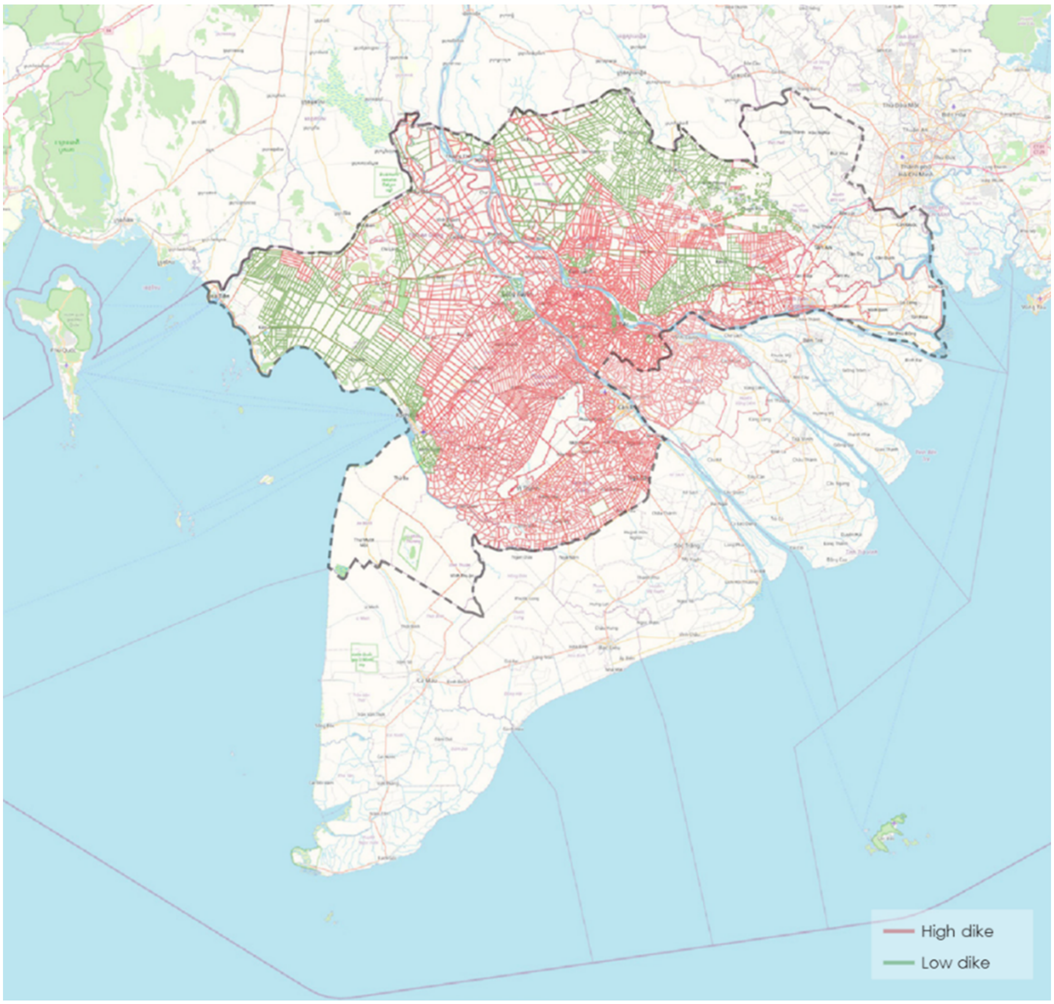
Internal Rate of Return



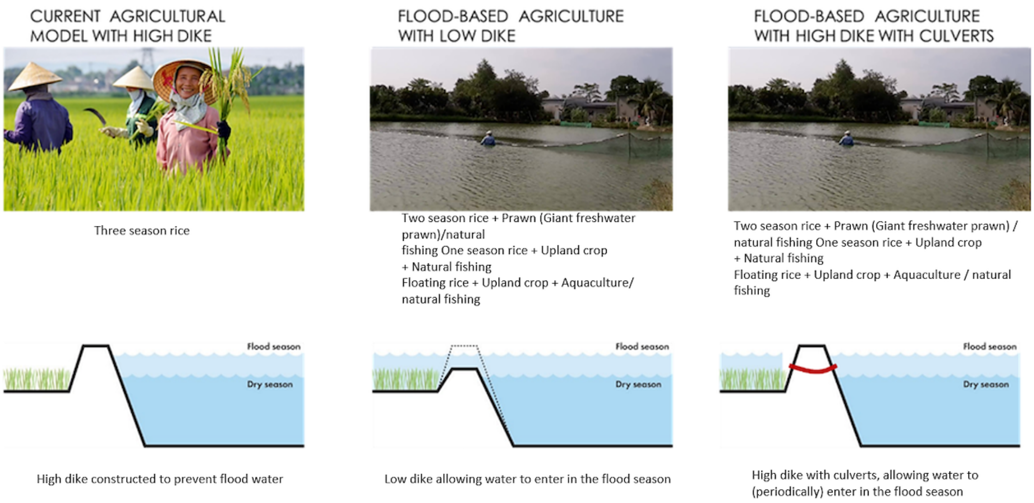
Background

Hydropower dams built upstream on regulated rivers, like the Mekong, significantly change water flows. This leads to less frequent and smaller flood pulses, causing a disconnect in the water system. This alteration has a negative impact on the supply of minerals and nutrients to floodplain soil, resulting in an unproductive habitat for plants and animals along the river. The local community, which depends on the Mekong River for their livelihood, is put at risk. To address this issue, various methods are available, with direct reconnection of floodplains being the most commonly used intervention.

Directly reconnecting floodplains involves physically restoring the connection between the river and its floodplains. There are multiple ways to do this, such as by removing or lowering embankments, or by lowering existing floodplains. However, in practice, these measures may not work in the project area in Vietnam because the area is heavily influenced by dykes and is already low-lying for flooding if there were no embankments. The extensive network of low and high dikes separates the previously natural floodplains from the river. Therefore, the most promising solution here is to reconnect some of these areas by using culverts under dikes to divert floodwater into surrounding areas (e.g., paddy fields), while utilizing the existing drainage channels and canals. The key to successful implementation will be to include the values of floods and sediments in the business plan, rather than considering them as problems to be mitigated.



Extensive network of dykes in Vietnam



Comparison of agricultural models in use today (modified from: RHDHV – ONE Architecture, 2021).

3.1.2 Benefits

Restoration efforts, such as adjusting levee positions, lowering floodplain elevations or installing culverts, are expected to activate floodplains and promote hydrologic connectivity. This activation is essential for improving spawning habitat availability for various fish species (Navodaru et al., 2005). Additionally, these measures bring extra benefits, including better retention of nutrients and suspended solids that are important to the soil quality of floodplains (Schneider, 2002; Suciu et al., 2002).

Most main levees in the Mekong are natural, so adjusting them may not be desirable or feasible. Adjusting their height might be an option, but this is of course dependent on adjustments to the floodplains behind them. Installing culverts may be an option in those cases, is period inundation is desired.

Expanding the width of the active river corridor through these actions increases the river's available "process space" (Ciotti et al., 2021). This approach aids in forming dynamic river-wetland corridors, contributing significantly to the overall functionality, biodiversity, and resilience of river systems (Wohl et al., 2021).

The resulting expanded area opens up new possibilities for community land-use practices, with flood-based livelihood strategy currently being implemented by WWF.

3.1.3 Flood-based livelihood implementation

Flood-based livelihood is a type of livelihood or economic activity that relies on the natural occurrence of floods and the use of floodplains. In areas where periodic flooding is a regular phenomenon, communities may develop livelihood strategies that harness the benefits of these floods. This can include practices such as flood-based agriculture, where the fertile soil deposited by floodwaters is utilized for cultivation, or fishing activities that take advantage of increased water levels.

Implementing flood-based practices positively influences hydrological conditions, reducing flood risks by implementing smart spatial planning and controlled flooding strategies. This approach will enhance rural flood protection in the future. The flood-based livelihood system improves soil fertility and texture by capturing essential sediments and facilitating diversified crop production. This system supports modernising (traditional Khmer) agricultural practices, fostering sustainability and yielding higher-value products. It plays a crucial role in meeting the evolving food demands of a growing middle-income urban population.

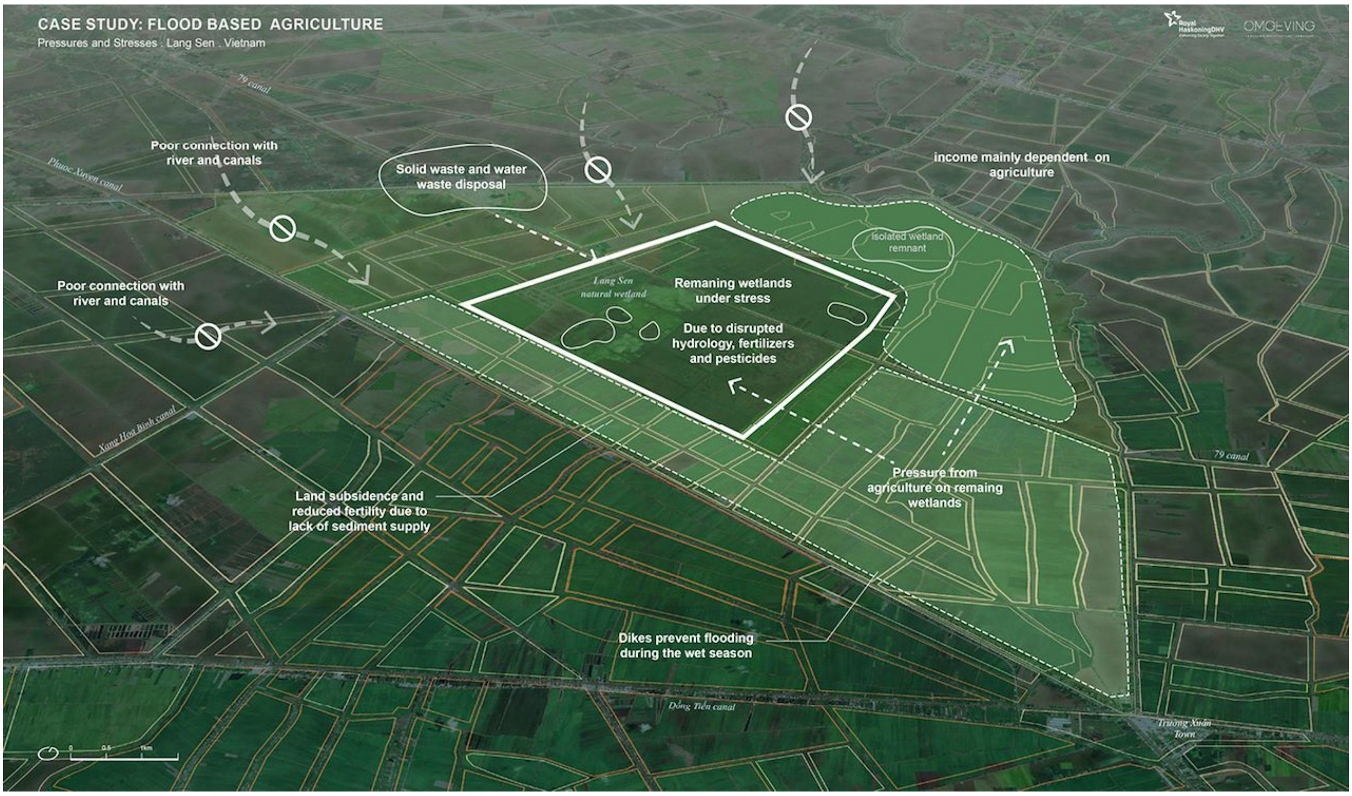
Figure 7-2 Inundated rice paddies in the wet season (Upper Delta) offer controlled retention of river floods after two crops.

Figure 7-3 Controlled flooding in the Upper Delta, using the inundated paddies for fish farming in the wet season or "floating vegetables", offering an attractive economic proposition.

Illustration of flood-based livelihood (source: Mekong Delta Plan: Long-term vision and strategy https://www.wur.nl/upload_mm/2/c/3/b5f2e669-cb48-4ed7-afb6-682f5216fe7d_mekong.pdf).

3.2 Case study: Lang Sen Flood-based Agriculture

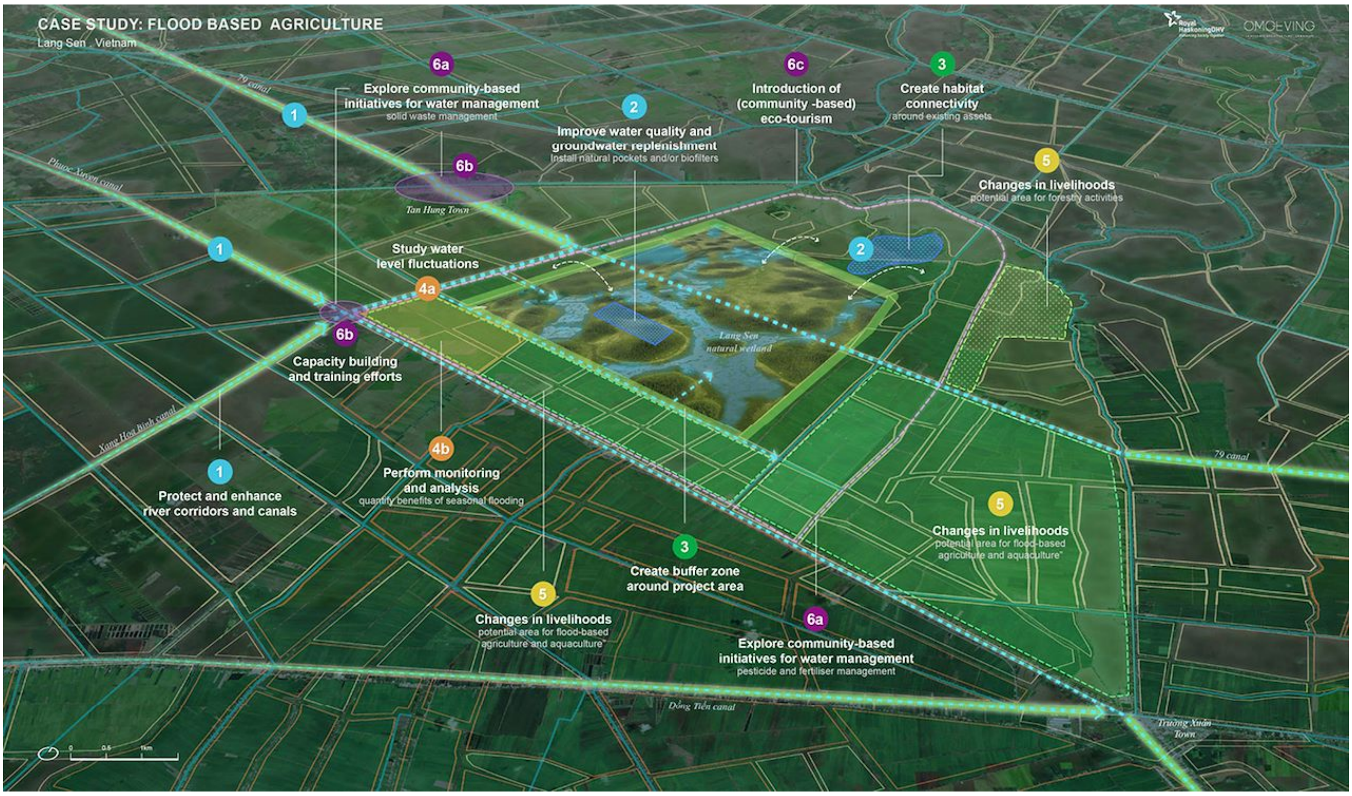
3.2.1 Stress & Pressure



The Mekong Upper Delta supports extensive agricultural production. This area used to be characterized by naturally occurring wide spread floods in the wet season (see figure above). To facilitate a third rice crop during the wet season, communities have developed an extensive and uncoordinated agricultural flood control system of around 20,000 km of dikes. The goal was to increase agricultural production, promote spatial development, and improve flood safety. However, these measures have significantly reduced the area's flood storage capacity and disrupted the natural flow of water, sediment, and nutrients.

The high dike strategy has not only reduced the positive effects of flooding, such as depositing sediment to counteract subsidence, replenishing soil fertility, and supporting groundwater recharge, but it has also made farmers more vulnerable. This is due to the decreasing economic efficiency of rice production and the growing impacts of climate change. While the high dike system protects large parts of the Upper Delta from smaller floods, it can be overtopped by extreme floods. Furthermore, due to encroaching infrastructure, upstream sand mining, and dam construction, the Upper Delta experiences extensive riverbank erosion and an increasing occurrence of serious landslides, causing damage to communities and livelihoods along the riverbanks.

3.2.2 Potential NbS measures



Upscaling flood-based agriculture systems and natural floodplain protection is proposed as a Nature-based solution for this region. This aims to achieve the following goals:

- Improved farmer incomes over a longer period of time
- Restore biodiversity
- Sustainable delta management

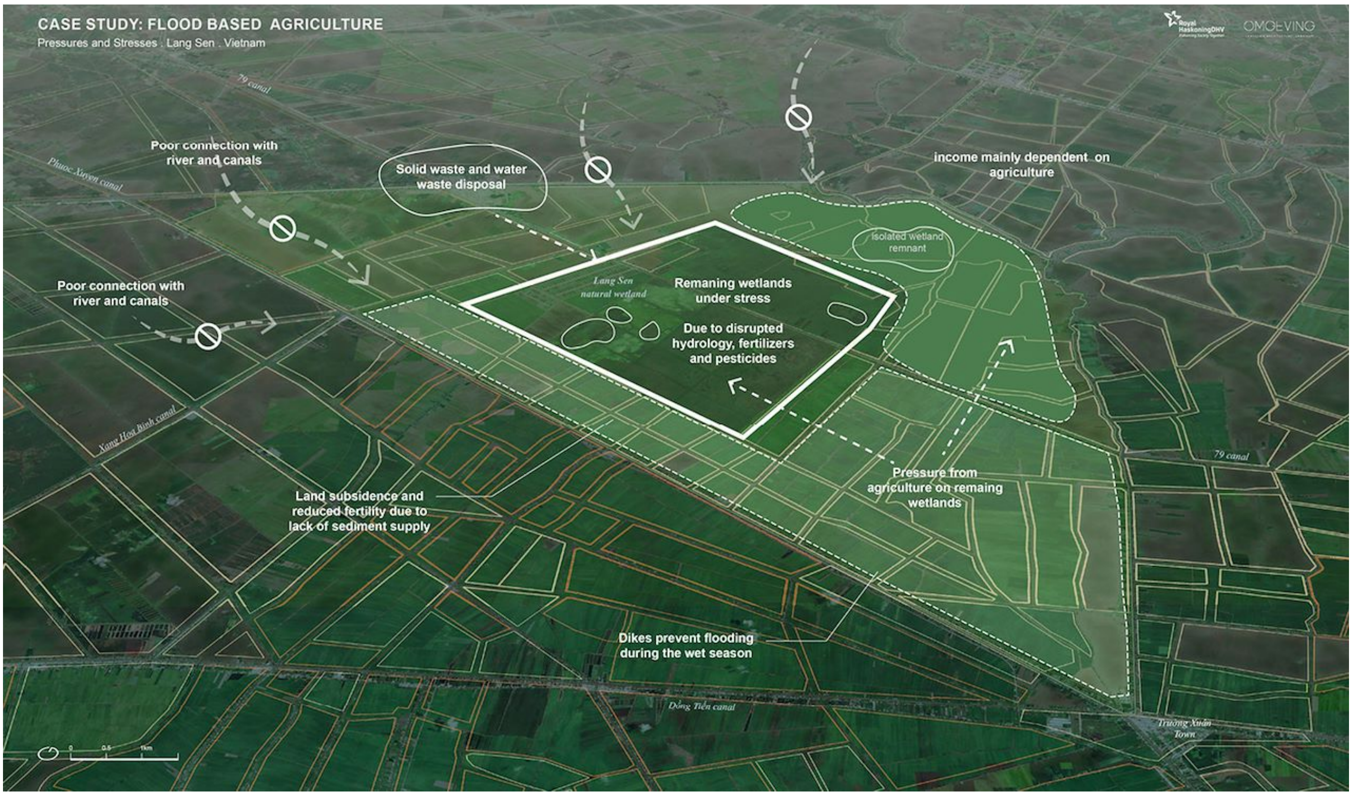
To achieve these goals, the fields must be inundated for a sufficiently long period during the flood season. Therefore, the flood levels need to be high enough to overtop the dikes, culverts, or sluice gates, which need to be installed to inundate the area within dike rings. permitting fields to floods brings the following benefits:

- Replenishment of the groundwater.
- Long-term inundation can act as a natural pesticide, flushing out pollutants like residual pesticides and alum in the field.
- Transport of fine sediments into the fields for re-fertilization, especially during the first floods as those contain a relatively high amount of sediment.
- Free passage for fish to move into and out of the inundated fields, providing more breeding places for some aquatic species.
- To maintain the growth of a delta, it is important for enough sediment to be deposited in the floodplains. Over time, the increase in land level due to sedimentation should be greater than the combined effects of sea level rise and land subsidence. This is essential for the ongoing processes of delta growth.

Therefore, the main structural measures related to this case include installing culverts or sluice gates to allow water in periodically and protecting and enhancing river corridors and canals leading to the designated areas (1 in the figure above). These measures could be further improved with non-structural measures, such as creating a buffer zone around the natural wetland (3) and establishing habitat connectivity around existing natural assets (3). The changes in land use also require a change in livelihoods, with agricultural activities transitioning from three-season rice to two-season rice with prawn (giant freshwater prawn)/natural fishing or a combination of rice with floating rice/vegetables, upland crop, aquaculture/fishing (5). Additionally, eco-tourism can be developed in the area (6c). Additional community-based activities include initiatives for water management (reducing pesticides and fertilizers) (6a) and training to increase capacity to implement flood-based agriculture (6b). As the project is still in a pilot phase, it is recommended to conduct monitoring and evaluation (4).

3.2.3 Stress and pressure

3.2.4 Stress & Pressure



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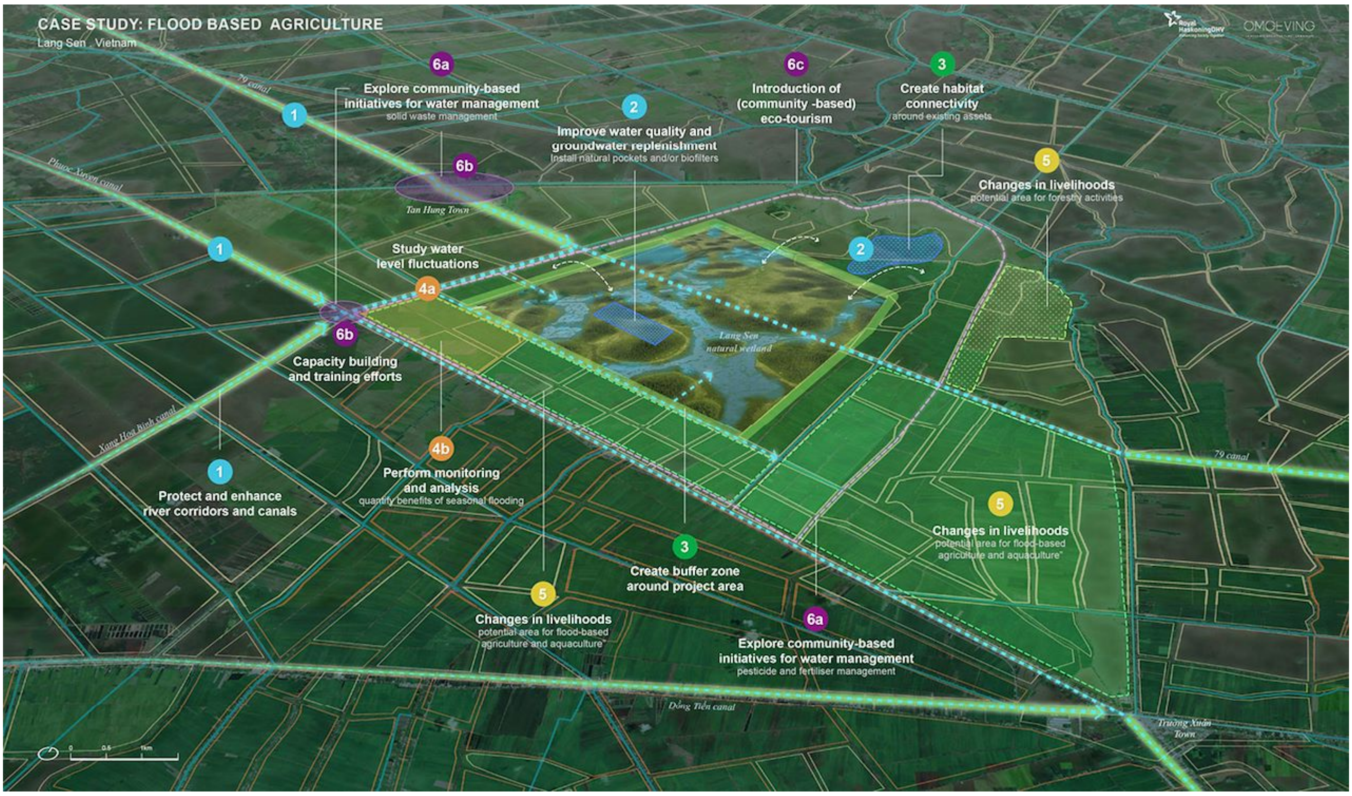
3.2.5 Potential NbS measures



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3.3 Technical feasibility

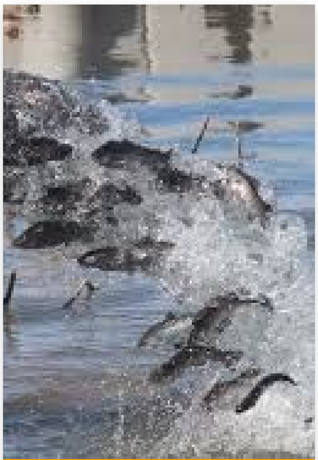
3.3.1 Technical upscaling potential

3.3.2 Upscaling potential

To understand the upscaling potential, the suitability of the area for this NbS has been mapped. In this case, the suitability mapping has been carried out for 4 groups of typologies, which each have similar flooding requirements:

Prawn (Giant freshwater prawn)

- (i) winter-spring rice, (ii) Prawn (Giant freshwater prawn)
- (i) upland crop, (ii) floating rice & Prawn (Giant freshwater prawn)
- (i) winter-spring rice, (ii) summer-autumn rice, (iii) Prawn (Giant freshwater prawn)

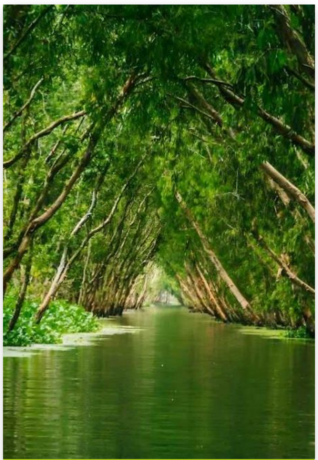


Fish stocking

- (i) upland crop, (ii) floating rice & fish
- (i) winter-spring rice, (ii) upland crop, (iii) fish
- (i) winter-spring rice, (ii) summer-autumn rice, (iii) fish

Lotus

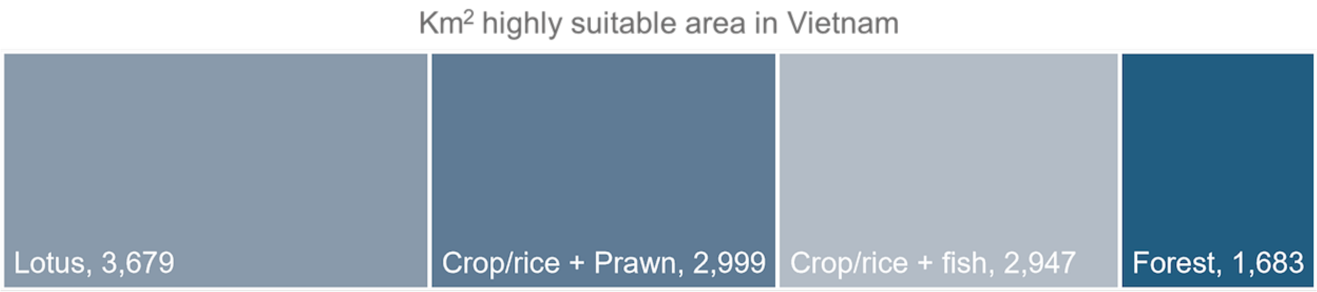
- (i) winter-spring rice, (ii) lotus
- (i) lotus (& fish)

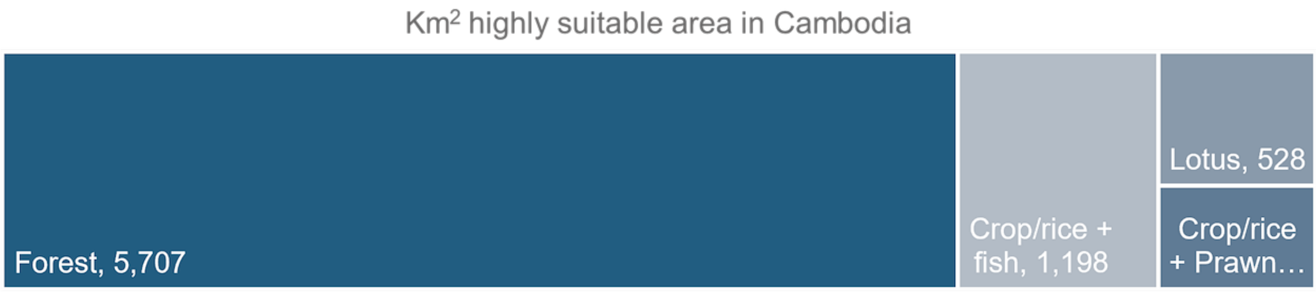


Forest

- (i) melaleuca timber plantations

Flood-based agriculture has a large technical potential for upscaling in Vietnam and Cambodia. The figure below shows the suitable area in km^2 per major flood-based agriculture type.





In Vietnam, the potential lies in farming cycles that include inundation-tolerant cash crops like lotus and freshwater aquaculture, such as prawn (giant freshwater prawn) and fish stocks.

In Cambodia there is also a potential for farming cycles that include inundation-tolerant cash crops or freshwater aquaculture. While the Melaleuca Forest offers the most technical potential for upscaling, other flood-based agricultural practices are economically more viable. Consequently, the overall scalability potential of the Melaleuca Forest is considered moderate.

3.3.3 Technical upscaling map

3.3.4 Upscaling potential maps

Below are the maps of suitable areas for the types of flood-based agriculture groups: Prawn (giant freshwater prawn), fish stocking, Lotus farming and Melaleuca forests. Dark green areas indicate high suitability, while yellow areas indicate lower suitability.

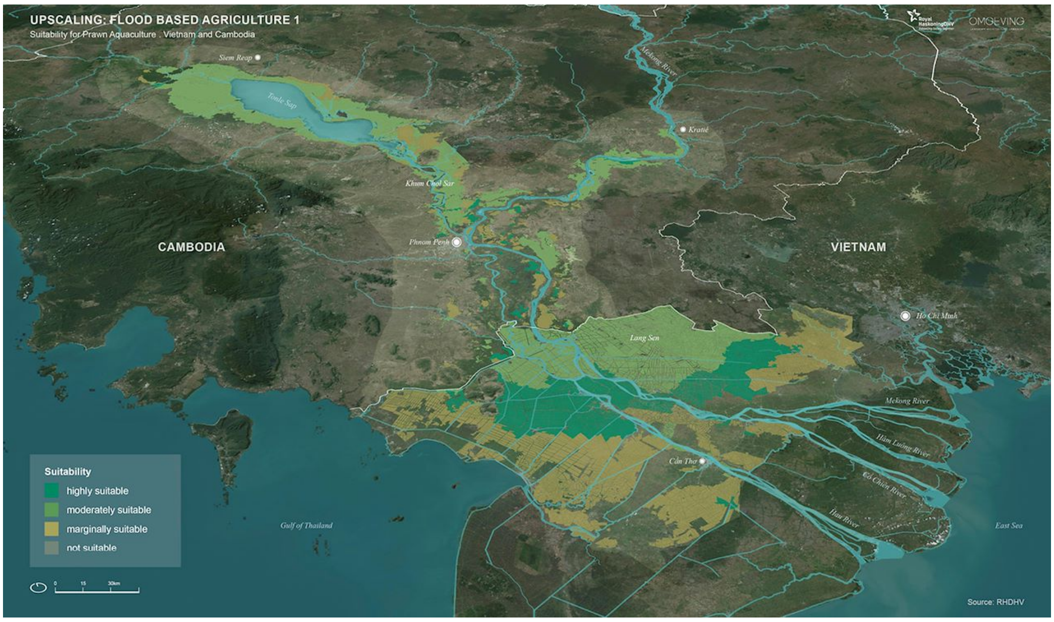


Figure: Suitable areas for Prawn Agriculture

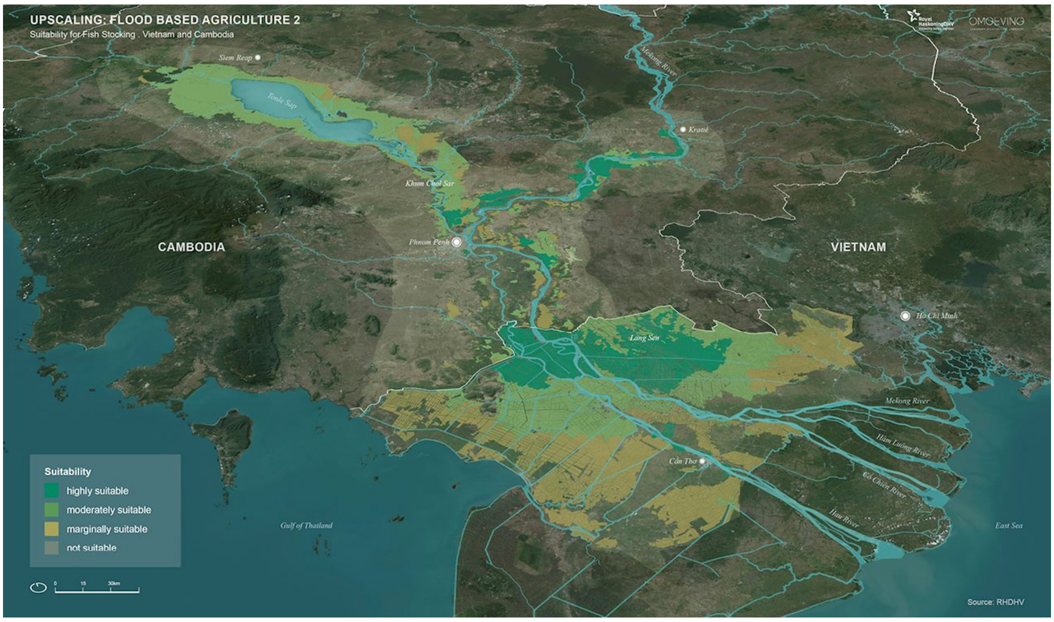


Figure: Suitable areas for fish stocking

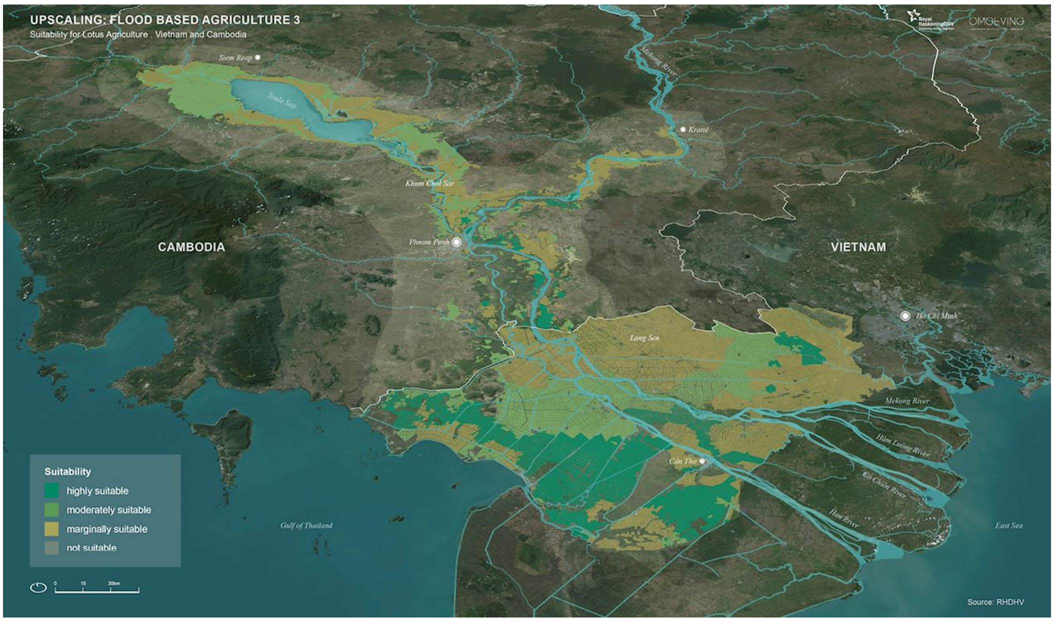


Figure: Suitable areas for Lotus Agriculture

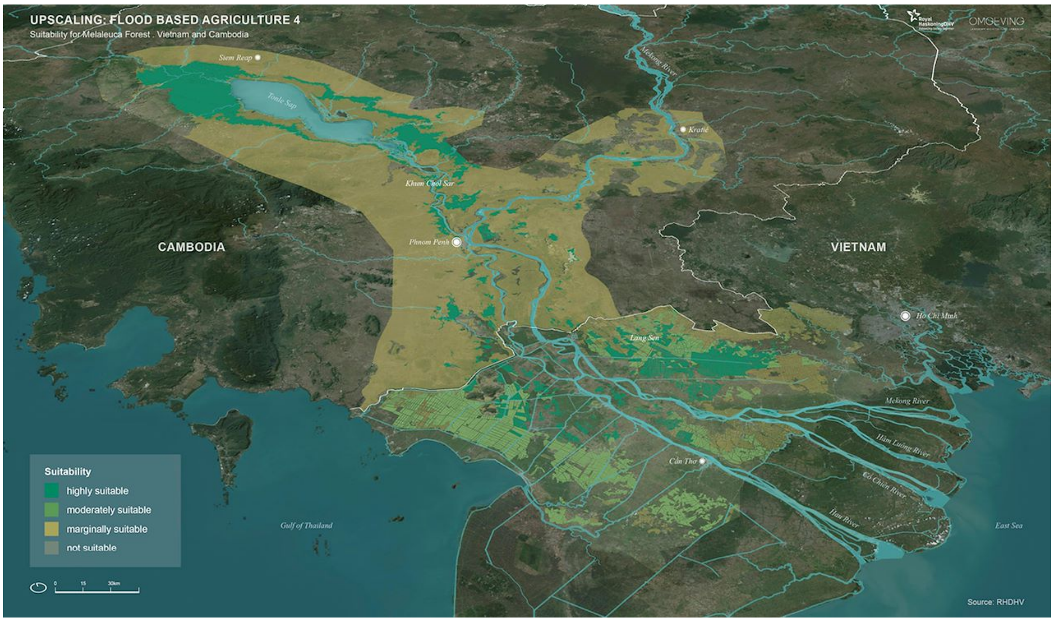


Figure: Suitable areas for Maleuca forest

3.3.5 Underlying methodology NbS 1

3.3.6 Methodology technical feasibility NbS 1

This map aims to showcase which areas are suitable for flood-based agriculture projects. Our methodology for analysing suitable areas for flood-based agriculture is based on two guiding principles:

- The area is currently protected by a dike and is therefore disconnected from the flood plain.
- The current biophysical conditions of an area are suitable for the specific agricultural practice.

Approach

The spatial potential of the selected NbS types is mapped by overlaying different geospatial datasets, like hydrologic, soil and climatic data. This provides a first high-level indication to the effective geographic scalability of NbS. The suitability for a specific NbS is, where possible, classified in 4 classes: highly suitable, moderately suitable, marginally suitable and not suitable.

The methodology applied for this study is derived from previous conducted studies by Royal HaskoningDHV for WWF on "*Upscaling of Flood-Based Agriculture in Mekong Delta in Viet Nam*" and for The World Bank Group on "*Assessing Land Suitability, Water Management Conditions, and Climate Risks in the Mekong Delta Region (2021-2030), with an Outlook to 2050.*"

All suitability factors that are described below were classified into two categories, an area is either suitable or not suitable given that suitability factor. Should any of the factors render an area unsuitable, regardless of the scores from other factors, the area is automatically labelled as unsuitable for this NbS. Inundation depth further classifies an area in marginally, moderately or highly suitable for flood-based agriculture.

The suitability class - highly, moderately or marginally suitable, thus depends on two factors:

- If the area is suitable given all suitability factors.
- If an area is highly, moderately or marginally suitable given the inundation depth suitability factor.

Suitability components for Flood-based Agriculture

Soil Type

Certain types of flood-based agriculture requires specific soil conditions. For example, Melaleuca Forest is mostly suitable on the acid sulphate soils.

Inundation depth

Dikes will need to be modified to be able to let the floods in, but flooding depth is then determined by the depth that an area would naturally flood in absence of flood protection.

Flood protection

Existing flood protection system: Suitable areas should currently be safeguarded by dykes and are therefore disconnected from the river.

Salinity intrusion

Some agricultural/ aquacultural activities are more vulnerable to salinity intrusion. For instance, Prawn (Giant freshwater prawn) exhibit low tolerance to saline conditions, whereas Melaleuca forests are more resilient to salinity.

Inundation Depth

The flood with an exceedance probability of 10% is used to determine the area classification related to inundation conditions. The classification of flood depth in the Mekong Delta is based on the experience in agricultural production and similar flood studied carryout by Southern Institute of Water Resources Research for the Mekong Delta. The following 5 classes have been identified within this classification:

- No flooding
- Low flood (inundation depth < 50cm)
- Medium flood (inundation depths of 50-100 cm)
- High flood (inundation depth 100 - 200 cm)
- Very high flood (inundation depth >200 cm)

Suitability factors classification, score and sources

The three tables below describe the classification scheme used per suitability factors, how the classified suitability factors are grouped into suitability score bins, and the sources of the suitability factors.

Suitability component categories scheme

The table below describes the classification scheme used per suitability factors.

Component	Code	Classification
Soil characteristics **(G)**	G1	Sand
	G2	Alluvium
	G3	Heavy saline soil and saline soil under mangroves
	G4	Low and medium saline soil
	G5	Potential acid sulphate soil (low active salinity) (0-50 cm)
	G6	Potential acid sulphate soil (high active salinity > 50 cm)
	G7	Potential acid sulphate soils (low active 0-50cm)
	G8	Potential acid sulphate soils (high active > 50cm)
	G9	Acrisol
	G10	Peat soil
	G11	Ferralsols
	G12	Others
	G13	Raised bed soil
Inundation depth caused by flood with 10% probability **(F)**	F1	Not flooded
	F2	Low (< 50cm)
	F3	Medium (50 - 100 cm)
	F4	High (100 - 200 cm)
	F5	Extremely high (> 200 cm)
Flood control conditions **(I)**	I1	Not flooded
	I2	Full flood prevention (with high dike system)
	I3	Semi flood prevention system (with a low dike system)
Salinisation: Salinity intrusion caused by low flow event with 85% exceedance probability **(Sa)**	Sa1	No salinity intrusion (concentration < 1g/l for duration < 1 month)
	Sa2	Salinity intrusion from 1 g/l to 4 g/l for duration 1 - 3 months
	Sa3	Salinity intrusion with concentration of 4 g/l to 10 g/l for duration 4-6 months
	Sa4	Salinity intrusion with concentration of 10 g/l for duration > 6 months

Suitability scoring scheme

The table below describes the scoring used per suitability factor.

Flood-based Agriculture type	Natural indicators	Highly Suitable	Moderately Suitable	Marginally Suitable	Not suitable
Crop/Rice & Prawn (Giant freshwater prawn	Soil (G)	G2, G4, G6, G8, G9, G5, G7, G10			G1, G3, G11, G12, G13
	Flood depth (F)	F4	F3, F5	F2	F1
	Flood prevention (I)	I3, I2			I1
	Salinity intrusion (Sa)	Sa1, Sa2			Sa3, Sa4
Crop/Rice & Fish	Soil (G)	G2, G4, G6, G8, G9, G5, G7, G10			G1, G3, G11, G12, G13
	Flood depth (F)	F5, F4	F3	F2	F1
	Flood prevention (I)	I2, I3			I1
	Salinity intrusion (Sa)	Sa1, Sa2			Sa3, Sa4
Lotus	Soil (G)	G2, G4, G6, G8, G9, G5, G7, G10			G1, G3, G11, G12, G13
	Flood depth (F)	F3	F4	F5, F2	F1
	Flood prevention (I)	I2, I3			I1
	Salinity intrusion (Sa)	Sa1, Sa2			Sa3, Sa4
Melaleuca forest	Soil (G)	G5, G7, G8, G10, G6, G2, G9			G1, G3, G4, G11, G12, G13
	Flood depth (F)	F2,F3, F4, F5		F1	
	Flood prevention (I)	I1, I2, I3			
	Salinity intrusion (Sa)	Sa1, Sa2, Sa3, Sa4			

Suitability components sources

The table below describes the data source per suitability factor.

No.	Data	Data source
VIETNAM		
1	Dykes	MDIRP, 2022
2	Flood inundation depth	Vietnam Mekong Flood maps, RHDHV Vietnam
3	Soil maps	MDIRP, 2022
CAMBODIA		
1	Flood inundation	MRC
2	Soil maps[1]	MRC Planning Atlas, 2011

1 *The soil source map used for Vietnam and the soil source map used for Cambodia have different soil typology systems. To ensure consistency, we have reclassified the Cambodian soil map to match with the soil types utilized in the Vietnamese soil map.*

3.4 Financial feasibility

3.4.1 Context

The Upper Vietnamese Mekong Delta comprises an extensive river, floodplain and canal network with seasonal movement of water in the floodplain. The area has undergone rapid changes in river flow regimes due to various factors, including the conversion of natural landscapes into agricultural and aquaculture facilities, urbanization, upstream development of hydropower dams, and the influence of climate change. These changes have had significant impacts on the overall function of the floodplain and the responses of wetland ecosystems. As a result, the main problems faced are the deterioration of soil quality and texture and reduced elevation of floodplains, caused by the disconnection of floodplains in an agricultural region, because of the development of dike systems. NbS that could address these problems are to rehabilitate, restore, and enhance natural floodplain dynamics and to implement flood-based agriculture. River mainstreams can re-establish connections with the floodplain, which in turn revitalizes the floodplain's role. This helps improve soil quality by depositing essential fertile sediments, increases and maintains the elevation of the floodplain and, at the same time, reduces the risk of floods in the agricultural area and potentially downstream, by storing water in the flooding season and releasing it slowly. Flood-based adaptation of agriculture can provide a sustainable alternative to intensive farming, such as triple-crop rice.

The case study location for the proposed NbS is the area surrounding Lang Sen Wetland Reserve, see Figure below. The total area is about 21,000 ha of which the Wetland Reserve covers 3,200 ha and the remaining area is mostly used for agriculture and aquaculture. Two villages are located in the area, and people live along the canals and levees. The case study area could be reconnected to main rivers through existing canals, and culverts can be installed in existing dikes to allow an area to periodically flood. As this is a large area, it could be redeveloped for flood-based agriculture in phases. For the financial analysis, it is assumed that initially, 500 ha will transition to flood-based agriculture.

On a larger scale, improving natural floodplain dynamics and flood-based agriculture could be established in areas that are suitable for the technical feasibility analysis. The highly feasible area for Group 2 (rice with fish stocking) in the Mekong Delta in Vietnam is 2,947.26 km^2 or 294,726 ha (see Table below). For the financial analysis, it is assumed that 25% of this area will transition to flood-based agriculture. This would be a total of 73,681 ha. For Cambodia, 25% of the highly suitable area for Group 2 would be a total of 29,947 ha. Hence, the total area of a basin-wide project would be 103,628 ha. The other groups are not considered as they have lower revenues or because of lacking data.

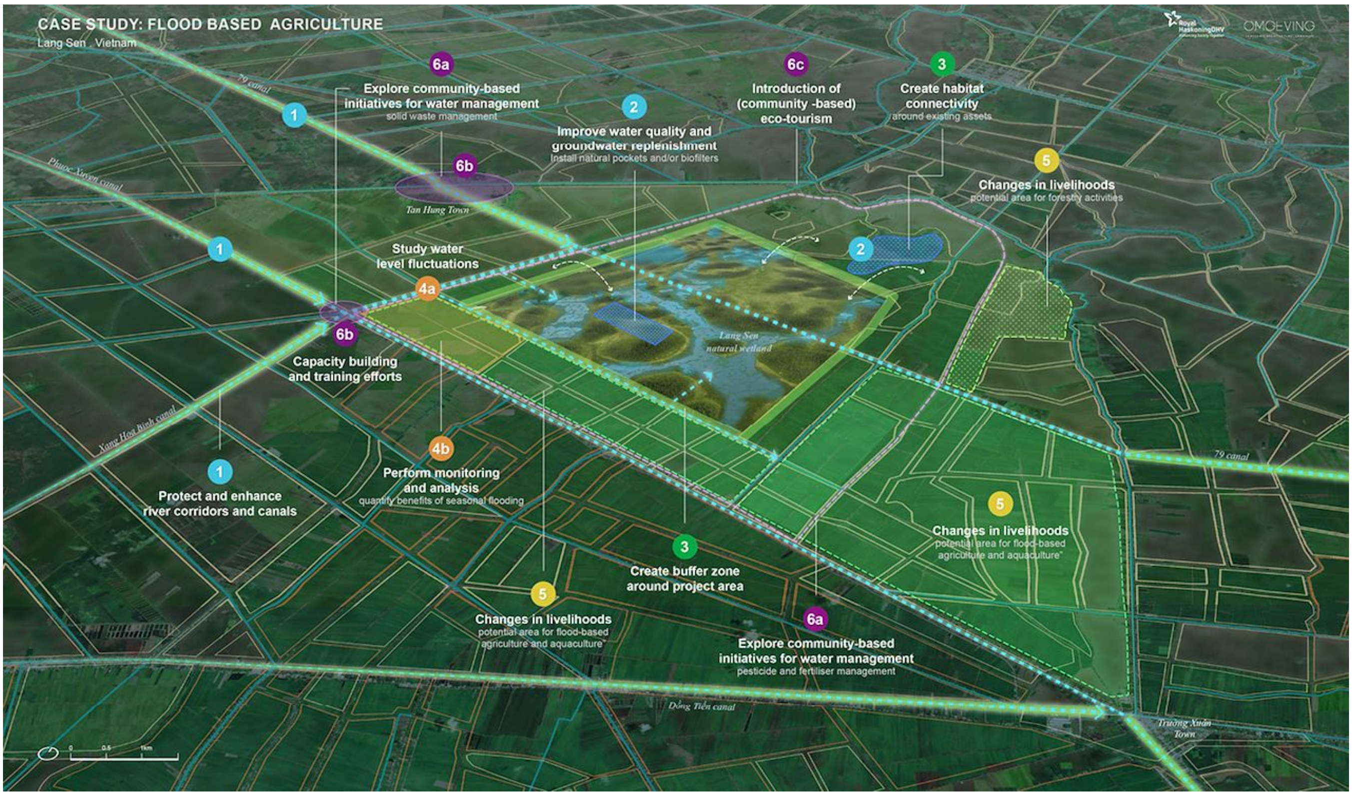


Table. Suitability statistics per group for Vietnam and Cambodia (km2)

Country	Group	Not suitable	High suitable	Moderate	Marginally
Vietnam	Group 1	8,590.11	2,998.69	3,853.26	5,295.85
Vietnam	Group 2	8,590.11	2,947.26	3,904.69	5,295.85
Vietnam	Group 3	5,712.91	3,679.03	3,459.34	7,886.63
Vietnam	Group 4	13,578.53	1,682.91	3,024.62	2,451.85
Cambodia	Group 1	35,131.24	408.51	7,655.49	1,754.93
Cambodia	Group 2	35,131.24	1,197.88	6,866.11	1,754.93
Cambodia	Group 3	33,360.13	528.08	4,825.27	6,236.68
Cambodia	Group 4	7,439.70	5,707.33	0.12	31,803.01

Note: Group 1 is rice/upland crop + (giant) freshwater prawn, Group 2 is rice/upland crop + fish stocking, Group 3 is rice + lotus or lotus with fish, Group 4 is Melaleuca timber plantations

Improving natural floodplain dynamics with flood-based agriculture would involve many stakeholders, including a large number of government agencies. These stakeholders can be categorised into the following main groups:

Stakeholder group	Involvement
Farmers / households / farming cooperatives	Direct beneficiaries of the project, are expected to change their farming model
Private sector companies	Potential beneficiaries of the project, adjusting to new or different business opportunities
Government organisations	Design, implementation and support of the projects
Funders	Provide loans, funds and other forms of financing for the project
Society	At a larger scale, social, economic and environmental co-benefits will affect society

In addition to these stakeholders, others can be identified, such as NGOs, knowledge institutions and contractors. However, these are not expected to be the main beneficiaries or responsible for the costs of the project and hence are not included in the financial and economic analysis. Note that there could be some overlap in stakeholder groups, e.g., government organisations could also be funders.

3.4.2 Reference alternative

The reference alternative is the scenario in which the NbS will not be implemented. Intensive agricultural practises, in which the land is kept free from flooding as much as possible through levees and grey infrastructure, and employing a model with three rice crops annually, are continued, both at the project level and at the basin level. The reference alternative assumes that no incremental investment costs are required to sustain the current systems, yet it is acknowledged that over time agricultural production is not sustainable and hence production may stall or decline, and costs of production increase substantially, mainly due to more fertiliser and pesticide use.[1] In the long run, a possible scenario is a severe decline in agricultural production of the Mekong Delta due to the sinking of soils below sea level and reducing soil fertility. However, this would be beyond the current project horizon.

[1] See Tran, D. D., van Halsema, G., Hellegers, P. J., Ludwig, F., & Wyatt, A. (2018). Questioning triple rice intensification on the Vietnamese mekong delta floodplains: An environmental and economic analysis of current land-use trends and alternatives. Journal of environmental management, 217, 429-441.

3.4.3 Project alternative

The project consists of improving natural floodplain dynamics and conversion to a flood-based agriculture/ aquaculture model. This requires some structural measures related to the water system to re-create a connection between the main river and the farmland and non-structural measures related to improving and/or restoring ecology and habitats. It also requires activities to support households and communities to transition to flood-based agriculture and aquaculture, such as outreach and training. Finally, it involves engaging other stakeholders, including those in the supply chain. For instance, for branding and promoting of farmer output and technical and organisational support. This will ultimately lead to a situation in which the benefits and co-benefits of flood-based agriculture are generated sustainably.

At the basin scale, it is assumed that the case study project would be replicated up to the point where 25% of the highly suitable land area has transitioned to flood-based agriculture. Implementing projects at the basin scale would likely lead to scale advantages in costs and benefits.

In economic and financial analyses, the project period or project horizon is relevant as cash flows are discounted to a present value and different stakeholders have different time horizons. The project may be regarded as having an infinite lifetime as the switch to flood-based agriculture would be permanent. However, households and private sector stakeholders may have a horizon of one to a few years, as they would like to see relatively short-term returns on their efforts and investments. Public sector investments and societal benefits have much longer horizons as infrastructure generally has a lifespan of several decades and some effects may only materialise in the long run. Costs and benefits also need to be placed in a timeline, and for this, it is assumed that for the local scale project implementation takes 2 years and that at the basin scale, it takes 10 years to achieve the 25% conversion to flood-based agriculture. A project horizon of 50 years, from 2024 to 2073, is assumed.

3.4.4 Identification and selection of effects

The identification of effects is one of the most important steps and is done by comparing the project alternative with the reference alternative and identifying the incremental costs and benefits of the project alternative. Following the action-process-services-benefits approach, nine tangible benefits and one intangible benefit were identified, as shown in the figure at the botom of this page. In addition, the project would result in a change in the agricultural model. Although this is not directly an ecosystem service, the change in agricultural production due to a change in the agricultural model is important to include in the analysis. Carbon credits and biodiversity credits are identified as potential financing mechanisms, though are not counted as benefits for people as they are considered financial transfers from one group of stakeholders to another group of stakeholders.

The effects are different at different scales and for different stakeholders. As ultimately everyone could benefit from each service through indirect effects, only the most directly affected stakeholder groups are considered. In the table below, the column "Scale of benefits" indicates if benefits are predominantly present if a project is done locally or at a basin scale. Yet, through aggregation local benefits are also present at basin scale.

Table. Benefits by scale and stakeholder

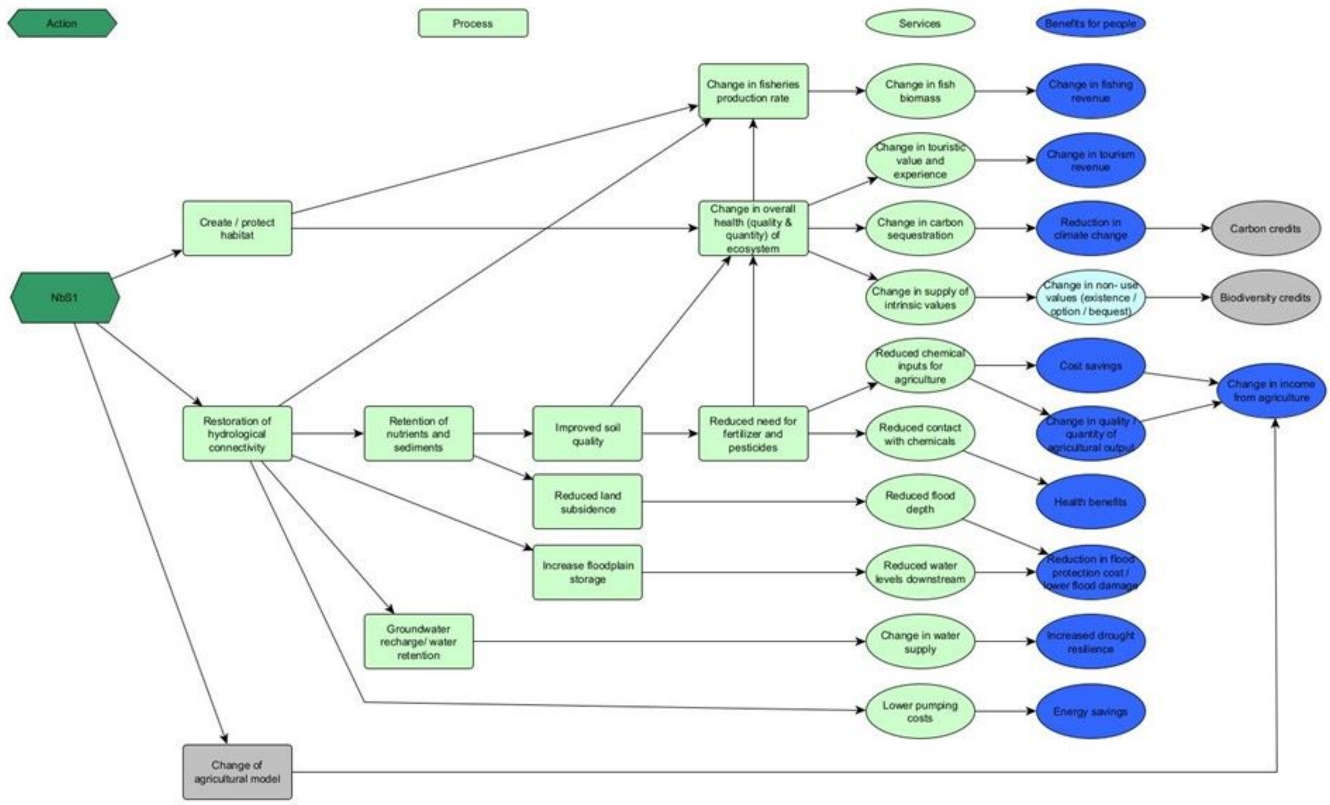
No.	Benefits for people	Scale of benefits	Stakeholders	Comments
1	Change in fishing revenue	Basin, with benefits expected to increase with scale	Farmers / households & private sector companies	Private sector companies could benefit from new market opportunities (e.g. dried fish value chain). Note that aquaculture revenue is included under No. 6.
2	Change in tourism revenue	Local	Private sector companies & households	
3	Reduction in climate change and associated effects	Basin, with benefits expected to increase with scale	Society	This is a global benefit and would ultimately also benefit the basin and local societies; carbon credits could benefit farmers / households.
4	Change in non-use values	Local & basin	All	All stakeholders have non-use values, also at the global scale, but the specific non-use values differ considerably among stakeholders.
5	Cost savings	Local	Farmers / households	This can be aggregated at the basin scale.
6	Change in quality / quantity of agricultural outputs	Local	Farmers / households & private sector companies	This can be aggregated at the basin scale.
7	Health benefits	Local	Farmers / households	
8	Reduction in flood protection cost / lower flood damage	Basin	Society	There might also be some local flood protection benefits
9	Increased drought resilience	Local	Farmers / households	Farmers are mostly affected by droughts, though impacts could be aggregated at the basin scale
10	Energy savings	Local	Farmers / households	This can be aggregated at the basin scale.

An effect that is not displayed in the figure below is the cost of the project. Implementation of the project comes with structural and non-structural costs for different stakeholders. Structural costs for the water system are generally borne by government organisations (though could be financed by other organisations), but ultimately are borne by society through taxes and fees. Non-structural costs are borne by government organisations, funders and farmers / households. Potential costs related to flood-based agriculture are related to:

1. Protection and enhancement of river corridors
2. Installation of culverts
3. Creating / maintaining habitat connectivity, e.g. through land zoning, regulations and planting of vegetation and install or designate buffer zones through land zoning and regulations
4. Installation or designation of buffer zones
5. Installation of natural pockets and / or biofilters
6. Studies, monitoring & analysis
7. Change of agricultural model

8. Initiating payment for ecosystem services to (former) landowners
9. Organised eco-tourism
10. Limiting activities / enforcement / community based water management

In the first instance, all identified tangible and intangible effects are selected for inclusion in the CBA. However, only a limited number can be quantified and monetised.



Quantification and monetisation of effects

3.4.5 Benefits

1. Change in fishing revenue

At the local scale, increases in fishing and aquaculture revenues are captured under the change in income from agriculture due to the change in the agricultural model.

At the basin level, recent estimates indicate that the economic value of the Mekong fishery dropped by more than a third between 2015 and 2020[1]. The estimated annual value of fish catches was estimated between USD 7.13 billion and USD 8.37 billion in 2019-2020.[2] While it is difficult to estimate the impact of flood-based agriculture on wild fisheries income in the basin in the absence of quantitative data, assuming that implementing the project in 25% of the highly suitable areas would only result in a 0.1% increase in fisheries, the revenues would generate about USD 7.75 million in annual benefits if the middle of the range of the 2019-2020 estimated annual value of fish catch (USD7.75 billion) is taken as a base.

[1] Cowx IG, Lai TQ and So N (2024). Fisheries Yield Assessment by Habitat Type at The Landscape Scale in The Lower Mekong

River Basin 2020. Vientiane: Mekong River Commission Secretariat.

[2] Ibid

2. Change in tourism revenue

At the local scale, the project could include components to attract tourists to the area. Tram Chim National Park received, pre-Covid, about 100,000 visitors per year, while the number of visitors in 2023 was about 60,000. Tram Chim is, however, a large well-known national park, while at Lang Sen Wetland Reserve there is no specific ecotourism component, although there are some simple visitor facilities. At this moment, Lang Sen is not open to the public, and only accessible to groups with academic- and/or research- purposes. However, it could be made suitable to open to the public in the future. If opened for tourism, it is assumed that the project would result in 10,000 additional visitors per year (10% of Tram Chim pre-Covid), who are assumed to generate an added value of USD 10 per visitor. Hence, the total annual benefit would be USD 100,000.

At the basin level, ecotourism cannot be implemented at all sites, as the total market demand for ecotourism is limited and not all sites are suitable, e.g., in terms of accessibility. In total, it is assumed that there would be 5 additional ecotourism sites throughout the basin, each would generate USD 100,000 per year, hence in total USD 600,000 per year.

3. Reduction in climate change and associated effects

Through the creation and protection of habitat, the project could contribute to increased carbon sequestration. Increased carbon sequestration reduces greenhouse gases in the atmosphere, mitigating climate change, and hence benefiting people as a reduction in climate change and associated effects compared to a baseline without the project. This benefit can be valued through the amount of carbon sequestered by vegetation and a social price for carbon. However, rice production causes significant emissions of methane, nitrous oxide and carbon dioxide.[1] A change to flood-based agriculture likely impacts these emissions, but further research is required to determine exactly the changes in emissions. Hence, at this stage, it is not possible to assess the net impact of the project on greenhouse gases and the resulting benefit of climate change mitigation. As such, it cannot be quantified in the CBA.

[1] https://blogs.worldbank.org/en/eastasiapacific/greening-rice-we-eat

4. Change in non-use values

Non-use values are numerous and different for each person. Such values include bequest values (leaving something for the next generation), existence values (attaching value to knowing that something exists, for instance, expressed to donations to charity) and option values (not using it now, but maybe in the future). A monetary estimate of non-use values can generally only be obtained by asking people for their willingness to pay to conserve or enhance certain habitats, ecosystems or ecosystem services.

While there are some studies on non-use values of wetlands in the Lower Mekong Basin, the results cannot be easily translated for use in the CBA in this study, as they are site-specific and because of methodological issues in using values derived from site studies at a larger, basin, scale. An example is an estimation of the biodiversity values of Tram Chim National Park (Do and Bennett, 2007)[1] which found that the aggregated values for a wetland conservation program resulting in an increase in healthy vegetation, an increase in the number of Sarus cranes and an increase in the number of fish species are about USD 3.9 million. This gives a clear indication that there are significant non-use values that could support the decision to implement projects.

The change in non-use values could be linked to the potential value of biodiversity credits. Biodiversity credits are a verifiable, quantifiable and potentially tradeable financial instrument that rewards positive nature and biodiversity outcomes (e.g., species, ecosystems and natural habitats) through the creation and sale of either land, freshwater or ocean-based biodiversity units over a fixed period.[2] The market for biodiversity credits is, however, still at an early stage of development and the pricing of biodiversity credits is still largely unknown.

[1] Thang Nam Do and Jeff Bennett, Estimating Wetland Biodiversity Values: A choice modelling application in Vietnam's Mekong River Delta, Australian National University Economics and Environment Network Working Paper EEN0704, 2007.

[2] World Economic Forum: https://initiatives.weforum.org/financing-for-nature/home

5 & 6. Change in agricultural income: cost savings and change in quality / quantity of agricultural outputs

Agricultural production and resulting agricultural income is evaluated together with the change in quality and quantity of agricultural outputs, as they both ultimately lead to a change in agricultural income for households and potentially the private sector through supply chains.

The impact on income from agriculture and aquaculture is the result of many individual effects. Firstly, there are changes in inputs, including labour, fertiliser, pesticides, irrigation, rice seeds, and fish seedlings, that in the aggregate lead to cost savings. Secondly, there are changes in outputs including changes in the quality and quantity of the yield, new outputs such as fresh and dried fish, and products from water hyacinth. In total, this leads to a change in incomes for households and the private sector through supply chains. WWF conducted a pilot study under the Climate Resilient by Nature programme that can be used to gauge the impacts of the project on income from agriculture. Table 3-4 shows the financial results of flood-based agriculture for a full production cycle for 2022 and 2023 and intensive triple rice crops for 2022 as a comparison. The table shows that the production costs for flood-based agriculture are considerably lower than for intensive triple rice crops. However, revenues are also substantially lower, leading to a lower profit, or income from agriculture for households.

While in those two years, the financial benefit from the project was negative, these results need to be seen in the context of the pilot project. It is expected that soil health will increase over time as a result of flood-based agriculture, thereby increasing the productivity of conventional rice crops and floating rice crops over time. As supply chains for the products from fisheries and aquaculture have not been established yet, the production resulted in a local, temporary oversupply, resulting in low prices. The global price of rice also increased by about 3% in 2022 and 21% in 2023 due to geopolitical tensions (War in Ukraine) and adverse weather conditions (El Nino) making intensive triple rice crops relatively more attractive due to higher output. Hence, the results are very much determined by market conditions.

In the CBA it is conservatively assumed that the change in income from farming due to the project is zero. The following arguments support this. Firstly, as value chains become more established (e.g., good distribution channels for outputs), prices for fish and other aquaculture products would be more stable and higher. Secondly, rice from flood-based agriculture could command a premium price that might be sufficiently large to bridge part of the gap caused by the higher output from intensive triple rice crops. This will depend, however, on global market conditions and the right value chains and marketing/certification of flood-based rice. Thirdly, the required input from fertiliser would increase over time due to deteriorating soil conditions in the intensive triple rice cropping system, while productivity would decrease due to soil degradation and pesticide use. Fourthly, households in the pilot study also earned from harvesting water hyacinth and water hyacinth knitting and fish trap making, which also makes up part of the difference from conventional agriculture. Hence, over time it is expected that flood-based agriculture can compete with intensive triple rice cropping.

	2 rice crops + floating rice integrated fish		2 rice crops + aquaculture		Intensive triple rice crops
	Results 2022	Results 2023	Results 2022	Results 2023	Results 2022
Production cost	1,887	1,846	1,591	2,049	3,050
Revenue	3,936	4,209	3,260	3,580	5,547
Profit	2,049	2,362	1,669	1,531	2,497

An intangible income-related benefit is that flood-based agriculture could provide a more stable household income as it is more climate and flood-resilient. Besides intangible social benefits from a more stable income, it could also support economic development. As the risk of loss of income or investments due to natural hazards decreases, households would be more inclined to invest their incomes, rather than saving for bad times. However, it is outside the scope of this study to estimate such benefits.

For private sector companies, upgrades in the value chain could lead to improved product quality and value, new sources of income, reduction of unit cost and increased scale of production and consumption.[1] This would lead to increased income and value-added from the private sector. The rice value chain in the Mekong Delta is, however, a large and complex system, linking thousands of small-scale rice farmers to large numbers of traders, processors, wholesalers, retailers, and exporters. Hence, it is difficult to quantify the change in revenues of the private sector due to the project. In line with the assumption for household income, it is assumed that there may be some shifts in revenues between products (e.g., less fertiliser sold, more fisheries revenues), but overall it is assumed that the net effect is zero.

[1] Source: Report on solutions for upgrading the value chains of products from livelihood activities in the project area – Tan Hung district, Long An province, Vietnam.

7. Health benefits

If farmers and other people in the local community are less exposed to chemicals, this would lead to health benefits. Theoretically, health benefits could be quantified and monetised as reduced medical expenditures, avoided loss of working days due to illness, or an increase in expected healthy living years. However, as data on the impact of specific chemicals on health is not available, this benefit cannot be quantified in this study.

8. Reduction in flood protection cost / lower flood damage

The introduction of the NbS at the basin level would lead to flood risk reduction downstream, as the storage capacity for flood waters increases. In addition, increased inundation would result in the deposition of sediments, partly mitigating the effects of land subsidence and aiding in maintaining the elevation of the delta. Almost every year, floods cause damage to agriculture, infrastructure and buildings and lead to loss of lives, which might be reduced with greater water storage upstream to reduce peak flows. Reduced flood levels could result in lower required protection levels, and hence lower costs for flood protection infrastructure.

In terms of water storage, it is estimated that flood-based agriculture could store 740 million m^3 of flood waters in Vietnam and 300 million m^3 in Cambodia, leading to a flood depth reduction of 0.7 and 0.3 meters respectively in the Mekong River, see Appendix A. However, assessing the quantitative impact of implementing flood-based agriculture on resulting flood damage reduction and flood protection is complex.[1] and hence only a very rough indication of the benefits can be given. The average annual cost of floods in the Lower Mekong Basin ranges between USD 60 to 70 million.[2] Assume the project would contribute to a 1% reduction in damages this would be USD 600,000 to 700,000 annually.

[1] See for instance Thanh, V. Q., Roelvink, D., Van Der Wegen, M., Reyns, J., Kernkamp, H., Van Vinh, G., & Linh, V. T. P. (2020). Flooding in the Mekong Delta: the impact of dyke systems on downstream hydrodynamics. Hydrology and Earth System Sciences, 24(1), 189-212 on the complexity of modelling and considerations to assess changes in the floodplain on flood levels.

[2] Mekong River Commission: https://www.mrcmekong.org/our-work/topics/flood-and-drought/

9. Increased drought resilience

Closely related to the reduction of flooding, the NbS would also lead to increased resilience to drought through groundwater replenishment. There is, however, no data available to quantify this effect. Groundwater replenishment however is very important to mitigate further subsidence, and thereby also indirectly positively affects flood risk.

10. Energy savings

A flood-based agricultural model would reduce the dependency on pumping and hence reduce the pumping costs. It is assumed that the benefits of energy savings are included under the change in agricultural income as a reduction in the costs of inputs.

Summary of benefits

The table below provides a summary of the benefits.

No.	Benefit item	Estimate project site (USD/year)	Estimate basin (USD/year)
1	Change in fishing revenue	-	7,750,000
2	Change in tourism revenue	100,000	600,000
3	Climate change mitigation	N/A	N/A
4	Change in non-use values	N/A	N/A
5	Cost savings	Included under 6	Included under 6
6	Change in quality / quantity of agricultural outputs	0	0
7	Health benefits	N/A	N/A
8	Reduction in flood damages and flood protection costs	0	650,000
9	Change in drought resilience	N/A	N/A
10	Energy savings	Included under 6	Included under 6
	Total annual benefits	100,000	9,000,000

3.4.6 Costs

The table below gives an overview of the cost estimates for the project site and basin. Note that these estimates are all very indicative and based on currently available data.

For the project, it is assumed that the investments costs are spread over two years at the beginning of the project period. Operational costs (items 1 and 10) are annual.

Table. Cost estimates and assumptions

No.	Cost item	Estimate project site	Estimate basin
1	Protection and enhancement of river corridors	USD 400 / year	USD 82,900 / year
2	Installation of culverts	USD 0	USD 82,902,400
3	Creating / maintaining habitat connectivity	No costs, part of overall planning and management costs, see 7	No costs, part of overall planning and management costs, see 7
4	Installation or designation of buffer zones	No costs, part of overall planning and management costs, see 7	No costs, part of overall planning and management costs, see 7
5	Installation of natural pockets and / or biofilters	USD 2,500	USD 518,140
6	Studies, monitoring & analysis	USD 50,000	USD 10,362,800
7	Change of agricultural model	USD 200,000	USD 33,160,900
8	Initiating payment for ecosystem services to (former) landowners	N/A	N/A
9	Organized eco-tourism	USD 25,000	USD 125,000
10	Limiting activities / enforcement / community-based water management	USD 3,000 / year	USD 621,768 / year
	Total Capital Expenditure	USD 277,500	USD 127,069,300
	Total Operational Expenditure	USD 3,400 / year	USD 704,670 / year

Notes for the calculation of costs

- Item 1: Costs for protection and enhancement of river corridors and canals that lead to the designated areas. For the main canals, it is assumed maintenance costs are similar to in the reference alternative, though operation and maintenance practices may change. For the smaller connecting canals, enhancement and maintenance (e.g., clearing vegetation, dredging, stabilising canal banks with plantings) along 10% of the length is assumed. The length of smaller canals in the project area is assumed to be 2 km. Cost is assumed to be 2 USD per metre (this is based on the cost of dredging, which is 2 USD/m^3). Maintenance is an ongoing process, and it is assumed that it needs to be conducted annually. To arrive at a basin estimate, the costs on a local scale are multiplied by the increase in area (i.e., an area 10 times larger would cost 10 times more). In this case, the area for upscaling is about 200 times larger (103,628 ha) than the area assumed for the case study scale (500 ha).

- Item 2: Installation of culverts or other water control structures to let the water in periodically and lower or remove embankments. Existing water control structures may be sufficient to manage flooding in the case study area as it is sufficiently low-lying. If the project is upscaled to the basin, more investments in water control structures may be needed in areas with less favourable conditions. A sluice gate under a dike would cost about USD 800,000 and annual operating and maintenance costs would be around USD 8,000 (1% of investment costs). At basin scale, it is assumed that one culvert per 1,000 ha is required.
- Items 3 and 4: Creating habitat connectivity/corridors/buffers around existing assets. It is assumed that the acquisition of land is not needed. Planning and management of land use can achieve connectivity and corridors. This would involve planning, legislation (e.g., banning pesticide use), management costs (manpower), and costs to support farmers in implementing the measures. These costs are included as a one-time project cost under item 7.
- Item 5: Installation of natural pockets and/or biofilters to enhance and improve water quality and groundwater replenishment. This would require some earthworks. It is assumed that per 1,000 ha, 0.25 ha or 2,500 m^2 needs to be deepened for USD 5,000, based on 1 m depth and earth moving costs of USD 2 per m^3.
- Item 6: Studies and monitoring costs: flood-based agriculture and NbS would require studies on water level fluctuations to understand flooding duration and frequencies, and monitoring and analysis of the effects on agriculture, biodiversity and sedimentation. To some extent, these costs would replace other costs of water management in the Mekong basin and would decline over time as more experience is gained with flood-based agriculture. An amount of USD 50,000 per project area of 500 ha is included as costs, and costs are scaled to the basin scale based on the proportional increase in area.
- Item 7: The costs to transition to flood-based agriculture could include outreach and engagement costs to convince farmers to make the transition. Outreach and engagement costs can also aid in obtaining buy-in from suppliers and buyers in the value chain, training costs of farmers, and project management costs. These costs would entail additional manpower for governments, technical support costs, project management costs, project execution costs and training costs. Based on the project conducted by WWF, these costs are estimated to be USD 200,000 per project area of 500 ha. At the basin level, we assume that costs are 20% lower due to economies of scale.
- Item 8: Setting up a system for payments for ecosystem services (carbon credits, biodiversity credits or other) requires a certain scale to cover fixed costs. These costs are currently unknown.
- Item 9: The costs of building a simple visitor centre and developing an ecotourism strategy, brochures, etc. are estimated to be USD 25,000. Ecotourism could not be implemented at all sites, as the total market demand for ecotourism is limited and not all sites are suitable, e.g., in terms of accessibility. In total, it is assumed that 5 sites could have ecotourism, with a budget of USD 125,000 in total.
- Item 10: It is assumed that enforcement costs would be USD 500 per month or USD 6,000 per year per 1,000 ha

3.4.7 Discussion of results

The table below shows the results from the CBA. The results are indicative due to the assumptions being made, but some conclusions can be drawn from them. Firstly, both at the site level and at the basin level flood-based agriculture is economically viable. Over the lifetime of the project, the net present values (NPV) are positive, while the benefit-cost ratios (BCR) are above 1. The internal rates of return (IRR) of 30.2% and 8.7% show that there is a high return on investment.

Secondly, at the site level, it turns out that there is only one tangible benefit – ecotourism revenues. The change in the agricultural model does – under the present assumptions – not generate any tangible economic benefits at the site scale or basin scale, though there are intangible benefits, such as health benefits and non-use benefits. At the basin scale, the benefits of fisheries are about 86% of the total benefits. Without benefits for fisheries, the project would not be viable as the benefits from ecotourism and reduced flood risk would not be able to cover the costs of the project. However, considering the potential of a severe decline in agricultural productivity and output over the long run due to the lack of seasonal flooding, leading to soils sinking below sea levels and reducing fertility, even without the benefits of fisheries the project could be viable beyond the current project horizon.

Thirdly, the study of Do and Bennett (2007, see footnote 6) shows that there are considerable non-use values, which could already cover the costs of several projects. Non-use values are, however, intangible and would not contribute to the funding of the project.

Table. Results of the CBA for flood-based agri- and aqua-culture, Present USD values at 6% discount rate over a 50 year project lifetime.

Indicator	Value for Site	Value for Basin
Total lifetime costs	USD 0.32 million	USD 105.41 million
Total lifetime benefits	USD 1.48 million	USD 132.88 million
NPV	USD 1.16 million	USD 27.47 million
BCR	4.62	1.26
IRR	30.20%	8.70%

3.4.8 Financial analysis

To make (parts of) projects financially viable, they need to generate tangible revenue streams that can be captured by a stakeholder. However, aside from revenues from ecotourism, there are no tangible revenue streams resulting from the projects. Ecotourism may contribute to funding the project at some of the wetlands linked to flood-based agriculture projects, though it is unlikely that it could fund a substantial part of the project. Revenues from ecotourism will go directly to the households and private sector companies as they sell their services, and only for instance an entrance fee or license fee paid by households and private sector companies could provide funding for the projects.

Biodiversity credits and carbon credits are a form of Payment for Ecosystem Services (PES). PES might provide a viable avenue for funding flood-based agriculture, though there are many challenges in setting up such schemes.[1] One of the challenges is financial viability: financial viability requires sufficient, stable, and sustained payments for project investment and operational costs and acceptable rates of return for project investors (including public financers seeking societal benefits). While biodiversity credits could contribute to the overall funding of the projects, this is still a largely undeveloped market. Other ecosystem services, including the most important one – an increase in fisheries – are difficult to capture under a (privately funded) PES scheme. Certification of some form of rice and other products from flood-based agriculture may provide a more viable way to increase revenues and convince farmers to adopt it.

Hence, public funding would need to cover the majority of the expenses.

[1] See Canning, A. D., Jarvis, D., Costanza, R., Hasan, S., Smart, J. C., Finisdore, J., ... & Waltham, N. J. (2021). Financial incentives for large-scale wetland restoration: Beyond markets to common asset trusts. One Earth, 4(7), 937-950.

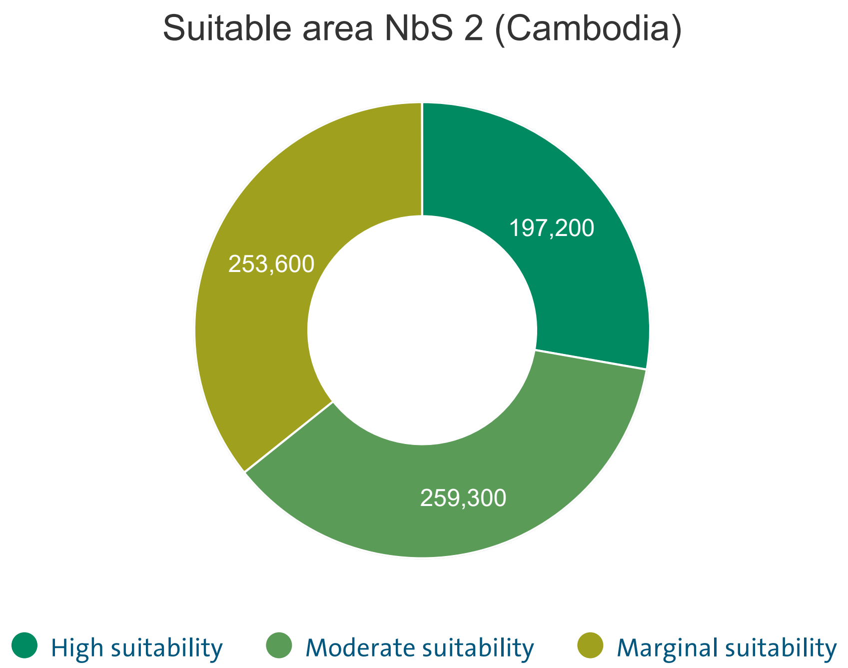
4 Improving the flooded forest ecosystem

4.1 Introduction

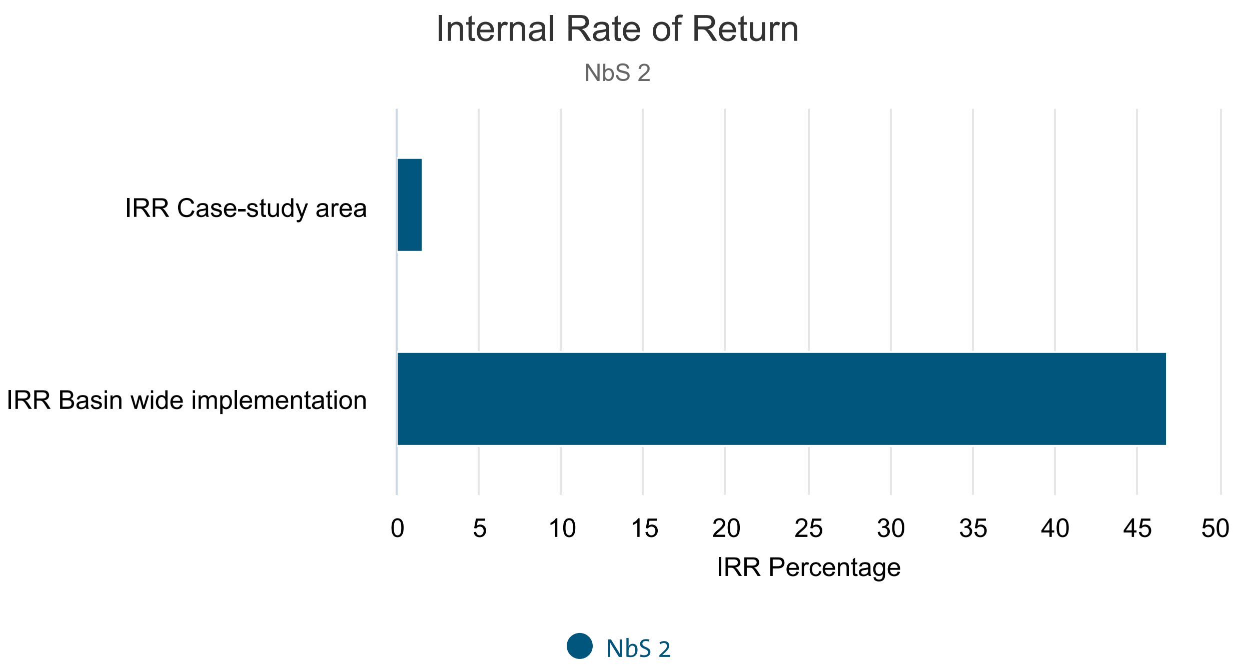
4.1.1 Improving the flooded forest ecosystem

Flooded forest is a specific type of ecosystem characterized by the regular inundation of water due to the natural flooding of the Mekong River. Within this region, the flooded forests are adapted to the seasonal rise and fall of water levels, creating a dynamic environment that supports diverse flora and fauna. These areas are vital for the Mekong River's ecology, providing habitat for various species and contributing to the overall health of the river ecosystem.

Suitable area



Internal Rate of Return



Background
In the Mekong Basin, the flooded forest is mainly located between the Strung Treng to Kratie region and around the Tonle Sap Lake. These areas, however, are markedly different from each other. The stretch from Stung Treng to Kratie features a rock-based, fast-flowing riverine environment, whereas the Tonle Sap area is a sedimentary lake environment influenced by both tributaries and lake conditions.

Ongoing developments in the Mekong Basin, particularly the construction of hydropower dams, have brought about changes in river flows and flood patterns. The effects of these changes are most noticeable in the dam's vicinity and gradually decrease downstream in the lower Mekong Basin. These modifications significantly affect the hydrology of the flooded forest, resulting in permanent inundation in specific areas. One specific example of such impact has been studied in Tonle Sap Lake.

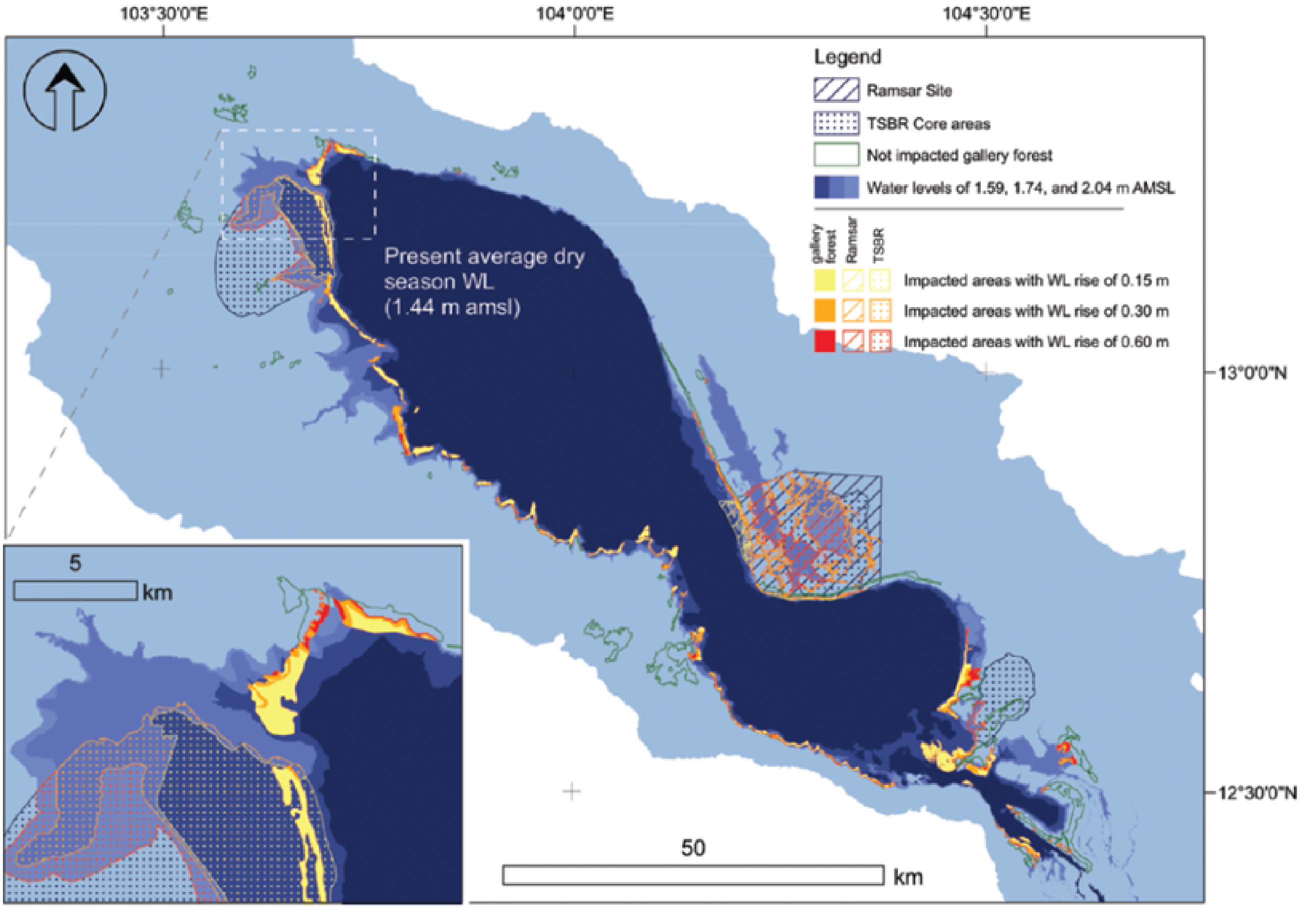
4.1.2 Threatened areas identification

4.1.3 Identify areas that are threatened to deteriorate

According to Kummu and Sarkkula (2008), cumulative impact assessments suggest that dry-season water levels are expected to rise, while wet-season water levels are likely lower than the current conditions. Moreover, the Tonle Sap Lake is filled with sediment from rivers. In contrast, significant river bed incision occurs in the main branch of the Mekong, reducing the water level and thereby the duration of reversal flow into the lake. These changes in the main stem of the Mekong directly impact the flood pulse of Tonle Sap Lake and the surrounding flooded forest. Utilizing data from the Mekong River Commission, Asian Development Bank (ADB), and Adamson (2001), it is estimated that the increase in dry-season water levels could elevate the water level in Tonle Sap Lake by 0.15 – 0.6 meters, posing a potential threat to the existing lake ecosystem.

Kummu and Sarkkula (2008) used simulations to visually show potential inundation areas resulting from elevated dry-season water levels, with increments of 0.15 m, 0.3 m, and 0.6 m, as depicted in Figure below. In the Ramsar core site, covering 149 km^2, the simulations suggest that 6% to 83% of the area could be affected. Similarly, within the Tonle Sap Biosphere Reserve, with a total area of 423 km^2, the simulations indicate potential inundation of 13% to 42% of the total area. The key point here is that even small increases in dry-season lake water levels may lead to the permanent submersion of relatively large, flooded forest areas, possibly impacting aquatic productivity and posing a threat to the livelihoods of those dependent on the affected ecosystems, especially for the inland fishing community.

Given the scenario, it becomes crucial to initiate planning for interventions that compensate for the anticipated loss of the flooded forest.



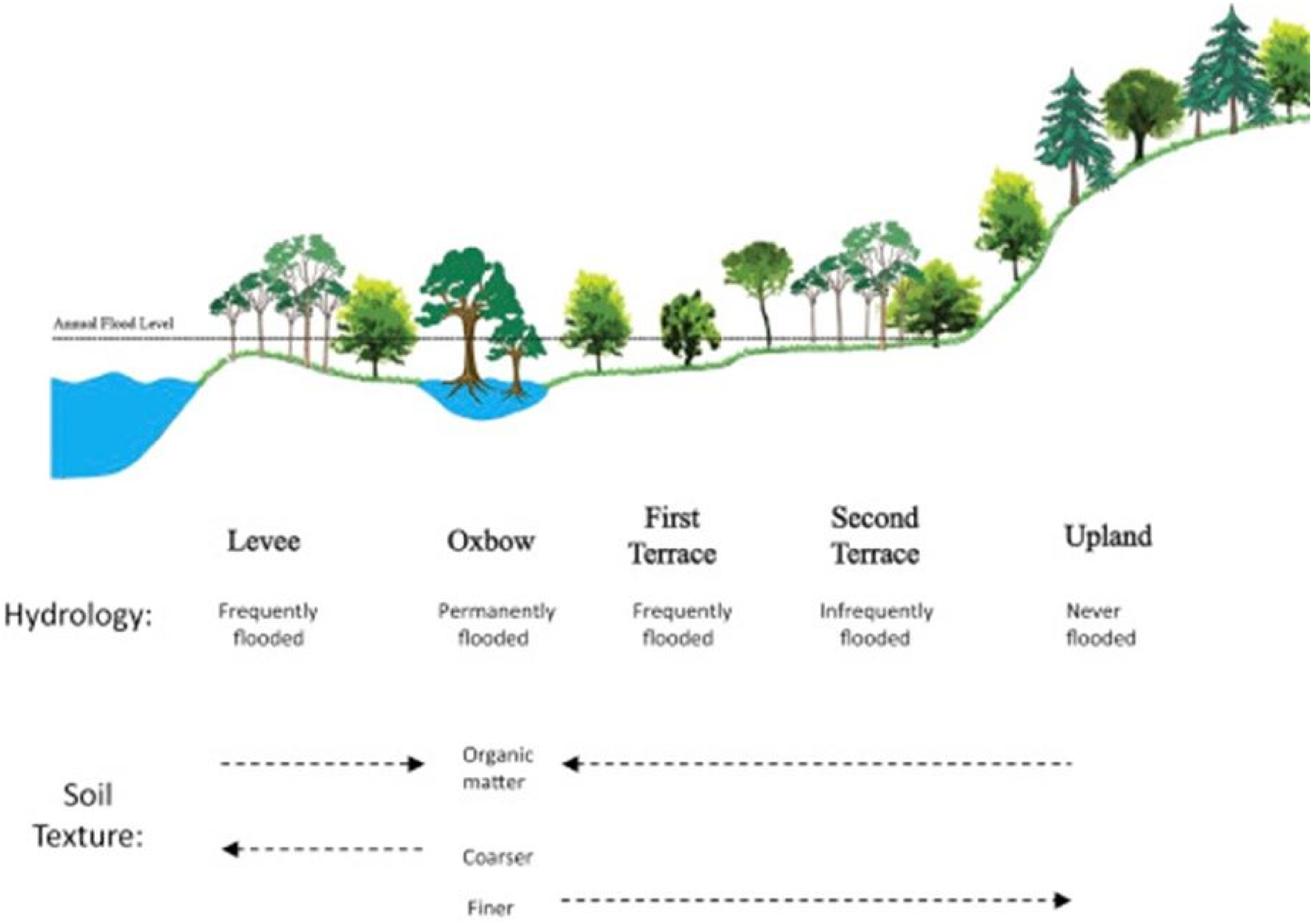
Example of impacted areas that occurred in gallery flooded forest (solid colour), Ramsar site (hatched areas in lines), and Tonle Sap Biosphere Reserve (hatched areas in points) during simulation of dry-season water level (source: Kummu and Sarkkula 2008)

4.1.4 Protected areas identification

4.1.5 Identify areas that are worthwhile protecting

By referencing the inundation map created by Kummu and Sarkkula (2008), it is noticeable that certain sections of the flooded forest in Tonle Sap Lake remain unaffected by the inundation resulting from elevated water levels during the dry season. Notably, some of these non-impacted flooded forest areas are situated within the Ramsar Site and Biosphere Reserve, adding weight to their consideration due to their established status as conservation areas.

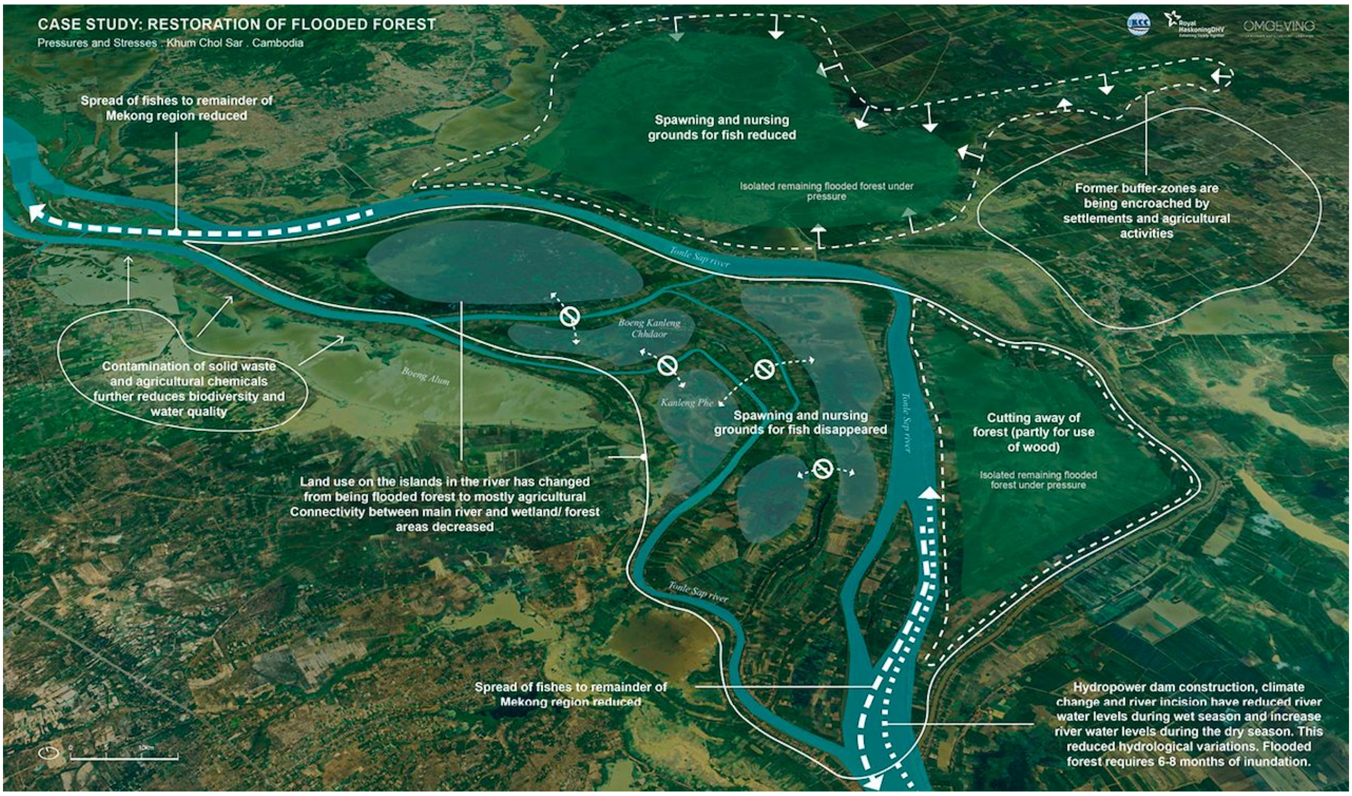
The ideal area for compensating the loss of flooded forest is characterized by a low risk of permanent inundation caused by the dry-seasonal flow pulse. Additionally, it should be a vacant space with limited human activity, or activities that can be relocated. Moreover, it is crucial that the chosen area experiences minimal hydrological disruption, ensuring proper sediment transport, nutrient flow, and functional river connectivity to support a successful revegetation process.



Cross-section of a forested floodplain wetland showing the major landforms and height of the annual flood pulse. Different assemblages of trees occupy the different habitats that vary with depth and duration of flooding (source: Craft, 2016)

4.2 Case study: Khum Chol Sar restoration of flooded forest

4.2.1 Stress & Pressure

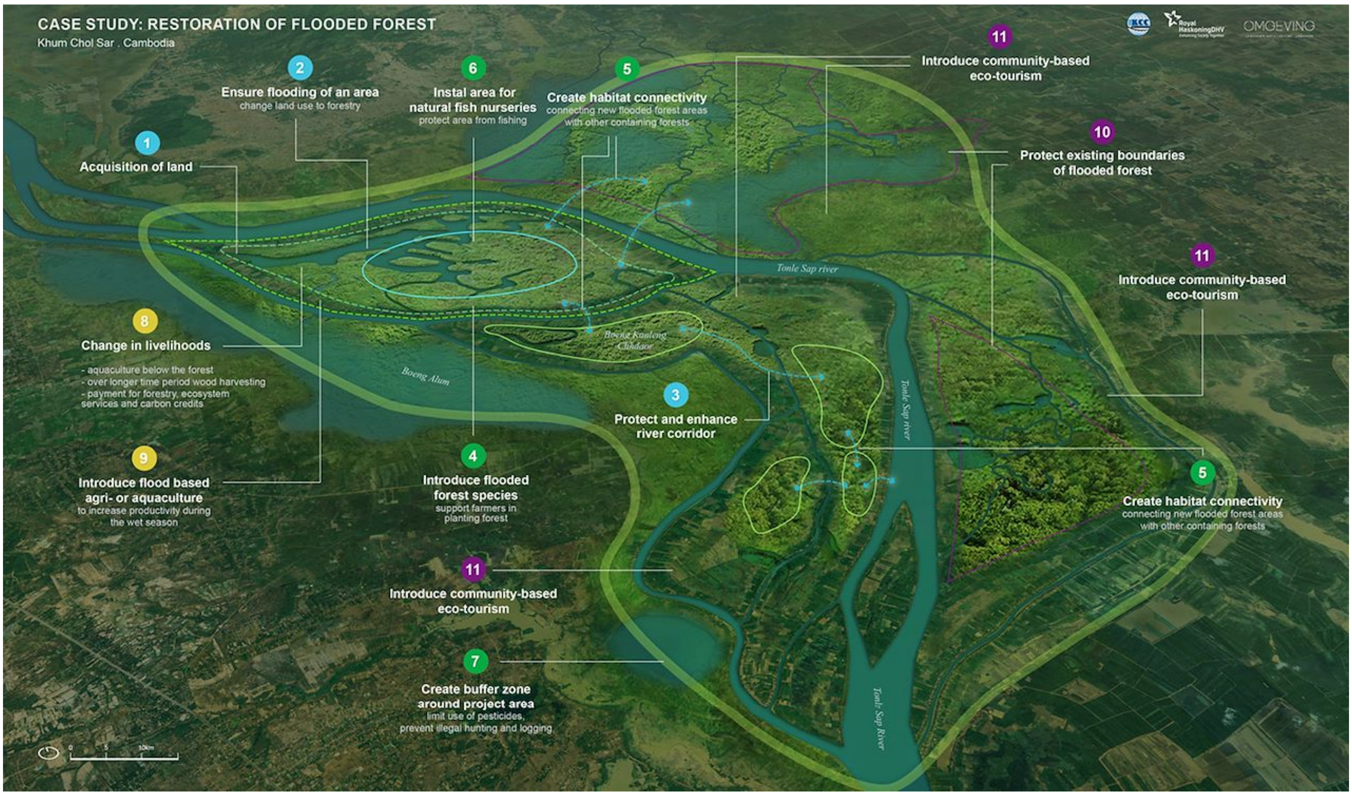


Uncontrolled encroachment of the flooded forest has led to declines in fish populations and reduced income from fishery. The conversion of flooded forest to agricultural land has destroyed the vital breeding grounds and nursery habitats for fish. Subsequently, fertilizers and pollutants are used on the converted lands, further deteriorating the water quality and further threatening the fish population. Furthermore, secondary causes for the local decline in the flooded forests and fish populations are forest fires and illegal fishing. The impact of low flows on rice and reduced income from fishery has further worsened the situation because to increase or maintain income, additional land is being converted for agricultural use.

Since 2018, approximately 10% of the flooded forest in the local area has vanished. There has been an estimated decline of 10-30% in fish catches during the same time period. On a larger scale, the loss of forest in the Mekong region is even more significant, leading to a staggering estimated decline of almost 90% in fish catches over the past 20 years.

On a larger scale, hydropower dam construction, climate change, and river incision have reduced river water levels during the wet season and increased them during the dry season, reducing hydrological variations. Parts of the original habitat of the flooded forest have, therefore, become unsuitable because the flooded forest thrives under certain months of inundation.

4.2.2 Potential NbS measures



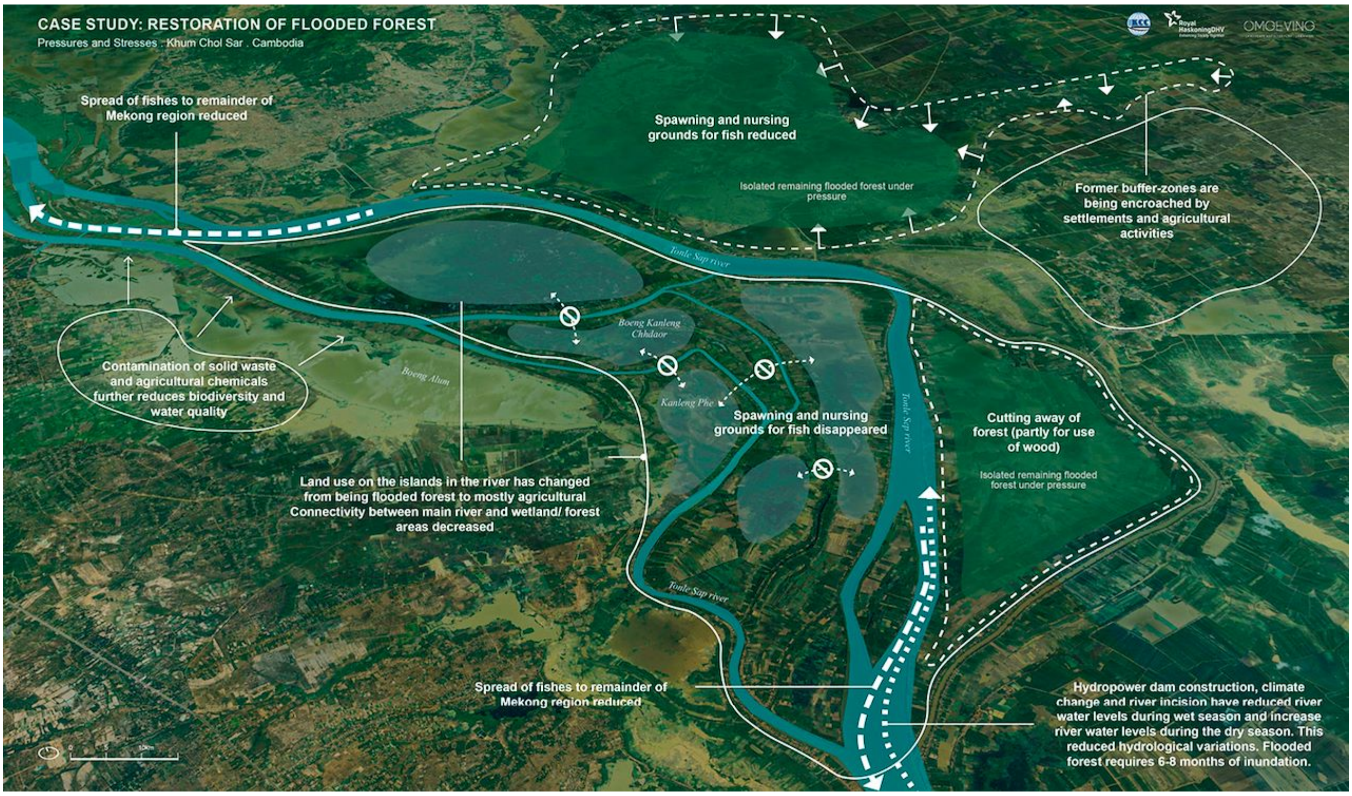
This case study area is located in Kampong Chhnang province, covering flooded forests along the Tonle Sap River, which connects the Mekong River with the Tonle Sap Lake. The area could be restored and protected by land acquisition, reconnecting low-lying areas, connecting habitats, protecting and restoring river corridors, and providing alternative livelihoods for farmers. Socio-economic actions are especially challenging in this complex social environment where people are very poor, and governance and enforcement of laws and regulations are weak. The main activities here would be to reduce further encroachment of the existing flooded forest, restore flooded forest where possible, and adjust livelihoods to guarantee a stable income.

Therefore, the main measures related to this case include purchasing land that is already capable of flooding 6-8 months a year **(1 & 2 in the figure above)** so that with some planting efforts, the area can be reforested **(4)**. Furthermore, the protection and enhancement of connections between existing patches of flooded forest **(3)** is considered an important measure. Those measures could be further enhanced with biodiversity measures, such as installing a buffer zone around the area, in which the use of pesticides and illegal logging are prohibited **(7)**. Besides, habitat connectivity can be improved and maintained around forest areas **(5)**. After all, the flooded forest facilitates the exchange of water, nutrients, and sediments between the river and the floodplain, supporting the ecosystem health. To increase fish stock and fish respawning, it is recommended to install zones designated for natural fish nurseries **(6)**: the submerged vegetation and complex structure of the forest provide shelter and food resources for juvenile fish, contributing to the overall productivity of the aquatic ecosystem.

The changes in land use also necessitate a shift in livelihoods, where agricultural activities transition to aquaculture beneath the flooded forest, wood harvesting over longer periods, and/or payment for ecosystem services (**8**). Although these changes may require further investigation, a case study in Vietnam has shown that flood-based agriculture or aquaculture can increase productivity during the wet season (**9**). This can partially compensate for the loss of income due to declining fish catches and reduced agricultural productivity, as well as the conversion of land from agriculture back to flooded forest. Further community-based activities include protecting the existing boundaries of the flooded forest (**10**), and there may also be opportunities for eco-tourism in the area (**11**).

4.2.3 Stress and pressure

4.2.4 Stress & Pressure



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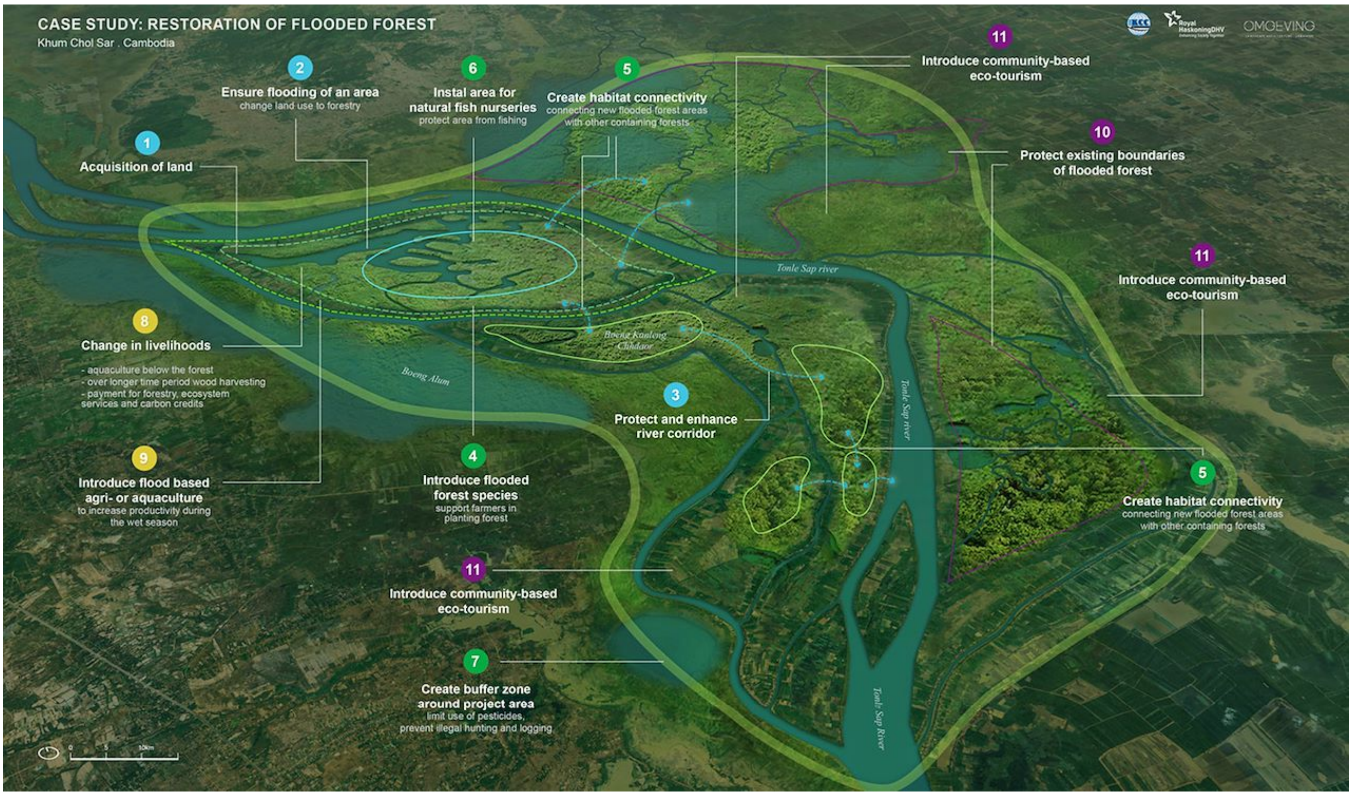

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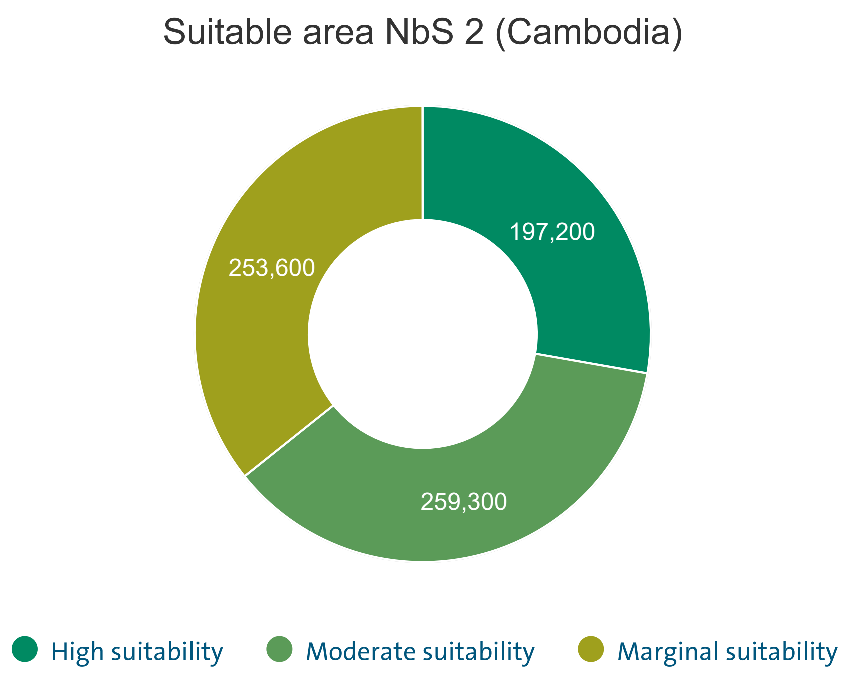
4.3 Technical feasibility

4.3.1 Technical upscaling potential

4.3.2 Upscaling potential

"Approximately 197200 hectares is highly suitable for reforestation - that is roughly 280,000 football fields"



To understand the upscaling potential, the suitability of the area for this NbS has been mapped. The upscaling potential for flooded forest restoration is large (i.e. 197200 hectares of highly suitable area). The relatively large potential has two main reasons.

Firstly, the conditions (e.g. Soil type and duration of inundation) are still very suitable for flooded forests. After all, flooded forest is the naturally occurring vegetation typology that would be present given the conditions of the areas surrounding the Tonle Sap Lake and Tonle Sap and Mekong River. Secondly, the flooded forest is mainly under pressure and degraded by anthropogenic pressure, such as encroachment by urban areas or conversion of forest areas into agricultural land.

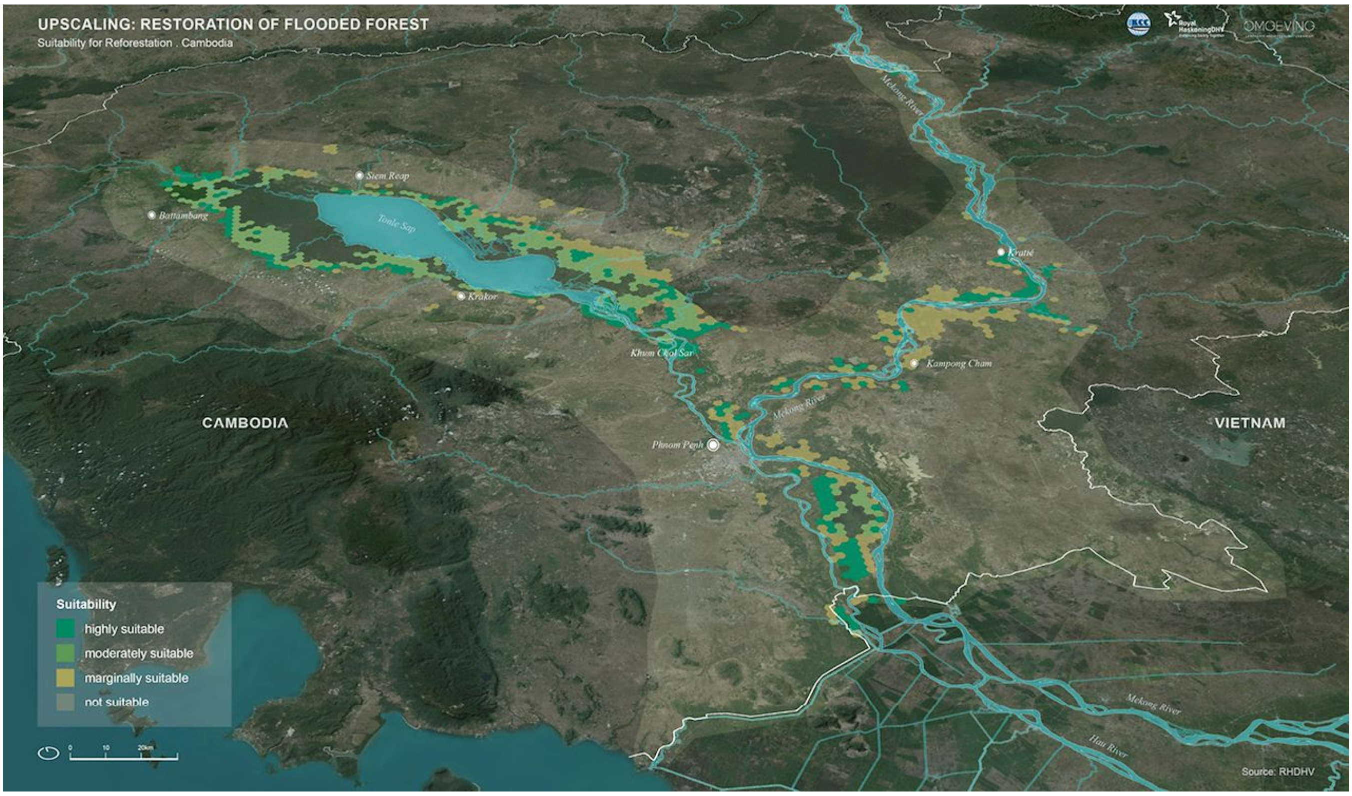
Urgent action is required to reforest and safeguard the remaining flooded forests. This includes protecting existing forests and designating areas for the restoration of flooded forests.

4.3.3 Technical upscaling map

4.3.4 Upscaling potential maps

The map below shows the suitability of restoration of the flooded forest in Cambodia. Areas in dark green are highly suitable for reforestation. In general, the following areas have potential for reforestation projects:

- Flooded forest along the fringes of the Tonle Sap lake. These areas are encroached due to anthropogenic pressures – mostly by human settlement and agricultural expansion towards the lake.
- Flooded forest along the Tonle Sap and Mekong River. These areas also have a high technical potential for upscaling reforestation projects. The shift of communities from fishing to agriculture (due to decreasing catch rates), particularly rice and other crops, has led to the conversion of flooded forest into new agricultural land. Nevertheless, the biophysical characteristics of these areas remain highly suitable for flooded forest to thrive.



4.4 Underlying methodology NbS 2

4.4.1 Methodology technical feasibility NbS 2

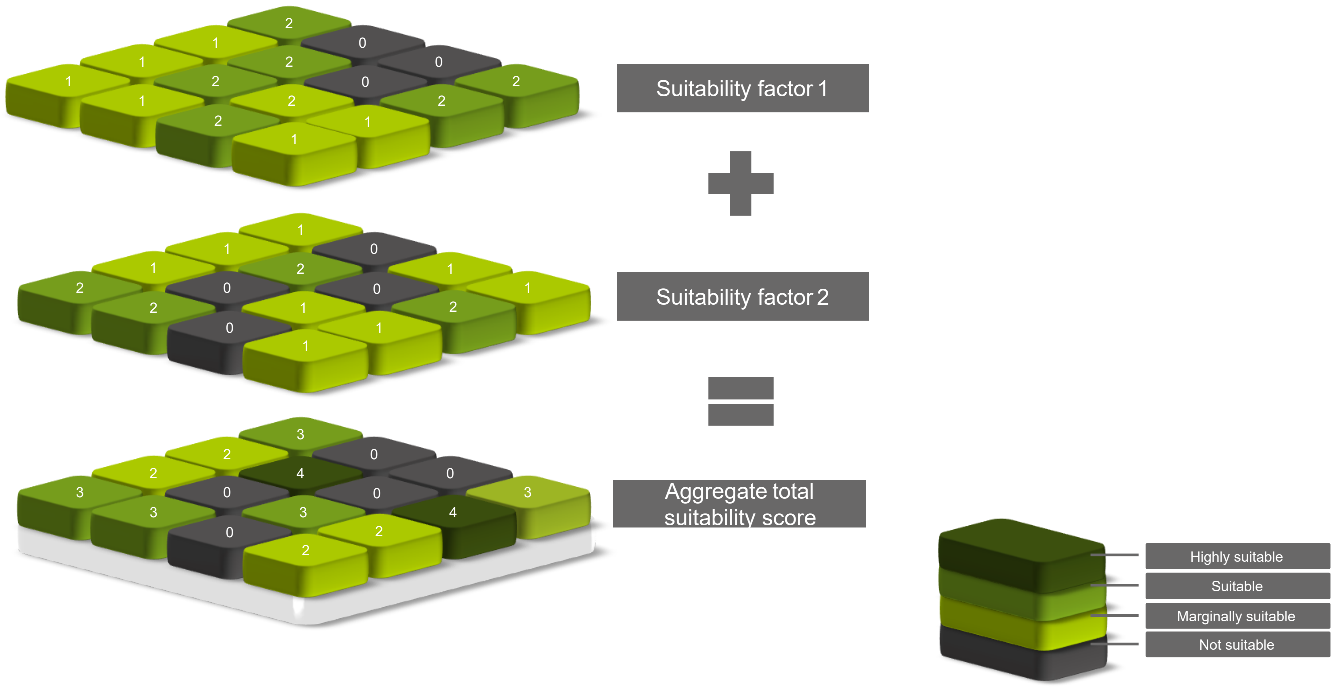
The objective of this map is to showcase which areas are suitable for flooded forest reforestation projects. Our methodology for analysing suitable areas for reforestation is based on two guiding principles:

- The flooded forest has undergone severe deterioration and reforestation projects will therefore have a large impact.
- The current biophysical conditions of an area should be suitable for flooded forest to thrive.

Approach

The spatial potential of the selected NbS types is mapped by overlaying different geospatial datasets, like hydrologic, soil, climatic data. This provides a first high-level indication to the effective geographic scalability of NbS. The suitability for a specific NbS is, where possible, classified in 4 classes: highly suitable, moderately suitable, marginally suitable and not suitable.

To assess the potential suitability for a specific NbS, several suitability factors we combined.



Each suitability factor dataset was scored using the following classification:

- Score of 0: Not a suitable area given the specific suitability factor
- Score of 1: Moderately suitable given the specific suitability factor
- Score of 2: Highly suitable given the specific suitability factor

After classifying each individual suitability factor, an aggregated suitability score was calculated by summing up all the scores to yield a single aggregated total suitability score. The suitability class - highly, moderately or marginally suitable, thus depends on the aggregate suitability score of all factors.

Furthermore, should any of the factors render an area unsuitable (score 0), regardless of the scores from other factors, the area is automatically labelled as unsuitable.

Suitability components for flooded forest reforestation

To assess the potential suitability for flooded forest reforestation projects three suitability factors were combined.

Flooded forest landcover and forest integrity

Flooded forest or flooded forest-related land use classes severely distressed and with a low forest integrity score are suitable areas for forest reforestation programs.

Soil Type

The suitability of an area for flooded forest reforestation partly relies on optimal soil conditions for a flooded forest to thrive.

Months of inundation

The suitability of an area for flood forest reforestation partly relies on the optimal duration of yearly inundation of an area.

Flooded forest integrity score

The Forest Landscape Integrity Index integrates data on observed and inferred forest pressures and lost forest connectivity to generate a continuous index of forest integrity as determined by the degree of anthropogenic modification. The study brought together 47 forest experts worldwide to apply recent developments in cloud computing and large new datasets.

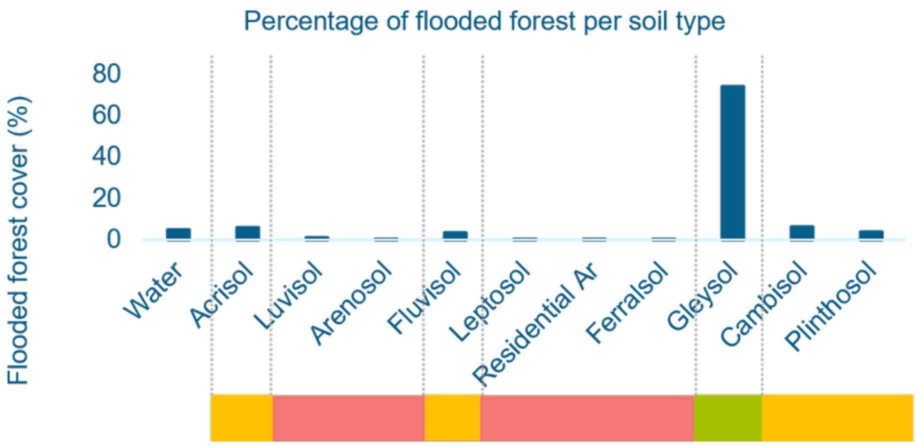
The Forest integrity score index was combined with flooded forest land cover to determine the integrity of flooded forests in Cambodia. The following classification system has been used:

- Highly suitable: Flooded forest cover with a forest integrity score of less than 5, meaning that the flooded forest in that area has a high degree of anthropogenic modification.
- Moderately suitable: Flooded forest cover with a forest integrity score between 5 and 8, meaning that the flooded forest in that area has a moderate degree of anthropogenic modification.
- Not suitable: Flooded forest cover with a forest integrity score of above 8, meaning that the flooded forest in that area has a low degree of anthropogenic modification.

Soil type

We combined the flooded forest land cover and a soil map to analyse in which soil conditions flooded forest thrives in Cambodia. The figure below presents the findings, illustrating the percentage of flooded forest coverage per soil type. This analysis has resulted in the following classification:

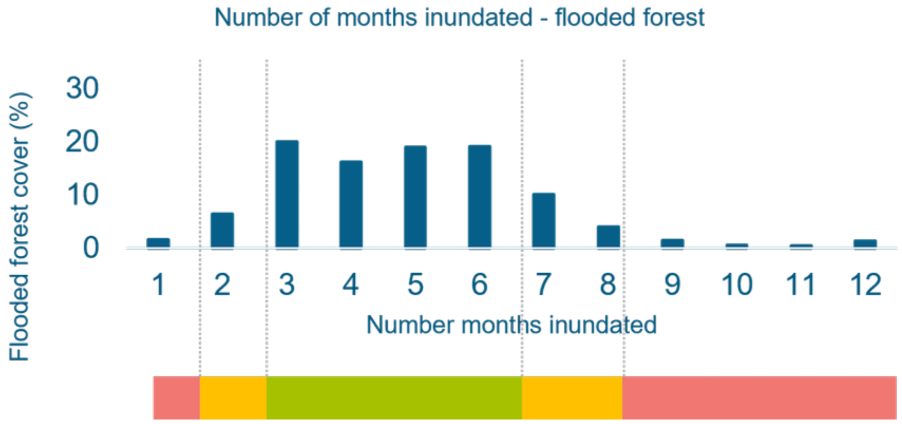
- i [Green] - Highly suitable: Gleysol
- ii [Orange] - Moderately suitable: Acrisol, Fluvisol, Cambisal, Plinthosol
- iii [Red] - Not suitable : All others



Duration of yearly inundation

We combined the flooded forest land cover and a dataset that shows the average months of yearly inundation to analyse in which inundation conditions flooded forest thrives in Cambodia. The findings are presented in the figure below, illustrating the percentage of flooded forest coverage across different durations of inundation in months. This analysis has resulted in the following classification:

- i [Green] - Highly suitable: 3 to 6 months of inundation
- ii [Orange] - Moderately suitable : 2,7 or 8 months of inundation
- iii [Red] - Not suitable: 0,1 or more that 8 months of inundation



Suitability factors classification, score and sources

Suitability factor classification scheme

The table below describes the classification scheme used per suitability factors.

No.	Component	Code	Classification
1	Land use **(L)**	L1	Flooded forest and related land covers types
		L2	All others
2	Soil characteristics **(G)**	G1	Optimal: Gleysol
		G2	Acrisol, Fluvisol, Cambisal, Plinthosol
		G3	all others
3	Forest Landscape integrity **(F)**	F1	Low forest integrity score (<5)
		F2	Moderate integrity score 5-8
		F3	High integrity score >8
4	N months inundated **(S)**	S1	3 – 6 months
		S2	2,7 or 8 months
		S3	1 month or more than 8 months

Suitability factor scoring scheme

The table below describes the scoring used per suitability factor.

Suitability component	Highly Suitable (Score = 2)	Moderately Suitable (Score = 1)	Not suitable (Score = 0)
Land use **(L)**	L1		L2
Soil **(G)**	G1	G2	G3
Forest Landscape integrity **(F)**	F1	F2	F3
Seasonally inundated area **(S)**	S1	S2	S3

Suitability factor sources

The table below describes the data source per suitability factor.

No.	Data type	Data source	Data description	Data type
1	Land use	MRC project: Land use cover	Land use cover	Raster (15x15m)
2	Soil map	MRC project: Soil map	Soil types	Polygon
3	Forest Landscape integrity	Grantham, H. S. et al. (2020). Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity. Nature communications, 11(1), 1-10.	four data sets were combined representing: (i) forest extent; (ii) 'observed' pressure from high impact, localized human activities for which spatial datasets exist, specifically: infrastructure, agriculture, and recent deforestation; (iii) 'inferred' pressure associated with edge effects, and other diffuse processes, (e.g. activities such as hunting and selective logging) modelled using proximity to observed pressures; and iv) anthropogenic changes in forest connectivity due to forest loss. These datasets were combined to produce an index score for each forest pixel (300m), with the highest scores reflecting the highest forest integrity, and applied to forest extent for the start of 2019.	Raster 300x300 m
3	Seasonally inundated area	Pekel, JF., Cottam, A., Gorelick, N. et al. High-resolution mapping of global surface water and its long-term changes. Nature 540, 418–422 (2016). https://doi.org/10.1038/nature20584	The Water Seasonality product provides information concerning the intra-annual behaviour of water surfaces. It separates 'permanent' water bodies (those that are present throughout the period of observation) [nominally a year] from 'seasonal' (those that are present for only part of the year); the degree of seasonality is also represented (i.e. the proportion of the total number of observed months in which water is present).	Raster (30x30m)
4	Water occurrence change	Pekel, JF., Cottam, A., Gorelick, N. et al. High-resolution mapping of global surface water and its long-term changes. Nature 540, 418–422 (2016). https://doi.org/10.1038/nature20584	The Water Occurrence Change Intensity product shows where surface water occurrence increased, decreased or remained invariant between 1984 and 2021. Both the direction of change (i.e. increase, decrease or no change) and its intensity are documented.	Raster (30x30 m)

4.5 Financial feasibility

4.5.1 Context

Flooded forest is a specific type of ecosystem characterized by the regular inundation of water due to the natural flooding of the Mekong River, the area surrounding the Tonle Sap Lake, and the connecting river between the lake and the Mekong River. Within this region, the flooded forests are adapted to the seasonal rise and fall of water levels, creating a dynamic environment that supports diverse flora and fauna. These areas are vital for the Mekong River's ecology, providing habitat for various animal and plant species and contributing to the overall health of the river ecosystem. But to remain, a flooded forest needs 6-8 months of inundation each year (not more, and not less). Ongoing developments in the Mekong Basin have brought about changes in river flows and flood patterns, particularly the construction of hydropower dams and the incision of the main river due to concentrated flows of water in the main channel, trapping of sediment behind dams and sediment mining. The alteration in the flow of the Mekong River results in higher water levels during the dry season and lower water levels during the wet season because dams are being filled in the wet season and water is released during the dry season to generate electricity. Thereby, the dams reduce ecosystem productivity because they disrupt fish migratory patterns and affect the habitat itself (including spawning areas) by for example vegetation patterns that adapt to the changing flooding regime. The proposed NbS to address this problem is restoring flooded forest areas, and assessing how the local population uses the flooded forest and whether that contributes to its degradation. This might require a change in livelihoods.

The case study area for NbS2 is located in Kampong Chhnang province covering flooded forests along the Tonle Sap River, which connects the Mekong River with the Tonle Sap Lake (see figure below). In this area, several villages rely on aquaculture and agriculture for their livelihoods. Uncontrolled encroachment into the flooded forest has led to declines in fish populations and reduced income from fisheries. The conversion of flooded forests to agricultural land has destroyed vital breeding grounds and nursery habitats for fish. Subsequently, fertilizers and pollutants are used on the converted lands, which leads to a further deterioration of water quality and further threatens the fish population. Secondary causes for local decline in flooded forests and fish populations are forest fires and illegal fishing. The impact of low flows on rice and reduced income from fisheries has further worsened the situation because to increase or maintain income, additional land is being converted for agricultural use. About 10% of the flooded forest has disappeared since 2018. Fish catches have been estimated to have declined by 10-30% over the same period. On the wider Mekong scale, the loss of forest is even larger, and fish catches have been estimated to have declined by almost 90% in 20 years or so (Hughes, 2024).

Through land acquisition, reconnecting low-lying areas, connecting habitats, protecting and restoring river corridors, and providing alternative livelihoods for farmers, the area could be restored and protected. Socio-economic actions are especially challenging in this complex social environment where people are poor, and governance and enforcement of laws and regulations are often weak. A field visit was conducted in three communes (Kampong Hav, Peam Chhkaok, and Koah Tkov) to understand the situation in the study area, focusing on household information, income, flooded forest use, flooding, and land ownership. Data collected from this visit was used in this CBA.

At the basin level, flooded forests can be found along the Mekong River in Stung Treng and Kratie and the Tonle Sap Lake area. Following the technical feasibility study, 197,200 ha was found to be highly suitable for flooded forests in Cambodia, see Table below. For the financial analysis, it is assumed that from the area with high suitability, 25% will be restored to flooded forests.

Table. Suitable area NbS 2

Country	Suitability category	Suitable area (ha)
Cambodia	Marginal suitability	253,600
	Moderate suitability	259,300
	High suitability	197,200

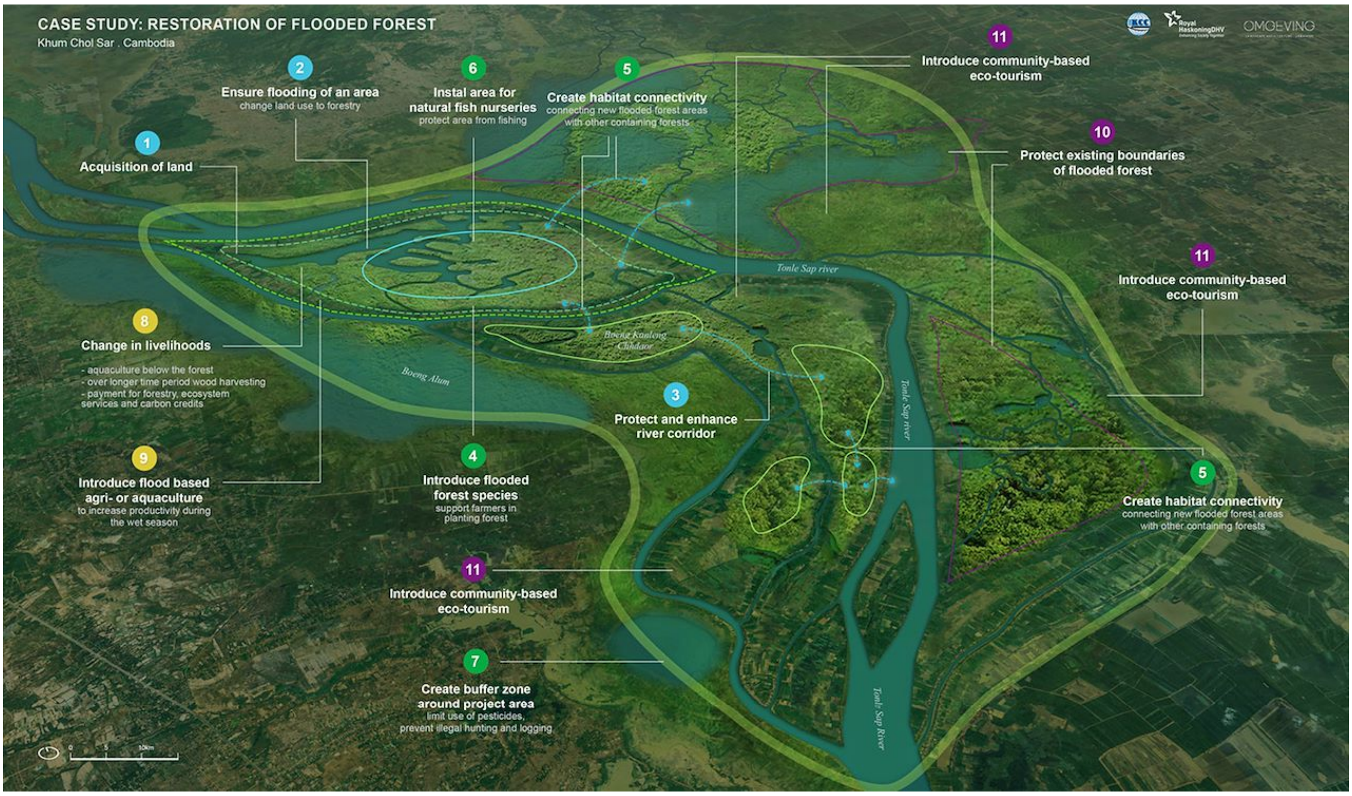


Figure. Case study for improving the flooded forest ecosystem

Improving natural floodplain dynamics with flooded forests would involve many stakeholders, including several government agencies. These stakeholders can be categorised into the following main groups:

Table. Stakeholders for flooded forest projects

Stakeholder group	Involvement
Households	Direct beneficiaries of the project, are expected to shift their sources of income
Private sector companies	Potential beneficiaries of the project, adjusting to new or different business opportunities
Government organisations	Design, implementation and support of the projects
Funders	Provide loans, funds and other forms of financing for the project
Society	At a larger scale, social, economic and environmental co-benefits will affect society

In addition to these stakeholders, others can be identified, such as NGOs, knowledge institutions and contractors. However, these are not expected to be the main beneficiaries or responsible for the costs of the project and hence are not included in the financial and economic analysis. Note that there could be some overlap in stakeholder groups, e.g., government organisations could fund part of the projects.

4.5.2 Reference alternative

The reference alternative is the scenario in which the NbS will not be implemented at the case study site or in any of the suitable areas. In this scenario, the flooded forests will continue to deteriorate due to further encroachment, changes in flooding patterns, climate change, and contamination of the flooded forests with solid waste and agricultural chemicals. The reference alternative assumes that no incremental costs are required to sustain the current systems, yet it is acknowledged that over time fish catch would decline due to loss of habitat for fish.

4.5.3 Project alternative

The project consists of restoring or creating flooded forest areas. This requires the acquisition of land and in some cases, structural measures related to the water system to create or recreate a connection between the main river and the flooded forests and non-structural measures related to improving and restoring ecology and habitats. It also requires activities, such as outreach and training, to support households and communities to change their livelihoods to more sustainable sources of income. Finally, it involves engaging other stakeholders, such as the private sector to set up eco-tourism in the area. This will ultimately lead to a situation in which the flooded forest sustainably provides its ecosystem services and works together with other livelihoods supporting a sustainable and complimentary income such as agriculture, aquaculture and tourism.

At the basin scale, it is assumed that the case study project would be replicated up to the point where it would be implemented in 25% of the highly suitable land area, which amounts to 49,300 ha. Doing the projects at the basin scale would likely lead to scale advantages in costs and benefits. An ecosystem of significant scale is required to provide ecosystem benefits.

In economic and financial analysis, the project period or project horizon is relevant as cash flows are discounted to a present value and different stakeholders have different time horizons. The project has an infinite lifetime as the restoration of flooded forests should be permanent. However, households and private sector stakeholders may have a horizon of one to a few years, as they would like to see relatively short-term returns on their efforts and investments. Public sector investments and societal benefits have much longer horizons as infrastructure generally has a lifespan of several decades and some effects may only materialise in the long run. Costs and benefits also need to be placed in a timeline, and for this, it is assumed that for the local scale project implementation takes 2 years and that at the basin scale, it takes 10 years to achieve the 25% restoration of flooded forests. A project horizon of 50 years, from 2024 to 2073, is assumed.

4.5.4 Identification and selection of effects

The identification of effects is one of the most important steps and is done by comparing the project alternative with the reference alternative and identifying the incremental costs and benefits of the project alternative. Following the action-process-services-benefits approach, five tangible and one intangible benefits were identified, as shown in the figure at the bottom of this page. In addition, the project would result in a conversion of agricultural land to flooded forest. Although this is not directly an ecosystem service, the change in agricultural production due to a change in land use is an important effect of the project. Carbon credits and biodiversity credits can be identified as financing mechanisms, though are not counted as benefits for people as they are financial transfers from one group of stakeholders to another group of stakeholders to sustain or enjoy a benefit.

The effects are different at different scales and for different stakeholders. As ultimately everyone could benefit from each service through indirect effects, only the most directly affected stakeholder groups are considered. In Table below, the column "Scale of benefits" indicates if benefits are predominantly present if a project is done locally or at a basin scale. Yet, through aggregation, local benefits are also present at the basin scale and in some cases (e.g., change in fishing revenue) benefits are present at both local and basin scales through slightly different processes (e.g., fish in local habitat versus migrating fish).

Table. Benefits by scale and stakeholder

No.	Benefits for people	Scale of benefits	Stakeholders	Comments
1	Change in fishing revenue	Local & Basin, with benefits expected to increase with scale	Households & private sector companies	Private sector companies would benefit from supply chain opportunities.
2	Change in income from non-forest timber products	Local	Households	
3	Change in tourism revenue	Local	Private sector companies & households	
4	Climate change mitigation	Basin, with benefits expected to increase with scale	Society	This is a global benefit and would ultimately also benefit the basin and local societies; carbon credits could benefit farmers / households.
5	Change in non-use values	Local & basin	All	All stakeholders have non-use values, also at the global scale, but the specific non-use values differ considerably among stakeholders.
6	Change in agricultural revenue	Local	Households & private sector companies	This is a disbenefit, though can be partly mitigated by optimising land use and changes in agricultural practices

An effect that is not displayed in Figure is the cost of the project. Implementation of the project comes with structural and non-structural costs for different stakeholders. Structural costs are generally paid by government organisations although they could be financed by other organisations, but ultimately are borne by society through taxes and fees. Non-structural costs are borne by government organisations, funders and farmers/households. Potential costs involved in restoring and creating flooded forests are:

1. Acquisition of land
2. Reconnecting low-lying areas with the main river, e.g. through digging canals or removing levees
3. Protect and enhance river corridors, e.g. through land zoning, regulations and planting of vegetation
4. Creating / maintaining habitat connectivity, e.g. through land zoning, regulations and planting of vegetation
5. Install or designate buffer zones through land zoning and regulations
6. Plant / introduce flooded forest species
7. Install zones designated for natural fish nurseries
8. Develop strategy for ecotourism development, e.g. through building a visitor centre and building resting huts in flooded forest, as well as promotion, engaging tour operators, etc.
9. Initiate payment for ecosystem services to (former) landowners
10. Limiting activities that could harm the flooded forest and enforcement of regulations.

In the first instance, all identified tangible and intangible effects are selected for inclusion in the CBA. However, only a limited number can be quantified and monetised.

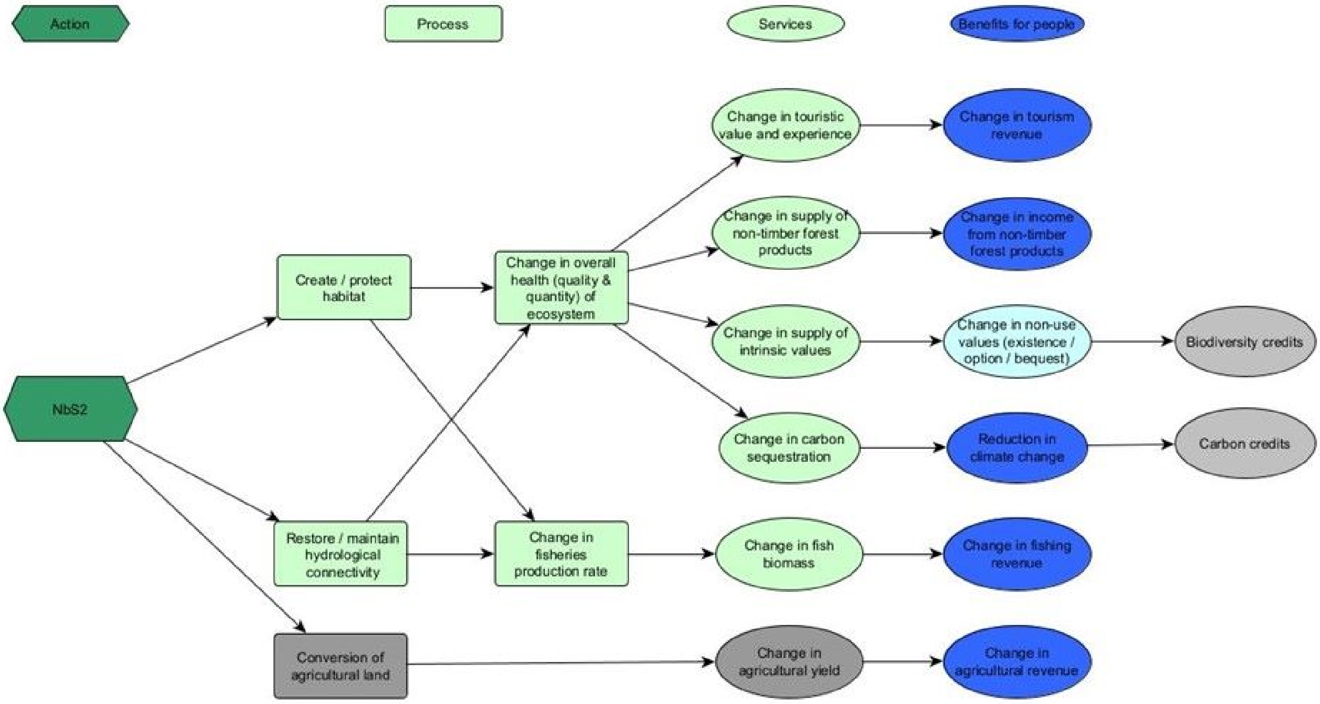


Figure. Effects of improving the flooded forest ecosystem

Quantification and monetisation of effects

4.5.5 Benefits

1. Change in fishing revenue

At the project site, fish catches have reportedly decreased by 30-40% since 2018. The income from fishing in the wet season is between USD 250 to 1000 per household, while there are about 1,700 households in three communes where interviews were conducted and whose primary source of income is fishing. Research in Tonle Sap Lake found that fish populations fell by 88% between 2003 and 2019[1] and recent estimates indicate that the economic value of Mekong fishery dropped by more than a third between 2015 and 2020[2]. The estimated annual value of fish catch was estimated between USD 7.13 billion and USD 8.37 billion in 2019-2020.[3]

These figures show the large economic importance of fisheries. For the CBA it is, however, not possible to quantify and monetise the impact of the project as it is not known how much the project would change the fisheries production rates, increase the fish biomass and hence change the fishing revenue.

As a very rough estimate, it could be assumed that at the local level, the project would partly reverse the decline since 2018 – e.g., assume 15% – as other factors, such as dam construction, climate change and impacts from outside the project site also affect fish catch within the site. Hence, taking the average income from fisheries per household (USD 625 during the wet season) as reported during the field visit, and 1,700 households, the benefits would amount to about USD 160,000 per year (note that there are more households than in the three villages that would benefit from more fish and there are also households whose main source of income is rice or crops that would benefit, so this is likely an underestimate).

At the basin level, it is more difficult to estimate the impact of larger areas of flooded forests on fisheries income. But taking a strongly conservative estimate, if implementing it in 25% of the highly suitable areas resulted only in a 1% increase in fisheries, the revenues would generate about USD 77.5 million in annual benefits if the middle of the range of the 2019-2020 estimated annual value of fish catch (USD7.75 billion) is taken as a base.

[1] Chevalier M, Ngor PB, Pin K, Touch B et al., (2023) Long-term data show alarming decline of majority of fish species in a Lower Mekong basin fishery. Science of The Total Environment, Volume 891.

[2] Cowx IG, Lai TQ and So N (2024). Fisheries Yield Assessment by Habitat Type at The Landscape Scale in The Lower Mekong

River Basin 2020. Vientiane: Mekong River Commission Secretariat.

[3] Ibid

2. Change in income from non-timber forest products

At the project site, there is no known harvesting of non-timber forest products, or at least it was not reported during the field visit. Yet, studies show that products such as resin, bamboo, rattan, wild honey and fuelwood are collected from forests in Cambodia.[1],[2] However, data on the amounts and values of these products is limited. A study by Sophanna et al. (2022) conducted a survey in 22 villages in the Tonle Sap Lake area that are located within 500 metres of a flooded forest to assess ecosystem services. They found the following annual economic benefits per person per year from flooded forests: fuelwood – USD 12; wild food – USD 8; traditional medicine – USD 1; honey – USD 1, hence in total USD 22 per person per year.[3] This is USD 121 per household per year at an average household size of 5.5 (as reported in the same study). It is, however, not known how many households at the site and in the basin are located within 500 metres of flooded forests and how restoration of flooded forests would affect this benefit. To still reflect these benefits, it is conservatively assumed that 10% of the households at the site (493 households) live within 500 meters of the flooded forest and that by restoring the flooded forest 25% of the annual value of non-timber forest products (USD 30) can be regained. Hence, the benefit at the site is USD 14,790 annually. At the basin level, the amount from the site will be scaled based on the area to be purchased, i.e., 50 times USD 14,790 is USD 739,500.

[1] Chou, P. (2017) The importance of Non-timber Forest Products in Rural Livelihoods and Ecosystem Services at Phnom Princh Wildlife Sanctuary, Cambodia. International Journal of Environmental and Rural Development, 8-1.

[2] Sophanna et al. (2022). Flooded Forests. in: C. Yoshimura et al. (eds.), Water and Life in Tonle Sap Lake, Chapter 32. Springer Nature Singapore.

[3] They also find an economic value for fisheries of USD 5021 per household per year, which is considerably higher than in the case study area.

3. Change in tourism revenue

In the case study area, there is no tourism at this moment. Based on other ecotourism sites, the assumption was made that the project site could attract 1000 to 5000 (average 3,000) tourists per year, of which half would stay overnight. Tourists would spend (added value, excluding costs of the tourism offering) on average USD 10 per person, while tourists that stay overnight would spend an additional USD 20. Hence, the total annual benefits would be USD 60,000.

At the basin level, ecotourism cannot be implemented at all sites, as the total market demand for ecotourism is limited and not all sites are suitable, e.g., in terms of accessibility. In total, it is assumed that there would be 5 additional ecotourism sites throughout the basin, each would generate USD 60,000 per year, hence in total USD 360,000 per year.

4. Climate change mitigation

Through the creation and protection of habitat, the project could contribute to increased carbon sequestration. Increased carbon sequestration reduces greenhouse gases in the atmosphere, mitigating climate change, and hence benefiting people as a reduction in climate change and associated effects compared to a baseline without the project. This benefit can be valued through the amount of carbon sequestered by vegetation and a social price for carbon. Measuring this would require an estimate of carbon sequestration in the project area without and with the project. For this, newly established vegetation, restored degraded forest and avoided deforestation could be considered. Calculating the amount of carbon sequestered is complex and falls outside the scope of this study. Yet, using a ballpark calculation, an indication of the benefit could be obtained. Assuming carbon sequestration is 5.5 tCO_2 $ha^{-1}yr^{-1}$ [1] and the value of a tonne of CO_2 is USD 5 [2], benefits would be USD 27.50 per ha per year, or USD 6,875 per year for the 250 ha planted area.

At the basin level, the planted area (assumed 12,325 ha, see below) would generate USD 338,938 as a ballpark figure.

[1] Based on Sasaki et al (2016). Forest reference emission level and carbon sequestration in Cambodia. Global Ecology and Conservation, Volume 7, July 2016, Pages 82-96

[2] The value of one tCO_2 varies widely: the recent social costs of carbon are estimated at USD 225 per tCO_2, the price of carbon under the EU ETS varied from about EUR 100 in February 2023 to EUR 50 in March 2024, and the value of REDD+ carbon credits under the voluntary market (most relevant in this context) were on average USD 4.7 per tCO_2, in 2021 and USD 1.46 at the time of writing this report.

5. Reduction in flood damages and flood protection costs

By restoring the flooded forests, the floodplain water storage capacity will increase. This could potentially lead to lower peak flood water levels and a reduction in flood damages and flood protection costs (e.g., lower requirements for levees). Moreover, there would be more water available in the dry season.

In terms of water storage, it is estimated that flooded forests could store 490 million m^3 of flood waters, leading to a flood depth reduction of 0.5 meters in the Mekong River, see Appendix A. However, assessing the quantitative impact of restoring hydrological connectivity on flood damage and flood protection is complex,[1] hence only a very rough indication of the benefits can be given. The average annual cost of floods in the Lower Mekong Basin ranges between USD 60 to 70 million.[2] Assuming the project would contribute to a 1% reduction in damages this would be USD 600,000 to 700,000 annually.

[1] See for instance Thanh, V. Q., Roelvink, D., Van Der Wegen, M., Reyns, J., Kernkamp, H., Van Vinh, G., & Linh, V. T. P. (2020). Flooding in the Mekong Delta: the impact of dyke systems on downstream hydrodynamics. Hydrology and Earth System Sciences, 24(1), 189-212 on the complexity of modelling and considerations to assess changes in the floodplain on flood levels.

[2] Mekong River Commission: https://www.mrcmekong.org/our-work/topics/flood-and-drought/

6. Change in non-use values

Non-use values are numerous and different for each person. Such values include bequest values (leaving something for the next generation), existence values (attaching value to knowing that something exists, for instance, expressed to donations to charity) and option values (not using it now, but maybe in the future). A monetary estimate of non-use values can generally only be obtained by asking people for their willingness to pay to conserve or enhance certain habitats, ecosystems or ecosystem services.

The non-use values are not included in the CBA as no good studies are available for flooded forests in Cambodia.

The change in non-use values could be linked to the potential value of biodiversity credits. Biodiversity credits are a verifiable, quantifiable and tradeable financial instrument that rewards positive nature and biodiversity outcomes (e.g., species, ecosystems and natural habitats) through the creation and sale of either land or ocean-based biodiversity units over a fixed period.[1] The market for biodiversity credits is, however, still at an early stage of development and the pricing of biodiversity credits is still largely unknown.

[1] World Economic Forum: https://initiatives.weforum.org/financing-for-nature/home

7. Change in agricultural revenues

Clearing of flooded forests in the study area partly happened because fish catches were reducing over time while growing rice provides a higher income of about USD 1,500 per ha per year. The purchase of land for flooded forest restoration would reduce the agricultural land available for rice cultivation and hence should be included as a disbenefit (cost). For the 500 ha to be purchased in the case study area this would amount to an annual disbenefit of USD 750,000. At the basin level, this would amount to almost USD 37 million annually.

It should be noted that the purchase of land (listed under costs) incorporates compensation for the loss of income. Hence, including both the cost and the disbenefit in the CBA would lead to double-counting. The cost of land is equivalent to about 12 years of income from growing rice (at a 6% discount rate of future revenues). In the CBA only the costs of the purchase of land are included, as the data on costs of land are better, and loss of agricultural revenue could partly be compensated by changing agricultural practices, such as implementing flood-based agriculture in the wet season.

Summary of benefits

The table below provides a summary of the benefits

No.	Benefit item	Estimate project site (USD/year)	Estimate basin (USD/year)
1	Change in fishing revenue	160,000	77,500,000
2	Change in income from non-timber forest products	14,790	739,500
3	Change in tourism revenue	60,000	360,000
4	Climate change mitigation	6,875	338,938
5	Reduction in flood damages and flood protection costs	0	650,000
6	Change in non-use values	N/A	N/A
7	Change in agricultural values (**excluded** in the benefits calculation)	-750,000	-36,975,000
	Total annual benefits	241,665	78,938,438

4.5.6 Costs

The table below gives an overview of the costs estimates for the project site and basin. Note that these estimates are all very indicative and based on currently available data.

For the project, it is assumed that the investments costs are spread over two years at the beginning of the project period. Operational costs (item 10) are annual.

Table. Cost estimates and assumptions

No.	Cost item	Estimate project site	Estimate basin
1	Acquisition of land	500 ha at USD 13,000/ha Total USD 6,500,000	Assume 50% of highly suitable land needs to be purchased, the remaining 50% is already owned by the government.[1] 24,640 ha at USD 13,000/ha Total USD 320,450,000
2	Reconnecting low-lying areas with the main river	Not required at the site as it is already flooding	At basin level, some sites may require some groundwork. Assume per 1000 ha, a canal of 2 meter width, 1 meter depth and 1,000 meter length needs to be created at USD 2/m^3. Total USD 197,200
3	Protect and enhance river corridors	No costs, part of overall planning and management costs, see 5	No costs, part of overall planning and management costs, see 5
4	Creating / maintaining habitat connectivity	No costs, part of overall planning and management costs, see 5	No costs, part of overall planning and management costs, see 5
5	Install or designate buffer zones	Planning, management, training, and engagement costs are assumed to be USD 200,000 for the site Total USD 200,000	Planning, management, and training costs are assumed to be USD 200,000 per project area of 1000 ha Total USD 9,860,000
6	Plant / introduce flooded forest species	Plant in 50% of the acquired land (250 ha). A tree costs USD 1; per ha 2,500 trees are required and people can plant about 75 trees per day for USD 10/day. Total USD 707,500	Same assumptions as for the project site Total USD 36,975,000
7	Install zones designated for natural fish nurseries	No costs, part of overall planning and management costs, see 5	No costs, part of overall planning and management costs, see 5
8	Strategy for ecotourism development	Costs of building a simple visitor centre and developing an ecotourism strategy, brochures, etc. is estimated to be USD 30,000	Ecotourism could not be implemented at all sites, as the total market demand for ecotourism is limited and not all sites are suitable, e.g., in terms of accessibility. In total it is assumed that there would be 5 additional ecotourism sites. Total USD 150,000
9	Training and support to help households move to more sustainable livelihoods	Training, support, and engagement costs for households are assumed to be USD 200,000 for the site Total USD 200,000	Training, support, and engagement costs for households are assumed to be USD 200,000 per project area of 1000 ha Total USD 9,860,000
10	Initiate payment for ecosystem services to (former) landowners	Setting up a system for payments for ecosystem services (carbon credits, biodiversity credits or other) requires a certain scale to cover fixed costs. These costs are currently unknown.	Setting up a system for payments for ecosystem services (carbon credits, biodiversity credits or other) requires a certain scale to cover fixed costs. These costs are currently unknown.
11	Limiting activities / enforcement	Enforcement costs are estimated at about USD 700 / month / 6 communes or about USD 1,400 / year / commune; the project site has 7 communes, so total USD 9,800	For the basin it is assumed the project would cover 100 villages Total USD 140,000
	Total Capital Expenditure	USD 7,637,500	USD 377,492,200
	Total Operational Expenditure	USD 9,800 / year	USD 140,000 / year

1 *Even if land would not need to be purchased (e.g., due to unclear or missing land ownership documents), still households would need to be provided with alternative livelihoods if they were to lose their agricultural land.*

4.5.7 Discussion of results

The table below shows the results from the CBA. The results are indicative due to the assumptions being made, but some conclusions can be drawn from them. Firstly, from the perspective of a single site, NbS2 does not seem economically viable, as the net present value (NPV) is negative, and the benefit-cost ratio (BCR) is below 1.0. However, on the basin scale, it is a very viable intervention. These results are mainly dependent on the assumption made for the value of the benefits for fisheries. As mentioned above, at the site level the benefits from fisheries are likely underestimated as not all communes are included. If the change in revenue from fisheries would be about 3 times as large as currently estimated, the project would break even. The change in revenue from fisheries at the basin level is a guestimate, however, even if the project would only increase the revenue from fisheries by 0.25% the project would already be able to break even.

Secondly, the price of carbon credits is volatile and in the analysis USD 5 per tCO_2 is being used. This price cannot cover the costs of planting flooded forests on cleared land (see also financial analysis below). The price of carbon would need to increase to at least USD 31 per tCO_2 to cover the costs of planting alone at the project level, which is excluding the costs of land, over 50 years (assuming this is the period over which the newly planted forest would sequester on average 5.5 $tCO_2\ ha^{-1}yr^{-1}$ – this period may be shorter). Thirdly, the non-use values have not been quantified, and there might be additional benefits that have not been identified, such as benefits related to restoring the floodplain hydrology. Taking into account that not all benefits are included, while most of the costs are, the results in Table below are expected to be conservative

Table. Results of the CBA for restoration of the flooded forest, Present USD values at 6% discount rate over a 50 year project lifetime.

Indicator	Value for Site	Value for Basin
Total lifetime costs	USD 7.57 million	USD 295.75 million
Total lifetime benefits	USD 3.57 million	USD 1,175.06 million
NPV	USD -4.00 million	USD 879.30 million
BCR	0.47	3.97
IRR	1.60%	46.8%

4.5.8 Financial analysis

To make parts of projects financially viable, they need to generate tangible revenue streams that can be captured by a stakeholder. However, aside from carbon credits and potentially biodiversity credits or Payment for Ecosystem Services (PES), there are no tangible revenue streams. Carbon credits and biodiversity credits could contribute to the overall funding of the projects, though will not be able to fully fund the projects. PES could be initiated for water storage, groundwater replenishment and fish spawning functions. As discussed in the CBA, revenues from carbon credits are small – only around 1% of the total project cost in present value - and the value of biodiversity credits is at this moment unknown. The price of a tonne of carbon in the nature-based offset market is currently, however, very low; end-2021 the price was peaking above USD 20 / tonne and it can be expected that prices will increase in the coming years. Ecotourism may contribute to funding the project at some of the wetlands, though it is unlikely that it could fund a substantial part of the project. Revenues from ecotourism will go directly to the households and private sector companies as they sell their services, and only for instance an entrance fee or license fee paid by households and private sector companies could provide funding for the projects.

Biodiversity credits and carbon credits are a form of Payment for Ecosystem Services (PES). PES could provide a viable avenue for large-scale flooded forest restoration and conservation, though there are many challenges in setting up such schemes.[1] One of the challenges is financial viability: financial viability requires sufficient, stable, and sustained payments for project investment and operational costs and acceptable rates of return for project investors (including public financers seeking societal benefits). Carbon credits alone are not sufficient, and while biodiversity credits could contribute to the overall funding of the projects, this is still a largely undeveloped market. Other ecosystem services, including the most important one – an increase in fisheries – are difficult to capture under a (privately funded) PES scheme.

Hence, public funding would need to cover the majority of the expenses.

[1] See Canning, A. D., Jarvis, D., Costanza, R., Hasan, S., Smart, J. C., Finisdore, J., ... & Waltham, N. J. (2021). Financial incentives for large-scale wetland restoration: Beyond markets to common asset trusts. One Earth, 4(7), 937-950.

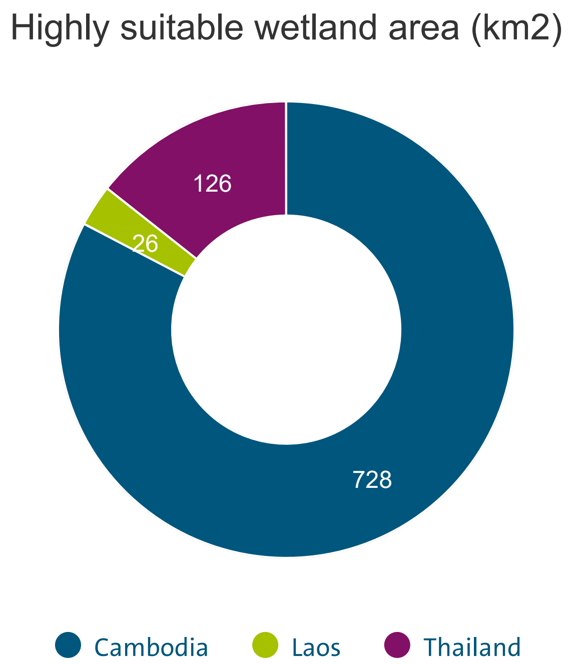
5 Improving riverine wetland ecosystems

5.1 Introduction

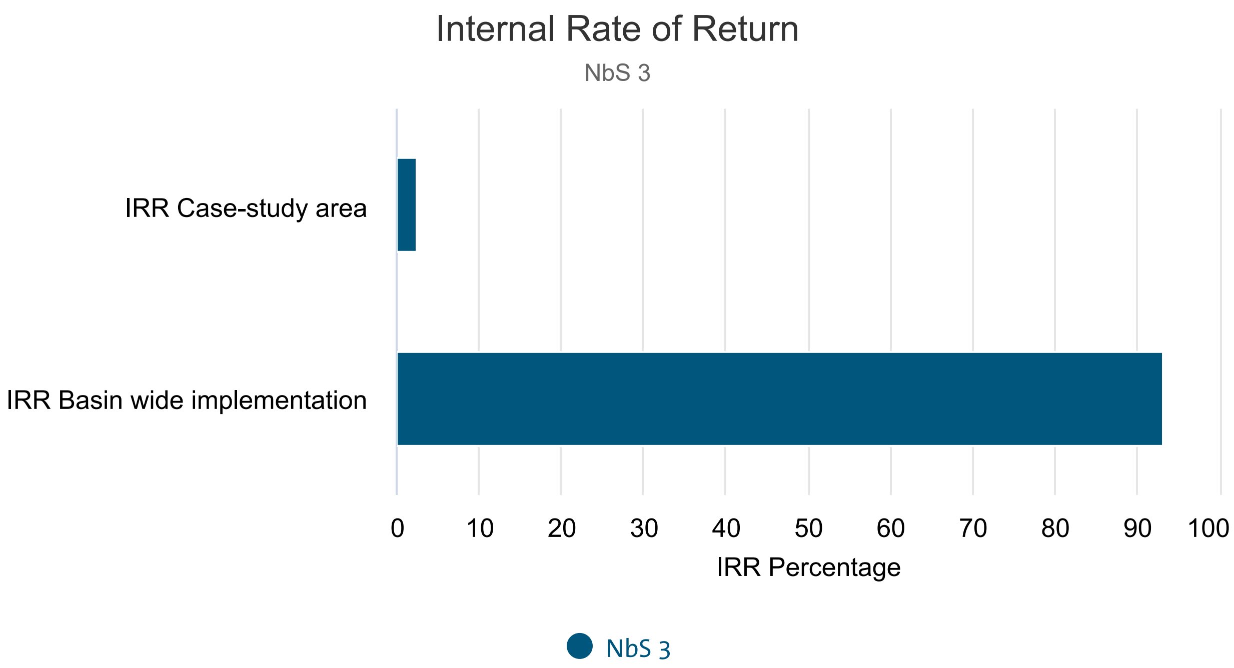
5.1.1 Improving riverine wetland ecosystems

Maintaining habitat connectivity is essential for species movements, resource flow, and ecological processes across landscapes. In aquatic environments, connectivity involves the continuous flow of water and linkage between water patches, which is crucial for enabling aquatic species to thrive and navigate the landscape (Januchowski-Hartley et al., 2013).

Highly suitable area per country



Internal Rate of Return



Background
The Mekong River basin is home to diverse wetland habitats that play a crucial role in supporting biodiversity. These habitats provide habitat for various aquatic vertebrates, including the critically endangered Siamese crocodile, Irrawaddy dolphin, resident and migratory fish species, and several frog and turtle species, including the endangered Asiatic softshell turtle and the vulnerable Giant Asian Pond turtle (Claridge, 1996). Many fish species in the Mekong region are known to undertake both lateral and longitudinal movements for their large-scale seasonal migrations.

Whitefish species, such as Pangasius, Boeseman, and white carp, engage in extensive longitudinal migrations between the Mekong mainstream, floodplains, and tributaries, covering long distances as transboundary migrants. In contrast, grey fish species, exemplified by silver barb and catfish, undertake short-distance lateral migrations in local tributaries and do not inhabit floodplain ponds during the dry season. Both groups of fish hold significant commercial importance for fishing-based communities in the Mekong region.

5.1.2 Disconnected areas identification

5.1.3 Reconnect wetlands

Disconnected wetlands, referring to wetland systems that experience a break or interruption in hydrological connectivity, exhibit several characteristic features. These features may vary depending on the degree and nature of disconnection, but common characteristics include:

- Different habitats in the ecosystem can become isolated from each other. This isolation can create barriers for certain species, especially fish, during important life stages like breeding or feeding. When organisms can't access specific habitats, it can disrupt their natural behaviors and life cycles.
- During a drought, wetlands that are not connected to water sources may be more vulnerable. The natural water flow disruption can result in larger dry areas within the wetland when there's little rain. This can worsen the impacts of the drought, affecting both the water and land parts of the ecosystem.
- Disconnected wetlands often lose their ability to provide essential ecosystem services, such as water purification, flood control, and habitat provision, due to the lack of natural connectivity.

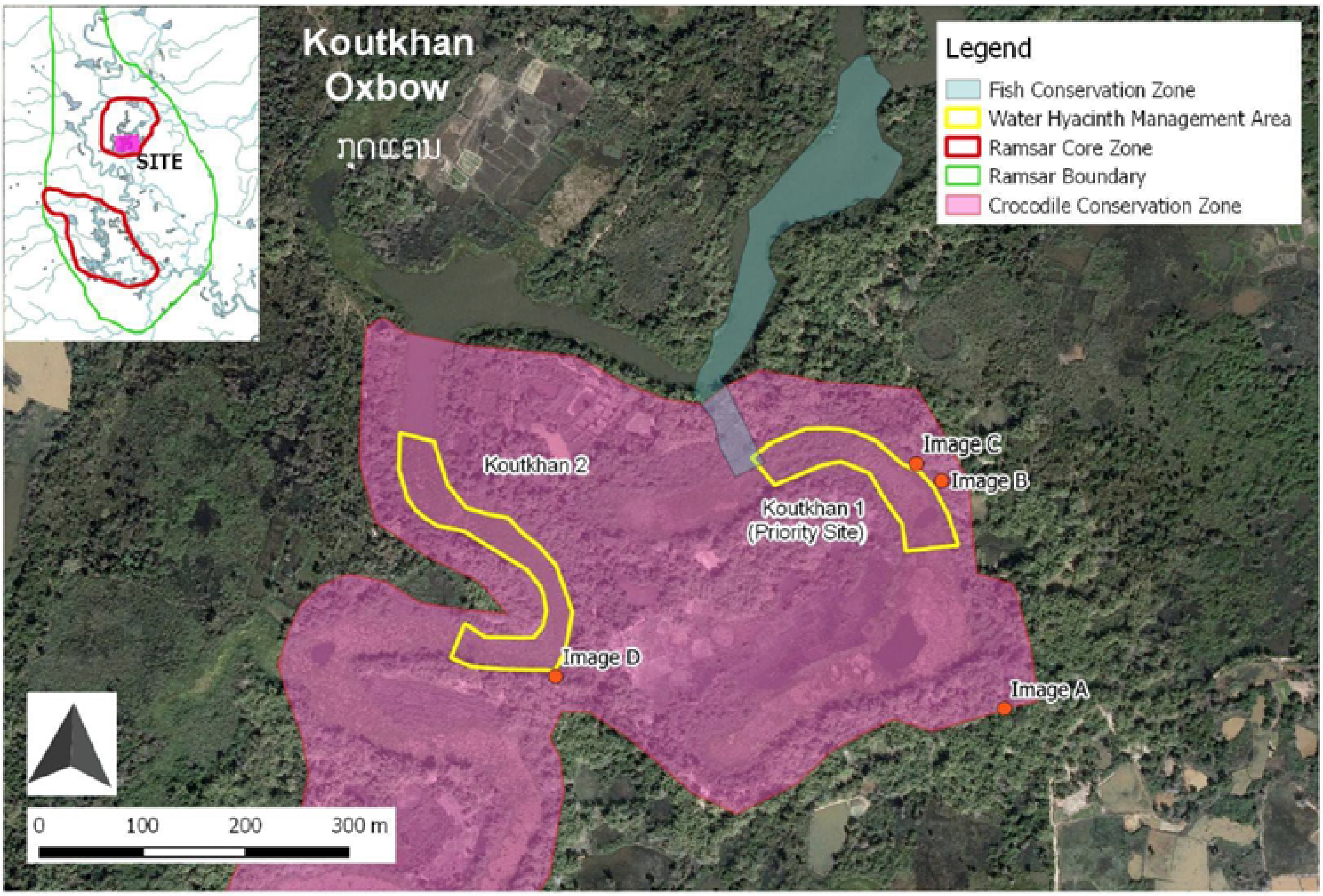
5.1.4 Intervention to increase connectivity

5.1.5 Example of interventions to increase connectivity at Kuot Kan

The ability of aquatic animals to move freely between feeding, breeding, and resting areas along sheltered waterways is crucial. The loss of both lateral and longitudinal connectivity stands out as a primary threat to the fish community in the Mekong River. Connectivity is pivotal in sustaining viable fish populations and preventing localized extinction in freshwater habitats is paramount. Interventions aimed at increasing connectivity include:

- Re-opening wetlands by removing dense patches of vegetation (native/invasive) that hinder fish movements and impede the free flow of water during the dry season.
- Removing invasive plant species, such as water hyacinth, which can diminish dissolved oxygen levels in the water, often leading to fish kills.
- Maintaining water quality to prevent chemical barriers, such as low dissolved oxygen and acid sulphate.
- If man-made structures are the cause of disconnection, they should be removed or locally opened to remove the disconnection

In Kout Kan, the focus of wetland rehabilitation in the oxbows is on improving connectivity, creating more open habitat, and enabling the passage of crocodiles and migratory fish. This involves managing the growth of mimosa and water hyacinth to prevent habitat closure and ensure that fish and crocodiles can move freely.



Management of invasive species, specifically Water Hyacinth, in Khan Oxbow aims to enhance connectivity within the wetland. This effort is intended to extend the corridor movement for crocodile (source: FAO 2017).

5.1.6 Protected areas identification

5.1.7 Protect and sustain well-connected wetlands

The wetland area that is worth protecting is characterized by its healthy system, which can be indicated by:

- Unobstructed water flow
- Well-vegetated floodplain wetlands
- Areas providing habitat for species with high conservation value
- Spawning areas for commercially important fish species
- Habitat corridors connecting to other wetlands (overland and via water)
- Fishing zones and natural resource utilization areas

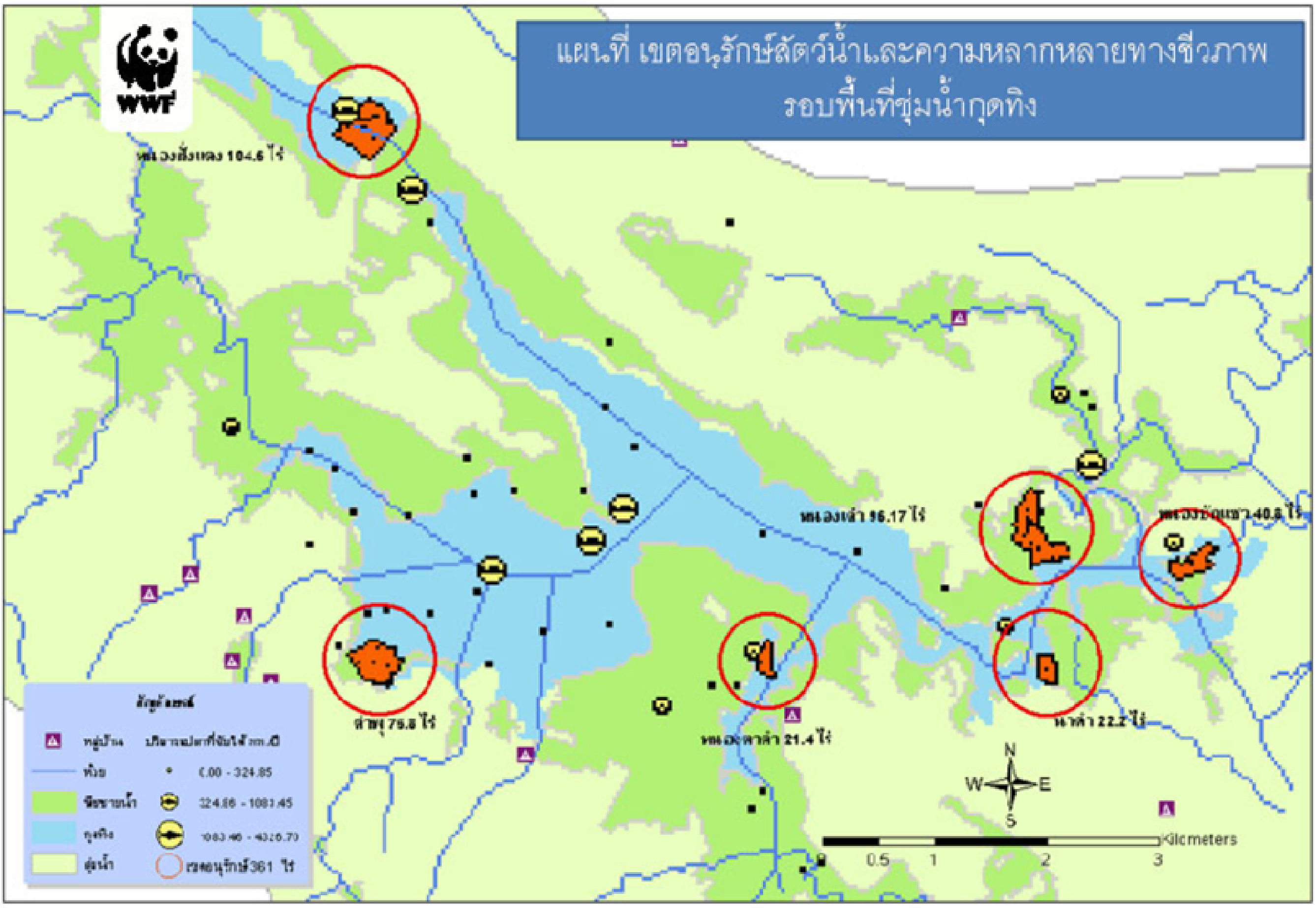
For instance, the Goot Ting Marsh in Nong Khai Province (Thailand) is pivotal in supporting an extensive wetland marsh complex. This site harbours over 120 freshwater fish species, including the endangered Giant Golden Barb, underscoring its remarkable biodiversity. With its high biodiversity, the site has been recognised as a site of international conservation and merits designation as a Ramsar site.

Despite its ecological importance, the Goot Ting Marsh is under threat from the development of hydropower dams upstream. This development disrupts the natural river flow, exacerbating the marsh's drying even at the end of the rainy season. This alteration in the natural flood-drought cycle and sediment transport adversely impacts the ecosystem, posing a serious threat to fisheries productivity, which is essential for the livelihood of the surrounding communities.[1].

Approximately 23,000 villagers across 40 communities depend on the Goot Ting Marsh for their primary livelihood. A 2006 survey revealed that these communities collected 33,541 kilograms of fish, along with substantial amounts of shrimp and edible marine plants, from the marsh for sustenance[2]. Most families rely on the marsh for income in the three largest villages – Nong Fang Daeng, Don Ho, and Huay Kam Phaeng. It's crucial to maintain a healthy marsh system to ensure the continued productivity of fisheries in the Mekong River and protect the livelihoods of these communities.

[1] https://www.benarnews.org/english/news/thai/thailand-china-02192020175528.html

[2] https://wwf.panda.org/wwf_news/?124240/A-Watershed-for-Conservation-WWF-and-Thailand-Celebrate-World-Wetlands-Day-with-a-New-Protected-Site

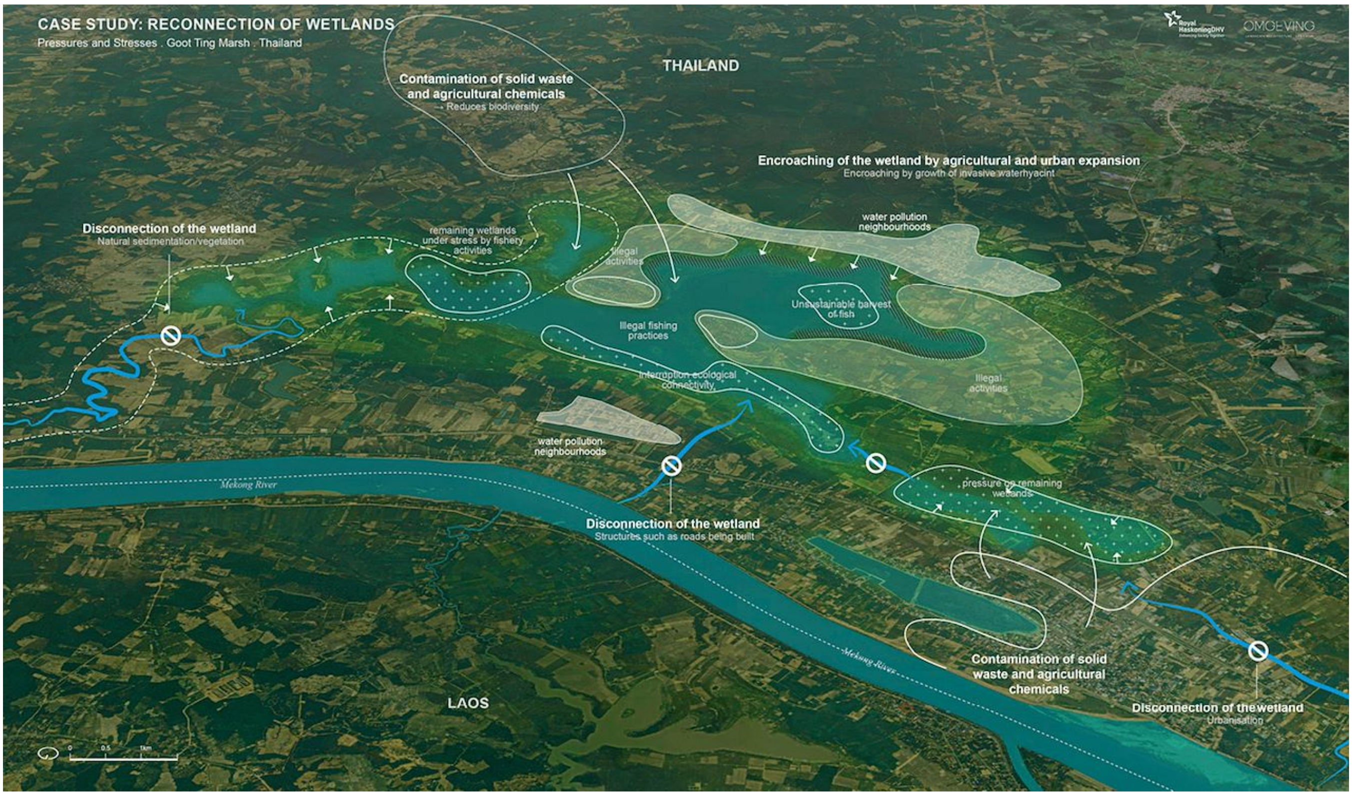


Map of conservation area around Goot Ting Marsh, indicated by red circle (source: https://wwf.panda.org/wwf_news/?124240/A-Watershed-for-Conservation-WWF-and-Thailand-Celebrate-World-Wetlands-Day-with-a-New-Protected-Site)

5.2 Case study: Goot Ting wetland restoration

5.2.1 Stress & Pressure

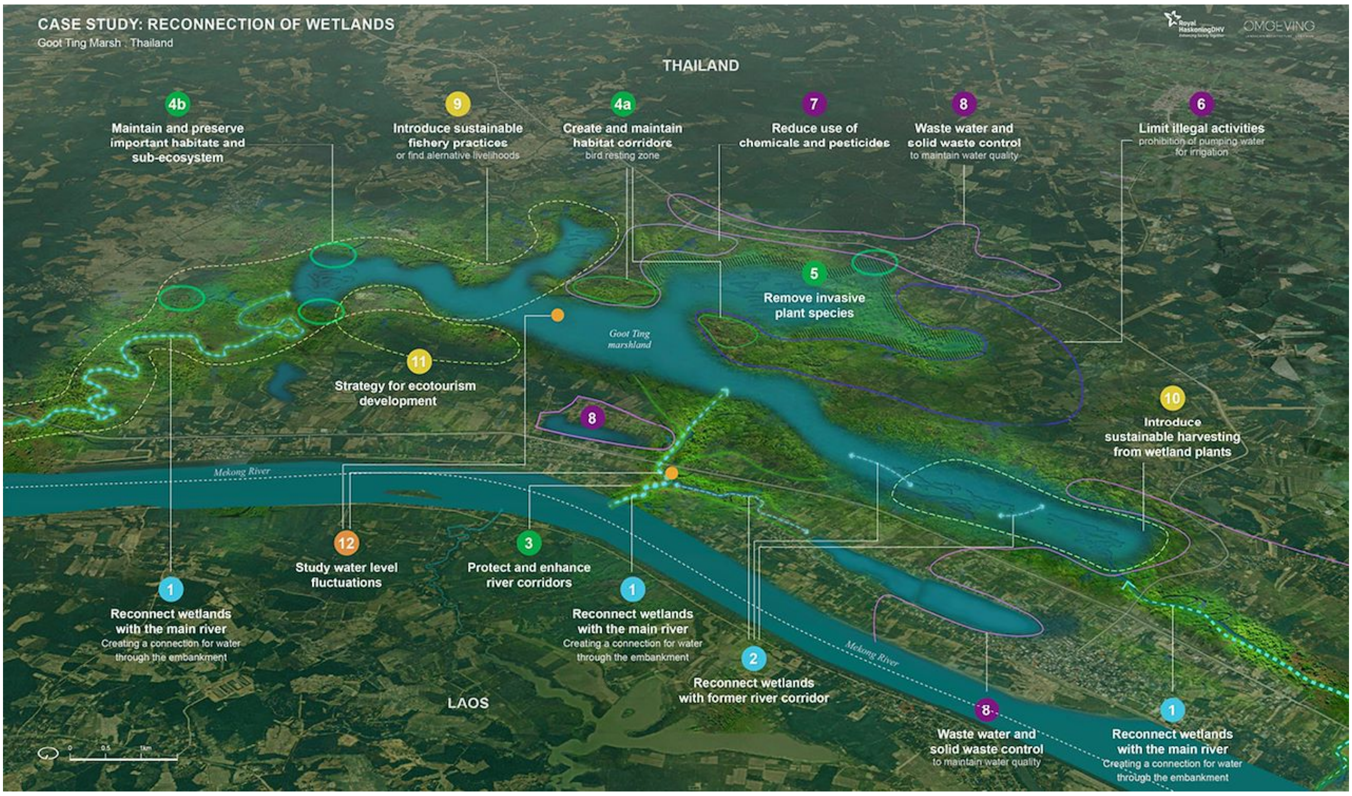
Large areas of Lao and Thailand were previously considered wetlands. These wetlands were crucial sources of water and food, providing rice, fish, and waterfowl, and supporting the livelihoods of millions of people. However, in recent decades, land development has increased, resulting in the construction of numerous reservoirs for irrigation, flood control, and hydropower. Human settlements have also expanded, encroaching on the wetlands with urban and agricultural development. This expansion has significantly altered the wetland habitats, reducing their size and disrupting their connection to the main Mekong river.



The Goot Ting Marsh is a large marsh covering around 2500 hectares. It was once well-connected to the Mekong River, but this connection has been mostly cut off, which limits the exchange of water, sediments, and species. The marsh faces several threats, including unsustainable human activities in the area. These activities involve overfishing and illegal fishing practices such as electro-fishing, as well as water contamination with solid waste and agricultural chemicals. Unregulated use of water resources and the conversion of surrounding land for intensive agriculture, including tomato growing and rubber tree plantations, also create significant pressure on the marsh. Additionally, invasive alien species like water hyacinth and patches of prickly mimosa are blocking connections between the wetlands and the main river, and they are converting wet areas into terrestrial environments.

5.2.2 Potential NbS measures

This case study area is located at Goot Ting wetland in Thailand, along the Mekong River, five kilometres south of Bueng Kan District, Bueng Kan Province. The site was recognized as a site of international conservation value and registered to the Ramsar site # 1733 in 2010. As described, the main problems are the disconnection of the wetland from the main river, the reduction in size (also see video above), and the reduced ecological quality of the area. To bring back the natural qualities of the wetland, it would be required to restore the connection of the wetland with the main river and restore the wetland's natural characteristics where possible. This might require adjustment of livelihoods to guarantee a stable income with practices that are less destructive to the natural environment.



To restore the connection with the main river, the main structural measure would be to remove an existing embankment locally or install a culvert or sluice gate **(1 in the figure above)** so that flood waters from the Mekong River can enter the wetland. The same holds for the downstream end of the wetland. A long, narrow channel now leads back to the Mekong River, but the channel may be locally obstructed by vegetation, and there is a weir at the end. Additionally, existing wetland patches can be reconnected (2) to facilitate the flow of water and species and create a significant-sized, fully connected wetland. This mainly concerns two areas west of Goot Ting, which have been disconnected from the main wetland in the past. The newly created connections and corridors should be protected to remain open and keep conveying water **(3/4)**.

Those measures could be further enhanced with biodiversity and conservation measures, such as maintaining or creating important habitats in the area, e.g. a bird resting zone since the area functions as a main important stopover area for migratory birds **(4a)** and further enhancing/expanding the existing conservation zones for fish **(4b)**. Additionally, invasive plant species, such as water hyacinths, can be removed or suppressed **(5)**. Water hyacinth can diminish dissolved oxygen levels in the water, potentially leading to fish kills, but it also reduces the size of the wetland over time by converting wetlands into land. Water buffalos can aid with removal by eating water hyacinths in shallow areas. Further removal can take place by harvesting and feeding to cattle or drying after harvesting and using it as natural fertiliser. If the stock of native herbivore fish improves in the area, this can also be a natural suppressor for invasive plant species. For the latter, installing specific fishing and no-fishing zones and only deploying sustainable fishing practices is important **(9)**.

To improve and maintain the water quality, it is recommended to reduce the use of chemicals and pesticides in the surrounding area **(7)** and install policies for water and solid waste disposal in the surrounding villages **(8)**. The high biochemical oxygen demand (BOD), low dissolved oxygen (DO), and high ammonia and coliform bacteria in the area have been associated with the high number of tomato growers and buffalo grazing. There are already some good examples in the area of fishermen encouraging the tomato growers to use organic fertilisers, bio-pesticides and bio-insecticides. Some 15 tomato growers established demonstration organic farms around Goot

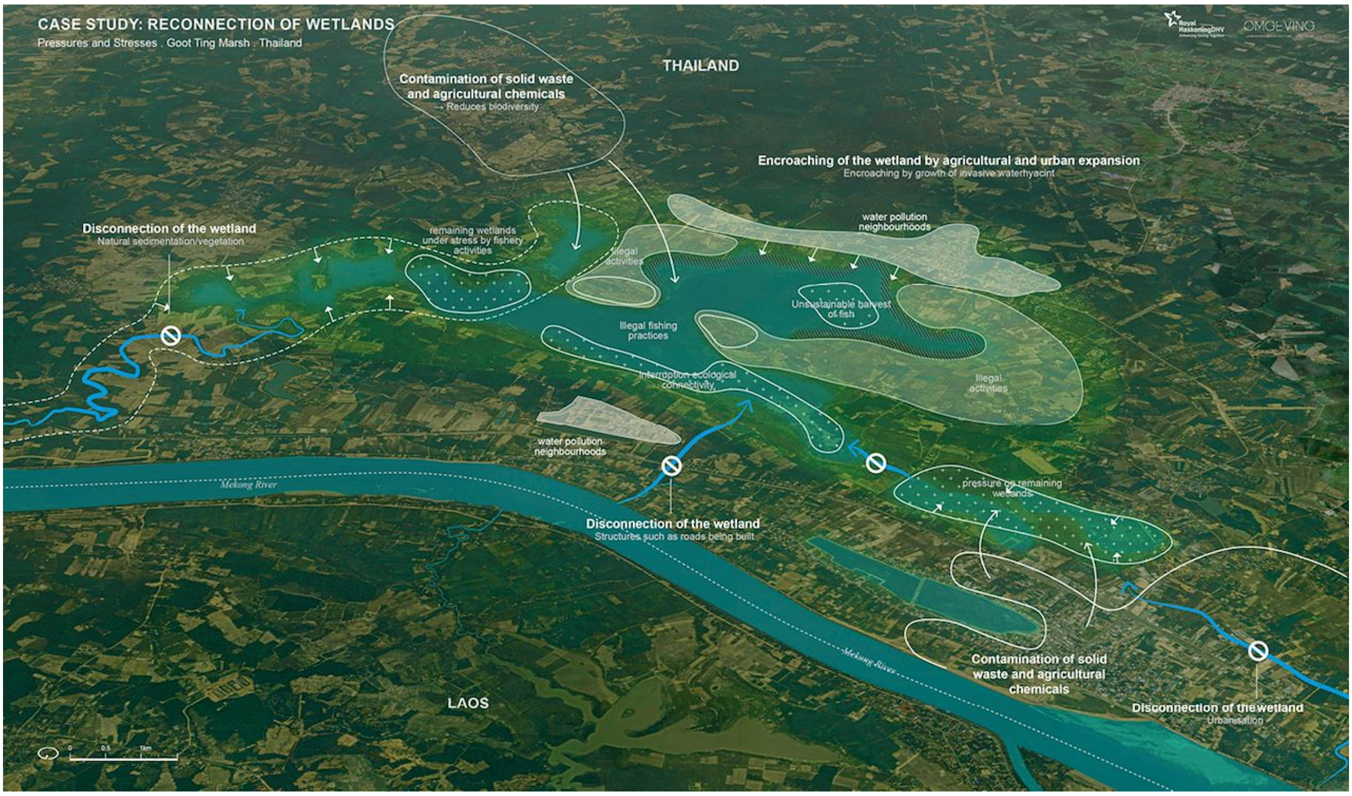
Ting. Furthermore, if water levels become too low during the dry season, pumping of water for agricultural uses should be limited **(6)**. This might require finding alternative storage areas where rain and/or river water can be stored during the wet season so that water is available during the dry season. Alternatively, agricultural practices could change to practices that require less water during the dry season. The continuous connection with the main river will also aid in improving the water quality within the wetland.

The proposed measures described above may also ask for some adaptation in livelihoods, which will need to shift more towards sustainable fishing practices **(9)**, harvesting of invasive species and/or other sustainable agriculture **(5/10)**, and potentially also the development of eco-tourism **(11)**. WWF has already proposed establishing bird-watching groups at local schools and providing training for bird-watching. Moreover, they have proposed to conduct bird-watching festivals and media tours to the migratory bird habitat sites to enhance eco-tourism. Since the project would still be in a pilot phase, it is recommended to conduct monitoring and evaluation, including at least a study of water levels **(12)** and monitoring biodiversity and income changes due to changing livelihoods.

5.2.3 Stress and pressure

5.2.4 Stress & Pressure

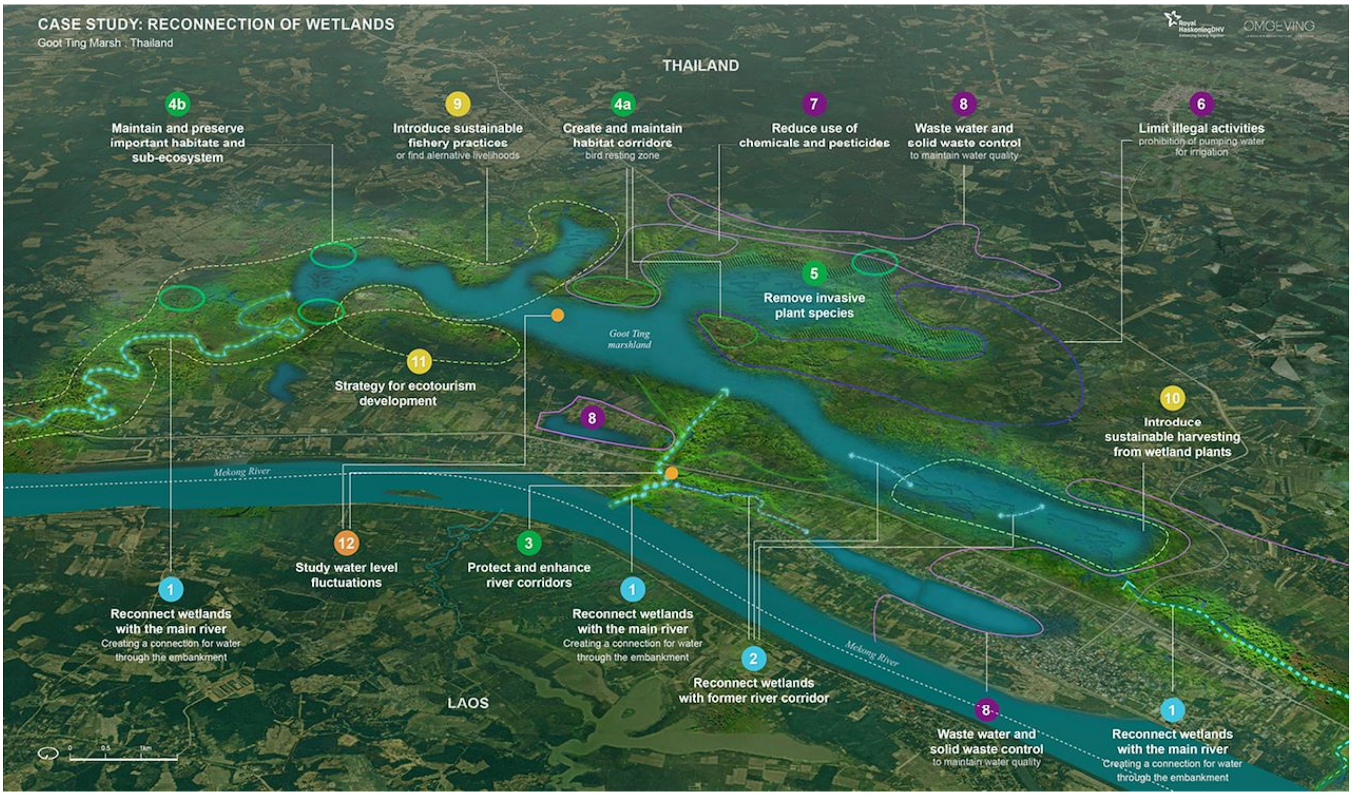
Large areas of Lao and Thailand were previously considered wetlands. These wetlands were crucial sources of water and food, providing rice, fish, and waterfowl, and supporting the livelihoods of millions of people. However, in recent decades, land development has increased, resulting in the construction of numerous reservoirs for irrigation, flood control, and hydropower. Human settlements have also expanded, encroaching on the wetlands with urban and agricultural development. This expansion has significantly altered the wetland habitats, reducing their size and disrupting their connection to the main Mekong river.



The Goot Ting Marsh is a large marsh covering around 2500 hectares. It was once well-connected to the Mekong River, but this connection has been mostly cut off, which limits the exchange of water, sediments, and species. The marsh faces several threats, including unsustainable human activities in the area. These activities involve overfishing and illegal fishing practices such as electro-fishing, as well as water contamination with solid waste and agricultural chemicals. Unregulated use of water resources and the conversion of surrounding land for intensive agriculture, including tomato growing and rubber tree plantations, also create significant pressure on the marsh. Additionally, invasive alien species like water hyacinth and patches of prickly mimosa are blocking connections between the wetlands and the main river, and they are converting wet areas into terrestrial environments.

5.2.5 Potential NbS measures

This case study area is located at Goot Ting wetland in Thailand, along the Mekong River, five kilometres south of Bueng Kan District, Bueng Kan Province. The site was recognized as a site of international conservation value and registered to the Ramsar site # 1733 in 2010. As described, the main problems are the disconnection of the wetland from the main river, the reduction in size (also see video above), and the reduced ecological quality of the area. To bring back the natural qualities of the wetland, it would be required to restore the connection of the wetland with the main river and restore the wetland's natural characteristics where possible. This might require adjustment of livelihoods to guarantee a stable income with practices that are less destructive to the natural environment.



To restore the connection with the main river, the main structural measure would be to remove an existing embankment locally or install a culvert or sluice gate **(1 in the figure above)** so that flood waters from the Mekong River can enter the wetland. The same holds for the downstream end of the wetland. A long, narrow channel now leads back to the Mekong River, but the channel may be locally obstructed by vegetation, and there is a weir at the end. Additionally, existing wetland patches can be reconnected (2) to facilitate the flow of water and species and create a significant-sized, fully connected wetland. This mainly concerns two areas west of Goot Ting, which have been disconnected from the main wetland in the past. The newly created connections and corridors should be protected to remain open and keep conveying water **(3/4)**.

Those measures could be further enhanced with biodiversity and conservation measures, such as maintaining or creating important habitats in the area, e.g. a bird resting zone since the area functions as a main important stopover area for migratory birds **(4a)** and further enhancing/expanding the existing conservation zones for fish **(4b)**. Additionally, invasive plant species, such as water hyacinths, can be removed or suppressed **(5)**. Water hyacinth can diminish dissolved oxygen levels in the water, potentially leading to fish kills, but it also reduces the size of the wetland over time by converting wetlands into land. Water buffalos can aid with removal by eating water hyacinths in shallow areas. Further removal can take place by harvesting and feeding to cattle or drying after harvesting and using it as natural fertiliser. If the stock of native herbivore fish improves in the area, this can also be a natural suppressor for invasive plant species. For the latter, installing specific fishing and no-fishing zones and only deploying sustainable fishing practices is important **(9)**.

To improve and maintain the water quality, it is recommended to reduce the use of chemicals and pesticides in the surrounding area **(7)** and install policies for water and solid waste disposal in the surrounding villages **(8)**. The high biochemical oxygen demand (BOD), low dissolved oxygen (DO), and high ammonia and coliform bacteria in the area have been associated with the high number of tomato growers and buffalo grazing. There are already some good examples in the area of fishermen encouraging the tomato growers to use organic fertilisers, bio-pesticides and bio-insecticides. Some 15 tomato growers established demonstration organic farms around Goot

Ting. Furthermore, if water levels become too low during the dry season, pumping of water for agricultural uses should be limited **(6)**. This might require finding alternative storage areas where rain and/or river water can be stored during the wet season so that water is available during the dry season. Alternatively, agricultural practices could change to practices that require less water during the dry season. The continuous connection with the main river will also aid in improving the water quality within the wetland.

The proposed measures described above may also ask for some adaptation in livelihoods, which will need to shift more towards sustainable fishing practices **(9)**, harvesting of invasive species and/or other sustainable agriculture **(5/10)**, and potentially also the development of eco-tourism **(11)**. WWF has already proposed establishing bird-watching groups at local schools and providing training for bird-watching. Moreover, they have proposed to conduct bird-watching festivals and media tours to the migratory bird habitat sites to enhance eco-tourism. Since the project would still be in a pilot phase, it is recommended to conduct monitoring and evaluation, including at least a study of water levels **(12)** and monitoring biodiversity and income changes due to changing livelihoods.

5.3 Technical feasibility

5.3.1 Technical upscaling potential

5.3.2 Upscaling potential

> *"Approximately 88000 hectares is highly suitable for riverine reconnection - that is roughly 123,000 football fields"*

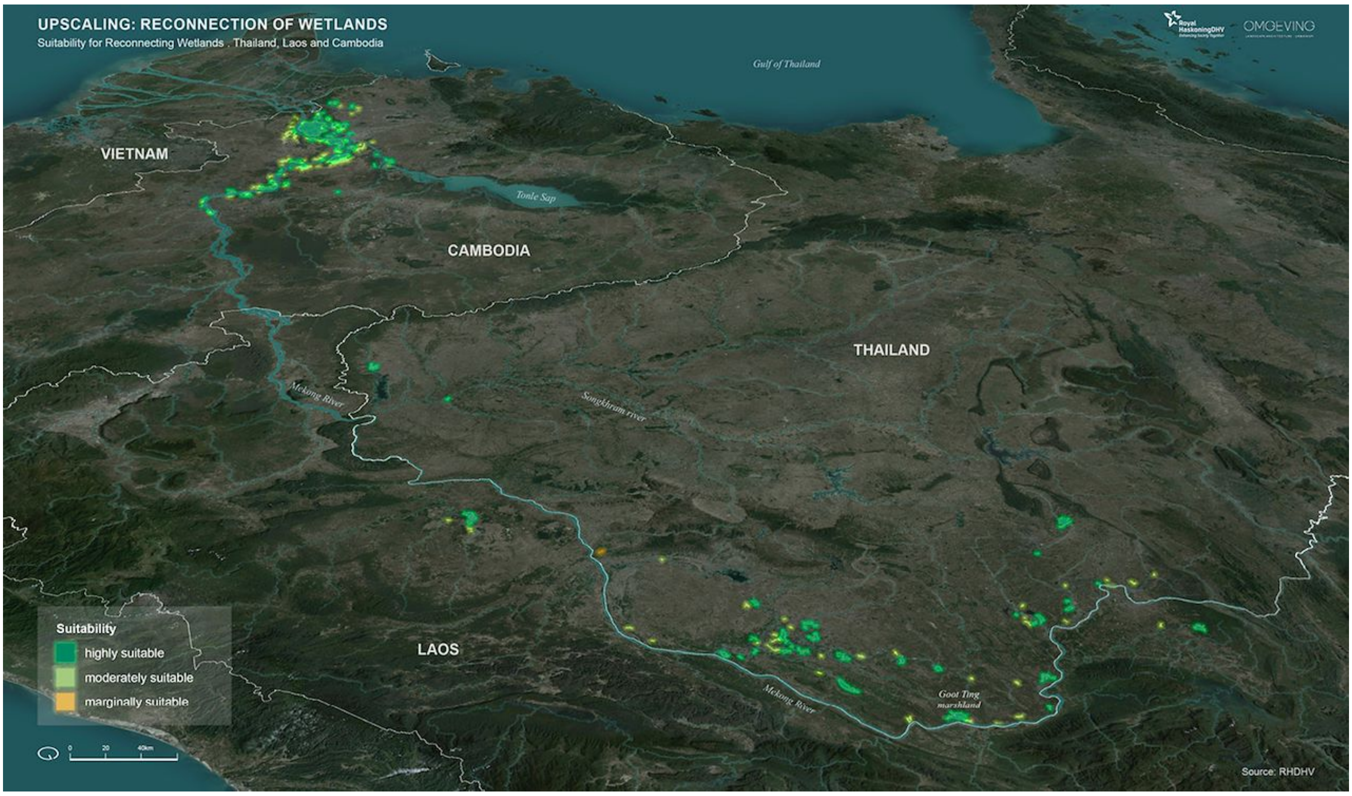
The suitability of the area for this NbS has been mapped to understand the upscaling potential. The upscaling potential for reconnecting riverine wetlands is considerable. Around 30% of Mekong Riverine wetlands are experiencing an increasing trend of water shortage. The total area covered by surface water wetlands has reduced by more than 20%.

A total of 93 wetlands have been identified as highly suitable for reconnection to the main Mekong River. Of these, 55 are located in Thailand, 35 in Vietnam, and 3 in Laos. These sites are well-known wetlands such as the Goot Tin Marsh, Songkhram, Bueng Khong Long Lake, and Champone wetland.

5.3.3 Technical upscaling map

5.3.4 Upscaling potential maps

The map below shows the suitable riverine wetlands for reconnection. Wetlands in green are highly suitable for a reconnection.



5.3.5 Underlying methodology NbS 3

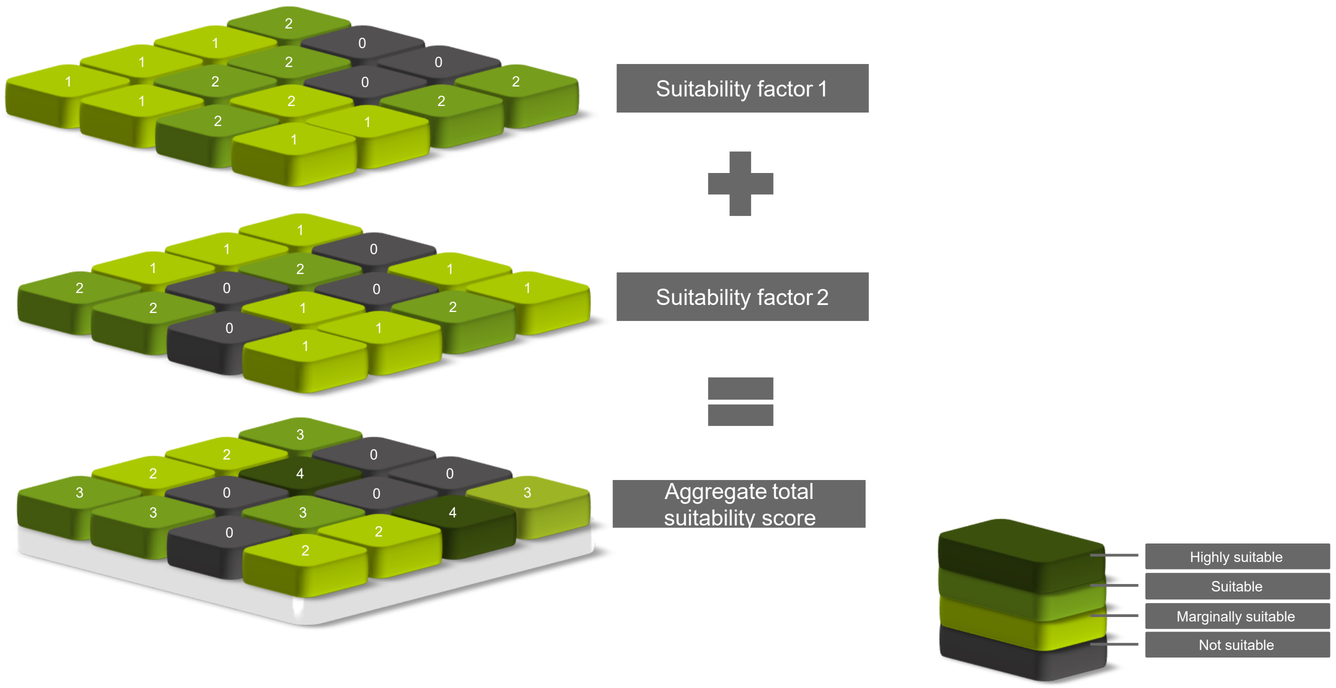
5.3.6 Methodology technical feasibility NbS 3

The objective of this map is to showcase which wetlands are suitable for reconnection with the main river. Our methodology for analysing suitable wetlands is based on two guiding principles:

- Suitable wetlands should show signs of water stress/deterioration and reconnecting the wetland to the river may reverse (part) of the deterioration process.
- The degree of difficulty of reconnection further determines the suitability. For example, if the distance between the wetland and the river is large, the required investment for reconnection may become prohibitive.

Approach

The spatial potential of the selected NbS types is mapped by overlaying different geospatial datasets, like hydrologic, soil, climatic data. This provides a first high-level indication to the effective geographic scalability of NbS. The suitability for a specific NbS is, where possible, classified in 4 classes: highly suitable, moderately suitable, marginally suitable and not suitable.



Each suitability factor dataset was scored using the following classification:

- Score of 0: Not a suitable area given the specific suitability factor
- Score of 1: Moderately suitable given the specific suitability factor
- Score of 2: Highly suitable given the specific suitability factor

After classifying each individual suitability factor, an aggregated suitability score was calculated by summing up all the scores to yield a single aggregated total suitability score. The suitability class - highly, moderately or marginally suitable, thus depends on the aggregate suitability score of all factors.

Furthermore, should any of the factors render an area unsuitable (score 0), regardless of the scores from other factors, the area is automatically labelled as unsuitable.

Suitability components for reconnecting wetlands to the river

To assess the potential suitability for reconnecting riverine wetlands four suitability factors were combined.

Relative height of wetland

The potential for reconnecting a riverine wetland partially depends on the relative elevation of the wetland in comparison to the river's elevation. Wetlands that are situated significantly higher than the nearest river are not suitable for reconnection.

Water stress

Disconnected wetlands are, for the purpose of this study, defined as wetlands that show signs of water stress, i.e., a shortage or deficit of water, either due to natural factors such as drought or human-induced causes like overuse of water resources.

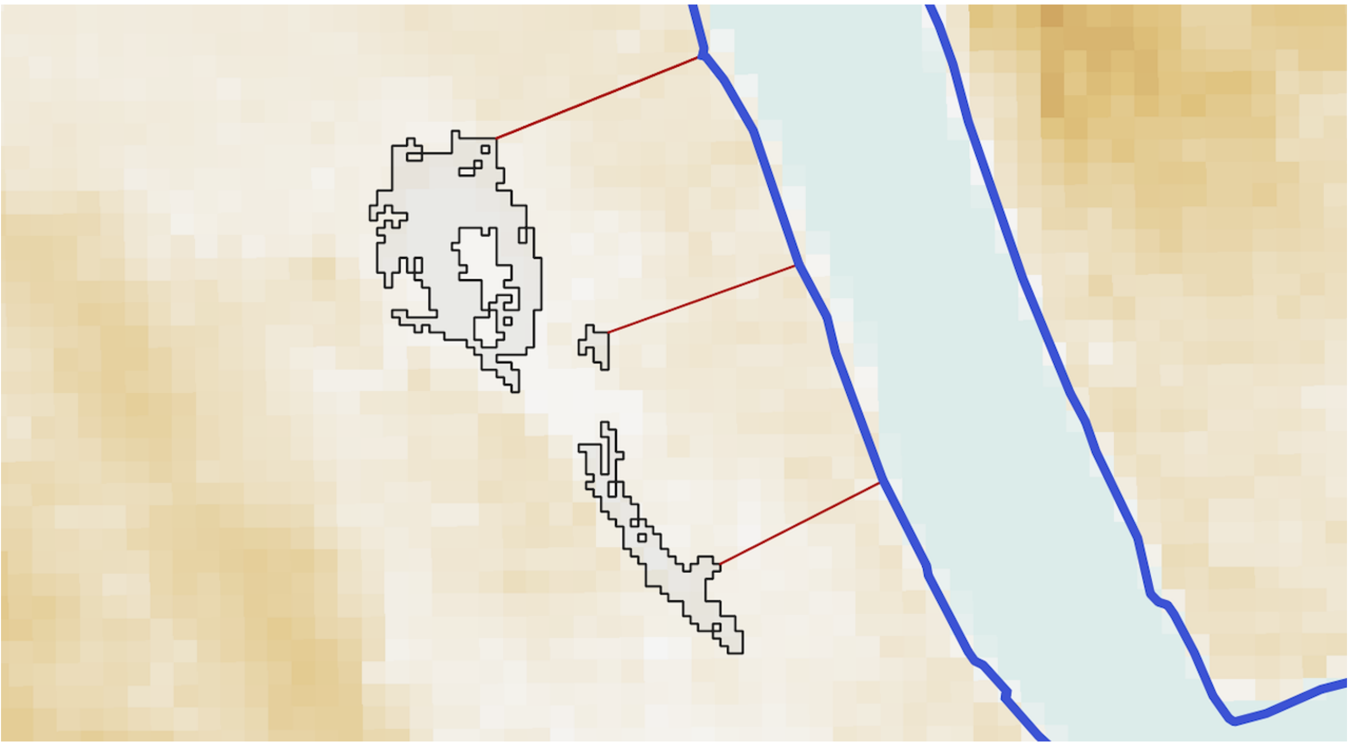
Distance to the river

Wetlands in close approximation to a river are generally easier to reconnect and therefore also more suitable to reconnect.

Size of wetland

Larger wetlands are better suited for wetland reconnection Nature-based Solutions (NbS), because reconnecting larger wetlands yields a more substantial impact.

Suitability factor 1: Relative height of a wetland
The median elevation was calculated for each wetland area. Additionally, the median elevation of the river was determined at the buffered endpoint of the shortest line connecting the wetland to the river. The relative height of a wetland was then computed by subtracting the median elevation of the wetland and the median elevation of the river point closest to the wetland.



The following classification system was used:

- Highly suitable: The wetland is elevated less than 10 meters above the nearest river.[1]
- Moderately suitable : The wetland is elevated more than 10 meters but no more than 25 meters above the nearest river
- Not suitable: The wetland is elevated more than 25 meter above the nearest river

1 *The global digital elevation model used as input has a vertical accuracy bias, especially in wetland areas with vegetation. Consequently, these wetlands may tend to have a higher elevation in the digital elevation model as compared to the actual elevation. 10 meters was therefore selected as a threshold, although it is on the upper end.*

Suitability factor 2: Water stress
Disconnected wetlands are, for the purpose of this study, defined as wetlands that show signs of water stress, i.e., a shortage or deficit of water, either due to disconnection with the main river or other factors such as drought or human-induced causes like overuse of water resources.

To compute which wetlands show signs of water stress we utilised the Water Occurrence Change Intensity product from the Global Surface Water Explorer. This product shows where surface water occurrence increased, decreased or remained invariant between 1984 and 2021. For each wetland we calculated the percentage of area that shows a decrease of surface water. The following classification system was used:

- Highly suitable: The wetland shows signs of severe water stress, with more than 20% of the wetland area showing a decreasing trend in surface water occurrence.
- Moderately suitable: The wetland shows signs of water stress, with 5 to 20% of the wetland area showing a decreasing trend in surface water occurrence.
- Not suitable: The wetland has no water stress, with less than 5% of the wetland area showing a decreasing trend in surface water occurrence.

Suitability factor 3: Distance to the river
For each wetland area, the shortest distance to the river was calculated. The following classification system was used:

- Highly suitable: The wetland is located less than 2.5 kilometers from the river and the investment to reconnect this wetland to the river is limited.
- Moderately suitable: The wetland is located between 2.5 and 5 kilometers from the river and the investment needed to reconnect this wetland to the river is moderate.
- Not suitable: The wetland is located more than 5 kilometres for a river branch and the investment needed to reconnect this wetland may be high.

Suitability factor 4: Size of wetland
The size of each wetland was calculated. The following classification system was used:

- Highly suitable: The wetland is larger than 3 square kilometers and reconnecting this wetland has a significant impact.
- Moderately suitable: The wetland is between 0.5 and 3 square kilometers and reconnecting this wetland has an impact.
- Not suitable: The wetland is smaller than 0.5 square kilometers and reconnecting this wetland has no significant impact.

Suitability factors classification, score and sources

Suitability factors classification scheme

The table below describes the classification scheme used per suitability factors.

No.	Component	Code	Classification
1	Relative height of Wetland **(H)**	H1	<10 meters height difference
		H2	10 - 25 meters height difference
		H3	> 25 meters height difference
2	Water stress **(W)**	W1	> 20 % of wetland area shows a decreasing trend in surface water occurance
		W2	5 - 20 % of wetland area shows a decreasing trend in surface water occurance
		W3	< 5 % of wetland area shows a decreasing trend in surface water occurance
3	Distance to river **(D)**	D1	< 2.5 km from the river
		D2	2.5 - 5 km from the river
		D3	> 5 km from the river
4	Size of wetland **(S)**	S1	> 3 km2
		S2	0.5 - 3 km2
		S3	<0.5 km2

Suitability scoring scheme

The table below describes the scoring used per suitability factor.

No.	Component	Highly suitable (Score = 2)	Moderatly suitable (Score = 1)	Not suitable (Score = 0)
1	Relative height of Wetland **(H)**	H1	H2	H3
2	Water stress **(W)**	W1	W2	W3
3	Distance to river **(D)**	D1	D2	D3
4	Size of wetland **(S)**	S1	S2	S3

Suitability factors sources

The table below describes the data source per suitability factor.

No.	Data type	Data source	Data description	Data type
1	Wetland database	Zhang, X., Liu, L., Zhao, T., Chen, X., Lin, S., Wang, J., Mi, J., and Liu, W.: GWL_FCS30: a global 30 m wetland map with a fine classification system using multi-sourced and time-series remote sensing imagery in 2020, Earth Syst. Sci. Data, 15, 265–293, https://doi.org/10.5194/essd-15-265-2023, 2023.	In this study, the Landsat reflectance and Sentinel-1 SAR time-series imagery, together with the stratified classification strategy and local adaptive random forest classification algorithm, was successfully integrated to produce the first global 30 m wetland product with a fine classification system in 2020. The wetlands were classified as four inland wetlands (swamp, marsh, flooded flat and saline) and three coastal tidal wetlands (mangrove, salt marsh and tidal flat).	Raster (30x30 m)
2	Water occurrence change	Pekel, JF., Cottam, A., Gorelick, N. et al. High-resolution mapping of global surface water and its long-term changes. Nature 540, 418–422 (2016). https://doi.org/10.1038/nature20584	The Water Occurrence Change Intensity product shows where surface water occurrence increased, decreased or remained invariant between 1984 and 2021. Both the direction of change (i.e. increase, decrease or no change) and its intensity are documented.	Raster (30x30 m)
3	Mekong river and tributaries	MRC project	-	Line
4	Digital Elevation Model	Merit DEM, MRC project	-	Raster (90x90 m)

5.4 Financial feasibility

5.4.1 Context

Maintaining habitat connectivity is essential for species movements, resource flow, and ecological processes across landscapes. In aquatic environments, connectivity involves the continuous flow of water and linkage between water patches, crucial for enabling aquatic species to thrive and navigate the landscape. The Mekong River basin is home to diverse wetland habitats that play a crucial role in supporting biodiversity, providing habitat for various aquatic vertebrates, including the critically endangered Siamese crocodile, Irrawaddy dolphin, resident and migratory fish species, and several frog and turtle species. The ability of aquatic animals to move freely between feeding, breeding, and resting areas along sheltered waterways is crucial. The loss of both lateral and longitudinal connectivity stands out as a primary threat to the fish community in the Mekong River. Connectivity plays a pivotal role in sustaining viable fish populations, and preventing localized extinction in freshwater habitats is of utmost importance. The proposed NbS to address this problem aims at increasing connectivity through re-opening wetlands by removing dense patches of vegetation (native/invasive) that hinder fish movements and impede the free flow of water during the dry season, removing invasive plant species, such as water hyacinth, which can diminish dissolved oxygen levels in the water, often leading to fish kills and maintaining water quality to prevent chemical barriers, such as low dissolved oxygen and acid sulphate.

The case study area for NbS3 is the Goot Ting Marsh, which lies along the Mekong River in Nong Khai Province, Thailand, see Figure below. The site has high biodiversity yet faces a threat from hydropower dam development upstream. This development disrupts the natural river flow, exacerbating the drying of the marsh even after the rainy season. This alteration in the natural flood-drought cycle and sediment transport adversely impacts the ecosystem, posing a serious threat to fisheries productivity – a vital component of the livelihood for the surrounding communities. Approximately 23,000 villagers across 40 communities depend on the Goot Ting Marsh for their primary livelihood. By connecting the wetlands with the main river and establishing interconnectivity within the wetland area, protecting and enhancing river corridors, creating and maintaining habitat corridors, removing invasive species, improving water quality and introducing sustainable practices for the use of ecosystem services, the area could be restored and protected. Some data for the case study was provided by the WWF country office.

At the basin level, the area that is highly suitable for NbS3 is 880 km^2. For the financial analysis, it is assumed that from the area with high suitability 25% will be part of the project area where riverine wetland ecosystems will be improved. This 25% is equivalent to 220 km^2 or 23 wetland sites.

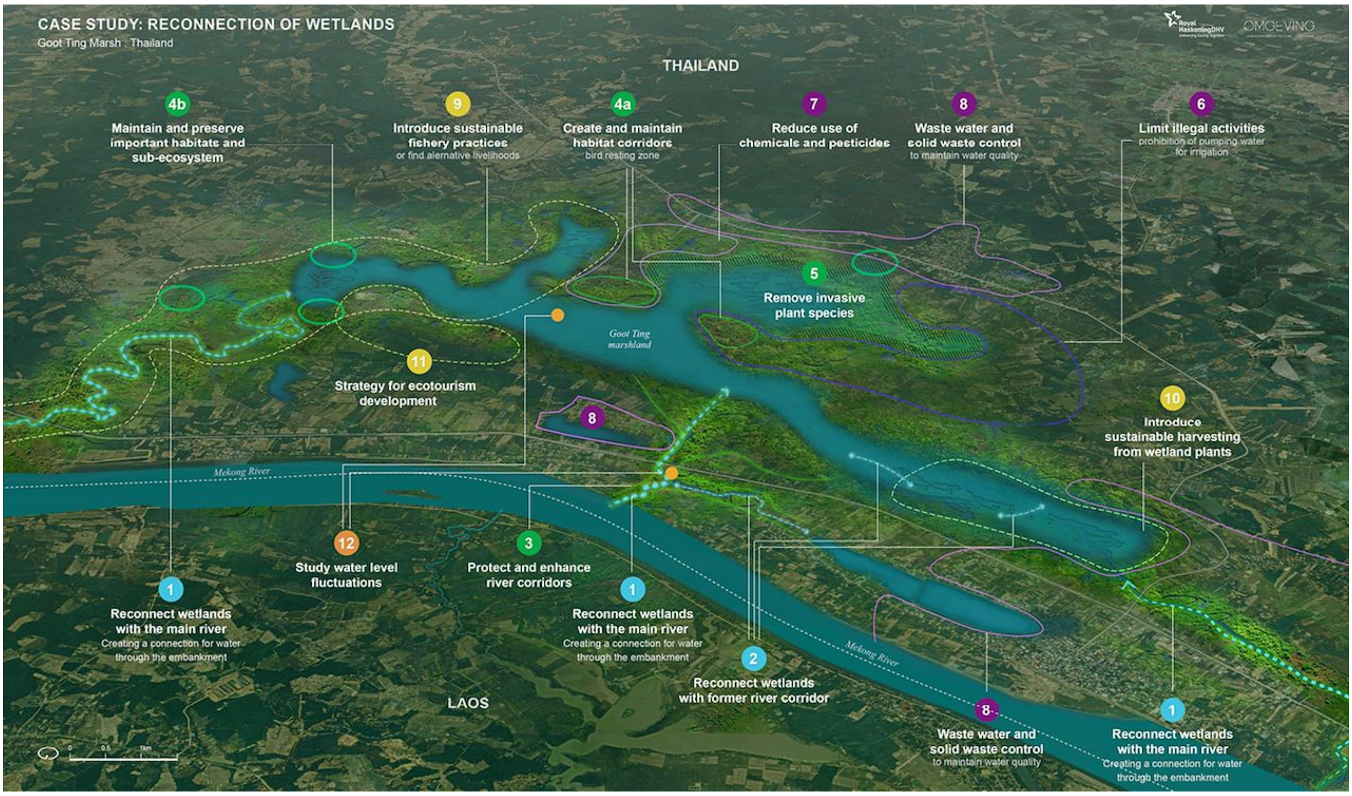


Figure. Case study area for improving riverine wetland ecosystems

Improving riverine wetland ecosystems and increasing the lateral and longitudinal connectivity with the main river would involve many stakeholders, including several government agencies. These stakeholders can be categorised into the following main groups:

Table. Stakeholders for flooded forest projects

Stakeholder group	Involvement
Households	Directly affected by the project; beneficiaries of the project and are expected to diversify and shift their sources of income to more sustainable resource use
Private sector companies	Potential beneficiaries of the project, adjusting to new or different business opportunities
Government organisations	Design, implementation and support of the projects
Funders	Provide loans, funds and other forms of financing for the project
Society	At a larger scale, social, economic and environmental co-benefits will affect society

In addition to these stakeholders, others can be identified, such as NGOs, knowledge institutions and contractors. However, these are not expected to be the main beneficiaries or responsible for the costs of the project and hence are not included in the financial and economic analysis. Note that there could be some overlap in stakeholder groups, e.g., government organisations could fund part of the projects.

5.4.2 Reference alternative

The reference alternative is the scenario in which the NbS will not be implemented in the case study area or any of the suitable areas. In this scenario, the riverine wetland ecosystems will continue to deteriorate due to further disconnection, encroachment, changes in flooding patterns, climate change, and contamination with agricultural chemicals. The reference alternative assumes that no incremental costs are required to sustain the current systems, yet it is acknowledged that over time ecosystem services of the wetlands, such as fish catch, would decline further.

5.4.3 Project alternative

The project consists of improving riverine wetland ecosystems and increasing connectivity with the main river. This requires structural measures related to the water system to create or recreate a connection between the main river and the wetlands and non-structural measures related to improving/restoring ecology and habitats. It also requires activities, such as outreach and training, to support households and communities to change their livelihoods that are aligned with sustainable use of the ecosystem services of the wetlands. Finally, it involves engaging other stakeholders, such as the private sector to set up eco-tourism in the area. This will ultimately lead to a situation in which the wetland sustainably provides its ecosystem services and works together with other livelihoods supporting a sustainable and complimentary income (such as agriculture, aquaculture and tourism).

At the basin scale, it is assumed that the case study project would be replicated up to the point where it would be implemented in 25% of the highly suitable land area for riverine wetlands, which amounts to 22,000 ha. Doing the projects at the basin scale would likely lead to scale advantages in costs and benefits. After all, an ecosystem of significant scale is required to provide ecosystem benefits.

In economic and financial analysis, the project period or project horizon is relevant as cashflows are discounted to a present value and different stakeholders have different time horizons. The project has an infinite lifetime as the improvement of riverine wetlands should be permanent. However, households and private sector stakeholders may have a horizon of one to a few years, as they would like to see relatively short-term returns on their efforts and investments. Public sector investments and societal benefits have much longer horizons as infrastructure generally has a lifespan of several decades and some effects may only materialise in the long run. Costs and benefits also need to be placed in a timeline, and for this, it is assumed that for the local scale project implementation takes 2 years and that at the basin scale, it takes 10 years to achieve the improvement of 25% of riverine wetlands. A project horizon of 50 years, from 2024 to 2073, is assumed.

5.4.4 Identification and selection of effects

The identification of effects is one of the most important steps and is done by comparing the project alternative with the reference alternative and identifying the incremental costs and benefits of the project alternative. Following the action-process-services-benefits approach, five tangible and one intangible benefits were identified, as shown in the figure at the bottom of this page. In addition, the project may result in a conversion of agricultural land to create channels, buffer zones or enlarged wetland areas. Although this is not directly an ecosystem service, the change in agricultural production due to a change in land use is an important effect of the project. Moreover, carbon credits and biodiversity credits can be identified as financing mechanisms, though are not counted as benefits for people (as they are financial transfers from one group of stakeholders to another group of stakeholders to sustain or enjoy a benefit).

The effects are different at different scales and for different stakeholders. As ultimately everyone could benefit from each service through indirect effects, only the most directly affected stakeholder groups are considered. In the table below, the column “Scale of benefits” indicates if benefits are predominantly present if a project is done locally or at a basin scale. Yet, through aggregation local benefits are also present at the basin scale and in some cases (e.g., change in fishing revenue) benefits are present at both local and basin scales through slightly different processes (e.g., fish in local habitat versus migrating fish).

Table. Benefits by scale and stakeholder

No.	Benefits for people	Scale of benefits	Stakeholders	Comments
1	Change in fishing revenue	Local & Basin, with benefits expected to increase with scale	Households & private sector companies	Private sector companies may benefit from supply chain opportunities.
2	Change in income from compost sale and cost savings from chemicals	Local	Households	
3	Change in tourism revenue	Local	Private sector companies & households	
4	Reduction in climate change and associated effects	Basin, with benefits expected to increase with scale	Society	This is a basin scale and global benefit and would ultimately also benefit the basin and local societies; carbon credits could benefit farmers / households.
5	Reduction in flood damages and flood protection costs	Basin	Society	
6	Change in non-use values	Local & basin	All	All stakeholders have non-use values, also at the global scale, but the specific non-use values differ considerably among stakeholders.
7	Change in agricultural revenue	Local	Households & private sector companies	This is a disbenefit, though can be partly mitigated by optimising land use and changes in agricultural practices.

An effect that is not displayed in Table above is the costs of the project. Implementation of the project comes with structural and non-structural costs for different stakeholders. Structural costs are generally paid by government organisations (though they could be financed by other organisations) but ultimately are borne by society through taxes and fees. Non-structural costs are borne by government organisations, funders and farmers/households. Potential costs involved in restoring and creating flooded forests are related to:

1. Acquisition of land
2. Reconnecting wetlands with the main river, e.g. through digging canals, removing levees or create a sluice or culvert to let the water in.
3. Removal of dense patches of vegetation and invasive plant species.
4. Protecting and enhancing river corridors, e.g. through land zoning, regulations and planting of vegetation
5. Creating / maintaining habitat connectivity, e.g. through land zoning, regulations and planting of vegetation and install or designate buffer zones through land zoning and regulations
6. Installing zones designated for natural fish nurseries
7. Implementing and enforcing regulation to maintain water quality.
8. Developing a strategy for ecotourism development, e.g. through building a visitor centre and building resting huts in flooded forest, as well as promotion, engaging tour operators, etc.
9. Training and support to help households move to more sustainable livelihoods
10. Initiating payment for ecosystem services
11. Limiting activities that could harm the wetland and enforcement of regulations.

In first instance, all identified tangible and intangible effects are selected for inclusion in the CBA. However, only a limited number can be quantified and monetised.

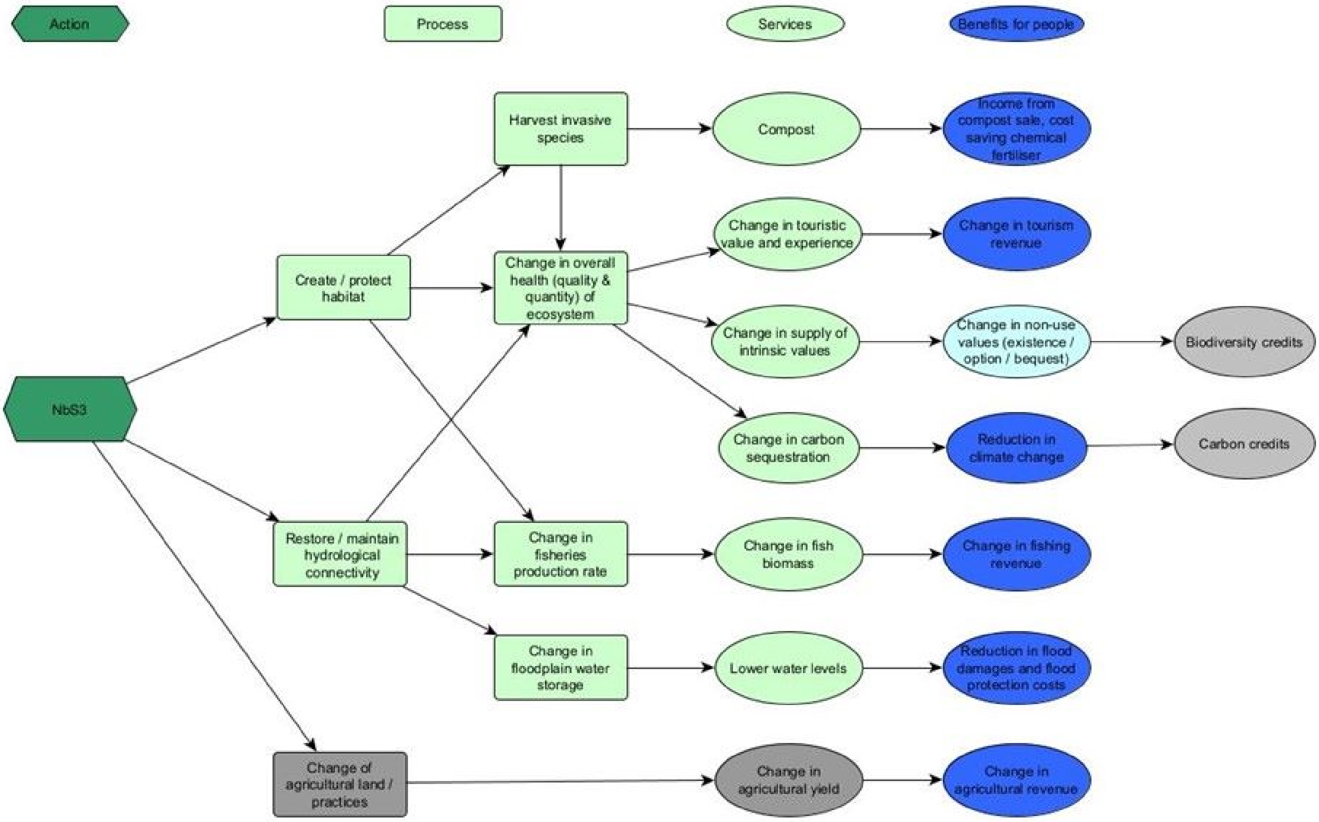


Figure. Effects of improving the connection between the wetlands and the main river

Quantification and monetisation of effects

5.4.5 Benefits

1. Change in fishing revenue

At the project site, fish catches have reportedly declined because of invasive plants and water level declines. The average income from fishing is about USD 12 per household per day for 4 kg per day. The catch in Goot Ting wetland is around 24,000 kg per year, hence the revenue is about USD 72,000 per year. On a local scale, implementation of the project might increase fish catches by 5% to 10%, which would mean a 5% to 10% increase in revenues from fisheries assuming prices remain the same. Taking the middle of the range, the benefits of the project would be USD 5,400 per year.

At the basin level, recent estimates indicate that the economic value of the Mekong fishery dropped by more than a third between 2015 and 2020[1]. The estimated annual value of fish catch was estimated between USD 7.13 billion and USD 8.37 billion in 2019-2020.[2] While it is difficult to estimate the impact of larger areas of flooded forests on fisheries income in the basin in the absence of quantitative data on the impact of wetland areas of fisheries, a rough indication is that if implementing the project in 25% of the highly suitable areas would only result in a 1% increase in fisheries, the revenues would already generate about USD 77.5 million in annual benefits if the middle of the range of the 2019-2020 estimated annual value of fish catch (7.75 billion) is taken as a base.

[1] Cowx IG, Lai TQ and So N (2024). Fisheries Yield Assessment by Habitat Type at The Landscape Scale in The Lower Mekong

River Basin 2020. Vientiane: Mekong River Commission Secretariat.

[2] Ibid

2. Change in income from compost sale and cost savings from chemicals

Invasive species can be used to make compost. Households can sell the compost or use it in their fields, which would reduce their production costs. As this would reduce the use of chemical fertilisers, it would also help to improve water quality.

Unfortunately, there is no quantitative information on the amount of compost produced by invasive species at the Goot Ting wetland or the basin scale, nor on the prices of such compost. Hence, it is not possible to include this in the calculation of the benefits. It is, however, expected that these benefits are relatively small.

3. Change in tourism revenue

Tourism at the Goot Ting wetland is currently limited to about 50 persons per year who come for bird watching. They stay on average two nights and spend about USD 30 per person. An ecotourism strategy, including building a simple visitor centre and developing information and promotion materials, could increase the number of visitors. Based on other ecotourism sites, the assumption was made that the project site could attract 1000 to 5000 (average 3,000) tourists per year, of which one-third would stay one night, one-third would stay two nights and one-third would just visit for the day. With wider accommodation and restaurant offerings, as well as boat rental and tours, it is assumed that a tourist staying one night would spend USD 20 (added value, excluding costs of the tourism offering), a tourist staying two nights would spend USD 40 and a day visitor would spend USD 15. Hence, the total annual benefits would be USD 75,000.

At the basin level, ecotourism cannot be implemented at all sites, as the total market demand for ecotourism is limited and not all sites are suitable, e.g., in terms of accessibility. In total, it is assumed that there would be 5 additional ecotourism sites throughout the basin, which each would generate USD 75,000 per year, hence in total USD 450,000 per year.

4. Climate change mitigation

Through the creation and protection of habitat, the project could contribute to increased carbon sequestration. Increased carbon sequestration reduces greenhouse gases in the atmosphere, mitigating climate change, and hence benefiting people as a reduction in climate change and associated effects compared to a baseline without the project. This benefit can be valued through the amount of carbon sequestered by vegetation and a social price for carbon. Measuring this would require an estimate of carbon sequestration in the project area without and with the project. While wetlands sequester carbon, and the project potentially could increase carbon sequestration through sustainable wetland management practices, it is difficult to calculate the increase in carbon sequestration due to the project. Moreover, there are no established or accredited methods to assess carbon sequestration for floodplain wetlands, hence they are generally not considered for carbon credits. Compared to reforestation of flooded forests (NbS2), the climate change effects for wetland restoration are likely much smaller. As such, the reduction in climate change will not be quantified in the CBA.

5. Reduction in flood damages and flood protection costs

By restoring hydrological connectivity between the rivers and wetlands at the basin level, the floodplain water storage capacity will increase. This could potentially lead to lower peak flood water levels and a reduction in flood damages and flood protection costs (e.g., lower requirements for levees). Moreover, there would be more water available in the dry season.

In terms of water storage, it is estimated that flood-based agriculture could store 220 million m^3 of flood waters, leading to a flood depth reduction of 0.2 meters in the Mekong River, see Appendix A. However, assessing the quantitative impact of restoring hydrological connectivity on flood damage and flood protection is complex,[1] hence only a very rough indication of the benefits can be given. The average annual cost of floods in the Lower Mekong Basin ranges between USD 60 to 70 million.[2] Assuming the project would contribute to a 1% reduction in damages this would be USD 600,000 to 700,000 annually.

[1] See for instance Thanh, V. Q., Roelvink, D., Van Der Wegen, M., Reyns, J., Kernkamp, H., Van Vinh, G., & Linh, V. T. P. (2020). Flooding in the Mekong Delta: the impact of dyke systems on downstream hydrodynamics. Hydrology and Earth System Sciences, 24(1), 189-212 on the complexity of modelling and considerations to assess changes in the floodplain on flood levels.

[2] Mekong River Commission: https://www.mrcmekong.org/our-work/topics/flood-and-drought/

6. Change in non-use values

Non-use values are numerous and different for each person. Such values include bequest values (leaving something for the next generation), existence values (attaching value to knowing that something exists, for instance, expressed to donations to charity) and option values (not using it now, but maybe in the future). A monetary estimate of non-use values can generally only be obtained by asking people for their willingness to pay to conserve or enhance certain habitats, ecosystems or ecosystem services.

While there are some studies on the non-use values of wetlands in the Lower Mekong Basin, the results cannot be easily translated for use in the CBA in this study. For instance, Rakthai (2018) estimated the willingness to pay for biological diversity conservation in the Lower Mekong River Basin by households located along the Mekong River and found a value of USD 3.99 per household per year or a total value of USD 153,471 per year based on the population sample.[1] This is, however, not specifically for wetlands and respondents gave their total value for biological diversity conservation, which may also include use values for some respondents. Hence, the non-use value cannot be quantified in the CBA.

The change in non-use values could be linked to the potential value of biodiversity credits. Biodiversity credits are a verifiable, quantifiable and tradeable financial instrument that rewards positive nature and biodiversity outcomes (e.g., species, ecosystems and natural habitats) through the creation and sale of either land or ocean-based biodiversity units over a fixed period.[2] The market for biodiversity credits is, however, still at an early stage of development and the pricing of biodiversity credits is still largely unknown.

[1] Rakthai, S. (2018). Willingness to pay for biological diversity conservation of the Lower Mekong River Basin in Thailand: A contingent valuation study. Songklanakarin Journal of Science and Technology, 40(3), 570-576.

[2] World Economic Forum: https://initiatives.weforum.org/financing-for-nature/home

7. Change in agricultural revenue

Surrounding the Goot Ting wetland, farmers grow rice, rubber trees and cassava and hold cattle. Farmers will need to shift to more sustainable agricultural practices – reducing the input of fertilisers and chemicals, stopping encroachment and limiting water pumping for irrigation – to conserve and restore the wetland. This may impact agricultural revenues. However, with proper outreach and training, the shift to more sustainable agricultural practices would not need to imply a reduction in agricultural revenues and could even increase agricultural revenues.

There is, however, not sufficient information to assess the impact of the project on agricultural revenue at the local or basin level. Hence, it is assumed that there is no impact on agricultural revenues (zero benefits / zero costs).

Summary of benefits

The table below provides a summary of the benefits.

No.	Benefit item	Estimate project site (USD/ year)	Estimate basin (USD/ year)
1	Change in fishing revenue	5,400	77,500,000
2	Change in income from compost sale and cost savings from chemicals	N/A	N/A
3	Change in tourism revenue	75,000	450,000
4	Climate change mitigation	N/A	N/A
5	Reduction in flood damages and flood protection costs	0	650,000
6	Change in non-use values	N/A	N/A
7	Change in agricultural values	0	0
	Total annual benefits	80,400	78,600,000

5.4.6 Costs

The table below gives an overview of the costs estimates for the project site and basin. Note that these estimates are all very indicative and based on currently available data.

For the project, it is assumed that the investments costs are spread over two years at the beginning of the project period. Operational costs (item 10) are annual.

Table. Cost estimates and assumptions

No.	Cost item	Estimate project site	Estimate basin
1	Acquisition of land (to reconnect wetlands with the main river)	1 ha at USD 150,000/ha Total USD 150,000	Based on 23 wetlands, their average distance to the main river and a canal width of 20 m, a total of 759 ha would be required at USD 150,000/ha. Total: USD 113,850,000
2	Reconnecting low-lying areas with the main river (digging of canals)	The groundwork required would be 500 m length by 20 m width by 2 m depth is 20,000 m^3 for a cost of USD 3/m^3 Total USD 60,000 In addition, two sluice gates (one at the inlet and one at the outlet) would be required to manage water levels for about USD 800,000 each Total USD 1,600 ,000	At basin level, groundwork would be required for 759 ha or 759,000 m^2 with 2 m depth at USD 3/m^3 Total USD 45,540,000 In addition, each wetland would require two sluice gates or culverts (one at the inlet and one at the outlet) for about USD 800,000 each Total USD 36,800,000
3	Removal of dense patches of vegetation	Assume 5 ha of dense vegetation would need to be cleared at a cost of USD 650/ha Total USD 3,250	Assume 5 ha of dense vegetation would need to be cleared for 23 sites at a cost of USD 650/ha Total USD 74,750
4	Protect and enhance river corridors	No costs, part of overall planning and management costs, see 6	No costs, part of overall planning and management costs, see 6
5	Creating / maintaining habitat connectivity	No costs, part of overall planning and management costs, see 6	No costs, part of overall planning and management costs, see 6
6	Implementing regulation to maintain water quality	Planning, management, training, and engagement costs are assumed to be USD 200,000 for the site Total USD 200,000	Planning, management, training, and engagement costs are assumed to be USD 200,000 per site for 23 sites Total USD 4,600,000
7	Installation of zones designated for natural fish nurseries	Estimated at USD 3,500 for one Fish Conservation Zone set up Total USD 3,500	Estimated at USD 3,500 for one Fish Conservation Zone set up, assume one FCZ at each of the 23 sites. Total USD 80,500
8	Strategy for ecotourism development	Costs of building a simple visitor centre and developing a ecotourism strategy, brochures, etc. is estimated to be USD 25,000. Total USD 25,000	Ecotourism could not be implemented at all sites, as the total market demand for ecotourism is limited and not all sites are suitable, e.g., in terms of accessibility. In total it is assumed that out of 23 sites, 5 could have ecotourism. Total USD 125,000
9	Training and support to help households move to more sustainable livelihoods	Training, support, and engagement costs for households are assumed to be USD 200,000 for the site Total USD 200,000	Training, support, and engagement costs for households are assumed to be USD 200,000 per site Total USD 4,600,000
10	Initiate payment for ecosystem services	Setting up a system for payments for ecosystem services (carbon credits, biodiversity credits or other) requires a certain scale to cover fixed costs. These costs are currently unknown.	Setting up a system for payments for ecosystem services (carbon credits, biodiversity credits or other) requires a certain scale to cover fixed costs. These costs are currently unknown.
11	Limiting activities / enforcement	The community is reportedly supportive of wetland conservation, hence there would be no enforcement costs	It is assumed that enforcement costs would be USD 500 per month or USD 6,000 per year per wetland Total USD 138,000
	Total Capital Expenditure	USD 2,241,750	USD 210,930,250
	Total Operational Expenditure	-	USD 138,000 / year

5.4.7 Discussion of results

The table below shows the results from the CBA. The results are indicative due to the assumptions being made, but some conclusions can be drawn from them. From the perspective of a single site, restoring the connection of wetlands with the main river does not seem economically viable, as the net present value (NPV) is negative, and the benefit-cost ratio (BCR) is below 1.0. However, on the basin scale, it is a very viable intervention. These results are mainly dependent on the assumption made for the value of the benefits for fisheries. At the site level, the benefits from the revenues in fisheries due to the project are rather modest, as it is assumed that the catch will increase by 5% to 10%. The present total benefits for the site are about USD 80,000 / year. If this would be around USD 160,000, the project would break even at the site level. Taking into account that several of the benefits cannot be quantified, such as revenues from composting, cost savings from reduction in chemical use, and non-use values, USD 160,000 may be achievable.

At the basin level, the benefits from fisheries are more than 98% of the benefits, with the remainder the benefits from tourism and flood impact reduction. Hence, for a more accurate CBA, it would be important to properly quantify the impact of restoring 25% of the wetlands on the fish caught in the basin.

Table. Results of the CBA for reconnecting wetlands, Present USD values at 6% discount rate over a 50 year project lifetime

Indicator	Value for Site	Value for Basin
Total lifetime costs	USD 2.18 million	USD 165.79 million
Total lifetime benefits	USD 1.19 million	USD 1,160.46 million
NPV	USD -0.99 million	USD 994.67 million
BCR	0.54	7
IRR	2.40%	93.20%

5.4.8 Financial analysis

To make parts of projects financially viable, they need to generate tangible revenue streams that can be captured by a stakeholder. However, aside from potential biodiversity credits, there are no tangible revenue streams resulting from the projects. Ecotourism may contribute to funding the project at some of the wetlands, though it is unlikely that it could fund a substantial part of the project. Revenues from ecotourism will go directly to the households and private sector companies as they sell their services, and only for instance an entrance fee or license fee paid by households and private sector companies could provide funding for the projects.

Biodiversity credits and carbon credits are a form of Payment for Ecosystem Services (PES). PES could provide a viable avenue for large-scale wetland restoration and conservation, though there are many challenges in setting up such schemes.[1] One of the challenges is financial viability: financial viability requires sufficient, stable, and sustained payments for project investment and operational costs and acceptable rates of return for project investors (including public financers seeking societal benefits). Reconnecting wetlands is unlikely to generate a large volume of carbon credits and while biodiversity credits could contribute to the overall funding of the projects, this is still a largely undeveloped market. Other ecosystem services, including the most important one – an increase in fisheries – are difficult to capture under a (privately funded) PES scheme.

Hence, public funding would need to cover the majority of the expenses.

Regarding the financial costs of projects, it should be noted that some sites would likely have lower project costs than others, for instance, if gates would not be required, as these make-up more than half of the project costs, or if they are located close to the main river with a smaller distance to connect. From a financial perspective, it would make sense to start with these less expensive projects.

[1] See Canning, A. D., Jarvis, D., Costanza, R., Hasan, S., Smart, J. C., Finisdore, J., ... & Waltham, N. J. (2021). Financial incentives for large-scale wetland restoration: Beyond markets to common asset trusts. One Earth, 4(7), 937-950.

6 Basin scale effects on climate resilience

6.1 Basin scale effects on climate resilience

Beyond addressing the resilience of communities on site, further upscaling of the solution across the Lower Mekong Basin can create meaningful contributions to systemic climate resilience impact. This section briefly explains how the selected NbS contribute to climate resilience on a basin scale, when scaled up, and compares the effectiveness of the selected NbS from economic perspective on a basin scale.

Effects are considered to be 'local' when they only occur at the site of implementation. Effects are considered to be on a 'basin scale' when implementation and upscaling would yield significant effects for areas outside the implementation zone. The table below gives a qualitative overview of the benefits, and a first order quantification of the costs and benefits that could be quantified, following from the financial analysis presented in this report. Below the table, each benefit will be briefly described.

	Nbs 1: floodplain dynamics		Nbs 2: flooded forest ecosystems		Nbs 3: riverine weland ecosystems	
Benefits	Local	Basin	Local	Basin	Local	Basin
Creating a more resilient ecosystem and improving biodiversity		✓	✓	✓✓	✓	✓✓
Food production	✓	✓✓	✓	✓✓	✓	✓✓
More stable and multi-source incomes	✓		✓		✓	
Improving water quality	✓	✓	✓	✓	✓	✓
Improving soil quality	✓					
Reduction of flood risk		✓✓		✓		✓✓
Mitigating subsidence		✓				
Increased drought resilience and increased access to clean water, by ground water replenishment	✓	✓	✓	✓	✓	✓
Reduction of GHG / carbon sequestration				✓		
Quantified Costs & Benefits						
Lifetime costs (million USD)	0.32	105.41	7.57	295.75	2.18	165.79
Lifetime benefits (million USD)	1.48	132.88	3.57	1175.06	1.19	1160.46
NPV (million USD)	1.16	27.47	- 4.00	879.30	- 0.99	994.67
BCR	4.62	1.26	0.47	3.97	0.54	7.00
IRR	30.2%	8.7%	1.6%	46.8%	2.4%	93.2%

Creating a more resilient ecosystem and improving biodiversity

Reconnecting river channels with floodplains was found to be the most promising solution to promote a more resilient ecosystem and improve biodiversity. The following factors have led to disconnection of the floodplains: presence of embankments, reduced sediment supply, increased incision of the main riverbed, and hydropower dams reducing peak flows and increasing base flows. This mostly has resulted in disconnection of floodplains, wetlands and starvation of flooded forest, which forms an important natural ecosystem. Not only area is disappearing, also the quality of those areas is deteriorating, due to a lack of the right hydrological and biological conditions.

Restoration efforts, such as adjusting levee positions, lowering floodplain elevations or installing culverts, are expected to activate floodplains and promote hydrologic connectivity. This activation is essential for improving spawning habitat availability for various fish species (Navodaru et al., 2005). Additionally, these measures bring extra benefits, including better retention of nutrients and suspended solids that is important to soil quality on floodplain (Schneider, 2002; Suciu et al., 2002).

Flooded forests and wetlands facilitate the exchange of water, nutrients, and sediments between the river and the floodplain, supporting the overall health of the ecosystem. Moreover, they provide habitat for a diverse range of flora and fauna by harbouring a variety of plant species, including trees and aquatic vegetation, which, in turn, sustain diverse animal species, such as fish, birds, and mammals. Lastly, those flooded forests and wetlands provide an important nursery ground for commercially important fish species. The submerged vegetation and complex structure of the forest provide shelter and food resources for juvenile fish, contributing to the overall productivity of the aquatic ecosystem.

Food production & more stable (multi-source) incomes

At the basin level, recent estimates indicate that the economic value of Mekong fishery dropped by more than a third between 2015 and 2020. The estimated annual value of fish catch was estimated between USD 7.13 billion and USD 8.37 billion in 2019-2020. It is difficult to make an educated guess on the impact of NbS on fisheries income. But if implementing an NbS in 25% of the highly suitable areas would only result in a 1% increase in fisheries, the revenues would already generate about USD 77.5 million in annual benefits.

Moreover, specifically for NbS 1, a reduction in chemical inputs reduces the cost of agricultural production. An intangible income-related benefit is that flood-based agriculture could provide a more stable household income as it is more climate and flood-resilient. Besides intangible social benefits from a more stable income, it could also support economic development.

For NbS 2, studies have shown that products such as resin, bamboo, rattan, wild honey and fuelwood can be collected from forests in Cambodia. However, data on the amounts and values of these products is limited. A study by Sophanna et al. (2022) conducted a survey in 22 villages in the Tonle Sap Lake area that are located within 500 metres from a flooded forest to assess ecosystem services. They found the following annual economic benefits per person per year from flooded forests: fuelwood – USD 12; wild food – USD 8; traditional medicine – USD 1; honey – USD 1, hence in total USD 22 per person per year. However, while the amounts and value may be low, they can be very important for low-income households who can obtain these natural resources for free.

For NbS 3, Invasive species can be used to make compost. Households can sell the compost or use it in their fields, which would reduce their production costs. As this would reduce the use of chemical fertilisers, it would also help to improve water quality.

Last but not least, for all NbS, tourism can be a significant source of income, further supporting the diversity of income from food production.

Improving water quality & improving soil quality

Restoring the natural function of floodplains will enable the system to facilitate the movement of aquatic organisms and transport of materials like sediment, minerals and nutrients that is important for soil on floodplains. The active floodplain plays a crucial role in maintaining water quality, mitigating flood stages, recharging ground water reserves, washing soil for excess salt, and it acts a natural pesticide. Re-establishing a connection with the floodplain is anticipated to improve livelihoods that depend on the quality of the floodplains. Additionally, active floodplains will also enhance resilience against droughts and extreme heat, because natural habitats and water mitigate heat.

Wetlands and flooded forests support the water purification processes by allowing for natural filtering and nutrient cycling, helping to maintain water quality.

Reduction of flood risk & mitigating subsidence

Introduction of the NbS at the basin level would lead to flood risk reduction downstream, as the storage capacity for flood waters increases. In addition, increased inundation would result in deposition of sediments, partly mitigating the effects of land subsidence and aiding in maintaining the elevation of the delta (mostly relevant for Vietnam).

Almost every year floods cause damages to agriculture, infrastructure and buildings and lead to loss of lives, which might be reduced with greater water storage upstream to reduce peak flows. Moreover, reduced flood levels could result in lower required protection levels, and hence lower costs for flood protection infrastructure.

Assessing the quantitative impact of implementing for example flood-based agriculture at the basin level on flood damage and flood protection is complex, hence only a very rough indication of the benefits can be given. The average annual costs of floods in the Lower Mekong Basin ranges between USD 60 to 70 million. Assuming the project would contribute to a 1% reduction in damages, this would be USD 600,000 to 700,000.

Increased drought resilience and increased access to clean water, by groundwater replenishment

Closely related to reduction of flooding, the NbS would also lead to increased resilience to drought through groundwater replenishment. Groundwater replenishment is very important to mitigate further subsidence, and thereby also indirectly affects flood risk in a positive way.

Moreover, the quality of the ground and surface water is likely to increase, because less chemicals and fertilisers are used. Cleaner water would lead to health benefits. Theoretically, health benefits could be quantified and monetised as reduced medical expenditures, avoided loss of working days due to illness, or increase in expected healthy living years.

Reduction of GHG / carbon sequestration

Reduction in climate change and associated effects can be valued through carbon sequestered by vegetation and a social price for carbon. Measuring this would require an estimate of carbon sequestration in the project area without and with the project. For this, newly established vegetation, restored degraded forest and avoided deforestation could be considered. Using a ballpark calculation, an indication of the benefit could be obtained. Assuming carbon sequestration is 5.5 $tCO2\ ha^{-1}yr^{-1}$ and the value of a tonne of CO2 is USD 5, benefits would be USD 27.50 $ha^{-1}yr^{-1}$, or USD 6,875 per year for the 250 ha planted area. At the basin level, a planted area of 12,325 ha would generate USD 338,938 as a ballpark figure.

Comparing the economic effectiveness of the selected NbS

In the study, costs and benefits of the selected NbS have been quantified where possible. Hence, a caveat in comparing the different NbS is that not all costs and benefits have been quantified.

From cost perspective, restoring flooded forests is the most expensive measure, which is mainly caused by the costs for acquisition of land. Reconnecting riverine wetland ecosystems also requires the purchase of land, though this is a relatively smaller area needed to create connections. Construction of culverts is the main costs for restoring floodplain dynamics through flood-based agriculture.

The benefits are largely determined by the impact on basin-level fisheries of the interventions. Restoring the flooded forest ecosystem (NbS 2) and riverine wetland connections (NbS 3) will have a larger impact on basin-level fisheries than flood-based agriculture (NbS 1), and hence generate more benefits.

Comparing the economic metrics (NPV, BCR, IRR) at basin level, investing in restoring riverine wetland connections would be the most effective NbS, followed by restoring the flooded forest ecosystem. However, at the local level these measures do not generate enough benefits to make them viable projects (which is also a main cause why these projects are challenging to implement). For flood-based agriculture the reverse is true: assuming the profit from flood-based agriculture for farmers can match triple rice cropping over time, the local benefits exceed the basin benefits (making them easier to implement).

7 NbS investment opportunities and challenges

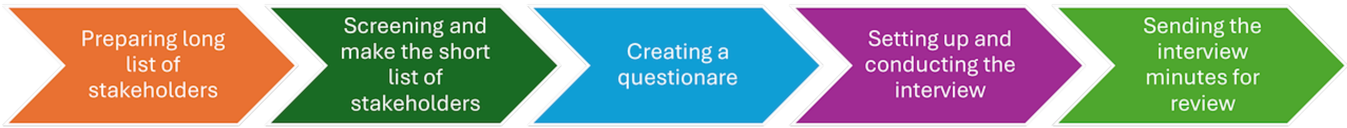
7.1 Financing Nature-based solutions

7.1.1 Financing Nature Based Solutions

Navigating the complexities of financing Nature-Based Solutions presents challenges and opportunities for stakeholders. This project delves into the potential for scaling up NbS investments and the hurdles financial institutions face in committing to these (innovative) projects. Through interviews with key players—from the Asian Development Bank to local research institutes—the project team has uncovered insights into the perceived risks, the evolving definition of return on investment, and the crucial role of collaboration in effective NbS integration.

7.1.2 Research method

The following approach was used to select stakeholders and conduct the interviews:



The chosen stakeholders have experience in financing structures for Nature-Based Solutions and come from private or public investors, governmental agencies, or research institutions. The selected stakeholders for the project included the Asian Development Bank (ADB), World Bank Group (WBG), Mekong Capital, Invest International, DFAT Laos, DFAT Vietnam, FAO, Temasek Foundation, Mekong River Commission, and The Mekong Delta Development Research Institute. All stakeholders work in the financial or donor sector and have either implemented or are considering projects in the Mekong River countries.

The interview guide, prepared by HaskoningDHV and approved by WWF, was sent to all stakeholders before the interviews. The interviews were recorded (solely for internal use), and the minutes of these interviews have been circulated to all stakeholders for their feedback.

7.1.3 Return on investment: how is it to be defined?

Understanding return on investment (ROI) is not only about financial gains. While investors prioritize cash flows, they also perceive ROI in alternative ways:

- **Environmental & Social Benefits:** Think cleaner water, more wildlife, and better incomes for farmers. Plus, less time and money spent on manual labor and avoiding risks.
- **Cost Savings:** NbS help fight climate change. Initial costs might be high, but they save money later, like reducing damage to buildings or lost work days.

The challenge is that the ROI of Nature-Based Solutions can take 5 to 10 years to materialize. Since they often involve public projects, they require significant upfront investments.

7.2 What are the barriers to financing NbS?

The long-term goals and outcomes of NbS pose challenges for conventional investors. Moreover, investors, donors, and research institutes have encountered various barriers to financing NbS. Some of these barriers are specific to a country or institutional context, with a key distinction being whether a country is an aid or a trade-focused nation. However, the following barriers are generally recognized:

- High perception of risk: NbS appears "new" and innovative, making it vulnerable to being cut off in case of project delays.
- Less visible compared to grey solutions (e.g., dams, dikes). Lack of widely spread data on proven NbS results among potential investors and governmental bodies.
- Lack of knowledge about NbS and a shortage of (policy) instruments for project designers and engineers, hindering the incorporation of NbS solutions into projects.
- Need to convince national, regional, and local stakeholders. Local economic benefits are crucial for stakeholders (farmers and government) to see the advantages of NbS.
- Uncertainty about who receives the benefits. Improvement is visible at a local scale but often not at the national level.
- There is difficulty connecting funding with ecosystem services, such as carbon credits. While NbS can be part of services like eco-tourism or certifications for flood-based agricultural products, measures like detention ponds or stream daylighting may not be easily translated into credits.

7.3 Opportunities

Stakeholders see promising opportunities to fund NbS. They suggest promoting NbS benefits clearly and consistently (advocacy), emphasizing general green solutions and not focusing on the term “Nature-Based Solutions”. Starting with small-scale tests can pave the way for larger projects and attract investments. Certifications, like those for organic products, could boost farmer incomes and are important for local support. NbS not only helps cut costs from climate damage but also needs a mix of funding types, including donations and investments. It is also important to involve the insurance industry, as investments in NBS can prevent severe damage to insured objects.

Collaboration for effective NbS integration

All stakeholders involved in NbS projects must collaborate for success. Financial institutions should require NbS in projects they fund, even if not initially proposed. Donors from financial institutions can lead innovation by setting their terms and offering technical help. Governments should embed NbS in project plans and create laws to support its implementation. Private companies, with their expertise, can provide technical guidance to incorporate NbS into project designs.

8 Approach financial and economic feasibility

8.1 Background and aim of the financial and economic feasibility analysis

The financial feasibility analysis aims to demonstrate to potential financiers the opportunities associated with Nature-based Solutions (NbS) investments in the Mekong Basin. This analysis identifies potential financial cashflows through a high-level assessment. However, focusing solely on financial feasibility proves too restrictive for the shortlisted measures, as they yield limited financial returns. Additionally, most of the stakeholders who were interviewed, consider not only financial feasibility but also economic feasibility. Therefore, the financial feasibility analysis should encompass both financial and economic aspects. The difference between financial and economic feasibility is as follows:

- Financial feasibility = project feasibility from the perspective of the funder(s); includes only tangible cashflows (expenses and revenues) for those who fund the project (which can include funding for which no return is expected, such as donations), provides investment rationale or business case for stakeholders that fund the project.
- Economic feasibility = project feasibility from the perspective of society, can include tangible and intangible societal benefits from a broad range of stakeholders, provides investment rationale mainly for governments, international financial institutions and funders providing grants and donations.

An important aspect in financial and economic feasibility – and in the context of this project – is the scale at which NbS measures are considered. For many funders, projects need to have a certain scale to be viable, and this scale differs by type of funder. For instance, a private investor would only consider investing in projects between $3 to $20 million, while an international financial institution would be interested to finance projects or programmes with a value of over $100 million. On the other hand, individual stakeholders involved in the measures, such as farmers, look at the impact a project has on the income and expenditures of their households. In addition, the benefits of implementing measures at regional or basin scale – in particular the environmental, climate adaptation and resilience benefits – are different when compared to individual project scales. As a consequence, the costs, benefits, and resulting financial and economic viability differs when different scales are considered.

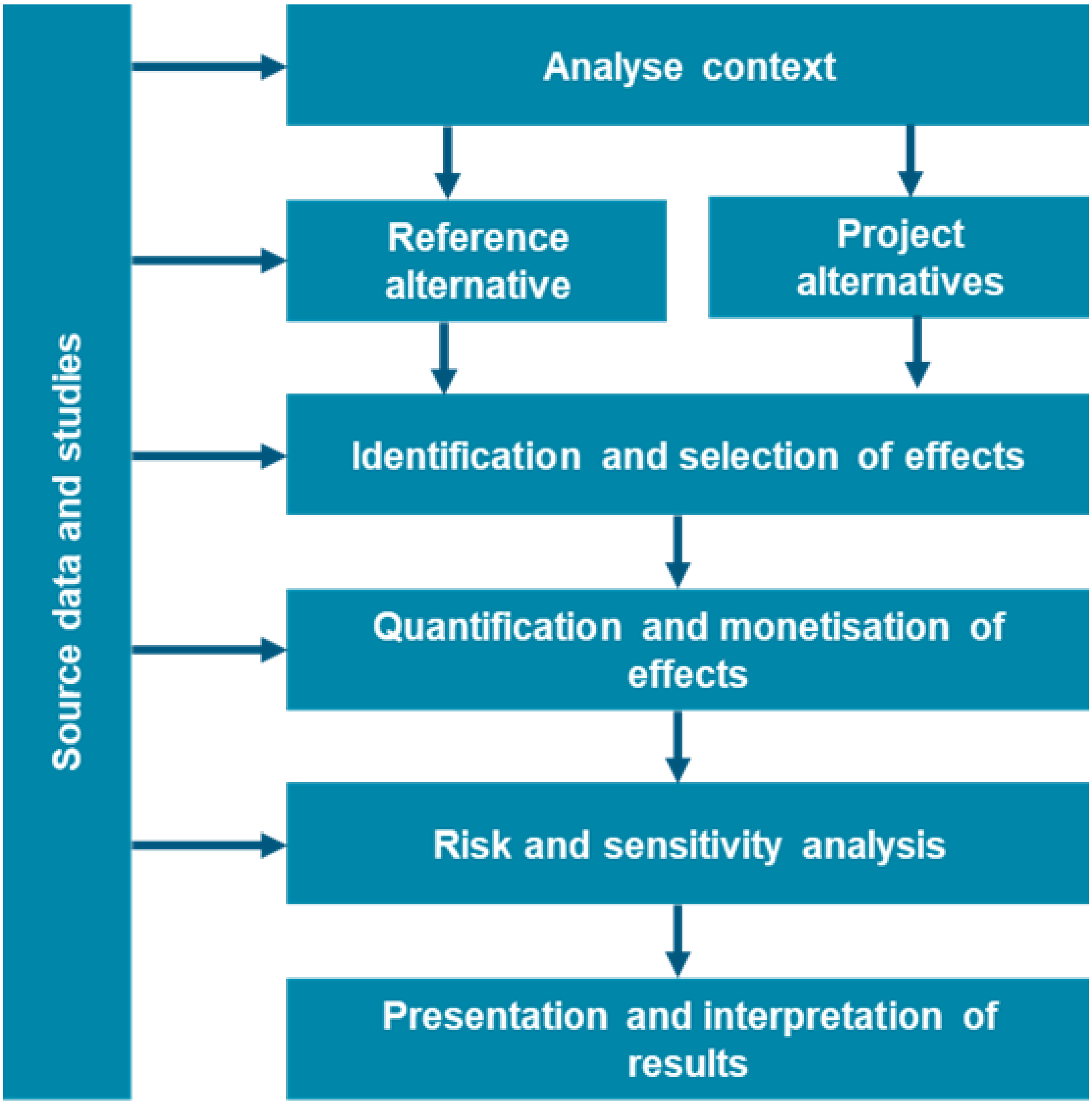
Hence, in this report, the financial and economic feasibility analysis aims to show potential funders (e.g. governments, international financing institutions, private investors, philanthropical organisations, etc.) the viability of NbS investments through a high-level cost benefit analysis disaggregated by scale and type of stakeholder.

8.2 Approach and methods

In this study, the financial and economic feasibility analysis is high-level because the proposed shortlisted NbS projects are in an early stage of development and design and data availability is limited. High-level means that the steps of a standardised cost benefit analysis (CBA) process are followed, but that identification of costs and benefits is mostly based on existing studies and information, and that quantification of identified costs and benefits is only indicative if (secondary) data is available. The results of a high-level feasibility analysis indicate potential financial and economic viability of the NbS measures. Moreover, by going through the CBA steps all costs and benefits of the NbS are systematically identified and evaluated, providing objective evidence for the financial and economic feasibility of the shortlisted NbS.

CBA is the main tool to help decision-making in financial and economic analysis. It is a systematic method to assess the effects, i.e. the costs and benefits, of a project on an organisation (financial CBA) or society (economic CBA). Financial and economic CBAs are largely similar, though they use some different terminology, consider different effects and there are some differences in the monetisation of effects. An economic CBA is more comprehensive in the sense that it considers costs and benefits on society, including intangible costs and benefits, that would not be considered in a private investment decision.

The steps in the figure below show the CBA process. The analyses for the shortlisted NbS go through each of these steps, yet quantification and monetisation of effects and risk and sensitivity analysis is only addressed to a limited extent due to the high-level nature of the analysis. In each of the steps a distinction between local (project) and basin level is made, and an overview is included which benefits are enjoyed by which stakeholder.



Step 1

The main purpose of this step is to get a thorough and complete understanding of the shortlisted NbS. This includes understanding the case study sites, key challenges, objectives and policy goals. The context will be considered at both the case study scale and the basin scale. Developing an understanding of which stakeholders are involved is also part of this step. The contexts for the shortlisted NbS are mainly developed in the technical analysis; here only a very brief summary is provided and the (potential) stakeholders are identified.

Step 2

The reference alternative is the case without the shortlisted NbS. Definition of the reference alternative is important, as it defines what the shortlisted NbS are compared with. Costs and benefits can only be determined incrementally; you cannot determine the effects of a NbS unless you have determined what would happen without their implementation. The reference alternatives will briefly describe the without-NbS situation.

Step 3

The project alternatives are the three shortlisted NbS. Project alternatives should be clearly defined projects or policies, so that their effects can be identified and quantified. At the local level, three case studies – one for each NbS – have been developed in the technical analysis. These case studies provide sufficient level of detail for a high-level economic and financial assessment. As there are no concrete project or programmes descriptions or designs at the basin scale, assumptions have been made on the scale of NbS implementation for assessment in the CBA.

Step 4

Implementing the shortlisted NbS will have several effects that ultimately lead to the costs and benefits of different stakeholders at different scales. Effects are wide ranging and include for instance costs for sluices and gates, costs for training of farmers, change in yield of rice leading to changing incomes for farmers, increased areas for spawning of fish leading to a larger fish stock, higher incomes from fisheries and reduced flood damages. Identification of effects will follow the structure of an ecosystem services assessment[1], which links an action to benefits for people through an ecological production function.

[1] The ecosystem services assessment approach is presented in Boris van Zanten, Gonzalo Gutierrez Goizueta, Luke Brander, Borja Gonzalez Reguero, Robert Griffin, Kavita Kapur Macleod, Alida Alves, Amelia Midgley, Luis Diego Herrera, and Brenden Jongman. 2023. Assessing the Benefits and Costs of Nature-Based Solutions for Climate Resilience: A Guideline for Project Developers. World Bank, Washington, DC.

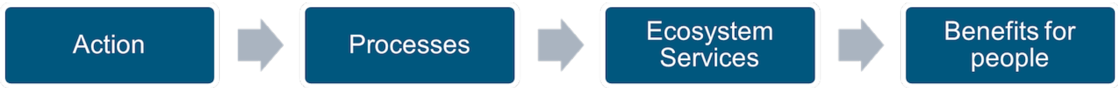


Figure. Ecosystem services assessment

Effects experienced by different stakeholders and at different scales could be different, hence identified effects will be related to stakeholders and to project versus basin scale. Moreover, effects could be tangible (e.g. investment costs, increased revenues) and intangible (e.g. increased resilience). Intangible effects are difficult to quantify or measure. Selection of effects for quantification is based on their expected significance for final outcome, the ability to quantify them, and data availability. Effects that are not selected, will be discussed qualitatively.

Step 5

Quantification of effects will be based on the high-level designs/ideas for the three case studies and based on the assumptions for upscaling the NbS. The quantification will be very indicative and only for effects for which data is available. Monetisation for effects that can be quantified will be based on secondary data, and existing studies and reports. Selected effects that cannot be quantified will be discussed qualitatively. With the quantified and monetised effects a simple present value calculation will be conducted to calculate an indicative economic net present value (NPV), benefit cost ration (BCR) and internal rate of return (IRR) for society.[1] The assumptions for these calculations are a social discount rate of 6%[2] and a project lifespan of 50 years. The base year and price levels of the calculations is 2024.

[1] Based on the available data and due to lack of tangible benefits it was not possible to calculate the financial NPV, BCR and IRR.

[2] While previously development banks used SDRs of 8-12%, increasingly lower discount rates are used, particularly for sustainability and climate-related projects (e.g. 6% for Vietnam, see World Bank (2022), Accelerating Clean, Green, and Climate-Resilient Growth in Vietnam: A Country Environmental Analysis, Supplementary Technical Note. World Bank.

Step 6

Due to the very preliminary nature of the analysis, it is not relevant to conduct a risk and sensitivity analysis.

Step 7

The final step is the presentation and interpretation of results, which is reported in the chapters below.

Following the CBA, a qualitative financial analysis will be conducted in which the tangible cashflows from the projects are identified and an assessment is made of potential avenues for funding the projects.

9 NbS Long list

9.1 Introduction Long list

This study focuses on the region surrounding the freshwater Mekong River countries. To identify NbS measures, a literature study was conducted, incorporating an Urban Ecosystem-based Adaptation to Climate Change in Vietnam (SIPA, 2022), NbS catalogue (World Bank, 2021), NbS for Building with Nature Concepts (Ecoshape, 2021), and Building Resilience in Towns and Cities: Case Studies from the Greater Mekong Subregion (ADB, 2016). We specifically focussed on finding suitable NbS for six major issues that have been identified on the Mekong River.

Major issues

1. **Changing Hydrology:** The operation of dams upstream, combined with the impact of land use change and climate change, affects the river's natural flow, altering the river's hydrological patterns, leading to increased variability in flow and water levels. This disruption in the river's hydrological regime can have severe consequences for agriculture, fisheries, and the overall ecosystem in the Mekong River Region.
2. **Erosion and Sedimentation**: Rivers are vital in carrying sediment downstream and are crucial for building and maintaining dynamic and fertile floodplains. In addition, sediments are crucial to the morphological stability of the channels, levees, and coasts that support many socio-economic activities. However, the construction of large dams with reservoirs upstream has disrupted this natural process. These dams have significantly reduced sediment supply, resulting in increased erosion in certain areas and excessive sediment deposition in others.
3. **Biodiversity Loss**: Biodiversity loss in rivers, lakes, and wetlands is occurring at an alarming rate, and it has become a global concern. Dudgeon and his colleagues (2006) identified five primary causes of freshwater biodiversity decline: flow alteration, pollution, habitat degradation and loss, overexploitation of species, and the introduction of invasive non-native species. In the context of the Mekong River, the presence of dams, with their distinct and conservation-focused purposes, leads to the fragmentation of freshwater ecosystems and disrupts the movement of water, species, sediments, and nutrients, all vital for sustaining biodiversity.
4. **Food Security**: The Mekong River and its delta are essential for food production in the region, providing a significant portion of the country's rice and fish supply. Climate change-related impacts on agriculture and fisheries can threaten food security for millions of people.
5. **Increased water demand**: During the dry season, the runoff of the Mekong River basin needs to increase by about 3000 m^3/s if it is to meet the water demand of all the riparian countries (Tang, 1999). Consequently, the water deficit in the dry season is nearly 47.30 km^3. The available water during the dry season is 82.26 km^3 (State of the Basin Report, 2017, Tang, 1999).

9.2 NbS Long list

Below, we have listed the NbS solutions for the Mekong Subregion based on our experience in the basin and the supportive information and literature collected from multiple sources. From this longlist, we have shortlisted high-potential nature-based solutions that are used as case studies, which were further analysed for their upscaling potential.

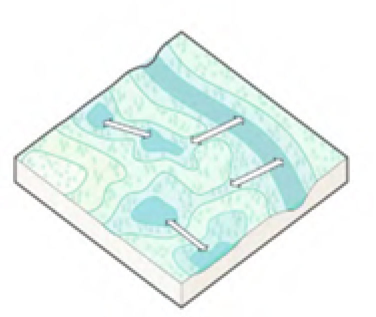
Protect and rehabilitate existing wetlands

Benefits

- Mitigate floods by capturing, buffering, reducing the velocity and the amount of peak flow.
- Improve water quality and act as natural sediment traps with the slow flow of water through wetland vegetation, promoting sediment deposition thus balancing land subsidence in the face of rising seas.
- Reduce the excess salt and pest in the land.

NbS Measures

1a. Natural inland wetlands



Source: *NbS catalogue (World Bank, 2021)*

The aim is to improve or restore the natural connectivity between the river channels and the floodplains. Reactivating wetland areas would improve its environmental performance and overall resilience of the river system.

1b. Drainage reduction

Source: NbS catalogue (World Bank, 2021)

Natural inland wetland areas have been used for agriculture in many regions around the world. To make the land suitable for crops, drainage systems are installed to control the water table and provide irrigation.

To reverse the destruction of the wetland, natural water fluctuation must be restored together with the composition of the anaerobic hydric soil formed over a long period. The first step is to remove a section of the underground agricultural tile that is draining the wetland basin or create a ditch plug by building an earthen wall to impound water.

Inspiration maybe be found in the cased of traditional Khmer agriculture system that enhanced both water and sediment natural cycles to irrigate and create soil texture suitable for different crops (Delvert 1961; L'Hamarttan1994).

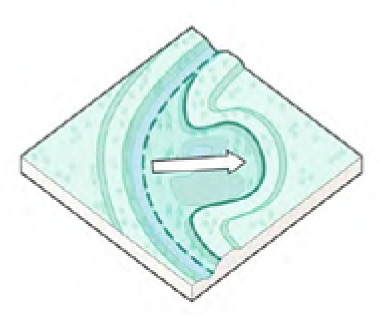
Rehabilitate, restore, and enhance natural floodplain dynamics

Benefits

- Reduce flood risk.
- Act as a protective buffer and store the water overflow from the river during a flood and slowly release the water back.
- Riparian and floodplain forests control river temperature preserving aquatic flora and fauna.
- Improve water quality, reduce environmental pollution, facilitate sediment transport and storage, and mitigates soil erosion
- Serve as an extensive agricultural development in certain cultures, offering a wide option of natural resources to local communities

NbS Measures

2a. Setting levees back

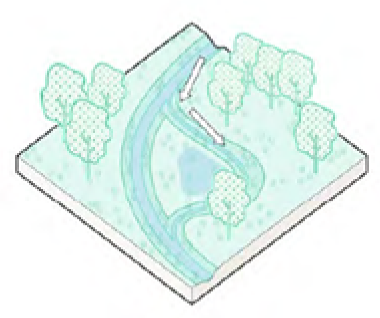


Levee setback is the process of relocating a levee further back in the floodplain to provide extra space for the river to flood. Levee setback provides the river with more floodplain area to interact with and can result in lower flood elevation.

The new space for the river allows new ecological and recreational activities and provides a greater diversity of floodplain habitats. In addition, this new space could also be used as natural resource production, such as agriculture.

Source: NbS catalogue (World Bank, 2021)

2b. River bypass or Oxbow

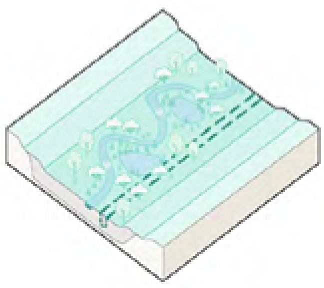


An oxbow is a historical river meander that is cut off from the main channel during the natural process of channel migration, or through man-made channelization. Water levels are maintained through larger flooding events overflowing into the oxbow and groundwater seepage.

Based on the habitat proposed, inlet and outlet structures may need to be constructed to regulate the inflow and outflow of water for the oxbow.

Source: NbS catalogue (World Bank, 2021)

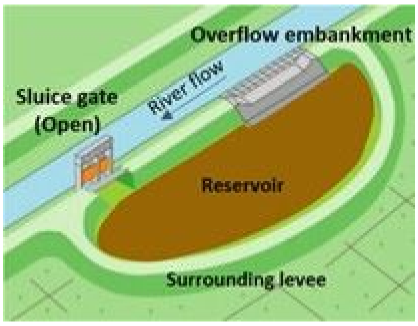
2c. Re-activating the floodplain



In incised floodplains, a new meandering stream channel is excavated on the original floodplain by raising the stream bed elevation. The former incised channel is then filled, converting it to a floodplain feature. This approach is used in areas where there are few lateral constraints and where flooding on the adjacent land can be increased.

Source: NbS catalogue (World Bank, 2021)

2d. Flood control basins utilising existing embankment system



The existing levee/embankment system can be utilised to create flood control basins for water retention (during discharge peaks), or to create additional flow-paths during predetermined discharge conditions. Flood-control basins are facilities that temporarily store river water in adjacent reservoirs to mitigate flood peaks and gradually drain the water back to the main channels after a flood (Ishiyama et al., 2019).

In some of the embankments (in Vietnam) are already sluices present. In others, they can be created, or an overflowing embankment can be implemented to increase connectivity between the floodplain and the main river.

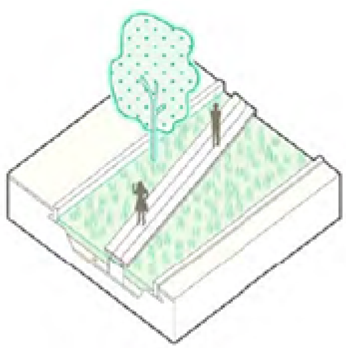
Pollution management, water and flood management

Benefits

- Trap and break down common pollutants.
- Improve water quality in surrounding water bodies.
- Reduce stormwater runoff rates and flood prevention.
- Recharge surrounding groundwater which will over time become available for use again.
- Provide habitat for aquatic and other wildlife, including species that can contribute to livelihoods

NbS Measures

3a. Bioswales and rain garden

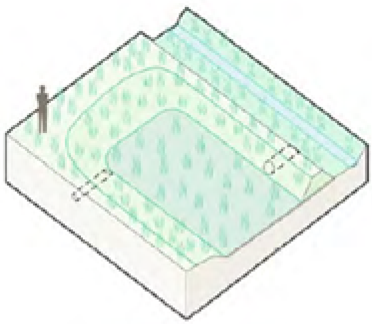


Source: NbS catalogue (World Bank, 2021)

Bioswales and rain gardens are shallow, densely vegetated ground depressions, with a variety of trees, shrubs, and grasses to collect stormwater from adjacent impervious surfaces

During storms, they become flooded and facilitate ground infiltration and cleaning of stormwater simultaneously. During dry seasons, swales and rain gardens contribute to the quality of public areas. Bioswales are common in streets and other linear infrastructure; rain gardens are common in parks, squares, and private gardens.

3b. Detention pond

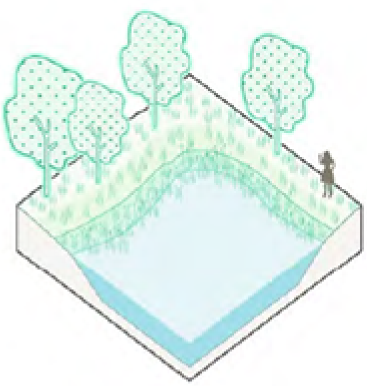


Source: NbS catalogue (World Bank, 2021)

Detention ponds are deeper and less biologically diverse bioretention areas than bioswales and rain gardens. Bioretention systems capture and temporally store stormwater during periods of heavy rain (Eisenberg and Polcher 2020).

Detention ponds can be completely filled with water during storms; they infiltrate much of it into the ground; and discharge the overflow into the sewer system. The remainder of the time they remain dry.

3c. Bioretention pond

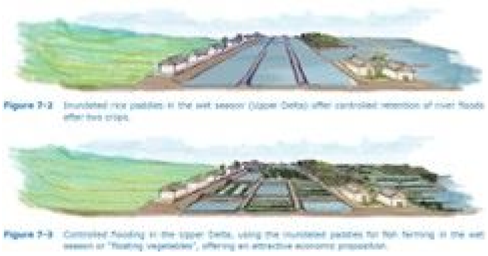


Source: NbS catalogue (World Bank, 2021)

Retention ponds are bioretention areas characterized by a permanent body of water and vegetated edges. Unlike detention ponds, they are permanently filled with water. Retention ponds collect stormwater from the surrounding areas; add storage capacity and ease the pressure on the surface water treatment and sewerage systems.

Retention ponds offer the added benefit of storing water for further reuse during drought conditions, while simultaneously providing habitat and enriching the diversity of public green spaces (Iwaszuk et al. 2019).

3d. Flood-based agriculture



Source: NbS catalogue (World Bank, 2021)

Flood-based agriculture is a traditional farming practice that harnesses seasonal floods in specific regions. It relies on the natural flooding and recession of rivers, lakes, or floodplains to cultivate crops. This approach reduces flood risks and helps replenish the essential fertile sediments crucial for agricultural productivity.

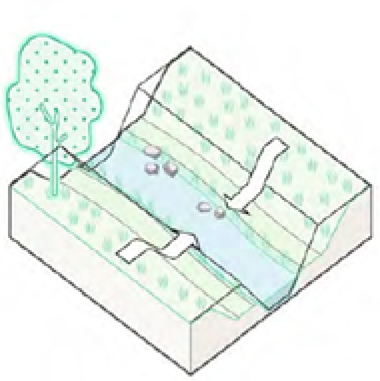
River and stream renaturation

Benefits

- Protect area from floods by increasing the capacity of waterbodies to hold excessive amounts of stormwater.
- Reduce river floods by creating water retention and infiltration capacity in the river system.
- River and stream renaturation can decrease pollution of water, soil, and air, stabilize soils and reduce soil erosion, and offset the loss of biodiversity by becoming critical conduits for the movement and propagation of biota.
- The growing aquatic vegetation creates a conducive environment for fish spawning.

NbS Measures

4a. Bank and bed renaturation

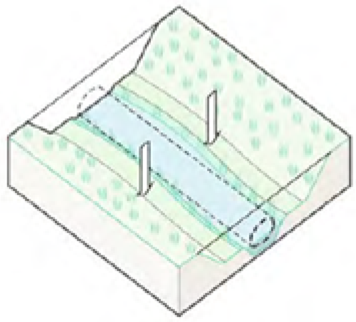


Source: NbS catalogue (World Bank, 2021)

The riverbank is an interface of aquatic and terrestrial ecosystems, an area protecting cities from riverine floods and often an important social place with recreational and cultural value. Its renaturation design should also safeguard ecological functions and flood control.

Riverbank and bed renaturation aim to restore the natural dynamic of the river, which may mean restoring its shape, creating natural/physical structures to direct the flow of water, and provide habitat for aquatic species.

4b. Stream daylighting



Source: NbS catalogue (World Bank, 2021)

Small streams provide a wide array of benefits to communities, such as nutrient and pollution removal, groundwater recharge, and flood mitigation. In some urban areas, streams were previously enclosed by concrete pipes or simply filled in. This could lead to floods, riverbed incision and consequently to severe damages such as building collapses

Daylighting is a technique to remove layers of concrete and recreate the natural shape and dynamic of streams, resulting in increased wildlife and aquatic habitat, and better regulated stormwater runoff treatment and intake (Eisenbert and Polcher, 2020).

4c. Bioengineering techniques

Source: NbS catalogue (World Bank, 2021)

Renaturation relies on several bioengineering techniques to recreate the natural course of a river and connect it to its landscape for floodplain and riparian corridor revegetation, riverbank stabilization, and restoration of the riverbed.

The natural river dynamic rests on the use of plants, rocks, and other natural elements, as well as geotextiles and membranes to create ecologically rich and structurally stable environment mimicking natural conditions, while providing space for recreation (Eisenbert and Polcher, 2020).

Water and flood management

Benefits

- Improved drainage during minor and major storms.
- Reduced flooding.
- Natural stormwater and pollution filtration.
- Increased habitat for native plant and animal species. Improved flow, which reduces stagnant water and associated odour and disease vectors.

NbS Measures

5a. Drainage corridors


Creating natural drainage corridors normally involves converting a ditch or storm drain into a natural creek flowing within a multipurpose corridor. They can also be created by rehabilitating and enhancing natural creeks and streams. They greatly reduce the number of drainpipes and other costly technologies required to manage stormwater runoff, and they reduce flood management costs overall.

Stormwater is collected in a traditional pit and pipe network within the road reserves. The pit and pipe network conveys flows to the drainage corridor where wetland conditions treat runoff before discharging to the natural watercourse.

Slope stabilization

Benefits

- Reduces length and steepness of the slope.
- Provides stable areas for establishment of other vegetation such as trees and shrubs.
- Provides immediate slope stabilization and helps to retain sediment and prevent soil degradation.
- Log terracing near the river has the potential to support agriculture. By creating terraces using logs or other materials, farmers can effectively manage soil erosion and water runoff.

- Can improve aesthetics and provide wildlife habitat.
- Live stakes are an effective method for introducing a specific plant species for food sources to a site that has the potential to be developed as a small-scale community plantation area.
- Slows the flow of water in high water stages.
- Staking a streambank helps dry out a wet, unstable bank and allows it to become more stable.

NbS Measures

6a. Log terracing


Log terracing is a way to intercept water running down a slope and comprises bedding logs or coir logs in shallow trenches along the corridor. Log terracing is used on burned slopes that have less than 30% of the original ground cover remaining and are at risk of increased erosion, and where there are enough logs of adequate size to construct a semicontinuous line at the desired horizontal spacing. It is better to use coir logs made locally, than to fell trees

Log terracing shortens the slope length and the gradient between each structure, providing stable planting areas throughout most of the slope face. Logs must be installed in trenches and staked into place.

6b. Live staking

Live staking and joint planting involve the insertion of woody shrub cuttings into the ground in a manner that allows the cutting (stake) to take root and grow. Live stake cuttings can be used to repair small earth slips and slumps. The stakes can help buttress the soil and arching

Nature restoration

Benefits

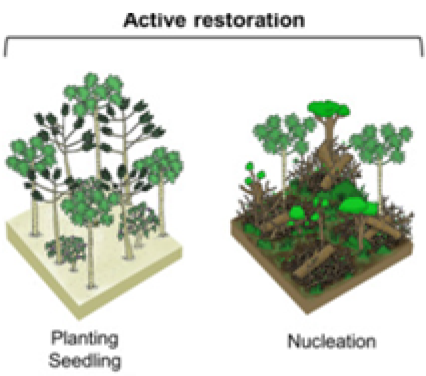
- Provide stability and protection against erosion to the riverbank.
- Improve water quality for downstream rivers and lakes.
- Support the aquatic invertebrate community, which acts as an important food source for fish.
- Mitigate the magnitude of flood events, which may be useful to save the Mekong flooded forest.

NbS Measures

7a. Rehabilitate: Riparian silviculture

Silviculture treatments aim to restore riparian areas by replanting trees and vegetation, often with protection from further harvest or removal. These treatments, including thinning, girding, pruning, and coppicing, are used to enhance riparian conditions. The ultimate goal is to establish a riparian buffer zone that can effectively mitigate flooding and erosion, stabilize riverbanks, and preserve the essential connection between the forest and the water system (Gashaw, 2015).

7b. Active restoration



Active restoration involves planting native species to ensure their successful growth. This revival is achieved through sowing seeds or planting seedlings. Sometimes, protection from herbivores, like fencing, may be necessary. It is crucial to remove invasive species beforehand to prevent their return and disrupt the restoration efforts. Starting restoration upstream and progressing downstream can help prevent invasive species from hindering the restoration process. This measure is particularly suitable in areas where the river's physical processes have been significantly altered by human activities, such as dams, levees, bank stabilization, and water diversions (Griggs, 2009).

7c. Passive restoration

Passive restoration relies on natural generation and requires minimal human disturbance for successful outcomes. This method encourages natural processes like flooding and seed dispersal. Over time, native plants recolonize the area, and the ecosystem regains its functionality. Monitoring the progress of natural regeneration is vital to ensure success. Passive restoration is particularly effective in climates and soil conditions with inherent resilience, such as relatively healthy soil and wetter climates. In arid climates, recovery may take longer (Eubanks, 2004).

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